

**Climate Adaptation Planning:**  
An urban structure type approach for  
understanding the spatiotemporal  
dynamics of risks  
in Ho Chi Minh City, Vietnam

Von der Fakultät für Umwelt und Naturwissenschaften  
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Doktor der Ingenieurwissenschaften (Dr.-Ing.)  
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vorgelegt von

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*“As a net is made up of a series of ties, so everything in this world is connected by a series of ties. If anyone thinks that the mesh of a net is an independent, isolated thing, he is mistaken. It is called a net because it is made up of a series of interconnected meshes, and each mesh has its place and responsibility in relation to other meshes”. - Gautama Buddha*

*“For things to reveal themselves to us, we need to be ready to abandon our views about them”. - Thích Nhất Hạnh*

## **Preface**

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This dissertation contributes to the emerging field of urban climate change adaptation. The work presented within is the result of intensive research into climate change adaptation strategies for rapidly developing urban centres. The majority of the research was undertaken within the project “Megacity Research Project TP. Ho Chi Minh: Integrative Urban and Environmental Planning Framework – Adaptation to Global Climate Change”, at the Brandenburg University of Technology Cottbus-Senftenberg in Germany. This project was one of ten research projects, funded by the German Federal Ministry of Education and Research (BMBF), as part of the research programme “Sustainable Development of the Megacities of Tomorrow”. The main aim of the project was to enhance Ho Chi Minh City’s response capacity to climatic risks. Evaluating the constraints of current climate change responses and the general shortcomings of the current planning system in relation to climate change considerations; the research project focused mainly on the two urban governance sectors, deemed crucial for climate change response: land-use planning and urban development planning.

Within this project, I worked in the research field “Urban Environment” which focused on the development of an “Adaptation Planning Framework”. This represented a central instrument for integrating the urban requirements and measures for adaptation to climate change from other thematic fields and supporting the development of land-use policy-relevant indicators. Strongly linked to this research theme, the main focus of this was laid on the development of an “urban structure type based- indicator framework for facilitation of climate change adaptation relevant knowledge. Only at the local level, was it possible to integrate the many layers of site-specific information and to work closely with the numerous administrative actors. The research presented within this dissertation has been carried out in collaboration with the Department of Natural Resources and Environment in Ho Chi Minh City. Ultimately, they have the most crucial of policy tools available for embedding adaptation to climate change, which is the task of determining the overall land-use and spatial zoning for the city.

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The work was embedded within the framework of the “Megacity Research Project TP. Ho Chi Minh - Integrative Urban and Environmental Planning Framework Adaptation to Climate Change”. This project was funded within the Future Megacities Programme of the German Federal Ministry of Education and Research (BMBF), whose support I gratefully acknowledge. Without the intense commitment of the individual German-Vietnamese members of the project this work would not have been possible. The research stemmed from the many experts, professionals and officials in Ho Chi Minh City. To the local research partners, Mrs. Nguyen Thi Cam Van, Dr. Le Canh Dinh and Dr. Bao Thanh, go particular thanks for providing me with local advice, hospitality support and encouragement during research stays.

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*Thank you*

*Dankeschön*

*Cảm ơn*

## Summary

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The share of the world's population living in urban areas is increasing rapidly. This implies more than only increasing numbers of urban inhabitants, but also changes to land cover, land-use, built structures and structural densities. These, in turn, affect urban temperatures, runoff and infiltration rates. The number and intensity of reported natural and anthropogenic hazards have grown over the last decades. Increasingly, hazards are occurring in urban areas, mainly due to greater exposure and the heightened sensitivity of spatially concentrated populations, assets and infrastructure.

Urban adaptation to hydro-meteorological hazards and climate change is a critical issue for many of the developing countries of Southeast Asia. Vietnam is likely to be among the countries most adversely affected by climate change. Moreover, its largest city, Ho Chi Minh City is considered worldwide as one of most vulnerable to a multitude of climate-related hazards, including flooding, sea-level rise and extreme heat events. Similar to other fast-emerging megacities in Southeast Asia, the city has developed at a breakneck pace and experienced rapid changes in recent decades. Ho Chi Minh City has become Vietnam's economic powerhouse and an important hotspot for direct foreign investment. Recently, the need to adapt to the multiple stressors of rapid urbanisation and climate change has become increasingly evident. There are concerns that climate change impacts, if unaddressed, will pose significant consequences and present further challenges infringing upon the overall urban functioning and liveability of the city as a whole.

Adaptation to climate change in urban areas depends on decision-makers' understanding of the current and future impacts of climate change. Land-use planning as a place-based and problem-solving strategy has been recognised as a key tool in this respect, to mainstream climate change adaptation and disaster risk reduction into urban development. Yet a key challenge is a lack of relevant information on exposed populations and assets at risk to planners and policymakers. Various climate risks to the city have been assessed in the past. However, previous assessments were limited to purely the physical aspects of climate change impacts and were undertaken at a city-

wide scale, neglecting the finer, structural, and socio-economic heterogeneity. Moreover, due to the high dynamics of urban growth and urbanisation, a large portion of population statistics and conventional sources of information become outdated and obsolete in a very short time, or are simply not available.

The dissertation outlines the development of an integrated framework predominantly based on an urban structure type approach. This approach was used to manually interpret high resolution, remotely sensed imagery in order to portray and understand patterns of settlement and urban structure layout of the current and emerging landscapes of Ho Chi Minh City. From this, classifications into homogenous areas which can be related to various questions were formed. The approach is able to capture the highly dynamic spatiotemporal, social and structural changes associated with rapid urbanisation. This is critical for planning and allows the opportunity for the monitoring of urban areas and the assessment of hazard generation and exposure.

The dissertation focuses on the hazard and exposure aspect of risk, highlighting the opportunities of the presented work at different scales to support risk assessments with coherent and credible indicators. The approach also provides a common spatial framework at the resolution of the urban block for multi-disciplinary data integration and for the compilation of existing vulnerability concepts at a spatial scale suitable for urban risk management. Furthermore, the approach is used to analyse the exposure of urban structures and population to future sea-level rise and current flood risk. The conceptual framework and density indicators developed within this dissertation have also been utilised in further studies to identify hazard-prone areas for urban heat in an urban climate assessment for Ho Chi Minh City, and the potential results for urban water balance modelling have also been demonstrated. Overall, planning recommendations and important policy implications were drawn for effective adaptation strategies, with both the potential and limitations of the development framework for urban monitoring and hazard and exposure assessments being demonstrated. Results emphasised the need for an understanding of risk which encompasses the interlinkages between hazard generation and exposure, and urban density monitoring. They also stress the importance of integrating fine grained data into risk-adapted land-use planning practices.

To evaluate both transferability and functionality, the developed urban structure type approach was applied to the central Vietnamese city of Da Nang to investigate the

relationship between urban structures and the four infrastructure sectors of energy, water and wastewater, solid waste and urban agriculture. On the basis of lessons learnt, a flexible and easy to use generic classification scheme, which can be applied to a variety of urban planning and management problems, is presented. The overall findings show the applicability of the developed framework to produce important input indicators. These are ultimately useful to determine hotspots for administrative interventions and to assist prioritising in spatial and urban planning decision-making.



## Zusammenfassung

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Ein großer und schnell zunehmender Anteil der Weltbevölkerung lebt bereits heute im urbanen Raum. Die steigende Zahl der Bevölkerung in urbanen Gebieten hat große Auswirkungen auf die Flächennutzung und manifestiert sich in einem Wandel der Landnutzung, der Struktur und der Dichte in den Städten und aufgrund der strukturellen Ausbreitung auch in den angrenzenden Gebieten. Die Änderung der Flächennutzung beeinflusst sowohl das Stadtklima als auch die allgemeinen Bodeneigenschaften, die Versickerungsfähigkeit, das Regenwasserrückhaltevermögen und den Wasserabfluss. Im Laufe der letzten Dekade sind die Anzahl und Intensität der gemeldeten anthropogenen und Naturereignisse mit schädlichen Auswirkungen deutlich gestiegen. Die urbanen Gebiete weisen aufgrund der hohen Bevölkerungsdichte und Konzentration von Infrastruktureinrichtungen eine hohe Sensibilität und ein erhöhtes Gefährdungspotential auf.

Die Anpassung der städtischen Strukturen an die derzeitig erwarteten Folgen des Klimawandels ist eine dringliche Aufgabe für einen Großteil der Entwicklungsländer in Südostasien. Vietnam gehört zu den Ländern, die voraussichtlich am stärksten durch den Klimawandel beeinflusst werden. Vietnams größte Stadt, Ho Chi Minh City, wird als eine der Städte weltweit angesehen, die basierend auf einer Häufung von klimarelevanten Risiken - Überschwemmungen, Anstieg des Meeresspiegels, Erwärmung der Städte - dem Klimawandel am stärksten ausgesetzt ist. Ähnlich wie andere, sich rapide entwickelnde Megastädte in Südostasien hat Ho Chi Minh City in den letzten Jahrzehnten enorme Veränderungen durchlaufen und entwickelte sich in kürzester Zeit zu einer, durch globale Prozesse und lokale Siedlungsformen geprägten, Megastadt. In letzter Zeit ist die Notwendigkeit, sich den multiplen Stressfaktoren einer rapiden Verstädterung und dem Klimawandel anzupassen, zunehmend offensichtlicher geworden.

Ohne eine Anpassung an die negativen Auswirkungen des Klimawandels werden signifikante Konsequenzen für die Funktionsfähigkeit und Lebensqualität in Städten befürchtet. Das Verständnis der Entscheidungsträger über die derzeitigen sowie

zukünftigen Auswirkungen der Klimaveränderungen spielt bei der Anpassung der Stadtgebiete an den Klimawandel eine große Rolle. Die strategische Planung der Flächennutzung als eine standortbasierte und problemlösende Strategie wird in diesem Zuge als ein Schlüsselwerkzeug angesehen. Damit soll eine Anpassung an den Klimawandel und eine Verringerung des Katastrophenrisikos innerhalb der städtischen Entwicklung erreicht werden. Die erfolgreiche Bereitstellung von relevanten Informationen, über die den Risiken ausgesetzte Bevölkerung und Vermögensgüter an die entsprechenden Stadtplaner und politischen Entscheidungsträger, stellt dennoch ein Kernproblem für einen dem Risiko angepassten Landnutzungsplan dar.

Ho Chi Minh City wurde bereits hinsichtlich unterschiedlicher Klimarisiken bewertet. Jedoch waren die vorangegangenen Betrachtungen rein auf die physikalischen Aspekte des Klimawandels und seiner Einflüsse limitiert und wurden innerhalb eines städtischen Maßstabes durchgeführt. Dies ließ die strukturellen Feinheiten und die sozioökonomische Heterogenität außer Acht. Zudem sind durch das dynamische Stadtwachstum und die zunehmende Verstädterung ein Großteil der relevanten Einwohnerstatistiken und anderer üblicher Informationsquellen innerhalb kürzester Zeit veraltet oder von vorneherein nicht verfügbar.

Die vorliegende Dissertation skizziert die Entwicklung eines integrierten konzeptionellen Rahmenwerks, dessen Ansatz hauptsächlich auf städtischen Strukturtypen basiert. Das Rahmenwerk wurde für die Interpretation von hochauflösenden Satellitenbildern verwendet, um die Siedlungsmuster und städtischen Strukturen der gegenwärtigen und sich entwickelnden Landschaft von Ho Chi Minh City als homogene Gebiete zu klassifizieren. Im Ergebnis wurden homogene Gebiete identifiziert, anhand derer Untersuchungen zu verschiedenen Fragestellungen durchgeführt werden können. Der Ansatz ermöglicht es zudem, die äußerst dynamischen raumzeitlichen, sozialen und strukturellen Veränderungen, die mit der rapiden Verstädterung einhergehen, konkret zu erfassen. Die Erfassung der Veränderungsdynamik ist von großer Bedeutung für alle Planungsschritte und bietet die Möglichkeit des Monitorings von Stadtgebieten und einer sachgemäßen Gefährdungs- und Risikobeurteilung.

Der Fokus der Arbeit liegt auf den Gefahren- und Gefährdungsaspekten von Risiken und zeigt die Möglichkeiten auf, die die einheitlichen und zuverlässig kalkulierbaren Indikatoren für die Risikobeurteilungen auf verschiedenen Maßstabsebenen bieten.

Entwickelt wurde ein Planungsrahmen auf der Maßstabsebene von Straßenblöcken, in dem Daten verschiedene Disziplinen und vorhandene Vulnerabilitätsanalysen integriert wurden und der als Grundlage für Strategien des städtischen Risikomanagements Anwendung findet. Des Weiteren wurden die Auswirkungen durch einen zukünftigen Anstieg des Meeresspiegels und der gegenwärtigen Überschwemmungen auf die städtische Struktur und Bevölkerung analysiert.

Das im Rahmen der Doktorarbeit entwickelte konzeptionelle Rahmenwerk und die Indikatoren zur Raumdichte konnte auch in weiteren Untersuchungen angewendet. Im Rahmen der städtischen Klimabeurteilung von Ho Chi Minh City wurden mit dem entwickelten Konzept Gebiete identifiziert, die durch die Erwärmung des Stadtklimas gefährdet sind. Potenzielle Ergebnisse konnten zudem für ein städtisches Wasserausgleichsmodell demonstriert werden.

Insgesamt wurden umfassende Planungsvorschläge und wichtige politische Richtlinien für effektive Anpassungsstrategien ausgearbeitet sowie die Möglichkeiten und Einschränkungen des konzeptionellen Rahmenwerks für eine städtische Kontroll- und Gefahrenbeurteilung demonstriert. Klassifikationen der städtischen Strukturtypen können besonders in Gebieten, in denen komplexe Strukturen vorherrschen, von besonderem Nutzen sein. Die Ergebnisse verdeutlichen die Notwendigkeit eines Risikoverständnisses, das die Gefährdungsursachen, die Risikoexposition als auch die Überwachung der städtischen Verdichtung verknüpft. Ebenso notwendig ist die Integration eines solchen Risikoverständnisses in die Landnutzungsplanung.

Um sowohl die Übertragbarkeit als auch die Funktionalität zu bewerten, wurde der entwickelte Ansatz des Stadtstrukturtyps auf die zentralvietnamesische Stadt Da Nang angewendet. In Da Nang wurde die Beziehung zwischen Stadtstrukturen und den vier Infrastruktursektoren Energie, Wasser und Abwasser, Abfall und städtische Landwirtschaft untersucht. Auf der Grundlage der gewonnenen Erkenntnisse entstand ein flexibles und benutzerfreundliches Klassifizierungsschema, das auf eine Vielzahl von städtebaulichen und verwaltungstechnischen Problemen angewendet werden kann.

Im Gesamtergebnis wird mit der Dissertation die Anwendbarkeit des entwickelten Rahmenwerks für die Erstellung wichtiger Input-Indikatoren für eine Risiko- und Gefahrenanalyse aufgezeigt. Diese sind letztendlich nützlich, um sogenannte Hotspots

für Maßnahmen und administrative Interventionen zu ermitteln und Prioritäten bei der Entscheidungsfindung in Bezug auf Raum- und Stadtplanung zu setzen.

## Tóm tắt

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Tỷ lệ dân số thế giới sống ở các khu vực đô thị đang gia tăng rất nhanh. Điều này không chỉ bao hàm ý nghĩa về gia tăng số lượng cư dân đô thị, mà còn là sự thay đổi về độ che phủ đất đai, sử dụng đất, cấu trúc xây dựng và mật độ đô thị. Tất cả những vấn đề này lại ảnh hưởng đến nhiệt độ đô thị, tốc độ chảy tràn và tốc độ thấm. Hơn nữa, số lượng và cường độ của các thảm họa tự nhiên và do con người gây ra đã tăng lên trong những thập kỷ qua. Các thảm họa được ghi nhận tại các khu vực đô thị ngày càng tăng, nhìn chung là do sự phơi nhiễm và tính nhạy cảm cao gây ra bởi mật độ dân cư đông đúc, sự tập trung dày đặc các cơ sở hạ tầng.

Sự thích ứng của đô thị đối với các mối đe dọa do biến đổi khí hậu là một vấn đề quan trọng đối với các nước đang phát triển trong khu vực Đông Nam Á hiện nay. Việt Nam có thể sẽ là một trong những nước chịu ảnh hưởng xấu nhất của biến đổi khí hậu. Hơn nữa, thành phố Hồ Chí Minh (TP.HCM) - thành phố lớn nhất Việt Nam hiện nay - được đánh giá là một trong những thành phố bị ảnh hưởng nhiều nhất trước vô số các mối nguy hiểm liên quan đến khí hậu, bao gồm lũ lụt, nước biển dâng và nhiệt độ đô thị. Tương tự như các thành phố lớn (đại đô thị) mới nổi với tốc độ phát triển nhanh trong khu vực Đông Nam Á, TP.HCM đang phát triển với tốc độ chóng mặt và có những thay đổi nhanh chóng trong những thập kỷ gần đây. Có thể nói rằng, Thành phố Hồ Chí Minh là trung tâm kinh tế lớn nhất Việt Nam và là điểm thu hút đầu tư trực tiếp nước ngoài quan trọng của nước này. Trong những năm gần đây, sự cần thiết của việc tăng cường khả năng thích ứng đô thị do những áp lực của quá trình đô thị hóa nhanh và biến đổi khí hậu gây ra ngày càng trở nên rõ nét. Điều đáng lo ngại là những tác động của biến đổi khí hậu, nếu không được giải quyết, sẽ gây ra hậu quả đáng kể và những thách thức ảnh hưởng tiêu cực đến chức năng tổng thể của đô thị và chất lượng cuộc sống nói chung. Khả năng thích ứng với biến đổi khí hậu ở các khu vực đô thị phụ thuộc vào những nhà hoạch định chính sách, sự hiểu biết của họ về những tác động hiện tại và tương lai của biến đổi khí hậu. Quy hoạch sử dụng đất - được xem như một chiến lược giải quyết vấn đề tại chỗ - đã được ghi nhận/chứng minh là một công cụ quan trọng để lồng ghép thích ứng biến đổi khí hậu và giảm nhẹ rủi ro thiên tai vào chiến lược phát triển đô thị. Tuy nhiên, một thách thức quan trọng đối với việc quy hoạch sử dụng đất

thích ứng với các nguy cơ chính là sự thiếu hụt nguồn thông tin đáng tin cậy liên quan đến dân số và rủi ro về tài sản cho các nhà quy hoạch và các nhà hoạch định chính sách. Đã có những báo cáo đánh giá về mức độ rủi ro liên quan đến khí hậu ở các đô thị khác nhau; tuy nhiên, những đánh giá này chỉ mới dừng lại ở khía cạnh vật lý của tác động biến đổi khí hậu trên quy mô toàn thành phố, mà chưa có sự nghiên cứu chuyên sâu hơn về cấu trúc và sự phân tầng kinh tế-xã hội của đô thị. Hơn nữa, do tính năng động cao của sự phát triển đô thị và đô thị hóa, phần lớn các thông tin, biểu đồ, thống kê dân số và nguồn dữ liệu nhanh chóng trở nên lạc hậu và lỗi thời trong khoảng thời gian rất ngắn hoặc không có sẵn dữ liệu.

Luận án đưa ra/ xây dựng/ phát triển khung khái niệm tích hợp, chủ yếu dựa trên cách tiếp cận các kiểu cấu trúc đô thị. Hướng tiếp cận này được thực hiện bằng việc sử dụng hình ảnh viễn thám với độ phân giải cao để miêu tả, và phân loại các mẫu nhà ở và các cấu trúc đô thị của toàn bộ cảnh quan hiện tại cũng như cảnh quan đang hình thành của TP.HCM thành các khu vực đồng nhất liên quan đến các vấn đề khác nhau. Cách tiếp cận này nhằm xác định những thay đổi về cấu trúc và xã hội của một đô thị năng động theo không gian và thời gian, liên quan đến quá trình đô thị hóa một cách nhanh chóng. Điều này là rất quan trọng cho việc lập quy hoạch và mở ra cơ hội cho việc giám sát các khu vực đô thị cũng như đánh giá khả năng hình thành và biểu hiện của thiên tai.

Luận án tập trung vào khía cạnh mức độ nguy hiểm và sự biểu hiện của các rủi ro, nhấn mạnh những cơ hội mà nghiên cứu đã đem lại ở các quy mô khác nhau để hỗ trợ cho việc đánh giá rủi ro bằng các chỉ số được tính toán chặt chẽ và đáng tin cậy. Hướng tiếp cận này cũng cung cấp một khung không gian chung có tính phân giải của một khối đô thị, điều đó giúp cho việc tích hợp dữ liệu đa ngành cũng như diễn giải các khái niệm về tính tổn thương hiện hữu ở quy mô không gian phù hợp cho quản lý rủi ro đô thị. Hơn nữa, cách tiếp cận này còn được sử dụng để phân tích phản ứng của các cấu trúc và dân số đô thị với mực nước biển dâng trong tương lai và nguy cơ lũ lụt hiện tại. Khung khái niệm và các chỉ số mật độ được phát triển/ đưa ra/ xây dựng trong luận án này cũng đã được sử dụng trong các nghiên cứu tiếp theo để xác định các khu vực có nguy cơ cao đối mặt với thảm họa do tác động của nhiệt đô thị trong một tài liệu đánh giá khí hậu đô thị tại TP.HCM. Các kết quả tiềm năng cho mô hình cân bằng nước đô thị cũng được trình bày/ minh họa trong luận án này. Nhìn chung, Kiến nghị quy hoạch tổng thể cũng như những chính sách quan trọng đã được phác họa cho các chiến lược thích ứng hiệu quả, bên cạnh đó tiềm năng và hạn chế của khung phát triển cho giám sát đô thị, đánh

giá rủi ro và biểu hiện của rủi ro cũng đã được trình bày. Kết quả của luận án nhấn mạnh sự cần thiết phải có những hiểu biết về rủi ro bao gồm các mối liên hệ giữa sự hình thành các mối nguy hại và sự biểu hiện của các mối nguy hại đó, cùng việc giám sát mật độ đô thị. Chúng cũng nhấn mạnh tầm quan trọng của việc ứng dụng/ áp dụng những hiểu biết/ kiến thức này vào công tác quy hoạch sử dụng đất thích ứng với các rủi ro.

Để đánh giá đồng thời khả năng chuyển đổi và chức năng của một đô thị, cách tiếp cận dựa trên loại hình cấu trúc đô thị đã được áp dụng cho thành phố Đà Nẵng- thành phố trọng điểm thuộc khu vực miền Trung Việt Nam- để xác định/ nghiên cứu mối quan hệ giữa cấu trúc đô thị với bốn yếu tố cơ sở hạ tầng: năng lượng, nước và nước thải, chất thải rắn và nông nghiệp đô thị. Trên cơ sở các bài học kinh nghiệm, luận án đã đưa ra một sơ đồ phân loại chung, linh hoạt và dễ sử dụng có thể áp dụng được cho một loạt các vấn đề về quy hoạch và quản lý đô thị. Những kết luận chung cho thấy khả năng ứng dụng của khung phát triển nhằm tạo ra các chỉ số đầu vào quan trọng để xác định các điểm nóng và hỗ trợ quá trình đưa ra quyết định chiến lược trong quy hoạch đô thị.

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## Acronyms and abbreviations

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%	Percent
°C	Degree Celsius
ADB	Asian Development Bank
AMSL	Above mean sea-level
APND	Action Plan Natural Disasters, Ho Chi Minh City
BMBF	German Federal Ministry of Education and Research
BMP	Best management practice
BTU	Brandenburg University of Technology Cottbus- Senftenberg
CBD	Central business district
CCAP	Climate Change Action Plan
CCFSC	Central Committee for Flood and Storm Control
CCSB	Climate Change Steering Board, Ho Chi Minh City
CDM	Clean development mechanisms
CIR	Colour infrared imagery
cm	Centimetre
DAWACO	Da Nang Water Supply Service Company
DISED	Da Nang Institute for Socio - Economic Development
DoNRE	Department of Natural Resources and Environment, Ho Chi Minh City
DoT	Department of Transport, Ho Chi Minh City
DPA	Department of Planning and Architecture, Ho Chi Minh City
DPI	Department of Planning and Investment, Da Nang
DPRSB	Steering Board on Natural Disaster Prevention, Response and Search - Rescue
DRI	Disaster risk index
DSM	Digital surface model
DTM	Digital terrain model
EIA	Environmental impact assessment
EU	European Union
EWEC	East-West economic corridor
FAR	Floor area ratio
FDI	Foreign direct investment
FEMA	United States of America Federal Emergency Management Agency
FIRM	Flood insurance rate map
GCR	Ground coverage ratio
GDP	Gross domestic product

GFA	Gross floor area
GHG	Greenhouse gas
GIA	Gross internal area
GIS	Geographical information system
GIZ	German Corporation for International Cooperation
GPS	Global positioning system
GSO	General statistical office
GSO-DN	General statistical office, Da Nang
ha	Hectare
HCCB	Ho Chi Minh City Climate Change Bureau
HCMC	Ho Chi Minh City
HFA	Hyogo Framework for Action
HVAC	Heating, ventilation, and air-conditioning
IMHEN	Institute of Meteorology, Hydrology and Environment, Hanoi
IPCC	Intergovernmental Panel on Climate Change
Km	Kilometre
LECZ	Low elevation coastal zones
LiDAR	Light detection and ranging
m	Metre
m <sup>2</sup>	Square metre
m <sup>3</sup>	Cubic metre
MARD	Ministry of Agriculture and Rural Development, Vietnam
MFA	Ministry of Foreign Affairs, Vietnam
mm	Millimetre
MoC	Ministry of Construction, Vietnam
MoF	Ministry of Finance, Vietnam
MoNRE	Ministry of Natural Resources and Environment, Vietnam
MoST	Ministry of Science and Technology, Vietnam
MPI	Ministry of Planning and Investment, Vietnam
NDPRM	Vietnamese National Strategy for Natural Disaster Prevention, Response and Mitigation
NTPRCC	Vietnamese National Target Programme to Respond to Climate
NUA	Non-urbanised areas
OECD	Organisation for Economic Co-operation and Development
PC	People's Committee
PV	Photovoltaic installations
Q	<i>Quận</i> = district
QCVN	Vietnamese National Contraction Law standard
SAR	Synthetic aperture radar
SCFC	Steering Centre for Flood Control, Ho Chi Minh City
SEA	Strategic environmental assessment

SEDP	Socio Economic Development Plan
SIHMETE	Sub-Institute of Hydrology, Meteorology and Environment, Ho Chi Minh City
SLR	Sea-level rise
SPRCC	Support Program to Respond to Climate Change
SRTM	Shuttle radar topography mission
SubNIAPP	Sub-National Institute of Agricultural Planning and Projection, Ho Chi Minh City
SUDs	Sustainable urban drainage systems
SVF	Sky view factor
SWH	Solar water heating systems
TP	<i>Thành Phố</i> = City
UCZ	Urban climate zone
UFA	Useable floor area
UHI	Urban heat island
UMT	Urban morphology types
UN-Habitat	United Nations Human Settlements Programme
UNDP	United Nations Development Program
UNEP	United Nations Environment Program
UNFCCC	United Nations Framework Convention on Climate Change
UNISDR	United Nations Office of Disaster Risk Reduction
URENCO	Da Nang Urban Environment Company Limited
USSH	University of Social Sciences and Humanities, Ho Chi Minh City
UST	Urban structure type
USU	Urban structural units
UTZ	Urban terrain zones
VNU-ITP	Vietnamese National University Information Technology Park, Ho Chi Minh City
WSUD	Water-sensitive urban design



# 1 Introduction

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## 1.1 Motivation

Widely identified as a key global challenge, climate change and its consequences are now generally seen as inevitable and unavoidable as outlined in the 2007 Fourth Assessment Report by the Intergovernmental Panel on Climate Change (IPCC, 2007a). Previously, the international response has focused mainly on the mitigation of greenhouse gas (GHG) emissions, to halt or minimise climate change in the long-term. However, the greater understanding of the significant locked-in shifts in climate variables forecasted for the 21<sup>st</sup> Century, together with the observed impacts of extreme weather and climatic events have represented a shift away from mitigation as the primary response tool.

Climate change research and policy now increasingly views adaptation<sup>1</sup> and disaster risk reduction<sup>2</sup> as necessary responses to proactively prepare for, and respond to the unavoidable impacts of climate change and are afforded the same level of priority as mitigation (Stern, 2006; Garnaut, 2008; IPCC, 2007; Mertz *et al.*, 2009). While different definitions of adaptation and disaster risk reduction are found across a range of studies, this dissertation considers disaster risk reduction as an intertwined element of adaptation to climate change, instead of an entirely separate scientific discipline. This is justified as reducing the risks of disasters and natural hazards as an effective long term form of adaptation, whilst exposure to climatic hazards is a common concern (IPCC, 2007b; UNISDR, 2008).

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<sup>1</sup> The IPCC (2001) defined adaptation as the adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. Moreover, Brooks (2003), definition of the term stressed that adaptation is an adjustment that enhances a systems ability to cope with external climatic stresses, whereas Willows *et al.*, (2003), understood adaptation as a process or outcome of a process that leads to a reduction in harm or risk of harm or realisation of benefits associated with climate variability and climate change.

<sup>2</sup> Disaster risk reduction can be defined as a conceptual framework and practice of reducing disaster risks through systematic efforts to analyse and reduce the causal factors of disasters (UNISDR, 2009). As such the concept of disaster risk reduction aids the planning, response and coping with or adapt to a range of natural and made-made hazards (Pelling, 2003; Turnbull *et al.*, 2012).

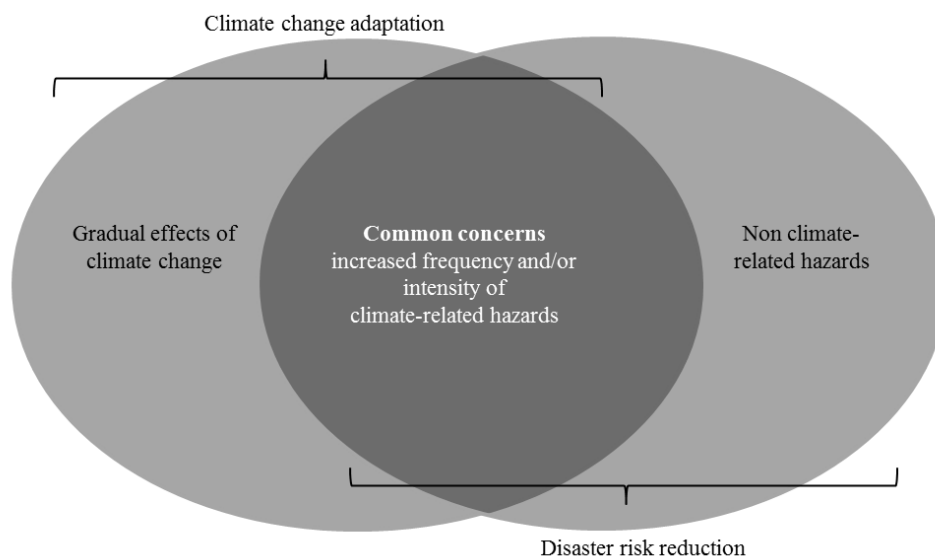


Figure 1–1 Common concerns of climate change adaptation and disaster risk reduction (source: adapted from Turnbull *et al.*, 2013)

Figure 1–1 elaborates the relationship between climate change adaptation and disaster risk reduction. The Figure highlights that there is a significant convergence between the problem fields of the two domains. Within a locality, already displaying a certain exposure to climate-related hazards, the effects will be at greater risk due to a projected increase in the frequency and/or intensity of hazards as a result of climate change. Climate change adaptation and disaster risk reduction also share a common conceptual understanding of the components that comprise and determine risk (Turnbull *et al.*, 2013).

The two domains regard risk as the product of both exposure and sensitivity either to hazard(s) or effect(s) of climate change, or both. In reducing climate change and disaster risk, exposure needs to be minimised, sensitivities reduced and capacities for coping and adaptation strengthened in ways that address both climate change and disaster risks concurrently.

Urbanisation has become a global megatrend and climate change is expected to have wide-ranging impacts to cities. Urban areas now house more than half of the world’s population and the majority of economic activity (UNPD, 2008). More than 90% of current urban population growth is taking place in developing countries and by 2030, it is estimated that almost 5 billion people (60% of the world’s population) will live in cities (UN, 2012; UN-DESA, 2012). The urban milieu has given rise to a large number

of megacities<sup>3</sup> and ensured that many of the most urgent challenges of our time have become urban challenges. Simultaneously, many cities are increasingly viewed as hotspots of disaster risk (Mitchell, 1999; UN-Habitat, 2011). Although difficult to attribute to climate change, natural disasters have become more frequent, deadly and costly to cities (Höppe and Grimm, 2008; Djalante, 2012; Peduzzi *et al.*, 2009). These events illustrate with increasing recognition the fragility of cities and the array of potential impacts from future climate variability (Betsill and Bulkeley, 2007; Dodman *et al.*, 2009; Dawson *et al.*, 2009; Rosenzweig *et al.*, 2010; Hoornweg *et al.*, 2011; Hallegatte and Corfee-Morlot, 2011; McEvoy *et al.*, 2006; Huq *et al.*, 2007; Revi, 2008; Boshier, 2015; Stone, 2012). With increasing scientific and policy discourse about the increasing risks that cities face from exposure to natural hazards, and the assumption that climate change will continue to exacerbate metrological events, cities, particularly megacities have risen in importance on the international climate and disaster risk agendas.

Historically, urban adaptation is not new. Cities are not static entities and in the course of their growth, they have tended to adapt in both their form and function to geographic and climatic conditions. Yet unprecedented urban growth, particularly in the form of rapid spatial expansion in developing countries, is a recent phenomenon. With high population densities, their importance for many socioeconomic activities and their roles as centres of administrative governance, cities play a critical role in the promotion of sustainable development. Well-governed, -designed and -constructed cities have the potential to be amongst the safest, most resilient, most socially just and sustainable places to live. Yet, in many countries with inherent development issues, where physical and social infrastructure is inadequate or weak and unsuitable to meet the future challenges of climate change, there is very a real threat that they will undoubtedly be among the worst positioned (UN-Habitat, 2007; Downes *et al.*, 2011; 2014). The very rapid urbanisation, a manifestation of ongoing modernisation processes accompanied by social-economic development, has often transcended the management capacity of governments in developing countries. This in conjunction with climate change and compounding disaster risks are imposing new constraints on urban planning.

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<sup>3</sup> The standard definition of a megacity is a city with a population exceeding 10 million inhabitants (Krass, 2007). This may be a single administrative urban area or two or more administrative areas that converge.

The study of the risks, climate change threats and variability to urban areas and of their ability to adapt to changes in climate hazards is a relatively new discipline that brings together experts from a wide range of fields. However, a large amount of research has been undertaken investigating the challenges that climate change poses to cities. Hunt and Watkiss (2010), identified and reviewed a number of likely potential climate change impacts, as well as benefits to cities, and stated that generally climate and disaster risks were exacerbated in urban areas. Furthermore, the three most recent IPCC reports in 2001, 2007 and 2014 draw conclusions on the effects of climate change to urban environments (Scott *et al.*, 2001; Wilbanks *et al.*, 2007; IPCC, 2014). Likewise, drawing on a number of studies in many parts of the world, it is suggested that inappropriate urbanisation seems to be the major driver behind increasing exposure to natural hazards (Dawson *et al.*, 2011; Storch and Downes, 2011; Swiss Re, 2014).

Figure 1–2 illustrates the broader context of social-economic development and the linkage between rapid urbanisation, natural disasters and climate change risks. The nature and extend of climate change and disaster risks to urban systems can be viewed as a combination of intrinsic factors related to the anthropogenic systems sensitivity and extrinsic factors related to the systems exposure to natural hazards. Climatic risks are a typical cumulative consequence, resulting through the coming together of many individual factors. Risks cannot occur if the elements at risk are not exposed. This connotes coincidence with hazard impact zones. There is no such thing as a 'natural' disaster, only natural hazards; where and in which ways cities grow can significantly affect the number of people and assets exposed to these various hazards. In this manner, planning decisions taken today can lock in risk profiles long into the future (Corfee-Morlot *et al.*, 2009; Bicknell *et al.*, 2012).

The process of urbanisation increases the concentration of populations in urban areas, which can lead not only to an increased exposure to hazards, but also to a rise in the concentration of populations, buildings, infrastructure and assets potentially exposed. Urbanisation additionally drives changes in land cover and land-use to both existing urban and peri-urban environments. This can lead to hydrological and microclimatic changes, which can intensify stormwater run-off and the effects of urban heat islands (UHI's).

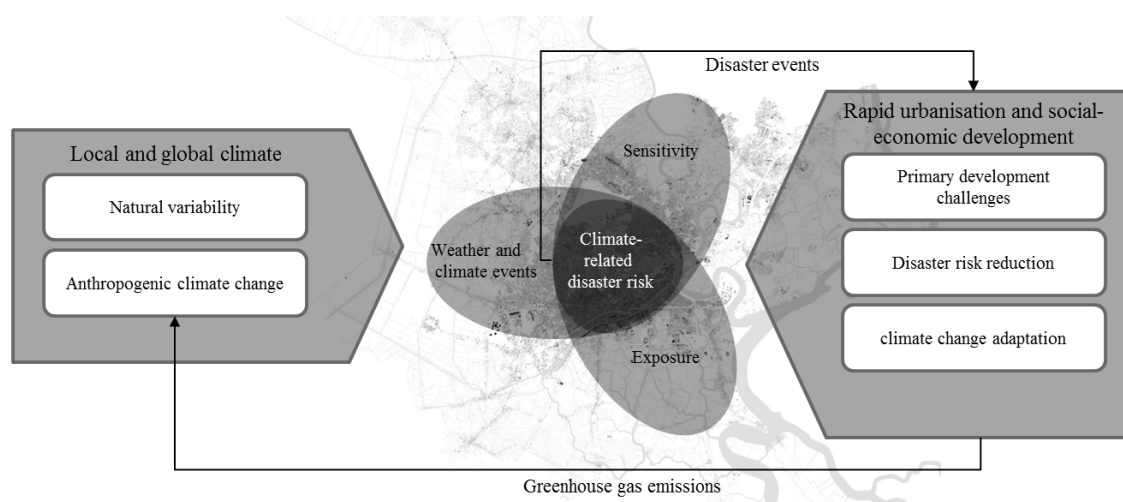


Figure 1–2 Links between rapid urbanisation, natural disasters and global and local climate change (source: adapted from Field, 2012)

The effects of climate change on urban systems are very complex and not static, thus cannot be assumed to be constant. As Lindley *et al.*, (2007) points out, the type of hazard, their spatial extend and their expected frequency and intensity cannot be predicted solely by relying on historical data. While urban disaster risk is a priority for adaptation policy, climate change impacts can be both gradually, slow onset trends (*i.e.* increase in the mean temperature or sea-level rise) and sudden and disruptive events such as changes in the intensity and frequency of extreme events (*i.e.* storms and heatwaves) (Wilbanks *et al.*, 2007; Corfee-morlot *et al.*, 2009).

Foresight is better than hindsight. Adaptation and disaster risk reduction policies must be both precautionary and forward looking to manage current, as well as future risks. In this context, although a large number of studies have generated knowledge to justify actions and generalise good practice principles, with an array of guidelines being developed, it has proved challenging for practitioners to translate these into more detailed practical recommendations for action. One of the main barriers for mainstreaming adaptation and disaster risk reduction in the context of on-going rapid urbanisation is that actions can only be undertaken once the nature of the impacts are well understood. This has resulted in a lack of policy relevant data for local end-users requirements (Adger *et al.*, 2005; Satterthwaite, 2007; Sanchez-Rodriguez, 2009; Birkmann and von Teichman, 2010; Fünfgeld, 2011).

Although advancements in climate science have provided a range of global circulation models with ever growing sophistication, and level of detail, allowing for more robust

ways to downscale climate change scenarios to regional levels, impacts are experienced locally. Global mean scenarios do not necessarily bridge the gap and provide the right information for urban decision-making at the local level (ADB, 2010). Furthermore, they cannot accurately simulate the likelihood of extreme events.

Numerous studies have highlighted a wide spectrum of possible adaptation and risk reduction responses. Figure 1–3 shows that several responses can be distinguished. At either end of the spectrum, responses can focus solely on confronting climatic impacts or addressing underlying non-climatic drivers of vulnerability *i.e.* exposure and sensitivity of the elements at risk. Only a few responses can be considered to cover a wider breadth of the spectrum. One of these is spatial planning. Both, Bulkeley (2006), and Wilson (2006), state that it is imperative for adaptive responses to be integrated into local development frameworks. Following Bulkeley and Tuts (2013), this dissertation considers adaptation and disaster risk reduction as a result of deliberate decision-making processes, consciously responding to current or projected climatic stimuli, within the context of the wider social, economic and political processes. In other words, policy decisions and measures at the urban-scale that facilitate the reduction of the adverse impacts of disasters and climate change.

Hecht (2009), differentiated three main means of adaptation relevant for spatial planning; spatial adaptation (including relocation), technical measures, and adjusting behaviour. Spatial adaptation comprises of decisions that directly deal with the spatial organisation of different types of land-use. Here, measures are the result of deliberate consideration of current and possible future exposures and/or sensitivities towards the effects of climate change and disaster risks, and adjusts the spatial distribution of land-uses.

The aim should be to avoid risks by locating certain types of land-uses in areas where their sensitivity towards the primary or secondary effects of exposure are low. As such, there is also mounting recognition of the vital role of formal spatial planning as a key public policy area, in particular the role that land-use planning approach plays towards climate change adaptation and disaster risk reduction (Burby *et al.*, 1998; Berke *et al.*, 2014).

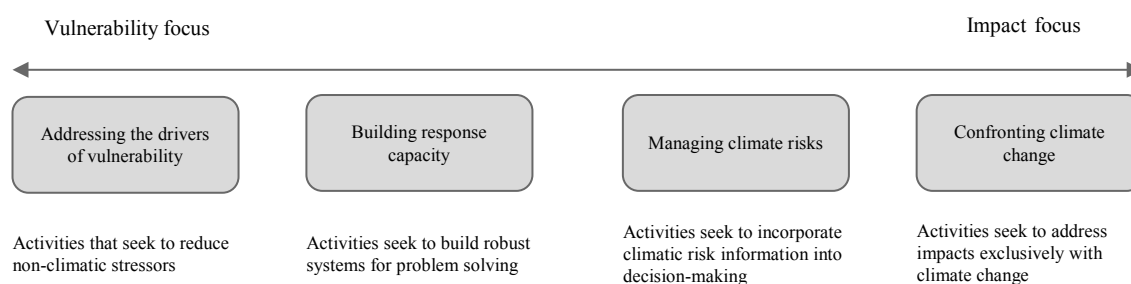


Figure 1–3 The adaptation and natural disaster spectrum (source: adapted from Klein and Persson, 2008)

Integrating climate change and disaster risk management into planning of urban growth pertains to proactive land-use and zoning, which can reduce the exposure of new and growing neighbourhoods. Furthermore, one of the benefits of land-use planning is that it is considered a relatively low cost, no regrets approach. It permits early action, which should be more cost-effective than responding retrospectively.

## 1.2 Research focus

Urban areas in the Southeast Asia are recognised as facing multiple shocks and stresses from disasters and climate change. Future climate change impacts are predicted to be unevenly distributed and represent real and urgent challenges to cities situated within climate sensitive inter-tropical low elevation coastal zones throughout this sub-region (IPCC, 2007; Nicholls *et al.*, 2008a; Fuchs, 2010). Threats are especially acute in the numerous rapidly emerging megacities of the sub-region. Distinctively, Vietnam is widely acknowledged as being increasingly exposed to effects of climate change and natural hazards with 70% of its population living in coastal areas and low-lying deltas (Bangalore and Veldkamp, 2016). The research focus of this dissertation originates from research undertaken within the framework of the “Megacity Research Project TP. Ho Chi Minh: Integrative Urban and Environmental Planning Framework – Adaptation to Global Climate Change”.

Located in southern Vietnam, within the Saigon-Dong Nai River basin, the administrative area of Ho Chi Minh City (HCMC) provides the geographic scope of this dissertation and an in-depth case study of a flood prone emerging megacity exhibiting growing exposure levels to climate and hydro-metrological hazards. As a centre of economy, culture, education and technology, the city has become Vietnam’s economic powerhouse and an important hotspot for direct foreign investment in Southeast Asia

(Schmidt *et al.*, 2013; Downes and Storch, 2014; Downes *et al.*, 2016). The city has been ranked within the top ten of cities worldwide to be at risk from climate change both in terms of exposure (McGranahan *et al.*, 2007; Nicholls *et al.*, 2008a), vulnerability (Hanson *et al.*, 2011) and potential (future) losses (Hallegatte *et al.*, 2013). These studies indicate that adaptation is a necessity.

Climate change, exacerbated by social-economic trajectories, is forecasted to aggravate the severity of the existing natural hazard exposure. The city is seen to be particularly susceptible to both current and future impacts of climatic change, mainly due to its specific geographic setting, its current development challenges, and its underlying rate of urbanisation (Storch *et al.*, 2011; Storch and Downes, 2011; 2014a; 2014b). Here climatic risks cannot be separated from development. Worryingly, if unaddressed, they may pose significant consequences that will infringe upon the overall functioning and liveability of the city as a whole, having the potential to reverse recent development gains.

As the definitions of climate change adaptation and disaster risk reduction both indicate, efforts should be made within the broader context of sustainable development. There is also an obvious relationship between climate change and climate-related hazards. At the international level, researchers have recognised this relationship and examined ways to confront both climate change adaptation and disaster risk reduction in a more coherent manner (O'Brien *et al.*, 2008; Birkman and von Teichman, 2010; Mercer, 2010). Despite stakeholder awareness in Vietnam, a major challenge hindering the effective combination of adaptation and risk reduction strategies in practice is the separate mandate of two national ministries, as well as insufficient data and knowledge regarding the local effects of climate change. Therefore, the necessity to integrate the issues of climate change and natural hazards in the sustainable development agenda requires that stakeholders and officials take a holistic view of the problems with an emphasis on risk adaptation and risk reduction. Within both regulatory and investment decisions, more attention should be paid to the questions of how, in what locations, in what form and at what densities future urban growth in HCMC should take place.

The city government took initial steps at the local level by developing strategies to address both climate change and disaster risks in line with National Target Programmes, at the same time addressing the current development challenges and future urban development needs. Climate change and natural disaster Action Plans were developed



and updated to implement concrete adaptation and actions to reduce disaster risks. However, these actions are often merely selectively employed by modifying and adding the wording of '*climate change*' to existing policy documents.

This leads logically to the main unanswered question of how the city administration can effectively and in a scientifically sound manner, integrate both climate change and disaster risk considerations into the current development agenda. Recommendations that are appropriate to the specific associated risks and development conditions need to be developed.

Since many of the main impacts of climate change exhibit a land-use dimension, such as the increased frequency of urban flooding events or the intensification of the already existing urban heat island (UHI) effect, land-use planning and controls can be viewed as the most appropriate risk management strategy (Storch and Downes, 2012; 2013; Downes and Storch, 2014). In principle, according to literature, land-use planning in HCMC should have a major role in reducing risk, yet in practice it lacks the capacity. The scale, pace and location of the growth makes the understanding of such landscapes and development patterns, as well as, the accentuation of risk critical. In HCMC, urban growth and land consumption indicators are just starting to be recognised in planning decisions, while a more regulatory use of core urban indicators is still limited (Storch and Downes, 2012).

HCMC is growing daily. As a result of the unprecedented rate of urban growth and despite the needs for up-to-date data, risks remain poorly understood and information needed for land-use planning and management is not updated frequently enough to accurately track change. The city is transforming faster than the drivers of change can be understood. At the same time, the local planning agency needs to reassess land-use planning policies in consideration to the current and anticipated challenges of climate change and urbanisation.

Relatively few assessment tools have been developed to spatially explicitly consider the urban climate, disaster risks and development challenges that face rapidly developing cities. Furthermore, studies on cities, disaster risks and climate change often overlook the multidisciplinary and complex nature of urban systems. Previous studies for HCMC consider the whole city as a single unit and neglected micro-level diversity, focusing solely on primary impacts. They generally failed to provide useful information to define policy strategies and measures. Climate change and disaster risks can and will vary

significantly within the city's administrative boundaries. For HCMC, climate risk data is needed that corresponds to the existing planning procedures and facilitates recommendations and meaningful guidance for adaptation actions that can be useful in planning decisions. In this manner, the local stakeholders need actionable information. Here the emphasis has to be placed on the obtainment and communication of understandable, up-to-date, area wide and spatially explicit information on location characteristics. The Hyogo Framework for Action (HFA) and the IPCC's fourth assessment report both emphasise the importance of understanding local risk patterns and trends before actions are undertaken (UNISDR, 2007; IPCC 2007).

In addition to the residing population, cities are defined by their geographical location, as well as, their built structures and densities – often the most apparent elements of physical and economic capital and development (Anas *et al.*, 1998; Downes *et al.*, 2016). While different areas in a city can face similar risks, the solutions will differ from one area to another. This is because the site-specific features of climate change and disaster risk management are highly local and scale dependant. Due to the large degree of spatial and temporal heterogeneity in HCMC, information is needed in regards to the determinants of biophysical exposure, the social economic sensitivity of the elements at risk and ultimately adaptation capacity functions to support planners and decision-makers in identifying hotspots and employing the most effective, locally-appropriate and acceptable responses.

In particular, density is an important issue in urban planning and management used to predict, describe and control land-use (Pont and Haupt, 2007; Fina *et al.*, 2014). The intensity of space taken up by the built structures that make up the urban environment has an important role in the shaping of urban form. Furthermore, there are well-studied, yet complex relationships between urban density and GHG emissions and between urban density and risk. Likewise, adaptation will vary across urban regions and will be greatly dependent on the availability of space in the form of land or built surfaces. In Vietnam, specifying planning densities is part of the legally based land-use planning system by which the state controls what may be provided. However, regarding HCMC, only sparse information is available about its size, structure and spatial distribution, or the dynamics of change to both its natural and built environments.

### 1.3 Overview of the research approach

Notwithstanding the importance of natural hazards and climate change, current and future risks to HCMC need to be first and foremost understood. Adaptation and disaster risk reduction is impossible without strong local knowledge about the likely changes. The urban landscape is a mosaic of structures. Risk is very dependent on location. One of the major steps of assessing spatial vulnerability is to understand the complex interaction of exposure, sensitivity and adaptive capacities in order to identify exactly what puts areas at risk.

In order to address the data needs of the local stakeholders of HCMC, the research outlines the development of a spatially explicit indicator framework based upon the detailed mapping of the actual HCMC urban structure types (UST). UST mapping is currently a commonly used tool in many German cities to support effective and efficient urban monitoring, management and planning (Heiden *et al.*, 2012). The approach has been used previously in many cities for the nuanced identification and categorisation of urban systems into distinct and analogical proportions of the major elements of urban heterogeneity—the built-up, the un-built up impervious and the pervious urban open and green spaces, as well as highlighting locations of critical infrastructure.

The concept of UST, which was established in the late 1980s and early 1990s in Germany, has since been applied to a wide range of German cities, as well as many other countries (Tang, 2007). The goal has commonly been to facilitate a deeper understanding of the relationship in the coupled anthropogenic-nature of urban systems, adding depth and functional meaning to land cover and land-use plans, detecting and evaluating the physical structure and composition of urban areas (Downes *et al.*, 2011; Li *et al.*, 2011). This approach linked to indicators provides comparable and comprehensible information towards specific planning goals. USTs typically comprise built structures in a defined area (groups of building, or mixes of building types) and are normally characterised by a range of features that describe their physical properties (*i.e.* construction materials), their environmental characteristic (*i.e.* climatic and hydrological properties) and their functional properties (*i.e.* land-use) (Paueit and Duhme, 2000). This dissertation investigates the potential of UST to structure HCMC in a manner that reduces the city's complexity into meaningful elements for adaptation and disaster risk reduction. The patterns within HCMC, resulting from numerous interacting factors and areas, are in a constant state of spatial temporal change.

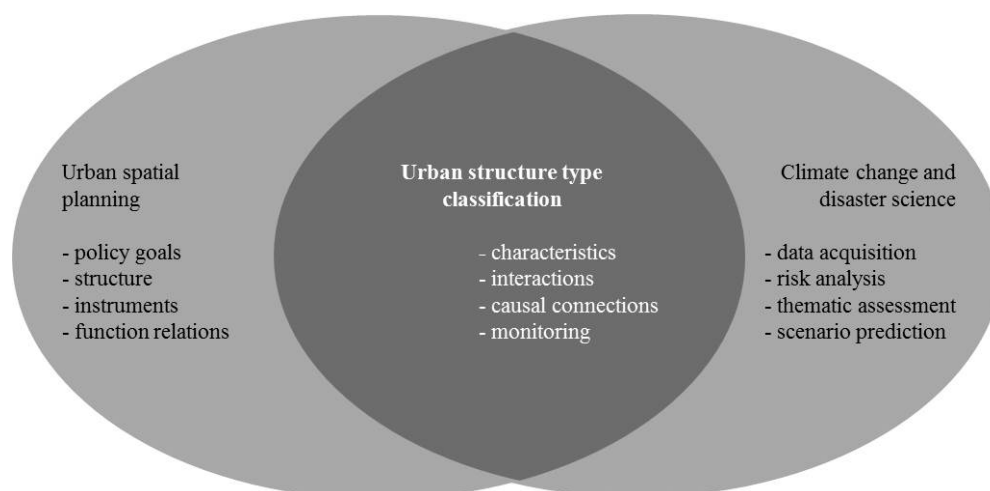


Figure 1–4 USTs as an interface between climate change, disaster science and urban planning (*source: adapted from Breuste et al., 2001*)

The differentiation of USTs and their change over time and space can then be used to describe the basic structure of the overall system, understand the main mechanisms and linkages at work (Figure 1–4).

This is important as the analysis of the total administrative area of HCMC, or the large administrative units, could not provide a fine enough differentiation and characterisation of the inherent heterogeneity of the city useful for adaptation. At the other end of the spectrum, the analysis of individual buildings would lead to a no longer controllable and interpretable complexity for stakeholders. This also led to questions about the most appropriate spatial level to act. Spatial planning strategies that focus on both risk reduction and adaptation strategies require information at a scale relevant to the area under investigation.

The most appropriate level to act and implement adaptation and risk reduction measures is very difficult, if not impossible to define. Yet, in order to understand and structure HCMC, it is necessary to subdivide the urban areas into smaller units independent from administrative boundaries. Pesaresi and Ehrlich (2009), state that at the basic level, urban areas are comprised of three fundamental properties: buildings, roads and open spaces. Focusing at the spatial scale of urban block, the UST classification provides a bottom-up context specific analytical lens to contend with the diversity of local conditions and to understand key concepts relating to urban adaptation and disaster risk reduction. As such, the work considers adaptation and disaster risk reduction as a development process and creates a framework flexible enough to consider the

complexity of land-use systems and the multidisciplinary analyses that climate change and disaster risks require— one that local stakeholders can relate to. Issues related to urban adaptation are best addressed when coordinated within a strategy conceptual framework and facilitated by a system of policy formulation that combines the local characteristics with scientific insights. This will benefit the assessment of current land-use arrangements, existing plans and aid the development of new strategies that involve modifying the form and function of land in response to risk. Beyond just providing an up-to-date assessment of current land-use patterns and building stock, this approach allows for the computation of core structural and density indicators useful in a range of climate and disaster risk assessments.

#### **1.4 Aim and objectives**

Aiming to remedy the current climate risk information deficit present in HCMC, this dissertation intends to assess the use of a UST classification for generating land-use planning data relevant in the specific context of urban climate change adaptation and disaster risk reduction. The current and future climate-related disaster risks facing Vietnam, as well as the data scarce and highly dynamic urban area of HCMC specifically, will be considered in depth. The current spatial planning system in HCMC and the data requirements for effective land-use planning are reviewed. This dissertation builds on recent studies involving the manual interpretation and classification of building archetypes, upon which a UST classification of HCMC will be developed. Selected obtained structural density indicators will be calculated and compared over USTs, paying particular attention to classification bias. Finally, in light of the scientific results, the UST classification will be evaluated for its potential effectiveness as a tool to support decisions regarding climate change adaptation and disaster risk reduction. The objectives of this research are therefore to:

- i. Examine the current urban and land-use planning approaches, management and key data requirements for effective planning in HCMC from both an institutional and governance perspective;
- ii. Develop a practical and improved building archetype, as well as an associated conceptual spatial UST classification framework, and to record USTs at the spatial resolution of the urban block to support the urban characterisation of risk and opportunities;

- iii. Calculate and assess the accuracy and suitability of risk-adapted land-use planning relevant density indicators for individual USTs;
- iv. Assess the current hazard exposure of individual USTs to varying sea-level rise scenarios and current flood risk;
- v. Examine the challenges and opportunities afforded by the developed UST framework to derive land-use planning relevant hazard generation and exposure information for monitoring spatiotemporal, social and structural changes that facilitate recommendations for climate change adaptation and disaster risk reduction within the context of rapid socio-economic development.

## **1.5 Expected outcomes and significance**

In Vietnam, climate change has become an important research topic. The major research fields have included social vulnerability to climate change (Adger, 1999; Adger and Kelly, 1999; Few and Tran, 2010); agriculture and food security and forest (Booth *et al.*, 1999; Wassman *et al.*, 2004; Mainuddin *et al.*, 2011; Vien, 2011; Garschagen *et al.*, 2011; Nguyen *et al.*, 2013; Le *et al.*, 2014) impact assessments (Carew-Reid, 2007; ADB, 2010); governance (Birkmann *et al.*, 2010; Garschagen, 2013) community-based adaptation (Shaw, 2006; Schinkel, 2015); disaster management and adaptation (Dang *et al.*, 2003; Nguyen 2007; Nguyen and Shaw, 2010; Danh, 2011; Thao *et al.*, 2014) . However, there are limited empirical studies on urban adaptation research at the local level, while, the integration of science-based research into the decision making processes has not been addressed fully.

This dissertation offers an improved understanding of adaptation to climate change in the context of rapid urbanisation, with the expectation that results will contribute to the current debate taking place in HCMC on how best to transform and respond to a changing climate and disaster risks within the context of rapid socio-economic development. The results are intended to support the HCMC administration, namely DoNRE, to establish a well-founded database with reliable information to overcome the current information deficit. The results are envisaged to function as a switchboard for adaptation and disaster risk reduction responses.

In terms of theoretical and academic contribution, the study develops and operationalises an integrated UST conceptual framework which incorporates structural

and socioeconomic factors in explaining climatic risks. The developed UST framework will provide a basis for the assessment of future development in term of hazard generation and hazard exposure. In this manner, future planning options can be founded on the basis of scientific findings and identify solutions of how best to respond to climate change while minimising the associated hazards. The developed UST framework, including the analysis, classified maps and statistical graphs delineating different urban structural units of the city, will advance and disseminate knowledge about the current and future hazards, elements at risk, and the different types of sensitives present. It can also aid the monitoring and evaluation of the environmental status and the future prospects for sustainable development in the city. In this sense, the results can contribute to sustainable development objectives, strengthening the existing urban governance, mitigating spatial disparities, minimising the risk divide within the city, and ensuring climate preparedness. The findings generate some policy implications for supporting effective adaptation and disaster risk reduction strategies which are beneficial to DoNRE and potentially applicable to both research and policy understanding in the urban environment of many further cities, where climate and socio-economic conditions are relatively similar to those in Vietnam.

## **1.6 Structure of the dissertation**

This dissertation comprises theory, methodology and application, and is structured into nine chapters which address the aforementioned aim and objectives of the research. The linkage amongst the Chapters of the dissertation is presented in Figure 1–5.

This dissertation begins with Chapter 1 which frames and provides a general overview and introduction into the research. The Chapter comprises the research background which motivates the investigation. The concepts that have shaped recent thinking and development in the area of urban adaptation and disaster risk reduction are then discussed. This Chapter also includes the research focus and scope of the study, as well as its methodology, the aim and objectives.

Chapters 2, 3 and 4, provide the theoretical and methodological discussions that are relevant to this research and the identification of research gaps. The first part of Chapter 2 is dominated by the analysis of the recent Vietnamese urbanisation, climate change exposure and disasters risks and their compound effects.

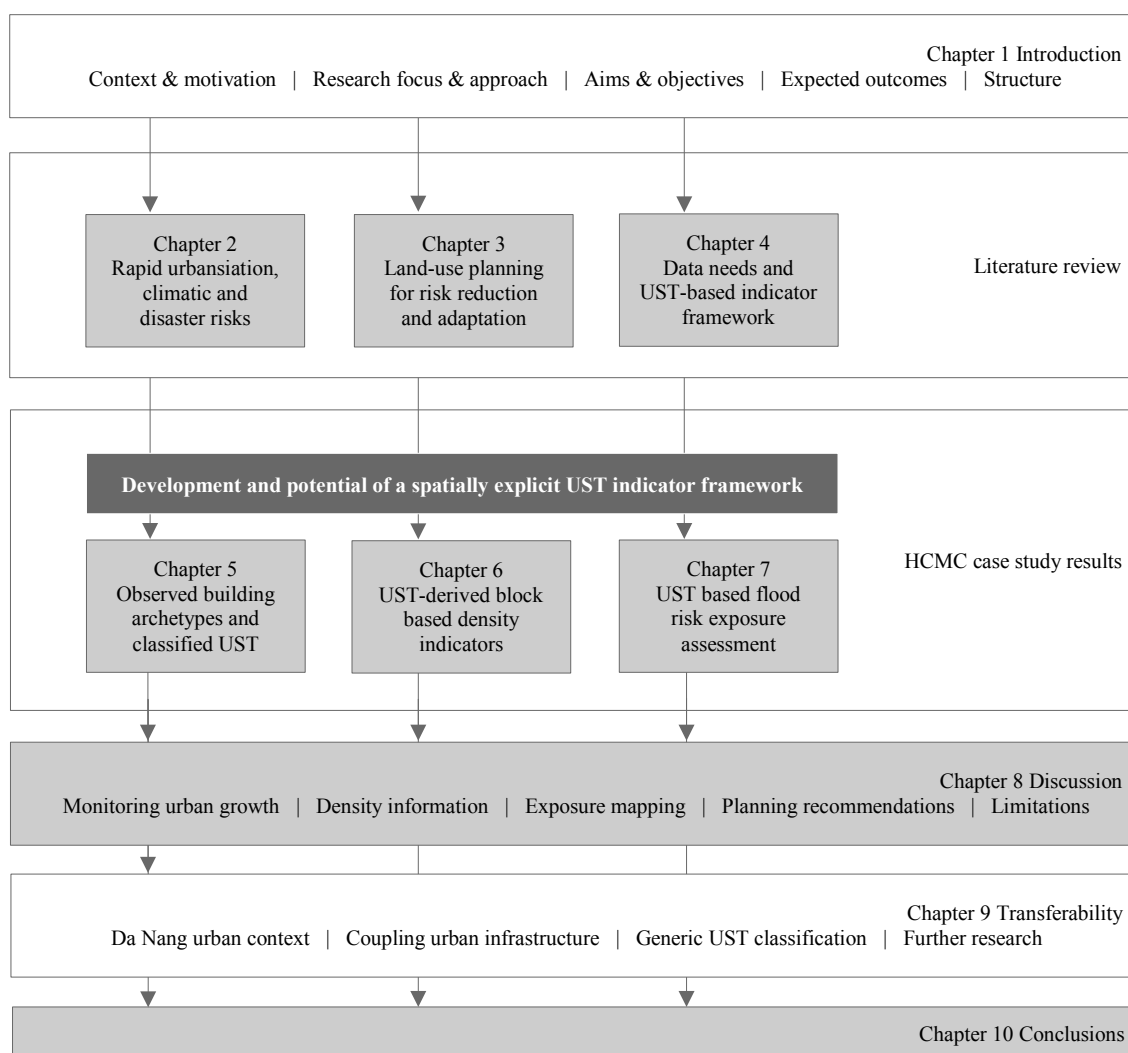


Figure 1–5 Structure of the dissertation (source: author's own)

The second part of Chapter 2, introduces the reader to the in-depth case study of HCMC. Attention is drawn to the recent spatial development and the way in which climatic risk is influenced by precarious growth. This has led to increased recognition of the need to address climatic risks in a development context and in an integrated and coordinated way. The final part of Chapter 2 addresses the national and local strategies and policies in place to address both climate change and disaster risk and the current implementation challenges and constraints at the local level. Whereas, in Chapter 3 the role and potential of land-use planning in HCMC for both disaster risk reduction and climate change adaptation are analysed and described in detail. An overview of the current practices and overall coordination of spatial planning and land-use planning in HCMC is given and the current constraints in decision-making for effective risk-based land-use planning are discussed.



Chapter 4 considers the spatial information needs and the significance of density indicators for land-use zoning. An emphasis is placed on the nature and use of density indicators in the context of policy- and decision-making with relevance for spatial adaptation and disaster risk reduction. General characteristics of indicators are highlighted and different types of indicators examined. Traditional data sources that are not coupled with increased knowledge to support spatial decisions are discussed before the Chapter introduces the UST methodology and reviews its use in previous studies. Finally, the Chapter ends with the outline of the conceptual structure and development of an UST based indicator framework based on the classification of HCMC's urban structures. This innovative methodology allows the understanding of spatial processes and their temporal dynamics.

Chapter 5 takes a look at the methodology for the UST classification of HCMC. First, the observed building archetypes are outlined and their relationship to the developed UST classification. The main categorised residential USTs and their spatial distribution over HCMC are described in detail. Finally, the Chapter outlines the distribution of green and open USTs in HCMC as well as compares the actual use derived from the UST classification to planned land-use for the city.

Chapter 6 outlines and discusses the selected UST derived indicators of building density, building height, ground coverage ratio (GCR), gross floor area (GFA), building volume, floor area ratio (FAR), population density, gross floor area per person, total soil surface sealing. In standalone sections, each indicator, in turn, is described and a clear definition is given. The key issues of its relevance for climate change and disaster risk reduction, as well as urban sustainability in HCMC, are outlined. The obtained block-based indicator results are spatially represented and interpreted. Chapter 7 highlights an assessment of the sea-level rise and current flood exposure to the classified USTs in terms of area exposure, percentage of UST and population exposed. On the back of this assessment, the Chapter presents broader conclusions and policy responses for the city.

Chapter 8 discusses, evaluates and draws together the key findings of the dissertation. The UST method is critically discussed, as well as the obtained results. This Chapter examines the utilisation and potential of the spatially reference UST classification to characterise, map and monitor with high thematic detail, the spatial structural and functional environment of HCMC. The experience and the applicability of the developed conceptual framework and risk based indicators for the development of

planning recommendations is documented and evaluated. The research constraints and known limitations are additionally discussed.

The penultimate Chapter, Chapter 9 outlines the transfer and application of the UST classification to the local conditions of the central Vietnamese city of Da Nang. On the basis of lessons learnt, the Chapter tests the applicability of USTs to investigate the relationship between the four infrastructure domains of energy, water and wastewater, solid waste and urban agriculture at the block scale. The Chapter concludes with proposing a generic UST classification scheme, widely transferable and applicable to other cities outside of Vietnam.

Finally, upon the basis of the overall findings of the dissertation a number of conclusions are given in Chapter 10. This Chapter contains an outlook, which includes reflections on the potential of UST classifications as a method for improved data actuations in the context of rapid urbanisation and a changing climate.

## 2 Background

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### 2.1 Urbanisation, climate change and disaster risks in Vietnam

Urbanisation in Vietnam is predominantly coastally oriented. With a coastline of over 3,200 kilometres in length, more than half of Vietnam's population is distributed in high concentrations within the "mega deltas" of the Mekong and Red River, and in low elevation coastal zones (LECZ<sup>4</sup>) along the breadth of the country. The Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report characterised Vietnam as a —"Hotspot of key future climate impacts and vulnerabilities in Asia" (Solomon *et al.*, 2007). The Stern review on the economics of climate change confirmed Vietnam's high vulnerability to the impacts of climate change while a number of global comparative studies addressing the impacts of climate change have also ranked Vietnam within the top rung of countries in terms of exposure to risk (Stern, 2007).

#### 2.1.1 Climate change exposure in Vietnam

In the first global review of population and urban settlement patterns in LECZ's undertaken by McGranahan *et al.*, (2007), Vietnam was classified amongst the top ten countries ranked in terms of both the total and the actual share of land and population located in low-lying coastal areas below 10 m above mean sea-level (AMSL). A further comparative study by the World Bank, published in the same year (Dasgupta *et al.*, 2007), investigated the impacts of a number of sea-level rise (SLR) scenarios, ranging from 1 m to 5 m for 84 coastal low-income developing countries. Here Vietnam was ranked within the top five countries worldwide to be most affected by SLR. This study noted that a 1 m rise in sea-level predicted for the year 2100 would directly result in a loss of more than 5% of the country's land area and more than 7% of agricultural lands, more than 10% of gross domestic product (GDP), 28% of wetlands; and impact 10.8% of the total population and urban areas (Dasgupta *et al.*, 2007). They ranked Vietnam first in terms of impact on population, GDP, urban and wetland areas, as well

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<sup>4</sup> LECZ is defined as a contiguous area along the coast that is less than 10 m above mean sea-level (McGranahan *et al.*, 2007).

as, second in terms of impact on total land area (behind only the island nation of the Bahamas) and agricultural land extend (behind only Egypt). Vietnam was also ranked fourth behind China, India, Bangladesh, for the largest absolute total number of people living in LECZs.

McGranahan *et al.*, (2007) estimated that approximately 55% of the overall population and 38% of the urban population, or 43 million Vietnamese reside in the LECZ. They stated that this was the highest percentage of all countries worldwide. According to Solomon *et al.*, (2007) a SLR of 1 m AMSL for Vietnam would lead to flooding in the Mekong River delta, a land area of up to 20,000 km<sup>2</sup> and of up to 5,000 km<sup>2</sup> in the red river delta. For the Mekong delta, over 1 million people would be directly affected and a flood of this extent would have severe implications for rice production in what are intensely cultivated low-lying areas<sup>5</sup> (Wassermann *et al.*, 2004).

Moreover, the extensive study on urban flood risk carried out by the Organisation for Economic Co-operation and Development (OECD) (Nicholls *et al.*, 2008b), focused on the current and future exposure to coastal flooding of 136 key worldwide port cities. It reaffirmed Vietnam's rank amongst the top five countries endangered, and additionally ranked the river port city of Ho Chi Minh City (HCMC) amongst the top five cities in terms of the largest exposed population by the year 2070. Hanoi was excluded from the assessment as it is not currently classified as having a port; however Hanoi's *de facto* port city Hai Phong was included and ranked also within the top ten in terms of population exposure. Additionally, taking into account both climate change and socioeconomic change Hanson *et al.*, (2011) investigated the same 136 port cities, ranking HCMC sixteenth in terms of assets exposed to coastal flooding by the year 2070 to a 1 m SLR.

Hallegatte *et al.*, (2011) assessed current and future economic average annual losses in 2005 and compared them to those expected 2050 with a 1 m SLR for the same 136 port cities. Taking into account all potential floods and existing protection measures, they ranked HCMC thirteenth for average annual losses and fourth according to relative vulnerability, which the authors defined as the ratio of average annual losses to the city's gross domestic product (GDP) for the year 2005. Here, Hai Phong was ranked eleventh. For the year 2050, HCMC is ranked within the top 20 cities with the highest

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<sup>5</sup> The Mekong Delta region is often termed the country's "rice basket" that accounts for half of the country's rice and more than half of its fisheries and fruit products (MARD, 2008; UNDP, 2007).

losses in 2050, assuming a SLR scenario of 1 m AMSL and adaptation options that maintain current flood probability levels.

All the above mentioned studies identified Southeast Asia as the flood-prone region with the greatest need for urgent policy measures. Most of these global assessment studies themselves are mainly responding to urgent policy needs by identifying countries and urban areas that are the most vulnerable to climate change (Storch and Downes, 2011). Despite the limitations of the global datasets used, the results are frequently used by both national policy-makers and international donor organisations for the informed targeting of financial resources towards adaptation measures to be undertaken within Southeast Asia.

Nationally, in 2009, the Vietnamese Ministry of Natural Resources and Environment (MoNRE) published the report “climate change, sea-level rise scenarios for Vietnam”. The report outlined climate change projections developed from three different global emission scenarios taken from the Fourth Assessment Report of the IPCC (MoNRE, 2009). The low (B1), medium (B2) and high (A2 and A1F1) scenarios were chosen and detailed changes in temperature, rainfall and sea-level over the period 2020 to 2100<sup>6</sup>. The published results in 2009 showed forecasts at the regional level and were updated in 2012 with on hand data from additional monitoring stations for each province (MoNRE, 2009; 2012). The updated climate change scenario report also provides trends in climate extremes.

For the purpose of impact assessments and adaptation planning, MoNRE officially proposes the use of the medium B2 scenario (MoNRE, 2012). According to MoNRE climate change is reported as being already very evident in Vietnam with the average temperature increasing between 0.5 to 0.7°C, the number of hot days and hot nights significantly increasing and sea-level increasing by ca. 0.20 m over the period 1958–2007<sup>7</sup> (MoNRE, 2009). As shown in Table 2–1, MoNRE (2009; 2012) projected sea-level to rise at an increasing rate over the period 2020–2100.

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<sup>6</sup> As climate change predictions incorporate the results of many physical and chemical models, each containing their own uncertainties and errors, the high level of uncertainty about the projections under scenarios should be noted. National and regional climate change scenarios, as these mainly consist of simplistic downscaling of global scenarios, based on model-driven scenarios with limited variables.

<sup>7</sup> It should be noted that these findings of past changes both in terms of average temperature and increasing sea levels in Vietnam over the last 50 years are often challenged by scientists working outside of MoNRE and IMHEN Vietnam on the grounds of insufficient measurement validity.

Table 2–1 Sea-level rise scenarios for Vietnam (*in cm*)

Emission scenarios		2020	2030	2040	2050	2060	2070	2080	2090	2100
High A1F1	High	11.6	17.3	24.4	33.4	44.4	57.1	71.1	86.1	101.7
	Average	6.5	9.7	13.6	18.5	24.4	31.0	38.1	45.4	52.9
	Low	2.6	3.9	5.6	7.6	10.0	12.6	15.2	17.8	20.3
Medium B2	High	11.7	17.1	23.2	30.1	37.6	45.8	54.5	63.8	73.7
	Average	6.6	9.5	12.7	16.2	19.9	23.9	28.0	32.4	37.0
	Low	2.6	3.7	4.9	6.1	7.4	8.7	10.1	11.5	12.9
Low B1	High	11.9	17.5	23.1	30.9	38.3	45.9	53.7	61.5	69.0
	Average	6.7	9.7	13.0	16.5	20.1	23.7	27.2	30.5	33.6
	Low	2.7	3.8	5.0	6.2	7.4	8.5	9.4	10.2	10.8

(source: MoNRE, 2012)

Models run using the IPCC highest emission scenario of A1F1 estimate a global maximum rise in mean sea-levels of 59 cm by 2100, due to the thermal expansion of warmer sea water. According to the B2 medium scenario utilised by the Government of Vietnam for planning purposes, the official Vietnamese prediction, which takes into account some melting of land ice masses, is approximately 30 cm by 2050 and up to 75 cm by 2100 under the B2 medium scenario (MoNRE, 2009). Beyond this however, Vietnams own planning parameter is a 1 m SLR by the year 2100, which is consistent with the predictions according to the A2 high emission scenario, whilst accounting for some melting of land ice. Without major action, a 1 m SLR would cause an estimated threat of undulation to 5.3% of Vietnams total land area (IMHEN, 2010a), submerge 11,000 km of roads (MoNRE, 2010) and cause significantly increased saltwater intrusion (IMHEN, 2010b).

MoNRE projected in 2012 an average temperature rise in Vietnam by 2100 of about 2–3°C compared to the last decades of the 20<sup>th</sup> Century. While according to the A2 high emission scenario, the average annual temperature rise could be as much as 3.7°C by 2100 for some central provinces. Furthermore, according to the B2 medium emissions scenario, the number of “excessively hot” days above 35°C will increase by 15–30 days. In terms of rainfall, overall, annual rainfall is expected to increase everywhere in Vietnam. An increase of 7–8% for northern Vietnam and a smaller increase of 1.5–3% for southern Vietnam is expected from the B2 medium scenario. Yet it is projected that the distribution of rainfall over seasons will change with the dry seasons projected to become drier and the wet seasons projected to get wetter. Hence the rainfall pattern will

become more concentrated than at current, which may lead to an increase in extreme rainfall events and in the frequency, intensity and duration of floods and an exacerbation of drought in the dry season. Especially in combination with extreme hot days above 35°C this will lead to an increased drought risk (MoNRE, 2003; 2012).

### **2.1.2 Disaster risks in Vietnam**

Irrespective of a shift in climate, due to the combination of Vietnam's geography, topography and current climatic conditions, the country has a long history of coping with natural disasters and mitigating their impacts (Few and Tran 2010; Imamura and Dand, 1997; UNDP, 2004; UNISDR, 2011). As Table 2–2 highlights, Vietnam is highly exposed to multiple natural disasters, including typhoons, flooding, landslides and droughts (MARD, 2008). The country is situated at the end of one of the most powerful typhoon tracks globally and virtually no stretch of the country's coastline can be termed typhoon free (Hoang *et al.*, 1998; Yusuf and Francisco, 2009; Kelly and Adger, 2000). On average, between the years 1954 and 2000, 6.9 typhoons per annum made landfall along Vietnam's coast (UNDP, 2007). The high winds, but also the storm surges and heavy rainfall associated with these events have caused vast amounts of damage.

In 2005 the World Bank classed Vietnam as a “Natural Disaster Hotspot” with over 71% of the population exposed to some sort of risk of hydro-metrological event and an estimated 59% of its total land area (Dilley *et al.*, 2005). Globally in this study, Vietnam was ranked seventh for economic risk, ninth for the percentage of land area and population exposed, yet only twenty-second on mortality from multiple hazards (Dilley *et al.*, 2005).

The Disaster Risk Index (DRI) development by the United Nations Environment Program (UNEP) Division of Early Warning and Assessment Global Resource Information Database project under contract to the United Nations Development Program (UNDP) additionally ranked Vietnam fourteenth for cyclone mortality risk and eleventh for drought mortality risk (Mosquera-Machado and Dilley, 2009). Vietnam's capacity to respond to hydro-meteorological disasters has been recognised internationally. In spite of disaster prevention programmes, damage caused by natural disasters in Vietnam has increase exponentially over the last two decades (Nguyen and Shaw, 2010).

Table 2–2 Typology of climate related natural hazards by region in Vietnam

Region of Vietnam	Disaster zone	Principle Disaster Hazards
North	Northern Uplands	Flash floods, landslides, earthquakes
	Red River Delta	Monsoonal river floods, typhoons, coastal storm surges
Central	Central Coast Provinces	Typhoons, storm surges, flash floods, droughts, saline water intrusion
	Central Highlands	Flash floods, landslides
South	Mekong River Delta	River flooding, typhoons, high tides and storm surges, salt water intrusion

(source: CCFSC, 2001)

The costs of disasters have been increasing fast. The climate risk index developed by Germanwatch, and comprising of GDP losses and deaths as a result of past climatic extremes ranked Vietnam sixth globally over the time period 1990–2010. During these twenty years 457 deaths and a loss of 1.2% of GDP occurred on average annually as a direct result of disasters (Harmeling, 2011; MARD, 2008). Recent flood events solely in the Mekong Delta have been especially devastating. In 2000 and 2001, respectively 481 and 393 people perished – the majority of which were children; about 900,000 houses were damaged in 2000 and 350,000 in 2001. While the floods in 2011 caused 85 deaths - out of which 75 were children, with 177,000 houses being damaged (MARD, 2008). Table 2–3 shows the worst single natural disaster events for Vietnam for each of the years 1999–2008.

Table 2–3 Major natural disasters in Vietnam from 1999–2008

Year	Event	No. of Deaths	Economic Loss (VND billion)	Area affected
2008	Storm Kammuri	133	1,939,733	9 North & Central provinces
2007	Storm Lekima	88	3,215,508	9 North & Central provinces
2006	Storm Xangsane	72	10,401,624	15 Central & Southern provinces
2005	Storm No. 7	68	3,509,150	12 North & Central provinces
2004	Storm No. 2	23	298,199	5 Central Provinces
2003	Rains & floods	65	432,471	9 Central Provinces
2002	Flooding	171	456,831	Mekong River Delta
2001	Flooding	393	1,535,910	Mekong River Delta
2000	Flash flood	28	43,917	5 Northern provinces
1999	Floods	595	3,773,799	10 Central provinces

(source: MARD, 2008)



### 2.1.3 Demographic and urbanisation trends and the interplay with risks

The Vietnamese housing census in 2009 confirmed that the country is currently undergoing rapid socio-economic transformations manifested predominantly as urbanisation. At the national level, urbanisation in Vietnam stagnated during the 1979–1989 period but grew from 1989 to 1999 as a result of economic reform policies. During the twenty-five year period from 1990–2015, the population increased by 25.6 million. Specifically, the urban population rose from 12.8 million or 19.5% of a total population of 66 million, to an urban population of 31.1 million or 33% of Vietnam’s total population of 91.7 million in 2015 (GSO, 2009; 2015). Figure 2–1 shows that by the year 2045, it is forecasted that 56% of a total Vietnamese population of 108.1 million will reside in urban areas or cities (GSO, 2011). Population growth for the period from 2000–2010 was fastest in Vietnam’s largest cities of Hanoi and HCMC, their surrounding regions and some secondary cities such as Da Nang. With a few exceptions, small cities grew the least or lost population (GSO, 2011). In the same period, the urban population grew at an average rate of 3.4% per year, while the rate for rural population growth was only 0.4% per year. The urbanisation level of Vietnam is far below those of developed countries and the world average, remaining relatively low compared to other Southeast Asian countries (Table 2–4).

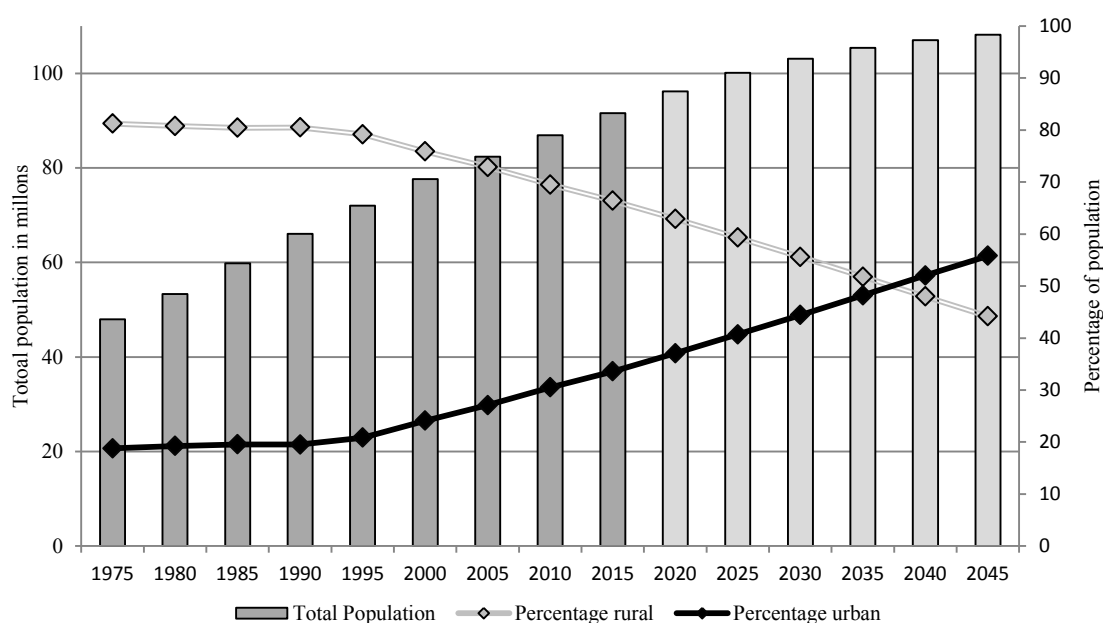


Figure 2–1 Total population growth and urban and rural population trends in Vietnam from 1975–2015 and forecasted growth from 2015–2045 (light grey) (source: data from GSO, 2009; 2011; 2015)

Table 2–4 Comparison of urban populations as a percentage of total populations (2010)

Country/ Region and urban population as a percentage of total population in 2010					
China	46	Laos	32	Vietnam	30
Japan	66	Malaysia	71	Bangladesh	27
Mongolia	62	Myanmar	22	India	30
Cambodia	20	Philippines	49	Pakistan	36
Indonesia	44	Thailand	33	Sri Lanka	14
World					51
Developed countries					75
Asia					42

(source: data from UN-DESA, 2009)

The Natural Hazard Risk Atlas 2012 and the index of the vulnerability to the impacts of climate change developed by the UK-based global risk and strategic consulting firm Maplecroft ranks Vietnam among the list of ten countries most at risk of natural hazards relative to an economic exposure index. Their index evaluates 43 social, economic and environmental indicators to assess national vulnerabilities across three core areas, (1) the exposure to climate-related natural disasters and SLR; (2) human sensitivity, in terms of population patterns and development; and (3) future vulnerability considering adaptive capacity of governments and infrastructure to address climate change effects. The index ranked Vietnam 13<sup>th</sup> globally and classified it as 1 of 24 countries at extreme risk over the next 30 years (Maplecroft, 2012).

The above cited global comparative studies of climate change impacts all evaluate the exposure of coastal regions, countries or urban areas to SLR; some include additional factors such as intensification of storm surges and land subsidence (Dasgupta *et al.*, 2009; Nicholls *et al.*, 2008a; Nicholls *et al.*, 2008b; Hallegatte, 2011). This focus has undoubtedly arisen due to a greater certainty about sea-level rise scenarios linked to future climate change in contrast to the difficulties in predicting many of the other likely climate impact variables and associated phenomena such as increased frequency of natural disasters, like typhoons, floods, heat waves and droughts (Hunt and Watkiss, 2011). Likewise, most studies tend simply to extrapolate the changes in the vulnerability of exposed elements without assessing the likely changes in vulnerability in sufficient detail. However, such transformations as on-going urbanisation and land-use changes can exert great control over both potential positive or adverse impacts to

levels of exposure as well as adaptation and coping potentials. Whatever the methodological constraints imposed or quality of datasets used, all rankings of countries for past disasters, disaster risks, climate change exposure or climate change vulnerability rank Vietnam amongst the more or most vulnerable countries.

The occurrence of disasters in Vietnam is expected to be exacerbated and compounded by the effects of climate change. Climate change is likely to worsen the frequency, severity and intensity of hydrometeorological events (Solomon *et al.*, 2007). Vietnam must recognise that some impacts of climate change are unavoidable, and as such, there is an urgent need to strengthen the current climate change adaptation and disaster risk reduction programmes and to start adapting the mega-urban regions and LECZ to the current impacts and the predicted impacts of climate change. While a proportion of the population residing in the mega-urban regions and LECZ maybe at an elevation that is above the currently predicted scenarios for SLR for Vietnam, these areas as Guzman *et al.*, (2009) points out often still lie within the reach of cyclones, storm surges and other indirect impacts of sea-level rise. Dasgupta *et al.*, (2007) and McGranahan *et al.*, (2007) both highlight that even a small increase in SLR can significantly heighten the impact of storm surges, as the impacts are amplified when they occur in combination with high tides or high river discharges. A higher sea-level provides storm surges with a higher ‘launch point’ for the surge, which may increase both the real extent and the depth of the surge in areas already vulnerable to coastal storms. Likewise, a number of studies suggest that an increase in sea surface temperature is likely to lead to an increased frequency of typhoons occurrences and also higher wind velocities once they occur (Lighthill *et al.*, 1994; Houghton *et al.*, 1996).

The damage potential from natural hazards should they occur appears to be on the rise as a result of increased population density in exposed areas as well as increased high value economic infrastructure in these areas. Asia’s urban population as a percentage of the world’s total urban population has increased from, 31% in 1950 to 50% in 2009 (Zhu, 2012). Asia urbanised much faster than the rest of the world in the last 60 years and Southeast Asia’s population for example, has been growing faster in the last 50 years than the World average. Table 2–5 highlights that Vietnam’s overall population density has risen significantly. Naturally, the population is unevenly distributed and the cities have even greater densities.

Table 2–5 Population density in the world and Southeast Asian countries (*person per km<sup>2</sup>*)

Region/country	1950	% of world average	2010	% of world average
World	19	100	51	100
Asia	44	232	131	257
Southeast Asia	40	211	131	257
Bangladesh	305	1,605	1,142	2,239
Philippines	67	353	312	611
Vietnam	83	437	268	525
Thailand	40	211	133	261
Indonesia	42	221	122	239

(source: data from Population Division United Nations, 2009)

Vietnam in 2010 had a population density five times higher than the world average, however as Table 2–5 suggested with urbanisation levels still far below its Asian peers and as further economic development is to a great extent equivalent to industrialisation and urbanisation, urbanisation is set to continue (Yeung, 2011). A central question is, how prepared is Vietnam for an urban future. The concern is that a change in the spatial demography will influence the exposure to hazards and that a transition to an increasingly urban Vietnam along current trends with continued population concentrations in LECZs will be accompanied with environmental degradation and by growing vulnerabilities and exposures to both assets and populations. A recent Asian Development Bank report even suggests the urban population of Vietnam who are at risk of multiple hazards, including climate hazards may more than triple from 21.2 million in 2000 to 68.4 million in 2050 (ADB, 2012).

The impacts of climate change for Vietnam are potentially disastrous and demand planning responses. While the precise extent of future climate change impacts are for Vietnam currently uncertain and difficult to predict, especially downscaled to the subnational and urban level, MoNRE (2009; 2012) both concluded that climate change and its affects for Vietnam are occurring at a faster rate than were previously forecasted. As such assessing the potential impacts of climate change and how best to adapt growing urban centres represents a new challenge for Vietnam, for which the country's past experiences in designing and implementing measures to mitigate the efforts of natural hazards on agriculture and other sectors may act as only a limited guide to steer actions.

## 2.2 Ho Chi Minh City: The challenges of an emerging megacity

The emerging megacity of Ho Chi Minh City (10°49' N, 106°37' E), formerly known as Saigon<sup>8</sup> and often abbreviated as HCMC, has recently been characterised by rapid environmental and socio-economic transformations. It has experienced the fastest urbanisation, industrialisation and most rapid population growth of all cities in Vietnam. For the city, urbanisation and climate change, individually and collectively, are a prompt and ever-growing challenge. Figure 2–2 overleaf, shows the city's location in the Dong Nai River system on the northeast of the Mekong delta and only fifty-seven kilometres up-river from the South China Sea, the city has undergone unprecedented urbanisation and development since the late 1980's.

HCMC is Vietnam's most populous city, almost twice the size of Hanoi, the capital. It has become Vietnam's economic and commercial hub and a hotspot for direct foreign investment (FDI) (Table 2–6). An important port city for Southeast Asia and beyond, the city contributes the dominate share to the national GDP. In fact, the city's economic activity and influence spills over into many of the adjoining provinces of Dong Nai and Ba Ria-Vung Tau to the Southeast, Binh Duong to the north, Long An in the west and southwest. The resulting area is sometimes collectively referred to as the Greater Ho Chi Minh Metropolitan Area.

Table 2–6 Population, GDP, FDI, and monthly income comparison of HCMC and Vietnam (2000–2015)

Year	Ratio population HCMC – Vietnam (%)	Ratio GDP HCMC – Vietnam (%)	Ratio Foreign direct investment HCMC – Vietnam (%)	Ratio Monthly income per capita HCMC – Vietnam (%)
2000	6.8	17.2	-	-
2001	6.9	17.6	19.7	-
2002	7.0	18.0	10.4	253.9
2003	7.2	18.4	9.9	-
2004	7.4	19.1	10.0	240.5
2005	7.6	19.6	9.4	-
2006	7.8	19.5	13.5	232.5
2007	8.0	20.0	10.9	-
2008	8.2	19.4	11.7	220.2
2009	8.4	20.0	4.5	-
2010	8.5	20.1	9.5	197.3
2011	8.6	20.2	19.0	-
2012	8.6	20.3	3.3	182.6
2013	8.7	21.3	5.0	-
2014	8.8	21.6	15.9	183.5
2015	8.9	22.8	12.6	-

(source: GSO, 2015)

8 Ho Chi Minh City, formerly known as Saigon, was founded in 1698. After reunification in 1975, Saigon was renamed Ho Chi Minh City. HCMC was originally a small fishing village inhabited by the Khmer known as Prey Nokor (meaning “forest city” or “forest land”) before the arrival of the first Vietnamese migrants from the North in 1698 (Vo, 2007).

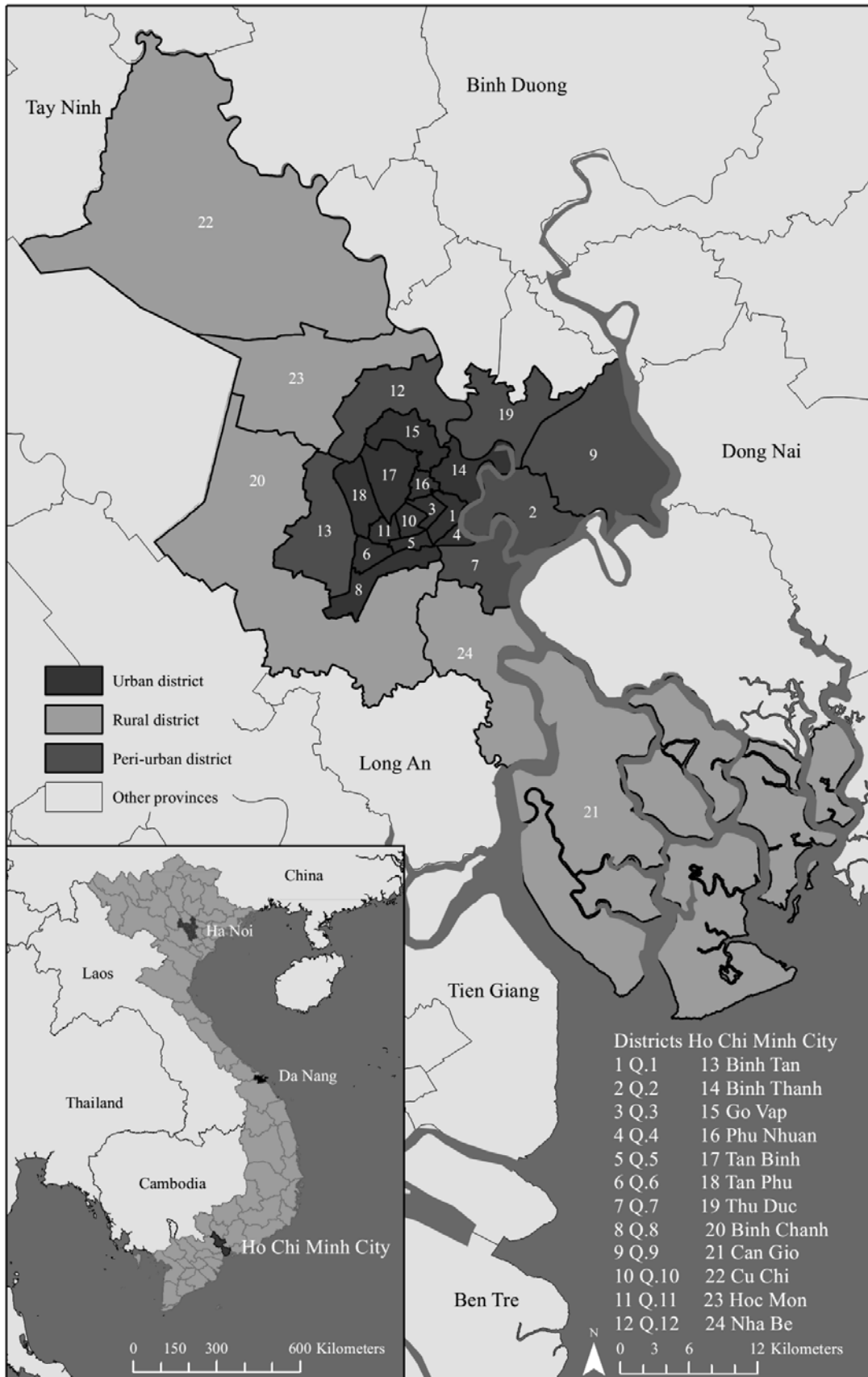


Figure 2-2 Map of HCMC showing the location of urban, peri-urban and rural districts (source: author's own)

With a large growing population and, much regionally and nationally critical infrastructure, the city has been considered a hotspot of vulnerability to the impacts of climate change (Nicholls *et al.*, 2008a; Nicholls, 1995; ADB, 2010; Carew-Reid, 2007; Dasgupta *et al.*, 2007; Birkmann *et al.*, 2010; World Bank 2010a, 2010b; Webster and McElwee, 2009; Fuchs, 2010; Fuchs *et al.*, 2011; Hanson *et al.*, 2011). Recently, the need to adapt to these multiple stressors of rapid urbanisation, hydro-meteorological hazards, and future climate change has become increasingly evident. Worryingly, these current stressors if not addressed adequately, pose significant consequences and present further challenges that will infringe upon the overall urban functionality and liveability of the city as a whole.

### **2.2.1 Demographic and spatial development of Ho Chi Minh City**

The recent transformation of HCMC during the last 20 years has been intrinsically related to the process of rapid industrialisation following the Doi Moi reforms of 1987 (also known as the *renovation*—market liberalisation policies enacted in 1986). The decisive political shift of the Doi Moi reforms enabled significant economic realignment of Vietnam with the overall aim of improving living standards. Reforms were targeted at agriculture, the expansion of consumer goods production and the increase in foreign trade. For Vietnam the opening up of its markets, the shift to an export-driven economy and economic globalisation led to remarkable economic growth and a reduction in poverty levels. The economic growth has to the greater extent been urban-based and manifested in the rapid urban expansion of HCMC beyond its juridical limits, via both in-migration and the incorporation of already densely populated rural areas into its administrative boundaries (Drakakis-smith and Dixon, 1997; Kontgis *et al.*, 2014; Saksena *et al.*, 2014). The population of HCMC has essentially more than doubled from 3.78 million in 1986 to 8.24 million in 2015 (see Figure 2–3) (GSO, 2015). This figure, however, does not include up to an estimated in 2002, additional 2 million unregistered migrants in the city (Jones, 2002) and excludes exurban areas beyond the administrative boundaries. Between the years 1989–1999, the population of HCMC grew at an average annual rate of 1.7%, while between the years 1999–2015 this rate decreased slightly to 1.2%. From 2015–2020, the city is forecast to grow at an average annual rate of 0.8% (GSO, 2015).

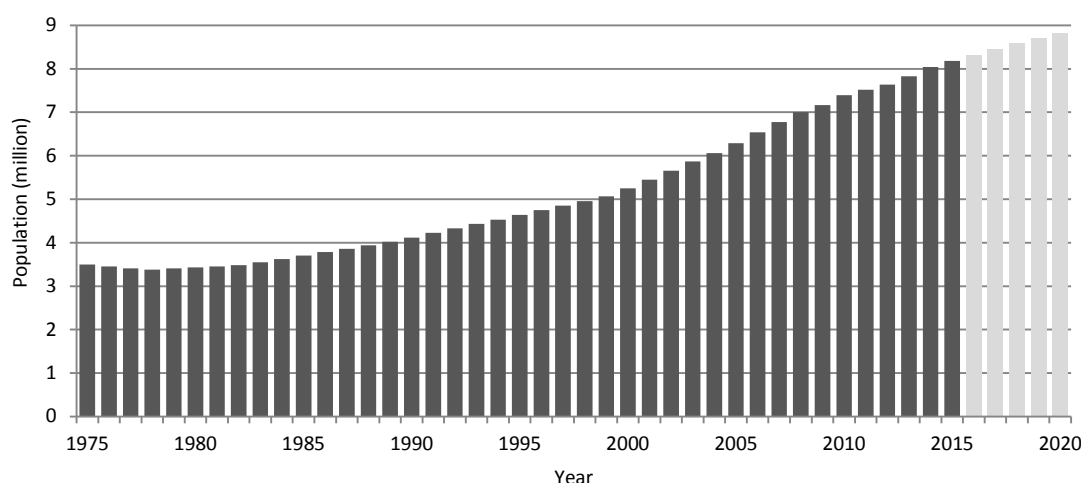


Figure 2–3 Evolution of population growth in HCMC 1975–2015 and projected till 2020 (source: GSO, 2015)

According to both official and independent population forecasts, HCMC will become a megacity and reach a population of between 10 and 12 million by the year 2025 (MoC, 1998; ADB, 2010; GSO, 2012). The rapid economic expansion and changing residence laws not only in HCMC, but Vietnam as a whole, have caused a distinct housing shortage and placed the country on a similar path as other Asian tiger economies, with a large net-migration pouring into cities such as HCMC, seeking work and often straining the existing infrastructure.

The total administrative area of HCMC is about 2,095 km<sup>2</sup> (or 0.6% of the total land area of Vietnam) and divided into 24 districts<sup>9</sup>. The districts division based on hierarchy includes 12 *urban* districts (districts 1 through 12), 7 rapidly urbanising *peri-urban districts* (Go Vap, Tan Binh, Tan Phu, Binh Thanh, Phu Nhuan, Thu Duc, Binh Tan) and 5 mainly outer *rural* districts (Cu Chi, Hoc Mon, Binh Chanh, Nha Be, Can Gio). The spatial profile of urban population changes for the years 2005 to 2015 can be seen in Figure 2–4 and absolute changes in Table 2–7. According to official statistics, 80.1% of the residents in 2015 were classed as urban and 19.7% as rural, with 50.2% or 4.1 million residing in the urban districts in inner and central HCMC, 29.9% or 2.4 million living in the peri-urban districts (adjacent to the inner urban districts, but differentiated because of their somewhat lower density), and 19.7% or 1.63 million in the outer rural districts.

<sup>9</sup> Each district and each province is governed by its own People’s Committee (PC), comprised mostly of members of the Communist Party.



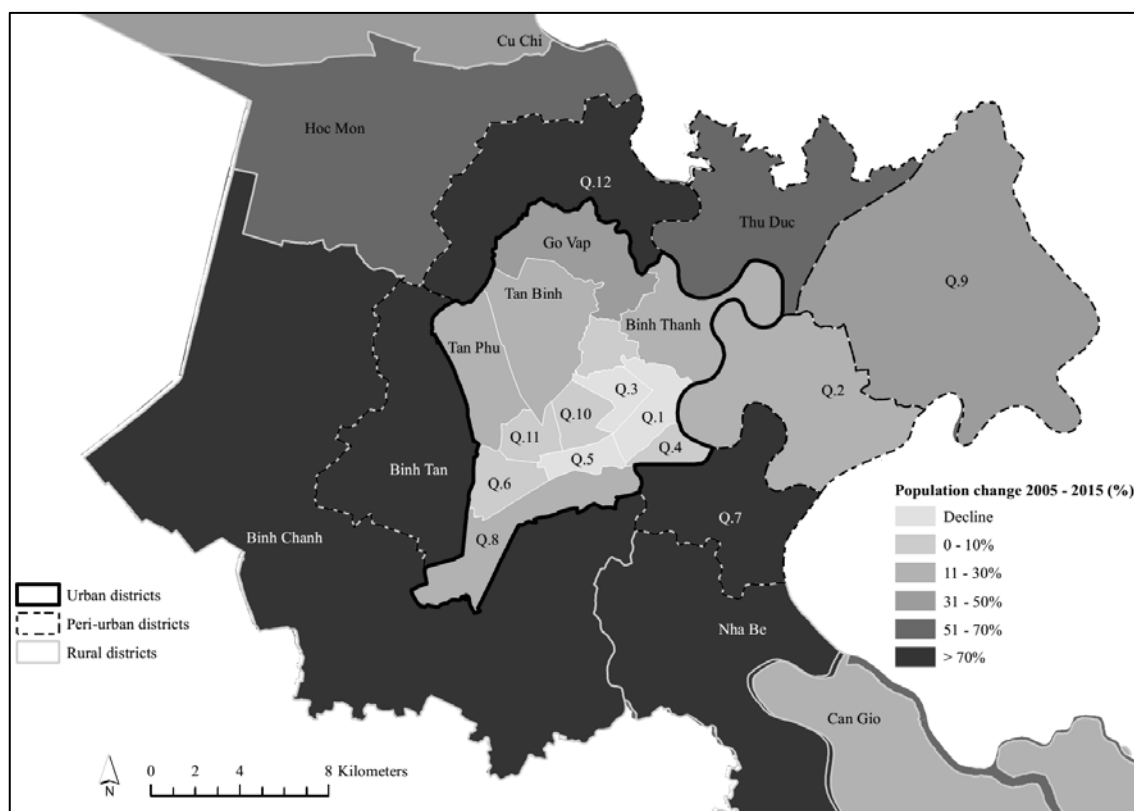


Figure 2–4 Spatial distribution of changes in population between 2005 and 2015 in HCMC (source: author's own)

The urban districts, making up the inner core, are particularly dense, with an average population density  $>28,883$  pers./km<sup>2</sup><sup>10</sup>. For the urban districts, the highest population density of 44,863 pers./km<sup>2</sup> is seen in district 11 and a low of 20,511 pers./km<sup>2</sup> in Tan Binh district. Moreover in total 10.2% of HCMC's population live in urban districts with population densities  $>40,000$  pers./km<sup>2</sup> (district 4, district 5, district 10, district 11). The peri-urban districts exhibit an average population density of more than 8,000 pers./km<sup>2</sup> while the rural districts are characterised by generally low population density, with an average 1,019 pers./km<sup>2</sup>.

<sup>10</sup> A cornerstone of urban policy and management in Vietnam, urban areas are officially designated and classified by the Ministry of Construction (MoC) and are required to have a population  $>4,000$  with  $>65\%$  employed in non-agricultural sectors. In total, Vietnam has 46 urban districts. HCMC with 19 urban districts currently has more than other city in Vietnam under its administration. Six area classes are based on population, population density, level and nature of economic activity, GDP and infrastructure provision. According to Decree No. 42/2009/ND-CP, for an administrative unit to be classified as urban, it must fulfil the below criteria which corresponds to the fifth class and marks the demarcation between urban and rural:

- Centre with role in promoting socio-economic development of Vietnam or a specific territory.
- Size of the urban population  $>4,000$ .
- Population density is consistent, with the size, nature and characteristics of class.
- Non-agricultural labour must be at least 65% of the total workforce.
- Achieve requirements for urban infrastructure (including social infrastructure)
- Achieve the requirements of architecture, built urban landscape.

Table 2–7 Absolute district level changes in population for HCMC between 2005–2015

Hierarchy	District	Population 2005		Population 2015		Population change 2005–2015	Population density 2015
		<i>Pers.</i>	%	<i>Pers.</i>	%	%	( <i>Pers./km<sup>2</sup></i> )
<i>Urban districts</i>		3,693,850	59.2	4,143,535	50.2	12.2	33,803
The historic inner city centre	1	199,899	3.2	193,632	2.3	-3.1	25,049
	3	199,297	3.2	196,333	2.4	-1.5	39,905
High level of development	4	185,268	3.0	186,727	2.3	0.8	44,672
	5	192,157	3.1	178,615	2.2	-7.0	44,183
High level of urbanisation	6	243,416	3.9	258,945	3.1	6.4	36,015
	10	235,370	3.8	238,588	2.9	1.4	41,706
	11	225,908	3.6	230,596	2.8	2.1	44,863
	Phu Nhuan	175,716	2.8	182,477	2.2	3.8	37,393
	8	366,251	5.9	431,969	5.2	17.9	22,522
	Binh Thanh	435,300	7.0	487,985	5.9	12.1	23,922
	Go Vap	468,468	7.5	634,146	7.7	35.4	32,124
Tan Binh	394,281	6.3	459,029	5.6	16.4	20,511	
Tan Phu	372,519	6.0	464,493	5.6	24.7	28,922	
<i>Peri-urban districts</i>		1,546,666	24.8	2,473,179	29.9	59.9	8,027
Periphery of urban districts	Thu Thiem 2	126,084	2.0	147,168	1.8	16.7	2,959
	7	163,608	2.6	310,178	3.7	89.6	8,691
Urban, industrial and rural land-uses	9	207,696	3.3	29,062	3.5	39.9	2,549
Rapid urbanisation	12	299,306	4.8	510,326	6.1	70.5	9,669
	Binh Tan	403,643	6.5	686,474	8.3	70.1	13,229
	Thu Duc	346,329	5.6	528,413	6.4	52.6	11,064
<i>Rural districts</i>		999,422	16.0	1,631,145	19.7	63.2	1,019
Low population density	Cu Chu	296,032	4.7	403,038	4.8	36.1	928
A mix of urban, industrial and rural land-use	Hoc Mon	251,812	4.0	422,471	5.1	67.8	3,869
	Binh Chanh	311,702	5.0	591,451	7.1	89.7	2,341
	Nha Be	73,432	1.2	139,225	1.6	89.6	1,387
	Can Gio	66,444	1.1	74,225	1.6	12.8	1,387
<i>Total HCMC</i>		6,239,938	100.0	8,247,829	100.0	32.2	3,937

(source: GSO, 2015)

Historically, the high-density development of the inner core was principally a manifestation of the requirement to adapt to the dominant flood risk situation of the city (Bolay *et al.*, 1997; Bolay and Ngoc, 1999). Suitable urban land resources were scarce and a compact, dense city was a necessity. Figure 2–5 demonstrates the role, that both the geographic and topography settings played in the location and planning of the city during the French colonial period.



Figure 2–5 Photograph of a map entitled “*Saigon et ses environs 1892*” translated as Saigon and its environment and dated 1892 on display at the Central Post Office in HCMC (source: author's own photograph)

From 1859 to 1945, Saigon was developed under French colonial rule. Figure 2–5, shows the clear settlement patterns of the French colonial city of Saigon (top right)—recognisable from its grid-like planned streets, and the historical Chinese influenced city of Cholon (bottom left) founded in 1799. Both cities were founded on relatively higher grounds; however apparent in Figure 2–5 are the extensive low-lying tidal and freshwater waterways to the south and east of Saigon and to the south of Cholon.

Historically, these were two separate cities located 11 km apart in what are now areas of district 1 and district 5 respectively. Following independence, in 1955, former Saigon was merged with Cholon to become one administrative unit known as *Đô Thành Sài Gòn* (Capital City Saigon), or *Thủ đô Sài Gòn* (National Capital Saigon). Saigon then became the capital of the then Republic of Vietnam until 1975. During this period, the city grew slowly on the back of industrialisation activities. The onset of the American War<sup>11</sup>, led to a large migrant influx and the development of large informal settlements. In Post-American War HCMC, the growth of the city lessened as residents were relocated to New Economic Zones established in adjacent rural provinces.

<sup>11</sup> The Vietnam War is called the American War in Vietnam.

Over time, HCMC gradually grew and densified through the infilling of open spaces or the redevelopment and extension of existing building footprints. Recently, however, with the vast majority of the administrative area distinctively low and flat, great concern has been raised at the city's rapid expansion into the lower-lying and former wetland surroundings (Van and Bao, 2007; Son *et al.*, 2012).

The economic liberalisation and a property boom that accompanied Vietnam's 2007 entry into the World Trade Organisation offered incentives for private investors to intensify real estate development into lower-lying and former wetlands.

In disparity to the underlying conditions, the previous Table 2–7 highlighted that between the years 2005 and 2015, the highest rates of population growth were seen in the three peri-urban districts of district 7 (+89%), 12 (+70%), Binh Tan district (+70%), and the two rural districts of Nha Be (+90%), and Binh Chanh (+90%).

These urban growth trends are similar to those recently experienced in many higher income urban areas on the rapidly urbanising Asian continent, with central districts of HCMC, often termed the “core”, experiencing little, no or declining population growth, whereas the peripheral districts (peri-urban and rural) experiencing much stronger growth over the same time period.

Here, there is a direct relationship between existing population density in the historical urban core districts (districts 1, 3, 4, and 5) and population growth, with many of the central urban districts of the highest densities, exhibiting declines in absolute populations (Figure 2–6).

This may be due to a number of factors, notably, the conversion of residential buildings to commercial and office space within the city core following the growing demand of the central business district (CBD), the establishment of large new suburban areas outside of the city centre, to the south and east of the city, most notably Saigon South New Town in district 7 (also known as Phu My Hung) and urban upgrading programmes, which have taken place in district 4 and district 2 and most notably along the Nhieu Loc-Thi Nghe canal (Douglas and Huang, 2007; Gubry *et al.*, 2010).



Figure 2–6 Photograph of the high dense urban core of HCMC. Nguyen Thai Binh Ward in district 1, where high dense shophouse developments sit among apartment blocks (*source: author's own photograph*)

From 1997 to 2003, in response to this high urbanisation pressure, the government was forced to expand the HCMC urban boundary consecutively, leading to the establishment of six new urban districts. The new suburbs can be seen as the spatial manifestation of the drivers of industrialisation and housing development for factory workers, migrants, and new members of the emerging and ever expanding middle class (Du and Fukushima, 2009; Douglass and Huang, 2007).

Van and Bao (2009) used remote sensing methods to evaluate urban growth patterns of HCMC. They concluded that the urban and built-up area of Ho Chi Minh City expanded by 6.5 times between 1989 and 2006. The growth of HCMC is further illustrated in Table 2–8. The Table highlights the officially documented land-use changes in HCMC between the years 2000 and 2010.

In the 10-year period rapid urbanisation and industrialisation have resulted in sharp land cover changes. Agricultural land decreased by 6% while non-agricultural land increased by 7%. According to the Department of Natural Resources and Environment (DoNRE), on the basis of the current HCMC urban development master plan for 2025, the available agricultural land (118,000 ha in 2010, ca. 58% of the total administrative area) will reduce to 83,000 ha, with 35,000 ha rezoned as construction land and becoming available for new developments.

Table 2–8 Land-use change in HCMC from 2000–2010

Category	2000		2005		2010	
	(ha)	(%)	(ha)	(%)	(ha)	(%)
Agricultural land	130,719.9	62.4	123,517.0	58.9	118,051.9	56.3
- Agriculture	91,139.3	69.7	77,954.9	63.1	72,143.3	61.1
- Forestation	33,472.2	25.6	33,857.9	27.4	34,116.5	28.9
- Aquaculture	4,149.3	3.2	9,765.2	7.9	9,441.2	8.0
- Salt marsh	1,959.2	1.5	1,469.09	1.2	1,943.37	1.7
- Other agricultural land			467.8	0.4	407.6	0.4
Non-agricultural land	74,294.2	35.5	83,773.8	39.9	90,867.6	43.4
- Residential land	16,685.5	22.45	20,614.3	24.5	23,666.0	26.0
- Public land	19,601.8	26.4	28,534.9	34.1	32,973.9	36.3
- Religious land			400.3	0.5	410.4	0.5
- Cemetery	997.9	1.3	924.6	1.1	951.0	1.0
- Rivers and lakes	36,163.2	48.6	33,250.0	39.7	32,812.5	36.1
- Other non-agricultural land	919	1.2	143.3	0.2	53.6	0.06
Unused land	4,414.5	2.1	2,263.7	1.1	635.5	0.30
Total land	209,501.8	100.0	209,554.5	100.0	209,554.9	100.0

(source: DoNRE, 2012)

Overall, future growth in HCMC is expected to follow the current trends of sprawl and suburbanisation and take place in the peri-urban areas adjacent to the traditional urban districts, where infrastructure provision is already strained (ADB, 2010; Storch *et al.*, 2011; Storch and Downes, 2011; Le, 2011). This has led to over development and environmental degradation. This trend is worrisome from an environmental standpoint, as without planning interventions of some degree, a high number of small- and medium-scale yet high-density developments fail to provide adequate open space provisions and environmental services.

### 2.2.2 Precarious growth and climatic risks to Ho Chi Minh City

HCMC geographic setting and rapid, haphazard and often precarious growth over the last two decades has affected its growing exposure to climate hazards (Storch and Downes, 2011; Phung, 2016). Due to its location in a low elevation intra-tropical coastal zone, northeast of the Mekong Delta and 50 km inland from the South China Sea, the city already experiences significant annual variations of climatic and weather extremes. Together with its large population, its economic assets and the dominant role it plays in the national economy, the city is considered a hotspot of vulnerability to the impacts of climate change (ADB 2010; Carew-Reid, 2007; Dasgupta *et al.*, 2007; Birkmann *et al.*, 2010).

However, while the precise extent of future climate changes are uncertain and difficult to predict, especially downscaled to the urban level, recent studies conclude that climate change and its effects for Vietnam are occurring at a faster rate than previously forecasted<sup>12</sup>. Local climate change will have profound impacts for HCMC, with the city being particularly at risk from heightened climate variability and sea-level rise. The most significant impacts are identified as flood risk, thermal stress, energy security and water resources (Ho, 2007, 2008; ADB, 2010; Storch *et al.*, 2011; Storch *et al.*, 2009; Yusuf and Francisco, 2009).

In recent decades, flooding has become one of the most pressing issues, with significant parts of the city already experiencing frequent flooding (Storch *et al.*, 2009; 2011; Downes and Storch, 2013). Part of the reason is that HCMC is exposed to multiple flood risks. The city is currently incised by a dense network of rivers and canals of around 8,000 km in length, which account for 16% of the total area. The Saigon River, Dong Nai River, Nha Be River and Long Tau River all flow through the city. These waterways and adjoining canals form a complex network that is affected by a semi-diurnal tide, subjected to a high-tide level as high as 1.5 m AMSL. Often coincident with annual rainfall peaks in September and October (Table 2–9), a significant percentage of the city’s neighbourhoods regularly experiences floods, due to a combination of tides, heavy monsoon rains, and storm surge floods. Flood events occur individually but more commonly in combination with high tides and fluvial flooding events. Flow in the city’s river systems are dominated by the monthly rainfall regime. High water levels in the receiving watercourses of HCMC caused by tides and overburdened or blocked drainage and sewage systems exacerbate the flood risk (Storch and Downes, 2010). The occurrence of localised urban flash and pluvial flooding (water not being able to enter the drainage system or ejected from the drainage system), following high intensity or prolonged heavy rainfall leading to overland flow and ponding, is a common occurrence on many streets (Figure 2–7).

Table 2–9 Average monthly rainfall in HCMC (*in millimetres*)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
5.7	4.3	17.3	42.7	164.5	185.6	211.8	220.8	254.3	219.4	104.3	38.8

(source: SIHMETE, 2014)

<sup>12</sup> As climate change predictions incorporate the results of many physical and chemical models, each containing their own uncertainties and errors, the high level of uncertainty about the projections under scenarios should be noted.



Figure 2–7 Photograph of a localised flash flood event following heavy rainfall in Nguyen Duy Trinh Street, District 2 of HCMC on the 1<sup>st</sup> October 2012. The cause of the serious flooding was two separate rainfall events of 60.6 mm and 76 mm respectively coinciding with a high tide event of up to 1.5 m (source: author's own photograph)

The urban development of HCMC has also exacerbated the urban flooding risks to the city. Recently, both planned and informal expansions into the lower-lying and former wetland surroundings and the densification of the inner city have resulted in the loss and degradation of valuable multifunctional natural areas in the urban periphery, as well as increased soil sealing.

Existing natural waterways have been channelled or replaced, while waterbodies, wetlands and vegetation structures have been sealed to different degrees, creating more impermeable surfaces and more hardscape features. The outcome is that dimensions of flooding are constantly changing due to urbanisation. Many of the areas recently developed were previously areas known to be prone to flooding by the current high-tide water level (Figure 2–8).

In former times, these spaces acted as a natural blue and green belts, akin to flood risk zoning by prevailing topographic conditions. Overall, space for water has been lost, including natural detention, retention and infiltration areas, which previously regulated the urban water balance. The altering of the drainage system and urban hydrograph has led to increased surface run-off volumes and velocities.





Figure 2–8 Photograph of the residential area of Thao Dien Ward in district 2. Recent luxury villa and apartment extensions of the city into low-lying riparian areas of the city (*source: author's own photograph*)

While developments are spatially limited, the risks posed by them are not. Synonymous with urban (infra-)structure expanding into flood prone areas, is the lost ability of areas to function as they had before, and the growing exposure to risk for both populations and assets in existing settlements, which were once significantly less exposed, as well as, the addition of new risks situated in recent developments in low lying areas.

Figure 2–9 illustrates the serious flood events reported annually from 2003 to 2012. Even following recent heavy investments in storm-water drainage upgrading and expansion, the number of flood-prone areas within HCMC, while remaining fairly constant between 2007 and 2009, was seen to decrease significantly in the urban districts (SCFC HCMC, 2011). Despite this, in contrast, peri-urban and rural districts saw an increase in the number of flood events during the same period.

For HCMC, flooding often causes loss of life and injury, damage to property and infrastructure and interruption of essential services and business supply chains. Such events also cause substantial personal stress and hardship to affected households, particularly the more vulnerable in society (CCFSC, 2006). There is evidence that flooding can also have long term impact on health and well-being (Few and Tran, 2010).

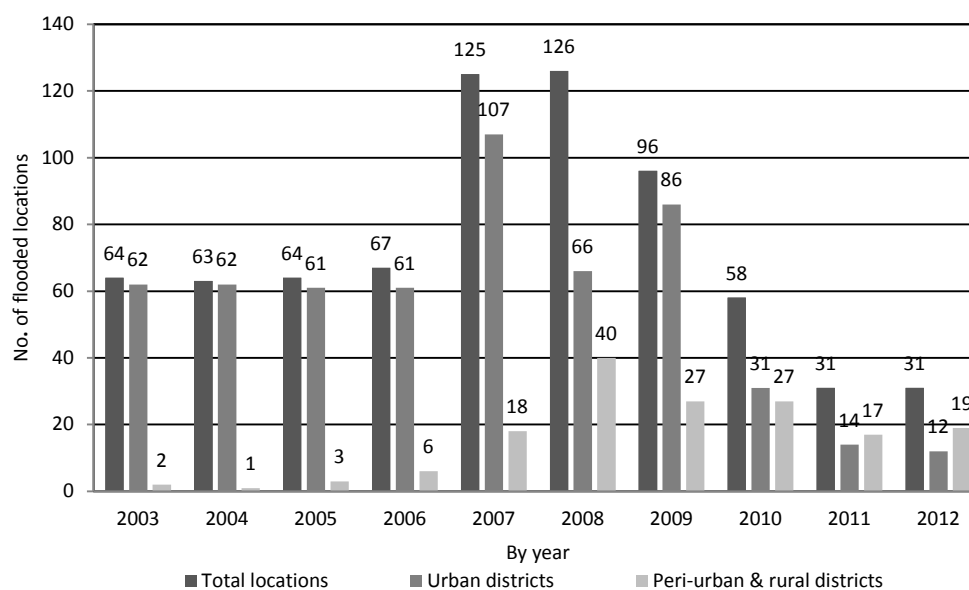


Figure 2–9 Number of flooding locations in the urban, peri-urban and rural districts of HCMC between 2003 and 2012 (source: SCFC HCMC, 2012)

According to HCMC statistics in the ten-year period 1997–2007, natural disasters occurred in the city with increasing frequency, and impacted the city on a large scale (HCMC PC, 2008). Natural disasters reported were storm surges, tropical depressions, storms, prolonged heavy rain causing flooding, river erosion and cyclones. In HCMC during the period, natural disasters have been blamed directly for 11 deaths, 47 injuries and 2 missing persons (HCMC PC, 2008). In total 478 houses collapsed or damaged beyond repair with 2,487 houses partially damaged. Furthermore, 5,528 ha and 100 ha of agricultural and aquaculture production was destroyed (HCMC PC, 2008). Natural disasters in the city have also led to loss of embankments through erosion, and many road works, trees, power systems, telecommunications, schools, hospitals, headquarter offices and factories being damaged.

The mean annual temperature throughout the administrative area of HCMC is between 27–28°C with maximum temperatures often exceeding 40°C. The city’s temperature is intensified by the effects of an urban heat island (UHI). This is shown by a distinct temperature difference between the city’s inner core and the vegetated surroundings. It is estimated the temperature difference between the densely built areas and the rural surroundings is up to 10°C (Tran *et al.*, 2006; Van and Bao, 2007, 2010; Thi Van *et al.*, 2009; Son *et al.*, 2017).

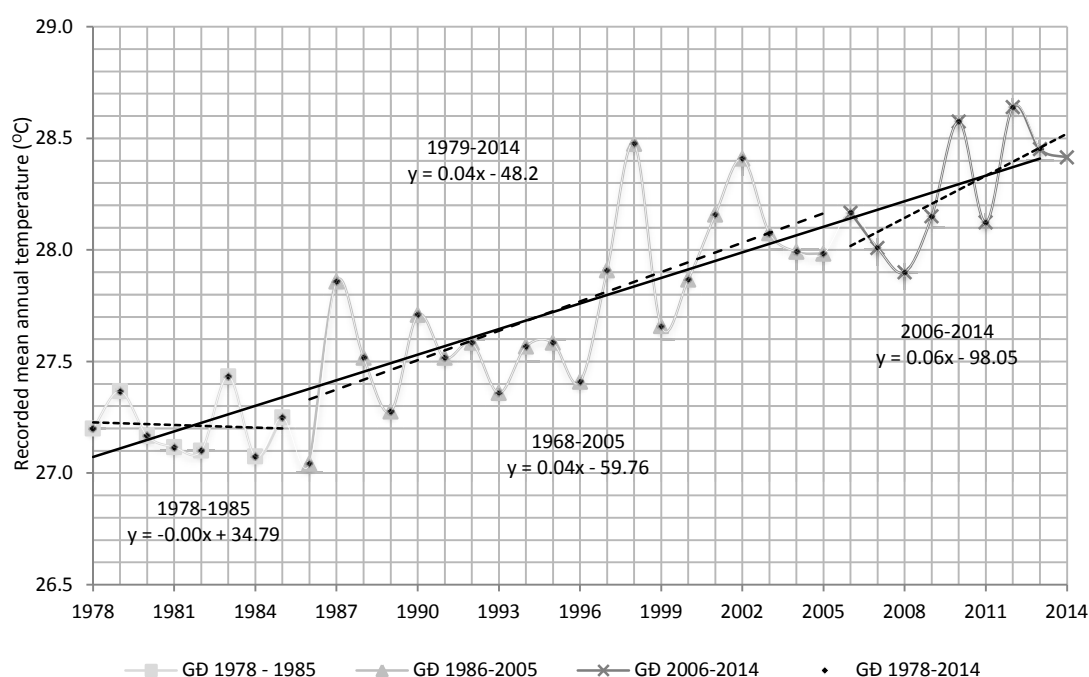


Figure 2–10 Changing trends of annual mean temperature at Tân Sơn Hòa Station from 1978–2014 (source: SIHMETE, 2014)

The loss of natural vegetation for fresh air generation and natural ventilation corridors, as well as increased anthropogenic generation through transport and energy consumption, such as air conditioning units have aggravated the thermal stress in high density urban districts of the city.

The UHI has consequentially caused air quality to deteriorate and decreased the thermal comfort of inhabitants (Katzschner, 2010). During the dry months energy shortages and power outages caused by the increasing demand for cooling are a common occurrence (Storch *et al.*, 2011).

Historically, the mean temperature of HCMC, measured at the city's Tân Sơn Hòa Station has increased roughly  $0.04^{\circ}\text{C}$  annually during the period 1978 till 2014 (Figure 2–10). From 1978 till 1985 only minor temperature changes were recorded with annual temperatures remaining almost stable. While from 1986 – 2005, complicated temperature fluctuations were recorded. Lowest temperature was in 1986 ( $\sim 27^{\circ}\text{C}$ ) and highest in 1998 ( $\sim 28.5^{\circ}\text{C}$ ). From 2006 to 2014, the mean temperature increased at a rate of  $0.06^{\circ}\text{C}$  per year (SIHMETE, 2014). Furthermore, the temperature in HCMC is forecasted to rise by about  $1.4^{\circ}\text{C}$  until 2050 in relation to the baseline period 1980–1989 (ABD, 2010). This forecast does not however consider the additional effects of urbanisation on the already existent UHI.

In general, the adverse climate change impacts have been causing perceptible and profound effects on both the tangible and intangible elements of HCMC. Yet the demographic and spatial development of HCMC is the main contributing factor that aggravates the current risks to the city. Development pressure has already resulted in population growth, economic growth and higher levels of resource consumption, including land, which has led to a sharp increase in land take, waste production, and traffic (Schmidt *et al.*, 2012). Despite the already known impact risks, the current urban planning strategy does not particularly address climate change. Future climate change will undoubtedly influence the future development path of HCMC. In other words, there is a pressing need for climate change issues to become a significant consideration in the city's development. Climate change will bring both challenges and opportunities for HCMC. Both future urbanisation and climate change create a multitude of opportunities to reassess development and consider how future growth can be more efficiently managed. An opportunity to identify synergies and minimise trade-offs is also presented. As such, the assessment of the urbanisation and climate change impacts present a very dynamic window in which to steer future development and affect urban change. While the very nature of both phenomena stresses a need for a new emphasis to be placed upon the forward planning of HCMC over the next decades.

### **2.3 Strategies and policies to address climate change and disaster risks**

The global comparative climate change impact and disaster risk studies outlined in the previous Chapter, together with a growing number of articles published in the Vietnamese local media, have played a prominent role in raising the awareness of the climate change and disaster risk issues among both political stakeholders, and the general Vietnamese population. As a result, the Vietnamese political and administrative authorities have become very conscious of their responsibilities in regards to the consequences and associated impacts of climate change and risk reduction. Without doubt, climate change will significantly increase the sustainable urbanisation challenges faced by many of the Vietnamese agglomerations, especially those faced HCMC. At the same time, with climate change and its impacts accepted by both the international and Vietnamese scientific communities alike, the focus is now shifting towards response mechanisms.

Internationally climate change is a fast-moving policy area. One approach to attenuating the impacts of climate change is through adaptation and the development of policies that facilitate this. Internationally, a range of different approaches to adaptation have been developed (Adger *et al.*, 2005; Smit and Wandel, 2006; Parry *et al.*, 2007). Climate change adaptation has become increasingly a requirement of national planning and design guidance worldwide (Berkhout, 2005; Biesbroek, *et al.*, 2010). For example, Massey and Huitema (2013) reported that a total of nine countries within the European Union (EU) now have national plans for adaptation, including some 30 sub-national plans, and every one of the twenty-eight Member State has policies to address adaptation in some form.

Vietnam signed the United Nations Framework Convention on Climate Change (UNFCCC) in 1992, (ratified in 1994), and the Kyoto Protocol in 1998, (ratified in 2002). Vietnam is also a signatory of the United Nations Office of Disaster Risk Reduction (UNISDR) Hyogo Framework for Action (HFA). To fulfil its obligations on environmental and climate protection as set forth in the above international treaties, as well as Vietnamese national law, policies to both assess and to respond to climate change impacts and disaster risk reduction are elevated high in the government's agenda.

### **2.3.1 National Target Programme to Respond to Climate Change**

#### 2.3.1.1 At national level

To overcome the current challenges and harness the country's resources to support growth, domestic adaptation options are guided by the Vietnamese National Target Programme to Respond to Climate (NTPRCC) which details the policies and measures which Vietnam is using to cut GHG-emissions and adapt to the impacts of climate change.

At the national level in Vietnam, the National Target Programme to Respond to Climate Change (NTPRCC) was approved in late 2008 (Decision No. 158/2008/QĐ-TTg). Divided up into three consecutive phases: from 2009–2010 (start-up phase), from 2011–2015 (implementation phase), and from 2015 onwards (development phase). The programme intends to prioritise adaptation and mitigation needs and requires all relevant sectors to mainstream adaptation in sectorial policies, programmes, plans and

decision-making processes at all administrative levels, as well as the development and implementation of related projects (MoNRE, 2008). The strategic objectives of the programme are to assess the climate change impacts on sectors and regions and to develop feasible action plans to effectively respond to climate change both in the short and long-term, to ensure sustainable development of Vietnam; to take opportunities to develop towards a low-carbon economy; and to join the international community's efforts in mitigating the effects of climate change. Assigned ministries, sectors, provinces and cities have the task to develop and implement action plans in response to climate change including:

- i. Assess climate change impacts on Vietnam;
- ii. Identify response measures;
- iii. Integrate climate change concerns into strategies, programmes and plans.
- iv. Strengthen the capacities of organisations involved in responding to climate change.

The National Target Programme identified a list of tasks and projects for implementing the programme, including:

- i. Assess climate change intensity and develop climate change and sea-level rise scenarios;
- ii. Develop and implement science and technology programmes on climate change;
- iii. Building capacity of organisation, institution and policy on climate change;
- iv. Awareness enhancement and human resources training;
- v. Enhance international cooperation;
- vi. Develop a standard framework for mainstreaming climate change issues into development;
- vii. Develop and implement action plans to respond to climate change.

Under the NTPRCC, a National Steering Committee was formed comprising directly of the Prime Minister and the Heads of the Ministries relevant for climate change response, namely Ministry of Natural Resources and Environment (MoNRE), Ministry of Planning and Investment (MPI), Ministry of Finance (MoF), Ministry of Agriculture and Rural Development (MARD), Ministry of Construction (MoC), the Ministry of Science and Technology (MoST) and the Ministry of Foreign Affairs (MFA).

MoNRE is the lead Ministry responsible for the long-term planning, promotion, coordination and overseeing of Vietnam's environmental policies and programmes at the

national level. MoNRE has been designated the lead agency for climate change coordination in Vietnam. This includes the implementation of the United Nations Framework Convention on Climate Change (NFCCC), Kyoto Protocol, Clean Development Mechanism (CDM) and NTPRCC. MARD holds the overall responsibility for natural disaster mitigation and response. In addition, the MoC is responsible for the country's drainage systems and major public works, while the MPI is responsible for social-economic planning and master planning, and the MoST together with the National Hydro-Meteorology Agency is a technical agency in charge of weather forecast, sea-level rise, hydrological information, and climate forecasts.

The mandate of the NTPRCC was adapted to go beyond the mere coordination of policies, but also to foster cooperation between different ministries, line departments, sectors and disciplines. Within the NTPRCC, the assessment of climate change impacts on socioeconomic activities and the identification and assessment of the costs and benefits of adaptation measures are fundamentally organised on a sectoral basis, emphasising the role of different Ministries in these actions. Furthermore, within the structure of the programme, a science and technology platform was developed in order to generate and promote a scientific basis for the formulation of policies, for the establishment of adequate institutions and for the development of action plans at different levels (MoNRE, 2008b).

Concurrently and in line with the NTPRCC, MARD approved the Action Plan Framework on Climate Change Adaptation and Mitigation of the Agriculture and Rural Development Sector for the period 2008–2020 also in 2008 (Decision No. 2730/QĐ-BNN-KHCN). The purpose of the framework is set on the development of policies and action plans that integrate climate change into sectoral development programmes and projects related to agriculture and rural development.

Climate change response is also specifically an objective of the Vietnamese Sustainable Development Strategy for 2011–2020 ratified in 2012 (Decision No. 432/2012/QĐ-TTg). One main objective of the strategy states “to reduce harmful effects of natural disasters, and to actively and effectively respond to climate change, especially sea-level rise”. In order to fully support the development and the implementation of NTPRCC, the Government of Vietnam and a number of donor agencies unveiled the Support Program to Respond to Climate Change (SPRCC) in 2009 (Decision No. 1824/QĐ-TTg). The main task of SPRCC is to nationally support donor harmonisation as well as

the coordination of policy-related activities. A series of assessment indicators for projects under the SPRCC were also formulated (Decision No. 1719/QĐ-TTg) in 2011.

### 2.3.1.2 At the city level

At the local level as set out in the NTPRCC, each province and first class city in Vietnam has the responsibility to address climate change. In accordance with NTPRCC, the city's People Committee are obliged to develop a local Action Plan in response to climate change and to establish a steering board as a cooperative mechanism between relevant city departments. The appropriately named HCMC Climate Change Steering Board (CCSB) was set up in accordance with the National Target Programme in 2009 (4842/QĐ-UBND) and also chaired by the Chairman of the People's Committee. DoNRE, whose Director is appointed as the Standing Vice Chairman of CCSB, has the mandate to head and coordinate the cross-sectoral response to climate change in HCMC (Figure 2–11).

The CCSB consists of line departmental leaders (directors or vice-directors) with the overall aim to improve the coordination between the departments on adaptation programmes. The Director of DoNRE provides recommendations directly to the HCMC People Committee and asks for coordination from other CCSB members, including recommendations from a seventy-eight person strong Technical Advisory Group (consisting of line department district-level staff).

Subsequently, the HCMC Climate Change Bureau (HCCB) was established as the secretariat for the CCSB (Decision 2816/QĐ-UBND) in 2012, (later modified at Decision 3480/QĐ-UBND in 2014). The HCMC Climate Change Bureau coordinates the activities of the CCSB in regards to the different functional agencies, such as the advisory group, research units, businesses and the general public in implementing more specialised plans and projects. It was the responsibility of HCMC CCSB to develop the HCMC Climate Change Adaptation and Mitigation Action Plan towards 2015 (HCMC CCAP) (Decision 2484/QĐ-UBND) which was approved in 2013.

The Action Plan addresses both adaptation and mitigation in order to safeguard the city's development. The aim of the HCMC CCAP is to assess the levels of climate change impacts on the city and its sectors, in order to develop both concrete and feasible actions to improve the resilience capacity of the city and reduce GHG-emissions towards a low-carbon approach.



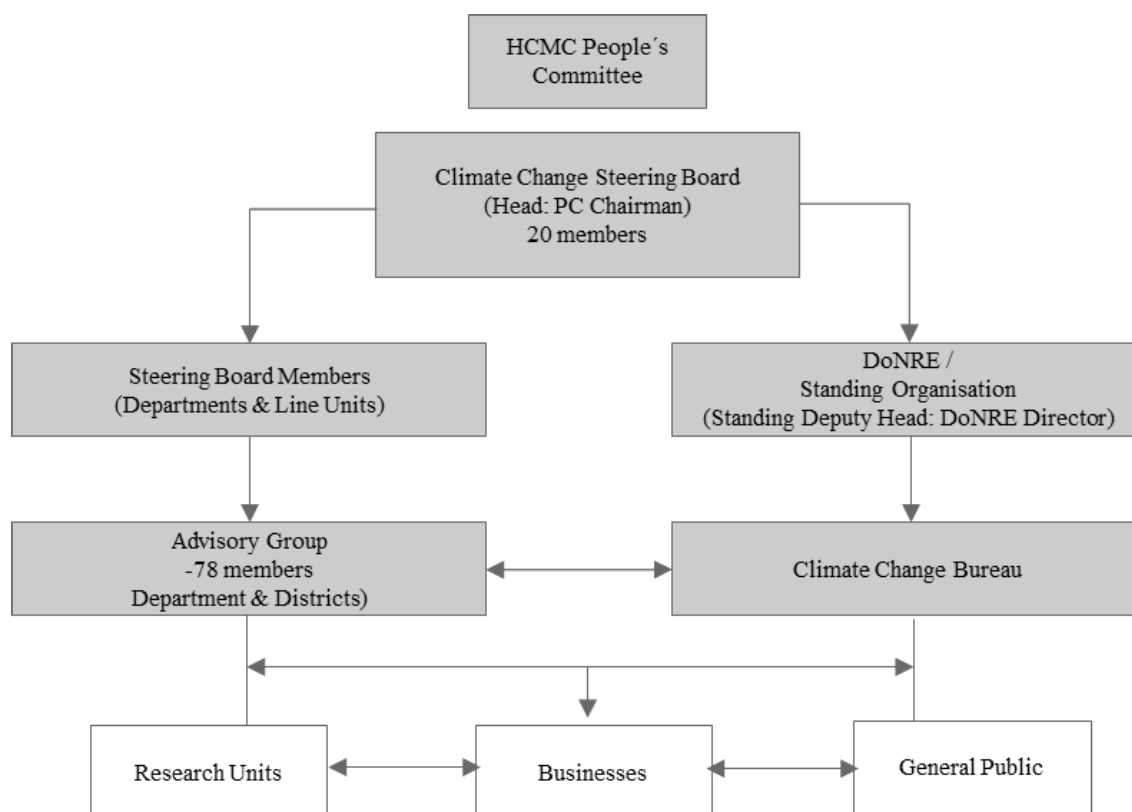


Figure 2–11 Organisation of HCMC Climate Change Steering Board (source: Vo, 2015)

The HCMC CCAP envisages research on the current and future climate change impacts and mitigation options, as well as the implementation of projects and activities in the fields of urban planning, water resource management, agriculture, public health, energy, waste and transportation. DoNRE is responsible for all information collection, synthesis, management, archiving and reporting of information connected to the NTPRCC. It is the responsibility of DoNRE and the Steering Board to review and comment on all other sector and spatial plans in the city with regards to their environmental sustainability, their effectiveness in meeting climate change adaptation requirements of the city and their consistency with the overall land-use plan.

### 2.3.2 National Strategy for Natural Disaster Prevention, Response and Mitigation to 2020

#### 2.3.2.1 At national level

As previously mentioned MARD has the clear national responsibility for natural disaster mitigation and response activities in Vietnam. MARD guides, assists and coordinates disaster risk reduction works with the other ministries, sectors and

provinces. Table 2–10 below, provides a summary of relevant legislation. Prior to 2015, two central committees shared the mandate for disaster risk activities in Vietnam, the Central Steering Board on Flood, Storm Prevention and Response and the Board on Flood, Storm Prevention, Response and Search – Rescue.

The Central Committee for Flood and Storm Control (CCFSC), which was chaired by the Director of MARD, provided a coordinating umbrella and focal point for all disaster risk management activities in Vietnam. The Committee is the successor to the Central Committee for Dyke Maintenance, established by then President Ho Chi Minh in 1946 (CCFSC 2014). Since 2015, the two central committees have merged to become the Central Steering Board for Natural Disaster Prevention and Response. This Central Steering Board is chaired by MARD and includes MONRE alongside MPI, MoF, MOST, MoC, the other relevant ministries are a member of the committee.

In 2007, the Government of Vietnam approved the National Strategy for Natural Disaster Prevention, Response and Mitigation (NDPRM) to the year 2020 (Decision No. 172/QĐ-TTg). With a main focus on floods, storms and droughts, the Strategy document outlines the country’s long-term orientations for disaster migration and management, general responsibilities and solutions. The Strategy has the overall aim to minimise the loss of human life and properties, the damage to natural resources and cultural heritages, and the degradation of environment. It contributes to ensuring the country’s sustainable development, national defence and security.

Table 2–10 Development of key legislation for disaster response in Vietnam

Basis	Content
Decision 349/TTg (1995)	Establishing the Central Steering Board for Flood and Storm Prevention and Response (or Control), chaired by the Minister of Irrigation Ministry; standing vice chair was Vice chairman of Irrigation Ministry.
1996: Decision 299/TTg (1996)	Appoint the Minister-Chairman of Vietnam Mekong Committee as the Chairman; standing vice chair was Vice Minister of MARD.
Decree 14/2010/NĐ-CP (2010)	Government regulating the organisation, responsibilities, authorities and coordination mechanisms of the Central Steering Board on Flood, Storm Prevention and Response, the Steering (or literally from Vietnamese meaning as ‘Command’) Board on Flood, Storm Prevention, Response and Search - Rescue of Line Ministries and Local Authorities.
2013	Law on Disaster Prevention and Response, ratified on 19 June 2013.
Decree 66/2014/NĐ-CP (2014)	Government on detailed regulation, implementation guidance of some articles in the Law on Disaster Prevention and Response. This is the directing document, listed in the legal basis section for all institutional settings up to date.
Decision 367/QĐ-TTg (2015)	Establishing the Central Steering Board for Natural Disaster Prevention and Response, chaired by the Minister of MARD; Standing Vice chairman is the Vice Chairman of MARD.

MARD together with CCFSC have been given the mandate to preside over its step-wise national implementation. The Strategy aims at integrating disaster prevention, response and mitigation into national socio-economic development planning for the relocation of populations from high-risk areas and ensure that the development planning and building codes of socio-economic structures and residential areas in places frequently affected by disaster meet regional standards for flood and storm control.

Moreover, the strategy provides very concrete and practical actions and considers disaster prevention, response and mitigation to be not only the sole responsibility of the national government, but also to involve local level government agencies, as well as important civilian organisations. The National Strategy includes tailored programmes on improving legislation and policies to raise community awareness, afforestation and protection activities for upstream forests, the consolidation and strengthening of disaster management capacities through science and technology, structural measures, and programmes on strengthening and improving forecasts and early-warning systems, as well as, search, rescue and emergency responses. However, Nguyen and Tran (2016), point out that the strategy omits to mention urban areas and there are no action plans for disaster risk reduction in cities, with many of the programmes not applicable to the complexity of urban areas. Furthering to the overall direction of the National Strategy for Natural Disaster Prevention, Response and Mitigation to 2020, to implement the strategy, a National Action Plan on disaster risk reduction was approved in 2009. The National Action Plan made it compulsory for all provinces and first class cities in Vietnam to draft their own strategic action plans in conjunction CCFSC. Accordingly, all line departments will formulate their own sectoral plan containing more detailed implementation actions.

#### 2.3.2.2 At the city level

In terms of natural disaster prevention and response activities at local level, following the vertical administrative system which is directed in the Decree 66/2014/NĐ-CP on 4<sup>th</sup> July 2014 of the Government on detailed regulation, implementation guidance of some articles in the Law on Disaster Prevention and Response, the focal point is the Steering (or ‘Command’) Board on Natural Disaster Prevention, Response and Search - Rescue of HCMC, established by Decision 739/QĐ-UBND on 14<sup>th</sup> February 2015 and chaired by a Vice Chairman of the PC. Its standing organisation is DARD with DARD’s Director as the Board’s Standing Vice Chairman. The Board’s Secretariat is the Agency

of Irrigation and Flood, Storm Prevention and Response of HCMC – an independent sub-unit of DARD. Basically in terms of authority level and administrative position, the Steering Board on Natural Disaster Prevention, Response and Search - Rescue of HCMC is similar to Climate Change Steering Board; while the Agency of Irrigation and Flood, Storm Prevention and Response of HCMC is similar to the Climate Change Bureau (both acting as Steering Board’s Secretariat offices) (Figure 2–12).

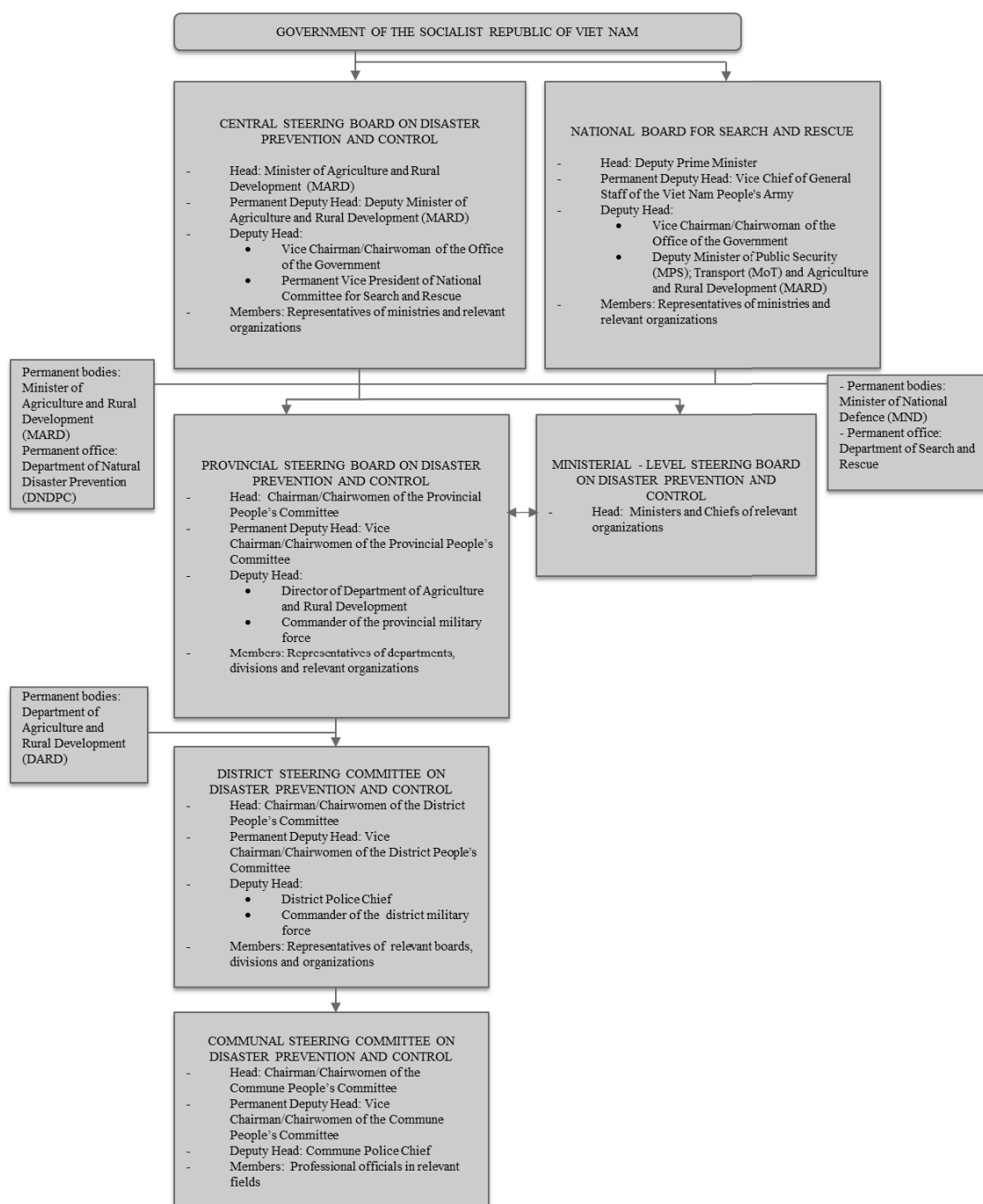


Figure 2–12 Organisational chart on disaster prevention, search and rescue responsibilities in Vietnam  
(source: CCFSC, 2016)

Meanwhile, SCFC's full name as decided is the Steering Centre of the Urban Flood Control Program. Therefore, its duties only focus on flood control, not disaster response in general. Consequently, SCFC is just a member of the Steering Board on Natural Disaster Prevention, Response and Search - Rescue of HCMC, not acting as the standing organisation.

HCMC has a local city based Steering Centre for Flood Control (SCFC). It works as an independent agency under the city's People's Committee and CCFSC, with the function of advising and assisting the Peoples Committee in implementing programmes, plans and projects in the fields of drainage and flood control for HCMC (CCFSC, 2014).

SCFC is responsible for effective implementation the of relevant contents, objectives, duties and measures as laid out in the Action Plan for the implementation of the National Strategy for Natural Disaster Prevention, Response and Mitigation to 2020 for HCMC (HCMC APND) that was approved in late 2008 (Decision No. 5745/ UBND). The overall objective of the HCMC APND was to mobilise all resources in implementing effective prevention, preparedness and mitigation of natural disasters in order to reduce to a minimum the loss of human life and property, to meet the requirements of sustainable development economic, social stability, security and defence in the city.

Specific tasks and solutions of the HCMC APND are divided and set-out into three phases; precaution, response and remedial. Tasks precisely outlined in the precaution phase include the management of flood and storm protection works related to flood control, storm surges and inundation, including the regular inspection and evaluation of the quality and level of safety of the facilities, in order to detect failures, defects or deterioration and take measures to repair or upgrade them. It is also outlined to take preventative measures to safeguard the encroachment violations of riparian areas, riverbanks and canals, as well as, unauthorised reclamation of land, also ensuring that transport infrastructure projects are secured against flood and high-tide events (Figure 2–13). The tasks outlined in the response phase concern timely warning systems, rapid deployment response measures, safe evacuations, safeguarding vital supply lines and rescue works. Moreover, the tasks set out in the remedial are listed as the organisation of the rescue missions of people and properties, the organisation of vital supply lines (food, clean water, healthcare, and sanitation), the organisation of damage assessment surveys, and repair assistance activities.

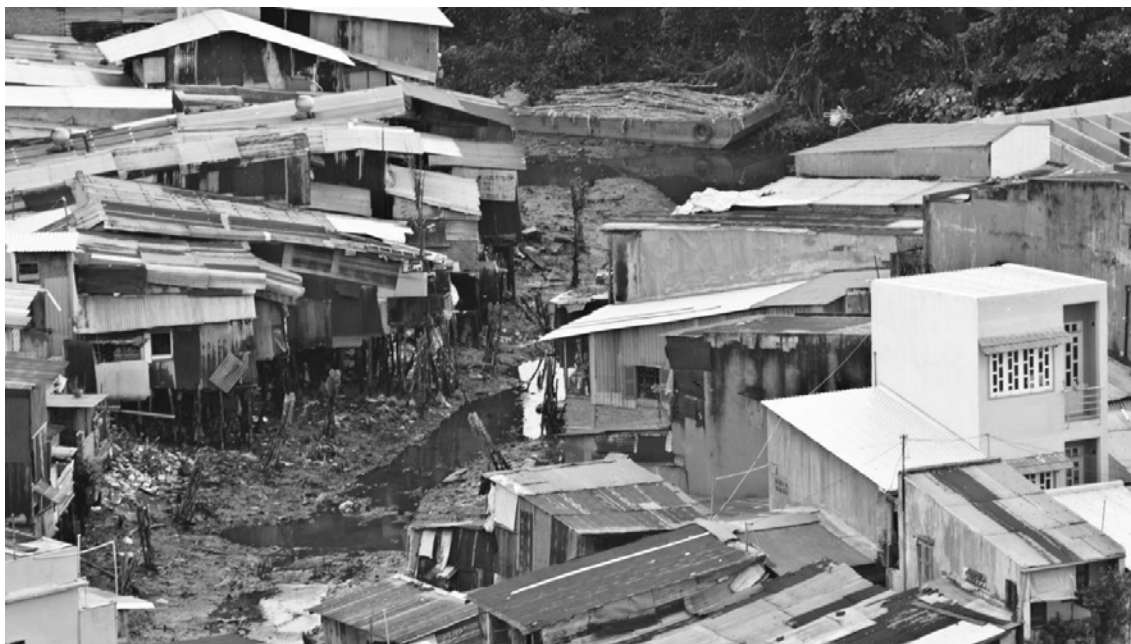


Figure 2–13 Photograph of informal settlement encroachment of temporary buildings along the Rạch Cầu Bông in Binh Thanh district. Formerly a main tributary stream that flowed into the Saigon River (*source: author's own photograph*)

The HCMC APND additionally outlines specific measures to actively prevent, avoid and adapt developments for specific areas of HCMC. Measures for Can Gio district, the peri-urban districts and the inner city districts are given in detail.

The SCFC of HCMC is chaired by the Vice-Chairman of the HCMC People's Committee with the other members coming from all relevant line departments. For the implementation of the city's Action Plan, the SCFC coordinates with the city's Police, Fire and HCMC Military Headquarters, DoNRE, DoT, DPI, DoF, and the district level People's Committees. HCMC SCFC meets quarterly or in times of emergency. An expert from the SCFC also is a member of the advisory group for the CCSB in HCMC.

In HCMC, the SCFC has historically had the mandate to study, formulate and coordinate strategies and solutions as the name suggests for flood control in particular. As such they are solely responsible for the overall long-term, medium-term and annual plans of both urban drainage and flood control measures. The SCFC are in charge of the collection and analysis of data in regards to flooding events and the prediction of future events. They advise on solutions to prevent, combat, cope and overcome flooding in the city. This entails identifying priority projects for implementation, ensure adequate investment for the construction and safety of the city's dyke systems, to enhance the capacity in managing the sewage system, and manage the tidal gates in drainage canals

to better control the current flood situation in the city. They also determine the boundaries protecting river and canal banks, and dredging activities. Once flooding and drainage upgrading projects commence the SCFC is also the lead agency responsible for checking and monitoring progress.

SCFC together with MARD, and the People's Committee of HCMC, have been especially active in fulfilling HCMC Drainage Master Plan (Decision No. 752/QD-TTg) approved in 2001 and the Planning of Drainage to Combat Flooding in HCMC (Decision No. 1547/QD-TTg) subsequently approved in 2008. Here the first task for SCFC was to carry out river basin planning of the Dong Nai-Saigon confluence and analysis of upstream flood and downstream tide controls in line with the overall development plan of HCMC.

### **2.3.3 Implementation issues and constraints at city level**

Interestingly within Vietnam, while developing fast and becoming increasingly attractive relevant policy concepts, both adaptation and disaster risk reduction policies as set out in the NTRPCC and NDPRM, are still to be seen at an early stage. Climate change and disaster risk responses have yet to be addressed systemically and there is a distinct lack of enforcement and implementation at the local level. Climate policy response has been focused mainly at the national level with a neglect, or very little research being undertaken into both the effects and challenges of climate change to urban areas.

One important constraint is coherence between government agencies. In HCMC there are clear overlaps in responsibilities among different departments at the city planning level (Nguyen and Tung, 2007). Some issues such as climate change adaptation and disaster risk reduction fall between the mandates of a number of different departments and agencies.

Without doubt, as the HCMC APCC and APND stress, both adaptation and risk reduction strategies must be applied comprehensively. However, currently there are only very few clearly successful examples of adaptation and risk reduction actions being undertaken. Both the CCSB and the Steering Board on Natural Disaster Prevention, Response and Search - Rescue of HCMC (DPRSB) and city policy makers face challenges towards the implementation of effective adaptation and risk reduction objectives as set out in their corresponding Action Plans.

The HCMC CCAP sets out very strong clear objectives and general principles for adaptation to the impacts of climate changes as perceived to be of greatest importance and a long list of potential projects are cited. However, the HCMC CCAP was drafted by local scientists and city officials with limited adaptation knowledge and experience in 2008 and it has proven to be a challenge to translate the objectives into more detailed recommendations for action. The Action Plan is very simple in nature and contains no clear implementation timeline, which has resulted in only a limited number of small projects being implemented. The CCSB alone is amongst the biggest steering boards in HCMC which consists of almost all line departments and organisations (18 to 19), yet the HCCB also suffers from a shortage of human resources relative to the extent of work to be done.

In regards to the prevention, response and mitigation for HCMC APND, the SCFC has completed a number of initial preparatory works to implement urgent projects in preparation for a time when funding can be secured. However, the implementation of the planning undertaken by the SCFC is very slow due to a lack of investment capital and difficulties of land availability. Although SCFC is more decentralised than most sectors, besides particularly urgent tasks, most of the SCFC activities still have to be approved by the HCMC People's Committee with the organisational structure and human resources managed by the city's People's Committee. Notwithstanding, in Vietnam, while the national government has the power to rapidly develop policies, plans and programmes to tackle climate change and disaster response, the local institutions in HCMC often lack the capacity for their retrospective implementation. In HCMC there is a large gap between climate change, disaster response management policies and programmes and the pace of urban development. Due to the rapid pace of urbanisation in HCMC, integrated solutions to synchronise and mainstream both disaster risk reduction and climate change adaptation into urban development are needed yet still inadequate. Often these policies are also in direct conflict to socio-economic policies.

Furthermore, since both the CCSB and the DPRSB are operated in a concurrent manner, consisting of personnel from different organisations, the Boards themselves do not hold any real administrative, legislative or executive power. Their members, HCMCs line departments do have power however. SCFC is different in that it is a single



organisation with full-time staff. Therefore, SCFC holds administrative and executive power within their authority limitation.

Both the NTPRCC and NDPRM recognises that planning has a crucial role to play in improving the adaptive capacity of urban development, as municipal adaptation and risk reductions measures are specially demanded to ensure the sustainable development of the country. As HCMC forms a vital part of the environmental, social and economic capital of Vietnam, ensuring it is able to cope with the effects of climate change is thus a high priority for not only the local government but also the national government. Their barriers, limits and costs of doing so however are not fully understood.

Integrating climate change and disaster risk reduction plans in to HCMC urban development is a complex decision making problem, which requires a careful assessment of the decision situation in relation to the concrete places and spaces. A wide array of adaptation options are available, but more extensive adaptation than is currently occurring is required to reduce vulnerability to climate change. However, another major challenge at the local level in implementing the Action Plans is the uncertainty about future climate risks. Both climate response and risk reduction require the consideration of likely impact locations, vulnerabilities and magnitudes and taking action to mitigate impacts, without causing the impact to progress elsewhere. Many of the city and district level environmental protection offices lack basic knowledge and awareness of the relevant issues, or are overburdened with other tasks. While approaches, measuring and sampling equipment for urban environmental assessments and monitoring are absent.

A key question for the implementation at the local level pertains to the identification of adaptation and risk reduction measures available for key sectors, and the assessment of the possible costs and benefits of these measures. This also requires the selection of appropriate actions that help preserve the environment, whilst meeting the needs of present and future generations in terms of the city's liveability and functioning.

Successful adaptation and disaster risk reduction will depend on the ability to anticipate and plan for the future impacts of both development and climate change. Storch and Downes (2011), point out that in terms of adaptation, there is a current methodological void between regional climate change models, and the absence of up-to date knowledge of the current urban fabric, let alone future urban development scenarios, which severely limits effective impact assessments from being undertaken. The deficiency of

such information and uncertainty of surrounding potential impacts hinder decisions being taken, limiting the capacity of governments at all levels to plan and implement measures, with decision-makers often unable to identify the best course of action. More often than not, knowledge of projected future temperature, precipitation and sea-level fluctuations have been used to carry out assessments of the urban environment without the adequate consideration of future social-economic and land-use changes (Storch and Downes, 2011).

### **2.3.4 Downscaled place-specific knowledge**

A number of authors have stressed that at the urban level adaptation requires place-based approaches (Adger and Kelly, 1999; Cutter, 1996; Cutter *et al.*, 2000; Turner *et al.*, 2003; Walker *et al.*, 2004; Bulkeley, 2006; Bulkeley and Kern, 2006).

Responses themselves are also only practical at the local level, in concrete spatial localities. Storch *et al.*, (2007) highlights that the local level is of great importance for climate change adaptation (as well as mitigation activities) and that practical adaptation actions and their feasibility are best examined in the local context with a sound scientific, technical and socio-economic understanding of the current location. The fundamental motivation for downscaling climate change impact assessments to the urban scale lies in the understanding that every region exhibits its own unique urban development issues and paths as well as inherent adaptation potentials (Stoch *et al.*, 2011).

The local level also allows the possibility to utilise local knowledge and institutional experience for intervention strategies most effectively. Selected options will depend on an area's particular characteristics, its topography, socio-economic structure etc. The best adaptive policies therefore differ from one place to another and should be specifically designed for that area (Viguié and Hallegatte, 2012; Corfee-Morlot *et al.*, 2009).

Studying climate change at the urban level however has only recently become a focus for climate and urban planning. As such, decision-makers and planners are beset with an absence of research at this scale (Blakely, 2007; Hunt and Watkiss, 2011). A wreath of literature has demonstrated the importance of a real and up-to-date spatial and rational characterisation of urban areas according to vulnerability relevant features for comparative analysis and study regarding the potential interactions of climate change

and key urban systems. The requirement is to consider not only the current urban development, the processes of urbanisation and industrialisation, patterns and pathways, but also the primary climate change impacts, as well as form an understanding of their interrelations and consider or foresee secondary climate change impacts and long term urban development challenges (Figure 2–14).

As outlined previously, the impacts of urbanisation often tend to outweigh those of current climate change and natural disaster risks. Figure 2–15, illustrates that climate and disaster risks arising from climate variability, climate change, and urbanisation are spatially heterogeneous across HCMC. They show distinct spatial differences and will be felt to different degrees in different areas and vary even within areas.

The current spatial pattern and settlement structures of HCMC are integrated into a system that is affected by a number of internal and external pressures. The potential impacts of climate change on the city and critical infrastructure should therefore be assessed with the context of the urban systems complexity. Furthermore temporally, in rapidly urbanising HCMC, it is difficult to predict how changes and risks in an urban system will indirectly reverberate, disseminate and shift in time and how these affect interdependence between various urban components.

Climate change requires urban development to be more sophisticated in the future. Here planning for adaptation in HCMC will require quintessentially much more site-specific information than is currently available. Facing with climate change and disaster risks, HCMC needs to address the key concerns which are common to both adaptation and disaster risk reduction. In doing so, the key priorities for the sustainable urban development of the city can be identified. In HCMC, currently only sparse information is available about the size, structure and spatial distribution and the dynamics of change to both its natural and built environments (Downes and Storch, 2014).

The HCMC authorities are overburdened with the social, economic and environmental challenges that are typical for the management, public servicing and resource allocation of an emerging megacity. Yet the city's authorities responsible for planning are very much aware of the gravity of risk the city is facing and their moral responsibility for risk reduction. There is also considerable agreement that a change in the current system of planning and urban management is needed.



Figure 2–14 Photograph of the skyline of Ho Chi Minh City's Central business district and low-lying areas at the riverbanks of Saigon River taken from Binh Thanh District. Thu Thiem Bridge connecting District 2 to Binh Thanh District is shown and the Thao Dien housing estate (*source: author's own photograph*)

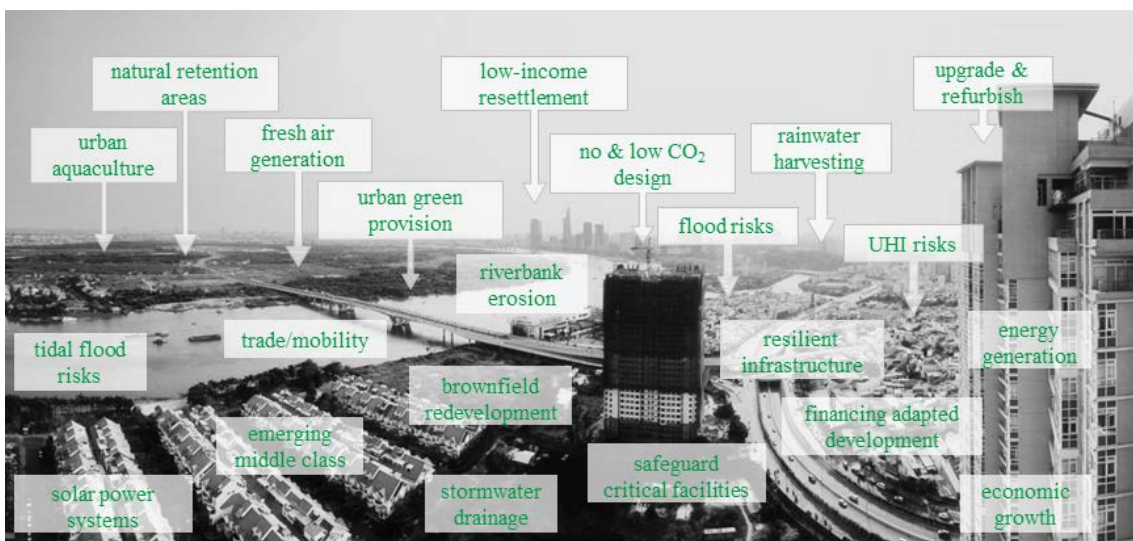


Figure 2–15 Overlaid photograph of HCMC to illustrate climate risks and opportunities (*source: author's own*)

### **3 Spatial planning in Ho Chi Minh City**

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Land is to all intents and purposes a fixed resource, while urbanisation is an extreme case of land-use change. The geographical patterns of the expansion of a city have a direct relationship with its environmental quality, particularly water flows, flooding and urban thermal stress. At the same time, the challenge of a changing climate influences the nature of urban and peri-urban spaces, having a profound effect on how they function. In times of climate change and heightened disaster risks, land-use planning is required to incorporate assessments of space and place as a basis for risk reduction or adaptation actions and interventions. To this effect, land-use planning needs to bring together, draw upon and integrate often discrete policies for both urban development and land-use. This Chapter provides an outline of the role of land-use planning for both disaster risk reduction and climate change adaptation. An introduction into the spatial planning system of HCMC and the overall coordination of land-use planning in HCMC is given, with the current constraints on effective risk-based land-use planning in HCMC discussed.

#### **3.1 Role of land-use planning for climate change adaptation**

Land-use planning has been defined as the allocation of space to balance economic prosperity with acceptable living standards and the conservation of nature (Selman, 1996). The importance of effective land-use planning as a strategy for adaptation (Campbell, 2006; Wilson, 2006; Davoudi *et al.*, 2009; Hallegatte, 2009; Roggema and Dobbelsteen, 2009; Wilson and Piper, 2010; Storch *et al.*, 2011; Hurlimann and March, 2012; Scott *et al.*, 2013; Wamsler *et al.*, 2013; Bendimerad *et al.*, 2016; Biesbroek *et al.*, 2009; Yuen and Kong, 2009; Hoa, 2017) and for better understanding of the relationship between future urbanisation and disaster risks is well documented (Burby, 1998; Godshalk *et al.*, 1998; Burby *et al.*, 1999, 2000; Sudmeier-Rieux *et al.*, 2013). Galderisi *et al.*, (2005) states that land-use planning, as a place-based and problem-solving strategy, will be a key-tool to mainstream climate change adaptation into urban development.

Urban populations are usually less vulnerable to many types of hazards (Peduzzi *et al.*, 2012). The level of construction, the built structures and critical infrastructure present, as well as their locations and densities provide or take away safe havens. For example, instead of providing shelter, a building or groups of buildings may actually escalate the risk. This could mean increasing surface run-off in the case of urban flooding, increasing thermal stress in the case of the urban heat island effect, flying corrugate roofing material in the case of a typhoon, or poorly constructed buildings in the case of an earthquake. Furthermore, the geographical patterns of the expansion of a city have a direct relationship with its environmental quality, particularly water flows, flooding and urban thermal stress. A key question for urban policy and planning is how to direct these changes in ways that minimise environmental impacts and risks. Since many of the main impacts of climate change in HCMC exhibit a land-use dimension, such as the increased frequency of urban flooding events or the intensification of the already existing urban heat island effect, planning and land-use controls can be seen as the most appropriate adaptation management strategy (Storch *et al.*, 2011; Storch and Downes, 2016). This may even be necessary in the face of a short-term cost to economic growth.

The planning decisions taken regarding land-use are often irreversible. Planning has the ability to shape how cities grow and can lock in development patterns for decades (Corfee-Morlot *et al.*, 2009). Both rapid- and slow-on-set climate and disaster risk considerations need to be incorporated early on (CEC, 2009). Land-use planning and development control functions actively seek to manage and regulate land development and ensure that all development takes place at an appropriate time and place and in such a manner that it conforms to a pre-determined set of objectives, policies or standards. Land-use planning and plans can influence the location, type, design, quality and timing of development. Table 3–1 outlines spatial planning measures for land-use policies and urban development planning that acknowledges both the risks associated with urban growth and anticipates that risks will be compounded by future urbanisation and climate change. Used proactively, both land-use and urban development planning has a pivotal role to aid prevention oriented mitigation strategies such as GHG-emission reductions, provide opportunities for renewable and low carbon energy technologies and for decentralised energy and heating/cooling infrastructure. Spatial planning can help shape urban development that is resilient to climate change and importantly ensure risks are fully acknowledged and understood.

Table 3–1 Spatial planning measures for climate change adaptation

Climate change strategy	Land-use and urban development planning
Prevention oriented mitigation	Spatial planning of settlement and transport structures that cause less greenhouse gas emissions
Non-structural adaptation: (a): reducing potential impacts	Maintenance of protective features of the natural environment (water retention areas, protective mangrove forests, cold air generation areas etc.) that absorb or reduce climate related impacts
Non-structural adaptation (b): reducing damage potential	Zoning instruments: Designations in urban land-use plans, e.g. flood hazard areas, adequate allocation of threatened infrastructure
Structural adaptation	Secure the availability of space for protective infrastructure (dikes etc.) Designation of prevention measures as a part of building permissions
Reaction: Disaster Preparedness and Risk Communication	Information sharing to enhance the preparedness of the urban population at risk

Planning can also consider future climate risks when allocating development sites, taking into account the impact and promotion of designs in response to flood risks and UHI for the lifetime of new developments. Planning also provides the opportunity to promote adaptation approaches in design policies for new developments. Conversely, Table 3–2 highlights land-use planning practices, including land-use regulations, representing suitable structural and non-structural solutions to minimise flood losses. These include opportunities to take climate change impacts into account when designing and developing new areas, as well as consideration of urban density.

Options include on the one hand, the maintenance of protective features of the natural environment that lessen or absorb the potential impacts of climate change, such as water retention areas, protective mangrove forests, and cold air generation areas. On the other hand, zoning instruments in land-use plans that designate development in both safe and suitable locations by avoiding development in flood-prone areas, protection measures and promoting appropriate land-use, agricultural and forestry practices.

However, rapid urban development means it is often impossible to halt all new developments in flood-prone areas, and a zero risk scenario does not exist. Planning regulations do not just concern areas at risk from flooding; they also influence, for example, the permeability of the soil, which has an influence on flooding risk. Land-use planning has the potential to build resilience and reduce episodic and regular risks prevalent in HCMC, yet there is a need to develop methodologies, criteria, and indicators, for assessing the need and degree of actions.

Table 3–2 Structural and non-structural land-use planning measures in response to flood risk

Land-use planning options	Description	Specific structural and non-structural land-use measure
Density control	Applying occupancy and density ceilings for permitted land-uses	Limit occupancy load Ground Coverage (GCR) and Floor Area Ratios (FAR) in high population density exposed to flooding Desealing of impervious surfaces or change surface coatings
Site selection and development	Maintaining inappropriate land-uses and development out of hazard areas	Avoid areas where development will increase the likelihood of risk or level of impact, including resettlement Maintain development out of risk and extreme-risk zones Flood proofing in medium to high risk zones
Design and building regulations	Application of appropriate building controls	Building controls in terms of elevation, high foundation walls, stilts, setbacks, minimum lot size, sealing degree, depending on risk levels Sustainable drainage systems, detention/ retention ponds rainwater collecting and reusing, green roofs, facades, tree planting
Protection of critical infrastructure	Critical facilities are ensured of their functionality during disasters	Construct overhead service lines Protect water and sewer lines, extension and optimisation of runoff and sewer system Hard protection measure ( <i>i.e.</i> dyke systems)
Open space preservation	Specific areas used for low intensity and low density use to minimise damage	Flood plains used only for urban agricultural use, avoid the development of additional settlement areas at risk of flooding Designation and maintenance of riparian vegetation, conserve and protect the existing natural or near-nature water balance, including afforestation Wetlands created as a means to absorb peak flows from floods: Establishment of suitable retention and detention areas

## 3.2 Planning, management and governance in Ho Chi Minh City

### 3.2.1 Legal context and role of land-use planning

Spatial planning in Vietnam is framed within a three-tiered system of local government. In accordance with Article 118 of the 1992 constitution, Vietnam consists of provinces and centrally-controlled cities. As Table 3–3 demonstrates, a province consists of prefectures, prefecture-level cities and towns, townships, counties and wards, while a centrally-controlled city like HCMC, consists of district's and communes (also known as wards).



Table 3–3 The three-tiered system of Vietnamese governance

Planning tiers		
1st	2nd	3rd
	District	Communes
5 Centrally-controlled cities (Hanoi, Ho Chi Minh City, Hai Phong, Da Nang, Can Tho)	Prefectures	Townships Countries
	Towns	Communes Counties
Vietnam	Prefectures	Townships Counties
58 Provinces	Prefecture-level cities	Communes Counties
	Towns	Communes Counties

In Vietnam, spatial planning is legally named: '*quy hoạch xây dựng*' (literally meaning "construction planning") in general for different scales from regional planning to rural planning; and '*quy hoạch đô thị*' (literally meaning "urban planning") for urban areas of different scales from city, districts to projects. Land-use planning is known as "*quy hoạch sử dụng đất*"<sup>13</sup>.

The current system of land-use planning in Vietnam aims at the economic, technical and political measures for the planning and management of land-use allocations in the most coherent, effective, scientifically-proven and rational manner possible. Policies are heavily orientated towards social-economic development (Decree30/2004/TT-BTNMT). The HCMC land-use plan period is fifteen years and approved land-use plans must be revised and updated in five years. In HCMC land-use planning is closely connected with urban development, showing the allocation of populations and activities.

Land-use planning in Vietnam is the system by which the Government regulates the effective use and development of land. The objective of land-use planning in Vietnam is to adopt the socio-economic strategy as identified within the Socio-Economic Plan in order to allocate land-use to effectively foster socio-economic development

<sup>13</sup> In Vietnamese, there are two terms with distinct meanings for "plan" and "planning". '*Quy hoạch*' translated means long-term planning, while '*Kế hoạch*' translates as short- or medium-term planning. While long-term plans have a high probability of implementation, Coulthart *et al.*, (2006) states that the term '*quy hoạch treo*', which translates as 'hanging plan', is used for plans that look nice hanging on the wall of the office of a high level official, but which rarely get implemented.

(Decree30/2004/TT-BTNMT). "Construction planning" is regulated by the National Construction Law, whereas Urban Planning by National Urban Planning Law. The preparation of the land-use plan resultantly is based on the following four regulations:

- i. Article 23, 25, 27 of Vietnamese Law on Land No.13 /(2003);
- ii. Chapter II of Decree181/2004/ND-CP on the implementation of the Vietnamese Law of Law;
- iii. Decree 30/2004/TT-BTNMT on guideline for preparing, revising and appraising land-use plan;
- iv. Decision 04/2005/QĐ-BTNMT on framework for preparing land-use plan.

In HCMC land assets are prior evaluated and assessed economically, environmentally, technically and politically as a basis for decision-making involving land disposition and utilisation in fulfilment of the Socio-Economic Plan. As such, land-use quotas are given nationally, with oriented targets for which the land-use plan develops a relative balance for land-use consumption (Decree30/2004/TT-BTNMT). In parallel, the HCMC Master Plan is the product and reflection of the combination of both socio-economic strategy and land-use planning.

### **3.2.2 Adapting planning to a changing climate: Current policy instruments**

Previously in Vietnam, climate change and disaster risk reduction were falsely seen as solely an environmental issue. This inhibited and delayed land-use planning in HCMC from being utilised effectively. Recently, land-use planning has been seen as having a key role to play in developing strategies to effectively anticipate and develop responses to climate change, while at the same time not hindering the social-economic development of the country.

Adding to the decisions and national strategies relating to climate change and natural disaster response and mitigation, which include both guidance and procedure for national and province level action in land-use planning, the Ministry of Planning and Investment (MPI) (Decision 1485/2013QĐ-BKHĐT) and the Ministry of Construction (MoC) (Decision 2623/2013/QĐ-BXD) require local governments to consider and mainstream climate change and disaster risk reduction into their planning activities. Table 3–4, highlights further that the Vietnamese Law on Construction, Law on Environmental Protection, and Law on Urban Planning all contain paragraphs that regulate environmental protection in urban activities suitable to promote environmental, disaster risk and climate issues into land-use planning practice.

Table 3–4 Key instruments for integrating climate-related issues into land-use planning

Basis	Content
No. 16/2003/QH11 (2003)	<p>Law on Construction</p> <p>Article 10: Conduct which is strictly prohibited in construction activities: “encroach on or illegally occupy safety corridors for irrigation works, dyke embankments” ...and “areas where there is a danger of landslide and flood”</p> <p>Article 13, 16, 20, 24: General requirements applicable to construction regional and urban master plans: “must fix areas of environmental protection, of natural resources and other functional areas” (Section 1), “must not adversely affect the landscape and environment” (Section 3)</p>
No. 52/2005/QH11 (2005)	<p>Law on Environmental Protection</p> <p>Article 6: “Protection and rational and economical use of natural resources to be encouraged” Article 121: Responsibilities of state management agencies “to meet environmental protection requirements in land-use planning and plans, national strategy on water resources” (Section 1- Clause k).</p>
No. 32/2009/QH12 (2009)	<p>Law on Urban Planning</p> <p>Article 35: Regulation on management at all level of urban plan “areas of conservation ...scenic places and landscape areas and environmental protection”.</p>
No. 445/QDTTg 07/04 (2009)	<p>Revising the Vision of General Planning for Vietnam Urban Development up to 2025, vision to 2050</p> <p>Article 6 on environmental protection, natural landscape, preserving the urban ecosystem balance</p>

### 3.2.3 Management scales

Each planning level is essentially managed by the component local authority, such as the HCMC people’s Committee or the district level People’s Committee. Furthermore, each authority uses a set of statutory planning documents to regulate the urban development in their administrative territory. According to the 2009 Law on Urban Planning (30/2009/QH12), the management and planning of the city takes place on three main scales.

#### 3.2.3.1 City General Planning (scale 1/25,000; 1/50,000)

HCMC people’s Committee uses the Master and Land-use Plans (scale 1:25,000) to regulate the development of the overall city. The General City Plan is established to indicate the main development directions for the city. The structural orientation and framework for technical infrastructure facilities and the models of urban development in HCMC for different typical areas, *i.e.* the city centre, the inner city, new district developments and rural development are given. The General City Plan clearly indicates the inner area and areas planned for development, including the development objectives

and driving forces, as well as development structure of the space of the inner area and suburbs. The plan includes the only main criteria of land-use, for example residential land, industrial land, green space, water bodies. Brief zoning of urban functional lands that demonstrate the application of the aforementioned land-use criteria is undertaken. Foreseen population sizes and population densities are given, as well as other basic criteria and norms on social and technical infrastructure. Strategic Environmental Assessment (SEA) and priority investment programmes and resources for implementation are undertaken at this level. The plan is approved at the national level by the Prime Minister. Article 25 of the Vietnamese Law on Urban Planning states that the approved General Plan of a centrally run city serves as a basis for conducting the subsequent specialised urban technical infrastructure planning and zoning planning for the city. District General Planning more specific to district scales was formerly undertaken and approved by the City People's Committee, but is now omitted in Urban Planning Law.

#### 3.2.3.2 Zoning Plan (scale 1/5,000; 1/2,000)

Article 29 of the Vietnamese Law on Urban Planning states that Zonal Plans are to be established to highlight and indicate the use functions for each lot of land. Zonal Plans are prepared at the scales of 1:5000 or 1:2000 (mostly 1:2000, which related to the scale of Detailed Plans according to the old Construction Law at the ward and neighbourhood level). Zonal Plans principally show the land-use representation and infrastructural systems, the organisation of space, architecture and landscape for the entire planned area; norms on population, land-use and technical infrastructure for each street block are given. Here land-use planning criteria are regulated for each block within the plan. Building height limits, floor area ratio (FAR), gross floor area (GFA), ground coverage ratios (GCR) and population are stated. Zonal plans also contain the arrangement of social infrastructure facilities in response to their use needs, the arrangement of the network of technical infrastructure facilities in each street suitable to each development period of the urban centre; providing information on boundaries for public space, like parks, open spaces, schools, health-care facilities, cultural centres, shopping areas, administrative areas and other functional areas. For HCMC the Zoning Plan is considered as the District Construction Plan and is approved by the HCMC People's

Committee. The approved Zonal Plan serves as a basis for identifying construction investment projects in the urban centre and conducting subsequent detailed planning.

### 3.2.3.3 Detailed Plan (scale 1/500)

Article 30 of the Vietnamese Law on Urban Planning, states that Detailed Plans are to be established to underline and indicate the norms on population, social and technical infrastructure provision. Detailed Plans are mostly undertaken as Project Plans (most commonly scale 1:500) and show the requirements for the organisation of space and architecture for the entire planned area. Plans are mostly used by the developer for complex developments like housing estates, shopping malls, factories and schools. At this level, information is provided for every building, for example, the setback, distance between buildings, the floor area ratio and the building coverage ratio. Detailed Plans also show the planning of social infrastructure facilities in response to their use needs; norms on land-use and design requirements for each lot. The organisation of technical infrastructure provision up to the boundary of each land parcel is also planned. Environmental Impact Assessment (EIA) is undertaken at this level. Within Detailed Plans, the land-use planning criteria are regulated for each parcel/plot, and often include additional details such as setbacks width, etc. They are approved by the local district authorities or the HCMC People's Committee in the case of important projects, with the approved detailed plan serving as a basis for granting construction permits and formulating.

### 3.2.4 Coordination of spatial planning

Planning and administration in Vietnam are highly dominated by hierarchical and formalistic elements. Currently, there are a multitude of actors involved in land-use and urban planning within the HCMC administrative system: socio-economic development planning (Department of Planning and Investment), urban construction planning (Department of Construction, Department of Planning and Architecture), regional planning (Regional Planning Steering Committee and Southern institute for Regional and Urban Planning), as well as various additional sectorial planning agencies and departments.

There are three main programmes related to and affected by the use of land: the Vietnam Socio-economic Development Plan, prepared by the Ministry of Planning and Investment (MPI), the Spatial Plan, prepared by the Ministry of Construction (MoC), and the Land-use Plan, prepared as a sector plan by the Ministry of Natural Resources and Environment (MoNRE). These plans are developed and controlled by different levels of local government management.

Figure 3–1 shows the position of HCMC Land-use Plan in relation to the three main national programmes, which are practiced and displayed horizontally. Vertically the three management scales for a centrally controlled city such as HCMC, City General Planning, Zoning Plan, and Detailed Plan are shown. For the purpose of land-use planning in HCMC, greater focus is given to the city scale (General Planning) and to the district level (Zoning Plan).

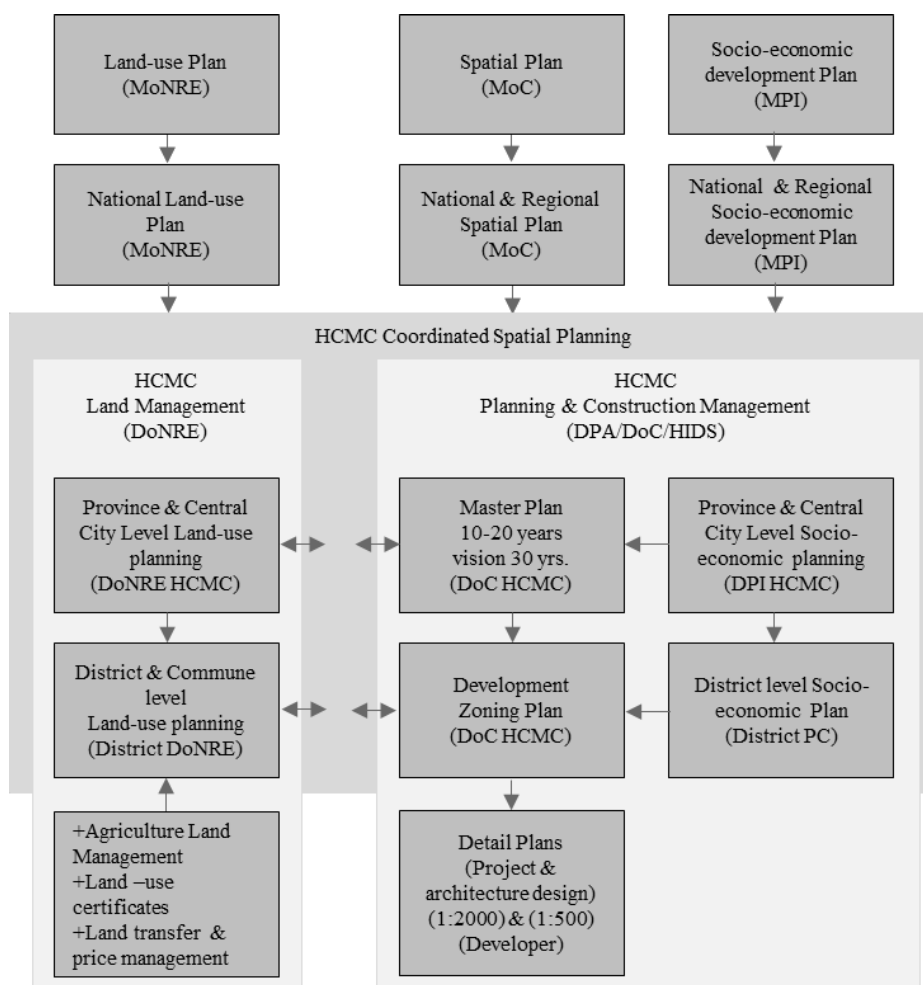


Figure 3–1 Coordination of urban planning and land-use within HCMC (source: author's own)

Table 3–5 Stratum of urban planning and land-use planning in Vietnam and HCMC

Plan	Competent agency	Basis
Regional Zoning Plan	MoC	Decision 322/1993/BXD-DT (1993)
Urban Development Master Plan HCMC Master Plan	MoC HCMC People's Committee	Decree 91/CP replaced by Decree 37/2010/ND-CP (2010) and Decision 24/2010/TTg (2010) Approval by the Prime Minister
HCMC Land-use Plan	DoNRE HCMC People's Committee	Approval by the National Assembly
District Master Plan	HCMC People's Committee	
Detailed Plan	Developers/investors	Decree 91/CP replaced by Decree 37/2010/ND-CP (2010)

For overall spatial planning, both urban development and land-use planning in HCMC, responsibilities and competences are shared, among several governmental organisations (Table 3–5). This means that no single organisation can ultimately make a decision without consulting the others.

Generally, the Ministry of Construction (MoC) is responsible for drawing up the Regional Construction Plan for centrally controlled cities such as HCMC. Plans are proposed by MoC and comments are sought from related agencies and their branches, other relevant ministries and the HCMC People's Committee. The Plan is then submitted to the Prime Minister for approval (Luu, 2011). Similarly, the Land-use Plan is prepared by the Ministry of Natural Resources and Environment (MoNRE), and then scaled down to the lower level of local administration. The HCMC provincial Land-use Plan is prepared by DoNRE (land-use plans for HCMC were formerly drafted by the Cadastral Department), with the consultancy with other related government agencies. Furthermore, all other social-economic aspects need to adhere to land-use, land-use planning needs to integrate all land-use demand projections of each programme and additional sectors. Along the additional sectors, the agriculture sector has the largest scope and scale of land management; bringing into the equation land attributes of land fertility and natural conditions for crops and livestock. Previous to 1995, land-use planning was not separated as a specific programme systematically from the national level down to the commune level, but was developed as an important component of all planning, such as social-economic development master planning (in the part of territory organisation), agricultural and rural development planning (to allocation land for the development of crops, livestock, forestry, aquaculture), residential development

planning and projects of agricultural development. From the 1996 onwards, with enforcing the Vietnamese Land Law (2003), land-use planning has been systemically undertaken (from the national level to provincial, district and commune level) and comprehensively with the planning participation of all sectors.

In HCMC, the Sub-National Institute of Agricultural Planning and Projection (Sub-NIAPP) acts as a specialised institution assisting in land-use plan development with technical support in land-use planning and land allocation activities.

The prescribed contents of land-use planning are stipulated in the Vietnamese Land Law. Land-use plans are to be drafted every 10 years and updated every 5 years. The prescribed contents for the HCMC Land-use Plan according to the Vietnamese Land Law are:

- i. Survey, studies, analysis and summary of the natural, economic and social conditions and the present land-use; evaluation of land potentials;
- ii. Identification of land-use orientations and objectives in the planning period;
- iii. Determination of land classes for socioeconomic development, defence and security demands;
- iv. Determination of land areas to be recovered for the implementation of works and projects;
- v. Determination of measures for land-use, protection and improvement and environmental protection;
- vi. Suggestion of ways to implement the land-use plan.

### **3.2.5 Development of spatial plans affecting land-use in HCMC**

Nguyen (2012) provides a good overview of the development of spatial planning legislation in Vietnam and specifically in HCMC since 1975 and the period after the economic reform, *Doi Moi* in 1986.

Table 3–6 shows the development of regulations related to both urban planning and land-use planning of HCMC following 1986. The frameworks of both urban development and land-use planning in HCMC have undertaken a number of changes since 1986. Most of these changes in terms of planning processes have been undertaken after 1990.



#### 3.2.5.1 Urban Master Plan 1993

The first Urban Master Plan for HCMC was developed and ratified in 1993 by the Prime Minister to provide a legitimate and institutional framework to guide the future spatial development of the city to the year 2010. According to the Master Plan, HCMC was foreseen to be the first industrial centre of the country and an area of communications for Southern Vietnam. The plan did not target a high rate of urbanisation and it was foreseen to constrain the city's population to no more than 5 million inhabitants by the year 2010. Within the plan spatial development, both in terms of industrial and residential development was focused towards Thu Duc district (Urban Master Plan, 1993; JBIC, 1999; DPA, 2010).

#### 3.2.5.2 HCMC Master Plan 1998

The HCMC Master Plan 1998 was the sole master plan of HCMC for the period up to 2020, approved in final form by the Prime Minister in 1998. The plan for the development of the whole area of the city is legally binding for all decisions of local administration, and it defines the main features of land-use. The plan took a wider perspective of the city, with a radius extending to a 30–50 km radius from the centre of the city covering parts of surrounding provinces, Binh Duong, Dong Nai, Long An, Tay Ninh, Ba Ria-Vung Tau. The plan emphasises the urban and industrial development on the periphery, to the south and the southeast (Nha Be, Binh Chanh, Hiep Phuoc-Can Gio), and to the Northwest (Cu Chi, Hoc Mon) (HCMC's Master Plan, 1998; DPA, 2010).

#### 3.2.5.3 HCMC Master Plan on Construction 2008

HCMC witnessed a rapid increase in population and investments during the ten year period from 1998 to 2008. This period however, was also characterized by inadequate planning guidance and control due to lack of specifics on permissible land-uses and density; cumbersome permitting process; and problematic coordination of policies between districts and city government (Nguyen, 2012). In 2008, the People's Committee of HCMC approved a revised Master Construction Plan to guide the development of HCMC up until 2025, replacing the 1998 Master Plan. Within the plan, HCMC is developed as a cultural megacity and a modern centre of industry and

commerce for the region and Southeast Asia. The stated aims of the plan are to accommodate the growing population and higher-income lifestyles, to avoid development in low-lying and wetland areas (*i.e.* Can Gio biosphere reserve) and to protect the historic urban core area of the city. It was planned that HCMC simultaneously develops with the other and adjacent regional urban areas of South Vietnam, with development planned in all four directions along four main corridors (Dapice *et al.*, 2010). Also in 2008, the additional Greater HCMC Regional Master Plan up to 2020 with a vision towards 2050 was prepared by MoC and approved by the Prime Minister.

#### 3.2.5.4 Revision of HCMC Master Plan on Construction 2010

HCMC's Master Plan on Construction 2008 up till 2025, was rendered obsolete by rapid gains in income and population and subsequently revised in 2010 in accordance to the requirements of the Social Economic Development Strategy of 2002, the Social-Economic Development Plan for the Southern Region, dated 2000 and in correlation with the Greater HCMC Regional Master Plan up to 2020 with a vision towards 2050. The Adjusted Master Plan on Construction of Ho Chi Minh City up to 2025 was prepared and approved by the Prime Minister through the Decision No. 24/QD-TTg.

Table 3–6 Major regulations related to urban land-use planning in HCMC after Doi Moi 1986

Legislation	Content
Decision 20/TTg 16/01/1993	HCMC Urban Master Plan for the period up to 2010, approved by the Prime Minister
Notice No.30/TB 20/03/1996	Readjusted overall planning for inner city and development of new urban sectors of HCMC. Instruct to prepare the Amended Master Plan of HCMC
Decision 123/1998/QDTTg 10/07/1998	HCMC Master Plan for the period up to 2020, Approved by the Prime Minister
Decision 1570/QD-TTg 27/11/2006	The Prime Minister approving the task of making the General Planning on Construction of Ho Chi Minh Region up to 2025
March, 2008	HCMC Revised Master Plan for the period up to 2025, Approved by the People's Committee of HCMC
Decision 589/QD-TTG 20/05/2008	Master Plan on Construction of the Ho Chi Minh City Region up to 2020, vision toward 2050, approved by the Prime Minister.
Decision 445/QD-TTg 09/04/2009	Revising the Master Plan Orientation for Vietnam's Urban System Development to 2025 with Vision to 2050
Decision 24/QD-TTg 06/01/2010	Ratifying the Adjusting Master Plan on Construction of H Minh City up to 2025, approved by the Prime Minister

(Source: Nguyen, 2012)

### **3.3 Current constraints**

From a review of the literature it is clear that spatial planning can make a positive contribution to adapting to and mitigating climate change, however the planning or absence of planning in the past in HCMC has delivered results which are detrimental for climate change. From the review of both the development and coordination of spatial planning in Vietnam, it is seen that both theoretically and practically land-use and urban planning are an expression of socio-economic development strategies. The Socio-economic Development Plan is designed to provide a context for the Urban Development Plan and the Land-use Plan. Although these three plans differ in both their legal origins and their responsible administrative agencies, in principle, they should share common required targets for a coordinated, adapted and more sustainable urban development.

DoNRE as responsible for land-use planning is currently engaged in activities relating to the regulation, planning, and provision of urban infrastructures. It has as such control over a consolidated set of instruments like land-use plans, zoning rules, and by-laws that are readily available for utilisation towards adaptation in HCMC. However, the instruments are presently more oriented towards the regulation and management of urban expansion, as they provide indications for only new development. The rate of transformation of HCMC highlights the grave challenges faced by DoNRE in enforcing a more precautionary approach. While adaptation has appeared on the national agenda since 2008, and disaster risk reduction since 2007, they have made little impact on the development control and zoning of plans. The two most prominent barriers to the integration of adaptation measures into the current land-use planning system are mentioned in detail below.

#### **3.3.1 Institutional constraints**

Within HCMC, DoNRE is not only responsible for the provincial land-use plan, but also for approving district land-use plans and detailed area plans (ward, industrial zone or project level), the issuance and administration of land-use rights and their transfer, as well as changes in land-use. DoNRE has also as previously mentioned the mandate to head and coordinate the cross-sectoral response to climate change in HCMC, the CCAP, in the appropriately named HCMC Climate Change Steering Board. It is also DoNRE's responsibility to apply Strategic Environmental Assessment (SEA) and to review all

other sector and spatial plans in the city with regards to their environmental sustainability, and their effectiveness in meeting climate change adaptation requirements of the city.

Land-use planning in HCMC finds itself juxtaposed within a strongly hierarchical top-down and sectoral system. This dictates the importance of rising awareness of climate change and disaster risk reduction aspects in urban planning among the political and technical bodies and the entire decision-making levels. The result is that the departments of HCMC are usually more reliant on the national ministries than their peer departments in the municipal governments. Ideally, the horizontal integration of different sectors and the vertical integration between different levels of government should take place (Schinkel, 2015). Furthermore, activities and decisions of neighbouring, regional and national administrations, as well as civil society actors, should be integrated. While ultimately, land-use decisions should be taken at the level that is most appropriate (Downes and Storch, 2014).

Spatial plans are prepared at three levels of detail; whereas land-use planning is orientated to socio-economic development planning, with land-use targets and designations for HCMC strictly set and allocated at the national level (specific targets stated in hectares for specific land-uses designations, for example in the draft the city's land-use plan 2020, 32 land-share targets were set from national level). The allocation and trickle down of too many rigid land-use targets from the higher levels makes the city's land-use planning inflexible and often not downscaled to local needs. At the same time, each actor and planning body has its own orientation and perception on the socio-economic plan. A lack of horizontal integration between these various actors is apparent.

To further complicate matters, plans are compiled at different intervals and for different planning timeframes (up to 2020 or 2025 and with visions up to 2025 or 2030) with only subsequent adoption or synchronisation. In theory, social-economic development planning should occur first and then orientate the ensuing plans; however, the timeframes of the plans vary widely and thus if there are inconsistencies with previously approved plans, revisions and supplements may be proposed. Plans, even sector plans which are previously approved at the national level, often form the basis for later plans. For example, the current social-economic development plan of HCMC until 2020, with a vision to 2025, was only approved in 2013 (Decision No. 2631/QĐ TTg) with a

timeframe of 10 years and a vision of 5 years, while the Master Plan on Construction HCMC until 2025 was approved in 2010 (Decision No. 24/QD-TTg) with a timeframe of 15 years divided into three 5-year terms. Subsequently, Land-use planning was approved in late 2013 (Decision No. 45/2013QH13). Regional planning was completed in 2010; transport planning was approved in 2007 and revised in 2013, and agricultural planning was completed in 2009.

Differences in land-use classifications also exist between the relevant plans. Interestingly, the land-use classification in the HCMC Master Plan on Construction 2010 does not correspond with that in the Draft Land-use Plan 2010. As Goedecke and Welsch (2016) point out, a provision of land for environmental protection measures is urgently needed. It is argued that the determination of land-use categories should be extended to include categories for protection areas and for their placement in HCMC (Goedecke and Welsch, 2016). Areas should be designated in planning as early as possible to counterweight the negative effects of development. Currently however, land-use cannot be appropriately controlled as planned as there are often ambiguous and non-transparent relationships between plans and implementation.

Moreover, Goedecke and Welsch (2016), in their review of the governance of land-use planning in HCMC, state that the HCMC administration is characterised by a significant lack of enforcement and transposition. These deficits are attributed to a lack of resources, time, and prepared planning principles, as well as a lack of suitably qualified staff which have experience with the integration of environmental concerns, climate change or risks. These deficits also apply generally with regard to the enforcement of environmental protection as a whole (Zschiesche, 2012; Goedecke and Welsch, 2016).

Nevertheless, short-term economic growth is set as a high priority in the socio-economic plan. Here, environmental issues play a subordinate role in planning. As is the case in many cities, planners and decision makers mainly get rewarded for the securement of investment and not in the prevention of disasters or the prevention of development sprawling into low-lying lands and additionally, often having more immediate infrastructural provision issues to content with. This is basically a systemic problem for all fast-growing metropolitan areas in developing countries (World Bank, 2011). The land-use distribution is essentially motivated by socio-economic requirements with a very high level of abstraction (Goedecke and Welsch, 2016).

HCMC planning departments naturally have multiple priorities including socio-economic development. This is clearly demonstrated by the HCMC Master Plan on Construction 2010, as well as by the Draft Land-use Plan 2010-2025 and the Irrigation Plan for Flood Control for the HCMC area to 2025 approved in 2009. These plans which diverge from adaptation needs are seen to direct urban development towards the historically flood-prone areas to the south and east of HCMC (Storch and Downes, 2011).

### **3.3.2 Lack of data**

In order to successfully integrate environmental considerations in the planning and to decrease uncertainty, a sound knowledge of the state of its environment and the natural resources is necessary. Adaptation planning is highly dependent on the reasonable understanding of the objects involved, their properties and often complex interrelationships. The lacking availability of planning prepared environmental data is already criticised by many experts (Carew-Reid, 2007).

A key component for mainstreaming adaptation into HCMC spatial planning will be the sound understanding of the current urban environment. Up-to-date information of current existing land-uses is a necessity for proper urban management and planning. Unfortunately, the properties of the urban environment in HCMC are not well understood due to the paucity of data and issues with data collection, processing and exchange. Due to the rapid pace of development, planning is often undertaken with outmoded datasets, data is scarce or data is protected by departments and not widely shared. The information regarding land-use planning and management is not updated frequently enough to accurately track change.

Analyzing the structural changes of HCMC is of greater importance than ever. In order to monitor changes in the urban environment, an understanding of the change in patterns of urban development over time is becoming increasingly important for the realisation and quantification of risks from impacts, as well as the benefits from timely adaptation. Once quantified, risks and benefits need to be communicated; decision makers require an understanding of future risks for evidence-based plan development.

In order to effectively address the climate-related environmental issues that HCMC is facing it is essential to have a better understanding of the nature of the physical fundamental underset of urban density information at all land-use planning scales. The

understanding and application of density data is still rudimentary. Nevertheless, the interest in quantifying has been growing over the last few years, especially for densely populated cities. While some institutional data exist to support the forecasting and assessment of climate change impacts, there is currently a lack of density information and consistency across platforms, which restricts urban growth monitoring, plan compliance assessments, and the sharing of data between the different planning actors.

For HCMC, currently only sparse information is available about the size, structure and spatial distribution and the dynamics of change to both its natural and built environments (Downes and Storch, 2014; Goldblatt *et al.*, 2018; Schaefer and Thinh, 2019; Cao *et al.*, 2019; Leitold and Diez, 2019). Climate change information alone is not sufficient for anticipating and reducing climate impacts in HCMC (Storch *et al.*, 2011). Enhanced urban monitoring is needed to support effective anticipatory efforts to increase societal resilience to potentially disruptive events, basing planning on evidence. By providing and disseminating access to more information about risk, the urban administration can implement management systems that include adaptation solutions. These will not only have environmental benefits, but will allow the more focused placement of scarce funds.

To be useful for DoNRE, information needs to be at a relevant scale, credible and available in an adequate timeframe for taking action (Amundsen *et al.*, 2010). DoNRE, through their land-use planning, are required to consider the impacts of climate change; however, there are insufficient studies and city-wide assessments on the impacts of climate change to provide inputs into planning. A lack of information has resulted in a failure to identify and implement policies and measures to address the risks posed. Furthermore, DoNRE notes that an additional formidable challenge is a general lack of targeted tools and methodologies—from data to planning recommendations, to instruct and inform decision-makers and advance implementation at the local level. Not surprisingly, a lack of information has resulted in a failure to identify and implement policies and measures to address the risks posed.

## 4 What can be measured can be managed

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So far the role and potential of land-use planning in HCMC and the current constraints for integrating both climate change and disaster risk considerations into planning have been discussed. It has been alluded to that in HCMC planning is often undertaken without sufficient attention to hazard risks yet urbanisation and climate risks are converging and forcing a re-examination of the way HCMC is planned. This Chapter now turns to the consideration of spatial information needs, the significance of indicators and the importance indicators describing density for land-use zoning. Sources of data are briefly alluded to before the urban structure type methodology is introduced. Finally the Chapter ends with the development of an urban structure type based indicator framework based on the classification of HCMC's urban structures.

### 4.1 Spatial information needs

A spatial component is associated with the majority of municipal activities, namely in urban planning and management, whilst spatial data are critical for the assessment of climate change impacts and responses, with all hazard risk components in HCMC varying across space. Yet there remain significant gaps in the availability of relevant spatial data for HCMC. The local policy- and decision-makers, as well as planners have the responsibility to create policy, plans, programmes, and implement projects that will decide the course of urban development in HCMC. It is important to understand likely climate impacts to HCMC in order to identify vulnerable systems, sectors and groups and potential adaptation responses. The assessment of risks and the implementation of adaptation and disaster risk policies in planning should trigger changes to HCMC. Actions need to be based on evidence and reliable urban data is becoming more and more crucial.

Only at the urban level is it possible to integrate the many layers of site specific information and to work closely with the many administrative actors involved directly in the day to day planning to be able to integrate both climate change and disaster risk reduction activities into spatial planning (Doytsher *et al.*, 2010). As described in the



previous Chapter, the drafting of adaptation and disaster risk reduction options in urban areas, the provision and existence of reliable data is a major challenge. The issues of hazard identification, risk assessment, and developing mitigation solutions are inherently spatial in nature. Long-term sustainable urban development calls for a strategical and conceptual examination of an appropriate urban form, land-use and future designation of urban areas (Carew-Reid, 2009).

In order to successfully integrate climate change and disaster risk reduction considerations into planning, relevant data must first be available. Reliable and up-to-date information over the relationship between socioeconomic and the ecological performance of the built environment is needed. Once available, data must be further processed, refined and evaluated in order to obtain its relationship and significance for planning to analyse the requirements of the city to then decide what actions would benefit specific locations most (Faensen-Thiebes and Goedecke, 2007; Faensen-Thiebes *et al.*, 2010). Since many studies have indicated that urbanisation can play a larger role in increasing local exposure and vulnerability, it is important to have an understanding of the existing state of the urban environment as well as the desired planned situation (Güneralp *et al.*, 2013; Dawson *et al.*, 2011; Storch and Downes, 2011; De Moel *et al.*, 2011).

Doygun and Uzun (2003), cite that understanding of landscape changes is essential for sustainable management of the urban environment, as it allows decision makers to take a broader holistic view of urban system and its components. This necessitates the undertaking of a baseline study to understand the current status quo of the urban components (Figure 4–1). Yet credible baseline information in HCMC is rarely available at a high enough resolution to be useful for policy analysis and decision making and what is available becomes rapidly outdated due to the strong dynamics of urban growth. Here, an important element is the determination of the current land-use and its disparity from the desired planned state.

Moreover, for baseline studies the determination of parameters, criteria and indicators are important. They should be easy to measure and should highlight the distance to both political and socially developed targets. However, obtaining reliable baseline information and monitoring urban development to assess spatial planning outcomes in terms of cross-sectoral adaptation and mitigation policy integration can be challenging, especially within the rapidly growing cities of the Global South.

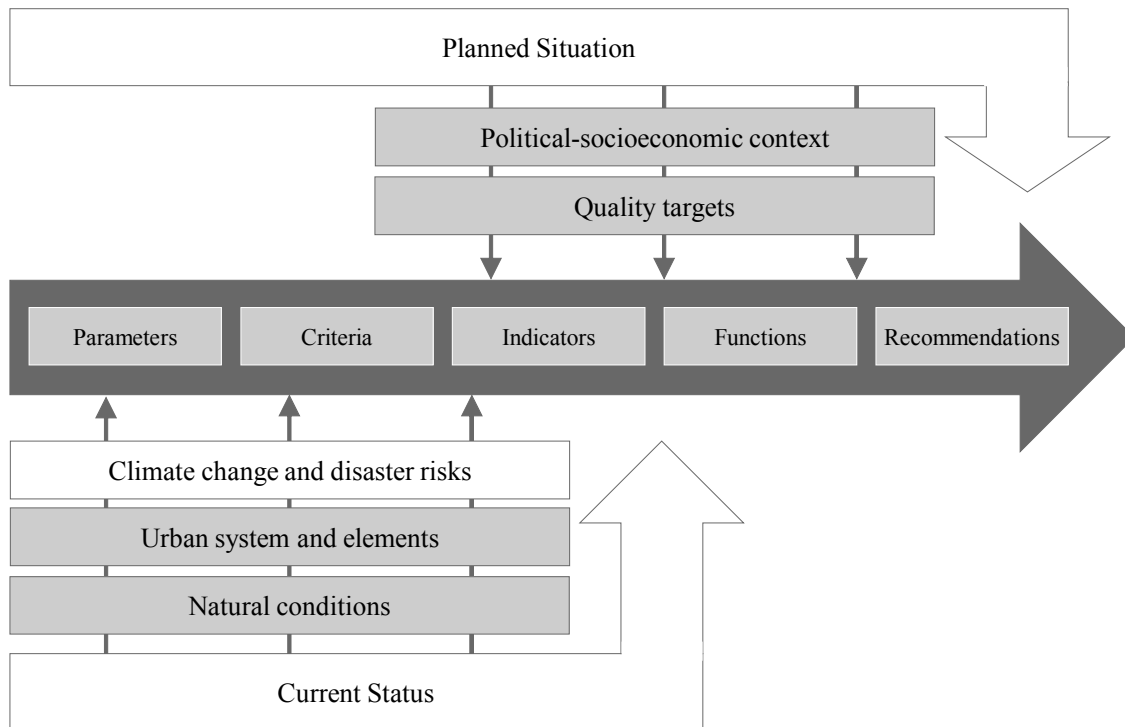


Figure 4–1 Towards adaptation: Integrating climate change considerations into the planning (source: adapted from Geodecke and Welsch, 2016)

#### 4.1.1 Indicators

A well-established approach in environmental management is to use indicators to provide information for a specific planning or management target (Zhao *et al.*, 2011). Several methods based on indicators have been proposed to evaluate climate and disaster risk issues. The contributions of Cutter (1994), Birkmann (2007), and Carreño *et al.*, (2007), among others, attempted to measure risk-related aspects using either quantitative or qualitative indicators. By taking measurements through the use of indicators, it may be possible to understand and assess how well a city is adapting to climate change and disaster risk reduction. Indicators are intended to present a link between policies and to highlight how policies are implemented on the ground. As Moussiopoulos *et al.*, (2010), writes, indicators provide crucial guidance for decision-making, since collected data are translated into management units of information.

Indicators can be used during monitoring in order to examine whether objectives are being achieved, and to identify the level of compliance with environmental targets.

Indicators are parameters, which serve to measure and provide information about phenomena, the “indicandum” or a complex system or process and to measure not

directly measurable circumstances, often aggregating information into a usable form. They have been defined as

*“A quantitative or qualitative factor or variable that provides a simple and reliable means to measure achievement, to reflect changes connected to an intervention, or to help assess the performance of a development actor”* (OECD-DAC, 2002).

They typically are “sets of information used to determine the status quo or changes of an inherent characteristic of a system” (Guy and Kibert, 1998; CLUVA, 2010). Where phenomena cannot be directly measured, often proxy indicators are used. Directly measured indicators usually focus on a minor and telling piece of a system that can offer a bigger representation. Here, proxy indicators are by definition the indirect measurement, which can be used as an alternate and/or substitute to provide an equal value with direct measurement (OECD, 1994). Most of the indicators are, in fact, simplifications of complex phenomena and provide only an indication of conditions or problems (Clarke and Wilson, 1994).

Moreover, because indicators are simplified and clarify raw information, they often can lead to better decisions and more effective actions (UNEP, 2012). They can help combine physical and social science knowledge into decision-making and they can help measure and calibrate progress towards being resilient to climate change and disaster risks. They can also provide an early warning to avert economic, social and environmental losses (UNEP, 2012). Indicators are also useful tools to help communicate ideas, thoughts and values of decision-makers to the general public. Information in its raw form is difficult to judge which are why indicators provide a simpler form of information than complex statistical data and are great instruments for political and practice purposes.

Urban indicators have traditionally had many different roles and many potential users. Indicators and proxy indicators are commonly used in risk assessments, in planning, in health, in environmental protection and many other fields due to their extensive application. They are especially used where there are specific requirements for policy, monitoring or evaluation. This means that indicators have different purposes and various forms, which is why they are considered tools of communication of information for decision-makers (CLUVA, 2010).

Alibegovic and De Villa (2006), describe how indicators can be used as learning tools, communication tools and management tools by policymakers. Specifically, urban indicators can be identified as ‘rate indicators’ which describe a change over time. They also can be identified as ‘target indicators’ which centre on a given aim and finally, as ‘performance indicators’ which are normally used to assess behaviours within any given political setting (CLUVA, 2010).

The OECD in (1994) defined three main functions of indicators as follows: *Simplification*, to reduce number of components and measurements required to assess the current condition/situation by limiting the scope and content; *Quantification*, Indicators should function for analyse and evaluation, in order to provide a synthetic account of specific condition/situation that can be analysed in further display; and *Communication*, indicators convey the message that should be easy to interpret. They should contribute to the practical implementation of measures by illustrating the status quo, as well as where action is required and therefore it is necessary to consider the aim and content of the message and who will interpret them.

To these three main functions both Walz (2015), and Leon (2005), added a fourth, stressing that indicators should demonstrate an overall *Planning function*: Indicators should reveal where action is required by (i) describing the general state of affairs, as well as (ii) providing more detailed spatial information to permit the identification of problem sites.

The selection of indicators is important. According to Hoon *et al.*, (1997) indicators should be;

- i. Developed within an agreed conceptual and operational framework;
- ii. Sensitive such that a small change to the measures should result in a measured change in indicators;
- iii. Clearly and consistently defined so as to be unambiguous regarding interpretation and consistent result in different situations
- iv. Specific and measurable in that they have an explicit scale ranging from undesirable states to desirable state, that allows them to be used for assessment purposes;
- v. Policy oriented so as to provide practical information by being able to record either change in the means recommended by policy or change in the development impact attributable to policy;

- vi. Reflect input, output process and impacts;
- vii. Be readily collectable and thereby lower the technical and collection costs.

The planners of HCMC can use basic urban indicators for risk assessments and risk based land-use planning. In reality it is important to have a range of indicators. Indicators need to be chosen which are significant and important for both climate change adaptation and disaster risk reduction.

Indicators should so not just map the physical but provide a proxy indication of social and economic parameters. These will provide helpful data, however if the indicators are hazard specific; they will fail to address the entire urban area. Though, single indicators are helpful for monitoring and evaluation of urban development, they are not necessarily sufficient in themselves for the evaluation of disaster risk reduction and climate change adaptation actions. As such, the analysis of urban development and risks will not solely focus on single indicator values, but increasingly on the combination of single base-indicators to yield meaningful representations and to build indicator frameworks (*i.e.* (proxy-) indicators and indexes).

A number of alternative approaches have been used for monitoring and representing the urban system based on indicators; urban metabolism or materials flow analysis (Kennedy *et al.*, 2011), footprint analysis (Rees and Wackernagel, 1996; Čuček *et al.*, 2010), carrying capacity analysis (Rees, 1996), systems diagramming (Zhang *et al.*, 2009; Perdicoúlis, 2010) and systems modelling (White and Engelen, 2000; Parker *et al.*, 2003).

The selection of appropriate indicators is the first step in any indicator based assessment of urban development and risk. A number of studies have used criteria, such as suitability, availability of data and sensitivity to formats, usefulness and ease of recollection for indicator selection (Huang *et al.*, 1998; Peduzzi *et al.*, 2001; Whitford *et al.*, 2001; Adger and Vincent, 2005; Venturelli and Galli, 2006; Guillaumont, 2008). In understanding the details of an urban space however, urban density indicators can be one of the most important indicator sets (Acioly and Davidson, 1996).

#### **4.1.2 Density information**

Density is an important issue in urban planning and management used to predict, describe and control land-use (Pont and Haupt 2007). The intensity of space taken up by

the built structures that make up the urban environment plays an important role in the shaping of urban form (Cheng, 2012; Kaufholz, 2004; Boyko and Cooper, 2001; Gordon, 2008). Density is also an indicator of a city's evolution, since structures constructed over varying time periods often exhibit very different densities and designs. Pan *et al.*, (2008), emphasises that urban densities are often dependent upon a city's age, history, context, culture, geography, policies, attitudes and economy.

There are well-studied, yet complex relationships between urban density and greenhouse gas emissions and between urban density and risk. The recent studies on sustainable urban development and climate change planning, as well as land-use and urban planning, support the relative merits of compact and dense urban development (Lerch, 2007; Ewing *et al.*, 2008; Berke, 2007; Wheeler, 2008; Jabareen, 2006; Stone *et al.*, 2012).

As Hamin and Gurran (2009) discuss, mitigating climate change often requires a denser urban environment to reduce distances travels, building energy use, minimising the cost of infrastructure provision and sprawl. Contrariwise, while adapting an urban environment to climate change often requires the careful organisation and allocation of space available for stormwater management and urban cooling among other goals. Low density land-uses such as open spaces and porous surfaces ameliorate flood risk and high temperatures, (Stone, 2005, 2009; Gurran and Hamin, 2008; Gill *et al.*, 2007; Gober *et al.*, 2010). These considerations are not only difficult to plan but also to manage. At a first, glance this may present a density conundrum. However, in rapidly growing cities such as HCMC, in areas less exposed to climate risks, a denser concentration of population, assets and infrastructure should be endorsed and effectively supported. This can contribute to reducing overall vulnerability. However, if populations, assets and infrastructure are concentrated in vulnerable locations without proper infrastructural or institutional frameworks, then densities ultimately create an increased risk (Dodman, 2009; Williams *et al.*, 2010).

While densities in areas at risk should be strictly regulated, they also play an important factor in long-term investment decisions by planners and policy makers for adaptation by preferring either central or de-centralised adaptation options in specific locations under certain current or target urban densities (Hallegatte, 2009).

### 4.1.3 Density indicators for zoning

Land-use zoning schemes with specific restrictions in terms of use functions and intensities are accepted as an appropriate response for HCMC (Storch *et al.*, 2011; Downes and Storch, 2014; Downes *et al.*, 2106). Land-use zoning can reduce the number of people living in areas whose location and attributes put them at significant risk.

Whilst in identified safer areas of the city, greater density can be encouraged. Nevertheless, even safe areas should be assigned appropriate environmental targets. A prerequisite to formulate zoning schemes is the analysis of the current natural conditions, the urban systems and its elements, as well as, the challenges posed by climate change. Urban density restrictions are often used to further quantify the designations of land-use in zoning schemes and to raise protection standards. Areas which exhibit clear and concrete environmental functions, that aid the mitigation of the current and future climate hazards, should be protected and safeguarded from development.

In Vietnam, specifying planning densities is part of the legally based land-use planning system by which the state controls what may be provided and where. The national density and building regulations aim to ensure a systematic and organised urban development. The 2008 Vietnamese Building Code for Regional and Urban Planning and Residential Rural Planning (QCVN: 01/2008/BXD) is the legal framework for planning criteria in Vietnam. This building code covers both construction planning and urban planning, and therefore also land-use plans.

The building code outlines standard requirements in regards to the height and the density of buildings, such as building density, floor area ratio, coverage ratio, soil sealing, population densities and requirements for green space and public amenities. Population density information is an important component of city planning, while floor area and coverage ratios ultimately determine the built-up densities, as well as the quantity, nature and density of green and open space. Nonetheless; in reality together with the top-down state controls of the local HCMC authority, the density of the city is influenced greatly also by bottom-up aspects such as the management of private spaces by residents and private interests.

The current manner in which the administrative area of HCMC is planned and governed has various effects on densities. The urban landscape of HCMC is subject to dynamic changes to new construction and reconstruction of urban features, especially buildings. HCMC's rapid growth brings fundamental changes to the form and structure of the city, including the number of buildings, their geometry, size, volumes, proximities and densities and causes various problems, such as poor infrastructure provision, urban flooding and the UHI phenomenon.

Information on current urban densities is important for the formation of development control measures, yet the changes of the physical characteristics of the city are poorly understood. Consequently, updating databases and detecting changes in build density is a challenging task for the local administration. In HCMC, a previous lack of enforcement and growth monitoring has failed to limit densities and regulate the use of land as per the plan, with planners increasingly unsure how set targets will translate in practice. Unsurprisingly, a lack of information on the current status of the urban environment and urban growth monitoring programmes in HCMC has resulted in a failure to identify and implement policies and measures to address the risks posed.

#### **4.1.4 Urban monitoring approaches**

The acquisition of up-to-date spatial information on building density is a challenging task (Santos *et al.*, 2011). The structural and environmental monitoring of HCMC represents one of the main requests and challenges for the local planning authorities in recent years. Continuous monitoring of HCMC is required in order to keep track of the loss of natural areas due to urban development, densification and structural changes, highlight the real utilisation of land, and to support urban areas planning activities. Besides, continual monitoring is essential to fully evaluate spatial urban information.

Blaschke (2002), defined monitoring as “The planned investigation of a landscape at regular intervals”, in order to “Capture and analyse changes and developments in its structure, function and human use”. Urban monitoring is a critical tool for investigating land-use and density changes over time. Cities are complex, associated with the complexity of the natural and built environments, and interactions with climate change and disaster risks at a wide range of scales. It is dependent on the availability of spatially differentiated information.



For the prediction of impacts (both positive and/or adverse) from both changes in temperature, precipitation, and natural hazards due to climate change, and development itself including the interplay that exists between people, infrastructures and natural or man-made risks, should be facilitated by a designated set of indicators.

Indicators need to be based on the current state of urban environment affected by both development and monitored to provide data for the decision making processes. It is essential that they are policy-relevant and there is a link between indicators, meaningful policy measures and related planning decisions, for guiding adaptation and mitigation measures.

Vovey and Pafka (2013), state that any sole measure of urban density is limited, and cannot adequately reflect the complexity and multidimensionality of urban environments. For many research questions, it is too simplistic to measure solely urban expansions and the urban-rural dichotomy. Furthermore, many of the components are interrelated and research needs to focus on the different scales evident in a mega-urban context (agglomeration, district, neighbourhood, street block, individual building) and their interactions.

The complexity, varying scales and dynamics of change make it difficult to outline credible sets of attributes for determining risks to HCMC (Figure 4–2). Nevertheless, the planners and decision makers of HCMC require precise tools to describe analyses and control urban development in a more climate appropriate manner. Here, urban monitoring requires a multi-disciplinary assessment framework to untangle the current wicked and nested planning. A comprehensive, integrated analytical approach based on a variety of structural indicators and scientific methods to characterise and measure the city is needed.

Knowledge of the physical structure of HCMC can be used to indirectly obtain indicators important for risk management (Downes and Storch, 2013). However, as Preston *et al.*, (2007) states, achieving spatial integration in such assessments, is non-trivial due to issues of data scarcity, quality, compatibility and scale. The quality and suitability of existing data and knowledge about emerging spatial planning problems and climate challenges needs to be assessed and gaps in existing spatial information identified. For urban planning and climate change purposes, information at different scales is needed. Spatial typologies can help to structure and provide an overview.

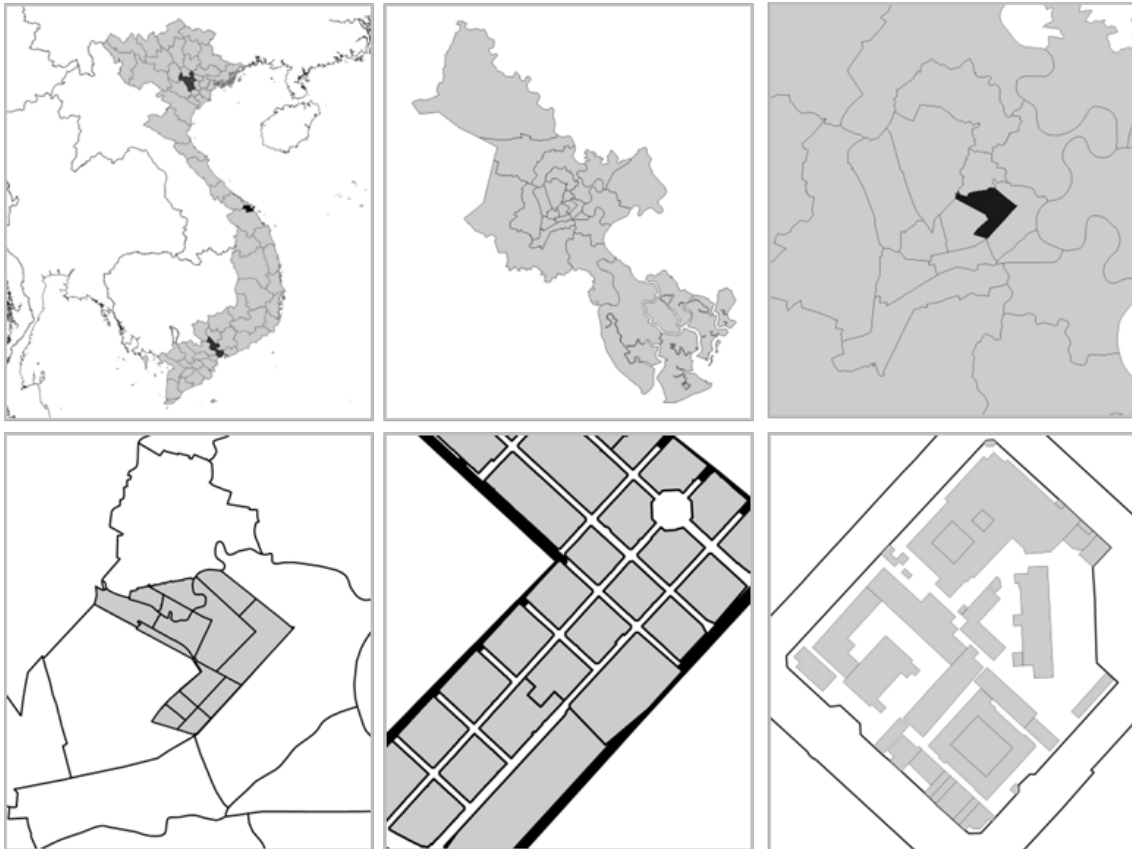


Figure 4–2 Possible levels of data acquisition for urban monitoring in HCMC. From top left to bottom right, national level, city (administrative level), district level (Quận 3), commune level (Phường 6), block level (Võ Văn Tần Street/ Công trường Quốc Tế), building level (*source: author's own*)

The natural landscape and urbanisation have both influenced the development of HCMC. The impacts of urbanisation and climate hazards on the environment are particularly dependent on the type and intensity of land-use. For this reason, the effects on the environment can be closely linked to land-uses and built structures. Urban areas are quite heterogeneous and therefore difficult to describe.

In the course of the development of HCMC, a complex arrangement of building archetypes and open spaces has emerged along differing construction periods and technology use. At the strategic city planning level, for the planning and of monitoring of land-use zoning actions there is a heavy reliance on the spatial distributions of a city's settlement types. Waste collection, transport planning, water supply and disposal, and energy consumption are just a few of the socio-economic and environmental planning categories that can be tailored according to the spatial distribution of different settlement types.

In an attempt to find efficient methods to undertake large-scale monitoring of urban areas, several studies have provided detailed analysis, description and quantification of

urban environments by developing classification systems. These methods aim to simplify the urban environment and to describe and analyse the physical characteristics of settlement structures and embedded resources, energy demands, typical land-coverage infrastructure demands, resource consumption for renovation/upgrading and waste streams. There are a variety of approaches applied in many different fields. Such systems often involve different classes of urban land-use, such as different types of residential, industrial and commercial areas as land-use functions such as urban climate/hydrological zones, pollution unit loading area, functional urban zones, and service providing units to describe the object of study. Most often such systems are aggregated at city-block scale.

## 4.2 Urban structure types

Since the 1970s, the ecological data for German cities has been collected in the form of biotype inventories (Sukopp and Weiler, 1988; Frey, 1999). These inventories however did not consider built structural information. Subsequently, a concept of urban structure types (USTs) (*Stadtstrukturtypen*) was established within Germany in the late 1980s and early 1990s to categorise and differentiate urban settlements into a variety of recurring patterns. Since, it has been a widely used tool as a main spatial indicator for planning and monitoring actions in support of effective and efficient urban planning programmes and plans (Schneider *et al.*, 2007; Novack and Stilla, 2014; Heiden *et al.*, 2012). The domain-independent concept allows for dynamics of a growing urban environment to be captured in both its quantity and quality and intended to facilitate investigation, and potentially plan interventions across multiple scales.

There is no standardised and universally accepted definition of the term in the literature. Definitions vary, due to their study sites and application field, USTs are usually understood as combining social and cultural aspects with the contextual and physical structure of different settlements (Novack and Stilla, 2014; Wurm *et al.*, 2010; Heiden *et al.*, 2012). Banzalf and Höfer, (2008) provided a general definition of USTs based after Wickop *et al.*, (1998), as:

*“UST are spatial indications that help to divide and differentiate the urban fabric into open and green spaces, infrastructure and building complexes so that their typical characteristics such as physical, functional, and energetic factors can be identified”.*

Whereas, Blum and Gruhler (2011), defined USTs as:

*“Basic urban spatial units with morphological and functional homogenous character demarcated by characteristic structures and development patterns of buildings, infrastructures and open spaces”.*

USTs have also been commonly called urban morphology types (UMT) (Wilson *et al.*, 2003; Gill *et al.*, 2008) and urban structural units (USU) (Osmond, 2011; Pauleit and Duhme, 1998; Pauleit and Breuste, 2011; Breuste, 2009; 2010). Ideally USTs are physiognomically uniform urban areas with a characteristic formation of buildings and open spaces. The approach has been used in many cities to categorise the urban system into its distinct proportions of the major elements of urban heterogeneity. USTs typically comprise artificial and natural surfaces, built-up structures and open spaces of different building archetypes in a defined area (formations or groups of buildings, or mixes of building types) and are normally characterised by a range of features that describe their built physical properties (*i.e.* construction materials), their built and green and open space environmental characteristic (*i.e.* climatic and hydrological properties), and their functional properties (*i.e.* land-use, critical infrastructures), as well as their spatial and topological relationships (Paueit and Duhme, 2000; Banzhaf and Höfer, 2008; Pauleit and Burkhardt, 2004). If classified well, a UST is a basic spatial unit more or less homogenous with regards to the type and density of buildings and the type of open spaces (degree of soil sealing and/or type and quantity of vegetation) and it can be taken as a proxy indicator of land-use.

In practice, a typology of urban structures can be constructed under consideration of different criteria. Pre-defined USTs are areas of relative morphologically homogeneous entities, recognisable in appearance. They are typically characterised by the (i) dominating building archetypes; (ii) the geometry, density and spatial configuration (arrangement, connectivity) of buildings; (iii) their social, cultural and economic utilisations (*i.e.* residential, commercial, industrial, agricultural) and (iv) their environmental properties like the presence and type of associated vegetation and water bodies which delineate distinct configuration of the built environment (Wickop *et al.*, 1998; Paueit and Duhme, 2000; Heiden *et al.*, 2012).

Due to the transient nature of urban areas, USTs are an instrument for monitoring, analysing, extrapolating, controlling and modelling tasks of urban planners and decision makers (Voltersen *et al.*, 2014). The goal has commonly been to facilitate a deeper

understanding of the relationship in the coupled anthropogenic-nature urban system (Cadenassio *et al.*, 2007; Downes *et al.*, 2011; Li *et al.*, 2011). USTs offer a descriptive perspective from which insights into the urban environment can be derived to support planning.

Blum and Gruhler (2011), state that USTs are a means to characterise and partition urban areas into spatially and thematically meaningful units, with respect to specific characteristics by comparison with predefined types. USTs can be defined by representations of relevant, typical elements with typical characteristics and compared using a number of indicators. While they state that USTs can be used for modelling and fast screening of characteristics of a superordinate system (*i.e.* the entire city) (Blum and Gruhler, 2011). Duhme and Pauleit (2005) state that the concept of USTs is based on the premise that there are causal links between the physical structure of a given urban area and the ecological and socioeconomic characteristics and functions. This enables associated environmental and socio-economic investigations, as well as the comparison between the patterns of different cities.

#### **4.2.1 Previous studies**

Several classifications for USTs have been developed for different cities, and for a multitude of applications (Table 4–1). USTs have been mapped and applied to a wide range of German cities, Berlin (Berlin Umweltatlas, 2008; Bochow *et al.*, 2010a; Voltersen *et al.*, 2015), Munich (Pauleit and Duhme, 2000; Heiden *et al.*, 2012; Heldens *et al.*, 2013; Montanges *et al.*, 2015), Dresden (Heber and Lehmann, 1993; Meinel *et al.*, 2009; Wurm *et al.*, 2009; Bochow *et al.*, 2010b; Krüger *et al.*, 2013; Nikolowski *et al.*, 2013; Lehman *et al.*, 2014; Behling *et al.*, 2015), Leipzig (Wickop *et al.*, 1998; Heber and Lehmann, 1993; Böhm, 1998; Banzhaf and Hofer, 2008; Weber *et al.*, 2014b), Rostock (Lindner *et al.*, 2011; Walde *et al.*, 2013), Cologne (Wurm *et al.*, 2009), Erfurt (Walde *et al.*, 2012) and Bonn (Meinel *et al.*, 2009). One of the most comprehensive UST studies was carried out by Thinh *et al.*, (2002), who evaluated USTs in 116 regional cities in Germany.

The UST approach has also been applied to the cities of Athens (Kontoes *et al.*, 2000), Alexandria (Haggag and Ayad, 2002), Mexico City (Taubenböck *et al.*, 2008a), Rio de Janeiro (Hofmann *et al.*, 2008), Lima, (Avelar *et al.*, 2009), Santiago de Chile, (Huck *et al.*, 2011; Höfer, 2013), Manchester (Gill *et al.*, 2007; 2008; Golz *et al.*, (2013),

Strasbourg and Toulouse (Puissant *et al.*, 2012), Sagunto (Hermosilla, 2010), Istanbul (Taubenböck *et al.*, 2006, Taubenböck *et al.*, 2008b; Geiß, 2015), Padang (Bochow *et al.*, 2010a), Sydney (Osmond, 2011), Santa Barbara (Herold, 2003; Herold *et al.*, 2004), Atlanta (Tang, 2007), New York City (Larondelle *et al.*, 2014) Xuzhou (Gamba *et al.*, 2012) and Delhi (Smollich, 2015).

USTs have been used to classify the urban environment with the objective to perform different analysis within interdisciplinary projects. Various disciplines use comparable approaches within their study contexts yet the number of classified USTs varies widely between studies because of different class depth and thematic questions. Even in Germany an accepted German-wide classification system is missing. Heiden *et al.*, (2012) analysed 9 USTs in the study of the city of Munich, Höfer (2013), analysed 17 USTs for Santiago de Chile, Wurm *et al.*, (2009) analysed 20 USTs in the cities of Cologne and Dresden, Böhm (1998), analysed 26 for the city of Leipzig, and Larondelle *et al.*, (2014) analysed 15 common USTs of Berlin and New York City.

Paulet and Duhme (1998) used an UST approach to facilitate the evaluation for urban metabolism. USTs have been used for the socio-spatial differentiation (*i.e.* population densities, income, living standards), while the classification of informal settlements have also been studied using USTs (Hofmann *et al.*, 2008; Netzband *et al.*, 2009; Niebergall *et al.*, 2008; Stasolla and Gamba, 2006; Kuffer and Barros, 2011). d'Oleire-Oltmanns (2011), used an UST approach to identify migrant housing in the mega-urban area of the Pearl River Delta, whilst, Taubenböck *et al.*, (2008a), developed a UST classification for modelling of spatial processes in the context of environmental monitoring and megacity mapping for Mexico City.

Moreover, in a further study Taubenböck *et al.*, (2013) used USTs to delineate the Central Business Districts (CBDs) of Paris, London and Istanbul. Knowledge of how various USTs interact with and determine ecosystem services has also been studied in regards to stormwater management, landscape planning, and urban heat island mitigation. USTs have been used for the extrapolation of ecological variables (Behling *et al.*, 2015; Gill *et al.*, 2008). Most of these studies have been undertaken in areas with low density.

Table 4–1 Selected UST studies for German cities

Reference	Paper title	Study area
Böhm (1998)	Urban structural units as a key indicator for monitoring and optimising the urban environment	Leipzig, Germany
Thinh <i>et al.</i> , (2002)	Evaluation of urban land-use structures with a view to sustainable development	116 Regional Cities, Germany
Banzhaf and Hofer (2008)	Monitoring urban structure types as spatial indicators with CIR aerial photographs for a more effective urban environmental management	Leipzig, Germany
Wurm <i>et al.</i> , (2009)	Urban structuring using multisensoral remote sensing data: By the example of the German cities Cologne and Dresden	Cologne & Dresden, Germany
Nuissl <i>et al.</i> , (2009)	Environmental impact assessment of urban land use transitions—A context-sensitive approach.	Leipzig, Germany
Deilmann and Hennersdorf (2009)	GIS analyses of low density urban areas—how much surface per floor space?	Dresden, Germany
Bochow <i>et al.</i> , (2010a)	Towards an Automated Update of Urban Biotope Maps Using Remote Sensing Data: What is Possible?	Dresden, Germany
Bochow <i>et al.</i> , (2010b)	An automated and adaptable approach for characterizing and partitioning cities into urban structure types	Berlin, Dresden, Germany
Lindner <i>et al.</i> , (2011)	An object-based multisensoral approach for the derivation of urban land use structures in the city of Rostock, Germany	Rostock, Germany
Heiden <i>et al.</i> , (2012)	Urban structure type characterization using hyperspectral remote sensing and height information. Landscape and urban Planning	Munich, Germany
Heiden <i>et al.</i> , (2013)	Analysis of surface thermal patterns in relation to urban structure types: a case study for the city of Munich	Munich, Germany
Pauleit and Duhme (2000)	Assessing the environmental performance of land cover types for urban planning	Munich, Germany
Krüger <i>et al.</i> , (2013)	A new heat sensitivity index for settlement areas	Dresden, Germany
Nikolowski <i>et al.</i> , (2013)	Analysing the vulnerability of buildings to climate change: Summer heat and flooding	Dresden, Germany
Lehman <i>et al.</i> , (2014)	Urban vegetation structure types as a methodological approach for identifying ecosystem services—Application to the analysis of micro-climatic effects	Dresden, Germany
Weber <i>et al.</i> , (2014)a	Zooming into temperature conditions in the city of Leipzig: How do urban built and green structures influence earth surface temperatures in the city?	Leipzig, Germany
Weber <i>et al.</i> , (2014)b	Assessing modelled outdoor traffic-induced noise and air pollution around urban structures using the concept of landscape metrics	Leipzig, Germany
Neubert <i>et al.</i> , (2014)	The Geographic Information System based flood damage simulation model HOWAD	Elbe River floodplain, Germany
Behling <i>et al.</i> , (2015)	Automated GIS-based derivation of urban ecological indicators using hyperspectral remote sensing and height information	Dresden, Germany
Montages <i>et al.</i> , (2015)	Classification of urban structural types with multisource data and structured models.	Munich, Germany
Voltersen <i>et al.</i> , (2015)	Expanding an urban structure type mapping approach from a subarea to the entire city of Berlin	Berlin, Germany
Berger <i>et al.</i> , (2018)	Robust Mapping of Urban Structure Types Across Three German Cities	Berlin, Cologne & Rostock, Germany
Novack and Stilla (2018)	Classifying the Built-Up Structure of Urban Blocks with Probabilistic Graphical Models and TerraSAR-X Spotlight Imagery	Munich, Germany
Hecht <i>et al.</i> , (2019)	Mapping Long-Term Dynamics of Population and Dwellings Based on a Multi-Temporal Analysis of Urban Morphologies	Landau, Germany

Table 4–2 Selected UST studies of non-German cities

Reference	Paper title	Study area
Haggag and Ayad (2002)	The urban structural units method: a basis for evaluating environmental prospects for sustainable development	Alexandria, Egypt
Taubenböck <i>et al.</i> , (2008a)	Urban structure analysis of mega city Mexico City using multisensoral remote sensing data.	Mexico City, Mexico
Gill <i>et al.</i> , (2008)	Characterising the urban environment of UK cities and towns: A template for landscape planning	Greater Manchester, UK
Steiniger <i>et al.</i> , (2008)	An approach for the classification of urban building structures based on discriminant analysis techniques	Zurich, Switzerland and Southampton, UK
Bochow <i>et al.</i> , (2010)b	An automated and adaptable approach for characterizing and partitioning cities into urban structure types.	Padang, Indonesia
Osmond (2011)	Application of the urban structural unit method to inform post-carbon planning and design	Sydney, Australia
Puissant <i>et al.</i> , (2012)	Urban morphology analysis by high and very high spatial resolution remote sensing	Strasbourg; Toulouse, France
Taubenböck <i>et al.</i> , (2013)	Delineation of central business districts in mega city regions using remotely sensed data	London, UK; Paris, France; Istanbul, Turkey
Höfer (2013)	Remote sensing based derivation of urban structure types to assess hydro-meteorological impacts in highly dynamic urban agglomerations in Latin America	Santiago de Chile, Chile
Golz <i>et al.</i> , (2013)	Assessing the Effects of Flood Resilient Technologies.	Greater Manchester, UK
Pauleit <i>et al.</i> , (2005)	Modeling the environmental impacts of urban land use and land cover change—a study in Merseyside, UK	Merseyside, UK
Angela <i>et al.</i> , 2013	Building extraction from remote sensing data for parameterising a building typology: a contribution to flood vulnerability assessment	Magdalena River floodplain, Colombia
Júnior <i>et al.</i> , 2015	A novel land use approach for assessment of human health: The relationship between urban structure types and cardiorespiratory disease risk	Federal District, Brazil
Geiß (2015)	Seismic vulnerability assessment of built environments with remote sensing	Padang, Indonesia; Istanbul, Turkey
Smollich (2015)	An integrative approach using remote sensing and social analysis to identify different settlement types and the specific living conditions of its inhabitants	Delhi, India
Wieland <i>et al.</i> , (2016)	Object-based urban structure type pattern recognition from Landsat TM with a support vector machine	Port-au-Prince, Haiti
Hernández <i>et al.</i> , (2016)	Urban Morphological Dynamics in Santiago (Chile): Proposing Sustainable Indicators from Remote Sensing	Santiago de Chile, Chile
Woldegerima <i>et al.</i> , (2017)	Characterizing the urban environment through urban morphology types UMTs mapping and land surface cover analysis	Addis Ababa, Ethiopia
Danumah <i>et al.</i> , (2017)	Remote Sensing Based Analysis of the Latest Development and Structure of Abidjan District, Cote d'Ivoire	Abidjan District, Cote d'Ivoire
Tam <i>et al.</i> , (2018)	Mapping of Highly Heterogeneous Urban Structure Type for Flood Vulnerability Assessment	Kota Bharu, Malaysia
de Castro <i>et al.</i> , (2019)	New perspectives in land use mapping based on urban morphology: A case study of the Federal District, Brazil	Federal District, Brazil

USTs have been successfully used in urban water balance modelling. Douglas (1985), described runoff coefficients and imperviousness for different land-use types in



Malaysia, and Ellis and Revitt (2008), identified 19 urban land-use types to define runoff and quality characteristics for two watersheds in the United Kingdom. Strauch *et al.*, (2008) highlighted the characteristic impacts of different USTs and impact of the urbanisation on urban surface and ground water using USTs as a proxy indicator to ground water pollution. The study of Van der Linden and Hostert (2009), investigated the influence of USTs on impervious surface maps for Berlin. Typologies of green urban structures have also been proposed by numerous authors (Duhme and Pauleit, 1994; Lehmann *et al.*, 2014; Neuenschwander *et al.*, 2014).

Höfer (2013), utilised USTs to assess the hydro-meteorological impacts of urban development in Santiago de Chile, while, Angela *et al.*, (2013) utilised USTs to carry out a flood vulnerability assessment in the Magdalena River floodplain in Colombia and Neubert *et al.*, (2008), Neubert *et al.*, (2014) and Gerli *et al.*, (2014), all used USTs to assess and simulate flood damage along the Elbe River floodplain in Germany. Naumann *et al.*, (2010) also used USTs to measure both resilience and resistance of buildings and built structures. Nikolowski *et al.*, (2013) analysed the vulnerability of USTs to extreme summer heat and flooding for the city of Dresden.

USTs have also been used in energy models in terms of urban climate modelling. Ellefsen (1991), developed a system of “urban terrain zones” (UTZ) based on the physical characteristics of USTs, street configuration, and construction materials of ten large US cities and characterised roughness, air flow and radiation access of urban areas. Davenport *et al.*, (2000) developed a roughness classification of urban and rural terrain based on the height and density of surface elements (e.g., buildings, trees, bushes, agriculture). Oke (2004), and subsequently Stewart and Oke (2009), classified climate conditions for the World Meteorological Organisation on hand UHI literature into 20 discrete, homogenous urban structure zones they termed “urban climate zone” (UCZ). The prototype zones were determined by aerodynamic roughness, mean aspect ratio, and impermeable surface coverage—and their ability to modify the local climate (Stewart and Oke, 2009).

Gill *et al.*, (2007) employed USTs in energy modelling, due to the influence on different USTs on local air temperatures. Using USTs Gamba *et al.*, (2012) successfully defined five urban climate zones in Xuzhou, while Weber *et al.*, (2014) studied the influence of USTs on the temperature conditions for the city of Leipzig, while Dugord *et al.*, (2014) studied the effect of USTs on the potential heat stress risk for Berlin, whilst Larondelle

*et al.*, (2014) compared the relationship between USTs and surface temperature in both Berlin and New York City.

In the context of vulnerability assessment of hazards, USTs have been used for urban planning and seismic risk assessments in Istanbul (Taubenböck, 2008; Geiß, 2015), Italy (Liuzzi *et al.*, 2019), and Padang (Geiß, 2015). Moreover, Júnior *et al.*, (2015) assessed the relationship between USTs and risk of cardiorespiratory disease, and Weber *et al.*, (2014) using traffic models, assessed the relationship between traffic noise and particle air pollution and USTs for the city of Leipzig.

## **4.2.2 Classification of urban structure types**

### 4.2.2.1 A note on typologies

Firstly, it is important to define what is meant by the concept of typologies. Typologies, in all scientific disciplines are used to functionally characterise and to reduce the complexity of the real world by combing and summarising similar elements, features or phenomena into groups or sets with the same characteristics. The aim is to provide an improved structured overview of a complex reality of a particular area. A clear demarcation of individual types from each other is thus an essential feature of a typology. Yet typologies also summarise similar but not completely identical objects into groups. Moreover, individual types may be very similar but contain variance within the same typology – being not completely the same. This is one of the main difficulties that arise in the use of typologies. Types are a simplification and can never truly represent the reality accurately, because even in reality, to a certain degree, variations will exist. Furthermore, since types are only excerpts of reality, of previously defined aspects, there is the danger that generalisations produce absolute or inadmissible distortions of reality. The advantages of using typologies to reduce the complexity of real-world issues, is at the same time, one of the greatest inherent weaknesses – the distortion and simplification of reality. Therefore, in any classification of USTs, it is important to find a balance between reducing complexity to a manageable level yet maintaining real-world reality.

### 4.2.2.2 Classification methods

The development of the classification scheme is dependent on the questions being asked. The structure of a system should facilitate information transfer to management

levels through simple and logical nomenclature (Bowker and Star, 2000). Scientific classification is effectively a process of definition (Black, 1952). Stewart and Oke (2009), state that classifications begin with the logical division of the urban environment, differentiated along physical and spatial criteria into classes and a hierarchy of sub-classes on the basis of differentiating principles. In most studies, USTs are typically classified firstly by the detection and identification of different building types (residential, industrial and commercial sites, infrastructure), and impervious surfaces and open spaces and secondly, by typifying recognisable (proto-) typologies of USTs through their individual component elements and their relationships with a classification framework.

The end-product is a classification system of names for groups of classes that exhibit regular properties. Each UST is assumed to be characterised by a typical composition of urban components (spatial structure, socioeconomic) resulting in specific indicator values. These values are obtained for a representative number of units of the same UST by detailed mapping. These obtained indicators are then commonly extrapolated to all mapping units of the same UST. However as Pauleit and Duhme (2000), note such an approach often neglects the spatial variability of indicator values for mapping units belonging to the same UST.

Recent literature shows there are a variety of methods and input data and nomenclatures to classify USTs. Traditionally UST were classified by field mapping in the area of interest. There is also the opportunity to classify remotely sensed images (aerial and satellite photographs) manually by visual interpretation and/or by drawing polygons around typical areas manually. In the German cities of Berlin, Munich, Dresden and Leipzig amongst others, the UST mapping has been carried out manually. Likewise Gill *et al.*, (2008), applied manual visual interpretation of aerial photography to characterise the urban environment of UK cities and towns.

Innovative GIS, remote sensing and digital image-processing methods have recently evolved to a stage where diverse classification methods are available. Area-wide spatial datasets are available with the necessary high resolution to identify the components of urban landscape and have been extensively used of land-use and land-cover mapping in urban areas (Meinel *et al.*, 2009). These techniques have the advantage of applying up-to-date and area-wide coverage with short temporal intervals between image acquisitions.

Yet even (semi-) automated determination of USTs is still a challenging task. Many issues of image understanding, delimiting the extent of various USTs and pattern recognition remain unsolved. Sliuzas *et al.*, (2010) states that traditionally, remote sensing applications have been used in the classification areas of homogenous urban land-cover (surface materials) or urban land-use (functions). To simply answer the question, “what” is “where”. While urban land-cover can be directly derived from high-resolution satellite images, the functional properties of land-use cannot be observed directly. Nor can imagery measure the economic, policy, or social causes of observed spatial phenomena (Entwistle *et al.*, 1998). For example, an urban landscape completely covered by impervious land cover may in reality represent a range of possible land-uses. To this affect, large commercial activities and industry building may appear difficult to distinguish from above. Mapping the physical semantics alone, from for example object-based image analysis, often describes building density, impervious surfaces or vegetation fractions, yet obtained urban land-cover classifications often lack the detail necessary for appropriate measurements and make no allowances for influences or the impacts of different human activities. Most urban land-uses are associated with combinations of various kinds of land-cover (roofs, vegetation, streets). Due to the complexity of urban areas, it is extremely hard for automatic pixel based classification methods to relate one specific form of land-use to one specific physical form of land-cover (Barnsley and Barr, 2000; Sliuzas *et al.*, 2010; Weng, 2012).

Such classifications are far from straightforward and can only be achieved through analysing a combination of structural, functional, structural morphological and topological properties of the various land-use classes (Walde *et al.*, 2013; 2014). Many studies have also developed (semi-) automatic algorithms for urban classifications of satellite images (Banzhaf and Hofer, 2008; Taubenböck *et al.*, 2006; Niebergall, 2008; Herold *et al.*, 2003; Wang, 2011). Here, a two stage process often is undertaken where first the land-cover is extracted and then USTs are classified subsequently on hand ancillary data such as socioeconomic, administrative, and regulatory data to increase accuracy. LiDAR data has also been used to obtain physical heights and enhance accuracy (Wurm *et al.*, 2011).

For urban areas, where structures involve the complexity of socioeconomic activities, visual interpretation is widely used and is still the most reliable method for classification to guarantee both accuracy and consistency in classifications. Coulter *et*

*al.*, (1999) and Kampouraki *et al.*, (2008) stated as a result of comparing remote sensing studies, that the accuracy of (semi) automated image classifications is still smaller than what could be provided by manual interpretation, and that the highest accuracy for urban data extraction and classification is generally still the result of visual interpretation. Blaschke *et al.*, (2002), states that humans neither observe nor think in pixels and as such, are able to identify and discriminate diverse and fine-scale urban land-use information from an image based on context, relationships to neighbouring objects, and complex variations in tone, colour, and pattern. Kampouraki *et al.*, (2008), outlines additionally that manual interpretation can be time-consuming and subjective and yet advantageous if undertaken by trained personal with knowledge of location in order to add additional contextual information. The advantage and disadvantages of manual recognition are described in Table 4–3. Remote sensing studies show a strong dependence on data availability and also require a compilation of relatively costly imagery. In many cases for most cities, there may often be better sources for the same information that could be obtained more economically. Furthermore, computing facilities and technical expertise are required to conduct such classifications.

Given all the limitations of remote sensing methods mentioned above, in practice, to avoid errors, mapping of USTs manually by the visual interpretation of aerial or satellite photographs is often preferred (Castilla *et al.*, 2008). The use of remotely sensed imagery and applications and analysed data is still not a common technique to aid urban planning decision making in Vietnam.

Table 4–3 Advantage and disadvantages of manual recognition

Advantages	Disadvantages
Interpretation of real objects	Subjective
Identification of complex patterns and situations	Time consuming
Ability to include or ignore features intelligently	A fixed scale is necessary
Multi-scale representation	Inconsistency in the use of a steady scale
Use of share, context, neighbourhood relationships	Human error
	Expensive

(source: adapted from Kampouraki *et al.*, 2008)

### **4.3 Urban structure type-based indicator framework**

#### **4.3.1 Conceptual structure**

Urban development is a spatiotemporal process. Risk is additionally complex, with distinct spatial dimensions, highly locality and scale dependent. Impacts arise out of place-specific processes. The spatial component of risk is critical for advancing the understanding about climate and disaster risks on the one hand, and potential management options and challenges on the other. The mitigation of natural hazards and climate change risks, as well as the planning of adaptation responses require an understanding of how risk and opportunities are distributed, both geographically and socially over an urban landscape. Here, the main interest is in risk adapted land-use planning which incorporates both adaptation and disaster risk reduction measures, yet adequately considers rapid urban development. Land-use monitoring and risk assessment to support affective management are required. Mainstreaming risk management into land-use planning is of increasing importance to mitigate the growing risks faced by HCMC. This in turn requires knowledge about present and future hazards, the elements at risk and the different types of vulnerability. The development of the spatially explicit UST-based indicator framework in this study is based on the acknowledgment that every part of HCMC faces a certain risk of being affected by a climate-related disaster. The magnitude of this risk depends on location-specific (i) hazards exposure, and (ii) the sensitivity of the elements at risk (Figure 4–3).

Assessing climate-related disaster risks within rapidly changing urban areas requires a methodology to assess the spatial distribution of these elements. Over the entire administrative area of HCMC, the vulnerabilities to the effects of climate change can be imagined to vary considerably from settlement to settlement and even within settlements. Hazards exposure is related to climate variability and extremes such as heat waves, heavy rainfall events, floods, sea-level rise etc., and refers to the physical precondition to be affected by natural hazards (Fuchs *et al.*, 2011). Exposure is not only driven by climate change, but also by socioeconomic and urban structural factors, as well as lifestyle choices that lead to vulnerabilities. Whereas, the elements at risk are not only assets, such as built structures, urban infrastructure services or economic losses, but also human health and livelihoods. In this study vulnerability is considered as the extent of harm which is expected under certain conditions of exposure, sensitivity and resilience (Balica *et al.*, 2009; 2012). Successful risk-adapted land-use planning

depends heavily on how well the current and probable future risks are understood. For HCMC, the inherent complexity of risks and vulnerabilities require improvements in the use of spatial information, in order to identify hazard patterns, vulnerabilities and risks at a scale that can provide guidance for planning. The location, urban structures, dominant building types, socio-economic characteristics and institutional capacity are key factors that all affect vulnerability and the responsive adaptation capacities (Storch *et al.*, 2009; Downes *et al.*, 2010). In the future, HCMC's land-use planners will play an increasingly important role through risk adapted land-use planning to directly review existing plans and policies, control development in high-risk areas and initiate climate conscious urban regeneration and climate conscious new developments, as well as the provision of building standards, early warning systems and emergency response plans. Land-use planning also has a role to play in indirectly mitigating the drivers of climate change and influence general behaviour. The spatial planning framework and subsequent urban planning decisions, as currently applied, fail to attach ample importance to the physical exposure and the rate of urban growth associated with the risk of disaster losses.

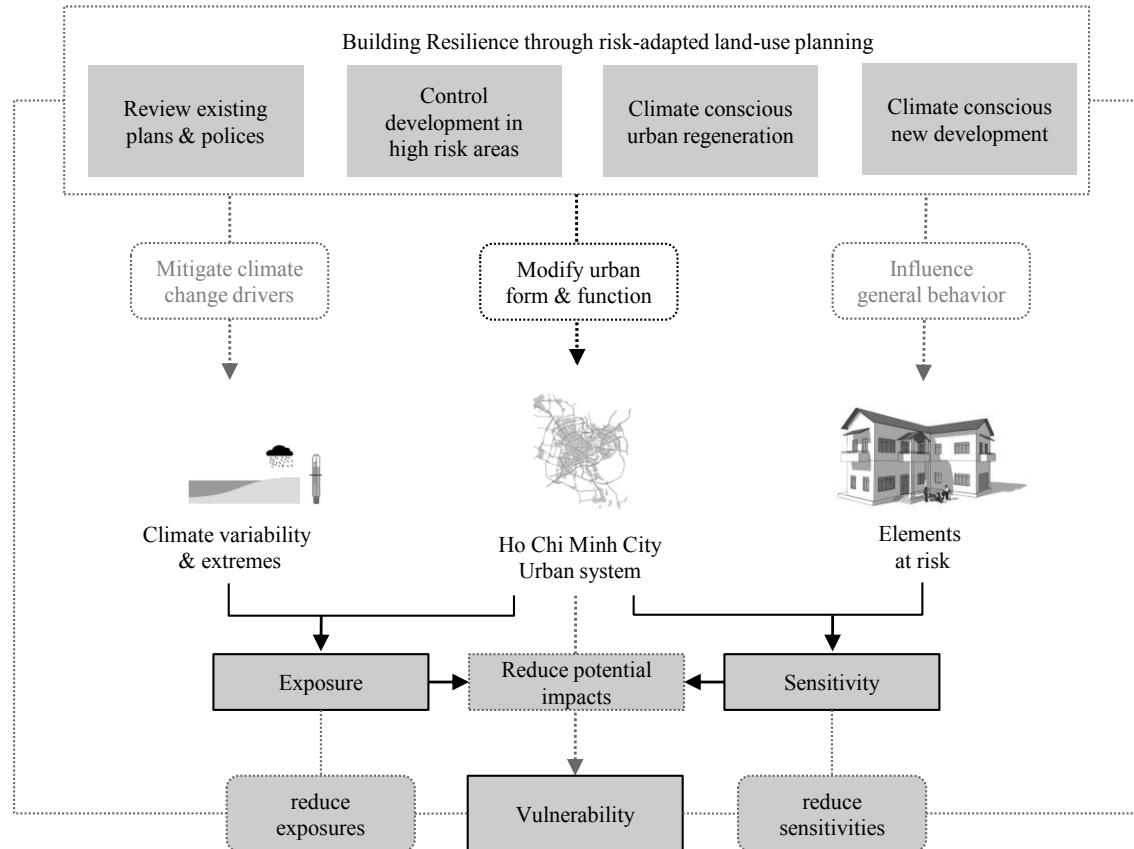


Figure 4–3 Relationship between land-use planning mechanisms and urban resilience (source: adapted from Lindley *et al.*, 2007)

As Figure 4–3 depicts, as a prerequisite, urban adaptation decisions require the rational characterisation and representation of the current urban landscape according to vulnerability and density relevant features. However, the analysis of HCMC presents a number of significant challenges for the fine-scale land-use and land-cover information required for disaster risk and climate change assessments. Distinct and subtle variations in the built urban structural archetypes are compounded by structural transitions from planned land-uses. Such complex mapping environments require innovative classification methodologies for the identification, description and analysis of land-use.

The development of an indicator framework based on a UST approach to represent the urban system has the potential to answer this challenge. Central to this framework is the detailed mapping and classification of HCMCs USTs. This spatially explicit inventory represents the status quo of the spatial and physical elements of the city. In the next step, density indicators assigned to each UST and together with their inter-linkages, provide the local context for the thematic assessments. This produces an integrated top-down and bottom-up approach where hazard exposure and sensitivities can be quantified on hand using planning relevant indicators.

In terms of monitoring, the framework allows for the direct and indirect consequences of urbanisation to be shown in a straightforward manner though connecting USTs with environmental indicators and parameters.

The UST framework assumes that the physical, functional and energetic factors are symptomatic of the USTs of HCMC and can relate to climate risk and disaster risk response. In relation to climate risks and opportunities, the subdivision specifically allows for a series of initial questions to be addressed such as;

- i. How robust or resilient are current urban structures in regards to their physical, social and economic conditions?
- ii. How do different urban structure types contribute to environmental impacts on local conditions?
- iii. Which potentials exist for the improvement of energy efficiency and the adaptation to climatic conditions in existing and future building structures?

#### **4.3.2 Building typologies**

Buildings are the most apparent elements of physical and economic capital and development. Buildings together with green and open spaces and streets are the “brick



components” that structure every urban environment. The building stock of HCMC directly affects the city’s urban structure, *i.e.* the urban form and density of buildings and also the distribution of the city’s growing population. This in turn, is strongly related to the distribution of workplaces, infrastructure, and water and energy consumption, as well as the use of raw materials for their construction and renovation. In this study, the dominant building typologies of HCMC are the starting point and lay a foundation for the subdivisions of HCMC into distinct USTs.

One of the most important functions of buildings is to provide shelter to protect residing populations adequately against climate extremes. Buildings are in fact as Ly *et al.*, (2010), states, not just a structure with a floor area, but a safe dwelling that provides health and wellbeing for occupants, adapts to regional climate and culture, and mitigates natural forces. Buildings can therefore be seen as a reflection of the local climate and culture, and represent long-term, capital-intensive investments designed to perform for decades into the future (Williams *et al.*, 2012; Boshier and Dainty, 2011; Nikolowski *et al.*, 2013).

Together with infrastructure such as roads and drainage system, buildings are often the most long lived components of settlement structures. In Vietnam, buildings represent the highest economic losses due to natural disasters (Lyons, 2009), and one of the most vulnerable sectors to climate change (MoNRE, 2008; Nhu *et al.*, 2011; Phong and Tinh, 2010). Risks will present both direct climate related damage to buildings and negative impacts for its residents in various ways. The level of construction and maintenance of a building as well as its location is important (Peduzzi *et al.*, 2012; Golz *et al.*, 2015).

Buildings have direct environmental and local climatic impacts. Instead of providing shelter, a building may actually escalate the risk, for example by increasing surface runoff in the case of urban flooding, increasing thermal stress in the case of the urban heat island effect, and flying corrugate roofing material in the case of a typhoon or structural failure in a badly constructed building in the case of an earthquake. Buildings vary and there are significant links between the date when a building is constructed and its physical structure, while certain parts of a building will be exposed differently depending on location, the hazard, the building typology, the construction materials used, and how the house is maintained. Here, important factors to consider are the structural stability and durability, adequate ventilation and lighting. As such, the

vulnerability of buildings has to also be investigated in relation to their direct surroundings.

Consequently, the potential for changes in climatic risks throughout a building's lifetime represents an immediate challenge for both planning and construction in HCMC. Furthermore, climate change means that new types of risks may need to be considered in planning throughout a building's lifetime (Coley *et al.*, 2012; Hallegatte, 2009; Gupta and Gregg, 2012; Almås *et al.*, 2011). William *et al.*, (2012), present a building typology of English suburbs and suggest structural adaptation measures. The important management issue of adapting individual buildings to climate change has grown in importance in HCMC. Building regulations and their enforcement have an important role to play in mainstreaming disaster risk reduction and climate change mitigation (Chmutina and Boshier, 2015).

Much of the work with building typologies have focused on assessing energy performance in terms of climate change mitigation. In the Global North, incorporating energy-related requirements during the initial designing or refurbishment phase of a building is a key driver for implementing energy efficiency and climate protection measures into the building sector. In the framework of the European Union, funded projects TABULA and EPISCOPE residential building typologies have been created in 20 European countries (Kragh and Wittchen, 2014; Loga *et al.*, 2016). These projects aim to make energy refurbishment more effective on hand European-wide residential building typologies. In a further study, Kalvelage *et al.*, (2014), examined US building typologies across varying climate zones to analyse the rising climatic temperature's effect on the building's energy demand. Carrión *et al.*, (2010), used building typologies to construct a three-dimensional model of Berlin and calculate the energy refurbishment state of the city.

### **4.3.3 Block based results**

HCMC is inherently a multi-scale system in which decision-makers require diverse multi-disciplinary data. This data needs to be made available with spatial and temporal attributes and in the correct format for decision-making. Furthermore, the differing thematic approaches to assess climatic hazards commonly require and utilise accepted discipline-specific spatial working bases. Individually, these approaches often need high-resolution spatial demographic, structural, environmental and/or economic

information at different scales. To conduct a truly trans-disciplinarily analysis of the urban system therefore additionally requires an adequate spatial explicit basis, or platform capable of ensuring that the individual heterogeneous investigations can be resultantly transdisciplinary integrated.

As was outlined in Chapter 3, for urban planning purposes HCMC is divided into spatial planning tiers representing different levels of aggregation, such as land parcels, blocks, communes and districts. Urban blocks are one of the smallest functional planning units of HCMC. This is also the spatial area of interest and the analysis unit utilised within the developed UST-based indicator framework.

Blocks are the spatial unit, which is most commonly used in Vietnam for land-use planning and urban planning, as well as design purposes. Blocks in HCMC either comprise of single development parcels or are the aggregation of a number of parcels. Consequently, transitions in building density are commonly seen to occur at this scale. Normally the street network serves as the boundary surrounding each block and provides a contextual frame.

Table 4–4 key examples of adaptation methods at both the individual building and block level

Adaptation of buildings (individual building)	Adaptation of urban blocks (UST scale)
Elevation of properties – to protect from pluvial and fluvial flooding	Planting of moisture retaining species – to provide shading, cooling, evapotranspiration and a reduction in rainwater run-off
Demolition of properties – to remove flood risk in low-lying areas, to release productive land, to create land for water retention, and opportunity for green infrastructure	Construction of ponds and reservoirs – to increase-evapotranspiration, increase bio-diversity and establish localised cooling
Installation of canopies – to increase shading and cooling within properties and externally	Construction of SUDS – to enhance water containment and reduce flooding
Installation of ‘green roofs’ – to reduce rainwater run-off, and evapotranspiration and to reduce UHI effects	Increase drainage capacity – to withstand more frequent and intense weather impacts, which in turn would prevent contamination of the surrounding environment and properties
Installation of ‘white roofs’ – to increase albedo, and create conditions for localised cooling	
Installation of passive ventilation – to aid cooling, improve air quality, reduce air-conditioning use and associated UHI, and improve internal temperature control	Construction and reinforcement of flood defences – (Hard) – embankments, walls, weirs, sluices and pumping stations (Soft) flood retention areas – to reduce rainwater run-off and protect key infrastructure
Installation and rain water capture systems – to decrease cost for water treatment, and rainwater run-off	Removal of non-porous sealing materials – to reduce rainwater run-off and flash flooding
Installation of solar panels (photovoltaic and thermal) – to reduce fossil fuel use and increase energy security	Development and conservation of green space – to reduce rainwater run-off, increase evapotranspiration and to reduce UHI
Provision of property flood gates, sand bags and pumps – to provide a fast flood defences which can be installed on demand by households	

Table 4–4 highlights some key examples of adaptation methods available for consideration at both the individual building and block level for which a UST derived classification can be useful. Block scale enables a certain degree of transferability within the hierarchical structure of Vietnamese urban administrative units, with direct reference to both the higher meso- and macro-scales (commune, district and city levels) and the micro-scale (the individual structural elements, buildings and open spaces).

In the developed framework, density indicators at the block level can be aggregated to show the city as a whole at the strategic scale, whilst the scale still allows the mapped indicator values to be immediately comprehensive to a wider audience in an efficient manner. On top of providing an up-to-date assessment of the current land-use pattern and building stock, it necessitates the integration of coherent and credible indicator sets providing a uniform methodological and spatial framework at the resolution of the urban block. This scale provides a clear instrument to generate portfolios of block-specific core indicators, move across scales, run scenarios and aggregate to larger planning horizons, ultimately useful to determine hotspots for administrative interventions at various levels and to assist prioritising in decision-making. For example, in terms of intervention and structural and non-structural land-use planning options and measures, adaptations can be undertaken at the household level, such as increasing shading by planting trees or installing on site water retention systems. Alternatively, adaptation measures may be undertaken at the larger planning block level. These could include providing additional green and blue infrastructure or public open space, installing sustainable urban drainage systems and greening public spaces.

#### **4.3.4 Plan assessment and recommendations**

The value added entity of UST can significantly inform and support the urban land-use planning and management functions of DoNRE in urban monitoring and the assessment of current land-use arrangements, urban development and climate change scenario analysis and planning recommendations (Figure 4–4). It can also contribute to an improved understanding of urban development in a holistic manner, by means of providing basic spatial information over risks and vulnerabilities. The spatial resolution of the urban block also allows for integration of current land-use data and the generation of portfolios of block-specific density indicators to support detailed planning at the most relevant resolution consistent with practice.

#### 4.3.4.1 Urban Monitoring and assessment of current land-use

Fundamental to the development of an UST-based indicator framework, is the identification of USTs at the block level that have similar climate change and disaster risk policy issues. This allows the ex-ante assessment of the built environment and current land-use arrangements, existing plans and aids the development of new strategies. The framework allows the assessment and mediation of all spatial plans in HCMC, in reference to their effectiveness in meeting climate change adaptation and disaster risk reduction policy requirements. Urban flood and urban climate risk maps can be compiled. This will be useful for upcoming versions of the Land-use and the Urban Development Plans. Furthermore, it can support more detailed urban planning schemes and serve as a decision-making support and strategic environmental assessment platform.

The spatial distribution of UST specific density indicator values can be overlain with occurrence of hazards datasets. Furthermore, patterns of risk and opportunity evolve over time. An understanding of the current USTs allows for the intermittent monitoring and assessment of the highly dynamic spatiotemporal structural and socioeconomic changes associated with rapid urbanisation processes. This permits measurable changes as indicators of risk, for the first time being captured in terms of exposure and sensitivity to climate change. The overall risk and vulnerability will be a result of changes in climate, as well as in society such as economic growth and demographic change. As a result, the framework will help provide a communicative and iterative learning approach to monitoring, which will embed monitoring right in the centre of the policy-making process.

#### 4.3.4.2 Urban development and climate change scenario analysis

By mapping the spatial heterogeneity of HCMC USTs, the framework allows for the integrated assessment of underlying urban risk and the inherent urban resilience of HCMC based on coherent and credible indicator sets. In further steps domain specific GIS applications, analytical models and thematic assessment methods will be used to develop customised packages, generating sector-specific risk and vulnerability analyses in a spatially explicit manner.

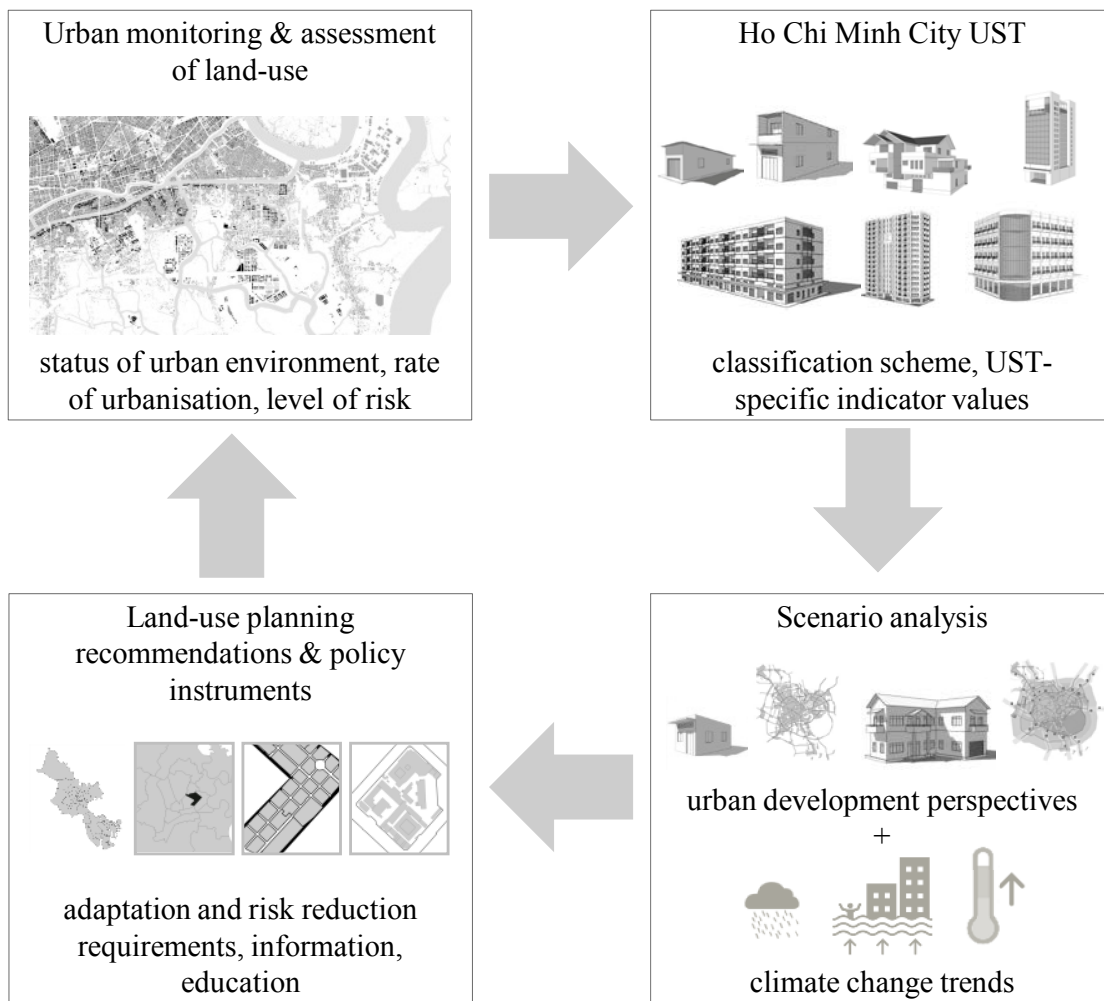


Figure 4–4 The functions of an UST classification (*source: author's own*)

The uniform framework also allows for inter-disciplinary data collection, integration and analysis of social and economic indicators for the compilation of existing vulnerability concepts from various thematic and scientific disciplines at the same spatial scale. The scale serves as a useful visualisation for the fine spatial and temporal modelling for future scenarios in planning documents reflective of assumptions over relation of specific spatial structures and development effects. Likewise, the assessment of the future impacts related to both development and plausible climate change scenarios can also be incorporated into the framework. Results are spatially disaggregated at the block level, to identify hot-spots of risk and to provide clear and concise information relevant to locals at a working level. By using urban land-use scenarios, this overcomes the methodological mismatch of previous studies which link

climate change and urbanisation with little consideration of the spatial dimension or urban growth (Storch and Downes, 2011).

The framework and scenario development allows land-use policies to become more closely tailored to geographically specific issues. Centrally it addresses how the dynamic pattern of urban development can assist or hinder risk adapted non-structural adaptation in land-use planning and land management and function as a switchboard for adaptation and mitigation responses through modifying the form and function of land-use. They also help avoid making decisions now that create vulnerability in the future, such as developing infrastructure on the edge of floodplains or in coastal areas.

#### 4.3.4.3 Land-use planning recommendations

The UST-based indicator framework allows for the delimitation of land-use zones based on block based density indicators and the results of both development and climate change scenario analyses. In the developed UST-based indicator framework, single indicators are not intended to be used in an isolated manner, but rather within an integrative framework, which views them as parts of the resulting zoning guidelines in spatially explicit planning recommendation maps. From the mutual usage of specific, as well as remotely sensed data, spatial-oriented indicator based maps are generated for individual indicator sets and are further refined to form analysis maps through model utilisation. To allow for a uniform scale and to be able to provide adaptation recommendations for particular urban structures, all thematic based and analysis maps are designed on the same scale as the urban block. Finally, planning recommendation maps and data banks containing planning relevant information will be produced.

Urban planners and key stakeholders can then utilise these plan-led indicators to revise their assumptions and core strategies that initially led to the policy actions. They will then be able to modify climate-related adaptation and energy-related mitigation policy in light of new issues and synergies identified. This aids the development of planning recommendations and geographically specific planning policies that reflect the key climate related risks, development pressures, opportunities and sensitivities across the city. Naturally, this type of analysis has to include the spatial dimension of the indicator system, by emphasising the importance of functional areas, spatial linkages and connections. Recommendations for natural system protection, rehabilitation and green

space zoning to increase the water retention capacity and or reduce the pressure of thermal load in the inner-city can be formulated.

Ideally, the UST framework will be valuable in informing policy development and development control. The framework should also aid decision-makers and others involved in the planning process to understand more clearly where development is more or less likely to be acceptable. The framework may also indicate the kinds of development that are likely to be relevant in different areas and may help inform the consideration of planning conditions. To provide greater certainty for the planning of HCMC by identifying areas where particular USTs are, all other things being equal, more, or alternatively less, likely to be suitable for the natural conditions.



## 5 Urban structure types of Ho Chi Minh City

### 5.1 Methodology

In order to accurately define the current land-use and urban extent, the current urban components and their characteristics, the applied UST methodology involved the classification, refinement and reclassification of building archetypes, building densities and open space configurations for the city. Figure 5–1, below schematically depicts the applied methodology.

The digital version of the official HCMC Land-use Plan 2010 at a scale of 1:25,000 from the Department of Natural Resources and Environment HCMC, (DoNRE) provided the common spatial geometry to which an UST map for the year 2010 was compiled (Figure 5–2). The official Land-use Plan 2010 used in this study was formed on the basis of its predecessor, the 5-year Land-use Plan 2001–2005, which was approved by the Prime Minister in the Decision No 844/QD-TTg on 31<sup>st</sup> July 2003. At its time of drafting, due to the urgency to plan, the city made the 5-year HCMC master plan initially, and then subsequently the official Land-use Plan 2001–2005.

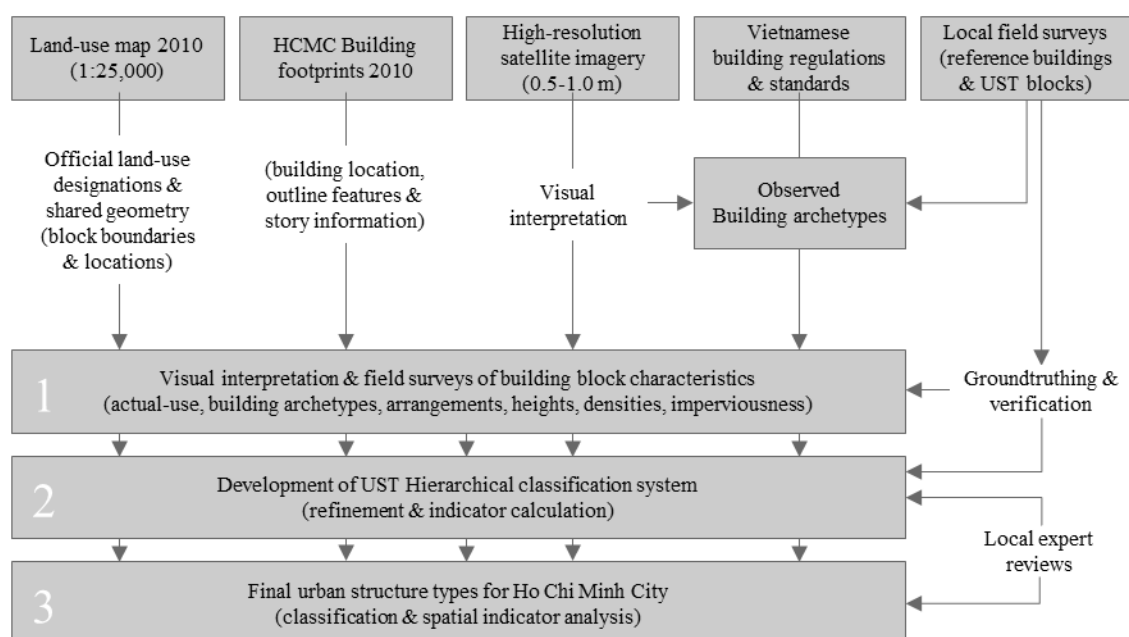
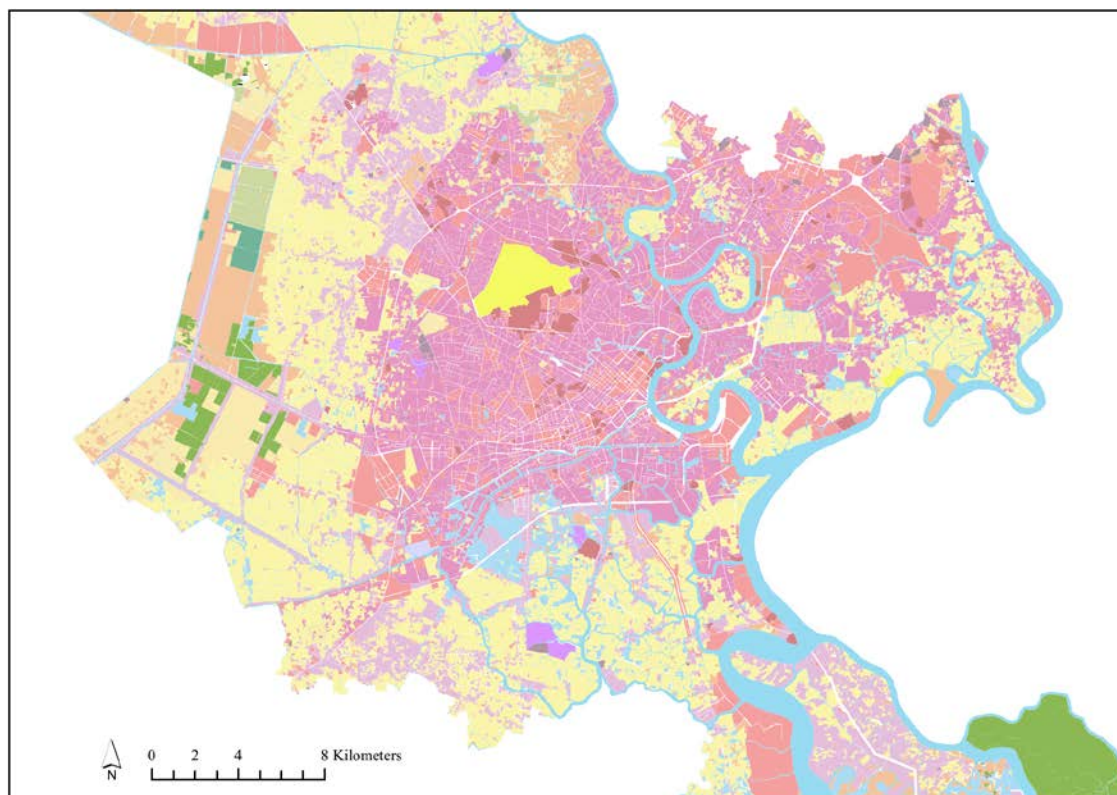


Figure 5–1 Schematic representation of the applied methodology (source: author's own)



Official HCMC land-use plan 2010

Other food crops	DYT Hospitals and health centres	RPK Land-use of recovering protective forest
ANI Security site	LDT Historical heritage sites	RPM Afforested protected greenbelt
BCS Unused land	LNC Agroforestry	RPN Land-use of protective natural forest
BHK Other annual crops	LNK Other perennial crops	RPT Planted protective forest land
CON Natural grassland	LNQ Orchard plantation	RSK Land-use of recovering productive forest
COT Planted grassland	LUC Water paddy land	RSM Planted production forest land
DCH Markets	LUK Remaining water paddy land	RST Land including planted production forests
DGD Training and educational sites	MNC Surface water for special use	SKC Production and business
DGT Road traffic	NKH Other agricultural use	SKK Industrial zones
DND Urban commercial agricultural service	NTD Cemetery	SKX Quarry sites
DNT Energy and communication infrastructure	NTT Temporary housing	SON Watercourses
DSN Historical site	ODT Urban residentials	TIN Area of traditional beliefs
DTL Irrigation works	ONT Rural residentials	TON Religious and worship sites
DTS Public offices	QPH Military areas	TSL Brackish and marine aquaculture
DTT Sport site	RAC Waste dumping and treatment sites	TSN Freshwater aquaculture
DVH Place of cultural arts	RDM Special use forest land	

Figure 5–2 Official Ho Chi Minh City Land-use plan 2010 (source: DoNRE/author's own editing)

Thereafter DoNRE drafted the Land-use Plan 2010 and adjusted the 5-year Land-use Plan 2001-2005, which were both approved by the Prime Minister in the Decision No. 060/QD-TTg on 4<sup>th</sup> October 2004. Later, because of the refinement of social-economic development indicators and the economic structures, as well as, changes in the land-use criteria set out under the Land Law 2003 (enacted 1<sup>st</sup> April 2004), HCMC adjusted its Land-use Plan until 2010 (with the vision into 2020) and the Land-use Plan

2006–2010. This was approved in the government Resolution No/2007/NQ-CP dated 13<sup>th</sup> December 2007. It is this version that was used as the basis within this study.

In addition to the official land-use map 2010, this study also utilised the official building footprint dataset of HCMC for the year 2006. The dataset was originally developed by the HCMC Department of Planning and Architecture (DPA), and was acquired from the Geomatic Centre of the Vietnamese National University Information Technology Park (VNU-ITP) in HCMC. The dataset contains the object attributes of the building plot area—defined by the perimeters of the building plan, building type in relation to the Vietnamese building classification standards (TCXDVN 353, 2005) and the number of stories of each building. In total, the 2006 dataset contained 787,860 individual building footprints.

This study also used an updated version of the dataset, actualised for the year 2010, in the course of a separate doctoral research undertaken at the Department of Environmental Planning, BTU-Cottbus-Senftenberg. The actualised version of the building footprint dataset contained an additional 2271 buildings (see Hoa 2014). A survey and understanding of the observed building archetypes of HCMC provided the initial starting point for the evolution of a (proto-)urban structure typology classification system. In this initial step, the classification of the observed building archetypes was first carried out for selected test areas via the visual interpretation of high resolution multispectral satellite imagery captured primarily in 2009 and 2010, as well as, a series of site visits Table 5–1. Of relevance for resilience and energy efficiency, the attributes of physical characteristics, building usage and age were considered. The building archetypes were categorised by building height, construction types, partly defined by national and HCMC-specific building codes, and their proximity to other structures.

Table 5–1 Satellite imagery utilised for classification of HCMC building archetypes and UST

Satellite	Spectrum	Resolution	Angle	Area (km <sup>2</sup> )	Date of capture
Worldview-2	multispectral	0.5 m	0°	104	2010/04/24
Quickbird	multispectral	0.6 m	0°	20	2010/03/17
Worldview-2	multispectral	0.5 m	0°	98	2010/02/09
Worldview-2	multispectral	0.5 m	0°	151	2010/02/01
Worldview-2	multispectral	0.5 m	0°	91	2010/01/29
Worldview-2	multispectral	0.5 m	0°	88	2009/12/19
Worldview-2	multispectral	0.5 m	0°	42	2009/12/11
Quickbird	multispectral	0.6 m	0°	300	2009/04/19
GeoEye-1	multispectral	0.5 m	30°	325	2009/03/27

Building heights ranged from low-rise (one or three floors), to mid-rise (four to eleven floors) and to high-rise (twelve floors and above), meanwhile, there were two main construction types, combustible buildings, which were built using lighter, nail, stud frame construction or wood joists on masonry bearing walls; and non-combustible buildings that use heavier steel and concrete frames (Table 5–2).

Buildings in HCMC could also be described by their proximity to each other: they can be detached (freestanding); semi-attached (sharing a wall with a neighbouring building) or attached (sharing walls on at least two sides with adjoining buildings). Finally, buildings in HCMC were categorised by their age. This is a key factor because it correlates to the building standards and styles applicable at the time of the buildings construction and thereby strongly to the method and materials of construction.

The undertaken classification was based in part on the Vietnamese standards (MoC, 2008), but adopted to include additional categories. Annex I provides an overview of the national and HCMC-specific building standards, codes, regulations and decisions reviewed in this study.

In a next step, the complied building types and (proto-)UST typology results from the test areas were scrutinised by relevant Vietnamese project partners from the city's administration (DoNRE, DPA, SIHMETE, SubNIAPP) and graduate students and staff from local universities (USSH, University of Architecture) for accuracy and correctness. The further categorisation and refinement built upon the development of existing (proto-)typologies of UST with integrated building types for the whole HCMC administrative area.

Table 5–2 Categorisation criteria for building typologies

Categorisation	
Building usage	<ul style="list-style-type: none"> <li>– Residential</li> <li>– Commercial/Office</li> <li>– Industrial</li> <li>– Mixed</li> </ul>
Building height	<ul style="list-style-type: none"> <li>– Low-rise: 1 or 3 floors</li> <li>– Mid-rise: 4-11 floors</li> <li>– High-rise: 12 floors and up</li> </ul>
Construction materials and type	<ul style="list-style-type: none"> <li>– Combustible building: built using lighter, stud-frame construction or wood joists on masonry bearing walls</li> <li>– Non-combustible building using steel or masonry and concrete frames</li> </ul>
Proximity	<ul style="list-style-type: none"> <li>– Detached: freestanding</li> <li>– Semi-detached: sharing a wall with another building</li> <li>– Terraced: sharing walls on both sides with adjoining buildings</li> </ul>

Further groundtruthing site visits were undertaken and special attention was given to areas of unknown or mixed USTs. Following the series of local expert reviews and site visits, the (proto-)typology was finalised and differentiated along the physical density-distinctive classes and spatial criteria that are required for both climate change and disaster risk research questions.

The methodology allowed for the differentiation of the urban landscape on the basis of each block structure's biophysical and socio-economic characteristics. For example, differing construction materials of structures or differing degrees of soil sealing exhibited by different structures are accounted for within the classification. The undertaken classification allowed for the higher differentiation than that of the official land-use map 2010. The official HCMC Land-use Plan 2010 itself displayed only the pure designation of land-use utilisations, which are directly related to the categories of the Vietnamese Land Law (2003), relevant for the whole of Vietnam.

As can be seen in Figure 5–2, while there are multiple categories provided for agricultural land uses for instance, urban areas are particularly undifferentiated and displays built-up land-use designations of solely urban residential, rural residential or industrial developments. The inherent qualities, *i.e.* environmental significance or the exposure or resilience of areas or structures, the urban structural densities or the actual real utilisation were not illustrated.

Throughout the evolution of the UST classification and further density indicator calculation and mapping, to support the dissimilation of the results, the geometry of the DoNRE land-use map was maintained. The developed differentiated USTs were assigned to the 16,292 building blocks in the common spatial geometry. Hence, the official planned land-types and the USTs correspond to the same basis, (*i.e.* the same digital block unit). This importantly resulted in every block unit retaining the designated land-use information, originally from DoNRE in addition to the classified UST and calculated density indicator information.

## **5.2 Observed building archetypes**

In total, 19 individual building archetypes were classified and subdivided into five groups. Variations of detached; semi-detached houses and terrace shophouses, and high-rise and low-rise apartments constituted the dominant building typologies seen in urban

districts, while more traditional houses were seen built in the rural districts. The majority of the urban houses are commercially constructed with modern material such as concrete, steel works and glass. Nevertheless, the more rudimentary and temporary building typologies were built by their owners with locally available and collected materials. The main archetypical groups are described below.

### **5.2.1 Shophouses**

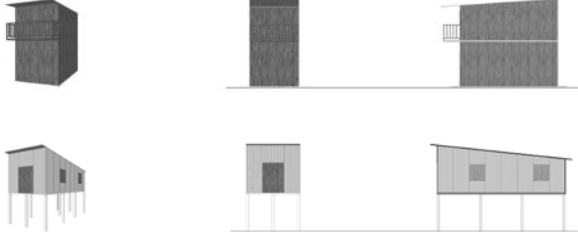



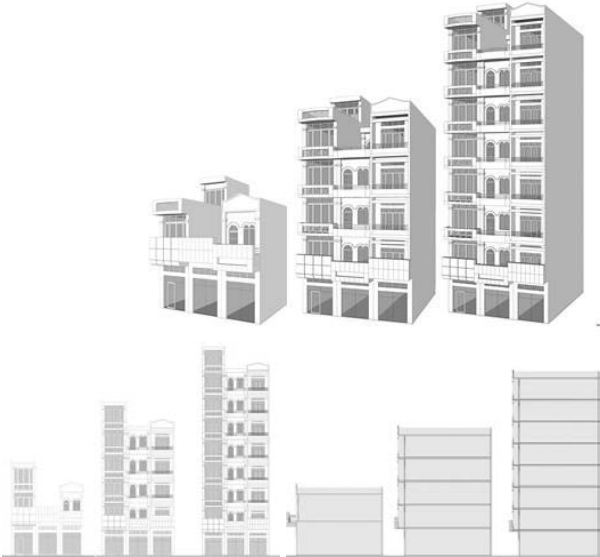
Shophouses are the dominant mixed-use archetype seen in HCMC (also often referred to as row- tube- or street houses in the literature). A building type common to many other regions of Vietnam, Martin (2001), states shophouses have evolved over centuries from more traditional rural one-story freestanding vernacular architecture. Observed present day shophouses are characteristically sited in a rectangular plot which has a length much greater than its width. Typical buildings are usually three-to-five metres wide and twelve-to-twenty metres long (Martin, 2001).

They usually have only one open façade sited on their narrow side, from which they are accessed and are constructed with fired walls on the remaining three sides. The name arises as “*shophouses*” are fronted to the street or alleyway side along their narrow side, with part or whole of the ground floor reserved for retail or office space opening directly to the street in front. Thus, the “*shop*” provides space for income generation while the “*house*”, the living quarters is situated at the rear or upstairs.

The single family typology is well adapted to occupants needs and enables them to live and work in the same area, with the narrow frontages allowing for high population densities and also concentrated commercial activities (Ly *et al.*, 2010; Ly, 2012). Dependent upon their locations, commercial activities may range from hotels in the inner city to residential housing and workshops in the urban periphery. Shophouses were seen to be detached or semi-detached but often sit together to form continuous terrace structures, which share the same infrastructure.

Three types of detached shophouses and one type of semi-detached shophouse were recognised (Table 5–3). Temporary shophouses are the most basic building type surveyed. They are typically built from light frame materials such as timber and roofed with reeds or coconut leaves. Temporary shophouses often develop spontaneously to

Table 5–3 Main shophouse building typologies observed in HCMC (source: author's own)

<p>Temporary shophouse</p> <p>Detached temporary housing with typically 1–3 floors. Residential and small-scale commercial use mix. Comprised of wood and an assortment of simple materials. Often located along inner city canals or built against existing structures such as walls. Average floor height is ca. 2.6 m.</p>	
<p>Standard alley shophouse</p> <p>Detached housing, with a mix of residential and commercial use. Low-rise with 1–2 floors. Comprised of wood, brickwork and reinforced concrete, tin roof. Often located along small alleyways or in peri-urban locations, often in districts 4; 5; 7 and 8. Average floor height is ca. 2.6 m.</p>	
<p>Detached shophouse</p> <p>Residential single-family freestanding house in various designs. Mid-rise with 3–5 floors. Comprised of reinforced concrete, brickwork. Located often in new residential areas. Average floor height ranges from 3.6 m–4 m for the ground floor and 2.7–3.3 m for additional floors.</p>	
<p>Semi-detached shophouse</p> <p>Residential use, semi-detached houses in various designs styles, multifamily dwelling, and pair of mirror image houses built side by side sharing parting wall. Often commercial premises on ground floor, reinforced concrete, brickwork, mid-rise with 3–5 floors. Average floor height ranges from 3.6 m–4 m for the ground floor and 2.7–3.3 m for additional floors.</p>	
<p>Terrace shophouse (low- and mid-rise)</p> <p>Built using wood, brickwork, glasswork and reinforced concrete. Low-rise terrace shophouses were located in peri-urban areas along traffic arteries and are used for residential, commercial use and to some extent small-scale industry. Mid-rise terrace shophouses were seen most predominately in the inner city districts, facing main traffic routes and are typically <math>\geq 4</math> floors high. Utilised for a mix of residential and commercial use. Terrace shophouses up to 9 floors high, were observed in the inner city especially in districts 1, 3 and 5. These were utilised for a mix of residential, intensive commercial use or hotels. Average floor height ranges from 3.6–4 m for the ground floor and 2.7–3.3 m for additional floors.</p>	

meet living space, trade and commerce needs and are seen often in the inner city districts along canals. Whereas, standard alley shophouses are often located along alleys and in peri-urban locations and are often built with simple timber framed or concrete walls and roofed with corrugated iron. Both temporary and standard alley shophouses displayed slightly pitched roofs.

In contrast, the detached and semi-detached shophouse typologies are more recent additions to the HCMC urban fabric and are often mid-rise with up to four floors. Detached shophouses are free standing buildings that have distinctive pitched gabled and tiled roofs and are built with reinforced concrete frames. Semi-detached shophouses share a wall with an adjoining property, and also use reinforced concrete for structural frames and additionally as the surface material for their flat roofs. Both are commonly seen in new urban districts.

In terrace shophouses the entrance to the street along the narrow side is also the only access with the remaining other three sides enclosed by adjacent property boundaries. In certain localities shophouses display only a single ground floor while in other localities they may exhibit up to nine floors, as such terraced shophouses can be classified as low-rise or high-rise. The individual leaseholders decide the height and according to HCMC planning codes, the number of floors of terraced shophouses is determined by the width of the street they face. Roofs may be flat or gabled.

### **5.2.2 Villas**




Villas are categorised as free-standing detached buildings of high quality, designed on an open plot of land so that windows can be installed on all facades. They are single family dwellings and commonly have between 3–4 floors with gabled and complex roofs. Three types of villas were observed in HCMC (Table 5–4).

Colonial villas were built during the French colonial era (1887–1954) and are often now in a refurbished state. They are found in the older districts of HCMC, sited along wide boulevards and are still constructed with timber frames, plaster and fired brickwork exhibiting steep pitched and tiled roofs.

Villas and luxury villas are modern additions to HCMC and are located in suburban districts. They are typically constructed in new residential quarters in large scale greenfield developments of the urban periphery. They can be found in districts 2 and 7.



Table 5–4 Main villa building typologies observed in HCMC (*source: author's own*)

<p>Colonial villa</p> <p>Often administrative or commercial use, built from brickwork, low-rise with 2–3 floors, located often in districts 1 and 3. Ground floor height is ca 3.9 m with all additional floors 3 m high.</p>	
<p>Villa</p> <p>Single family detached dwelling, low-rise 2–3 floors, built from brickworks and concrete. Located in new urban districts. Ground floor height ranges from 3.9–4.2 m with all additional floors 3.3 m high.</p>	
<p>Luxury villa</p> <p>Single family detached dwelling, low rise-2–4 floors, built from brickwork or concrete, located in new urban areas. Ground floor height is 4.2 m with all additional floors 3.3 m high.</p>	





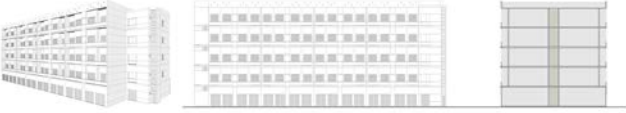
Typically, villas and luxury villas are constructed with reinforced concrete. The difference between villa and luxury villa is the size, with the luxury villa being a substantially larger dwelling within a larger plot, often including a swimming pool and typically sited within a gated community and with individual plots often enclosed by fenced gardens.

### 5.2.3 Apartments

Apartments are a sub-set of building types defined as having at least two floors. Table 5–5 shows sketches of the five apartment building archetypes observed in HCMC. All apartments typically comprise of self-contained housing units that occupy only part of the building, while the residents share entrances, staircases or elevators and infrastructure systems.

Mid-rise and high-rise apartments are both newer additions to the HCMC urban fabric and are typically high dense, with the majority built after 2000. They often contain commercial and parking spaces and adjacent recreational facilities. High-rise apartments tend to be upscale apartment buildings and contain more luxurious housing units and high-rise apartments tend to have up to twenty-five storeys, whereas mid-rise apartments will typically exhibit only up to seven floors. They both exhibit characteristic flat roofs.

Table 5–5 Main apartment building typologies observed in HCMC (*source: author's own*)

Mid-rise apartments	High-dense low-rise apartments with multiple residential units'. Often commercial premises on ground floor. 4–11 floors. Built with Reinforced concrete. Ground floor height ranges from 3–4 m with additional floors 2.7–3 m high.	
High-rise apartments	High-dense high-rise apartments, with multiple residential units and commercial premises on ground floor. >12 floors. Built from reinforced concrete. Found in the new development areas on the urban periphery. Ground floor height is typically 4 m with additional floors 2.7–3 m high.	
Social apartments	Residential and commercial use. Shops on ground floor. Mid-rise 3–5 floors. Located in inner city and peri-urban locations. Built with concrete. Balconies. Ground floor height is typically 3.6 m with additional floors 2.7–3 m high.	
Old Chinese apartment	Multiple residential units with 2–3 floors, built from concrete and brickwork. High occurrence in District 5. Ground floor height is typically 3.3m with additional floors 2.7–3 m high.	
American apartments	Multiple residential units, 3–5 floors. Shops on ground floor, built with reinforced concrete. Ground floor height is typically 3.6m with additional floors 2.7–3 m high.	

Social apartments are often older and are owned and managed by the state and designated for low-income earners. Typically the social apartment buildings have no more than 5 stories and unit size no greater than 70 m<sup>2</sup> (Social housing decree 71/2010/NĐ-CP). Each building may contain up to 90 units. The apartment building archetypes classified as Old Chinese apartments are Chinese-influenced buildings containing individual housing units dating from as early as the early or mid-20<sup>th</sup> century. They are typically 2 to 3 stories high and built from brickwork, timber and concrete. They often have a corrugated iron gabled roof. The ground level building peripheral units are used for small market orientated commercial purposes, while

residential units are to the middle and on higher floors. Not surprisingly they were often seen located in the Chinese- influenced areas of HCMC, namely the western half of district 5 as well as several adjoining neighbourhoods of district 6. Finally, American apartments are remnants of the Vietnam War. They were formerly used for American barracks. They were built between 1956 and 1975 using mainly reinforced concrete. They are found exclusively in the Thanh Da peninsula of the Saigon River in Binh Thanh district and are typically 3–5 stories high. As with the Old Chinese apartments, the ground floor units have been converted for commercial purposes with the upper stories used for residential use.

#### 5.2.4 Other buildings

Additional building archetypes were important for the UST categorisation as they often occur adjacent or in conjunction with the aforementioned buildings (Table 5–6).

Table 5–6 Main additional building typologies observed in HCMC (*source: author's own*)

<p>Low-/mid-rise commercial &amp; administrative buildings</p> <p>Administrative, commercial and retail buildings with numerous floors. Often found in the inner urban districts. Ground floor height is typically 4–4.2 m with additional floors between 2.7–3 m high.</p>	
<p>High-rise commercial</p> <p>Commercial and retail building with above 9 floors. Located in the central business district. Average floor height ranges from 4–4.2 m for the ground floor and 3.3 m for additional floors.</p>	
<p>Hotels</p> <p>Hotels of various designs. Refurbished colonel hotels are located in the main CBD districts of HCMC. Average floor height is 4.5 m for the ground floor and 3.3 m for additional floors.</p>	
<p>Markets</p> <p>Traditional markets often located towards the centres of districts or sub-districts. Floor height varies.</p>	
<p>Industrial</p> <p>New pre-fabricated industrial halls, located in industrial areas of the city. Floor height varies.</p>	

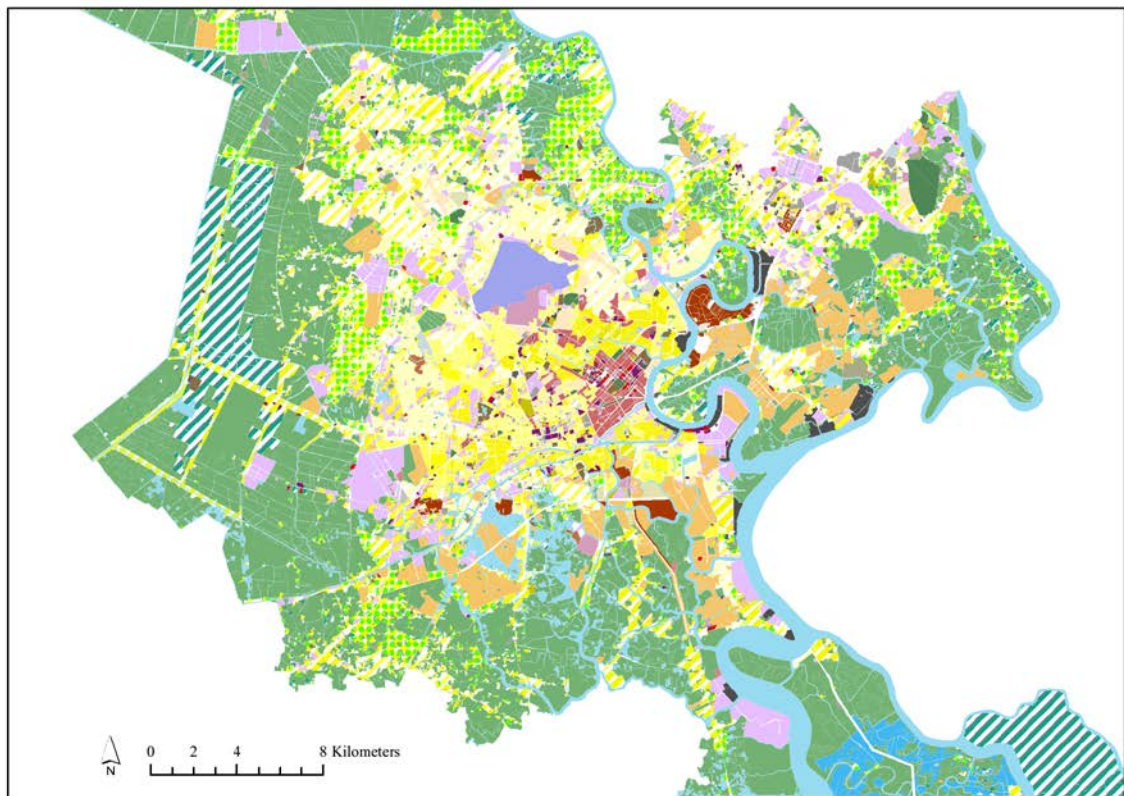
The range of non-residential buildings is characterised by a large range of different archetypes, each with specific functional, structural and morphological properties and characteristics. These buildings were classified according to their principal activity, which was the primary business, commerce or function carried out within each building. Low- to mid-rise commercial and administrative buildings were observed in many of the urban districts. These buildings are used for general office space or administrative offices or for the sale and the display of goods. They are normally constructed from reinforced concrete, steel and glass with flat concrete roofs. High-rise commercial buildings are seen exclusively in the central business district (CBD) of district 1. These buildings are often used for administrative or professional office, government offices, mixed-use office and bank or other financial institutions and also constructed with steel frames, reinforced concrete and glass. Furthermore hotels, and other buildings used to offer short-term accommodation, markets, buildings used for retail or wholesale of food, as well as, industry halls, buildings used for manufacturing and production of goods were the other dominate building archetypes observed.

### **5.3 UST classification of Ho Chi Minh City**

A large variety of USTs were distinguished in HCMC. In total, 80 differentiated USTs were developed and assigned to the 16,292 building blocks of the common spatial geometry of the official land-use map 2010 (Figure 5–3).

The classified USTs were divided into main four utilisation categories on the basis of their predominant utilisation, either being assigned as residential; public and special use; industrial and commercial use; green and open space, and with the remainder of the surface area comprised of street and water networks. Each utilisation category was then additionally further arranged into classes, then groups and finally the individual USTs.

USTs were predominately arranged into classes based on the dominant housing typologies they contained. This is a common criterion in visual interpretation. Within the residential utilisation category this could be either shophouse based, villa based, apartment based or central business district (CBD) based. Blocks were then assigned an order as a reflection of the observed level of planning, the buildings and space arrangements, densities and age.



Urban structure types of HCMC 2010

111 Shophouse regular new	410-420 Central business district	592 Security site
112 Shophouse regular new comm	511-512 Education	611-612-621-622 Industry
113 Shophouse regular w/ narrow street	521 Traditional market	711-712 Park
114 Shophouse regular w/ yards	522 Shopping centres	721-728 Agriculture
121 Shophouse irregular highdense	531 Religious and worship site	729 Urban commercial agricultural service
122 Shophouse irregular w/ yards	532 Site of traditional beliefs	731 Brine and sea aquaculture
123 Irregular shophouse scattered	540 Hospital & Health Centre	732 Freshwater aquaculture
124 Irregular shophouse clustered	550 Administration / Public Offices	741-752 Agroforest
125 Irregular shophouse w/ large gardens	561-562-566 Transport infrastructure	753 Unused land
126 Shophouse irregular temporary	563 Airport	754 Under construction
131 Shophouse with industry	564 Harbour/Port Passenger	761 Municipal solid waste site
132 Shophouse irregular and regular	565 Harbour/Port Container	762 Wastewater plant
211-212 Regular villa	570 Cultural arts theatre/Museum	771-773-772 Sport site
221-231 Mixed villa	571-572-573 Historical site	780 Cemetery
311-312 New apartments	580-581-582 Energy and comm. infrastructure	791-792-793 Surface water
321-322-323 Old apartments	591 Military area	

Figure 5–3 USTs of Ho Chi Minh City (source: author's own)

Table 5–7 provides an overview of the classified UST for HCMC. Blocks were classified into the utilisation category residential use if they were predominantly used for residential purposes. Residential blocks can therefore be of mixed use but overall exhibit residential character. As such, they can include additional residential related buildings, public facilities, local open and green spaces and adjacent large fields.

Table 5–7 Classified USTs of Ho Chi Minh City

Utilisation Category/class	No. urban structure types	No. of blocks	Surface Area (ha)	Percentage utilisation category (%)	Percentage of total HCMC surface area (%)
Total urban structure types	80	16,292	170,960.5	-	81.7
Residential (4 classes)	23	6,717	44,404.6	100	21.1
Shophouse based-	12	6,347	42,315.3	95.2	20.1
Villa based-	4	107	844.7	1.9	0.40
Apartments based-	5	103	500.1	1.1	0.24
<i>Central Business Dist. based-</i>	2	160	744.5	1.7	0.35
Public, commercial & special use (9 classes)	20	772	5,249.7	100	2.43
Industrial (2 classes)	4	828	5,637.5	100	2.67
Green & open space (9 classes)	33	7,995	115,668.7	100	55.5
Remaining street and surface water	-	-	38,539.5	-	18.3

In total just over 21% of the overall HCMC administrative area was classified as residential. Residential USTs were seen to vary from the dense planned and unplanned developments of the inner urban districts to the more open settlement patterns and USTs characteristic of the peri-urban areas. Overall 23 distinct residential USTs were observed and sub-divided into the four classes of shophouse based (12 types), villa based (4 types), apartment based (5 types) and central business district (CBD) based (2 types). The 12 shophouse based residential USTs were the dominant class of structures in HCMC, accounting for 95% of all seen residential urban structures. A definition and description of the individual residential urban structure types of areas can also be found in the following section.

Twenty well-defined USTs were assigned in the utilisation category of public, commercial and special use. This category included 9 classes in total, including classes for the public facilities of education, higher education and research, religious institutions (*i.e.* pagodas, temples and churches), health care and administration. Commercial uses included traditional markets, as well as, large-scale retail trade, including associated parking facilities. Furthermore, this utilisation category also

included areas for energy and communication infrastructure, nodes of transportation and sites of security and defence. In total, 2.4% of HCMC was classified as of public, commercial or special use.

Four individual USTs were assigned to the utilisation category industrial use. Blocks of this category describes areas with industrial use and some partial commercial use. The characteristically exhibited large single-storied manufacturing buildings, warehouses and either sealed or unsealed yards and associated loading and parking spaces. The density of industrial use was seen to vary and as such the category is divided into two classes, low-dense and high-dense industry.

Residential use may also occur in the low-dense industry class blocks, as long as it does not exceed more than one third of the block area. The category also includes freight yards and industrial areas, which were seen to be often in the outskirts of the urban area, mainly in areas with favourable traffic conditions, such as highways, waterways and to some extent railway lines. Overall, industrial use was seen to make up 2.6% of HCMC total administrative area.

The utilisation category of green and open spaces encompasses 33 individual USTs divided into 9 classes. The classes in this category include publicly accessible green space such as parks, mixed parks and afforested parks, harvested crops, aquaculture, and forests. Blocks depicting harvested crops such as rice cultivation, aquaculture, mangrove forests, and agroforestry were clearly visible and identified by the imagery and checked to correspond with the designated land-use classification of the land-use map 2010. If the UST did not match with the land-use designation, it was assumed that the exact nature of agricultural use may alternate on the same block relatively frequently. The UST mapping therefore reflects the state of the block at the time of mapping.

Also included in this category is the class of open field. This class includes planted and natural grasslands, unused land and land under construction. For the purpose of classification, unused land was defined as land that is no longer used, brownfields or is largely free of vegetation. Blocks were mapped as land under construction if the block surface was seen to display typical construction site character, usually bare and open ground, and often the presence of construction equipment. If the foundations and first floors of new buildings were already seen, the classification was carried out according to the planned use. Further classes included sports and recreational sites, including both

uncovered and covered sports facilities, including sport fields and golf greens, waste dumping and treatment sites, including municipal solid waste sites and wastewater plants, cemeteries and surface waters. In total, the utilisation category of green and open spaces was seen to account for 55% of the total HCMC administration area.

For readability, Figure 5–4 shows the classified four main UST utilisation groups mapped for HCMC and their distribution throughout the city’s administrative area. In addition, Figure 5–5 illustrates the distribution of the utilisation categories over the individual districts of HCMC in percentages. The urban districts of HCMC (from left to right on the graph from district 1 through to Tan Phu), showed high percentages of built-up land. Built-up land here is defined as developed land areas, *i.e.* blocks which were classified as containing either a residential, CBD, public and commercial or industrial based urban structures; *i.e.* no green or open based urban structures. The built-up land percentages for the urban districts range from 54% in district 8 to 100% in district 3. Of the 13 urban districts (from left to right on the graph districts 1 through to Tan Phu), 11 of the districts display built-up land areas greater than 90%.

The peri-urban districts (districts 2 to Thu Duc) show built-up land percentages ranging from 81% in district 12 to 36% in district 2 and 9 respectively. In contrast and as to be somewhat expected, the rural districts (districts Cu Chu to Can Gio) show significantly higher percentages of green and open space. The percentage of built-up land in the rural districts was seen to range from 48% in Hoc Mon to 2% in Can Gio.

As displayed in Figure 5–5, with the exception of district 1, the majority of built-up land in HCMC districts was classified as residential housing. The urban districts of 1, 3, 10, 8, Phu Nhuan and Go Vap; show relatively lower proportions of residential USTs and consequently, their percentage shares of central business district, public, commercial and green and open space based USTs are higher respectively.

The highest percentage share of CBD- based USTs was seen in the older districts, with 54% in district 1 and 30% in district 3. Not surprisingly purely residential, CBD and public commercial based USTs were seen significantly more in the urban districts than the peri-urban and rural districts. Districts 4, 8 and Tan Phu however exhibited no CBD based USTs, while only 0.5% of the total area of Go Vap district was classed as containing CBD based USTs.



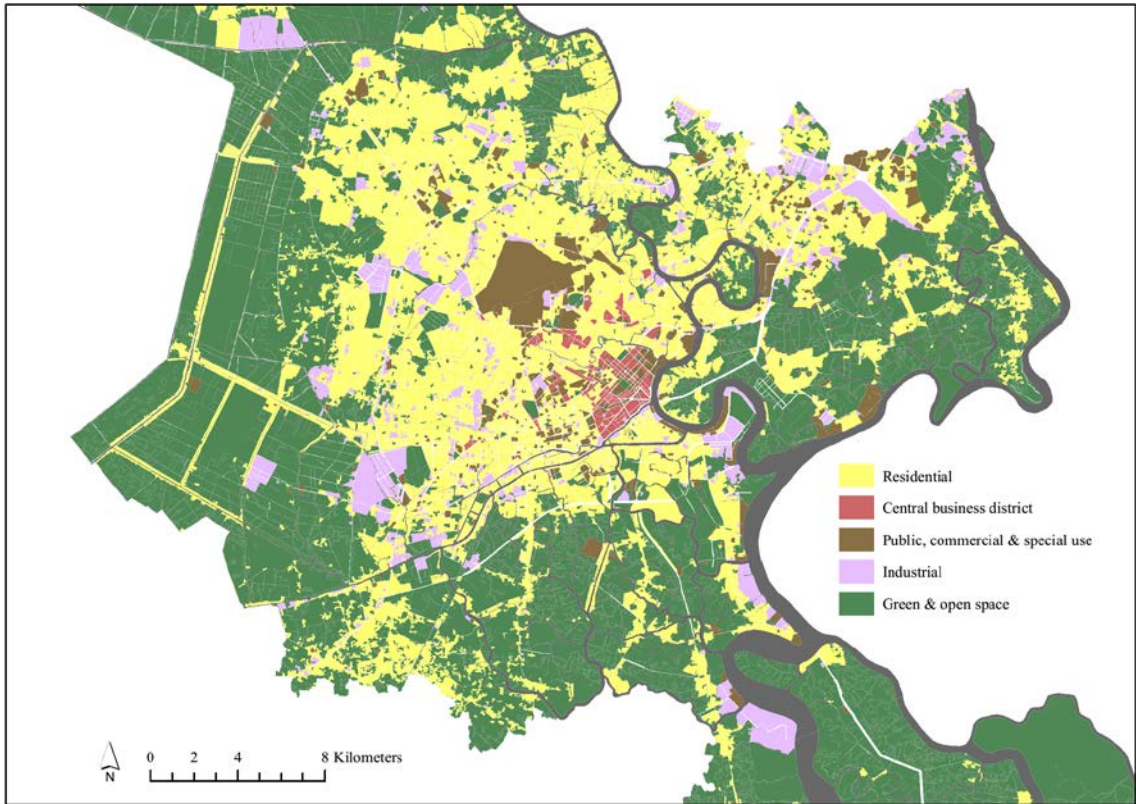


Figure 5–4 UST utilisation categories of Ho Chi Minh City (Note: CBD UST is separately plotted but in this study was assigned as residential utilisation) (source: author's own)

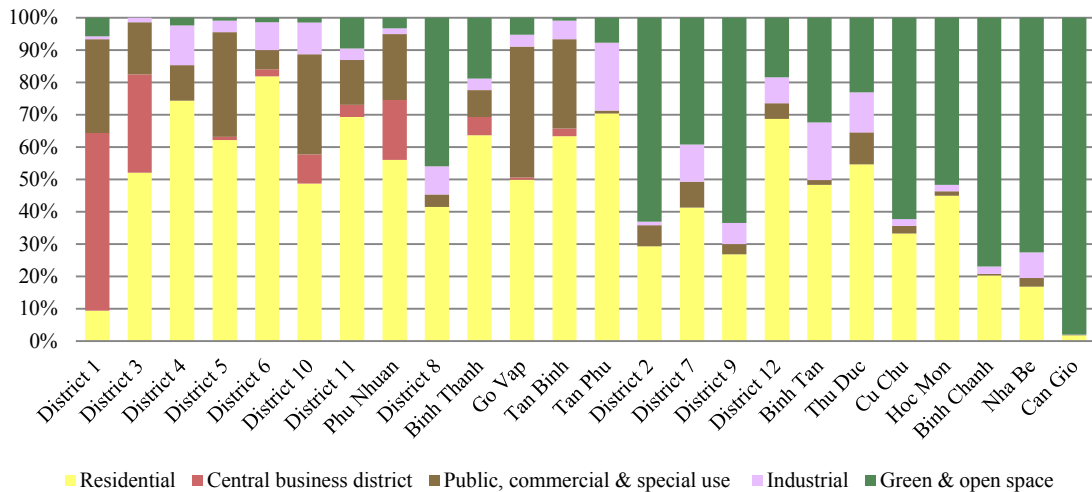


Figure 5–5 Relative distribution of UST utilisation categories over districts (in %)

Industrial and public, commercial and special use based USTs were seen in all districts with the exception of Can Gio. Areas containing public, commercial and special use (i.e. public facilities) were found to be relatively evenly distributed throughout the entire metropolitan urban districts. With the exception of districts 6 (6%), 8 (4%), Binh

Thanh, (8%) and Tan Phu (1%), all other urban districts displayed a greater than 10% share of their surface are reserved for public, commercial and special-use USTs. Industrial based urban structures were seen to cover 20% of Tan Phu, 17% of Binh Tan and 12% of both district 4 and Thu Duc. Industry was also prevalent in districts 6 (8%), 10 (10%) and 8 (9%).

Examples of the characteristic distribution of USTs in the peri-urban districts can be seen in the district 2 and district 9 each with 29% and 27% residential use based USTs respectively and both exhibiting 63% green and open space. Whereas district 1 with approximately 9.4% residential based USTs and 54% CBD based USTs and over 29% public and commercial use clearly reflects its central function.

#### **5.4 Description of residential urban structures**

The residential USTs of HCMC were initially classified and further differentiated upon the basis of their functional properties (land-use), as residential use, and secondary in to classes by their distinct configurations of building archetypes, and thirdly into groupings reflective of the observed arrangement of building archetypes to each other, as well as characteristic open spaces, built-up densities, building alignments, open spaces, urban green spaces and infrastructure.

Table 5–8 shows the relationship between the classified residential USTs and related observed building archetypes. Table 5–8 also highlights the sub-division of the residential utilisation categories into the four main classes of shophouse based, villa based, apartment based and central business district based USTs. As mentioned in the previous section, each class, with the exception of CBD based USTs, were further differentiated into orders. As seen in Table 5–8, the class of 12 shophouse based USTs was for example differentiated into, regular, irregular, peri-urban and mixed shophouse types, while the four villa based USTs were identified and subdivided into two orders namely regular villa and mixed villa and the five apartment based USTs were subdivided into either new apartments or old apartments.

While the residential USTs are described in detail over the following pages, Table 5–9 provides a comparison of the classified surface area for each residential UST in terms of both hectare and percentage of the total classified residential area.

Table 5–8 Relationship between residential USTs and observed building archetypes

Building archetype Residential UST	Temporary shophouse	Standard alley shophouse	detached shophouse	Semi-detached shophouse	Low-rise terrace shophouse	Mid-rise terrace shophouse	High-rise terrace shophouse	Colonial villa	Villa	Luxury villa	Mid-rise apartment	High-rise apartments	Chinese apartments	American apartments	Social apartments	Low-mid-commercial	High-rise commercial	Hotel	Market	Industry
<b>Shophouse based</b>																				
<i>-Regular shophouse</i>																				
Shophouse regular new			X	X	X											X				
Shophouse regular new comm.			X	X	X	X											X			
Shophouse regular narrow streets	X	X			X	X	X									X		X		
Shophouse regular w/ yards	X	X			X													X		
<i>-Irregular shophouse</i>																				
Shophouse irregular high-dense	X	X			X	X	X									X		X	X	
Shophouse irregular w/ yards		X			X	X														X
Shophouse irregular temporary	X	X			X															X
<i>-Peri-Urban shophouse</i>																				
Shophouse irregular scattered	X	X	X		X															X
Shophouse irregular clustered	X	X			X															X
Shophouse irregular w/ large fields		X			X															X
<i>-Mixed shophouse</i>																				
Shophouse with industry	X	X			X											X				X
Shophouse irregular & regular		X			X											X				X
<b>Villa based</b>																				
<i>-Regular Villa</i>																				
Villa									X											
Luxury villa									X	X										
<i>-Mixed Villa</i>																				
Villas in established UST	X	X			X	X		X	X											
Colonial villa								X	X											
<b>Apartments based</b>																				
<i>-New apartment</i>																				
Mid-rise apartment										X										
high-rise apartment											X									
<i>-Old apartment</i>																				
Chinese apartment												X								
American apartment													X							
Social apartment														X						
<b>Central business district based</b>																				
CBD		X		X	X	X				X	X	X			X	X	X	X		
CBD w/high dense				X	X	X				X	X	X			X	X	X			

Note: UST classes in bold and UST groups in italics.

Table 5–9 Calculated surface area and percentages of residential USTs

<b>Class</b> <i>(dominant building archetype)</i>	<b>Group</b> <i>(observed local manifestation)</i>	<b>Code</b>	<b>Name</b> <i>(individual UST)</i>	<b>Surface area</b> <b>(ha)</b>	<b>Percentage of total residential area (%)</b>
<b>Shophouse based</b>					
	Regular shophouse			4,923.3	11.0
		111	Shophouse regular new	449.0	1.0
		112	Shophouse regular new comm.	392.9	0.8
		113	Shophouse regular narrow streets	2,062.7	4.6
		114	Shophouse regular w/ yards	2,019.5	4.5
	Irregular shophouse			6,131.5	13.8
		121	Shophouse irregular high-dense	1,602.3	3.6
		122	Shophouse irregular w/ yards	4,443.9	10.0
		126	Shophouse irregular temporary	85.2	0.2
	Peri-urban shophouse			29,613.5	66.6
		123	Shophouse irregular scattered	6,989.4	15.7
		124	Shophouse irregular clustered	5,490.8	12.3
		125	Shophouse irregular w/ large fields	17,133.2	38.5
	Mixed shophouse			1,646.9	3.7
		131	Shophouse with industry	1,269.5	2.8
		132	Shophouse irregular & regular	354.4	0.8
<b>Villa based</b>					
	Regular villa			665.7	1.5
		211	Villa	274.7	0.6
		212	Luxury villa	390.9	0.9
	Mixed villa			178.9	0.4
		221	Villas in established UST	150.7	0.3
		231	Colonial villa	28.2	0.1
<b>Apartment based</b>					
	New apartment			370.8	0.8
		311	Low-rise apartment	152.5	0.3
		312	high-rise apartment	218.2	0.5
	Old apartment			123.2	0.3
		321	Chinese apartment	55.9	0.1
		322	American apartment	40.7	0.1
		323	Social apartment	32.5	0.1
<b>Central business district based</b>					
		410	CBD	531.5	1.2
		420	CBD w/high dense	212.9	0.5

## 5.4.1 Shophouse based urban structures

### 5.4.1.1 Regular shophouses

The grouping of regular shophouse USTs comprising of 4 distinct USTs can be seen in Figure 5–6. They are so—termed due to its regular layout and orientation. In total, this grouping of USTs covered 4,943 ha and made-up 11% of the total residential area of HCMC. Shophouse regular (*code 111*) contains detached and semi-detached and terraced building archetypes orientated perpendicular to the main streets with a back to back development pattern. The terraced houses give the blocks a spatial pattern by not standing too loosely scattered, but equally perpendicular to the street, so that the short sides are aligned to the street. The three- to five-storied buildings are lined up in parallel rows to each other. The UST shophouse regular was seen in predominantly in the peri urban districts of Go Vap, Tan Phu, and district 7. In total, shophouse regular UST was seen to cover 450 ha of the HCMC administrative area.

Shophouse regular community (*code 112*) is a perimeter block development around a communal area serving the residents and therefore has a higher percentage of open area. It commonly contains the same permanent building archetypes of detached and semi-detached with a typically four storied back to back development muster. The UST was observed with high frequency and spatial extents in the peri-urban districts of Go Vap, Tan Phu, district 7, Binh Tan and Binh Chanh and was seen to cover 390 ha in total.

Shophouse regular with narrow streets (*code 113*) is a much denser development and contains low to high-rise terrace shophouses, orientated to the main street. The regular development is incised by narrow semi-public passages, side streets and alleyways of less than 3 metres width. The spaces between the buildings are narrow and elongated and open on the short sides. The typology is widespread in HCMC and was found in the older urban districts and covered 2,060 ha in total.

Shophouse regular with yards (*code 114*) is a less dense and sealed heterogeneous development but still exhibits this group's characteristic regular arrangement of shophouses. This UST typically contains a loose configuration of one- to two-storied temporary, rudimental shophouses with each building displaying adjacent sparsely leafed backyards. The typology also contains occasionally low-rise terrace shophouses along main streets. The UST was seen chiefly in the peri-urban and rural districts of HCMC and covered 2,020 ha.

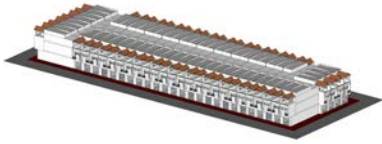
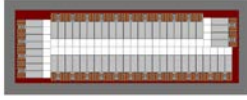



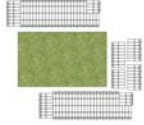







Illustration 3D	Illustration plan	Example	Building footprints	
111: Shophouse regular				
112: Shophouse regular community				
113 Shophouse regular narrow streets				
114 Shophouse regular with yards				

Figure 5–6 Exemplary building blocks of the observed regular shophouse USTs (*source: author's own*)

#### 5.4.1.2 Irregular shophouses

Three distinctive USTs were classified in the group irregular shophouses (Figure 5–7). The group was seen to cover 6,141 ha or 14% of the total area classed as residential. The UST Shophouse irregular high dense (*code 121*) is a high dense irregular development with narrow streets. It is characterised by terraced shophouses along the outer edges on the main streets and by unplanned inhomogeneous infilling within the block interior. The block interior is observed to be riddled with temporary and standard alley shophouse archetypes. The UST shows a very high utilisation of the land for housing with the vast majority of the few remaining open spaces additionally sealed. The phenomenon was found to occur in the vast majority of HCMC districts, covering over 1,600 ha in total.









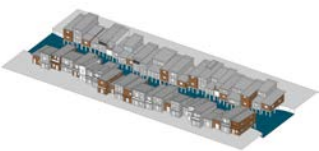



Illustration 3D	Illustration plan	Example	Building footprints
121: Shophouse irregular			 
122: Shophouse irregular with yards			 
126: Shophouse irregular temporary			 

Figure 5–7 Exemplary building blocks of the observed irregular shophouse USTs (*source: author's own*)

Shophouse irregular with yards (*code 122*) is a less dense variation of above-mentioned shophouse irregular. The random arrangement of rudimentary and low- to mid-rise shophouse with open spaces that have yard appearance characterise this UST. The yards themselves were often seen to be free of vegetation, *i.e.* bare soil and partly sealed. The yards in the block interior are often associated with commercial workshops and warehouses, but also occasional private use and vegetable and fruit garden production was seen. This type of UST was found in all districts apart from districts 1, 3, 5 and 10 and covered 4,450 ha.

Polygons were classified as Shophouse irregular temporary (*code 126*) if the block contained, small mostly single- to two-story temporary buildings, randomly distributed in high-dense clusters. The structure type may also contain rudimentary and other shophouse building archetypes in lesser fractions. The UST is only partly used for commercial purposes and was seen often along canals predominately in districts 8, 7 and Binh Chanh districts and to lesser extends in districts 2, 9, 4, 6 and Tuc Duc covering in total 85 ha of the HCMC administrative area.

### 5.4.1.3 Peri-urban shophouses

Figure 5–8 shows examples of the peri-urban group of shophouse based UST. This group is found almost exclusively as the name suggests, in the peri-urban and rural districts of HCMC. In total, the group was found to cover 29,613 ha and majority 66% of total residential area of HCMC. The residential UST Shophouse scattered (*code 123*) showed a disperse pattern of generally standard alley shophouse archetypes but may also contain sporadic low-rise terrace buildings. This UST covered a total area of 7,000 ha.

The shophouse clustered (*code 124*) UST is made up of irregular arrangements rudimental, temporary and low-rise terrace shophouses. The UST is found essentially in clustered arrangements at traffic junctions or linear arrangements along traffic routes. The buildings are found close together with more or less elongated gardens. The size of the garden plot is instrumental that own consumption of vegetables, rice and fruit could be covered and the keeping of small livestock and chickens is possible. The houses were always seen built perpendicular to a road. This structure type was seen to cover 5,500 ha in total.




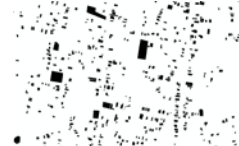

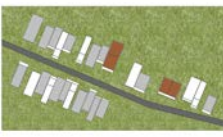






Illustration 3D	Illustration plan	Example	Building footprints
123: Shophouse irregular scattered			
			
124: Shophouse irregular clustered			
			
125: Shophouse irregular w/ large fields			
			

Figure 5–8 Exemplary building blocks of the observed peri-urban shophouse USTs (*source: author's own*)



The UST, shophouse with large fields (*code 125*) is representative of a low dense peri-urban structure composed of rudimental building distributed sparsely and irregularly on large agricultural fields. The blocks are characterised generally by a smaller building volume. The UST covered 17,100 ha of the HCMC administrative area.

#### **5.4.1.4 Mixed shophouses**

Figure 5–9 shows the group of mixed shophouses that are made up of shophouse based UST that did not fit conveniently into the previous shophouse regular, shophouse irregular or shophouse peri-urban groupings. In total, this group was seen to cover 1,269 ha or 2.8% of the total classified residential area of HCMC.

Blocks were designated as shophouse with industry (*code 131*), if they were seen to contain roughly 50% shophouse and 50% industrial building archetypes. The blocks consist mostly of old buildings archetypes with also some commercial buildings together with factory buildings. Temporary shophouses are also seen to a large extent, while industrial elements were recognised by the large and modest formed buildings with extensive paved areas which are often used as loading yards. The UST is characterised by a strong mixing of the residential and manufacturing workplaces and follows no clear spatial structural form from the images. Yards are often permanently sealed. Blocks like this were seen frequency in districts 8, 6 and Tan Phu and to lesser extents in all districts of HCMC excluding Can Gio. Altogether, this UST was seen to cover 1,300 ha.

The urban structure type shophouse irregular and regular (*code 132*), is a medium density residential block mainly composed of older shophouse building archetypes but was also seen to contain various other shophouse and other building archetypes in lesser extents. A characteristic of this UST is that the building orientation was seen to be arranged in both regular and irregular alignments. Often regular buildings were seen to line the periphery of the blocks so that blocks are largely characterised by a closed regular perimeter which is then incised by an array of irregular alleyways and small side streets. On the inside of the blocks irregular shophouses were seen to make up the interior. The split between the layout patterns is roughly 50% irregular and 50% regular. The UST was seen scattered in an array of urban, peri-urban and rural districts and covered 350 ha.









Illustration 3D	Illustration plan	Example	Building footprints
131: Shophouse with industry			
			
132: Shophouse irregular & regular			
			

Figure 5–9 Exemplary building blocks of the observed mixed shophouse USTs (*source: author's own*)

## 5.4.2 Villa based urban structures

### 5.4.2.1 Regular villa

Figure 5–10 shows examples of regular villa group. This group of the class villa based UST denotes recent planned villa developments comprising typically of residential single-family homes with uniform or individually shaped buildings. The homes are sited often adjacent to a garage with paved access to the road and have a simple or a terraced garden or pool. The group displays low sealing and site coverage. In total, this group was seen to cover 665 ha or 1.5% of the total defined residential area.

The UST villa (*code 211*) depicts blocks that are of low to medium density and show regular arrangement of the villa building archetypes with paved driveways and fenced gardens. The gardens of the houses are slightly larger than those of the UST regular shophouse. The actual garden area is used mostly for recreational activities or as an ornamental garden, but almost never for fruit and vegetable production. This UST was found chiefly in districts 2 and 9 and to lesser extends in other per-urban and rural districts of HCMC. In total, this UST was observed to make up 275 ha.

The UST luxury villa (*code 212*) is a development that comprise solely of the building archetype luxury villa. This residential UST often includes fenced larges gardens and swimming pools associated with each property and are set in luxurious well-maintained grounds with loosely distributed trees.

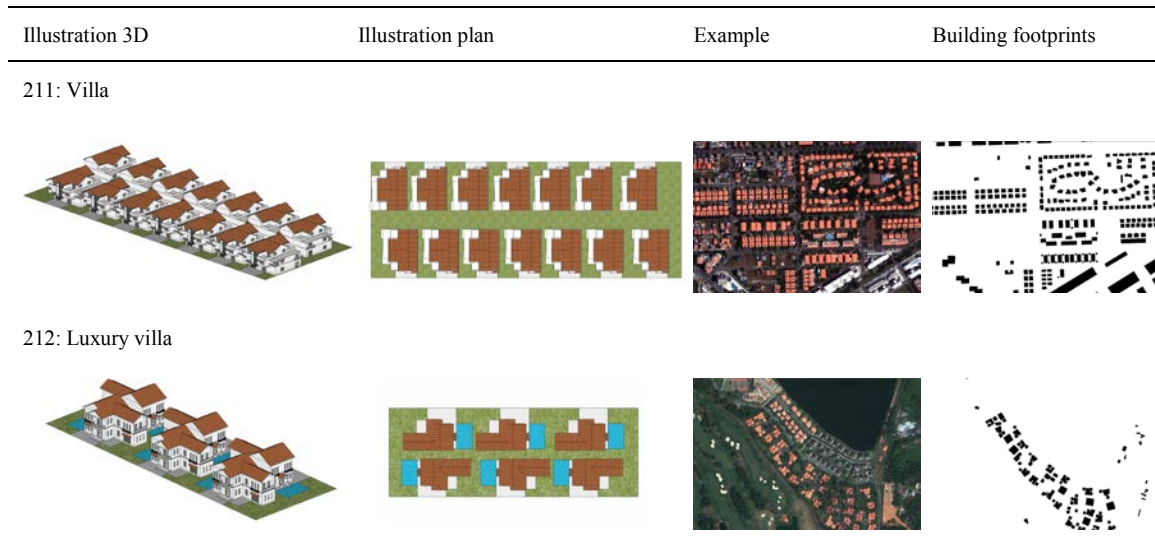


Figure 5–10 Exemplary building blocks of the observed regular villa USTs (source: author's own)

The buildings here are often homes with a slightly larger volume than compared to the previously described UST. The UST was seen solely in the peri-urban districts of district 8, 2, 7, 9, 12, Tan Binh and Thu Duc. In total, the UST luxury villa was seen to cover 390 ha of the HCMC administrative area.

#### 5.4.2.2 Mixed villa

The mixed villa group denotes UST of low to medium density urban developments that contain assemblages of villas with other building archetypes. Overall, this group was seen to cover only 150 ha of HCMC, approximately 0.4% of the total residential area of the city.

The UST villas in established UST (*code 221*) refers to blocks which are predominantly comprised of the villa building archetypes of colonial villa or villa but maybe also comprise of no greater than 30% shophouse archetypes. This urban structure type was seen in districts 2, 3, 9, Binh Thanh and Go Vap. The villa in established UST structure type was seen to cover 150 ha.

The UST colonial villa (*code 231*) refers to residential areas with remains of villas and associated buildings, gardens, courtyards that arose during the French colonial period. The block may be penetrated with both single and multifamily archetypes or commercial buildings and accordingly is quite heterogeneous. Often gardens take up at least one third of the block area (Figure 5–11). This UST was seen solely in the old town centre of district 3 and covered 28 ha in total.

Illustration 3D	Illustration plan	Example	Building footprints
221: Villas in established UST			
231: Colonial villa			

Figure 5–11 Exemplary building blocks of the observed mixed villa USTs (*source: author's own*)

### 5.4.3 Apartment based urban structures

#### 5.4.3.1 New apartments

The new apartments group outlined in Figure 5–12, comprises of recent additions to the HCMC urban fabric, seen often on the outskirts of the city. In addition to their primary residential functions, they are often seen to contain additional public facilities such as retail malls, administrative centres, restaurants, cafes, workshops and warehouses, and often with spatially non-condensed open spaces serving as semi-public green space with playgrounds and recreation areas, gardens or parking. They may also in addition contain underground garages or parking lots and act as local sub-centres. In total, the USTs making up this group were seen to cover 370 ha or 0.8% of the total HCMC residential area.

The UST mid-rise apartments (*code 311*), contain primary assemblages of the archetype of mid-rise apartments. They are mainly larger housing projects, well maintained of the late 1990s and the first years of the 21st Century, which were realised in the context of urban development measures. The UST was seen in districts 4, 5, 6, 8, 11, 12, Binh Thanh, Go Vap, Tan Binh, Tan Phu, Tan Binh, Thu Duc, Binh Chanh and Nha Be and covered 150 ha in total.

The UST high-rise apartments (*code 312*), consists of the building archetype high-rise apartments. These include tower blocks of various heights and forms often related to large settlements in the outskirts of HCMC and smaller assemblages in the inner city.

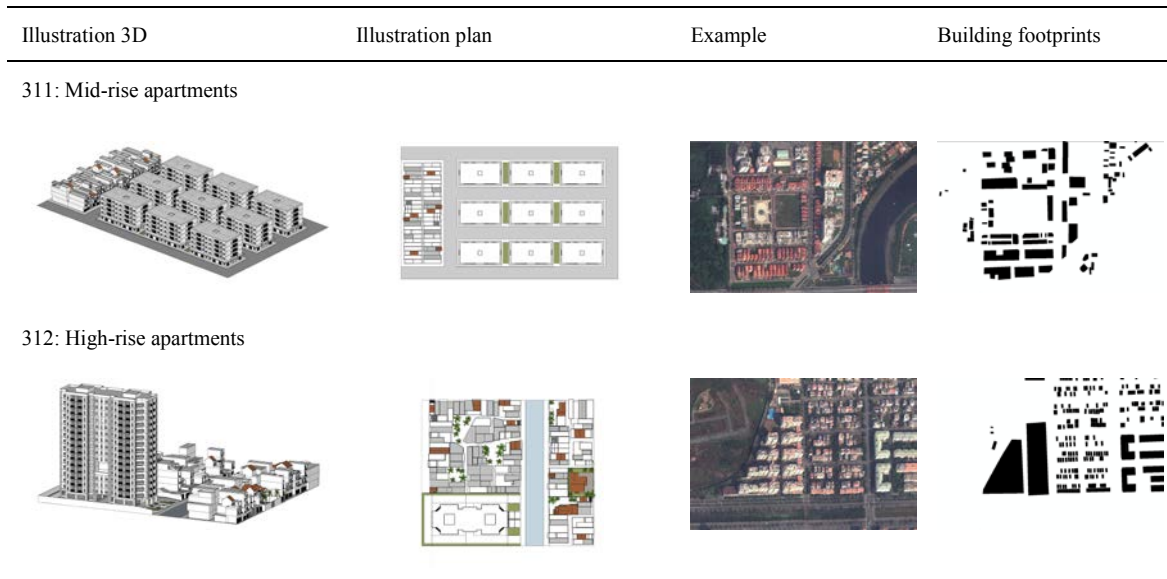


Figure 5–12 Exemplary building blocks of the observed new apartments USTs (*source: author's own*)

In smaller arrangements of tower blocks, often the high rise apartments are alienated to the street network along their periphery, while in particular; large tower block estates buildings were seen to have no relation to the street network, so that a homogenous distance to roads was missing. In addition, the larger estates also often display large spatially not aggregated open spaces between the individual buildings. The UST was seen in districts 4, 8, 10, 11, 7, 12, Phu Nhuan, Binh Thanh, Tan Binh, Tan Phu and Nha Be. In total, they were seen to cover 220 ha of the HCMC administrative area.

#### 5.4.3.2 Old apartments

The old apartments group contains a mixture of pre-war, as well as, post-war versions of low-rise to mid-rise apartments. In total, this group was seen to cover 123 ha or 0.3% of HCMC total residential area (Figure 5–13). The UST Chinese apartment (*code 321*), contains the high dense, low-rise building archetype of Chinese apartment. This UST was seen in districts 4, 8, 7 and 9 and was seen to cover 56 ha in total.

The UST American apartment (*code 322*) consisted of the building archetype with the same name, arranged in parallel row developments. The residential blocks have a large, simple rectangular form and are aligned regularly. The buildings are more than three stories in height, with an intermediate sealing intensity. This UST was seen solely in Binh Thanh district and was seen to cover 41 ha in total. The UST social housing apartment (*code 323*) contains the building archetype social apartment. This UST was seen only in districts 3, 10 and 11 and was seen to cover 33 ha.






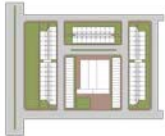






Illustration 3D	Illustration plan	Example	Building footprints
321: Chinese apartments			 
322: American apartments			 
323: Social housing apartment			 

Figure 5–13 Exemplary building blocks of the observed old apartment USTs (*source: author's own*)

#### 5.4.4 Central business district based urban structures

Blocks classified in the class of CBD based USTs showed a high intensity of both use and density. Figure 5–14 provides examples of this group. The USTs were classified exclusively in the central areas of the inner city and the former centre of Cholon in district 5. In total they were classified to cover 744 ha or 1.7% of the total residential area of HCMC. They act as important areas for commercial, private and public services and cultural institutions. Alongside a high proportion of residential shophouse and apartment archetypes, this UST group, also included administrative offices and high-rise buildings and embassies archetypes etc. Residential use in these USTs typically varies between 30–55%, while trade and services make up the remaining 45–70%.

The UST central business district (*code 410*) displayed a heterogeneous mixture of building archetypes. Partial office buildings are built in lines or sporadically on the block edges, which often ignore historic layouts and orientations. Remains of colonial architectural may also be seen. This structure type was seen in districts 1, 3, 5, 6, 10, 11, Phu Nhuan, Binh Thanh, Go Vap and Tan Binh and covered a total of 532 ha.

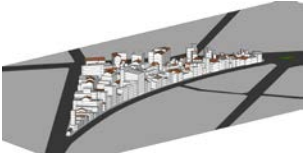







Illustration 3D	Illustration plan	Example	Building footprints
410: central business district			
			
420: high-rise central business district			
			

Figure 5–14 Exemplary building blocks of the observed central business district USTs (*source: author's own*)

The UST high-rise central business district (*code 420*), is likewise but higher density development with detached close-set high-rise buildings. The UST was seen in districts 1, 3, 5, 10, 11 and Phu Nhuan and covered a total of 213 ha.

## 5.5 Distribution of residential USTs in Ho Chi Minh City

The mapped distribution of residential USTs over the administrative area of HCMC can be seen in Figure 5–16. Figure 5–16, additionally shows a comparison of the residential USTs over the districts of HCMC. It can be seen that both district 1 and 3 display high shares of CBD based urban structure. Annex III additionally outlines the distribution of residential USTs over HCMC.

Regular shophouse based USTs were recorded in all districts albeit district 1 and Nha Be. It can be seen from Figure 5–16 that the highest shares of residential area covered by regular shophouse based USTs were seen in district 11 with 64% coverage. Regular shophouses were also seen to cover 56% of district 10 and 54% of the residential areas of districts 5, Tan Binh and Tan Binh.

Irregular shophouses USTs were seen in all districts and accounted for the dominate share of residential structures in districts Go Vap (55%), 4 (54%) Binh Thanh (52%), and district 6 (48%). The peri-urban and rural districts of HCMC show overwhelmingly urban structures belonging to the peri-urban shophouse group.

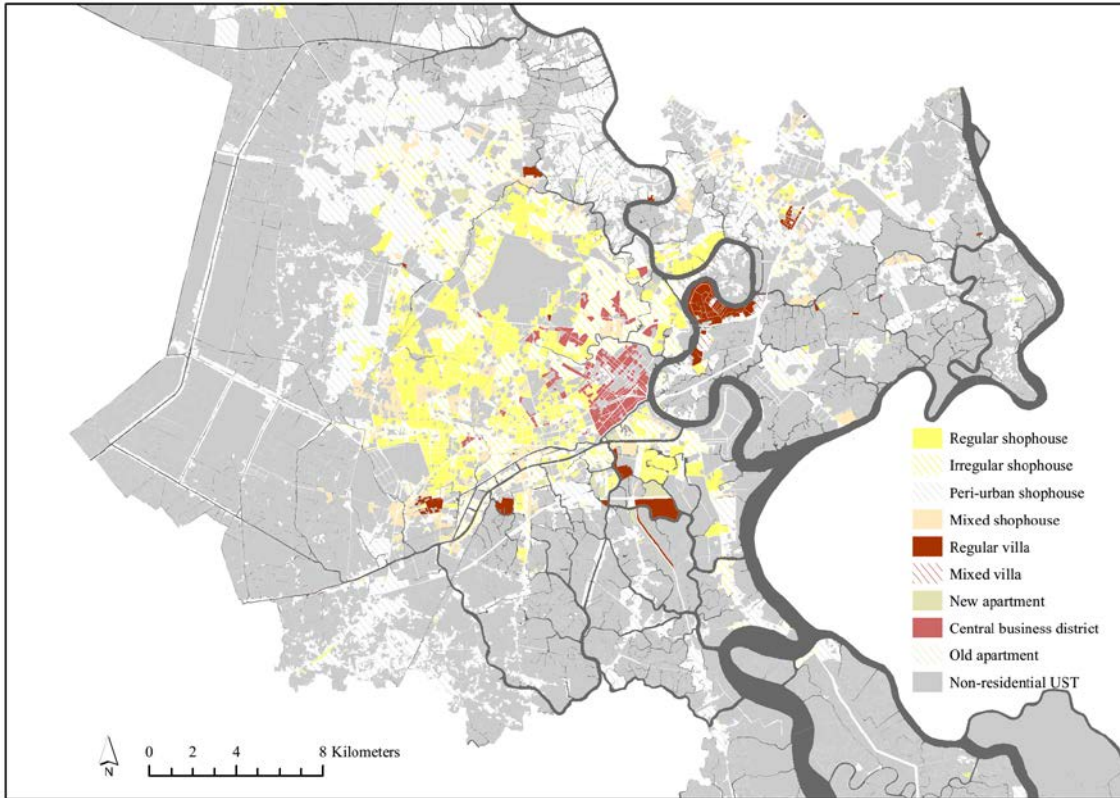


Figure 5–15 Residential UST groups of Ho Chi Minh City (source: author's own)

Ninety-six percent of residential USTs in Cu Chi district belonged to this grouping. Peri-urban shophouses were also seen to account for 90% of residential structures in Binh Chanh 87% in Hoc Mon, 86% in Can Gio and 85% Nha Be. In district 9 and Thu Duc peri-urban shophouses were seen to account for 77% and 61% respectively. Mixed shophouse based USTs were seen to account for over 10% of all residential structures in districts, 4, 5, 6, 8, Tan Phu and Binh Tan.

Urban structure types belonging to the grouping regular villa were seen in all peri-urban districts in lesser extents, but were predominantly seen in districts 2 and 7, where they covered 26% and 15% of the mapped residential area. They were also seen to cover 6% of the district 8 and 3% of Binh Tan. In contrast, mixed villa urban structures types were only seen to cover 9% of district 3, 7% of district 2 and 2% of both Binh Thanh and district 9.



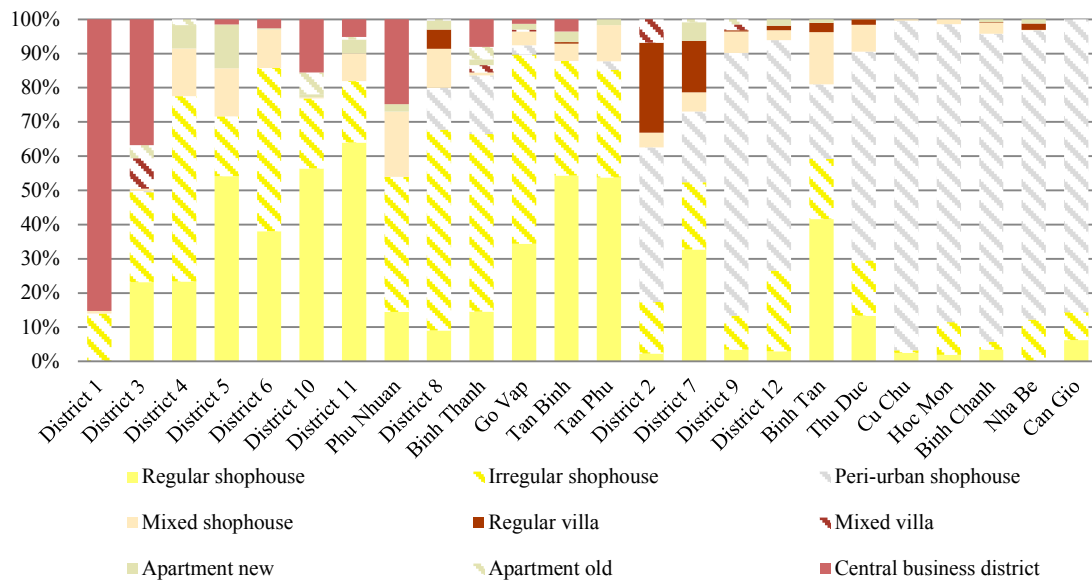


Figure 5–16 Relative distribution of residential UST groups over districts (*in %*)

Urban structure types in the apartment new group were mapped in all urban districts apart from districts 1 and 3. They were identified to cover 13% of all residential areas in district 5, 7% in district 4, 5% in district 7 and 4% in district 11. Urban structures belonging to the group apartment old group were seen to cover 6% of the residential area of district 10, 4% of districts 3 and Binh Thanh and 2% of districts 9 and 4.

Central business district based USTs accounted for 85% of total classified residential area in district 1 and 37% in district 3. They also accounted for 25%, 16% and 8% of the residential USTs identified in districts Phu Nhuan, district 10 and Binh Thanh.

The location of USTs within the urban environment of HCMC is important. The distance of residential USTs to the centre of HCMC may give indication of the socioeconomic status of the inhabitants and the accessibility in times of disaster. It can also be indicative of distance to city services such as market areas, and healthcare facilities. Figure 5–17 shows the medium distance (in kilometres) of residential USTs to the city centre of HCMC. It is important to note that the assessment does not use the transport network based distance of an individual US's to the city centre but rather the straight line (*as the bird would fly*) distance from centroid point of individual USTs to the centre.

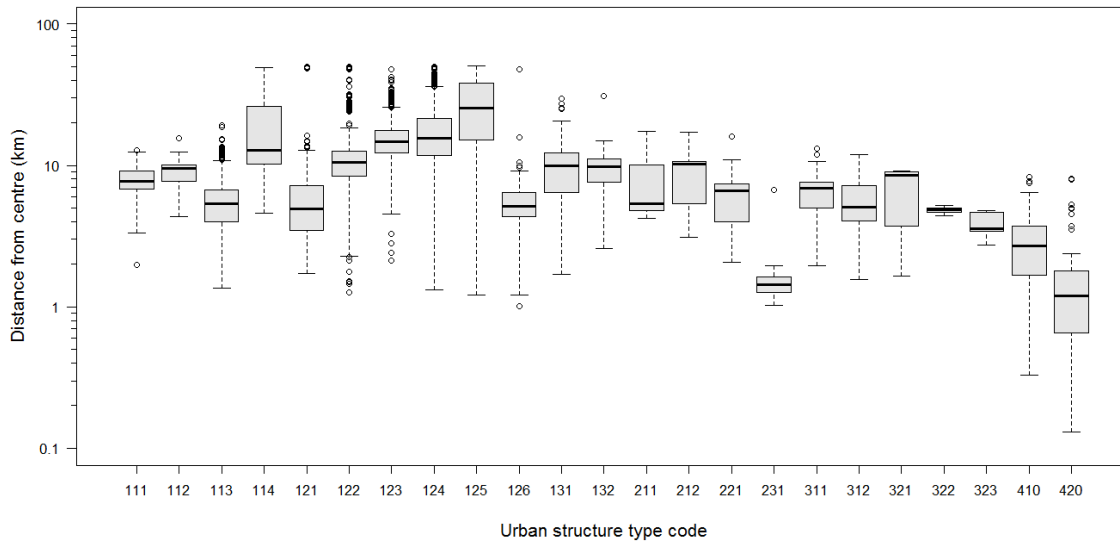


Figure 5–17 Relationship between residential USTs and distance from city centre (*km*)

The City Hall in District 1 of HCMC is taken as the centre of the city. Not surprisingly, the UST CBD high-dense (*code 420*) was seen to be closest to the city centre with a medium distance of 1.2 km. Also close to the city centre was the UST Chinese apartment (*code 231*) with just a medium distance of 1.4 km. The UST shophouse with narrow streets (*code 113*) was calculated to have a medium distance of 5.4 km, the UST Shophouse irregular high dense (*code 121*) had a medium distance of 4.9 km and the UST shophouse irregular temporary (*code 126*) had a medium calculated distance of 5.1 km. The most distant from the city centre were the UST blocks classified as shophouse irregular with large field's (*code 125*) which exhibit a medium distance from the city centre of 25.5 km.

## 5.6 Distribution of green and open space USTs in Ho Chi Minh City

Not surprisingly, most of the green and open spaces are seen in the rural districts of HCMC. The size of green and open areas was seen to increase from the city centre towards the city outskirts. The green and open spaces in the peri-urban and rural districts often occur in conjunction with each other thus providing a larger contiguous green and open area. While in the urban districts, green and open space is dominated mostly by isolated parks and recreational and sports sites sounded by built-up areas. Figure 5–18 shows the green and open UST spatially mapped. While, Figure 5–19 shows the percentage distribution of green and open USTs over the districts of HCMC.

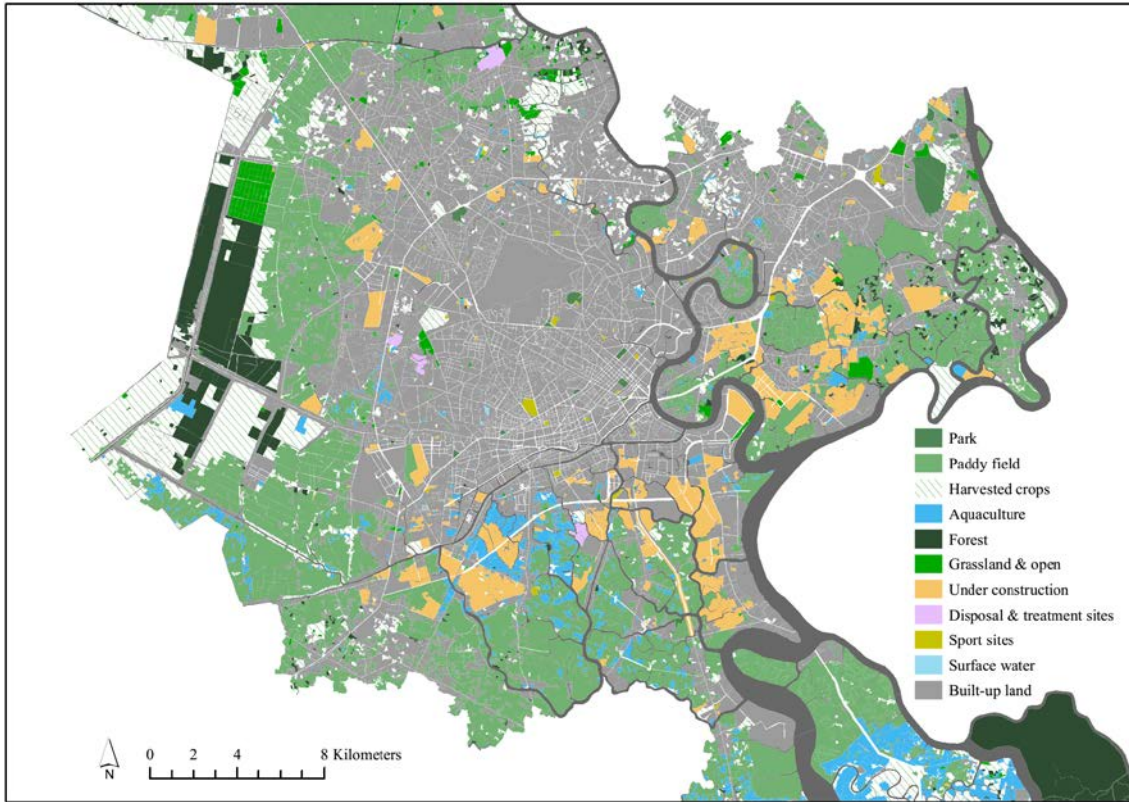


Figure 5–18 Green and open USTs of Ho Chi Minh City (Note: for readability only the main classes are shown) (source: author's own)

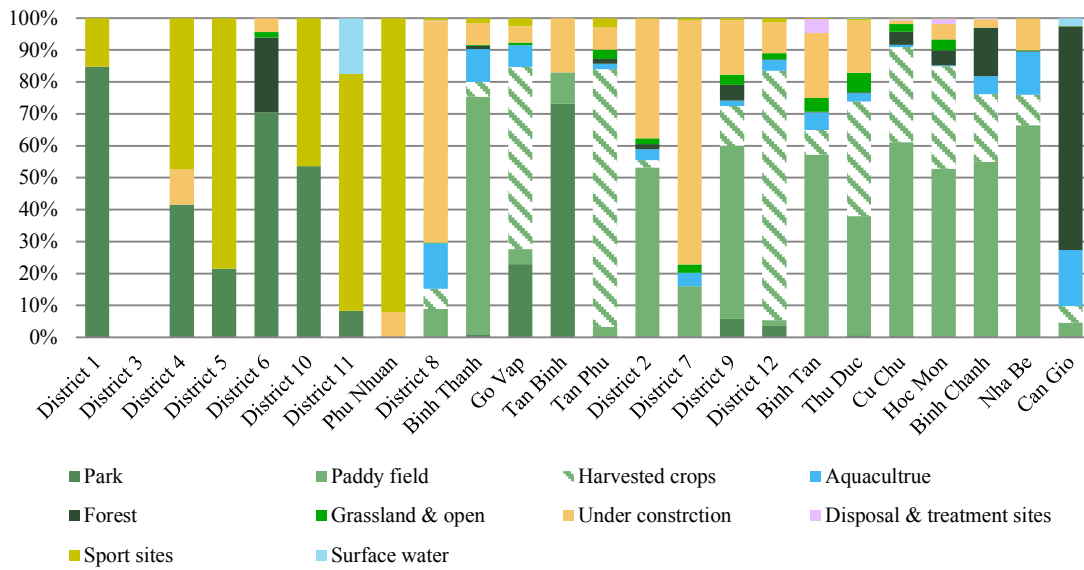


Figure 5–19 Relative distribution of green and open space UST groups over districts (in %)

Of importance is the major forest area in Can Gio district, which accounts for 70% of the districts green and open area. Other major forest areas are seen in district 6 and Binh Chanh district, which account for 23% and 15% respectively. Overall forest areas account for 33% of all green and open areas in the HCMC administrative area.

Rice cultivation (Paddy fields) accounts for 34% of the overall inventory of green and open space. A high share of rice cultivation was found particularly in Binh Thanh (74%), Nha Be (66%), Cu Chi (60%), Binh Tan (57%), Binh Chanh (55%), district 9 (54%), district 2 (53%), Hoc Mon (52%) and Thu Duc (37%).

Harvested crops, other than rice cultivation accounted for 16% of the total green and open area in HCMC. They were particularly found in the northern districts of Tan Phu, district 12, Go Vap, Thu Duc and Binh Chanh where harvest crops were seen to account for 80%, 78%, 57%, 32% and 21% of total green and open areas respectively.

Aquaculture was seen to account for 9% of the total green and open areas of HCMC. These practices were mostly seen in districts Can Gio (18%), District 8 (14%), Nha Be (13%) and Binh Thanh (10%). Grassland accounts for only 1% of total green and open areas in HCMC, 6% in a Thu Duc, 4% in Binh Tan and 3% in district 9 and district 7. Areas for the supply and disposal occur mainly in the rural outskirts of the city in the rural districts. Interestingly, in 2010, construction sites were seen to spread across the entire city. In total, they made up 4.6% of the total green and open area of HCMC and where especially predominate in district 7 (76%), district 8 (69%), district 2(37%), Binh Tan (20%), district 9 (17%), Thu Duc and Tan Binh (16%) and district 4 (11%).

## **5.7 Distance to green and open areas**

Urban green and open areas, also known in the literature as non-urbanised areas (NUAs), are part of agricultural and green infrastructures that provide ecosystem services. High density urban environments, are normally characterises by a lack of green and open space (Tratalos *et al.*, 2007; Zhou and Wang, 2011). Importance of preserving and maintaining green spaces and open spaces in urban environments is widely acknowledged. Distance to green and open areas is an appropriate indicator because of the role they play in mitigating climatic-hazards such as heating and floods.

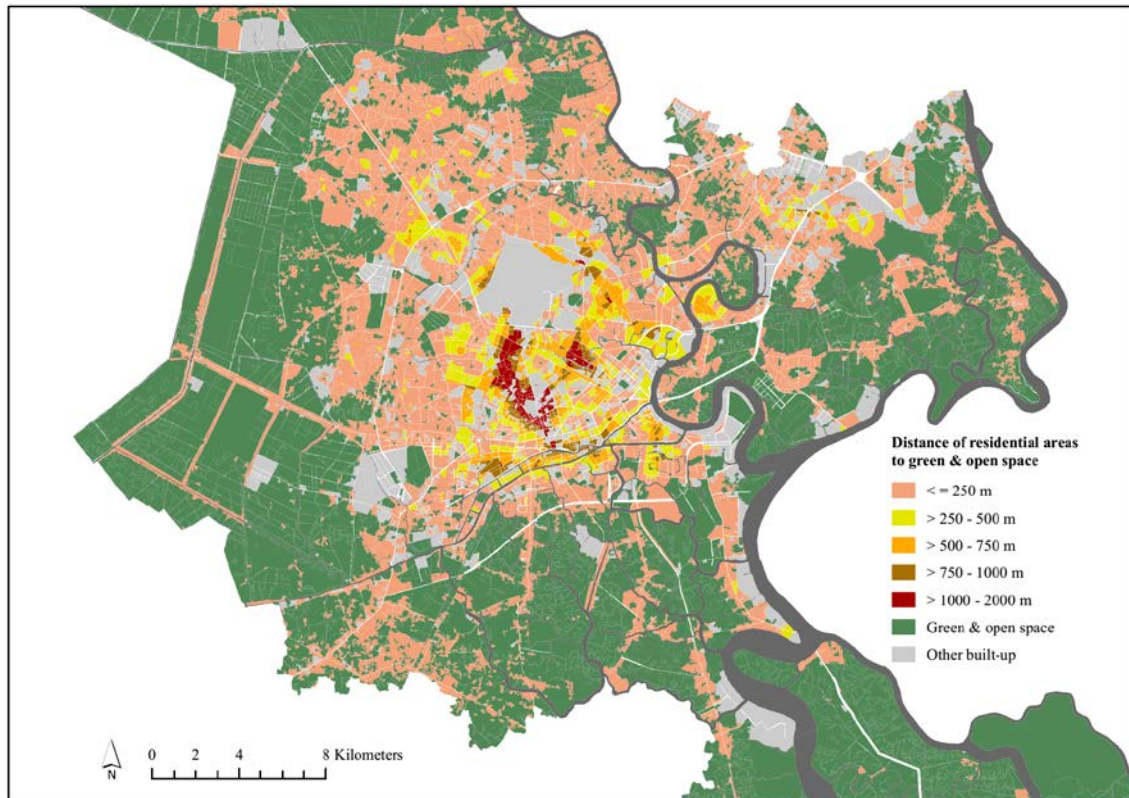


Figure 5–20 Distance of residential USTs to green and open USTs (*source: author's own*)

Figure 5–20 highlights the distance of residential classified USTs to green and open classified USTs. The mapped distances provide a means to identify and localise areas for potential (re)planning and restructuring within the city.

Green and open areas are important for microclimate regulation, air quality, water regulation, biodiversity, and noise mitigation in the urban environment. In particular, green and open areas have received much attention as effective measures to manage both fluvial and pluvial flooding. They are typically incorporated into sustainable urban drainage systems (SUDs) in the United Kingdom which is also known as water-sensitive urban design (WSUB) in Australia and New Zealand and low-impact develop or best management practice (BMP) in the United States. When contemplating green and open areas for adaptation, the primary premise is often to maximise the protection and expansion of existing and potential green infrastructure spaces within the city. Furthermore, a lack of green and open spaces, assessable to the public contributors to the physical risk of the area. In terms of climate change mitigation, large open spaces may also enable larger decentralised renewable energy production in the city.

Table 5–10 Greenery planning standards for HCMC

	Greenery land standards for public utilities	Greenery land standards of parks	Greenery land standards of flower-gardens	Greenery land standards of streets
m <sup>2</sup> /person	12 – 15	7 – 9	3 – 3.6	1.7 – 2.0

(Source: TCXDVN 362 2005)

Quantitative measures like the open space ratio, which is the inverse measure of ground coverage ratio (to be discussed later), indicates the amount of open space available on the development site (Ong, 2003). However, the term is sometimes also expressed quantitatively as area of greenspace per person. This is the case in the National Vietnamese design standards for “Greenery planning for public utilities in urban areas” (TCXDVN 362 2005). These are standards used by the planning authorities in HCMC to safeguard a reasonable provision of outdoor space for the population. They set out specific greenspace targets for HCMC in per person terms of public utilities, parks, flower gardens and greening along streets (see Table 5–10). However it is important to note that quantitative standards often tend to ignore issues of quality and accessibility. While it is important to map distance to green and open space, it was not possible in this study to determine the accessibility to the public. What is noticeable in Figure 5–20, is that within the dense city centre of HCMC the levels of provision are quite likely to be well below the standard, while at the same time the opportunities for a rapid improvement may be severely limited. The HCMC’s Park and Greenery Office, as well as, DoNRE have reported a 50% loss of green space in the years 1999–2010. Currently there is only on average 0.7 m<sup>2</sup>/person greenspace in the city (DoNRE, 2012).

## 5.8 Land-use compliance

A central component that the UST approach provides is the mapping of the actual land-use in order to clearly make the changes from the planned visions visible. As discussed in Chapter 2, the pace of socio-economic transformations in HCMC has meant that land-use compliance was required to be assessed to understand if developments in HCMC have or have not adhered to land-use designations and whether planning has been implemented or kept pace with development. Figure 5–21, shows the classified USTs spatially mapped in the colour groupings of the official Land-use Plan 2010.

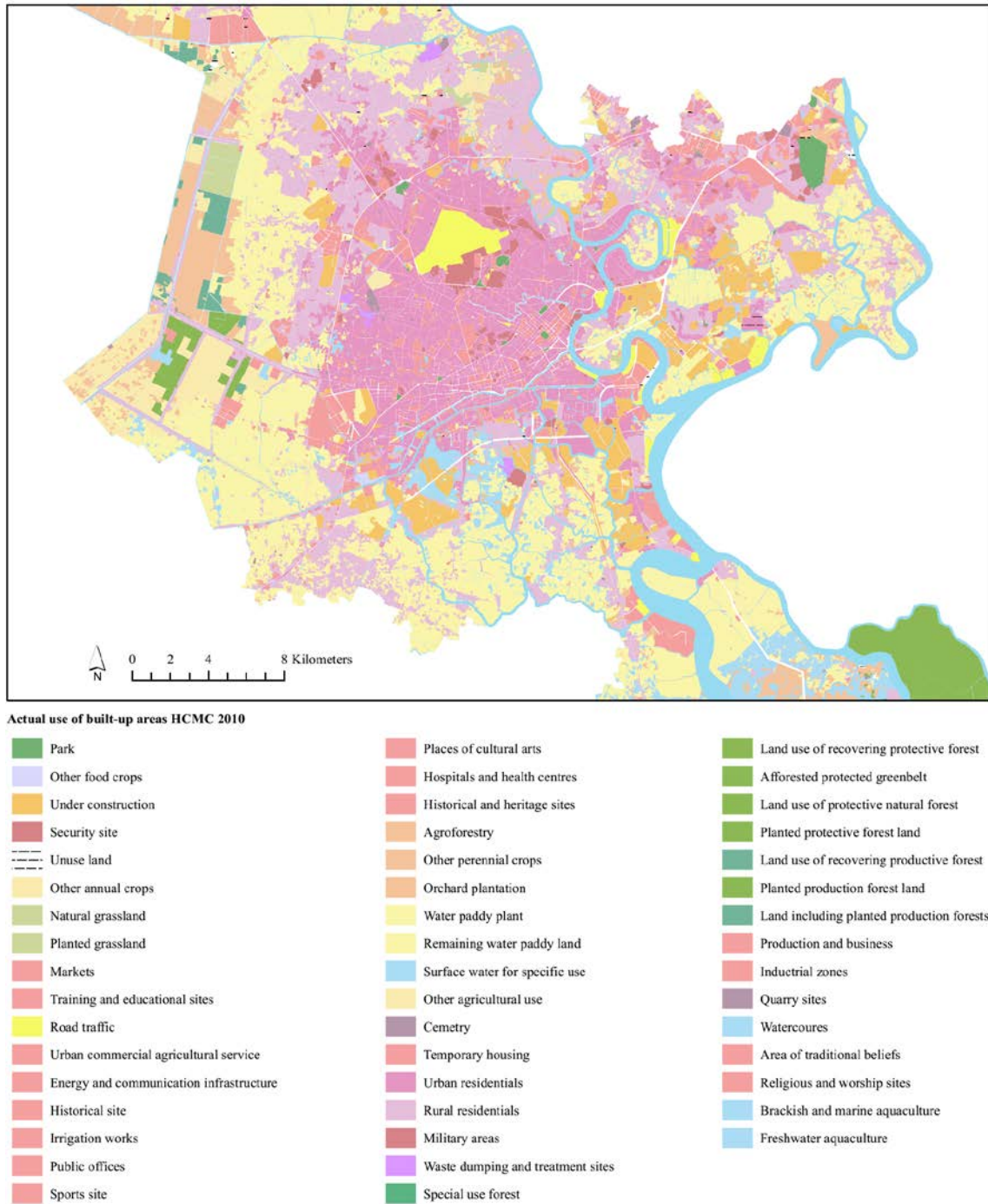


Figure 5–21 Actual land-use of Ho Chi Minh City (Note: Land-use designation ‘park’ was not a determined land-use category in the official Land-use Plan 2010) (source: author’s own)

Figure 5–22 shows the comparison of the actual-use map 2010 derived from the UST classification with the official Land-use Plan 2010, and the official draft Land-use Plan up to the year 2025 (version late 2010). The mapped results show that planned land-use designations were seen to be very different to actual land-use.

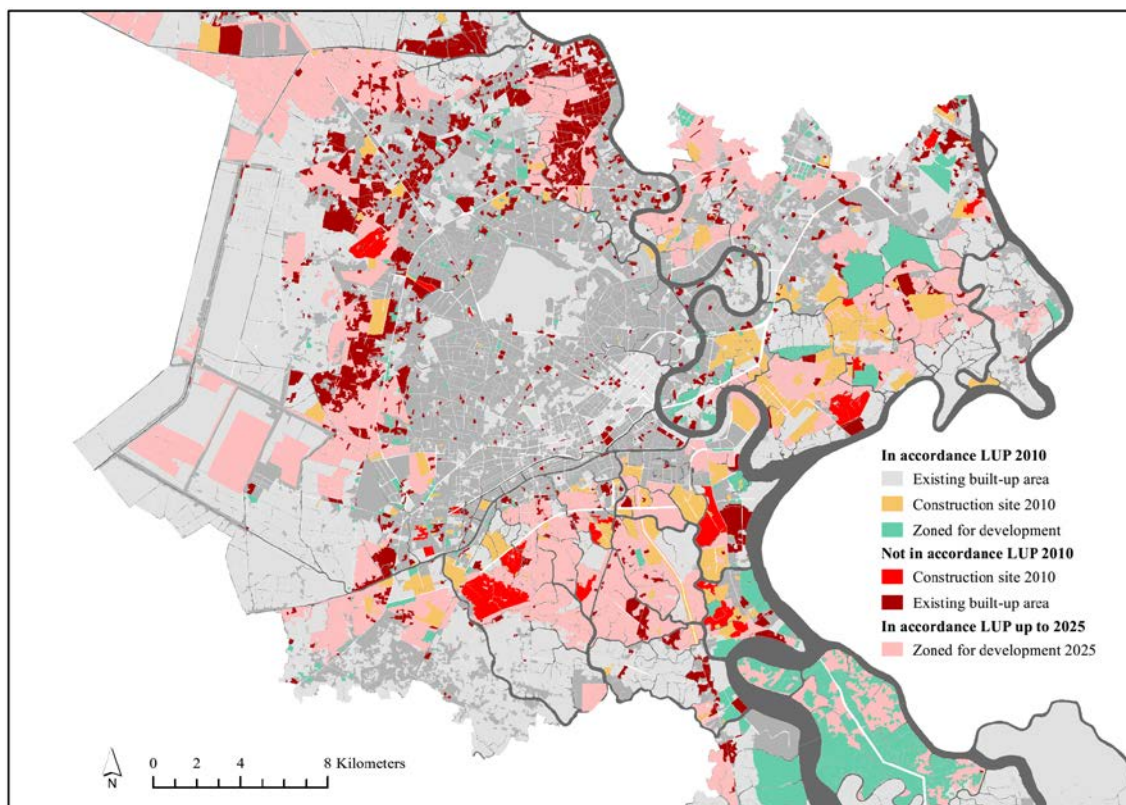


Figure 5–22 Actual land-use and planned land-use comparison (source: author's own)

Figure 5–22 shows that not only single developments but agglomerations located in the peri-urban and rural districts of HCMC have ignored specific land-use designations. Additionally, Table 5–11 shows land-use compliance in absolute terms over the districts of HCMC. Whilst, the majority of the 55,592 ha of classified built-up area (residential and industrial classified USTs), was found to adhere to land-use designations, 9,954 ha or 18% of classified built-up area was seen to be in conflict with designations in the Land-use Plan 2010.

Deviations of actual land-use from planned land-use were seen often in the informal development encroachments of the irregular shophouses and peri-urban shophouse based USTs groups predominantly in the northern and western peri-urban and rural districts of Cu Chi, Hoc Mon, northern Binh Chanh, Binh Tan and Thu Duc and in lesser extents in the eastern peri-urban district 9 and district 12. The UST shophouse irregular with yards was for example observed on 20% of areas designated as orchard plantations and 13% of area designated as unused land. The UST shophouse irregular with large fields was also seen highly prevalent on land designated for agricultural use in the 2010 Land-use Plan.



Table 5–11 Land-use compliance

	In accordance with Land-use Plan 2010 (ha)			Not in accordance with Land-use Plan 2010 (ha)		In accordance with Land-use Plan up to 2025
	Existing build up	Construction site	Zoned for development	Existing build up	Construction site	Zoned for development
<i>Urban districts</i>						
1	533.3	-	-	9.7	-	-
3	405.3	-	-	10.4	-	-
4	252.6	0.8	1.9	29.6	-	41.2
5	308.4	-	-	10.1	-	-
6	623.7	0.4	0.3	9.7	-	-
10	494.5	-	-	0.7	-	-
11	754.6	0.7	1.3	13.8	-	-
Phu Nhuan	427.3	1.1	-	0.5	-	-
8	1,003.9	598.5	50.5	56.8	25.7	64.7
Binh Thanh	1,283.0	20.7	40.1	42.0	-	-
Go Vap	2,430.1	7.0	28.4	57.4	-	29.6
Tan Binh	1,162.1	1.9	19.3	42.1	-	-
Tan Phu	1,288.2	7.8	12.1	26.7	-	-
<i>Peri-urban districts</i>						
Thu Thiem 2	1,188.4	872.9	100.5	177.5	0.5	1,620.4
7	1,293.6	599.8	82.7	216.3	143	1,139.8
9	2,974.0	908.7	833.5	440.4	103.4	2,790.4
12	2,819.0	60.6	239.9	888.0	20.2	1,066.9
Binh Tan	2,591.4	271.8	146.3	424.4	22.6	1,197.5
Thu Duc	2,986.3	136.8	139.4	158.5	16.8	1,403.7
<i>Rural districts</i>						
Cu Chi	11,092.2	227.0	321.1	4,068.5	46.1	4,945.5
Hoc Mon	2,809.4	185.1	79.4	1,715.2	46.6	3,989.8
Binh Chanh	4,445.6	259.5	96.6	953.4	215.6	7,461.2
Nha Be	1,602.9	364.0	813.7	507.0	190.9	2,975.7
Can Gio	868.4	43.7	287.8	95.3	-	3,248.4
<b>Total</b>	<b>45,638.2</b>	<b>4,568.8</b>	<b>3,294.8</b>	<b>9,954.1</b>	<b>831.4</b>	<b>31,974.7</b>

It is also interesting to note, the scale of observed construction activities during the classification of UST and mapping of the actual land-use map. Over the entire administrative area of HCMC, 5,400 ha of visible construction activities could be identified. This equates to an additional 9.7% of the overall built-up area. The majority, 4,586 ha of these construction activities are in accordance with the official land-use map 2010 and the draft Land-use Plan 2025. However, some developments are seen located in areas that will be first approved following the draft Land-use Plan. Only 83 ha or 15% of the seen construction activities are found not in accordance with the Land-use Plan 2010. As the UST classification was undertaken on the basis of satellite imagery captured in the time period 2009–2010, the mapped construction activities presents a fascinating snap-shot. Yet it is important to realise that many of the identified construction sites have been subsequently developed. It is additionally interesting to note, that in contrast to the more informal northwest direction of developments not in accordance with the Land-use Plan 2010, the strong majority and focal points of

construction activities both in accordance and not in accordance with the Land-use Plan 2010 are located in district 8 and the peri-urban districts 2 (Thu Thiem), 7 (Phu My Hung) and 9 to the south and east of the current city core, the current location of large-scale real estate projects.

Although the Land-use Plan 2010 was revised in the further refinement of the Land-use Plan 2020 up to the year 2025, comparison with the actual use-map reveals that large industrial and residential designated areas in the southern and eastern districts were yet to be developed. Table 5–11 shows that 3,294 ha of land was seen to be undeveloped but zoned for development in the Land-use Plan 2010. This equates too roughly an additional 6% of the current built-up area of HCMC. With the development of the remaining land zoned for development in the Land-use Plan 2010 together with the identified construction sites in total an additional 8,695 ha of land is zoned or subject to development. This would equate to an increase of 15.6% on top of the current built up area of HCMC. Furthermore, an additional 31,974 ha of land is zoned for development in the draft Land-use Plan 2025. This would account for a 57.2% increase in relation to the current built up area. While a 40,700 ha or 73.1% increase in built-up land could be expected when the existing construction sites and the land-zoned for development in the Land-use Plan 2010 are additionally considered to the land zoned for development in the draft Land-use Plan 2025. This would give a total future built-up area of approximately 96,260 ha or an additional 46% of the total HCMC administrative area.

## 6 Urban structure type based indicators

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### 6.1 Building density

#### 6.1.1 Description and use in planning

Building density is a measure of building units within a given area, typically per hectare. It is one of the most frequently used measurements of the physical dimension of urban growth and is one of the most commonly mentioned concepts in planning that provides useful information for planning, developing and managing cities (Acioly and Davidson, 1996; Batty, 2006; Borukhov, 1978; Mitrany, 2005; Aubrecht *et al.*, 2009; Pun, 1994; van der Waals, 2000; Hanham and Spiker, 2005; Patel, 2011; Masser, 2001). The measurement is related to the intensity of built structures and dwellings, in other words, the built form of the city, *i.e.* how built up an area is and as such it directly affects the loss of open and surrounding rural land.

In practice, building density is commonly used to control development, calculate development yields, and define development targets for areas *i.e.* residential dwellings per hectare for new developments in response to social and demographic development pressures (Pafka, 2013; Dodson and Glesson, 2007). It is a very common measure of urban density in the United Kingdom, Australia, India, Israel, the Netherlands and USA.

Traditionally maximum building density controls has been used to limit overcrowding, while minimum density controls have been used to ensure cost effective local service and infrastructure provision and make significant land take savings. In the UK, the minimum target for building density is 30 buildings per ha (*ibid*). While, for instance in Australia, Griffiths (2009), reports that typically minimum density targets aim to improve access to public transport and community services, while maximum density controls aim to protect private space amenity. However, opinions and perspectives on what constitutes high building density and acceptable levels of building density vary widely from one country to another. A building density of 60 buildings per ha is termed high density in Australia, yet for instance in the Netherlands, high density starts 100 buildings per ha, and in Israel it starts at 290 buildings per ha (Churchman, 1999).

Currently worldwide, one of the most significant urban sustainability issues is urban sprawl. Urban sprawl is synonymous with the continued horizontal expansion of cities. Sprawl is characterised by low building density and high rates of agricultural land loss (Bhatta *et al.*, 2010). Due to urbanisation, peri-urban areas face intense land-use change pressures from urban encroachment (*i.e.* higher density development), that have important implications for the loss of essential soil functions, local food production, water resources, biodiversity loss, urban climate and flood risk management. Peri-urban areas in developing countries also face the unique challenge that infrastructure and other urban service provision often do not keep pace with both formal and informal urbanisation. Furthermore, urban sprawl has been demonstrated to greatly increase the costs of land development and that of the provision of services and infrastructure by increasing the distance between recent developments and already established roads, sewage lines and transit systems (Trubla *et al.*, 2010; Burchelle *et al.*, 2002).

### **6.1.2 Importance for climate change and disaster risk reduction**

Building and other engineered structures that form cities are responsible for a significant share of the impacts of climate change (Jo and Otanicar, 2011). In terms of mitigation policy goals, a growing body of literature suggests that a sprawling city with low building densities, increases traffic, distances travelled, travel times and congestion (Kahn, 2000; Ewing *et al.*, 2003; Pickrell and Schimek, 1999; Ewing, 2008; Brueckner, 2000; Mindali *et al.*, 2004; Johnson, 2001; Cervero and Murakami, 2010; Rentziou *et al.*, 2012; Zhao, 2010; Bento *et al.*, 2005; Brownstone, 2008; Kenworthy and Laube, 1999; Badoe and Miller, 2000; Cameron *et al.*, 2004; Wheeler and Beatley, 2014; Holtzclaw *et al.*, 2002), leading to greater energy consumption and greenhouse gas (GHG) emissions and also greater air pollution (Salomon and Pont, 2012; Stone, 2008; Frumkin, 2002; Van Metre *et al.*, 2000; Norman *et al.*, 2006; Hui, 2001; Haney and Marshall, 2010; Andrews, 2008; Bart, 2010; Liu *et al.*, 2003; Steemers, 2003; Pitts, 2010). Urban sprawl has also been linked to a decrease in physical activity of residents (Jerrett *et al.*, 2013), increased obesity and morbidity (Ewing *et al.*, 2007; Owen, 2004; Papas *et al.*, 2007; Burton, 2000; Brownson *et al.*, 2005, 2009; Frumkin *et al.*, 2004; Booth *et al.*, 2005; Berke *et al.*, 2007). Furthermore, building density also influences residential energy use (Ewing and Rong, 2008; Ewing *et al.*, 2008; Randolph, 2008; Rode *et al.*, 2013; Ko, 2013; Hui, 2001). Studying cities in the United States, Ewing and Rong (2008), and Randolph (2008), all found that lower

density housing tends to be of a larger building volume and more often than not detached, requiring more energy to heat and/or cool, as well as, additional energy output to establish and maintain electricity transmission and distribution networks. Brownstone and Golob (2009), suggest that building density can also be interpreted as a proxy indicator for access to both employment and shopping distinctions.

To combat urban sprawl many authors have argued for increasing building density in cities and creating generally more compact urban forms. Much of the discussion on urban density has thus been based around the concept of the compact city. One way to increase building densities is via infilling in areas where sprawl has already taken place, centralising services and reducing actual land take. The concept of the compact city aims at ensuring a mix of uses and building types, proximity to facilities, transport and work, achieving social and economic diversity and vitality and most importantly the containment of urban sprawl and reduction of urban land take (Jenks *et al.*, 1996; Williams *et al.*, 2000; Jenks and Dempsey, 2005; Brueckner, 2001). It is a commonly held belief that the compact city is the single best policy goal to reduce the negative effects of urbanisation on the environment and resultantly the principles of the compact city have been enshrined in the land-use planning policy legalisation of many countries (Van der Waals, 1999; Burton, 2001). The argument that concentrating development and inducing higher building densities is more sustainable than low-density cities has been studied and argued extensively (Burton, 2000; 2002; Jenks and Burgess, 2000; Holden and Norland, 2005; Lin and Yang, 2006; Newman, 2006; Muñiz and Galindo, 2005). Numerous studies report that the key advantages of a compact city design are the efficient public transport system and an urban layout that encourages walking and cycling, a lower ecological footprint, low energy consumption and less CO<sub>2</sub> emissions and reduced pollution (Alexander and Tomalty, 2002; Dempsey, 2010; Jenks and Burgess, 2000; Williams *et al.*, 2000; Newman, 2006; Muñiz and Galindo, 2005; Burchell and Listokin, 1982). Ewing *et al.*, (2009), notes that in such a way the compact city concept promotes the development of low-carbon cities through the preservation of open space, and increased road and other infrastructure energy (and possibly maintenance) savings.

The key land-use planning implication for mitigation actions is the concentration of development so that transportation and building energy uses are reduced. However, in reality, the effects of urban density on the total urban energy demand are complex and

often conflicting (Hui, 2001; Tong and Wong, 1997). Highly dense cities will bring benefits to energy distribution and transport system designs, but overcrowded conditions may create congestion and undesirable local microclimates (Hui, 2001). High dense urban development may also facilitate the introduction of innovative sustainable technologies. In high building density settings alternative energy generation sources are also feasible but, given the less space per person, they may not provide as much per capita energy as they would in a lower density settings which would enable larger decentralised renewable energy production systems (Arboit *et al.*, 2008). Hamin and Gurran (2000), give the example of solar roofs which in a dense setting, with less roof space per person, would provide less energy per capita than they would potentially at a lower building density, bigger roof share per person setting.

Many planned urban adaptation and disaster risk reduction options also require space. Hamin and Gurran (2000), state that many, although certainly not all adaptation options, require more land left as open space and/or less densely built-up space and Tratalos *et al.*, (2007) explored if a denser and more compact city, can still maintain natural habitats and levels of ecosystems services useful for adaptation such as, storm-water interception, urban climate regulation, and biodiversity. Tratalos *et al.*, (2007) studying five UK cities found that once building density reached a certain critical threshold, almost all species start to decline as vegetation cover reaches very low levels. While Evans *et al.*, (2009) investigating urbanisation and bird assemblages stated that current trends for the densification of many British urban areas are likely to be detrimental for countless bird species. Thus, the comparatively low ecological impact of compact urban growth depends crucially on maintaining high-quality interstitial green spaces between the high-density developments. However, conversely, with very low density developments spread over a larger area, it would be unwise to predict a lesser effect on biodiversity as the impact will be much more spatially extensive (Sushinsky *et al.*, 2013; Jonhson and Klemens, 2005; Hanson *et al.*, 2005; Kowarik, 2011).

Deterioration of ecosystems service provision is certainly one significant ramification of increased building density in urban areas. For example in HCMC one current approach to inner city floodwater management emphasises more natural infiltration and less drainage convenience of flood waters. However, space for water rainwater harvesting, bioswales and retention ponds requires space that underground sewer and drainage pipes do not. Resultantly in HCMC, space for flood waters needs to be heavily planned

(Zevenbergen *et al.*, 2012; Hankin *et al.*, 2008; Godschalk, 2003; White, 2008; Lloyd *et al.*, 2002). Furthermore, building density is a major factor that determines the urban ventilation conditions (Theodoridis and Moussiopoulos, 2000), as well as, the urban temperature and local microclimate (Yu *et al.*, 2009). Under given circumstances, an urban area with a high density of buildings can experience poor ventilation and a very strong ‘urban heat island’ (UHI) effect (Coumts *et al.*, 2007; Jusuf *et al.*, 2007; Wong and Yu, 2005; Tso, 1996; Bridgman *et al.*, 1995). In warm-humid regions these features would lead to a high level of thermal stress and a rise in the use of air conditioning devices and resultantly, to increased energy use (Konopacki and Akbari, 2002; Akbari, 2005; Akbari and Konopacki, 2005), elevate ground-level ozone (Rosenfeld *et al.*, 1998; Harlan *et al.*, 2006) and increase mortality rates (Changnon *et al.*, 1996; Lo and Quattrochi, 2003; Pascal *et al.*, 2006; Founda and Giannakopoulos, 2009).

Developments that are planned at a low enough building density to enable ventilation between individual buildings provides adaptation to higher temperatures and the UHI effect, as does not removing, but sustaining or adding urban greenery. Hamin and Gurrán (2000), state that such adaptation options therefore would aim typically for a reduction of building density. However, there is little adaptation benefit from very low density scattering or sprawling developments. A moderate building density with adequate provision and space for cost-effective infrastructure may be the most effective form.

Stone and Rodger (2001), studying urban form and thermal efficiency in Atlanta found that lower density patterns of residential development contributed more radiant heat energy to surface UHI formation than higher density development patterns within the Atlanta region. They recommended more compact moderate-to-high-density new construction and area-based tree ordinances as policy strategies for mitigating the effects of urban development on regional climate change. In another study, Coumts *et al.*, (2007) investigated the impact of increasing housing density on the surface energy balance to investigate the relationship to Melbourne’s local climate. They found greater nocturnal temperatures were observed with increasing density as a result of variations in heat storage release that are in part due to urban canyon morphology. However many authors have also found that night-time cooling and offsetting potential of the UHI effect is primary a function of building density (Mills, 1997; Adolphe, 2001).

### 6.1.3 Relevance for Ho Chi Minh City

In HCMC, accurate and up-to-date knowledge of building locations and building density is of fundamental importance to the local planners who seek to adapt the city and avoid the irreversible, cumulative and synergistic affects from the combination of urban growth, climate change and disaster risks. Knowledge of building density is important because it provides important baseline information for monitoring and evaluating plans and sustainability targets and the impacts of development on the urban-environmental system for the optimisation of urban basic service provision (Boori *et al.*, 2005; Alpha, 2003; Dewan and Yamaguchi, 2009; Salvati, *et al.*, 2013;). Building density information can be used for planning the demands on public services, planning control, urban growth monitoring, estimating population and monitoring unplanned developments (Loannidis *et al.*, 2009; Thinh *et al.*, 2001; Turskis *et al.*, 2006; Zagorskas *et al.*, 2007). The existing urban structure and land-use efficiency can be evaluated to highlight temporal and spatial changes in urban form and residential structure and their relation to building density and land utilisation. Building density in HCMC is often controlled by bottom-up factors such as the management of private spaces by residents and the top down factors such as density control polices at the local district planning level. The quantification and precise spatial representation of building stock also plays an important role in risk assessments. Risk assessments are paramount for disaster risk management, climate change adaptation planning, emergency assessments and formulating pre-event mitigation strategies (Eguchi *et al.*, 2001; Zerger and Smith, 2003).

Assessments require information on hazards but also on the spatial distribution and value of the elements exposed or at risk for both estimating losses and the costs of reconstruction. As buildings are the major elements of the built-up urban system, assets are more often than not represented as building stock in risk assessment models. Buildings are also the locations where working and residing population spend most of their time and savings and turn to for shelter during times of disasters. As such, buildings can act as a proxy indicator for population and building density and building vulnerabilities can represent and identify potential losses in terms of assets and population at risk and, also highlight important service provision needs related to adaptation infrastructure investments to safeguard assets. Furthermore, to assess the severity and situation after an event, most (rapid) post event assessments focus on



changes to buildings and damage and the destruction of buildings, as well as potential populations affected, which has proved crucial for initiating effective emergency response actions.

One consequence of high building density is that the impacts of climate change or disasters occurring can be more severe than those that would occur in a lower density area because of the higher concentrations of buildings, population, infrastructure, other assets and economic activities. Impacts however may be reduced if a higher building density allows for greater access to the adaptation or relief responses, increased social support structures and networks or improved building construction and general planning that may not exist for lower building density areas (Burby *et al.*, 2001; Cross, 2001; Birkmann, 2007; Adgar, 2010; Pelling and High, 2005; Kellenberg and Mobarak, 2008; Ng, 2009a). Conversely, however higher building densities may simply overwhelm response capabilities by clustering poorly constructed buildings and populations in areas with poor accessibility and poor emergency response times. Fire risks and access for responders for example, have always been and remain a serious hazard in congested urban areas (Barnes *et al.*, 2001; Vlahov *et al.*, 2007).

For the planners of HCMC, it is on the utmost importance to have accurate data on building location and density in order to limit vulnerability, by avoiding implanting people and buildings in areas at risk and to formulate protection strategies for those that already reside there. Low building densities in HCMC may provide opportunities for integrating climate change adaptation options into the design of individual buildings or in the vacant spaces between buildings. In areas of higher building density, more attention will need to be given to individual building design, the surroundings and how they are best used and managed in order to maximise both current and future climate change adaptation potentials. Reducing building densities in the most at risk areas is one possible way to reduce potential losses, however high building densities are often coupled with high amenity values and as such may not be the most cost-effective option (Henderson, 2002). As a general rule, knowledge of building locations can encourage greater building density in safer areas and conversely therefore avoid building in exposed areas. Higher density regulations in safer areas however, will have an impact on the risk of flooding and UHI development, which demonstrates the important of a systematic approach to climate change adaptation, disaster risk reduction and spatial planning.

#### 6.1.4 Previous studies

A rich literature of remote sensing building detection studies exists and various remote sensed data and classification methods used to map building stock have been reported during the last few decades (Wang and Lui, 2005; Müller and Zaum, 2005; Lagunovsky and Ablameyko, 1999; Huertas and Nevatia, 1988). Studies have commonly focused on detecting building information for urban planning and notably urban city growth modelling (He, 2006; Netzband *et al.*, 2007; Harris and Ventura, 1995; Zhang, 1999; Chen *et al.*, 200; Bhaskaran *et al.*, 2010; Bahr, 2004; Hardin *et al.*, 2007; Hathout, 2002; Herold *et al.*, 2003; Jat *et al.*, 2008; Fan *et al.*, 2009; Jenson and Im, 2007; Liu and Lathrop, 2002; Maktav and Erbek, 2005; Taubenböck *et al.*, 2009a, 2010; Zhou and Kurban, 2008; Vermeiren *et al.*, 2012; Ridd and Liu, 1998; Yang, 2002; Yuan, 2008; Barnsley and Barr, 1996; Martinuzzi, *et al.*, 2007; Alphan, 2003; Lopez *et al.*, 2001; Xiao *et al.*, 2006; Yang and Lo, 2002; Yuan *et al.*, 2005).

Numerous researchers have also focused on buildings damage assessments post disasters (Adams *et al.*, 2004; Ehrlich *et al.*, 2013; Guillaso *et al.*, 2005; Matsuoka and Yamazaki, 2005; Aufbrecht *et al.*, 2009; Chesnel *et al.*, 2007; Joyce *et al.*, 2009; Ehrlich and Tenerelli, 2013; Tralli *et al.*, 2005; Taubenböck *et al.*, 2008a; Dell Acquat *et al.*, 2011; Lu *et al.*, 2014; Su *et al.*, 2015; Mückel *et al.*, 2015; Geiß *et al.*, 2014; Filippi, 2008; Rahman, 2007; Guha-Sapir *et al.*, 2011; Yonezawa and Takeuchi, 2001; Van Oosterom *et al.*, 2006; Monotya, 2002; 2003; Yamazaki, 2001, Voigt *et al.*, 2007; Stramondo *et al.*, 2006; Saito *et al.*, 2004; Matsuoka and Yamazaki, 2004; Ehrlich *et al.*, 2009, 2010; Dong and Shan, 2013; Taubenböck, 2008; Taubenböck *et al.*, 2009b; Gerke and Kerle, 2011; Suppasri *et al.*, 2011; Miura *et al.*, 2006; Eckert *et al.*, 2012; Oesaresi *et al.*, 2007; Hill *et al.*, 2006). From a review of the literature and dependent upon the data source utilised, techniques can be categorised into three main groups: (i) using airborne or satellite imagery; (ii) using three-dimensional information; and (iii) combining both data sources (Yu *et al.*, 2010; Gamba and Houshmand, 2002; Priestnall *et al.*, 2000; Stilla *et al.*, 2003). Traditionally manual digitising of building footprints from aerial images have been undertaken, however with the advent of spatial resolution commercial satellites; high-resolution satellite imagery has become a more cost-effective alternative (Awrangjeb *et al.*, 2010; Lee *et al.*, 2008; Li and Wu, 2008). Tanathong *et al.*, (2008) reported a seventy-five percent accuracy rate for using remote sensing object orientated change detection technique for rectangular buildings

following damage caused by the Indian Ocean Tsunami in December 2004. Vu (2011), developed a building extraction tool as one component of a tsunami early damage detection system. Barnes *et al.*, (2007) investigated storm impacted buildings in the aftermath of Hurricane Katrina for emergency response planning purposes.

Wu *et al.*, (2011) used Synthetic Aperture Radar (SAR) to detect building density in Wuhan, China; while Brunner *et al.*, (2010) investigated buildings damaged by the Sichuan earthquake in China in May 2008 using SAR images. Recently, Light Detection and Ranging (LiDAR) remote sensing technology has improved automatic the surveying and mapping of buildings in urban environments (Shaker *et al.*, 2011; Qin *et al.*, 2015; Matsuoka *et al.*, 2013; Sohn and Dowman, 2007; Sirmacek *et al.*, 2010). Yu *et al.*, 2010 reports that LiDAR offers highly accurate delineation of building footprints and the potential for the reconstruction of three-dimensional buildings for use in both urban modelling and visualisation. Nevertheless, automatically extracting urban features from high resolution remote sensing data is still a challenging task and some limitations are inherent. Niemeyer and Canty (2001) state that despite the rich body of literature, most techniques reported still neglect or miss-detect small-sized buildings. This is especially the case in unplanned or informal areas, which often exhibit high building densities and relatively small amounts of unsealed bare soil between structures or continuous rooflines, which makes it difficult for remote sensing techniques at even high resolutions to distinguish between single buildings (Owen and Wong, 2013; Hay and Castilla, 2006).

Further difficulties in building detection arise from the complexity and heterogeneity of built structures, diverse construction and roofing materials, their extreme geometric variability and issues of roof- and shadow- casts obscuring buildings (Liao *et al.*, 2007; Pan *et al.*, 2008; Kuffer and Barros, 2011). A final consideration is that such assessments require very high resolution images, which is relatively costly. Miller and Small (2003), states that one important factor to be considered is that there are often better sources of the same information to be obtained more economically than from remote sensing applications.

### **6.1.5 Block-based results and discussion**

HCMC has been subject to dynamic changes in the construction and further development of urban features, especially buildings. Consequently, developing and

updating databases and detecting changes in building density is a challenging task for the local administration. In reality, quantitative information about buildings is often unavailable, incomplete, or out-of-date. To determine building density values for HCMC, this study used traditional man-made feature extraction methods. Building density was calculated for all of the administration area of HCMC on hand the updated building footprint inventory data associated with the corresponding DoNRE land-use block geometry. Building information was extracted from the map data at block level, and building density was calculated by dividing buildings footprint units by the official land-use block area. The results can be seen mapped in Figure 6–1. The distribution of building density values in terms of the number and area of land-use blocks can also be seen for reference in Table 6–1.

In Figure 6–1, it is clear to see considerable higher building density in the numerous local core areas of HCMC. This shows the polycentric structure of HCMC with the high values around areas in both District 1 and District 5. The map also allows for the identification and localisation of potential vacant land in which the actual degrees of building densities are less than legally permitted or deemed appropriate. In terms of spatial planning for disaster risk reduction and climate change adaptation, discussions of the densification of the city core in these results have particular significance. The urban districts of district 11, district 3 and Phu Nhuan were seen to display the highest calculated building densities. Districts 4, 5 and 10 also displayed relatively high building density values, with on mean of over 30 buildings per ha. In total, the urban districts of HCMC displayed a mean building density of 26 buildings per ha, the peri-urban districts 11 buildings per ha and the rural districts 3 buildings per ha.

Noteworthy is the fact that 73% of land-use blocks and 86% of the total area of HCMC exhibited building density values below 10 buildings per ha, while only 5.3% of the land-use blocks and 1.9% of the total area of HCMC displayed building densities above 40 buildings per ha. However, it is important to also mention that these results reflect the investigation of the whole administration area of HCMC and not solely the UST blocks classified as built-up. For the whole administration area, the mean building density was calculated to be 22 buildings per ha.

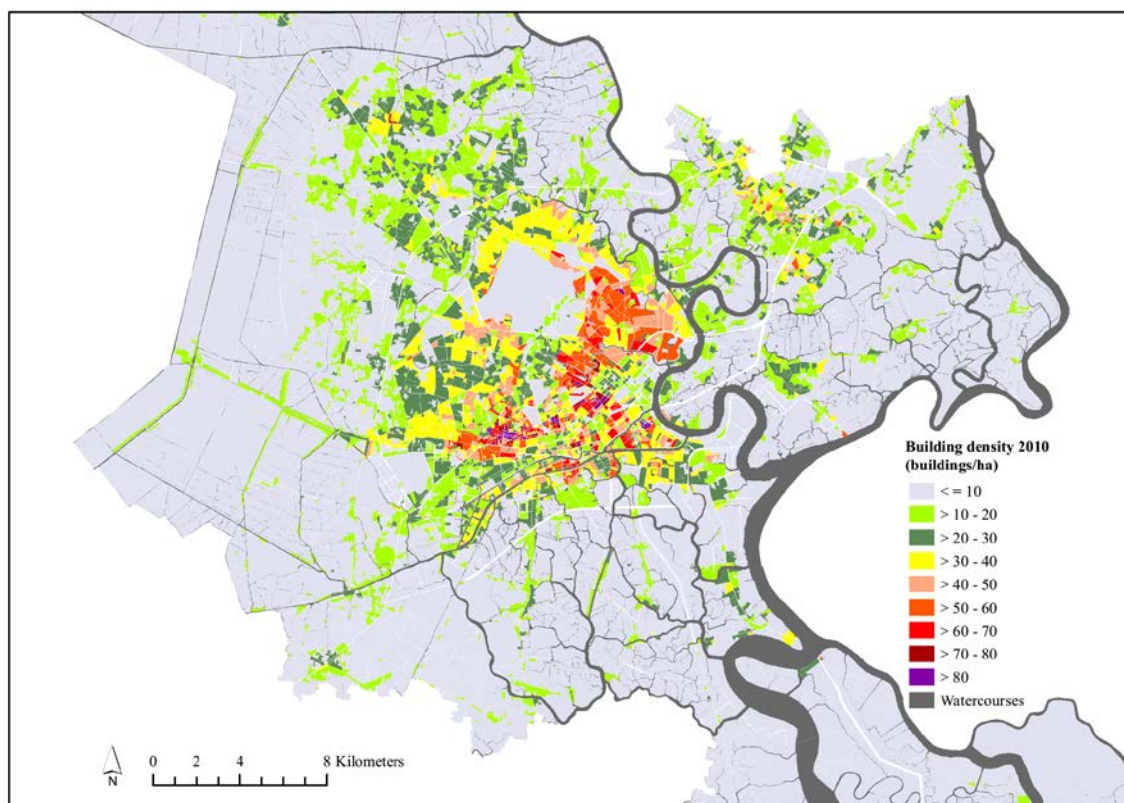


Figure 6–1 Calculated mean building density per block for Ho Chi Minh City (*buildings/ha*) (source: author's own)

Table 6–1 Distribution of mean building density values (*buildings/ha*)

Range	No of blocks of land-use	(%) of blocks of land-use	Block area (ha)	Block area (%)
<=10	11,918	73.2	148,769	86.4
>10–20	1,858	11.4	11,030	6.4
>20–30	1,022	6.3	5,621	3.3
>30–40	632	3.9	3,635	2.1
>40–50	312	1.9	1,401	0.8
>50–60	219	1.3	1,064	0.6
>60–70	147	0.9	450	0.3
>70–80	77	0.5	111	0.1
>80	107	0.7	94	0.1
Total	16,292	100	172,179	100

Figure 6–2 shows the relationship between the calculated mean building density values and distance from the city centre. Here the city centre was taken to be the City Hall in District 1. Building densities within 1 km of the centre were seen to be relatively low in comparison to those calculated from 2–4 km from the city centre. This could show a

high potential for densification, however in fact this is due to the presence of relatively large number of high volume buildings in the CBD of HCMC and the presence of additional parks. Building density as a single measure of urban densification will underestimate the urban density in city centres because of the relatively small proportion of buildings that are residential. This will become apparent in the following sub-sections, which outline the results of other calculated density measurements. The locations within 2–7 km of the city centres have middle to high building densities, which denotes efficient use of space for residential purposes. These medium to high building densities suggest centralised adaptation measures and the potential for the provision of cost effective public transit and energy systems. Within the range of 8–14 km from the centre, much of HCMC has medium building densities. This could be an indication of unsustainable urban development practices due to wastage of land and is likely to encourage dependency on individual transportation modes. From 20 km from the city centre outwards, the outlying areas of a city as expected have a lower building density.

Figure 6–3 shows boxplot results of the calculated medium building density values for each UST. Table 6–2 also highlights the highest and lowest three individual values. The highest medium building density values was found in UST Shophouse irregular high dense, with a value of 46 buildings per ha. The CBD and shophouse regular narrow USTs also recorded medium values above 40 buildings per ha. As to be expected the lowest building density was seen in the UST Shophouse irregular with fields.

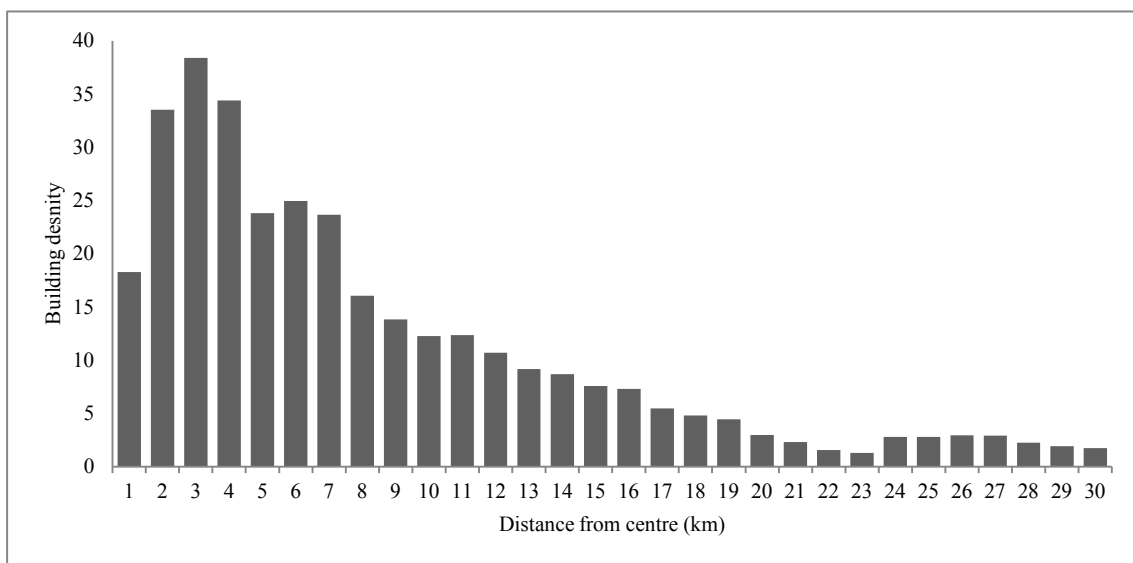


Figure 6–2 Relationship between mean building density and distance from city centre (*buildings/ha*)

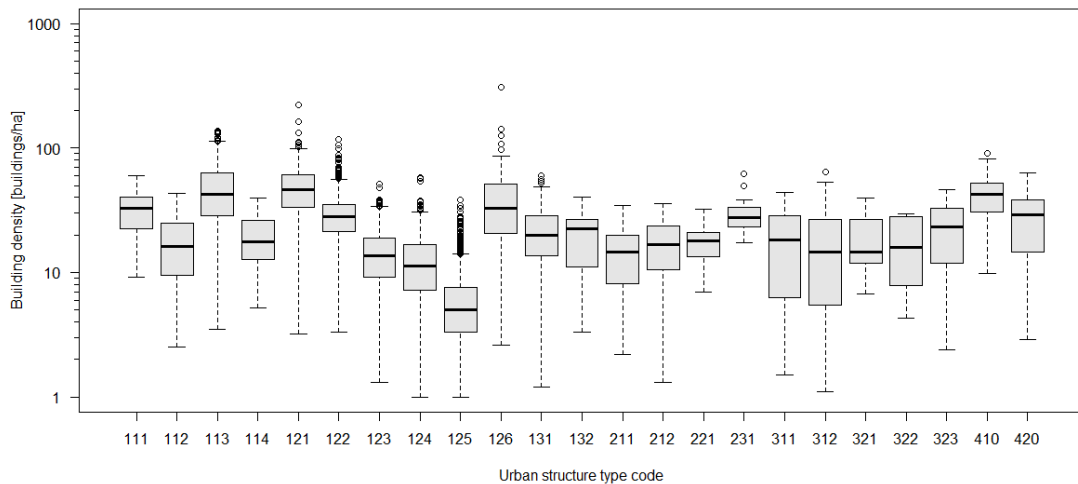


Figure 6–3 Relationship between medium building density and UST

Table 6–2 Highlighted medium building density values for individual USTs (*buildings/ha*)

Highest		Lowest	
Shophouse irregular high dense (code 121)	46.5	Shophouse irregular with fields (code 125)	5.0
Central business district (code 410)	42.3	Shophouse irregular clustered (code 124)	12.2
Shophouse regular narrow (code 113)	42.1	Shophouse irregular scattered (code 123)	14.4

In total, the classified residential USTs of HCMC exhibited a medium building density of 13.8 buildings per ha (Table 6–3). The regular shophouse group displayed a medium building density of 34 buildings per ha, while the irregular shophouse group had a calculated medium building density of 32 buildings and the peri-urban shophouse group 7 buildings per ha. The mixed shophouse group was calculated to have medium building density of 20 building per ha. The regular villa group and the mixed villa group displayed medium building densities of 17 and 22 buildings per ha respectively.

The new apartment group showed a medium building density of 15 buildings per ha, while the density of the old apartment group was measured to 17 buildings per ha. Here, the social apartment UST displayed the highest value of 23 buildings per ha followed by the low-rise apartment UST with 18 buildings per ha. Here, high-rise apartments with 15 buildings per ha displayed a lower building density than low-rise buildings. On medium, the CBD group was calculated to a density of 36 buildings per ha.

Table 6–3 UST groups and medium building density values (*buildings/ha*)

Regular shophouse (codes 111, 112 , 113, 114)	33.7	Mixed villa (codes 221, 223)	21.8
Irregular shophouse (codes 121, 122, 126)	31.6	Apartment new (codes 311, 312)	14.5
Peri-urban shophouse (codes 123, 124, 125)	7.4	Apartment old (codes 321, 322, 323)	17.3
Mixed shophouse (codes 131, 132)	20.1	Central business district (codes 411, 412)	36.1
Regular villa (codes 211, 212)	16.5	All residential	13.8

It is important to be aware that the building footprint data contained digitalisation errors. Inaccuracies were seen when comparing the satellite imagery with the building footprint data. The oversights were seen to occur frequently in the irregular group of shophouse UST, particularly the UST shophouse irregular high dense (*code 211*) and shophouse irregular temporary (*code 216*). Here often many close buildings due to their approximation were digitalised as one single building. It is therefore expected that the actual building densities in these two USTs is somewhat higher.

It is additionally important to highlight that the calculated results do not separate between residential, commercial or industrial buildings. An additional important consideration is the scale of measurement. Both Pefka (2013), and Forsyth (2003), state that the scale at which building density is measured greatly influences the outcome as more non-residential land is included. This can be seen in the building density results of peri-urban results. It is reasonable to assume the method used in this study to calculate density can dramatically distort the results. For instance, while densely arranged buildings on one segment of a large land-use block would have the same gross building density as the same number of buildings spread out evenly over the same land-use block, the two developments would have substantially different net densities. Therefore, it is important to remember that land-use block size and building arrangements can result in very different building density results.

The results highlight the challenges in measuring urban density and indicate that in HCMC, as in other emerging Asian megacities, the measurement of building densities and the monitoring of building footprints will not suffice. This is because, while easy to calculate, building footprint density data is not depicted to fully assess both urban sustainability and climate change response options. Building density measurements are highly problematic and often vague as they do not account for the size of dwellings as can be seen in Figure 6–1 in the mapped results for District 1 of HCMC or in Figure 6–



2 the mean buildings within 1 km of the city centre, the functional mix of uses or size of households, factors that vary significantly both temporally and spatially in HCMC. Spatially analysing solely building densities across HCMC can be misleading given the large difference between dwelling sizes and household's size and between inner city areas and peri-urban areas. These difficulties can only be partially offset with a well-developed UST approach. Furthermore, while building density limits can be set for HCMC, concomitantly, with trends in the increasing size of dwellings, internal net density would diminish.

Resultantly knowledge of the number of buildings per ha alone is not useful for planning climate change responses and it does not reflect population density. Also, temporal relationships and comparisons quickly loose validity as both buildings and household sizes change over time and space. In order to analyse and monitor, urban density and spatial development trends over time, and to have a good understanding of how urban dynamics are related to both disaster risk reductions and climate change adaptation, additional densities indicators are needed.

## **6.2 Building height**

### **6.2.1 Description and use in planning**

Urban morphology is characterised not only by the heterogeneous distribution of different building densities, but also by the physical parameters that characterise the building structures, such as the heights of the buildings. Building heights are a key structural feature for dividing homogeneous zones within the complex urban landscape (Taubenböck, 2008; Dini *et al.*, 2014). In urban planning, building height is normally measured in the number of stories (floors), and the number of stories is taken as a proxy indicator for building heights. Building height is normally defined as the vertical distance by which the uppermost portion of a building extends above the surface or ground level. Building height is an important planning fact contributing to a sustainable urban environment with building heights in some cities being also an indirect measure of land values. Building urban objects higher and creating multi storey buildings has been a practical solution to rising land prices and decreasing land availability and demand of living space in HCMC. Taller buildings have also been an adaptation to

tackle the natural geographical conditions, flood risk and the rising population growth of the city.

### **6.2.2 Importance for climate change and disaster risk reduction**

Table 6–4 outlines the main impact of increased building height on overall urban sustainability. Jones and MacDonald (2004), reported that the height of buildings is closely related to building density and strongly influences both the social and economic, as well as, the environmental costs of development. While, Musakwa and Van Niekerk (2014), argue that a building with solely a single floor can be regarded as less sustainable than a building with between 2–12 floors, because of inefficiencies in the use of space, lower returns on investment and higher infrastructure connection costs.

McLennon (2009) argues that the benefits of high-rise buildings diminish when the number of floors exceeds 12. While literature on specific high dense cities highlight that a concentration of high-rise buildings promotes the formation of increased urban surface energy, the UHI effect, and increased energy costs (De Wilde and Van den Dobbelsteen, 2004; Wong *et al.*, 2011; Ng *et al.*, 2012). More energy is also used for the construction of high-rise buildings, and they may block the use of solar energy on nearby buildings.

Elevated objects, such as buildings or entire blocks of close-set high-rise buildings constitute barriers, the effect of which may be to break the wind even to the point of complete standstill, or to channel wind to the effect of accelerated wind flows though the city. Furthermore, varying building heights create obstacles and rough surfaces that enhance the blocking or drag effect on wind flows. Due to a larger urban aerodynamic surface roughness, the average wind speed is lower in cities than in the surrounding rural areas.

Whereas the height of the UHI is typically three to five times the average building height (Givoni, 1998). In the cities the narrow streets and high buildings, create canyons and this vertical geometry plays an important role in intensity of UHI. Here, the indicator sky view factor representing a good measure of openness of the urban texture is related to building height (Watson and Johnson, 1987; Golany, 1996; Grimmond *et al.*, 2001; Ratti *et al.*, 2003; Hien and Jusuf, 2009).

Table 6–4 Impact of building height on urban sustainability and climate change adaptation

<b>Positive</b>	<b>Negative</b>
<b>Environmental</b>	<b>Environmental</b>
Efficient use of space	Congestion
Increase potential for local heating and cooling systems	Urban Heat Island development which increases need for air conditioning
Increase in energy efficiency	Concentration of high-rise buildings reduces potential for natural lighting and ventilation, thereby increasing energy use
Encourages other modes of transport	
<b>Economic</b>	<b>Economic</b>
Reduces trips by private vehicles	Need for lifts, which may increase energy consumption and need for increased maintenance
Amortisation of infrastructure costs (and possibly maintenance) for basic urban service provision energy and water supply, drainage, roads, buildings and public transport, climate change adaptation	
Great returns on investment	
<b>Social</b>	<b>Social</b>
Increased social interaction and vibrancy	Decline in cultural heritage
Encourages and promotes efficient public transit systems	Overload existing locations and infrastructures

(compiled from Ding, 2013; Yabuki *et al.*, 2011; Musakwa and van Niekerk, 2014)

In terms of energy, the energy performance of buildings is linked to the quality of the urban environment (Stemmers *et al.*, 1997). Increased building heights increase energy use not only because of increased UHI, but also because of changes in shadow and daylight distributions. Taller buildings results in the reduced ability of sunlight and daylight availability to the interior. The energy implications are both increased lighting and potentially heating or cooling. For HCMC, this result in more and more buildings moving from being naturally ventilated and lighted, to air conditioned and artificially lighted. Here, an important consideration is access rights to solar, wind, and light (see Roaf *et al.*, 2009). Taller buildings also permit residing and daytime populations to overload locations, placing strain on existing infrastructure.

Roaf *et al.*, (2009) provide a critic of both the design and spatial planning limitations and challenges for incorporating renewable energy technologies into high-rise buildings and also the problems of high-rise buildings in times of crisis, such as longer emergency evacuation times.

For aesthetic considerations, building height restrictions have been often introduced for historical and scenic districts of many cities. It is argued that planning policy, especially zoning should provide sensible height restrictions, as well as, urban design solutions to prevent UHI build up (Musakwa and Van Niekerk, 2014). Often policy includes height considerations that promote fresh air corridors that allow the straight and free flow of air to reach into the city centre. Indeed height restrictions are a regulatory tool, which governs land-use in the central core areas of many cities worldwide (Bertuad and Brueckner, 2005). Furthermore, surface roughness along these corridors should be low. The land-uses in these corridors should have a cooling effect on the air moving towards the city centre and pollution should be minimised in the areas from which the air moves to the centre and along the paths. Bertuad and Brueckner (2005), however suggest that height restrictions can cause a city to expand spatially, and as a consequence have lower densities resulting in more sprawl.

### **6.2.3 Relevance for Ho Chi Minh City**

In Vietnam building heights are controlled by the National building code TCXDVN 353:2005 and Decision No. 04/2008 QĐ-BXD issued by the MoC (MoC, 2008). However, to be more in keeping with the characteristics of the city, the HCMC Peoples Committee issued the local Planning Codes Decision 135 in 2007 (135/2007/QĐ-UBND) and Decision 45 in 2009 (45/2009 QĐ-UBND) which both regulate the heights of local shophouse based developments. The number of stories and height of a shophouse is determined by the width of the street they face. HCMC has also introduced differential height limitations by districts rather than imposing one limit for the entire city. Exceptions to the height limits are allowed in the inner urban districts of 1, 3, 4, 5, 10 and Phu Nhuan, here 1 additional story may be added to the national regulations. An additional story is also permitted for buildings on major commercial or transport streets in the city or for larger development plot sizes. In other areas of the city this policy is not applied because of ongoing planning projects, gentrifications or special architectural projects. The building heights in these areas are then purposed by the local district's People's Committee with the final decision being taken by the HCMC People's Committee. Table 6–5 outlines the shophouse building height regulations as set out in Decision 45/2009 QĐ-UBND. The maximum height a shophouse based development is allowed is 8 stories, with the 8<sup>th</sup> floor, reduced in area with a minimum set back of 3.5 metres.

Table 6–5 Shophouse building height regulations in Ho Chi Minh City

Width of street in metres	Basic permitted height in stories	Permitted additional no of stories for inner city districts	Permitted additional no of stories for buildings on major commercial or transport routes	Permitted additional no of stories for large plot size	Maximum height of ground floor	Maximum number of permitted stories + area reduced stories	Maximum number of permitted stories
≥25	5	+1	+1	+1	7.0 m	7+1	8
20≤-<25	5	+1	+1	+1	7.0 m	6+2	8
12≤-<20	4	+1	+1	+1	5.8 m	5+2	7
7≤-<12	4	+1	0	+1	5.8 m	4+2	6
3.5≤-<7	3	+1	0	0	5.8 m	3+1	4
<3.5	3	0	0	0	3.8 m	3+0	3

(Source: 45/2009 QĐ-UBND)

For HCMC precise and detailed knowledge about building heights is important. For example, detailed knowledge of buildings from the elevation of the ground surface is essential for predicting flood inundation and future flood risks and the potential effects of sea-level rise. Detailed knowledge is also important for the promotion and guiding of urban research and planning from the two-dimensional to the three-dimensional and the further deduction of important indicators such as gross floor area (GFA), building volume, floor area ratios (FAR) and population distribution.

The knowledge of the geometrical dimensions, as precisely as possible, leads to a much more accurate representation, and an improved locating and evaluation of many current urban problems in HCMC. These outcomes are of particular importance in areas of access difficulty, data scarcity, budget limitation, and in areas of HCMC where population density increase is due to the rise buildings height instead of built-up area extension, such as in the core area of HCMC. Moreover, a detailed model of the buildings that would be affected by a flood for examples is essential for property owners, planning authorities and insurance companies (Bates and De Roo, 2000).

Furthermore, as HCMC has experienced a reduction in sky view and wind speed as building heights have increased over time, it becomes increasingly important to study urban microclimatic environments and to apply these findings to improve comfort and to decrease the energy consumption in the city (Storch *et al.*, 2011; Storch and Downes, 2016; Katzschner *et al.*, 2016). Foremost, building height information is useful in a

database form to provide further information for example for more precise microclimate investigations and urban climate modelling. It can also aid the more complete mapping of green roof potentials, solar potentials, noise simulations, heat and exhaust spreading simulations, siting of telecommunication transmitters and emergency beacons, and virtual city reality designing. It is also evident that building height information in a changing climate will need to be reflected in future building design and refurbishments in buildings forms. Building higher and changing building use patterns are one commonly cited way in which to climate proof buildings and cities (Hallegatte, 2009; Roaf *et al.*, 2009). One important policy option in this respect is of raising minimum building and floor height in new areas or rising existing infrastructure in already developed areas in line with topographical constraints and hazard exposure. For example, in flood-prone areas, height limits could be increased for new developments where the developer increased the ground floor about a certain hazard level.

#### **6.2.4 Previous studies**

Many remote sensing studies have attempted to derive building heights automatically for urban modelling applications. The automated creation of digital surface models (DSM) or digital terrain models (DTM) from remotely sensed data has offered a representation of both the ground surface and the buildings objects on that surface (Priestnall *et al.*, 2000; Rottensteiner and Briese, 2002; Zhou *et al.*, 2004; Zhou and Neumann, 2008; Yu *et al.*, 2009; Gonzalez-Aguilera *et al.*, 2013). The extraction of building heights is a typical remote sensing technique from stereo data (Taubenböck, 2008; Krauss *et al.*, 2005; Müller *et al.*, 2006; Toutin, 2004). Here, building shadows are indicative of the three-dimensional information of buildings, with shadow length correlating directly with the respective building height. Most recent remote sensing studies for the derivation of building heights from remote sensing data are based on radar techniques (Gamba *et al.*, 2000; Luckmann and Grey, 2003) or stereo analysis (Grodecki, 2001; Baillard and Mairtre, 1999).

However, the vertical dimensions of buildings are generally not well represented by satellite images (Alexander *et al.*, 2009). Some remote sensing technique work in stand-alone buildings or in low compacted areas, yet fail in the estimation of building heights in high-density urban settings. Automatically extracting building information as was outlined in the review of remote sensing techniques for extracting solely buildings

themselves is still an essentially unsolved problem. The main limitations are the detection of height variations within flat roof buildings with mixed roof types, shadows and the detection of ridgelines and surfaces in pitched roof buildings. Buildings with pitched roofs are especially difficult in remote sensing, since they cannot just be extruded to a certain height. To overcome these difficulties, the extraction of buildings and digital terrain models in urban areas is still currently done by manual-guided interactive operations and the process is both costly and time-consuming (Zhao *et al.*, 2004). In many cases, original data or survey data is necessary. Building heights is an important indicator for the different elements of risks namely exposure and vulnerability. It is widely used to yield necessary information in building classification taxonomies due to its direct relationship to structural failures or whether it has collapsed during an extreme event and for the evaluation for large earthquake scenarios.

### **6.2.5 Block-based results and discussion**

The ascertainment of the number of stories within a building was carried out by entering the number of storey data from the official building database. For the buildings for which the number of stories was absent, an estimated value was used to calculate the mean number of stories per building per block and highest building for each block. The overall quality of the results therefore depends to a large extent on the quality of the input data. Figure 6–4 shows the mapped mean number of stories per building per land-use block of HCMC. The first story is the first level above ground level. Buildings with solely a ground floor were assigned no number or the number zero in the official building database. Therefore, the next story up is assigned the number 1 and is taken as the first story. The next story up then becomes the second story and so on. The numbering of the higher floors continues sequentially. It is important to note however that subterranean levels were not recorded in the building database. In Figure 6–4 the land-use blocks classified as having on less than one story per building means the majority had solely just a ground floor. Table 6–6 also shows the distribution of the mean number of stories values in terms of number and area of land-use blocks. It is clear from the results that, although there are some high-rise buildings in HCMC, the majority of buildings are solely ground floor or only have one additional floor. In total 66% of the area of HCMC contained land-use blocks, which had typically only one additional story or less.

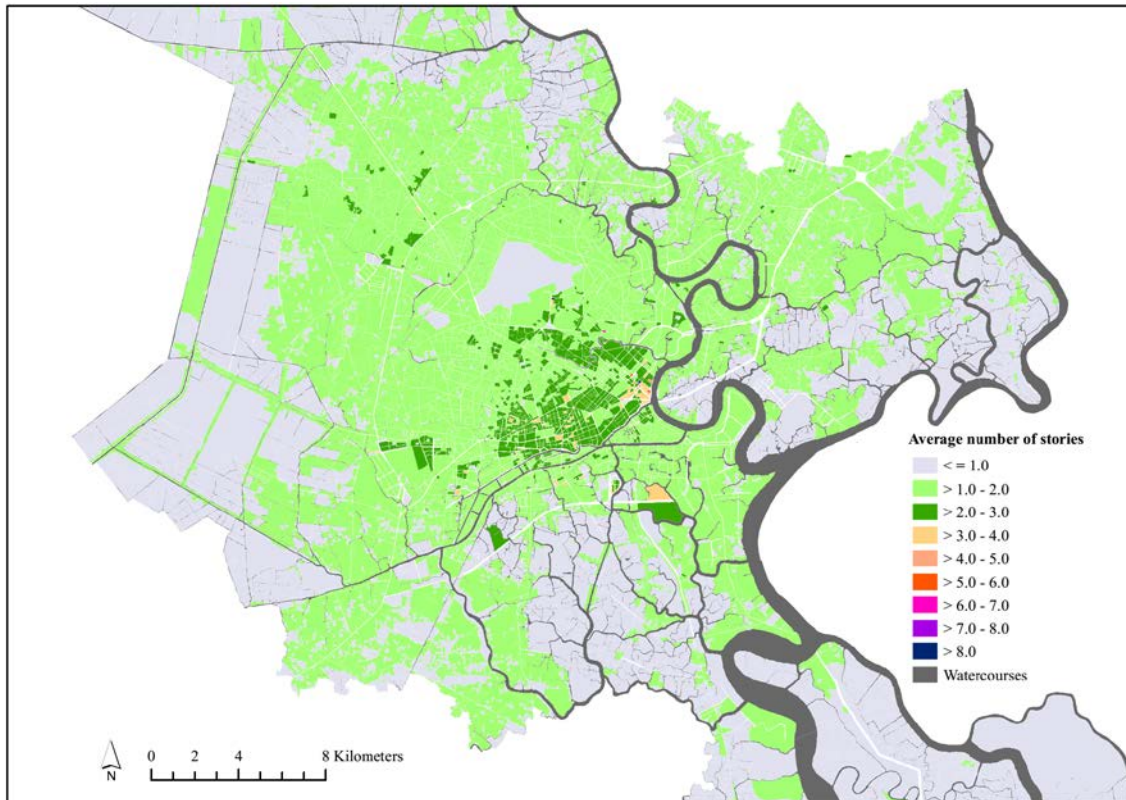


Figure 6–4 Calculated mean building height per block for Ho Chi Minh City (*stories per building/block*) (source: author's own)

Table 6–6 Distribution of mean building height values (*stories per building/block*)

Range	No of blocks of land-use	(%) of blocks of land-use	Block area (ha)	Block area (%)
<=1.0	10,271	63.0	113,605	66.0
> 1.0–2.0	5,215	32.0	55,912	32.5
> 2.0–3.0	723	4.4	2,459	1.3
> 3.0–4.0	71	0.4	184	0.1
>4.0	12	0.1	18	0.1
Total	16,292	100	172,179	100

Further to this, 32% of the area of HCMC had buildings with between 1 or 2 additional stories (*i.e.* including ground floor and additionally between 2–3 stories in height) and only 1.3% land-use block area of HCMC had buildings with a mean of 2–3 additional stories. Not surprisingly, the highest medium building heights were seen in the urban districts of district 1, 5, 10 and 11. All land-use blocks in these districts had between 2–3 additional stories in addition their ground floors. The lowest medium building heights per land-use block were seen in the rural district of Can Gio with more than half of the



buildings exhibiting only a ground floor. The high proportion of low rise buildings in HCMC suggest that there is much potential for vertical growth.

Figure 6–5 shows the relationship between the mean number of additional stories per land-use block and distance from the city centre. As to expected the mean number of stories and therefore heights decrease steady from the city centre outwards. The mean number of additional stories per land-use block remains fairly constant within 7 km of the city centre. This suggests that there is indeed a potential for densification.

Figure 6–6 shows boxplot results of the calculated medium number of stories values for each UST. Table 6–7 also highlights the highest and lowest three individual values. The highest medium values were found in the UST social apartment, with a medium value of 3 additional stories.

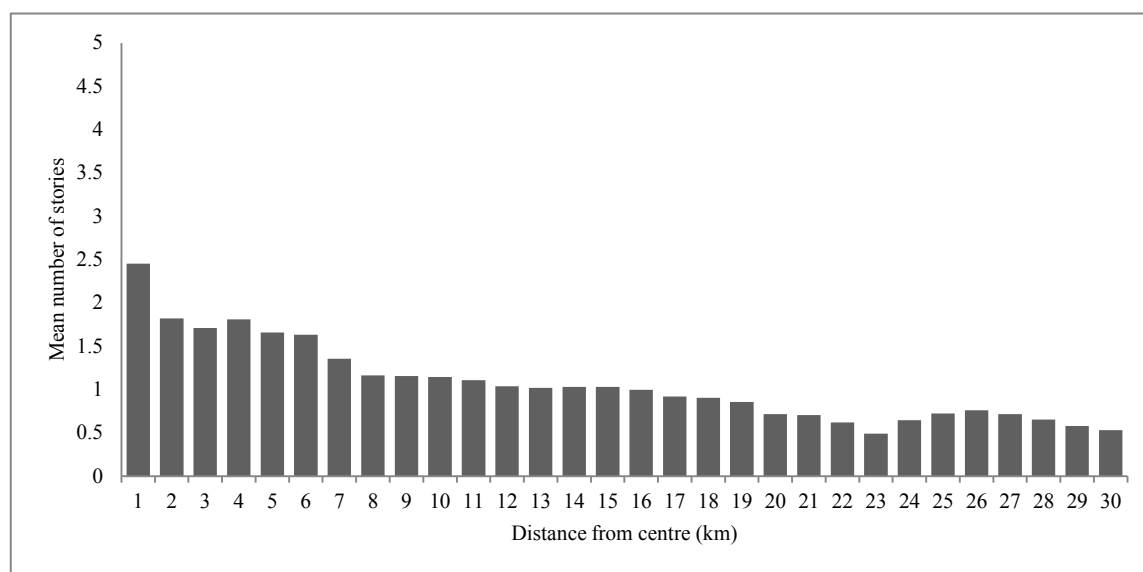


Figure 6–5 Relationship mean building height and distance from city centre (*stories per building/block*)

Table 6–7 Highlighted medium building height values for individual USTs (*stories per building/block*)

Highest	Lowest
Social apartment (code 323)	3.0 Shophouse irregular with fields (code 125) 1.0
Shophouse regular narrow (code 113)	2.0 Shophouse irregular clustered (code 124) 1.0
Low-rise apartment	2.0 Shophouse irregular scattered (code 123) 1.1

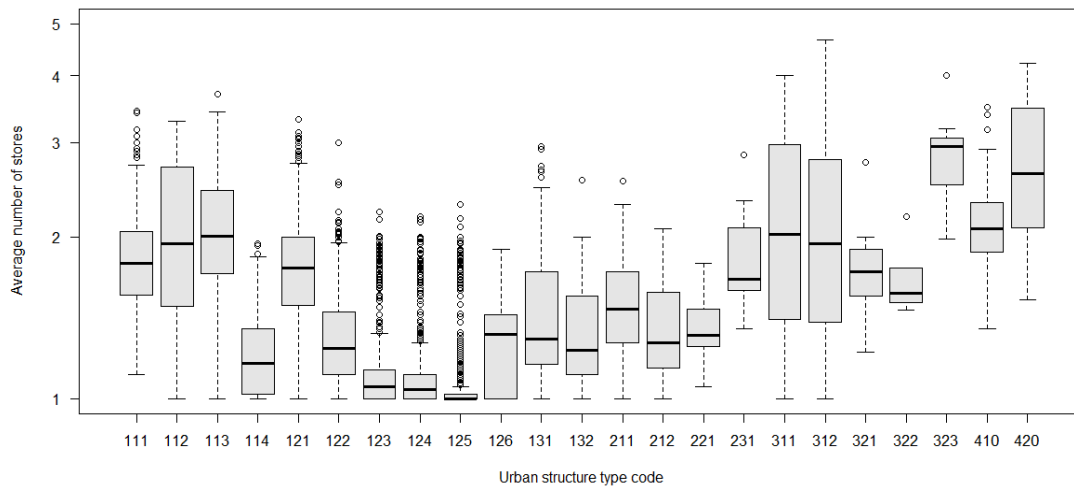


Figure 6–6 Relationship between medium building height and USTs (*stories per building/block*)

The UST shophouse regular narrow, low-rise apartment, CBD, and CBD with high dense, all exhibited medium values of at least 2 or more additional stories. The lowest medium values for additional stories were seen in the peri-urban shophouse UST, shophouse scattered, shophouse irregular cluster, and shophouse irregular with fields.

Table 6–8 shows that in terms of shophouse based UST, the regular shophouse group, displayed a medium value of 1.8 additional stories, while irregular shophouse group, had a calculated medium 1.4 additional stories and the peri-urban shophouse group, only 1 additional story, while, the mixed shophouse group, was calculated to have medium number of additional stories of 1.3.

The regular villa group and the mixed villa group displayed medium additional story values of 1.3 and 1.6 buildings per ha respectively. The new apartment group and the old apartment group, showed an medium of 2 additional stories.

Table 6–8 UST groups and medium building height values (*stories per building/block*)

Regular shophouse (codes 111, 112, 113, 114)	1.8	Mixed villa (codes 221, 223)	1.6
Irregular shophouse (codes 121, 122, 126)	1.4	Apartment new (codes 311, 312)	2.0
Peri-urban shophouse (codes 123, 124, 125)	1.0	Apartment old (codes 321, 322, 323)	2.0
Mixed shophouse (codes 131, 132)	1.3	Central business district (codes 411, 412)	2.2
Regular villa (codes 211, 212)	1.3	All residential	1.1

Interestingly the UST high-rise apartment was calculated to have a medium value of only 1.9 additional stories (code 312). Buildings within the CBD group were calculated to have 2.2 additional floors.

In comparison to the results for the medium number of additional stories per land-use block and to give an indication of urban roughness, Figure 6–7 shows only the tallest building in each block mapped in terms of stories above their ground floor. The tallest buildings, greater than 30 stories, are seen in districts 1 and 5. While a great deal of tall buildings are also seen in districts 3, 10, 11 and Phu Nhuan. The medium tallest building per block in urban districts was 3.8 additional stories, 1.4 additional stories in peri-urban districts and 0.2 additional stories for rural districts.

Table 6–9 also shows the distribution of the tallest building per block in terms of number and area of land-use blocks. In total, 15.5% of HCMC’s land area is made up of blocks where the tallest building is only 3 stories or less in height, *i.e.* where the tallest building the ground floor is equal to or less than 2 additional stories. Furthermore, almost 10% of the HCMC area is made up of blocks where the tallest buildings were seen to be between 3–5 stories high *i.e.* the ground floor of the building plus 2–4 additional stories above. Additionally 2.9% of the HCMC area is made up of blocks where the tallest buildings were seen to be between 5–7 stories high. Finally, only 3.2% of the HCMC administrative area contained blocks where the tallest building was higher than 7 stories.

Table 6–9 Distribution of the tallest building per block values

Range	No of blocks of land-use	(%) of blocks of land-use	Block area (ha)	Block area (%)
Non-built up	8,184	50.2	117,954	68.5
<2	4,846	29.7	26,718	15.5
>2–4	2,261	13.9	17,093	9.9
>4–6	762	4.7	5,078	2.9
>6–8	106	0.7	1,013	0.6
>8–10	63	0.4	644	0.4
>10–20	59	0.4	604	0.4
>20–30	8	<0.1	42	<0.1
>30	3	<0.1	28	<0.1
Total	16,292	100	172,179	100

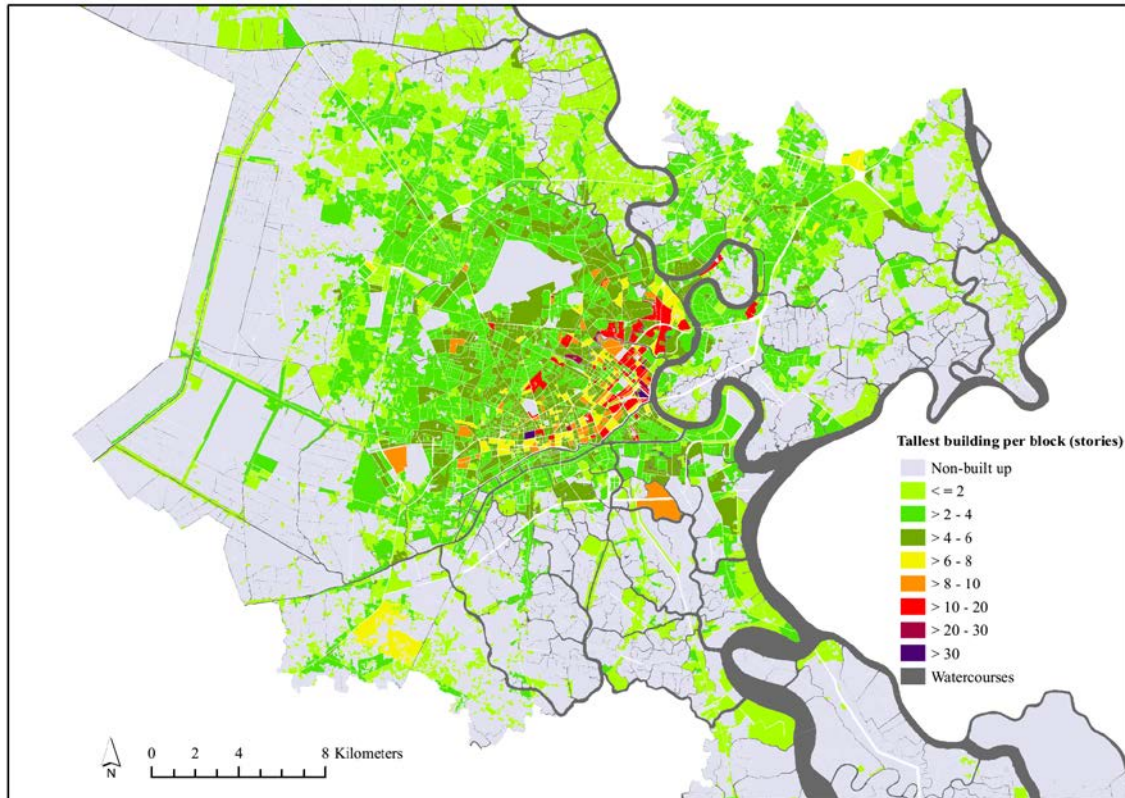


Figure 6–7 Calculated tallest building per block for Ho Chi Minh City (*source: author's own*)

Figure 6–8 shows the relationship between the mean tallest building in terms of stories per land-use block and distance from the city centre. The mean of the tallest buildings within 1 kilometre of the city centre is almost 9 stories plus ground floor.

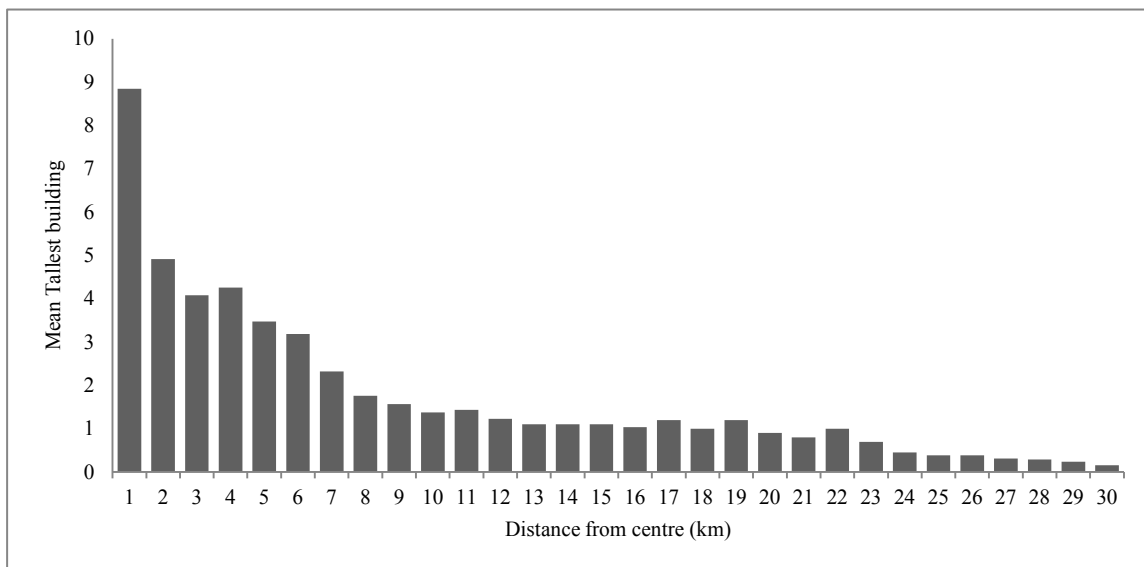


Figure 6–8 Relationship between mean tallest building per block and distance from city centre

Beyond 1 kilometre distance from the city centre, in contrast to Figure 6–5, values for the tallest building per block were seen to dynamically decrease. This can also be seen spatially in Figure 6–7. After a distance of approximately 12 kilometres from the city centre the mean tallest building per block becomes relatively stable at around one or less additional stories.

Figure 6–9 shows boxplot results calculated for the medium tallest building in block per UST. Table 6–10 also highlights the highest and lowest three individual values. The highest medium values were seen in the UST CBD with high dense with a medium tallest building of 10 stories. The UST high-rise apartment and CBD show values of the medium tallest buildings of 6 stories, and both the UST American apartment and social apartment displayed a medium tallest building of 5 stories. The lowest medium values for tallest building were seen in the shophouse irregular with fields with only one additional story. Table 6–11 shows that in terms of shophouse based UST, the regular shophouse group displayed a medium tallest building value of 4 stories, while for the irregular shophouse group the calculated medium of the tallest building was 3 stories and for the peri-urban shophouse group only 1 additional story.

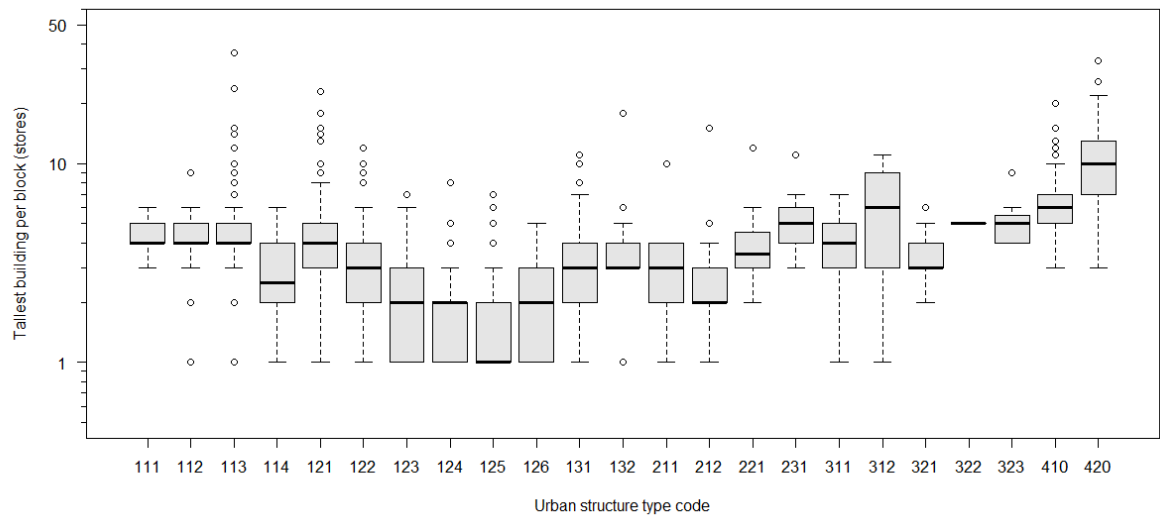


Figure 6–9 Relationship between medium tallest building in a block and USTs

Table 6–10 Highlighted tallest building in a block values for individual USTs

Highest	Lowest
CBD with high-dense (code 420)	Shophouse irregular with fields (code 125)
High-rise apartment (code 312)	Shophouse irregular clustered (code 124)
CBD (410)	Shophouse irregular scattered (code 123)

Table 6–11 UST groups and tallest building in a block values

Regular shophouse (codes 111, 112, 113, 114)	4.0	Mixed villa (codes 221, 223)	4.0
Irregular shophouse (codes 121, 122, 126)	3.0	Apartment new (codes 311, 312)	5.0
Peri-urban shophouse (codes 123, 124, 125)	1.0	Apartment old (codes 321, 322, 323)	4.0
Mixed shophouse (codes 131, 132)	3.0	Central business district (codes 411, 412)	6.0
Regular villa (codes 211, 212)	3.0	All residential	2.0

The irregular shophouse group the calculated medium of the tallest building was 3 stories and for the peri-urban shophouse group only 1 additional story. The mixed shophouse group showed a medium tallest building of 3 stories. The regular villa group and the mixed villa group displayed medium tallest building values of 3 and 4 additional stories respectively. While the new apartment group showed a mean tallest building of 5 additional stories and the old apartment group, only 4 additional stories. Finally, buildings within the CBD group were calculated a medium tallest building of 6 additional stories.

It is important to remember that the accuracy of the building height data is dependent upon the accuracy of the official building dataset. As with the results from building density, the results for medium number of stories per building per block are assumed to be highly influenced by the size of the block. This can be seen particularly well in Figure 6–6 where high-rise apartments (*code 312*), recorded lower medium number of stories than low-rise apartments (*code 311*). This is due to the location of this UST often in the outer urban locations in larger sizes of land-use blocks which also accommodated many other smaller buildings, which in turn affect the calculated medium values. Therefore, a block containing high-rise apartments is not necessary of high density as they were often seen as isolated high-rise towers in large blocks or as towers surrounded by temporary housing. As very few blocks contained homogenous buildings, and the results for medium number of stories were divided by number of buildings. The results are theoretically distorted and appear similar for very different UST types. The analysis of solely the tallest building per block goes somewhat to address these issues and provides a more realistic presentation of spatial and vertical distributions of building heights. However, it is also important to note that the number of stories data presented here does not link directly to building heights as the exact height specifications for different stories are building and UST specific.

## **6.3 Coverage ratio**

### **6.3.1 Description and use in planning**

In general, the ratio between built-up and unbuilt land provides an initial overall impression of land-use intensity and the spatial character of an urban area. Coverage ratio is also known as building coverage ratio, building site coverage, ground space ratio, ground space index, and land to building ratio in the literature. It is a two-dimensional indicator commonly used by both architects and urban planners. It represents the ratio or percentage of the built up area to its land parcel or administrative unit area. Therefore, coverage ratio is the direct measure of the proportion of the site area occupied by buildings and indicates the shares of built-up space and open space left on the site (Pont and Haupt, 2009; Whitford *et al.*, 2001).

In many urban areas worldwide, coverage ratios of individual developments are often commonly controlled in urban master planning. They are used as a development regulation in order to directly control the maximum allowable built-up ratio in individual developments and overall building densities. In doing so, maximum coverage ratios prevent over-build, and preserves areas for greenery, landscaping and aim to minimise adverse environmental problems.

Development control is an integral component of urban land-use policy and the planning parameter of coverage ratio is highly desired in practice for both urban design and planning policy analysis. The results of coverage ratio analysis can help planners to identify the appropriate distribution of built-up areas to open space in urban areas.

### **6.3.2 Importance for climate change and disaster risk reduction**

Knowledge of building coverage ratio is important for both urban flooding and urban climate considerations. For HCMC, knowledge of the building coverage ratios provides information on the built-up imperviousness fraction of a given area – an important constituent for the overall generation of surface water runoff. Furthermore, high coverage ratios and buildings in a densely developed urban area play a crucial role on the further spatial propagation on floods as they limit the space for flood waters. These are important considerations for any kind of future implementation of sustainable water surface management in HCMC.

Urban microclimate and local urban air quality can also be seen both as the consequence of building coverage ratios and as the prerequisite of improved and enforced urban planning and design activities (Yeo *et al.*, 2009; Ng, 2009b). Ng *et al.*, (2011), states that for the city Hong Kong, the effect of building layout, especially in terms of building site coverage, has a greater impact on the pedestrian wind environment than that of building height. They note that compact integrated developments with full or large ground coverage on extensive sites typically found in Hong Kong particularly impede air movement. This is significant because pedestrian-level winds play an important role in the dispersion of traffic-related pollutants and diffusion of urban heat affecting both the health and thermal comfort of residents.

Coverage ratios can also be used to both model and predict local average pedestrian level urban ventilation performance. Kubota *et al.*, (2008), also showed that there is a strong relationship between the building coverage ratio and recorded mean pedestrian-level wind velocities for 22 Japanese cities. Given the typical building characteristics of HCMC, open space between buildings becomes very limited. This environment prevents air flow and affecting thermal comfort and the UHI (Huynh and Echert, 2012; Eckert and Huynh, 2016; Katzschner *et al.*, 2016).

### **6.3.3 Relevance for Ho Chi Minh City**

The Vietnamese Ministry of Construction issued in 2008, the Vietnamese national building code for both regional and urban rural planning of residential developments (Decision No. 04/2008 QD-BXD) (MoC, 2008). The building code includes regulatory maximum coverage ratios for both the urban level and also the construction level. The urban level maximum allowable coverage values can be seen in Table 6–12. Within HCMC, depending on the scale of the project the local People’s Committee, the Department of Construction (DoC), and the Department of Architecture and Planning (DPA) are responsible for enforcing and inspecting the coverage ratio in all new construction projects and ensuring that the urban master planning and land-use type coverage rates for the city are in line with the national urban level values.

In Vietnam, the existing regulations for building coverage ratios of single residential buildings at the construction site level are tiered according to plot size. Table 6–13 provides an overview of the site coverage regulations at the construction level for single residential buildings. These regulations are the national standard, but for shophouse



based developments higher regulations are allowed as outlined in HCMC People's Committee Decision 135/2007/QĐ-UBND. The Decision aims to be more fitting with the characteristics of HCMC.

The coverage ratios for both urban and peri-urban districts are determined by Table 6–14. These regulations have promoted the dense development of the inner core area as majority of the plots in the inner core area are small or medium sized (less than 100 m<sup>2</sup>). Building coverage ratios in these categories are permitted to be up to 100%. Additionally, in many instances, developers try to achieve the maximum allowed site coverage to maximise profits and investment return.

Table 6–12 Vietnamese site coverage requirements at the urban level

Land-use type	Maximum allowable site coverages
Neighbourhood unit	60%
Resort	25%
Industrial areas	50%
Public parks	5%
Theme parks	25%
Special greenery	5%

(Source: MoC, 2008)

Table 6–13 Vietnamese maximum site coverage regulations at the plot level for individual buildings

Single residential building developments							
Building area (m <sup>2</sup> )	≤50	75	100	200	300	500	≥1000
Site coverage (%)	100	90	80	70	60	50	40

(Source: MoC, 2008)

Table 6–14 Vietnamese maximum site coverage regulations at the plot level for individual shophouse archetypes

Shophouse based developments							
Building area (m <sup>2</sup> )	≤50	100	200	300	400	500	
Site coverage (%)	Urban districts	100	90	85	80	75	70
	Peri-urban districts	100	90	80	70	60	50

(Source: 135/2007QĐ-UBND)

Table 6–15 highlights additionally the maximum allowable site coverage values for residential apartments. It can be seen from Table 6–15 that for an apartment constructed on a site less than 3,000 m<sup>2</sup> in size irreverent of the building actual height, a site coverage of up to or equalling 75% is allowed, whereas for an apartment over 46 metres constructed on a 35,000 m<sup>2</sup> sized site, only 35% of the plot is allowed to be covered.

Table 6–15 Vietnamese maximum site coverage regulations for apartments

Low-rise apartment developments				
Building height (m)	Site coverage (%) by plot area			
	≤3,000 m <sup>2</sup>	10,000 m <sup>2</sup>	18,000 m <sup>2</sup>	35,000 m <sup>2</sup>
≤16	75	65	65	65
19	75	60	58	55
22	75	57	55	52
25	75	53	51	48
28	75	50	48	45
31	75	48	46	43
34	75	46	44	41
37	75	44	42	39
40	75	43	41	38
43	75	42	43	37
46	75	41	39	36
>46	75	40	38	35

(Source: MoC, 2008)

For complex apartment structures such as high-rise residential buildings, which often have both base podiums and residential towers above, the maximum allowable coverage follows the regulations as outlined in Table 6–15 and depends on the height of the base podium and tower above respectively. For example on a 10,000 m<sup>2</sup> sized parcel, the construction of a residential high-rise building with a base podium 16 metres high and a 46 metres high residential tower above the maximum allowable coverage would be 65% for the base and 41% for the tower.

#### 6.3.4 Previous studies

Various remotely sensed data and classification methods have been used to derive the building coverage ratios (Yan *et al.*, 2015; Gonzalez-Aguilera *et al.*, 2013; Fujii and

Arikawa, 2002; Gamba and Houshmand, 2000, Lhomme *et al.*, 2009, Paparoditis *et al.*, 1998, Shufelt, 1999; Thiele *et al.*, 2007). Yu *et al.*, (2010), demonstrated that coverage ratio and other building density indicators for downtown Houston can be numerically and automatically derived from high-resolution airborne LiDAR data. They extracted building objects, with the associated and corresponding land lots, and computed building density indicators at both land lot and urban district scales.

In this study, the coverage ratio per block was calculated by dividing the ground floor areas of all the building footprints within a single land-use block by the area of that block. The calculation provides a decimal number with two fractional digits.

Block measurements of building coverage ratios are often used when the parcel boundaries are not known of the individual plots with blocks are measured to the street kerb. Block level measurements of building coverage also reflects the actual experience of the environment better than parcel-by-parcel calculations and by using the official land-use geometry block, data can directly be fed back into the land-use planning system used by DoNRE and up-scaled to higher administrative units on a needs be basis.

### **6.3.5 Block-based results and discussion**

Figure 6–10 shows the mapped calculated coverage ratio values per land-use block for the inner core area of HCMC and Table 6–16 shows the distribution of coverage ratio values in terms of both number and area of land-use blocks. It is clear to see from the results that there are some areas of HCMC that suffer from extreme coverage values. Land-use blocks exhibiting high levels of coverage where seen fairly evenly distributed within the inner urban districts.

As to be expected the majority of land-use blocks displayed very low coverage values. In total, 82.7% of the area of the administrative area of HCMC was calculated to contain blocks with coverage values of 10% or less. Further to this, 6.0% of the land-use blocks of the total area exhibited coverage values of between 10%–20%, while 7.3% of the land-use blocks were calculated to have coverage values of between 20%–50%. Only 4% of the total land-use block area was calculated to have coverage ratio values of between 50%–100%. Overall 119 or 0.7% of the land-use blocks equally 94 ha and 0.1% of the total HCMC administrative area were recorded as having a 100% coverage ratio.

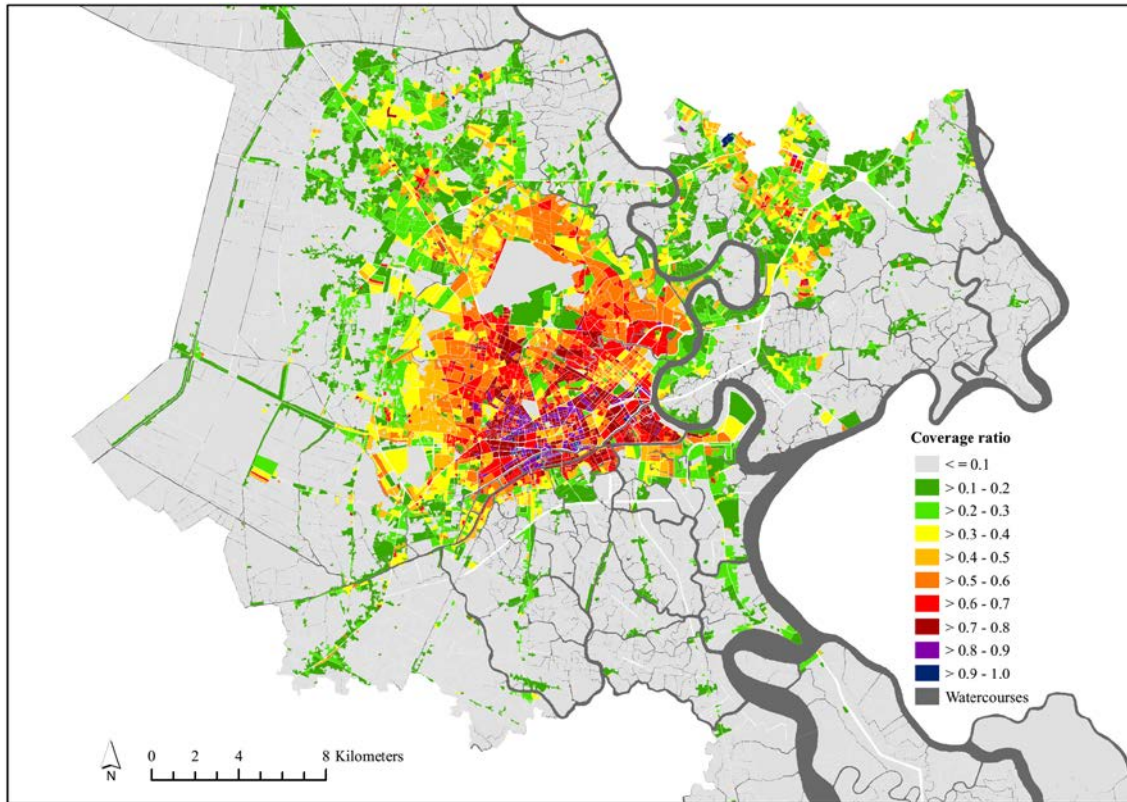


Figure 6–10 Calculated coverage ratio per block for Ho Chi Minh City (source: author's own)

Table 6–16 Distribution of coverage ratio values

Range	No of blocks of land-use	(%) of blocks of land-use	Block area (ha)	Block area (%)
<0.1	10,914	67.0	142,401	82.7
0.1–<0.2	1,406	8.6	10,407	6.0
0.2–<0.3	935	5.7	5,685	3.3
0.3–<0.4	707	4.3	4,132	2.4
0.4–<0.5	519	3.2	2,657	1.5
0.5–<0.6	545	3.3	3,146	1.8
0.6–<0.7	444	2.7	1,990	1.2
0.7–<0.8	427	2.6	1,269	0.7
0.8–<0.9	276	1.7	395	0.2
0.9–1.0	119	0.7	94	0.1
Total	16,292	100	172,179	100

The highest mean coverage value was seen in District 11. Land-use blocks in this district had a mean coverage ratio of 0.74. The urban districts of district 2, 4, 5, 6, 10,

and Phu Nhuan all recorded medium coverage ratio of above 60%. The blocks of District 1 were calculated to have a medium coverage ratio of 0.58. The urban district of Tan Phu was the only other district to have a medium coverage ratio below 50%. However, the total of 13 urban districts of HCMC had a medium coverage ratio of 0.60. The peri-urban districts of HCMC displayed the medium coverage ratio of 0.20 and the rural districts 0.03.

Figure 6–11 highlights the relationship between the mean coverage ratio per land-use block and distance from the city centre. Within 1 km of the city centre the mean coverage ratio were calculated to be 0.51. In the Figure, the highest coverage ratios can be seen to occur between 3 km and 4 km from the city centre with a high of 0.54. After this peak coverage ratio values are seen to steadily decrease with distance for the centre. It is not until a distance of 11 km from the city centre is reached before mean coverage ratio values fall below 20%.

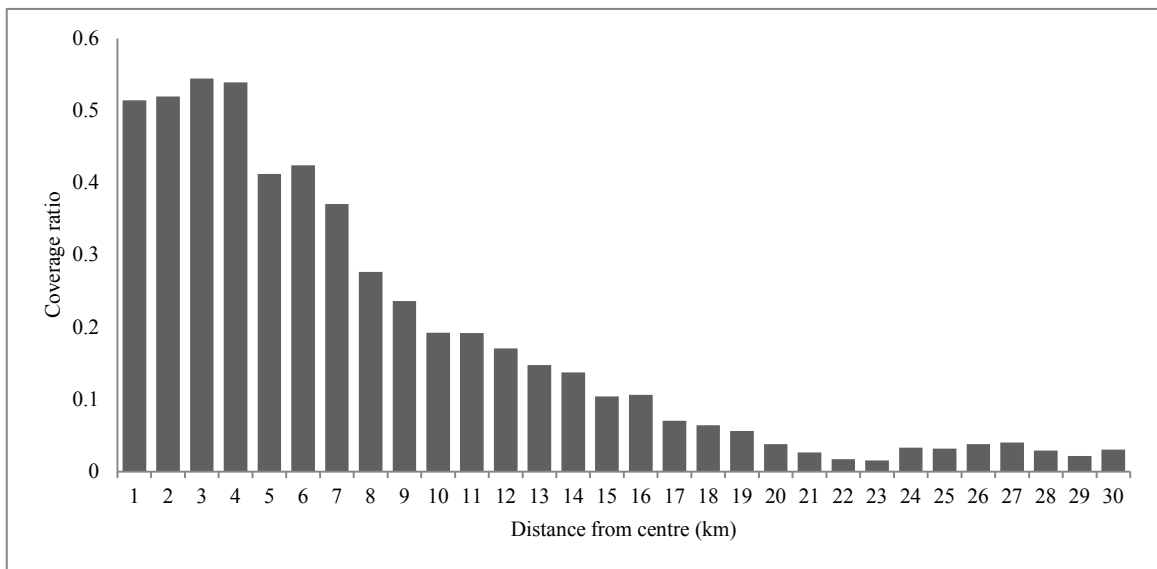


Figure 6–11 Relationship mean coverage ratio and distance from city centre

Figure 6–12 shows boxplot results of the calculated medium coverage ratio values for each UST. The highest medium values were found in two USTs shophouse regular narrow and shophouse irregular high-dense, both with a medium coverage ratio of 0.72 (see Table 6–17) The UST shophouse irregular temporary displayed the third highest coverage value with 0.70. Chinese apartment (*code 311*) and Social apartment (*code 313*) showed coverage ratios of 0.67 and 0.69 respectively.

Table 6–17 Highlighted medium coverage ratio values for individual USTs

Highest		Lowest	
Shophouse regular narrow (code 113)	0.72	Shophouse irregular with fields (code 125)	0.04
Shophouse irregular high-dense (code 212)	0.72	Shophouse irregular clustered (code 124)	0.13
Shophouse irregular temporary (code 126)	0.70	Shophouse irregular scattered (code 123)	0.15

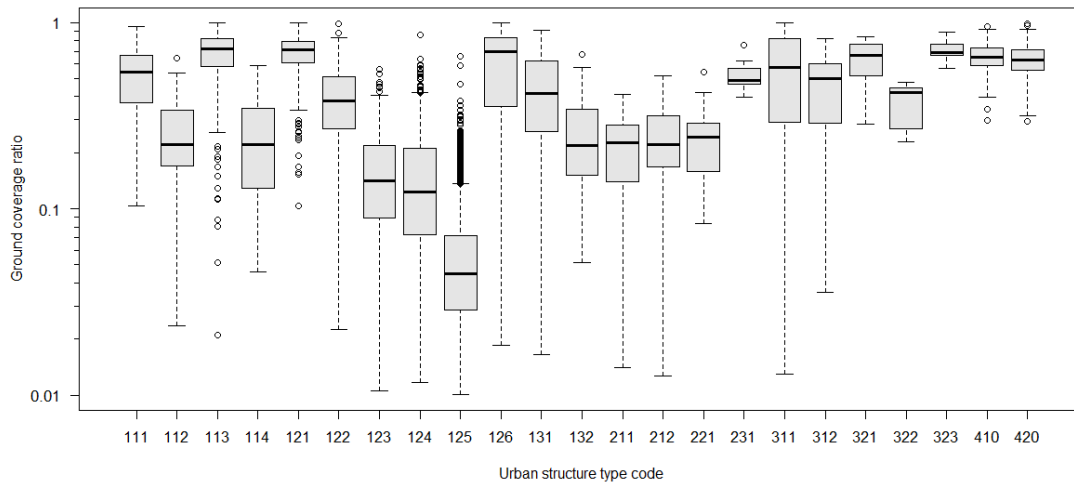


Figure 6–12 Relationship between medium coverage ratio and USTs

The UST CBD (*code 420*) exhibited medium coverage ratios of 0.65. The lowest medium coverage ratios were seen in the peri-urban shophouse irregular with field UST which was calculated to have a value of 0.04. Other low values were seen in the USTs shophouse irregular clustered with a value of 0.13 and shophouse irregular scattered with a value of 0.15.

Table 6–18 highlights that in terms of shophouse based UST, the regular shophouse group displayed a medium coverage ratio of 0.62, while irregular shophouse group had a calculated medium coverage ratio of 0.48 additional stories and the peri-urban shophouse group 0.07. The mixed shophouse group was calculated to have medium coverage ratio of 0.39.

The regular villa group and the mixed villa group displayed medium coverage ratios of 0.22 and 0.42 respectively. The new apartment *group* had a medium coverage ratio of 0.51 while the old apartment group had a higher medium coverage ratio of 0.67. Finally on medium coverage ratios of the land-use blocks within the CBD group were calculated to be 0.64.

Table 6–18 UST groups and medium coverage ratio values

Regular shophouse (codes 111, 112, 113, 114)	0.62	Mixed villa (codes 221, 223)	0.42
Irregular shophouse (codes 121, 122, 126)	0.48	Apartment new (codes 311, 312)	0.51
Peri-urban shophouse (codes 123, 124, 125)	0.07	Apartment old (codes 321, 322, 323)	0.67
Mixed shophouse (codes 131, 132)	0.39	Central business district (codes 411, 412)	0.64
Regular villa (codes 211, 212)	0.22	All residential	0.17

The results show many areas of HCMC are extensively covered by built structures. This is enforced by the current building regulations that permit up to 100% coverage rates on small plots. Both the row- and back-to-back- development patterns of dominant inner city shophouse based UST result in very low levels of unbuilt space. This results in the very high building coverage ratios per block of up to 100%. Where such values have been calculated, reasonable solutions must be found for natural lighting and ventilation. One solution would be to ensure that developments leave space at the back of developments or adjacent to buildings.

The results will allow the HCMC planning authorities to check compliance with the national regulations on a range of administrative spatial levels. In the future for large new developments and re-developments of existing sites, particularly in the inner urban areas, it will be critical to decrease coverage ratios to reduce the risks of UHI and flooding in HCMC. In the inner-city areas the permeability of buildings at street levels needs to be provided for ventilation and thermal comfort considerations. Here ventilation corridors and setbacks parallel to the prevailing wind patterns need to be respected. Increased setbacks would also have the added benefit of creating more space for flood water retention.

## 6.4 Gross floor area

### 6.4.1 Description and use in planning

Gross floor area (GFA) also known as total floor space, measures the floor space of an individual building or the total floor space area of a number of buildings in an administrative unit. It is an indicator commonly measured in square feet or square metres and used by planning authorities for development regulation and control, designers, architects, builders, and the real estate market. However, the term GFA is

very confusing because the term and its meaning may differ between different countries or even between regions within the same country as different planning authorities often have very different approaches to its measurement. The way of defining GFA is ultimately dependent upon which or what elements of a building are to be included or excluded in the calculation. Thus comparing the results of GFA studies from one country to another is extremely difficult. Generally, the three main approaches of measuring GFA can be seen in Figure 6–13.

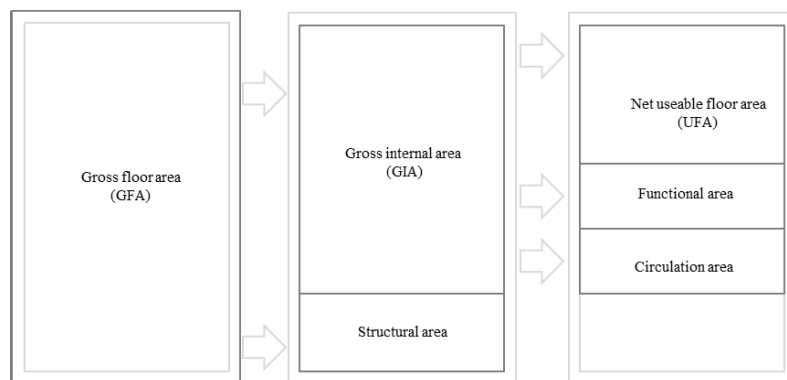


Figure 6–13 Gross floor area and its relationship to other area measurements (*source: author's own*)

The majority of countries define GFA as the whole area of the building including the external walls, measured from and to the external faces of the external walls. GFA includes also corridors, lifts, functional plant rooms, mezzanines. Whereas, gross internal area (GIA) is defined as the total enclosed area of a building within the external walls, taking each floor into account but excluding the thickness of the external walls. It is measured from the internal faces of the external walls. The internal area can then be further subdivided into the net useable floor area (UFA). The UFA is the internal gross net area which is normally the habitable space that is the treated, heated or cooled part of a building. It is the GIA minus the floor areas taken up by functional area and the circulation area such as parking garages, lobbies, attics, enclosed machinery rooms, stairs and escalators, mechanical and electrical services, elevator shafts, columns, sanitation air ducts and even below ground stories.

#### 6.4.2 Importance for climate change and disaster risk reduction

It is widely recognised that the built sector is one of the key consumers of energy (Sivak, 2009; Leth-Petersen and Togeby, 2001; Thiers and Peuportier, 2012; Zhu *et al.*, 2009). Typically, in studies of urban energy demand, total energy use is measured per



GFA, and corrected with building types or UST. Many studies in the literature have investigated the concept of UFA, ‘useable’ or ‘treated’ floor area, referring to the portion of a building that is treated with some form of heating and/or cooling (Isaac and Van Vuuren, 2009). As can be seen in Figure 6–13, this still excludes areas such as underground car parks and other non-treated spaces.

In HCMC, a significant proportion of total city-wide energy consumption is due to direct electricity-use in the ever-growing demand for improved thermal comfort, especially in terms of air conditioning indoor environments (Schwede *et al.*, 2016). In tropical climates, the energy consumed by heating, ventilation and air-conditioning (HVAC) can often exceed 50% of the total energy consumption of a building (Chau *et al.*, 2012). Furthermore in HCMC, the increase in energy intensity per unit area of floor, combined with an increase in floor area, has placed heightened pressure on city-wide energy demands. Climate change and UHI effects are likely to increase thermal discount in the city and will result in higher cooling demand, and more electricity use for air-conditioning, which in turn leads, depending on the electricity sources, to larger GHG emissions and exacerbated climate change effects both globally and locally. Decreasing energy demand or improving the energy performance of buildings is determined by the decisions of a large number of individual owners or developers. However, knowledge about GFA, and other building characteristics that affect a building energy performance is needed for energy modelling.

Monitoring GFA also has the potential to act as a proxy indicator for quantitative information on residential building energy use to determine the growth rates in energy consumption and identify the savings potentials in building types and USTs (Zhou and Lin, 2008). Hereby an UST investigation of GFA can aid the assessment of the needs and benefits of potential policy interventions in the residential sector and recommend future actions to target and harvest energy saving potentials. Furthermore, often minimum energy prices related to specific floor areas for most residential buildings and additional charges are introduced for larger buildings or tax breaks could be introduced for energy saving designs (Tompkins and Eakin, 2012).

#### **6.4.3 Relevance for Ho Chi Minh City**

In Vietnam, floor area limits are governed in the Law on Housing no. 71/2010/ ND-CP and the Construction Law No 16 /2003 (No.16 / 2003/QH11) issued by the MoC. Both

population and economic growth in HCMC has led to growing demand for floor space. In HCMC, measuring GFA is important to estimate and monitor the available residential and commercial floor space in the city, but also for the calculation for additional structural indicators such as floor area ratio (FAR), and the spatial distributions of population and floorspace per person within the city. The amount of floorspace developed per year for employment by type is an economic performance indicator for a number of sectors, as is the amount of GFA in square metres completed for offices, financial services and social housing. Furthermore, by measuring GFA, the spatial pattern of buildings and assets can be assessed to improve urban development planning and adaptation responses. Integrating the GFA information into scenario development can aid the calculation of potential losses following a flooding event. Here the value of the assets can be estimated by multiplying the average cost of specific building types or USTs by the number of buildings for structural damages and losses and average cost times per square meter by the sum of the area to be affected for the potential content loss. Additional GFA calculations and monitoring GFA over time are also important for annual and seasonal energy consumption forecasting.

#### **6.4.4 Previous studies**

Remote sensing studies have typically attempted to automatically detect and measure the area of building footprints as described in Section 6.1.4 and infer building height as described in Section 6.2.4. From this data they have often calculated both building density and GFA subsequently (Bifan, 2005; Li *et al.*, 2007).

Yu and Ng, (2007) measured GFA change as one indicator when investigating the spatial and temporal dynamics of urban sprawl in Guangzhou, China, while, Cheng *et al.*, (2011); carried out a trend analysis of both building height and total floor space in Beijing, China, where they calculated the annual change of GFA for detected buildings using LiDAR sensor data from 2003–2008. Taubenböck *et al.*, (2013) detected GFA to assist in the delineation of the CBDs in London, Paris and Istanbul.

#### **6.4.5 Block-based results and discussion**

For the calculation of GFA within this study, the official building footprint data was used. Here the measured area of each individual footprint, *i.e.* the coverage area was multiplied by the number of stories count that the building contained. In a further step,

the gross floor areas of all buildings in a land-use block were calculated and normalised over the block area so that the results are comparable and not solely influenced by block size. However, it is important to note, although relatively straightforward, this approach has distinct limitations. Generally buildings have large variations in non-residential areas and the results do not taken into account the structural and functional differences between building types.

Figure 6–14 shows the groundfloor plans of both a villa and a terraced shophouse building type. In the Figure, it is apparent that the approach used to calculate GFA does not account for differences in structural areas such as wall thickness, which is dependent upon the building type and the different construction materials utilised, or for functional differences such as the presence of shared lobby or elevator shafts or staircases.

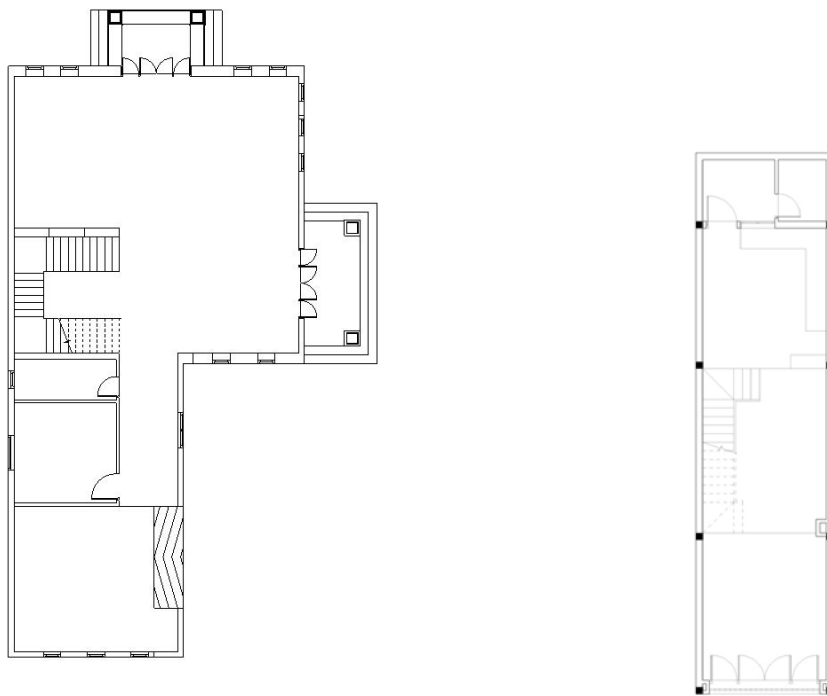


Figure 6–14 Ground floor plans of a villa (*left*) and a terraced shophouse (*right*) (*not to scale*) highlighting the gross floor area, usable floor area and functional and structural areas of both building types (*source: author's own*)

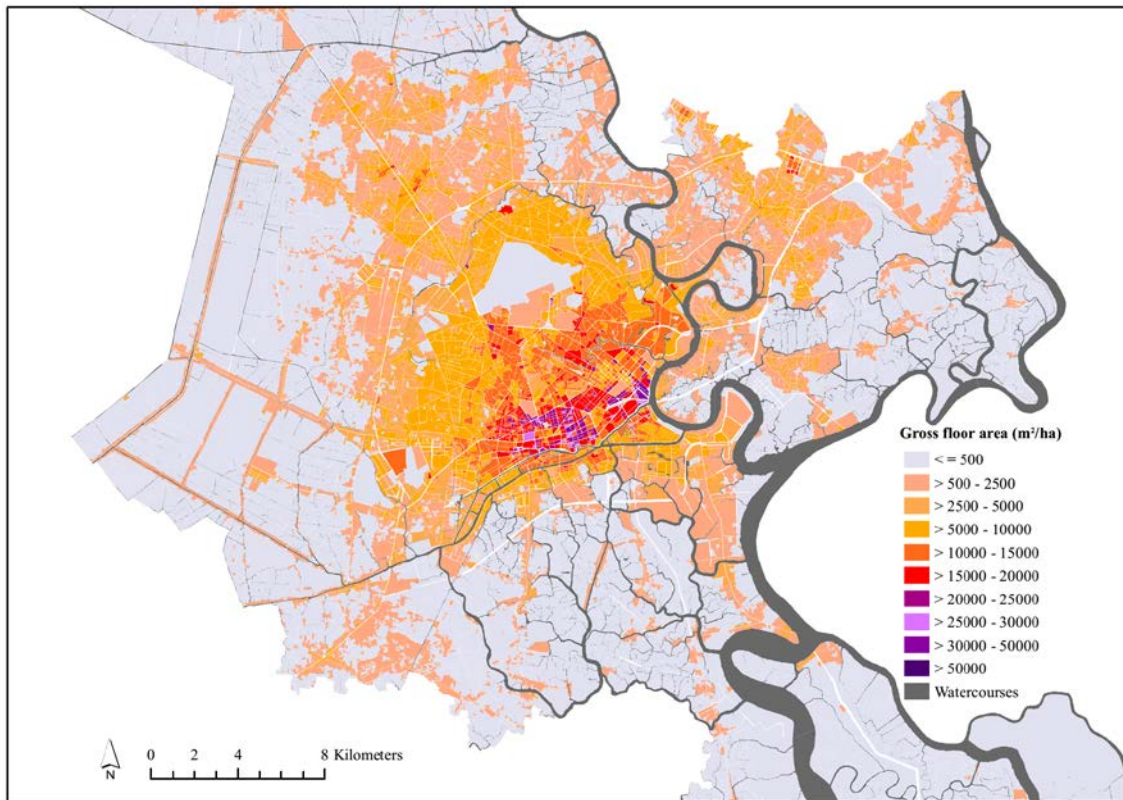


Figure 6–15 Calculated gross floor area per block for Ho Chi Minh City (source: author's own)

Figure 6–15 shows the mapped calculated GFA values per land-use block for the inner core area of HCMC and Table 6–19 shows the distribution of GFA values in terms of both number and area of land-use blocks. Not surprisingly, the land-use blocks showing the highest GFA values were seen in the inner urban districts. Over the whole administrative area the majority of land-use blocks displayed very low GFA values. In total, 75.6% of the administrative area of HCMC was calculated to contain blocks with GFA values of 500 m<sup>2</sup> per ha or less.

In more detail, 13.4% of the land-use blocks total area exhibited GFA values of between 500–2,500 m<sup>2</sup> per ha, while 5.1% of the land-use block were calculated to have GFA values of between 2,500–5,000 m<sup>2</sup> per ha. Only 3.7% of the total land-use block area was calculated to have GFA values of between 5,000–10,000 m<sup>2</sup> per ha. Overall less than 3% of the total block area of HCMC's administrative area was calculated to have GFA values exceeding 10,000 m<sup>2</sup> per ha. The highest medium GFA values per block were seen in the blocks of District 5 and District 1. In these districts some blocks were calculated to exceed 50,000 m<sup>2</sup> per ha of GFA.

Table 6–19 Distribution of gross floor area values ( $m^2$ )

Range	No of blocks of land-use	(%) of blocks of land-use	Block area (ha)	Block area (%)
<500	9,324	57.2	130,193	75.6
>500–2500	3,100	19.0	23,072	13.4
>2,500–5,000	1,466	9.0	8,748	5.1
>5,000–10,000	1,229	7.5	6,301	3.7
>10,000–15,000	640	3.9	2,683	1.6
>15,000–20,000	318	2.0	827	0.5
>20,000–25,000	136	0.8	218	0.1
>25,000–30,000	40	0.2	69	>0.1
>30,000–50,000	35	0.2	58	>0.1
>50,000	4	>0.1	5	>0.1
Total	16,292	100	172,179	100

Land-use blocks in District 5 had a medium floor space of 18,510  $m^2$  per ha, while land-use blocks in District 1 exhibited a slightly lower medium GFA value of 17,033  $m^2$  per ha. The urban districts of District 3, 6, 10, 11 and Phu Nhuan all revealed medium GFA values per block of over 10,000  $m^2$  per ha. Tan Binh and Tan Phu districts were calculated to have medium GFA values per block of 8,928  $m^2$  and 7,314  $m^2$  per ha respectively. All together the 13 urban districts displayed a medium GFA of 10,337  $m^2$  per ha. The blocks in the peri-urban districts of HCMC displayed the medium GFA of 2,358  $m^2$  per ha, while the blocks in the rural districts exhibited a medium GFA of 356  $m^2$  per ha.

Figure 6–16 highlights the relationship between the mean GFA per land-use block and distance from the city centre. The results provide clear insight into the structure and distribution of floorspace within HCMC. The highest mean GFA values were seen within 1 km of the city centre with a mean of 16,700  $m^2$ . The second highest GFA values can be seen at 4 km from the city centre with a mean 11,139  $m^2$  of GFA. Following this slight second peak, at 7km from the city centre mean values fall below 4,000  $m^2$  and steadily decrease with distance from the city centre.

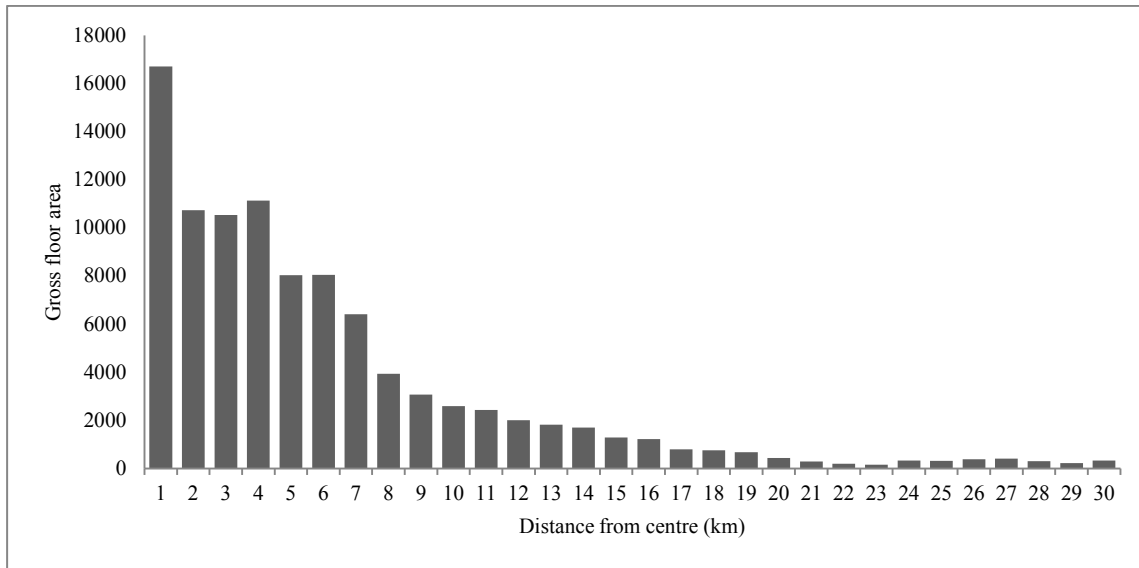


Figure 6–16 Relationship between mean gross floor area and distance from city centre ( $m^2$ )

Figure 6–17 shows boxplot results of the calculated medium GFA values for each UST, while Table 6–20, highlights the highest and lowest three individual values. The calculated medium GFA values vary significantly between USTs. The highest medium values were found in the social apartment UST with a medium GFA of 24,344  $m^2$  per ha. The second highest recorded values were seen in the CBD with high dense with a medium GFA of 19,308  $m^2$  per ha. The low-rise apartment UST was seen to have the third highest medium GFA value with 14,202  $m^2$  per ha. Land-use blocks classified as CBD UST (*code 410*) displayed a medium GFA of 13,385  $m^2$  per ha, while blocks classified as shophouse regular narrow (*code 113*) displayed a medium GFA of 13,314  $m^2$  per ha and the blocks classified as shophouse irregular high-dense (*code 121*) a medium GFA of 11,367  $m^2$  per ha.

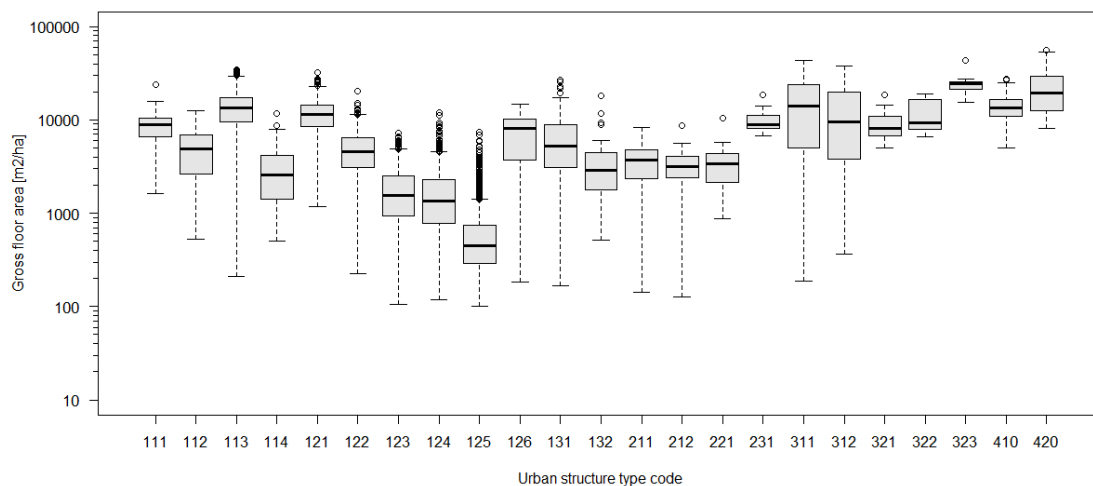


Figure 6–17 Relationship between medium GFA and USTs

Table 6–20 Highlighted gross floor area values for individual USTs (m<sup>2</sup>)

Highest		Lowest	
Social apartment (code 323)	24,344	Shophouse irregular with fields (code 125)	453
CBD with high-dense (420)	19,308	Shophouse irregular clustered (code 124)	1,432
Low-rise apartment (312)	14,202	Shophouse irregular scattered (code 123)	1,656

The lowest medium GFA values were seen in the peri-urban shophouse irregular with field UST which was calculated to have a value of 453 m<sup>2</sup> per ha. Other low values were seen in the USTs shophouse irregular clustered with a value of 1,432 m<sup>2</sup> per ha and shophouse irregular scattered with a value of 1,656 m<sup>2</sup> per ha.

In terms of shophouse based UST, the regular shophouse group displayed a medium GFA of 10,349 m<sup>2</sup> per ha, while the irregular shophouse group had a calculated medium GFA of 5,965 m<sup>2</sup> per ha and the peri-urban shophouse group 734 m<sup>2</sup> per ha (Table 6–21). The mixed shophouse group was calculated to have medium GFA of 5,031 m<sup>2</sup> per ha. The regular villa group and the mixed villa group displayed medium coverage ratios of 3,308 m<sup>2</sup> per ha and 6,674 m<sup>2</sup> per ha respectively. The new apartment group had a medium GFA of 11,651 m<sup>2</sup> per ha, while the old apartment group had a higher medium GFA of 14,332 m<sup>2</sup> per ha. Finally on medium GFA value of the land-use blocks within the CBD group were calculated to 14,413 m<sup>2</sup> per ha.

Table 6–21 UST groups and medium building density values (m<sup>2</sup>)

Regular shophouse (codes 111, 112, 113, 114)	10,349	Mixed villa (codes 221, 223)	6,674
Irregular shophouse (codes 121, 122, 126)	5,965	Apartment new (codes 311, 312)	11,651
Peri-urban shophouse (codes 123, 124, 125)	734	Apartment old (codes 321, 322, 323)	14,332
Mixed shophouse (codes 131, 132)	5,031	Central business district (codes 411, 412)	14,413
Regular villa (codes 211, 212)	3,308	All residential	1,930

## 6.5 Building volume

### 6.5.1 Description and use in planning

The urban environment of HCMC is made up of both solid built volumes and empty spaces. The analysis of these solid buildings or the built mass, in terms of volume is

important and essential for planners and decision makers to control urban morphology and the intensity of development (Venturelli and Galli, 2006). The building volume basically portrays the three-dimensional extent of the built up area. The determinants of building volume are the socio-economic functions, building types, their shape, size, and number per block. In practice, building volume is an important indicator useful for urban risk, urban energy and urban climate studies.

### **6.5.2 Importance for climate change and disaster risk reduction**

Building volume as an indicator has undergone considerable development in terms of energy efficiency studies (Anderson, 1996; Ratti *et al.*, 2005; Blesi, 2010; Parshall *et al.*, 2010; Chen *et al.*, 2011; Baiocchi *et al.*, 2015). The building stock of HCMC, as in other major cities, is the major energy consumer and emitter of CO<sub>2</sub> (Salat, 2009; Makido *et al.*, 2012; Marcotullio *et al.*, 2012; Ou *et al.*, 2013). Tackling the energy demand of the existing and newly developed building stock is a priority for HCMC. Locally energy consumption in the built sector is dependent upon the various factors including urban morphology, building archetypes, construction technologies, energy systems, and inhabitant behaviors (Yoshida and Omae, 2005).

For energy studies, authors have suggested that building volume is a better indicator for treated space than GFA, because it is the volume of air that is heated or cooled. The volume specific heating or cooling demand of a building correlates with the physiognomic building characteristics, as well as the usage of a building. High building volume rates also have the disadvantage of reduced solar and daylight availability (Swaid, 2003; Lam, 2000; Steemers, 2003; Miguët, and Groleau, 2002; Robinson, 2006). Furthermore, typical green building standards and energy performance standards make use of the relationship between a building's volume and its surface area (surface to volume ratio) in cataloguing a building's efficiency using energy performance (Ratti *et al.*, 2005).

The UHI affect is greatly influenced by building volumes. Ng and Ren (2015), underline that the built mass of a city stores a significant amount of solar energy received during the duration of the daytime. This elevates both the surface and air temperatures of the local urban environment, especially at night when it is released back into the surroundings. A principle cause of the high thermal load in a city such as HCMC is a low sky view factor (SVF). This is where a high volume urban development



decrease the sky view. Additional factors that cause the high thermal load are the effect of the urban canopy and an increased surface roughness parameter. All these factors lead to a reduction of air flows and natural ventilation, reduction in micro-winds and ultimately a reduction in the cooling potential during non-daylight hours.

Built urban volumes per se and building height, as well as, street block patterns and configurations affect both the wind speed and wind direction and determine the friction of exposed urban land with respect to the wind field (Sanaieian *et al.*, 2014; Hoechstetter *et al.*, 2010). High volume buildings built close together also tend to act as wind-blockers, blocking the amount of energy that can be released back to the atmosphere (Katzschner *et al.*, 2016). UHI intensity has been shown to decrease with increasing wind speed in many studies, leading to a reduction in convective heat removal.

There is a general perception that low-density development has less impact on the microclimate of cities (Ackerman, 1985; Park, 1986; Travis *et al.*, 1987; Rizwan *et al.*, 2008; Kidder and Essenwanger, 1995; Eliasson, 1996; Ripley *et al.*, 1996; Figuerola and Mazzeo, 1998; Magee *et al.*, 1999; Morris *et al.*, 2001; Unger *et al.*, 2001; Sanaieian *et al.*, 2014). Moreover, building volume together with SVF and the height-width ratio of building's are important input parameters for urban climate modelling and simulation (Zhao *et al.*, 2011; Petralli *et al.*, 2014; Geiß *et al.*, 2011; Andersson-Sköld *et al.*, 2015). Planners have often control of site coverage ratios and building volumes, building alignment and composition. Fundamentally, it is important to ensure that buildings and their planning do not block the ambient background wind synoptically (Yang *et al.*, 2013).

Urban built volume data enables the evaluation of the local urban climate in terms, which are useful to urban planners and architects. Building volume data was used together with coverage data in the Hong Kong Urban Climatic Map Project to estimate both UHI and wind speeds (Ng, 2009; Ren *et al.*, 2011; Katzschner, 2011). Higher urban temperatures also lead to an increase of the energy consumption in cities for cooling requirements, leading to a significant increase in the peak electricity demands (Santamouris *et al.*, 2001, Kolokotroni *et al.*, 2012). The problem is further aggravated by the anthropogenic heat released by air conditioning units, vehicles and other heat sources, as it further raises the urban air temperature. In terms of risk, disaster and emergency assessments, knowledge of the spatial distribution of buildings volumes is

essential. Reliance on solely other indicators may lead to wrong assessment decisions and evaluation outcomes. If for example building footprint and building density information is only used for a specific area that has a low building density, but high building volume, a risk assessment could lead to an underestimation of both the potential losses and reconstruction costs.

Dolce *et al.*, (2006), state that knowledge of building volume values can aid the better calculation of both cost and loss functions and additionally can aid the calculation of structural vulnerability information. The most precise and detailed building assessments are obtained by measuring the volume of individual single buildings. The height and footprint of a building can then determine the volume of a building, which can be used for example to estimate the number of people living in a certain building, or if extrapolated, to estimate the population in a specific area, to more precisely estimate population densities and human exposure to potential risk.

Building volume information also plays a crucial role in the expanding three-dimensional city model market (Krüger and Kolbe, 2012). Three-dimensional city models offer a wide range of applications for urban governance, including architectural applications, disaster and emergency assessment, facility mapping, real estate business, environmental studies and simulations, and utility provision (Nichol and Wong, 2005). Building volumes are also particularly interesting for material flow modelling and enhanced population mapping.

### **6.5.3 Relevance for Ho Chi Minh City**

In Vietnam, the only national legislation which addresses building volume is decree No 79/2014/NĐ-CP issued by the government in 2014. The decree outlines fire hazards and fire safety standards and thresholds for new developments. The development of educational centres greater than 5,000 m<sup>3</sup>, entertainment centres greater than 1,500 m<sup>3</sup>, public offices greater than 1,000 m<sup>3</sup>, markets greater than 1,000 m<sup>3</sup>, hotels greater than 5,000 m<sup>3</sup>, institutes greater than 5,000 m<sup>3</sup>, underground car parks greater than 1,000 m<sup>3</sup> and storage facilities greater than 1,000 m<sup>3</sup> must have approved detailed fire safety designs and fire protection.

The effect of built volumes in dense areas of HCMC is very significant. A small number of countries regularly collect data on building volume. However this is not the case in Vietnam. The precise building volume is notoriously difficult to measure. In this study,

the building volumes in HCMC were defined to be the result of the building ground floor area multiplied by the corresponding building height derived from the number of additional stories of the building. As such building volume per land-use block was measured as the sum of the volume of all buildings and is calculated on the basis of the building footprint and differentiated building type-related number of stories and floor heights. Building shapes and layouts in reality are normally very complex. Typical assumptions define walls as being vertical and roofs as being a composition of planar faces. This leads to an idealisation of the buildings. To increase the reliability of the building volume results, as well as, the range of possible applications, additional knowledge of the building archetypes was incorporated into the calculation process. As such, the physical parameters of building footprint area and building heights were calculated individually for every building footprint of every land-use block. The results of building volume ( $\text{m}^3/\text{ha}$ ) describes the ratio of building volume to the reference area of the land-use block and therefore provide an indicator for the quantification of development densities.

#### **6.5.4 Previous studies**

Commonly in the literature, remote sensing methods have been used to measure building volume and produce three-dimensional city models (Taubenböck *et al.*, 2011). However, these methods can only estimate building volume from sensed height and area information at best. Here building area information is derived from the sensed building footprints (Li *et al.*, 2007; Wang and Wang, 2009).

As discussed previously, there are two main methods for estimating the height of buildings remotely. One option is to derive the height of buildings by evaluating the shadows from an image and then relate shadow length to height. Another method is the estimation of building heights from airborne LiDAR technology or stereo imagery, which requires two slightly offset images of the same area and specialised software and expertise and therefore is much more expensive. Yoshida and Omae (2005), Yu *et al.*, (2010), and Hermosilla *et al.*, (2014) all defined descriptor geometric and volumetric attributes to describe the size and shape of buildings for the quantitative interpretation of urban areas using LiDAR data in Tokyo, Houston and Valencia respectively. While Vanderhaegen and Canters (2010), used descriptive geometric and volumetric attributes

to study radial urban block profiles that characterised the volumetric distribution of buildings in Brussels.

### **6.5.5 Block-based results and discussion**

The residential buildings archetypes of HCMC were seen to vary remarkably in terms of individual story heights, whereas non-residential building categories showed an even larger variation in terms of size and story heights. For the residential building archetypes, the exact heights of stories were difficult to define with suspended ceilings and raised floors often complicating the measurements.

In this study, building volume per block is calculated with the aid of UST specific mean story heights based on the building archetypes they contained. Here the actual floor heights were groundtruthed in HCMC, as well as discussed with local architects. The final volume measurement did not however, take into account below ground stories, and assumed also that all roofs were flat. The height of a building was taken to be the sum of the floor to ceiling height of each story plus the floor thickness of the construction materials and spaces between each story.

Generally, story heights above the ground level were seen to vary between 2.7 m–3.0 m, however heights were seen to vary widely for the ground floor of buildings. Likewise, the technical service space between floors was seen to be uniformly on average 0.3 m thick. Furthermore, stories within a building need not be all the same height - typically the ground story of a building in HCMC is always taller than the additional stories. This is the case for example, for both newly developed shophouses and apartments where the ground level story is more spacious and taller. The floor thickness between stories is also significantly thicker in both low- and high-rise apartments.

Figure 6–18 shows a cross section of a detached shophouse building archetype highlighting the differences in average story height for the ground story and the additional stories above. Additionally a prominent feature in many very tall buildings is that higher stories may become smaller in area than the stories beneath.

Calculated and mapped spatial distributions of building volume for the urban core HCMC are presented in Figure 6–19. The distribution of building density values in terms of the number and area of land-use blocks can also be seen for reference in Table 6–22.

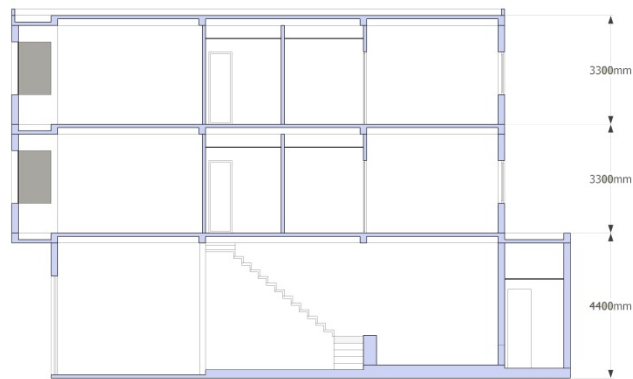


Figure 6-18 Cross-section of a detached shophouse building archetype showing an average ground story height of 4.4 m and an average height of 3.3 m for all additional floors (*source: author's own*)

Since different districts and localities of a city accommodate distinctly different urban economic, social and cultural functions, it is to be expected that building size, height, volume, density, heterogeneity and vertical roughness vary from district to district. It is immediately apparent from Figure 6–19 that the mapped results visibly show the concentric structure of the calculated building volumes in HCMC, with the highest values found in the inner core areas, which in terms of high built volumes stretch linear between District 1 and District 5 from east to west. The mapped values show that a number of areas of the urban districts already exhibit particularly high built volumes above 20,000 m<sup>3</sup> per ha. In terms of climate change adaptation discussions on the appropriate built volumes to safeguard against enhanced UHI, these results have particular significance. The highest absolute building volumes were seen in an individual land-use block of District 1, while the highest mean values were seen in District 5. The mean building volume for land-use blocks in District 5 was 18,500 m<sup>3</sup> per ha and in District 1 slightly over 17,000 m<sup>3</sup> per ha. District 10 and District 11 both had a calculated mean building volume of over 15,000 m<sup>3</sup> per ha while, District 3, 4, 6 and Phu Nhuan exhibited calculated mean building volume values of over 10,000 m<sup>3</sup> per ha. As the results in Table 6–22 outline the whole administration area of HCMC and not solely the UST blocks classified as built-up it is not surprising that 51.9% of land-use blocks and 71.4% of the total area of HCMC exhibited building volume values below 1,000 m<sup>3</sup> per ha. Approximately 19.9% of land-use blocks and 14.2% of the total area of HCMC displayed building volumes of between 1,000–<5,000 m<sup>3</sup> per ha. Only 28.1% of the land-use blocks and 14.3% of the total area of HCMC displayed building volumes above 5,000 m<sup>3</sup> per ha.

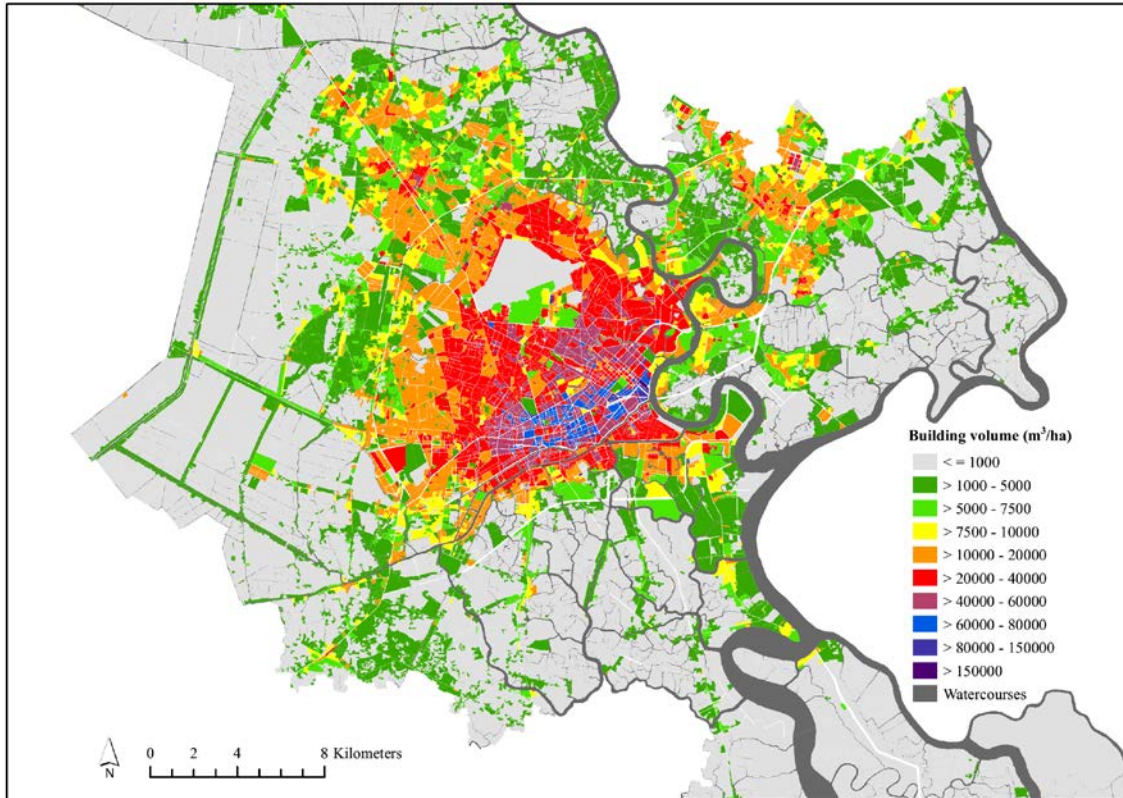


Figure 6–19 Calculated building volume per block for Ho Chi Minh City (source: author's own)

Table 6–22 Distribution of building volume values ( $m^3$  per ha)

Range	No of blocks of land-use	(%) of blocks of land-use	Block area (ha)	Block area (%)
<1,000	8,448	51.9	123,009	71.4
1,000–<5,000	3,240	19.9	24,468	14.2
5,000–<7,500	736	4.5	5,753	3.3
7,500–<10,000	587	3.6	3,830	2.2
10,000–<20,000	1,421	8.7	7,801	4.5
20,000–<40,000	1,124	6.9	5,334	3.1
40,000–<60,000	493	3.0	1,509	0.9
60,000–<80,000	171	1.0	351	0.2
80,000–<150,000	66	0.4	108	0.1
$\geq 150,000$	6	0.0	14	0.0
Total	16,292	100	172,179	100

Figure 6–20 shows the three-dimensional density in terms of mean volumes of buildings and distance from the city centre. The Figure further visualises the concentric pattern to

building volumes in HCMC. The results indicate the relatively large number of high volume buildings in the CBD of HCMC and this in short will ultimately increase the localised heat capacity (*i.e.* thermal load) and significantly affect the local micro-wind environment, leading to a poorer urban ventilation condition and a stronger UHI effect. In warm and humid regions like HCMC, these conditions will elevate the level of thermal stress experienced by residents. The calculated mean building volumes within 1 km of the city centre were relatively high in comparison to further distances away from the city centre. Out of all the land-use blocks within 1 km of the city centre the mean building volume was calculated to be 56,300 m<sup>3</sup> per ha. The mean values at a distance of 2 km, 3 km and 4 km from the city centre generally show similar mean building volumes with 35,000 m<sup>3</sup> per ha, 32,500 m<sup>3</sup> per ha and 34,180 m<sup>3</sup> per ha respectively. The mean building volume values in the land-use blocks at distance 5 km and 6 km also show comparable results at both approximately 24,600 m<sup>3</sup> per ha. Moreover, the mean building volume values for the land-use block at a distance of 7 km from the centre was 19,200 m<sup>3</sup> per ha. Thereafter building volumes are seen to more gradually decrease with distance to the urban towards the periphery.

It is also interesting to explore the building volume results to the classified UST. For visualization, Figure 6–21 shows boxplot results of the calculated medium building volume values for each UST. While Table 6–23 shows the individual values for selected USTs.

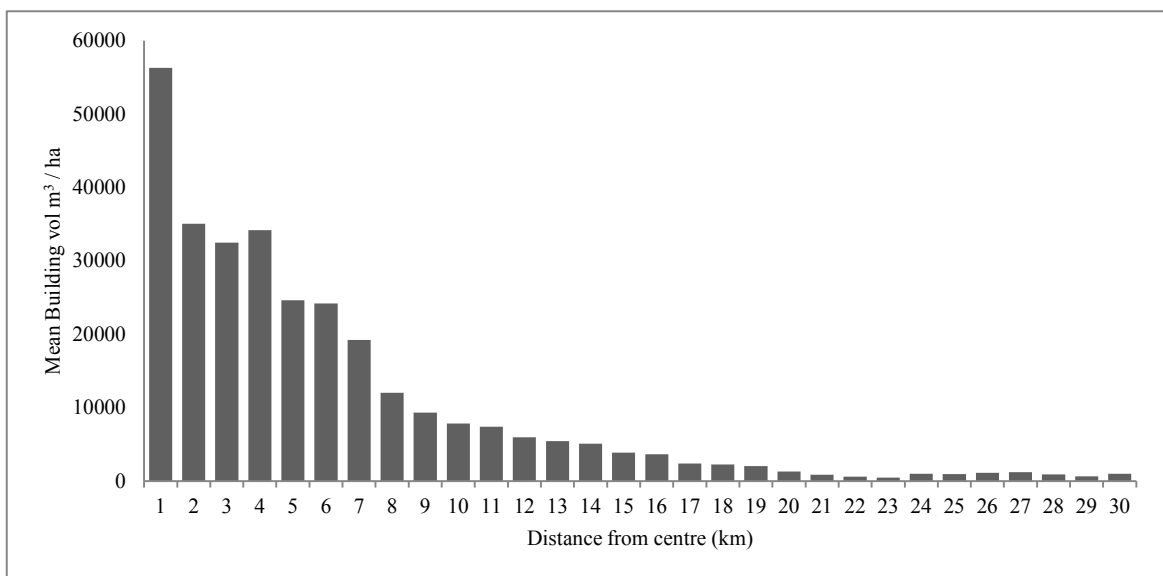


Figure 6–20 Relationship between mean building volume and distance from city centre (m<sup>3</sup> per ha)

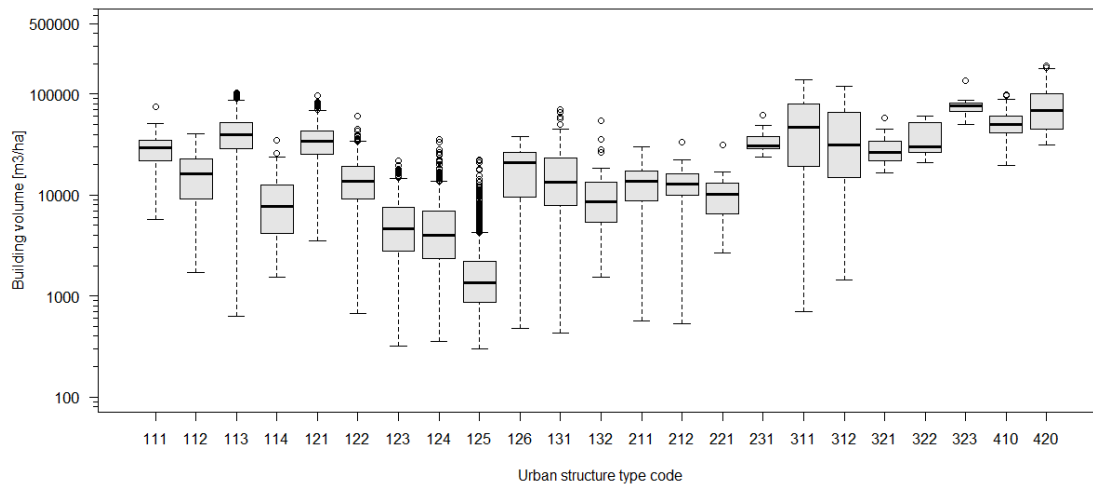


Figure 6–21 Relationship between medium building volume and USTs

Table 6–23 Highlighted medium building volumes for individual USTs ( $m^3$  per ha)

Highest		Lowest	
Social apartment (code 323)	77,047	Shophouse irregular with fields (code 125)	1,360
CBD with high-dense (420)	69,164	Shophouse irregular clustered (code 124)	4,296
Low-rise apartment (311)	46,878	Shophouse irregular scattered (code 123)	4,969

The highest medium building volume values were displayed in the UST social apartment with a calculated value of 77,047  $m^3$  per ha and the second highest values were seen in the UST CBD with high dense with a value of 69,164  $m^3$  per ha. The land-use blocks classified as low-rise apartment UST had a medium building volume of 46,878  $m^3$  per ha. The land-use blocks with the UST shophouse regular with narrow alleyways (*code 113*) had a medium building volume of 39,943  $m^3$  per ha, while the UST shophouse irregular high-dense (*code 121*) had a calculated medium building volume of 34,101  $m^3$  per ha. The only other UST to display medium building volumes over 30,000  $m^3$  per ha were the colonial villa (*code 231*) and the high-rise apartment (*code 312*) UST. The lowest building volumes were seen in the UST Shophouse irregular with fields (*code 125*) with a medium building volume of 1,360  $m^3$  per ha.

Table 6–23 shows the UST group results for calculated medium building volume values. Overall the regular shophouse group displayed a medium building volume of 32,401  $m^3$  per ha, while the irregular shophouse group had a calculated medium building density of 17,723  $m^3$  per ha, and the peri-urban shophouse group 2,201  $m^3$  per ha.



Table 6–24 UST groups and medium building volumes ( $m^3$  per ha)

Regular shophouse (codes 111, 112, 113, 114)	32,401	Mixed villa (codes 221, 223)	23,961
Irregular shophouse (codes 121, 122, 126)	17,723	Apartment new (codes 311, 312)	42,166
Peri-urban shophouse (codes 123, 124, 125)	2,201	Apartment old (codes 321, 322, 323)	45,436
Mixed shophouse (codes 131, 132)	13,164	Central business district (codes 411, 412)	53,490
Regular villa (codes 211, 212)	13,287	All residential	5,768

The mixed shophouse group was calculated to have a much larger medium building volume of 13,164  $m^3$  per ha. This is to be expected as a characteristic of this UST group is its association with industry with a relatively smaller proportion of buildings that are residential.

The regular villa group displayed a medium building volume of 13,287  $m^3$  per ha, while the mixed villa group displayed the larger volume of 23,961  $m^3$  per ha. The new apartment group showed a medium building volume of 42,166  $m^3$  per ha, while the medium building volume of the old apartment group was measured slightly higher at 45,436  $m^3$  per ha.

The CBD group was calculated to have the highest medium building volume of any group of UST with 53,490  $m^3$  per ha. The extreme volumes in this group highlight as shown in Figures 6–19 and 6–20, the high volume development of the inner city as one of the main influencing factors for the UHI effect and an important consideration for urban climate planning. In total the classified residential USTs of HCMC exhibited a medium building volume of 5,768  $m^3$  per ha.

## 6.6 Floor area ratio

### 6.6.1 Description and use in planning

Floor area ratio (FAR) has historically been used as a key indicator and tool to monitor urban development and to regulate density in zoning ordinances in many cities worldwide. FAR also known as floorspace ratio (FSR) or floorspace index (FSI) is used by planners to control the extent of the built-up area on a given development parcel (Gao *et al.*, 2006). FAR is defined simply as the ratio of gross floor area (GFA) on a zoned land parcel in relation to the size of the parcel. Resultantly the value of FAR is

determined not only by the planimetric form of the building, but also by the three-dimensional building form (Khan and Mahmud, 2008; Chan *et al.*, 2009; Joshi and Kono, 2009; Yu *et al.*, 2010; Behling *et al.*, 2015). Because FAR represents this relationship, it is also used to describe the bulk or mass volume of a development. It typically restricts building size by stating the maximum GFA permitted for each square metre of land parcel area; regardless of the building height. As such, it has gained widespread acceptance because it limits the GFA in a development parcel, while permitting developers and architects more flexibility in the shape of the structure.

In nearly every planning ordinance in which FAR is used, it is simply calculated by dividing the GFA of all buildings within a land parcel in square metres by the area of the land parcel in square metres. In planning practice, FAR is constant for a specific zone. A FAR of 1.0 would equate that the GFA is equal to the development parcel. A building with a FAR 2.0 would indicate that the total floor space of the buildings within a land-use block is twice the total gross area of the block upon which they are constructed. This would be found in a multi-story building. If for example the relevant zoning ordinance permits development on a land parcel, and if any said development must adhere to a FAR 0.10 then the total GFA of all in all buildings constructed on that parcel must be no more than one-tenth or 10% of the gross area of the parcel itself. In this sense, a maximum FAR of 5.0 would permit a GFA of up to five times as large as the development parcel area, while a maximum FAR of 0.5 would only allow GFA of no more than half of the development parcel area.

Figure 6–22 illustrates a series of FAR measurements and their relation to both gross coverage ratio and number of stories. While FAR can be used as a proxy indicator for both building size and scale, it does not represent the shape of the development. Therefore as seen in Figure 6–22, two developments that have the same FAR can result in very different number of stories and ground coverage ratios. FAR also does not regulate the placement of the building within the development parcel. Resultantly, Gao *et al.*, (2006) stated that FAR can and should be used in combination with other building spacing requirement such as maximum height and minimum set-backs. Nonetheless maximum FAR regulations not only control GFA but also indirectly building height, volume, population density and floor area consumption per capita (Joshi and Kono, 2009; Kono *et al.*, 2010; Kumar, 2013).

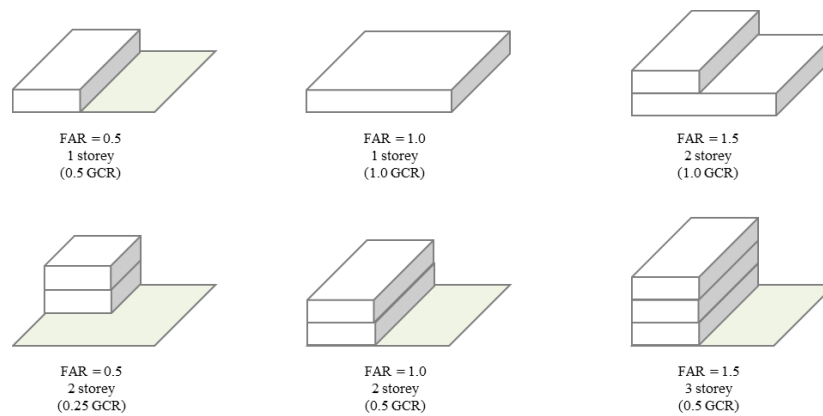


Figure 6–22 Theoretical explanation of FAR

While used extensively, maximum FAR regulations should also be used with caution. Growing urban areas which are zoned with a relatively low maximum FAR restriction, may encourage low-density horizontal expansion and potentially urban sprawl, resulting in a more dispersed pattern of urbanisation. Bertaud and Brueckner (2005), found that by limiting population densities close to the city centre, a FAR restriction caused the city to expand spatially, which in turn affected commuting distances and house prices in Bangalore, India. Low FAR and minimum development and housing standards that are expensive have been found to restrict the supply of land and housing for low income households in safe areas (Nallathiga, 2003; Lall and Deichmann, 2011). This often results in the occupation of hazardous unsafe areas. Another noted disadvantage of FAR regulations is that they do not directly control population densities, solely only the available GFA of a development in a parcel without controlling the per-capita floor space consumption. Consequently, as tighter FAR regulations reduce the GFA, per capita use of floor space can simply decrease. However, by allowing higher FAR regulations, floorspace per capita use may also increase. Ng and Wong (2004), report that increasing the FAR in Hong Kong, actually let to an increase in the floorspace per capital between 1970–1980, while Bertaud (2011), reported the same findings for Shanghai.

### 6.6.2 Importance for climate change and disaster risk reduction

The actual setting of FAR is challenging and dependent on the overall planning vision (Tsai, 2014; Bertaud and Brueckner, 2005). As urbanisation and population growth rates change, the specific environmental consequences of development vary. For that

reason, FAR regulations should also be subject to review concomitantly with urban development (Yu *et al.*, 2010). Occasionally, minimum FAR regulations are set to increase building density or to potentially prevent underdevelopment in certain areas and promote reinvestment. Increasing FAR limits likely leads to an increase in population density, which in turns will place extra pressure on existing infrastructure that now has to accommodate the increased density and also the resultant loss of greenspace. Therefore, when considering increasing FAR, suitable infrastructure capacities also have to be considered and planned which have the ability to absorb the increased build densities and populations.

The expenditure of infrastructure is a clear function of urban density (Deilmann and Hennersdorf, 2009). From a climate change adaptation perspective, developments should be prohibited unless public infrastructure is in a place to support or protect. Any increase in FAR, which cannot be supported by the existing infrastructure, for example by dykes has to occur hand in hand with infrastructure up-grading and improvement.

FAR like other density regulations indirectly limits the occupancy load in a specific area. It has the potential to be used as an analytical tool to make broad projections of the impact of different land-use and development intensity scenarios based on a set of land-use characteristic and climate change assumptions. Excessive FAR regulations may lead to shortages in formal land supply in safe areas. Halting high population densities developing in areas exposed to flooding can be enforced via higher FAR ceilings in safe areas, while tougher regulations in unsafe areas. This will ultimately control the number of elements exposed to the hazard by control of GFA.

Higher FAR regulations which permit and promote higher volume multi-story and high-rise buildings, will affect both wind speeds and the urban climate in the manner as outlined previously, leading to a potential increase in the UHI effect (Giridharan *et al.*, 2005). Dugord *et al.* (2014), found that alongside soil sealing and distance to city centre, FAR is a good predictor of land surface temperatures in the German city of Berlin. Larger, more spacious buildings use more energy, while higher FAR values will also affect natural lighting, which together with an increased UHI will affect electricity consumption (Lundgren and Kjellstrom, 2013). Cui *et al.* (2010), related FAR to the geology-environmental capacity of buildings and land subsidence in the Shanghai region. They stated that there is a limit to the weight of the buildings that the ground can

sustain in a certain geological situation if particular environmental criteria are to be met.

### **6.6.3 Relevance for Ho Chi Minh City**

In Vietnam, FAR is used to manage both housing and planning. In Vietnamese cities, the FAR determines the total built-up space that a development parcel is allowed to hold. Circular no. 10/2014/TT-BXD, define how to calculate FAR via GFA, for buildings in which basement and technical floor areas are not be included in GFA. Within HCMC, the People's Committee is in charge of defining FAR values, based on the zoning and detailed panning of the city and the DPA and local district level people's committees are charged with compliance testing. The introduction of FAR regulations in HCMC has led to the abolishment of mandatory building height restrictions for some areas of the city.

In HCMC, correct and up-to-date information on FAR is essential for the proper empirical and scientific investigation of an assortment of urban environmental and social issues and to provide detailed results on the exposure of critical urban land-uses, as well as their spatial distribution (Fedeski and Gwilliam, 2007). In reality in HCMC due to the pace of change, quantitative information about urban buildings and actual FAR values is often unavailable, incomplete, or out-of-date. In HCMC, nonetheless there seems a lack of guidance on FAR distribution.

For HCMC, up-to-date knowledge of FAR is important for carrying out density compliance analysis, design briefing and development budgeting. In such a manner, areas where authorities or developers have failed to construct buildings as per the FAR can be highlighted. Areas where buildings are using all or nearly all of the available FAR allowance can be shown to already exhibit a high intensity of development, whereas buildings which only have a low percentage of their permitted GFA, can be highlighted to have low intensity of development. Rather than simply mapping the zoned regulations, such an assessment showing the compliance of the actual calculated FAR values would analyse how the current zoning polices in HCMC may hinder or restrict development and identify how near land-parcel developments are to their given zoning values.

#### 6.6.4 Previous studies

While FAR is commonly used in urban planning, it is the most unambiguous gross measure of density. FAR is easy to calculate with the aid of GIS, yet can be very difficult to calculate from field visits and physical observations, due to the fact that the development parcel or site boundaries are not always visible. In order to compute FAR many remote sensing studies have used the techniques outlined in the previous subsections, to compute building footprints and building heights (see for example Wu and Li, 2012; Liao *et al.*, 2007).

#### 6.6.5 Block-based results and discussion

In this study FAR values were calculated on basis of the building footprint, full building story height information and the location and size of the land-use blocks which are taken as the land parcels. The sum of all the floor areas of all buildings located in an individual land-use block was divided by the block size. The calculated FAR values were assigned and mapped to every land-use block. Figure 6–23 shows the actually existing inventory of FAR values for HCMC. As expected, the map generally depicts a concentric staggered degree of FAR values. The higher FAR values can be recognised from the deep red to deep blue colouring.

It is apparent from Figure 6–23 that the mapped results visibly show the concentric structure of the calculated FAR in HCMC, with the highest values found in the inner core areas and on the periphery of this core with FAR values of between 1.0 to 2.5. In the outer parts of the city, the low FAR values of 0.2 or less predominate. Also in the outer areas of the city, the main developed areas with the highest FAR stand out along the main radial traffic routes. In particular, the high density of certain blocks can be seen even in peripheral areas of the city centre to the northwest, northeast and southwest. Following the results of building volume, the highest absolute FAR values for a land-use block were seen in District 1. District 5 also contained the highest mean FAR values per district with a FAR of 1.82, while the land-use blocks of district 1 contained the second highest values with a FAR of 1.64. These values highlight the local core areas and also show the polycentric structure of HCMC in a higher resolution.

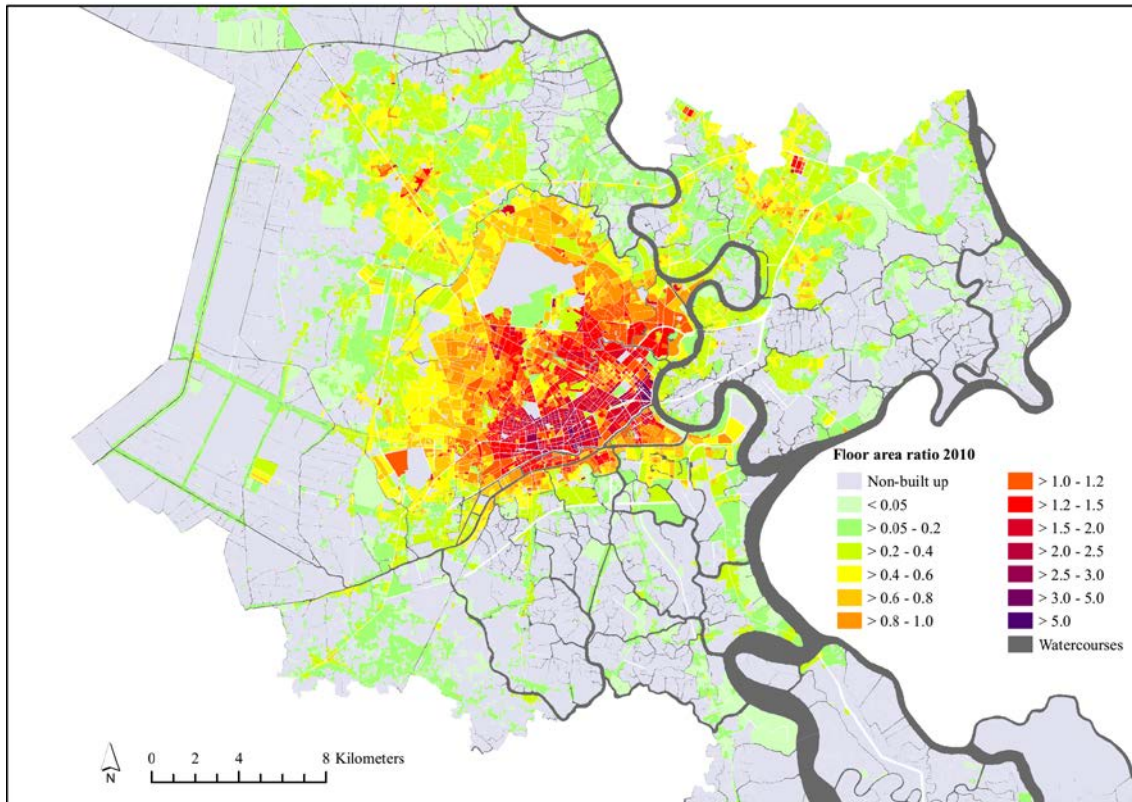


Figure 6–23 Calculated floor area ratio per block for Ho Chi Minh City (source: author's own)

Districts 3, 10, 11 and Phu Nhuan all displayed medium FAR values over 1.0. These results are comparable to those reported by Bertaud (2004). He states that most large cities around the world, the FAR varies from 5 to 15 in the CBD to about 0.5, or below, in the suburbs (Bertaud, 2004). The results show on the whole, a very high intensity of development in the inner core of HCMC. In terms of planning for climate change and disaster risk deduction, the mapped results of the calculated FAR results have particular significance for the discussion on the densification of the city centre.

Table 6–25 outlines the FAR results for the whole administration area of HCMC. It is worth remembering that over 49% of the administrative area of HCMC was classified as non-built up. Overall 10.5% of the land-use blocks and 8.7% of the total administrative area of HCMC was classed to be built-up but have FAR values of equal less than 0.05. Approximately 14.7% of land-use blocks and 10.4% of the total area of HCMC displayed FAR values of between 0.05 and 0.2. Furthermore, it was calculated that 18.5% of the land-use blocks and 10.4% of the total area of HCMC displayed FAR values of between 0.2 and 1.0. Only 5.1% of the total land-use blocks and 2.1% of the total administrative area displayed FAR values above 1.0.

Table 6–25 Distribution of floor area ratio values

Range	No of blocks of land-use	(%) of blocks of land-use	Block area (ha)	Block area (%)
Non-built up	8,001	49.1	117,709	68.4
<=0.05	1,717	10.5	14,970	8.7
>0.05–0.2	2,402	14.7	17,983	10.4
>0.2–0.4	1,296	8.0	8,538	5.0
>0.4–0.6	842	5.2	4,754	2.8
>0.6–0.8	474	2.9	2,540	1.5
>0.8–1.0	397	2.4	1,839	1.1
>1.0–1.2	307	1.9	1,443	0.8
>1.2–1.5	330	2.0	1,250	0.7
>1.5–2.0	313	1.9	801	0.5
>2.0–2.5	136	0.8	215	0.1
>2.5–3.0	40	0.2	73	0.0
>3.0–5.0	33	0.2	52	0.0
>5.0	4	0.0	5	0.0
Total	16,292	100	172,179	100

Urban models predict that FAR values all with distance from the central business district. Figure 6–24 shows mean FAR values plotted against distance from the city centre (City Hall in District 1). The results show that the highest mean FAR values were seen in the blocks within 1 kilometre of the city centre. Blocks within this radius exhibited a mean FAR value of 1.6. As with the study of building volume, these results indicate potential issues with localised heat capacity (*i.e.* thermal load) that may significantly affect the local micro-wind environment, leading to a poorer urban ventilation condition and a stronger UHI effect.

The FAR values in the land-use blocks at distances 5 km and 6 km from the city centre also show comparable results at both approximately FAR values of 0.60. The calculated mean FAR values for the land-use blocks at a distance of 7 km from the centre was 0.35. Thereafter FAR values were seen to dramatically decrease with distance to the urban towards the periphery.

Figure 6–25 shows boxplot results of the calculated medium FAR values for each UST. The results demonstrate that FAR is a common variable across HCMC and distinct differences in the FAR values of the USTs can be seen. Table 6-26 additionally outlines the values for selected USTs.



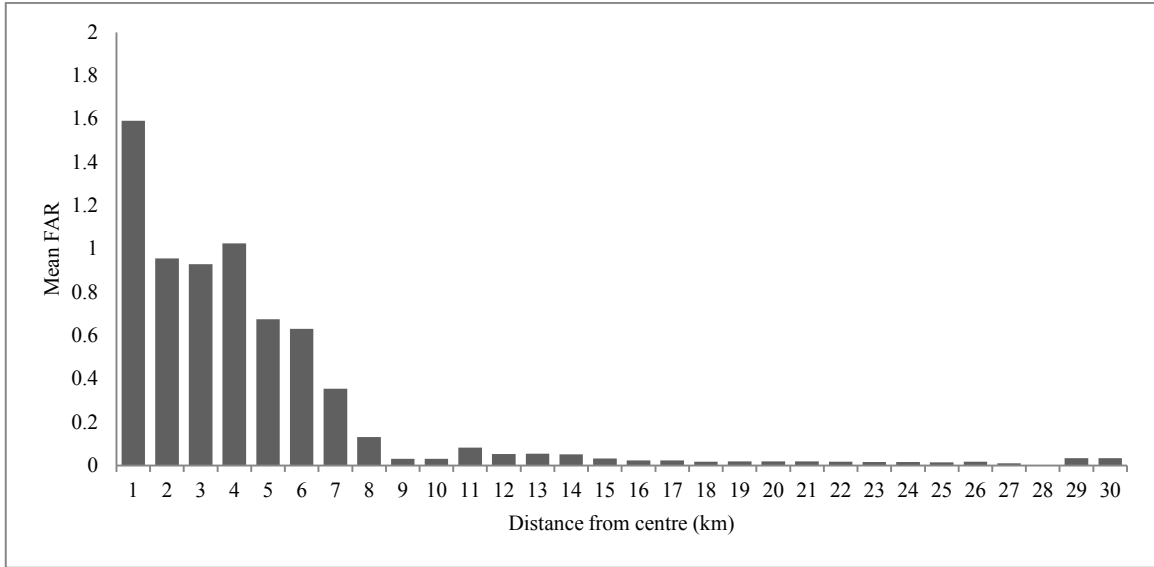


Figure 6–24 Relationship between mean floor area ratio and distance from city centre

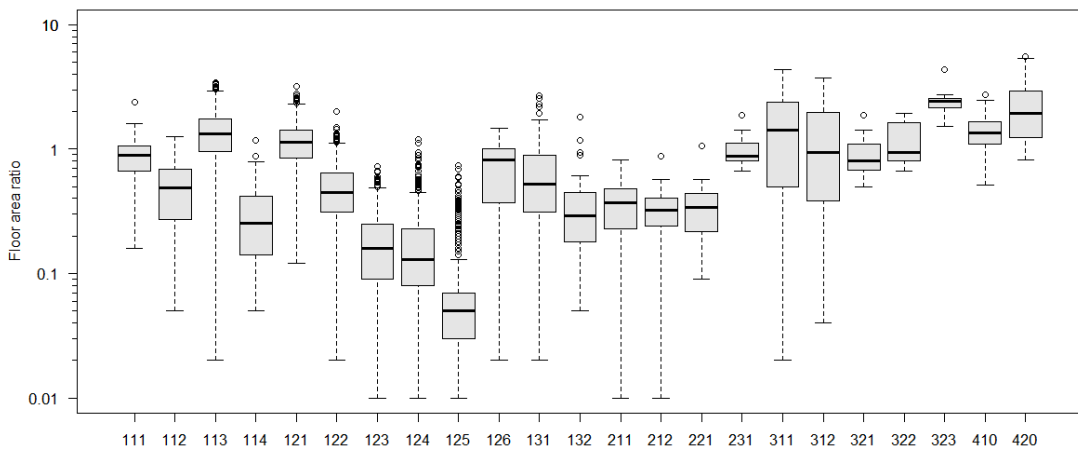


Figure 6–25 Relationship between medium floor area ratio and USTs

Table 6–26 Highlighted medium floor area ratio values for individual USTs

Highest		Lowest	
Social apartment (code 323)	2.43	Shophouse irregular with fields (code 125)	0.05
CBD with high-dense (420)	1.93	Shophouse irregular clustered (code 124)	0.14
Low-rise apartment (312)	1.42	Shophouse irregular scattered (code 123)	0.17

The highest FAR values were seen in the built-up land-use blocks classified as UST social apartment with a medium FAR value of 2.43. The second highest values were seen in the UST CBD with high dense. These blocks had a calculated medium value of 1.93. The third and fourth highest values were seen in the USTs low-rise apartment and CBD with FAR values of 1.42 and 1.34 respectively.

The land-use blocks with the UST shophouse regular with narrow alleyways (*code 113*) had a medium FAR of 1.33, while the UST shophouse irregular high-dense (*code 121*) had a slightly higher calculated medium FAR of 1.35. The USTs, American apartment (*code 322*), Chinese apartments (*code 321*), high-rise apartment (*code 312*), colonial villa (*code 221*), shophouse irregular temporary (*code 126*) and shophouse regular new (*code 111*) all displayed medium FAR values above 0.80. The lowest building volumes were seen in the UST Shophouse irregular with fields with a medium FAR value of 0.05.

Overall the regular shophouse group displayed a medium FAR of 1.03, while irregular shophouse group had a calculated medium FAR of 0.60, and the peri-urban shophouse group 0.07 (Table 6–27).

The mixed shophouse group was calculated to have a FAR value of 0.5. The regular villa group displayed a medium FAR of 0.33, while the mixed villa group displayed a FAR of 0.67. The new apartment group showed a medium FAR of 1.17 while the medium FAR of the old apartment group was calculated higher at 1.43. The CBD group were calculated to have the highest medium FAR value of any group with 1.44.

Table 6–27 UST groups and medium floor area ratio values

Regular shophouse (codes 111, 112, 113, 114)	1.03	Mixed villa (codes 221, 223)	0.67
Irregular shophouse (codes 121, 122, 126)	0.60	Apartment new (codes 311, 312)	1.17
Peri-urban shophouse (codes 123, 124, 125)	0.07	Apartment old (codes 321, 322, 323)	1.43
Mixed shophouse (codes 131, 132)	0.50	Central business district (codes 411, 412)	1.44
Regular villa (codes 211, 212)	0.33	All residential	0.19

## 6.7 Population density

### 6.7.1 Description and use in planning

Cities are often described as concentrations of people, and urban areas are typically defined by governments, law makers, demographers and scholars according to the dual criteria of population size and population density. Knowledge of the spatial distribution of population in an urban area is of considerable importance both to the management of current urban activities and for forward planning. It is also essential for both understanding and responding to many urban problems (Fabos and Petrasovit, 1984; Dobson *et al.*, 2009; Sutton *et al.*, 2012). Indeed, Baudot (1993), suggested that most of the problems about urban areas are directly related to their population.

Effective sectorial and cross-sectoral urban management itself demands good diagnostic tools of the urban population. The precise knowledge of the population actually is mandatory for almost any type of urban management or planning operations. Accurate and reliable demographic information is moreover, required to quantify both the status quo and to predict a range of future urban scenarios and trends. Population data can be used to plan for new key infrastructure and development expansions needed for an area. This can be highlighted for example, in the planning of provision of urban basic services, and supply and disposal services, which requires information on both how many people, reside where, and more specifically their consumption, income and education requirements (Balk *et al.*, 2009a; Martine *et al.*, 2009).

Furthermore, information on patterns of current and planned future land-uses are obviously inherently linked to and built upon basic datasets on the spatial distribution and growth rates of the population within an administrative unit. Urban land-use and urban population estimates are interwoven, since population growth creates pressure on the land in terms of increased demand for new developments, and supporting infrastructures. Conventional sources of information on population are unfortunately also frequently inadequate. In many parts of the developing world, census data is often outdated, unreliable, in some cases, simply unobtainable or not collected at the appropriate scales.

In general, the studying and mapping of urban populations has two main purposes; firstly to portray the extent and density of population across an area of interest; and

secondly, to derive quantitative population density estimations for subsequent analytical tasks and modelling (Martine and Schensul, 2013; Lwin and Murayama, 2009). Population density is the most commonly used measure in population statistics and is a measure that simply describes the number of people in a given area and is usually expressed as the number of people per ha (which may include or exclude inland waterbodies). It is commonly calculated for a county, city, and province in Vietnam.

### **6.7.2 Importance for climate change and disaster risk reduction**

An urban population exposed to the effects of both natural and human-induced hazards is an increasing reason for concern, especially in developing countries (Acioly and Davidson, 1996; Hofstee and Islam, 2004; Blaikie *et al.*, 2004; Bigio, 2003; Pelling, 2003). Spatial data on population distribution is crucial information within climate change adaptation and disaster management for the estimation of population at risk (Hofstee and Islam, 2004). This is especially true in the case of rapid onset hazard events and emergency management. The potential consequences of such hazards require population data to be spatially linked to risk assessments in order to both reduce overall vulnerability and mitigate losses. For example in flood modelling, knowledge about population distribution aids quantification of both buildings and people at risk. Maantay and Maroko (2009), for example, present the study of estimating the population potentially impacted by 100-year flooding in New York City.

In addition to the essential spatial component, demographic information is also often required to be socio-spatial differentiated (*i.e.* population densities, incomes, living standards). Risk assessments often need to identify pockets of poverty and conversely wealth among the urban population, which often go hand in hand with adaptation capacity (Hardoy *et al.*, 2012). It is worth noting that the demographics of a population are also greatly related to the ability to cope independently in the event of a hazard. Here age is a key factor in dependency and an individual's ability to cope. During heat waves and flooding events, older people and children tend to be disproportionately affected in terms of their physical health, particularly if they have limited or no social support structure.

It is obvious that urban areas are different from more rural areas in regards to the concentration of hazards and the number of people at potential risk. Population density greatly influences both the local and individuals ability to respond to a disaster and

adapt to climate change effectively. Concentrating large populations in a limited geographical area poses particular problems regarding exposure to many natural and climate change induced hazards, as well as the possible synergy between hazards (*i.e.* floods contaminating water supplies, or earthquakes causing large-scale fires) and increased levels of both air and water pollution. Highly densely populated urban areas also promote the spread of vector-borne diseases due to higher rates of person-to-person contact (Campbell-Lendrum and Corvalán, 2007).

Dodman (2009), examines in his paper entitled “Urban density and climate change” the role population density plays in increasing exposure to the effects of climate change and vulnerability and also the role that a high population density can play to reduce risk. He argues that if cities are governed well, high population densities can be supported in safe locations leading to a reduction in vulnerability to the direct and indirect impacts of climate change, however if cities are governed weakly with high population densities in vulnerable locations and without adequate infrastructural protection, risk levels can be increased.

While certain climate change impacts will also be identical in both urban and more rural areas, they will call for particular responses depending upon the degree of urbanisation. The range of climate change adaptation options open for discussion cannot be undertaken similarly in areas with high or low population densities. For example, higher population densities are more cost-effective with infrastructure provision and higher population densities means often higher and better access rates to facilities and amenities for protection and safeguard in times of disaster. Conversely however, high population densities can also strain existing often inadequate infrastructure and health care provision. This highlights the essential need for urban decision-makers and risk managers to have access to both timely and trustworthy spatial population data. This is particularly relevant in urban areas like HCMC, which are changing continuously. A lack of consistent and accurate information on urban populations can hinder adaptation and disaster planning, preparedness, mitigation and recovery.

Increasing population densities in cities has also been explained as the primary social driver of the UHI phenomenon. Many studies in a range of cities have noted UHI intensity positively correlated with urban population size (Hung *et al.*, 2005; Stone and Rodgers, 2001; Wilson *et al.*, 2003; Park, 1986; Yamashita *et al.*, 1986; Hogan and Ferrick, 1998; Oke, 1973). Although UHI patterns within a city are more complex and

the correlation with population may be either a direct result of more heat generation from an increased population or the indirect effects from an increased number of buildings, industrial and transport activities. Other density and design variables also play a role in UHI formation; therefore increased population may but not necessarily always be seen to increase the heat load of an urban area. An increased urban population is equally directly and indirectly responsible for the extent of environmental degradation, ecosystem loss and alteration, and often urban flooding events caused by an increase number of buildings, while sky view factor is a good proxy for the population density. Furthermore, the distribution of population within an urban area plays a major role in determining its levels of energy use and GHG emissions (Morikawa, 2012; Kamal-Chaoui and Robert, 2009). Many studies suggest that energy consumption and CO<sub>2</sub> emissions are lower in cities with higher population densities (Glaeser and Kahn, 2010; Ewing and Rong, 2008; Su, 2011; Lariviere and Lafrance, 1999). Kim and Kim (2013) found that higher population densities decreased both the carbon footprints of residents and net housing energy use in Seoul.

### **6.7.3 Relevance for Ho Chi Minh City**

In Vietnam, an exhaustive national demographic census traditionally forms the main source of population information. Censuses tracts are carried out every five year and the last census was carried out on 1<sup>st</sup> April 2014 with data made available at administrative commune level for specific cities such as HCMC. This data is extremely useful in that it captures the changes in the socioeconomic and demographic structure of the city, but it lacks spatial details and is too large and heterogeneous to provide insights in to the spatial distribution of populations at risk, vulnerabilities or loss estimates. Individual building-based population data is not collected and if so not available for public or private use in Vietnam due to privacy and security concerns.

The national statistical office of Vietnam publishes a general annual report, which includes amongst other information, population data at the provincial and city level in Vietnam. Here for the cities of Vietnam, population is reported at district level only. For this study, the census data of 1<sup>st</sup> April 2009 at commune level was used to more closely correspond with the classification of UST undertaken for the year 2010.

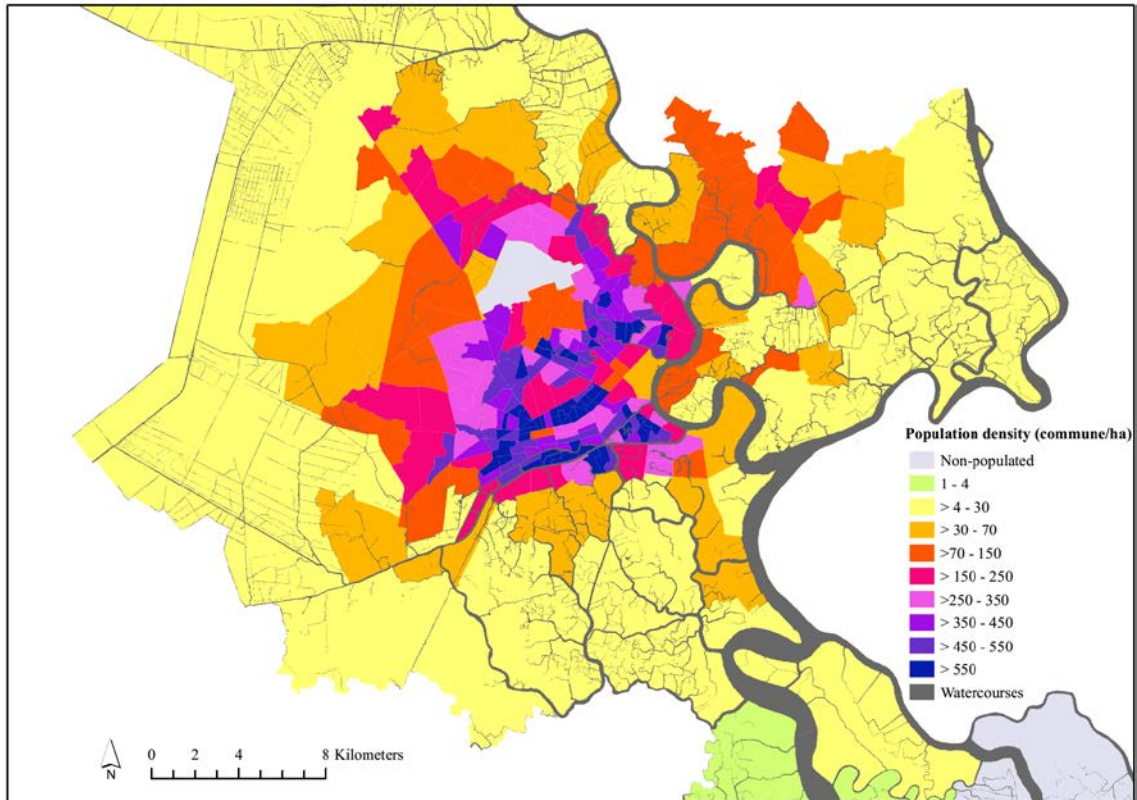


Figure 6–26 Mapped 2009 census information for the core area of HCMC plotted at commune level (source: author's own editing)

Figure 6–26 show the 2009 census information for HCMC plotted at commune level. The 2009 data reveals that population densities vary noticeably from area to area. However, the map was produced based directly on a fairly standard method of plotting census data, and has serious drawbacks and is quite misleading. The population distribution is generally much more heterogeneous. The commune level obscures much of the diversity of the socio-economic conditions that would be seen at a finer small-area level. The census commune scale is not an ideal window in which to assess population densities because densities are as much diverse as they are uniform at this resolution. This calls into question the internal homogeneity of the units of analysis, which is especially true in commune areas that are larger enough to contain mixed building typologies interspaced with unpopulated areas such as paddy fields, parks, waterbodies or government institutions and other non-residential use.

#### 6.7.4 Previous studies

Numerous remote sensing studies have documented the ability to extract population information from remotely sensed data (Wu *et al.*, 2005; Weeks *et al.*, 2000; Rashed *et*

*al.*, 2001; Kubanek *et al.*, 2014). Wu *et al.*, (2005), provides a review of the main remote sensing methods for estimating population. Traditionally, in the absence of census information, aerial photography and later satellite imagery have been used to obtain data on urban population densities by simply counting the number of residential buildings per unit area and inferring socio-economic information such as the average number of people per dwelling from the analysis of homogenous building areas (Baudot, 1993; Langford and Unwin, 1994; Holloway *et al.*, 1999; Donnay *et al.*, 2003; Kunze and Hecht, 2015; Lwin and Murayma, 2009; Sleeter, 2004; Jenks and Dempsey, 2005; Lwin and Murayama, 2011). Miller and Small (2003), argue that remote sensing can never expect to obtain population counts that are as accurate as census data but may facilitate the spatial refinement of census-derived population data.

Often additional (or ancillary) data has been used to help refine locations of population (Mennis, 2003). With the addition of census data, the spatial disaggregation of census data has typically been undertaken for administrative units with respect to the environmental factors that are believed to directly influence population distribution so that areas of population homogeneity more closely resemble the actual real world phenomena, rather than based on administrative or other arbitrary boundaries (Maantay *et al.*, 2007; Maantay and Maroko, 2009; Maantay *et al.*, 2010; Li *et al.*, 2007; Konecny *et al.*, 2010; Mennis, 2003). Ural *et al.* (2011), weighted population against detected medium building volumes of houses and apartments, while Meinel *et al.*, (2009), presented extracted building footprints and calculated population densities for eight differentiated residential building types using census data at the city block level.

Naturally, these approaches require both very up-to-date imagery for fast-growing cities and an in-depth cultural understanding of the area and living conditions. The characterisation of building footprints in terms of their function plays a key role, with remote sensing results often becoming distorted with the addition of non-residential buildings (Lwin and Murayma, 2009). This is particular the case in the over overestimated of residing populations in the centre CBD and along main commercial streets areas of cities with high floorspace (Wurm and Taubenböck, 2010; Hofstee and Islam, 2004). In such areas, as is the case in Vietnam with the traditional shophouse typology, the ground floors of buildings are used for commercial rather than residential purposes. This highlights that remotely sensed data cannot provide all of the information required about the characteristics of the urban population. Therefore, an



approach must involve also additional complementary or ancillary information and data sources, such as input census data and groundtruthing to provide an improved understanding and spatial distribution of population.

### **6.7.5 Block-based results and discussion**

Population density is dependent upon where the boundaries are drawn. Population at commune level is suitable for local and regional analysis, but not for micro-spatial analysis, consideration in spatial models, climate change adaptation and site specific decision-making processes. For detailed analyses such as modelling and identification of hazards and risk exposures, there is a need for even more detailed population distribution and a substantially greater granularity. Here spatially referenced demographic data is required and the transfer of population data from commune to the smaller unit block level is necessary.

To enhance the prospects for meaningful spatial analysis and to provide a more actual representation of the HCMC's population, the block level population density was mapped by distributing the 2009 commune level population data among USTs within each commune via block areal weightings and UST adaptive population weightings and UST specific floorspace values. This ancillary data is important to disaggregate the census information. This approach is based on the hypothesis correlation between the structural characteristics of the urban environment and its population, with populations living in areas showing homogeneous USTs will have near similar social and demographic characteristics. As such, residential areas and floorspace are used as proxies for population distribution. It is worth noting that combining population data from 2009 with UST data from 2010, undoubtedly has the drawback of missing out on some changes in population that have occurred in the interim. Assigning population data to the block level and calculating population density is also an important step to the further calculation of related indicators such as floorspace per person or medium size of households. This indicator in particular describes the amount of people that may be either potentially affected negatively or capable of coping with a disaster as larger households may be better resisting natural hazards due to larger social networks, manpower or financial means.

Calculated and mapped spatial distributions of population for the urban core area of HCMC is presented in Figure 6–27. The distribution of building density values in terms of the number and area of land-use blocks can also be seen for reference in Table 6–28.

The mapping of HCMC’s population density at block level shows interesting patterns due to the much finer spatial resolution. It is interesting to view and compare Figure 6–26, the choropleth map of commune level population density with the dasymetric map of the calculated block level population density in Figure 6–27. Figure 6–26 provides commune level single counts for large areas, thus averaging areas with high and low population densities. The map disguises huge variations in population concentrations and the comparison highlights the advantage of having population densities at finer resolution as Figure 6–27 clearly demonstrates the hyper heterogeneous structure of HCMC. The results show that simply knowing if an area is residential or not is insufficient for calculation population, as population density can vary widely even within a district or even smaller a commune. The commune level population density map tells us little about the reality. While the calculated and mapped population density data at block levels offers a more realistic picture of the city because it shows only residential areas and does not artificially reduce density in most of the non-residential areas.

Table 6–28 highlights that in the block based distribution of population almost 29% of the land-use blocks were classified as non-populated. Noticeably, 62.5% of the land-use blocks and 79.4% of the total area were calculated to have population densities below 30 persons per ha. Approximately 30.3% of land-use blocks and 18.4% of the total area of HCMC exhibited population densities between 31–450 persons per ha. Only a mere 7.1% of land-use blocks and 2.2% of the total area of HCMC were calculated to have population densities above 450 persons per ha. HCMC is characterised by high population density concentration around the city centre. Many blocks in the urban districts of District 4, 5, 6, 8, 10, 11, Binh Thanh, Tan Binh, Phu Nhuan and Go Vap are seen to exceed population densities of 550 persons per ha. While many land-use blocks in District 7, 11, 10, Tan Phu and Tan Binh displayed population densities in the range of 350 to 550 persons per ha. The lowest population densities were found in land-use blocks in Cu Chi and Hoc Mon districts. The highest absolute densities were seen in land-use blocks directly surrounding the CBD and commercial areas of the city.

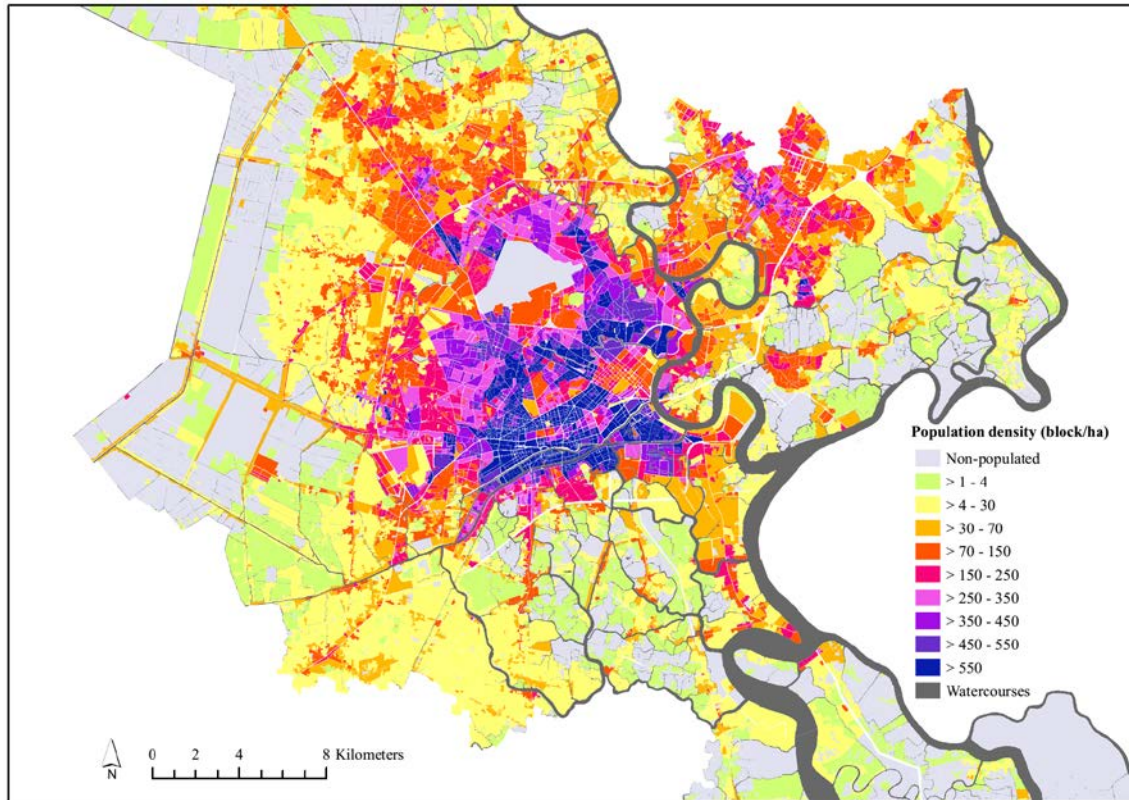


Figure 6–27 Calculated population density per block for Ho Chi Minh City (source: author's own)

The land-use blocks in District 4 displayed the highest mean values with a population density of 677 persons per ha. District 11 and District 10 both had calculated mean population densities of 652 and 520 persons per ha respectively.

Table 6–28 Distribution of population density values (persons per ha)

Range	No of blocks of land-use	(%) of blocks of land-use	Block area (ha)	Block area (%)
Non-populated	4,701	28.9	77,229	44.9
1–4	1,578	9.7	23,370	13.6
4–30	3,892	23.9	36,069	20.9
31–70	1,702	10.4	12,454	7.2
71–150	1,456	8.9	9,412	5.5
151–250	935	5.7	5,137	3.0
251–350	512	3.1	2,817	1.6
351–450	355	2.2	1,958	1.1
451–550	296	1.8	1,321	0.8
>550	865	5.3	2,407	1.4
Total	16,292	100	172,179	100

The mean population density for land-use blocks in District 5 was 593 persons per ha, while in District 3, District 6, and District Phu Nhuan the calculated mean population densities were 485, 463, and 453 persons per ha respectively. The urban peripheral and peri-urban districts are dominated by land-use blocks calculated to have a comparatively lower population density of between 71–150 persons per ha for example in Thu Duc, Binh Tan and District 12.

An important consideration for urban adaptation planning and climate-related disaster responses is that the high population densities may indicate hotspots for possible negative environmental, health and even economic outcomes, when high density is not accompanied by the necessary planning, and management. Over-development will result in an overload to the existing limited basic urban services and infrastructure in these areas. For future sustainable growth, it is important to understand and not lose track of the future challenges and the requirements for the provision of basic urban services, as well as that of technical urban infrastructure. In general, standard urban models suggest decreasing negative density gradients within cities, where there is a gradual decline in population density from the city centre to its outskirts. Figure 6–28 highlights the relationship between mean block population densities and distance from the city centre (City Hall in District 1). The Figure visualizes the concentric pattern of population densities in HCMC.

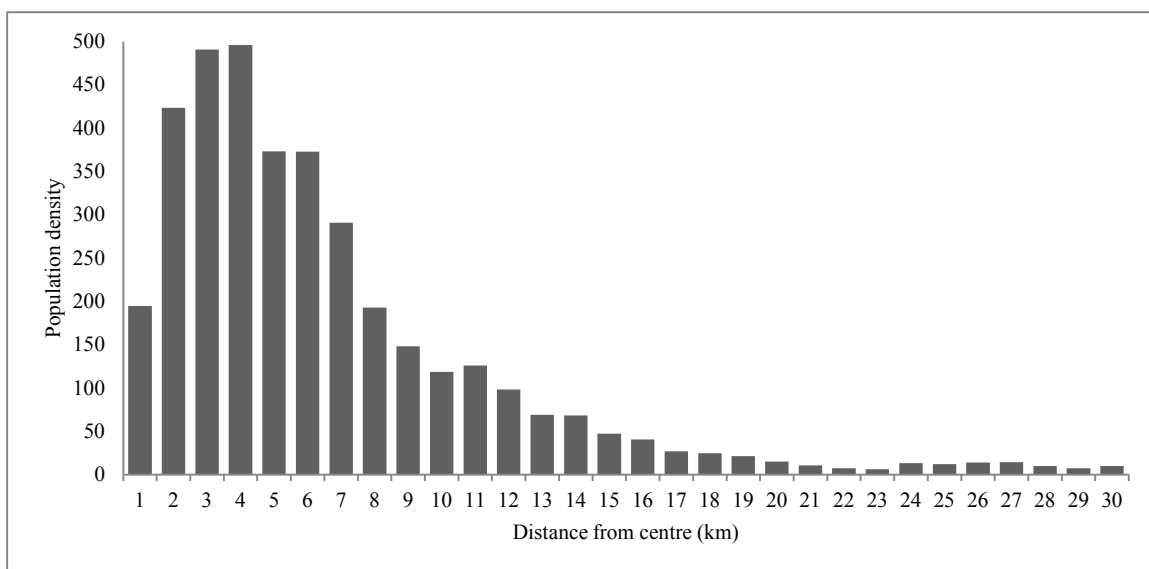


Figure 6–28 Relationship between mean population density and distance from city centre (*persons per ha*)

The results indicate the relatively low population densities in the city centre of HCMC with calculated mean population density within 1 km of the city centre low in comparison to further distances away from the city centre. Out of all the land-use blocks within 1 km of the city centre the mean population density was calculated to be 194 persons per ha. From then on, the mean population density is seen to significantly increase at a distance of between 1–2 km from the city centre to 423 persons per ha. At distances from 2–3 km and 3–4 km from the city centre, the calculated block based mean population densities peak with similar values of 490 and 495 persons per ha respectively. The mean population densities of the land-use blocks at distance 4–5 km and 5–6 km also show comparable results at 374 and 372 person per ha. The mean building volume values for the land-use block at a distance of 6–7 km from the centre was calculated at 290 persons per ha and at 7–8 km, 192 persons per ha. Thereafter population densities are seen to gradually decrease with distance to the urban towards the periphery.

Figure 6–29 explores the relationship between the classified USTs and medium population density within HCMC. Whereas, Table 6–29 shows the medium values for selected USTs. The highest population density values were displayed in the UST social apartment with a calculated value of 1,084 persons per ha and the second highest values were seen in the shophouse irregular high-dense with a value of 620 person per ha. The UST Chinese apartment had a medium population density of 594 persons per ha, UST shophouse regular narrow (*code 113*) displayed a medium population density of 579 persons per ha, while the shophouse irregular temporary (*code 126*) was calculated to have a medium value of 507 persons per ha. The land-use blocks with the UST CBD (*code 410*) had a medium population density of 494 persons per ha, while the UST low-rise apartment (*code 311*) had a calculated medium population density of 446 persons per ha.

Table 6–29 Highlighted medium population density values for individual USTs (*persons per ha*)

Highest		Lowest	
Social apartment (code 323)	1,084	Shophouse irregular with fields (code 125)	19
Shophouse irregular high-dense (code 121)	620	Shophouse irregular clustered (code 124)	60
Chinese apartment (code 321)	594	Shophouse irregular scattered (code 123)	65

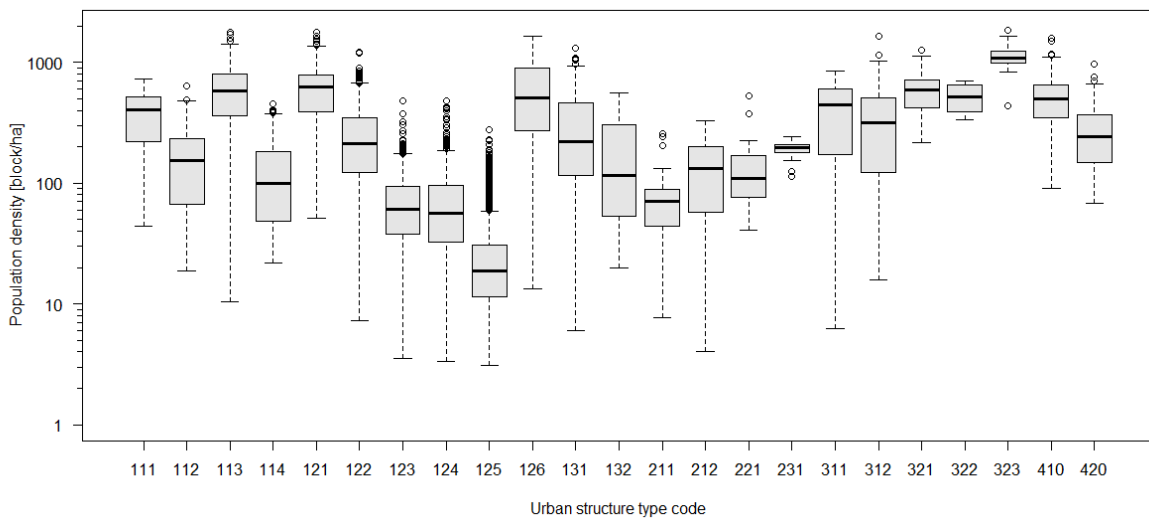


Figure 6–29 Relationship between medium population density and USTs (*persons per ha*)

The only other UST to display medium building volumes over 400 persons per ha was shophouse regular new (*code 111*) with a medium population density of 408. The lowest population densities were seen in the UST Shophouse irregular with fields (*code 125*) with a population density of 19 persons per ha.

In terms of UST groups, overall the regular shophouse group displayed a medium population density of 434 persons per ha, while the irregular shophouse group had a calculated medium population density of 311 persons per ha, and the peri-urban shophouse group much lower at 30 persons per ha (Table 6–30). The mixed shophouse group was calculated to have a medium population density at 212 persons per ha.

The regular villa group displayed a medium population density of 89 persons per ha, while the mixed villa group displayed the larger population density of 175 persons per ha. The new apartment group showed the medium population density of 344 person per ha, while the medium population density of the old apartment group was measured higher at 697 per ha.

Table 6–30 UST groups and medium population density values (*persons per ha*)

Regular shophouse (codes 111, 112, 113, 114)	434	Mixed villa (codes 221, 223)	175
Irregular shophouse (codes 121, 122, 126)	311	Apartment new (codes 311, 312)	344
Peri-urban shophouse (codes 123, 124, 125)	30	Apartment old (codes 321, 322, 323)	697
Mixed shophouse (codes 131, 132)	212	Central business district (codes 411, 412)	398
Regular villa (codes 211, 212)	89	All residential	73

The CBD group were calculated to have a medium population density of 398 persons per ha. In total, for the whole administration area of HCMC the classified residential USTs exhibited a medium population of 73 persons per ha.

Interestingly, the results also indicate that the type of the UST, has a dominant effect on population density. The results show that a comprehensive UST classification can facilitate spatial refinement of census-derived population distributions that are provided by conventional censuses. The approach has the potential to improve the spatial resolution and accuracy of existing population data to supply information for risk assessments. The block-scale population data can help answer where and how many people are currently and in the future living at risk of one or several hazards, and to which are they most exposed at the finer block level. This knowledge regarding the current spatial arrangements of population densities and locations is currently limited for HCMC and therefore risk analysis based solely on unbroken down commune level population data, can produce misleading results. The types of further applications for such data are also almost limitless; examples include planning utility service planning, emergency planning, and floodplain modelling.

## **6.8 Gross floor area per person**

### **6.8.1 Description and use in planning**

At the urban level, a city's demographics exert major influence on its ability of coping with climate change, cope and recover from disaster events or reduce residential GHG emissions. Gross floorspace per person (also known as per-capita floor area) measures the available floorspace in residential buildings. It is both a demographic and housing indicator and is defined as the gross floor area (GFA) of an individual residential building to the number of occupants.

### **6.8.2 Importance for climate change and disaster risk reduction**

For urban planning and management considerations, GFA per person is a common proxy indicator for many socioeconomic factors such as both housing quality and housing supply. Measured in square meters, low values are indicative of overcrowding. It also measures the adequate living space within a building and therefore it measures the appropriateness of the need for shelter. The need for shelter is especially strong in

times of disaster. It is also an important measure for the design of basic urban service provision (UN, 2005). As with GFA the amount of space available for individual occupants has implications for the energy required to heat (or cool) the space and the number, size of appliances that can be accommodated within an individual building, and the provision of safety facilities.

The factors that determine the gross floorspace per person are complex, dependent upon a number of socioeconomic factors and heavily influenced by the private sector. The construction of new housing for example, plays a critical role in the HCMC economy and the picture of floorspace in the city is shifting and complex. Floorspace per person also results from factors such as income, land and house prices. Due to this complexity, floorspace per person is not easily amenable to policy interventions, yet is more precise and policy-sensitive than other related demographic indicators (Williams, 2009).

Globally, higher income economies tend to have more floorspace per person than lower income economies, which should result in larger habitable areas for all urban dwellers if shared evenly. However, human settlement conditions in many parts of the world are worsening mainly as a result of a low level of investment, as well as inadequate planning for low income groups. The United Nations reported in 1996 that in low-income settlements, reduced floorspace per person can be associated with certain health risks (UN, 1996).

### **6.8.3 Block-based results and discussion**

Both land-use planning and construction policies in Vietnam greatly affect living conditions. Typically in HCMC, GFA per person is assessed at the city-wide level by simply dividing the constructed total floor area throughout the city by its population. It is heavily influenced by the real estate market, which is all too often tailored to the middle and high income groups. The current HCMC People's Committee targets a medium GFA per person of 16 m<sup>2</sup> by 2012, and by 2015, 17 m<sup>2</sup> per person (HCMC PC, 2012). Within this study GFA per person was calculated simply by dividing GFA by the population attributed to each block and normalized per ha. In investigating and mapping this indicator at the block-level, the progress towards meeting these objectives can be evaluated. The level of overcrowding can also be investigated and thusly help identify potential hotspots of vulnerability. Following on, proper policies and regulations can be



put into place to safeguard the health and sanitary condition of habitable spaces and ensure greater resiliency in times of disaster.

Figure 6–30 shows the mapped calculated GFA per person values per land-use block for the inner core area of HCMC. As seen in Figure 6–30, the highest levels of the GFA per person were seen in blocks of the central core districts of HCMC and new developments in District 2 and District 7. In some areas, these blocks exceed GFA per person of 70 m<sup>2</sup>. The lowest GFA per person values were calculated for individual land-use blocks in Districts 4, 8 and Go Vap.

District 1 was calculated to have the highest medium GFA per person. Blocks within district 1 had medium floor space of 68.33 m<sup>2</sup> per person, while land-use blocks in District 3 exhibited the second highest medium GFA per person value at 39.14 m<sup>2</sup>. District 7 recorded the third highest GFA per person value with 39.09 m<sup>2</sup>. The urban districts, district 5 and 10, the peri-urban district, Thu Thiem, and the rural district, Hoc Mon were the only other districts to display GFA per person values of greater than 30 m<sup>2</sup>. The GFA per person was 35.29 m<sup>2</sup> in district 5, 33.91 m<sup>2</sup> in district 10, 32.93 m<sup>2</sup> in Thu Thiem and 35.46 m<sup>2</sup> in Hoc Mon. The lowest medium GFA per person value was seen in District 4 with 16.24 m<sup>2</sup>. All other urban districts were seen to display GFA per person values of over 20 m<sup>2</sup>. All together the 13 urban districts displayed a medium GFA per person of 30.38 m<sup>2</sup> per ha. The blocks in the peri-urban districts of HCMC displayed the medium GFA per person of 27.55 m<sup>2</sup>, while the blocks in the rural districts exhibited a medium GFA per person of 28.71 m<sup>2</sup>.

Table 6–31 shows the distribution of GFA per person values in terms of both number and area of land-use blocks. In total, 21.8% of land-use blocks and 13.2% of the whole administrative area was calculated to exhibit an extremely low GFA per person of less than <5 m<sup>2</sup>. Overall, 28.4% of the land-use blocks and 17.9% of the total area of HCMC was calculated to contain blocks with GFA values per person of less than 15 m<sup>2</sup>. Additionally, 16.9% of the land-use blocks and 21.3% of the total block area was determined to have a medium GFA per person of between 15–<20 m<sup>2</sup>. The vast majority of land-use blocks and block area in HCMC, measured at 35.4% and 38.3% respectively were determined to have medium GFA per person of between 20–>30 m<sup>2</sup>. Exactly 14% of land-use blocks and 18.3% of the land-use block area contained GFA per person values of between 30–40 m<sup>2</sup> whereas, merely 5.5% of land-use blocks and 4.2% of the total block area contained GFA per person values above 40 m<sup>2</sup>.

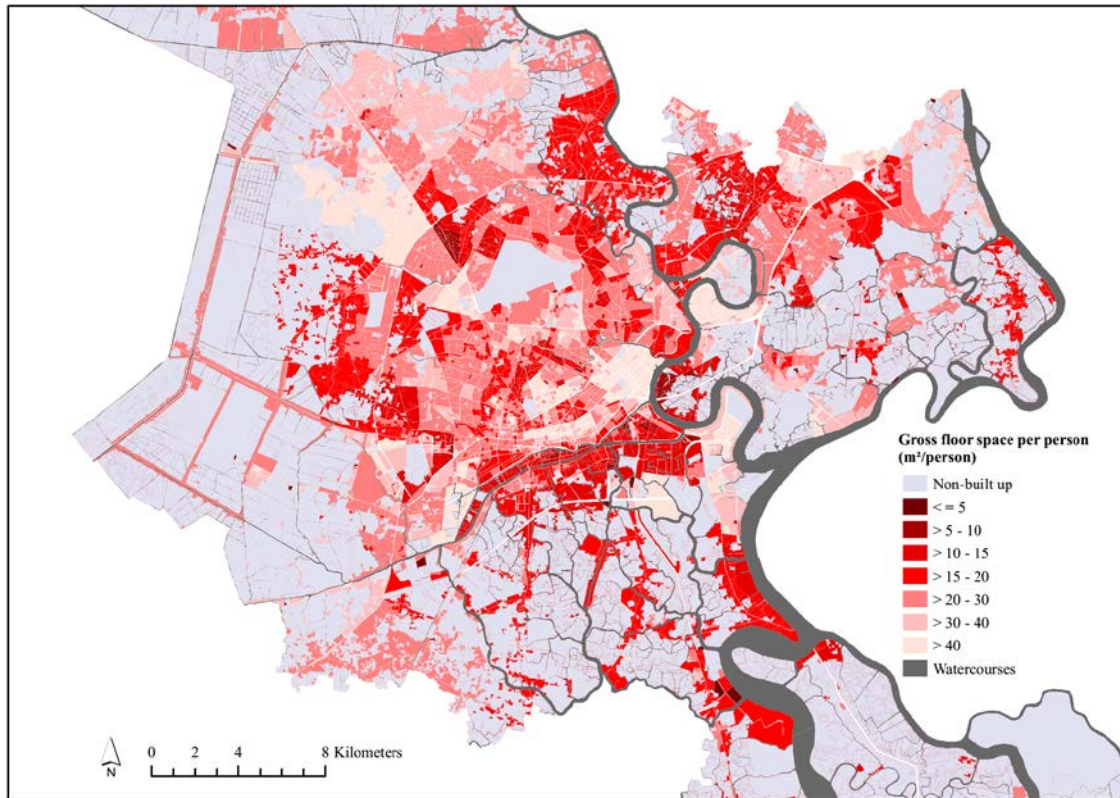


Figure 6–30 Calculated gross floor area per person per block level for Ho Chi Minh City (*source: author's own*)

Table 6–31 Distribution of gross floor are per person values (*m² per person*)

Range	No of blocks of land-use	(%) of blocks of land-use	Block area (ha)	Block area (%)
<5	3,549	21.8	22,767	13.2
5–<10	139	0.9	426	0.2
10–<15	922	5.7	7,687	4.5
15–<20	2,751	16.9	36,662	21.3
20–<30	5,765	35.4	65,977	38.3
30–<40	2,278	14.0	31,475	18.3
>40	888	5.5	7,182	4.2
Total	16,292	100	172,179	100

Figure 6–31 highlights the relationship between the mean GFA per person per land-use block and distance from the city centre. The results provide clear insight into both the structure and distribution of GFA per person within HCMC. Not surprisingly, the highest mean GFA per person values were seen within 1 km of the city centre with a mean of 110 m<sup>2</sup> per person.

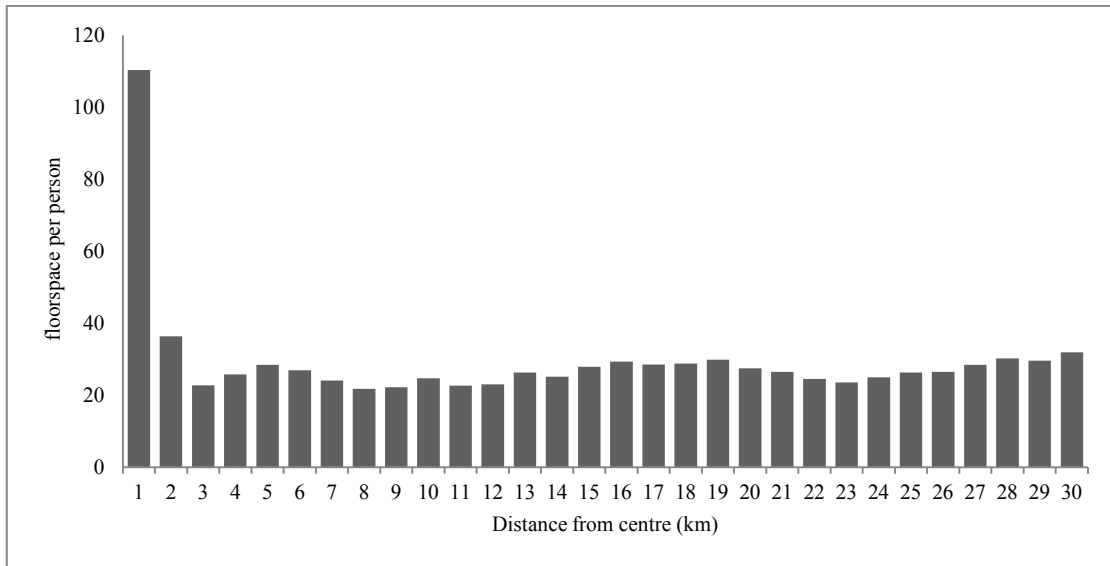


Figure 6–31 Relationship between mean GFA per person and distance from city centre (*m<sup>2</sup> per person*)

Such a large mean value is undoubtedly related to difficulties in separating mixed commercial and residential space into factions of purely residential or purely commercial space in the central core of the city. Between 1 km and 2 km from the city centre, the mean GFA per person was determined to be 36 m<sup>2</sup>. After a distance of 2 km from the city centre, surprisingly the GFA per person values appear to show no distinct pattern and are relatively uniform alternating between values of approximately 22 m<sup>2</sup> and 29 m<sup>2</sup>. At around 13 km from the city centre, the GFA per person values are seen to progressively increase with distance from the centre.

Figure 6–32 shows boxplot results of the calculated medium GFA per person values for all residential USTs. The calculated medium GFA per person values vary notably between certain USTs. The highest medium GFA per person values were recorded for the CBD with high dense UST, with a medium value of 58.5 m<sup>2</sup> per person (Table 6–32). There are also a large number of outliers for the UST, which once again highlight the difficulties of distinctly separating residential and commercial floor space for analytical purposes. The second and third highest recorded values were seen in the Villa UST with a medium GFA per person of 50.5 m<sup>2</sup> and in the colonial villa UST with a medium GFA per person of 47.7 m<sup>2</sup>. The UST shophouse with industry (*code 131*) displayed a medium GFA per person of 34.5 m<sup>2</sup>, whilst, the UST low-rise apartment (*code 312*) showed a medium GFA per person of 31.4 m<sup>2</sup>. The highest medium GFA per person value for shophouse based USTs was seen in the UST shophouse regular new community (*code 112*) with a medium value of 29.9 m<sup>2</sup>.

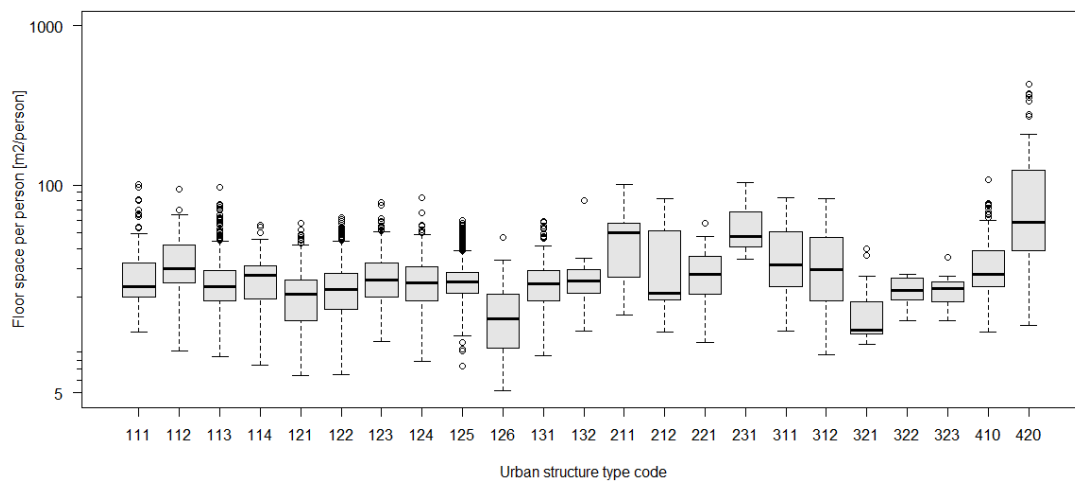


Figure 6–32 Relationship between medium GFA per person and USTs ( $m^2$  per person)

Table 6–32 Highlighted medium floorspace per person values for individual USTs ( $m^2$  per person)

Highest		Lowest	
CBD with high-dense (420)	58.5	Chinese apartment (code 321)	12.4
Villa (211)	50.5	Shophouse irregular temporary (code 126)	14.5
Colonial villa (code 231)	47.7	Shophouse irregular high-dense (code 121)	20.7

The lowest medium GFA per person values were seen in the Chinese apartment UST which was calculated to have only a GFA per person of  $12.4 m^2$ . The shophouse irregular temporary UST was also calculated to have a low GFA value of  $14.5 m^2$  per person.

Table 6–33 highlights the medium UST group results. In terms of shophouse based USTs, the regular shophouse group displayed a medium GFA per person of  $24.0 m^2$ , while irregular shophouse group had a calculated medium GFA per person of  $21.2 m^2$  per person and the peri-urban shophouse group slightly higher at  $24.9 m^2$  per person. The mixed shophouse group was calculated to have medium GFA per person of  $34.2 m^2$ .

The regular villa group and the mixed villa group displayed a medium GFA per person of  $29.6 m^2$  and  $36.9 m^2$  respectively. The new apartment group had a medium GFA per person of  $30.8 m^2$ , while the old apartment group had a lower medium GFA per person of  $19.5 m^2$ . Finally, the medium GFA value of the land-use blocks within the CBD group, were calculated to be  $33.2 m^2$  per person.

Table 6–33 UST groups and medium floorspace per person values (*m<sup>2</sup> per person*)

Regular shophouse (codes 111, 112, 113, 114)	24.0	Mixed villa (codes 221, 223)	36.9
Irregular shophouse (codes 121, 122, 126)	21.2	Apartment new (codes 311, 312)	30.8
Peri-urban shophouse (codes 123, 124, 125)	24.9	Apartment old (codes 321, 322, 323)	19.5
Mixed shophouse (codes 131, 132)	34.2	Central business district (codes 411, 412)	33.2
Regular villa (codes 211, 212)	29.6	All residential	24.2

The results of GFA per person highlight that for HCMC, it is not only important to know the future growth in population by a certain target year, but also how many will live in each household and how much space will they occupy and where they will be located within the administrative boundaries of the city. Whilst not easily amenable to policy, it is important to understand demographic trends such as increasing demand for living space in order to develop a reliable estimate of future energy demand and consequent carbon emissions.

## 6.9 Total soil surface sealing

### 6.9.1 Description and use in planning

The term impervious surface sealing is often used in the literature, however, here the term soil sealing is preferred because it clearly expresses to the HCMC administration, the fact that due to uncontrolled urbanisation, previously pervious surfaces have been sealed. The European Union defined soil sealing in 2006 as “Changing the nature of a soil such that it behaves as an impermeable medium and describes the covering or sealing of the soil surface by impervious materials” (EEA, 2006), while in 2014 the European Commission defined soil sealing as “the loss of soil resources due to the covering of land for housing, roads or other construction work, rendering it relatively impermeable to water” (European Commission, 2014).

In essence, soil sealing is generally understood to be any material, natural or man-made, that prevents the infiltration of surface water to the underlying strata (Arnold and Gibbons, 1996; Wessolek and Facklam, 1997; Jennings and Jarnagin, 2002; Erickson and Stefan, 2009; Mejia and Moglen, 2010; Kampourak *et al.*, 2006; Chithra *et al.*, 2015). Man-made sealing is generally permanent. Sealed surfaces include built sealed such as individual buildings and rooftops, and unbuilt sealed surfaces such as paved

surfaces (tarred, asphalt, concrete), roads, driveways, pavements and parking lots, and other non-infiltrating surfaces, even significantly compacted bare soil, where water can no longer infiltrate (Weng, 2012). For many years it has been recognised that urbanisation results in the increased sealing of surfaces to different degrees in relation to the urban densities and a decrease in the percentage of lands such as forested lands, wetlands and other forms of open spaces that can absorb and allow infiltration of rainwater, as well as buffer, retain and clean stormwater. In other words, as soil sealing increases within a city, a watershed or administrative unit, the vegetation cover decreases, leading to an alteration of the urban hydrograph and to a separation of the atmosphere/hydrosphere and the pedosphere (Leopold, 1968; Carter, 1961; Klein, 1979; Galli, 1991).

As such the study of the soil sealing degree, a measure how much of a reference surface is impermeable, has recently emerged not only as a quantifiable land-use indicator for the degree of urbanisation, but also as a major indicator of environmental quality and anthropocentric-environmental interactions. It is important for urban planning, environmental and resources and disaster management at both city and regional scales (Schueler, 1994; Arnold and Gibbons, 1996; Carlson and Arthur, 2000; Weng, 2012; Chithra *et al.*, 2015).

### **6.9.2 Importance for climate change and disaster risk reduction**

Rather than the degree of urbanisation *per se*, soil sealing has become the indicator of choice for assessing the negative impacts of urbanisation. The environmental impacts of soil sealing have been discussed in many previous studies. The soil sealing degree, as well as the location, and spatial pattern of sealed surfaces have impacts to the urban hydrograph, disrupting natural drainage channels, creating new flow paths and playing a crucial role in the water balance in the city. An increase of soil sealing has been documented to lead to the increase in the volume, duration and intensity of urban run-off, an overall decrease of groundwater recharge and an increase in stormflow and flood frequency (Schueler, 1994; Brun and Band, 2000; Weng, 2001; Aubrecht *et al.*, 2009; Carle *et al.*, 2005; Wessolek and Facklam, 1997; Paul and Meyer, 2001; Scalenghe and Marsan, 2008; Whitford *et al.*, 2001).

Not surprisingly, the responses of urban catchments following urbanisation have been well-researched, and have led to the development of many rainfall run-off models

(Haase, 2009; Rujner *et al.*, 2010; Finch, 1989; Huber and Dickinson, 1988). Furthermore, soil sealing is related to water quality in receiving drainage channels and water bodies and habitat health (Arnold and Gibbons, 1996; Hatt *et al.*, 2004; Yin *et al.*, 2005; Alberti *et al.*, 2007; Lee and Heaney, 2003). An increase in soil sealing and runoff exhibits a direct impact on the transport of non-point source pollutants including pathogens, nutrients, toxic contaminants and sediment (Arnold *et al.*, 1982; Bannerman *et al.*, 1993; Slonecker *et al.*, 2001; Sakhar and Rao, 2002; Brabec *et al.*, 2002; Brabec, 2008; Hurd and Civco, 2004; Schueler *et al.*, 2009; Slemph *et al.*, 2012; Dougherty *et al.*, 2004). In addition, the soil sealing degree, the spatial extent and spatial pattern of sealed surfaces significantly influences urban climate and leads to an increase in ambient temperatures by altering both sensible and latent heat fluxes (Katzschner, 2011). Hence soil sealing is the main driving force behind UHI formation and has been stated to directly affect resident's quality of life, negatively impacting on effects to combat climate change (Oke, 1982; Yang *et al.*, 2003; Aubrecht *et al.*, 2009; Heldens *et al.*, 2012; Zhang *et al.*, 2012; Slemph *et al.*, 2013; Thi *et al.*, 2010; Collier, 2006; Yuan and Bauer, 2007). Soil sealing prevents infiltration and limits the space for evaporating plants. Thus data in regards to soil sealing is important as an input for models on municipal climate (Huttner *et al.*, 2008).

Nowak and Greenfield (2012), have even demonstrated how an increase in soil sealing reduces the aesthetic appeal and environmental quality of urban areas. Furthermore, since soil sealing is related to residential, commercial or industrial areas, information on the distribution and degree of soil sealing is used frequently for population estimations (Azar *et al.*, 2010; Liang *et al.*, 2007), to examine settlement patterns, or to analyse the spatial-temporal dynamics of urbanisation (Ridd, 1995; Xian and Crane, 2005; Lu *et al.*, 2006; Chapman, 2003; Herold *et al.*, 2003; Yang *et al.*, 2003; Yuan *et al.*, 2005; Woods *et al.*, 1999; Sleavin, 1999; Prisloe *et al.*, 2003). Graham *et al.* (1974) for instance showed a significant relationship between demographic variables and total soil sealing. Population density, household number and distance from centre have all been shown to be useful in estimating soil sealing (Alley and Veenhuis, 1983; Miltner, 1997; Jones and Clark, 1987).

### 6.9.3 Relevance for Ho Chi Minh City

Rainfall is only one component of flooding. A rainfall event of 5 millimetres produces 5 litres of runoff per square metre of sealed surface. Soil sealing is a policy relevant indicator because it is responsible for flood or UHI hazard generation in areas not supported with adequate drainage or ventilation. An UHI can also lead to higher and more frequent rainfall events on the lay-side of the urban area compared to the surrounding landscape (Shepherd and Burian, 2003; Burian and Shepherd, 2005; Collier, 2006). Mapping soil sealing helps to locate areas potentially affected by flooding and/or UHI, and gives a further link to the overall spatial area exposed, which is why this indicator is appropriate for adaptation assessment. Crowell *et al.* (2007), reports that the United States Federal Emergency Management Agency (FEMA), has developed a tool called the Flood Insurance Rate Map (FIRM) which produces flood maps used for calculating flood insurance and potential losses in flood-prone areas based on soil sealing estimates. Kulkarni (2012), also states that accurate and rapid classification of soil sealing aids in emergency management following extreme events like flooding, earthquakes, fires, tsunamis, and hurricanes, by providing quick estimates and updated maps for emergency response.

Soil sealing is therefore namely an important key policy and proxy indicator on the urban environmental quality of HCMC because of the myriad of ways it affects the urban landscape, correlating with increased surface runoff causing urban flooding and UHI. Mitigating the effects of both UHI and increased surface runoff are two of the major environmental challenges currently being faced by HCMC. Urban floods are significant for HCMC in terms of economic losses both direct and indirect. Dedicated site specific risk assessments and planning knowledge of the spatial distribution and extent of pervious and sealed areas in HCMC are important variables for planning, mitigating, preparing and responding to potential urban flood events.

Furthermore, although sealed surfaces in HCMC do not directly generate pollution, there is a clear link between soil sealing and urban hydrograph changes that degrade water quality in the adjacent or receiving water bodies. Moreover, soil sealing is a characteristic of the intensity of urbanisation and the sealing of soil conveys pollutants into adjacent waterways typically through the often overloaded stormwater drains. To this effect, the stormwater drains in HCMC are grossly polluted and often clogged with plastic shopping bags, refuse and sediment, restricting the effectiveness of drainage and



presenting unique maintenance and clean-up problems (ADB, 2010; Storch and Downes, 2011). Soil sealing can also lead in HCMC to the pooling of stormwater and the need to design decentralised retention systems, which both in turn may increase the potential breeding areas for mosquitos, the disease vectors for dengue fever and other infectious diseases (Few *et al.*, 2004; Thomson *et al.*, 2015; Anders *et al.*, 2015).

Traditional strategies to manage stormwater require large infrastructure investments and in dense urban settings face technical challenges (Santos and Freire, 2013). The understanding of spatial distribution and intensity of soil sealing is therefore important from a planning perspective so that appropriate strategies can be applied at the spatial scales of both site-level planning and design and land-use regulations to reduce sealing and both run-off and UHI effects.

#### **6.9.4 Previous studies**

Weng (2012), in the review of remote sensing methods for detecting soil sealing, well-summarised the numerous techniques that have been applied to characterise and quantify soil sealing using both ground based measurements or remotely sensed techniques. The determination of the sealing is carried out conventionally by using real estate and cadastral maps, and the thorough analysis of multispectral satellite imagery. Bauer *et al.*, (2004), maintains that remote sensing has been widely applied for estimation of soil sealing due to its relatively low cost and suitability for large area mapping, yet an accurate, fast, transferable and cost effective technique for soil sealing assessment has, as yet not been established. Many studies have attempted to automatically classify surface impermeability by pixel-based techniques by using satellite or aerial imagery. However, they have proven to be unsuitable as a high degree of user interaction is still needed due to the complexity of urban impervious materials and significantly the fact that remotely sensed applications cannot directly measure whether a surface is permeable, it can simply monitor land cover types and infer permeability.

Furthermore, building shadows and vegetation can obscure the surface underneath, leading to an inaccurate extraction of soil sealing values and often to an overestimation of vegetation and an underestimation of sealed areas (Cushie, 1987; Netzband and Meinel, 1998; Irons *et al.*, 1985; Yang and Li, 2015; Slonecker *et al.*, 2001; Lu and Weng, 2006; van der Linden and Hostert, 2009; Dare, 2005; Hsieh *et al.*, 2001). For

example, Grenzdörffer (2005), studying soil sealing in the German city of Rostock, simply categorised sealed areas as either built-up or non-built-up, omitting the non-built up sealed component. Nevertheless, for the purposes of urban planning and the modelling of urban environmental indicators such as urban climate, and urban run-off, it is often important to further distinguish soil sealing into built up seal and non-built-up sealed shares (Nichol and Wong, 2005; Pauleit *et al.*, 2005; Choi and Ball, 2002; Shuster *et al.*, 2005). Further studies have demonstrated that field surveys with GPS, and aerial photography interpretation although expensive and time-consuming, can provide more accurate and reliable information on soil sealing conditions (Bird *et al.*, 2001; Yuan and Bauer, 2006; Heber and Lehmann, 1993).

Meinel and Hering (2005) carried out arguably one of the most detailed recordings of urban soil sealing for the German city of Dresden. On the basis of aerial photography interpreted at a scale of (1:50,000 scale), they digitised soil sealing values for the whole city, assigning an estimated degree of sealing for each housing plot.

In another detailed study of soil sealing, the Senate Department of Urban Development in Berlin, Germany, estimated in 1993 the degree of sealing at the city block level by using the visual interpretation of Landsat-TM satellite imagery for the former West Berlin in 1985 and 1988 and Colour Infrared (CIR) aerial photographs for the former East Berlin (Department of Urban Development). The city's 1985 Environmental Atlas contained an early map of sealing for West Berlin based on analogue aerial photography taken in 1979. This was further updated by the visual interpretation of Landsat images in 1985 and 1988, which were classified on the basis of a ten point scale for sealing. The digital land cover map of Berlin was then overlain, and the degree of sealing was recalculated as percentage of each block. Following the fall of the Berlin Wall, the dataset was updated in 1991 by visual interpretation of aerial photographs taken in 1990.

In the case of Berlin, Schneider *et al.* (2007), quotes that solely knowledge of the soil sealing degree was insufficient in order to aid the various environmental protection tasks and it was necessary to take into account both the type of sealing, either built-up or non-built-up and the material with which the non-built-up areas were sealed. In the case of Berlin, non-built up sealed surfaces were also classified into one of four surface sealing classes according to their effect on the ecosystem.

### 6.9.5 Block-based results and discussion

Information on soil sealing degree does not exist in HCMC. In order to provide city-wide block-related soil sealing information to the HCMC authorities, mean values were determined for each individual UST. The previously classified UST of HCMC displayed substantially different soil sealing surfaces in terms of types, abundance and geometry.

The determined values for the portions of both built sealed and unbuilt sealed, as well as the total sealed percentages can be found in Table 6–34. The previously calculated mean coverage ratio calculated on hand the building footprint data and DoNRE land-use block geometry were used for calibration of the mean built-up sealed values. The unbuilt sealed element was determined via visual examination of high resolution satellite images.

In total twenty blocks for each individual classified UST of differing size and location where selected and the unbuilt sealing degree estimated, and confirmed during site visits. The mean of these measurements was then applied to all blocks of the same UST. Here, the surrounding road surfaces were not included in the estimation and it is possible that sealing value of highly sealed urban districts is partly underestimated.

The site visits were undertaken to various areas that had been identified as difficult to interpret in the satellite photography and to become familiar with the UST characteristics of the area. The ground verification acted as a supportive tool that also helped to understand errors and misclassifications that could occur. Difficulties in the estimate of soil sealing were found in the peri-urban USTs, where it was difficult to determine the percentage sealed where tree canopies covered part of the blocks. The percentage of soil sealing was seen to vary little in most USTs.

The highest total soil sealing degrees above 90% were determined for the shophouse regular with narrow streets, the shophouse irregular high-dense, low-rise apartment and central business district high-dense UST. The lowest total soil sealing value was determined for the peri-urban shophouse irregular with large fields UST. Here the large block size in the peri-urban areas likely distorted the results.

Both engineers and water professionals are interested in measures of soil sealing rates at both parcel and block scales. The mapped results of the soil sealing analysis of HCMC are presented in Figure 6–33.

Table 6-34 Determined soil sealing values for residential USTs

Urban structure type	Built up (%)	Sealing degree non-built up (%)	Total (%)
<b>Regular shophouse</b>			
Shophouse reg. new	70	11	81
Shophouse reg. new comm.	60	16	76
-Shophouse reg. narrow	75	15	90
-Shophouse reg. w/yards	44	15	59
<b>Irregular shophouse</b>			
Shophouse irreg. high-dense	78	14	92
Shophouse irreg. w/yards	57	10	67
Shophouse irreg. temp.	70	15	85
<b>Peri-urban shophouse</b>			
Shophouse irreg. scattered	28	8	36
Shophouse irreg. clustered	30	10	40
Shophouse irreg. w/fields	5	5	10
<b>Mixed shophouse</b>			
Shophouse w/ industry	74	15	89
Shophouse irreg/reg.	69	14	83
<b>Regular villa</b>			
villa	30	14	44
Luxury villa	17	20	37
<b>Mixed villa</b>			
Villa in est. UST	55	20	75
Colonial villa	53	25	78
<b>Apartment new</b>			
Low-rise apartment	84	8	92
High-rise apartment	61	20	81
<b>Apartment old</b>			
Chinese apartment	50	35	85
American apartment	40	23	63
Social apartment	73	10	83
CBD	72	10	82
CBD w/high dense	73	20	93

In Figure 6–33, the dominant purple colour clearly demonstrates that the highest mean soil sealing values are seen to correlate with increasing building density and are to be found predominantly in the high dense urban core of the city. Additionally, vast areas of the core of HCMC show sealing rates of above 60%. These areas are the most likely to increase the flood exposure and UHI risks to the city. Areas with low percentages of soil sealing (>40%) are found predominately in the peri-urban districts of HCMC. The highest mean soil sealing rates were recorded for the land-use blocks in District 3, 4, 5 and 11 with values above 86%.

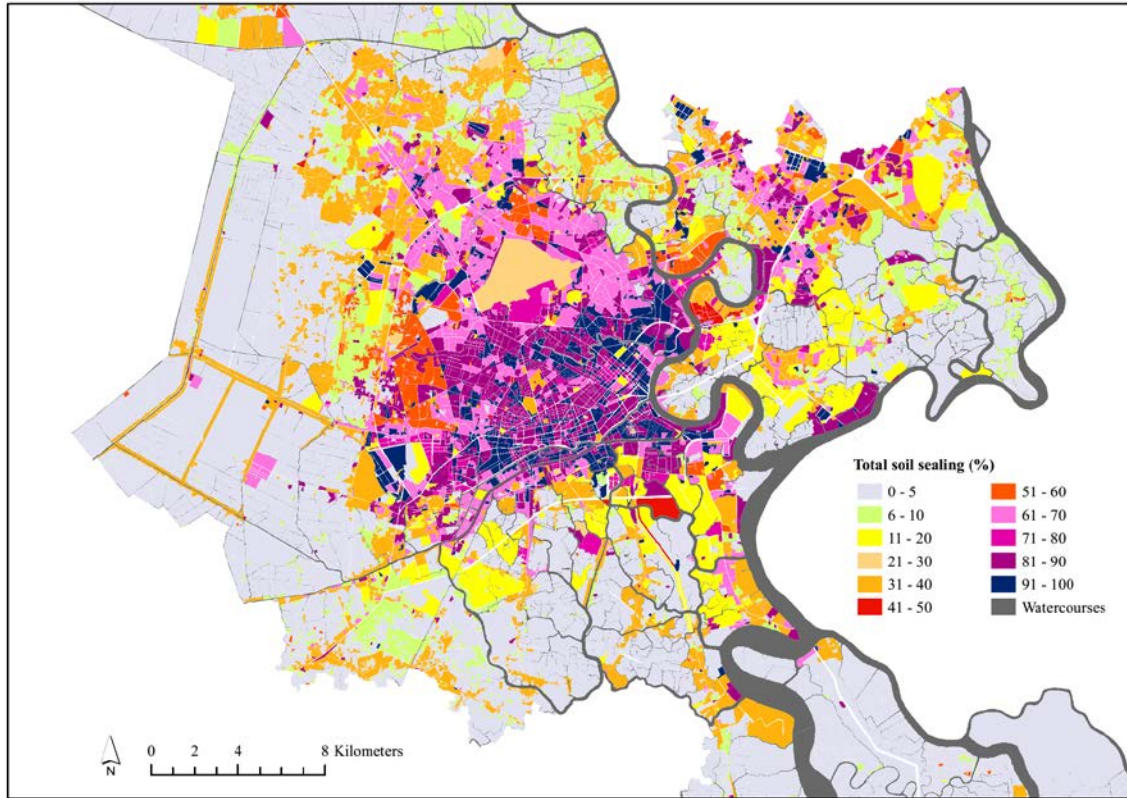


Figure 6-33 Calculated soil sealing degree per block for Ho Chi Minh City (source: author's own)

Table 6-35 Distribution of soil sealing values

Range	No of blocks of land-use	(%) of blocks of land-use	Block area (ha)	Block area (%)
0-5	7,370	45.2	109,329	63.4
6-10	2,394	14.7	17,725	10.2
11-20	380	2.3	6,058	3.5
21-30	46	0.3	1,084	0.6
31-40	1,979	12.1	16,146	9.3
41-50	36	0.2	304	0.1
51-60	281	1.7	2,420	1.4
61-70	1,224	7.5	7,707	4.4
71-80	160	1.0	1,159	0.6
81-90	1,539	9.4	6,786	3.9
91-100	883	5.4	3,457	2.0
Total	16,292	100	172,179	100

District 1, 6, 10, and Phu Nhuan also had mean soil sealing rates of greater than 80%. Not surprisingly, the lowest mean soil sealing values were seen in the land-use blocks of rural district Can Gio with 7%.

Table 6–35 shows the distribution of soil sealing values in terms of both number and area of land-use blocks for the whole administration area. As the results outline the whole administration area of HCMC and not solely the UST blocks classified as built-up it is not surprising that 45.2% of land-use blocks and 63.4% of the total area of HCMC exhibited soil sealing values of between zero and five percent. Approximately 74.6% of land-use blocks and 87.1% of the total area of HCMC displayed soil sealing values below 51%. Finally 883 land-use blocks (5.4%) and 3,457 ha (2%) of the total area of HCMC displayed soil sealing values of between 91–100%.

The relationship between soil sealing and distance from city was also investigated to identify spatial patterns. Figure 6–34 shows the three dimensional densities in terms of mean soil sealing rates and distance from the city centre (City Hall in District 1).

The graph demonstrates the relatively high sealing values in the core area of HCMC. Out of all the land-use blocks within 1 km of the city centre the mean soil sealing was calculated to be 80%. The mean values at a distance of 2 km, 3 km and 4 km from the city centre generally showed similar sealing rates of 76%, 76%, 77% respectively.

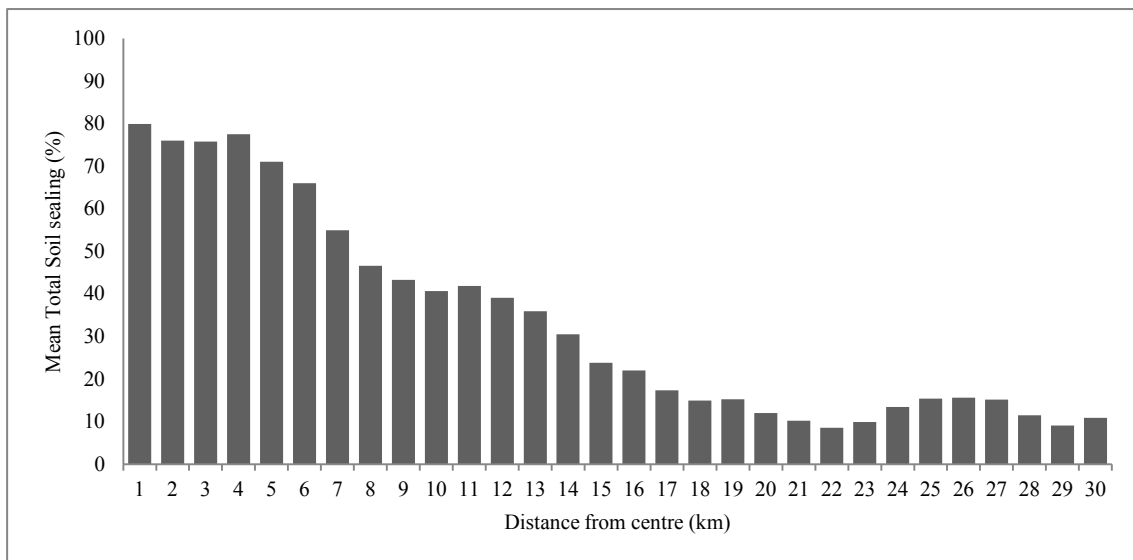


Figure 6-34 Relationship between mean total soil sealing and distance from city centre

The mean building volume values in the land-use blocks at a distance 5 km showed a mean sealing rate of 71%, whilst the mean soil sealing rate at between 5 km and 6 km from the centre was 66%. At a distance from 6 km to 7 km the mean sealing rate was 54%. Thereafter the mean soil sealing rates are seen gradually to decrease with distance from the centre.

It is worth noting that increasing block size was seen to correlate with decreasing soil sealing at a site-special level. However, it is worth noting also that most likely the soil sealing per capital would increase in these areas, largely due to the additional traffic route to access these areas.

The high percentage of sealed surfaces in these central areas of HCMC will intensify both urban runoff and the UHI with adverse effects on human health and comfort. A further effect to be expected is flooding and the increased energy consumption as a consequence of the additional demand for cooling. The results show that it is possible to carry out an approximate determination of soil sealing for HCMC on the basis of the UST classification with an expected much lower error rate than remote sensing techniques. With this method, the planning authorities of HCMC can determine soil sealing values in a highly efficient way.

## **7 Exposure to sea-level rise and current flood risk**

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The previous Chapters have discussed the classification of the observed UST of HCMC and reviewed the importance of obtained relevant density indicators for the entire city. This Chapter demonstrates further, using the example of a simple flood exposure assessment, how a spatially referenced UST classification allows us to undertake a wide variety of further assessments. Flooding has been and continues to be a major concern for many areas of HCMC. The exposure and risks to the city from inundation, in particular to its built and social assets, are expected to be more pronounced as a result of sea-level rise. Important indicators of urban flood risk in HCMC are the buildings, the critical infrastructure, the populations and land areas that will be inundated. This information is critical for both pre-disaster adaptations and real time disaster responses. The Chapter highlights how the UST approach can aid the identification and better understanding of both direct and indirect potential losses from flood events in HCMC and how these could be prevented through better land-use planning.

### **7.1 Flood exposure assessments**

Due to the relative greater scientific understanding of sea-level rise scenarios in regards to other predicted and forecasted impacts of climate change, numerous global comparative studies have attempted to assess the exposure of coastal urban areas to sea-level rise (Dasgupta *et al.*, 2009; Nicholls *et al.*, 2008a; Hunt and Watkiss, 2011). The studies have typically based their results on available spatially-disaggregated global datasets for the quantitative assessment of exposed elements such as land, population, and GDP (Storch and Downes, 2011). Elevation data obtained from the Shuttle Radar Topography Mission (SRTM) has also been commonly used to map inundation extents (Storch and Downes, 2011). However, Shortridge and Messina (2011), and Weydahl *et al.* (2007), are among a number of authors who have reported that SRTM data detected for both urban areas and forested areas have very well-known accuracy issues which can in turn lead to inaccurate assessment results. They report that the actual heights detected are that of the surface features, such as the structural roof heights of buildings



and the tree canopy heights of forests, yet not the needed elevation of the ground-level surface above sea-level.

There are a multitude of examples of assessments from Vietnam that help emphasise why SRTM data should not be used for sea-level rise assessments at both the national and urban scales. Storch and Downes (2011) reported that the nationwide rapid sea-level assessment study for Vietnam undertaken by Carew-Reid (2007), was based upon such datasets and as such, systematically underestimated the impacts to both built-up areas and mangrove forests. Furthermore, the official sea-level rise study for Vietnam undertaken by the MoNRE and published in 2009 also showed similar assessment problems related to the use of solely remotely sensed surface elevations in the calculation of inundation extents (MoNRE 2009). The spatial resolution of the input data has significant influence over results. More realistic results however were obtained in the 2010 report on climate risks in Asian Coastal Megacities (Pillai et al., 2010). In this study, the detailed mapping of flooding and inundation zones for HCMC were based not on STRM data, but on large-scale digital terrain information.

Aside from sea-level rise scenarios and ground level elevation data, another vital consideration for sea-level rise assessments is the incorporation of socio-economic data. Important for assessments is not just the status quo of an area, but also the temporal and spatial socio-economic changes in regards to population growth, land-use change and changes in the number and values of assets which could potentially be exposed.

Traditional remote sensing studies investigating the environmental effects and spatiotemporal land-use changes in Asian cities have recently also begun to give climate-related impacts more attention (Tran et al., 2006; Trung, 2009; Van, 2008; Van and Bao, 2007; Wu et al., 2006). Often however, these studies have been heavily theoretical and lack any link to practical planning relevance. Advances have not been coupled with improved decision-making and they have failed to overcome the all-important science-policy Lacking cooperation with the local planning institutions, the findings have resulted in little practical influence. Even the most recent and most detailed climate change assessments for HCMC to date (ADB, 2010; ICEM, 2009; World Bank, 2010a), have failed to represent the city in enough detail to be relevant for planning requirements. They all have neglected the actual current and up-to-date extent of the urban area, representing the urban settlement only by population mapped at coarse district or commune level within the existing administrative

boundaries. They also fail to take into account the built assets and other elements that also make up the city.

The ultimate aim of the assessment is to enhance spatial planning decisions and produce purposeful results regarding the current exposure of HCMC to coastal and tidal flooding. Within this assessment the emphasis is placed on the current spatial extent of built-up land which is derived from the UST classification and combined with future scenarios of sea-level rise projections. As such, the assessment presents a first estimate of the exposure of the current HCMC form to sea-level rise, as well as in the future through the coupling with sea-level rise scenarios. The analysis addresses the exposure of built-up land, USTs and population to current and future flooding. As such, the assessment sees built-up USTs and population as the further determinants of socioeconomic vulnerability (Klein and Nicholls, 1999), thus integrating biophysical vulnerability with social vulnerability. The results are a series of maps at the same spatial scale as the official land-use map, highlighting the exposure of the current built-up land and population. The results provide detailed information on the exposure of USTs, which can aid the identification of hotspots of greatest exposure, or most in need of further, more in-depth adaptation studies.

## **7.2 A method to assess sea-level rise and current flood exposure**

To quantify the current built-up land, USTs and population exposed to various sea-level rise scenarios, an elevation-based geographical information system (GIS) analysis was carried out. The classified and mapped USTs were correlated to a digital terrain model (DTM). In the absence of an appropriate model, a DTM was especially constructed from the official land surveying dataset. This dataset contained over 600,900 elevation points, and provided point data at distance intervals of 20 m for the urban districts and 200 m for the rural districts of HCMC. The spline with barriers interpolation method was applied to provide a raster layer representation of the surface topography at a 20 m resolution (Nhat 2012). The method interpolated a surface from the elevation points using a minimum curvature spline. The approximate elevations of the land-use blocks were then determined using the specific elevation of each individual block's centric point. Here the centric point's elevation was interpolated using a bilinear approach based on the DTM raster layer. This used a weighted mean between the four closest raster centres neighbouring the interpolation point.

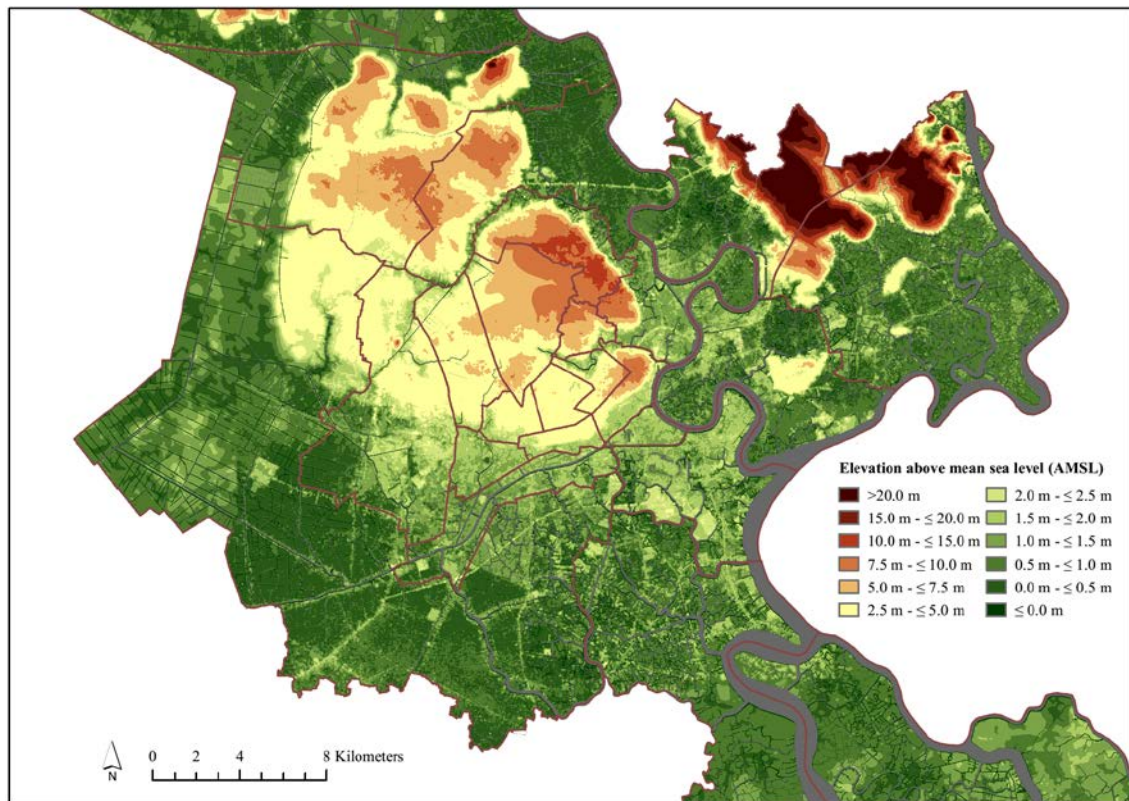


Figure 7–1 Digital terrain model mapped for the core area of HCMC (source: author's own editing)

From the assigned average elevation of each separate land-use block, their difference in elevation to specific water levels could be determined. Figure 7–1 illustrates the final compiled and mapped digital terrain model for the core of HCMC. Most of HCMC's area is distinctively low and flat. The terrain elevation varied from 4–32 m above mean sea-level (AMSL) in the north-northeast to the southern coastal lowlands at 0–1 m or below AMSL. It was calculated that 70% of the whole urban area of HCMC is below 2 m AMSL. Furthermore, 98.9% of the southern rural districts of Nha Be and Can Gio are below 2 m AMSL, while in contrast, for the two northern rural districts, Cu Chi and Hoc Mon, the figure is 38.2%.

Due to the large uncertainties surrounding future sea-level rise (Solomon *et al.*, 2007), the analysis was not constrained to a single sea-level rise event, but instead to two possible amplitudes of change. Water levels that corresponded to the current tidal maximum of 150 cm<sup>14</sup> at the time of the study and sea-level rise increases of 50 and 100 cm respectively were chosen. As such, the quantity and spatial pattern of USTs and population exposed to the water levels of 150, 200 and 250 cm above current mean sea-

<sup>14</sup> The tidal maximum has since risen to 168 cm in 2013, while between 2011 and 2014 the previously high tide maximum of 150 cm was reached 76 times (285/TB-OG 2015).

level were calculated (Table 7–1). These increases in sea-level can be taken as the potential effect from upper boundary climate scenarios projected from the extreme IPCC high emission scenario A1F1 for Vietnam for approximately the years 2070 and 2100 (MoNRE, 2009). Storch and Downes (2011), noted that the official Vietnamese SLR prediction is 75 cm, based on downscaling of the global predictions to the local level (B2 medium emissions scenario) (MoNRE, 2009). At the same time, Vietnam’s own planning parameter used in the National Target Programme to Respond to Climate Change (NTPRCC) (MoNRE, 2008) is a 100 cm rise in mean sea-level by 2100; that is consistent with predictions according to the A2 high emissions scenario whilst allowing for some melting of land ice (UN-VN, 2011).

Table 7–1 Summary of the scenarios used to analyse flood exposure and development interactions

Scenario	Water level		
	Current tidal max (150 cm)	Sea-level rise 50 cm (200 cm)	Sea-level rise 100 cm (250 cm)
Built-up extent			

It is important to note, that flood protection measures were not included in this assessment. Firstly, it is very difficult to ascertain spatially accurate data on current levels of flood protection for HCMC as data on the city’s existing flood defences is scarce. Secondary, where data does exist, it is seen that the defences which do exist are not spatially linked and there is no guarantee that they are sufficiently maintained to be fully effective in the event of a flood. Moreover, as Storch and Downes (2011), reported their inclusion would, for the circumstances in HCMC, dramatically overestimate current protection levels in comparison to reality.

In HCMC, the protection works that have been built may lead to a false sense of security. People and decision-makers may perceive areas, some of which have been designated as “high-risk zones”, as safe to develop, leading to an increase in population densities and building densities in unstable areas. This is the well-know “levee effect” (Jha *et al.*, 2012). These areas may now be subject to less frequent flooding than before the traditional flood control measures were in place. However, extreme events may still occur from time to time that exceed the design standards and the resulting disaster damage is often extremely high as the result of the structural protection works. Only relying on traditional flood control measures is increasingly recognised as inadequate,

as structural protections sometimes fail due to poor design or a lack of maintenance. The assessment highlights exposure as a central spatial indicator of risk and as such can be viewed as a worst case scenario. However, this exposure can be taken to illustrate the losses following an extreme or catastrophic event arising from a potential failure of the current flood defences.

It is important to recognise, that the UST assessment had inherent limitations. Overall, the level of flood risk will result from an interaction of the flood water exposure, and the actual vulnerabilities and sensitivities of the elements exposed in this assessment, the actual USTs and distributed population. The assessment takes into account only the first-order direct impacts of flood exposure. Here, it is important to remember that the assessment is a simplified representation of reality, and no further modelling of flood water propagation and dynamics was undertaken. Ultimately, the specific flood damages occurring from a flood event will be dependent upon both the actual flood water velocity and the flood duration (Hanson *et al.*, 2011). Furthermore, land subsidence has been observed at many discrete locations within the HCMC administrative area (Ho, 2007; 2008; Minh *et al.*, 2015). Over decades, locally this is likely to highly exacerbate the effects of sea-level rise. However, the small number of research studies assessing, the true extent of land subsidence in HCMC are both temporally and spatially limited, the impact of land subsidence was not considered in this assessment.

### **7.3 Exposed land and built-up area**

The sea-level rise exposure series shown in Figure 7-2 shows the spatial distribution of flood footprints for the total land area of HCMC and also both of the built-up and non-built up shares of land. The results of the assessment demonstrate that a significant proportion of the total land area of HCMC already displays a certain degree of exposure to flood risk. Approximately 120,800 ha or 71% of the total land (170,951 ha) is exposed to flooding following a 150 cm event above current mean sea-level, *i.e.* a current maximum tide event. This figure rises to 128,123 ha or 75% of the total land area of HCMC for a 200 cm event and 131,723 ha or 77% of the total land area of HCMC for a 250 cm event respectively. These would equate to either 50 cm or 100 cm rise in sea-level occurring simultaneously with a present day maximum tide event.

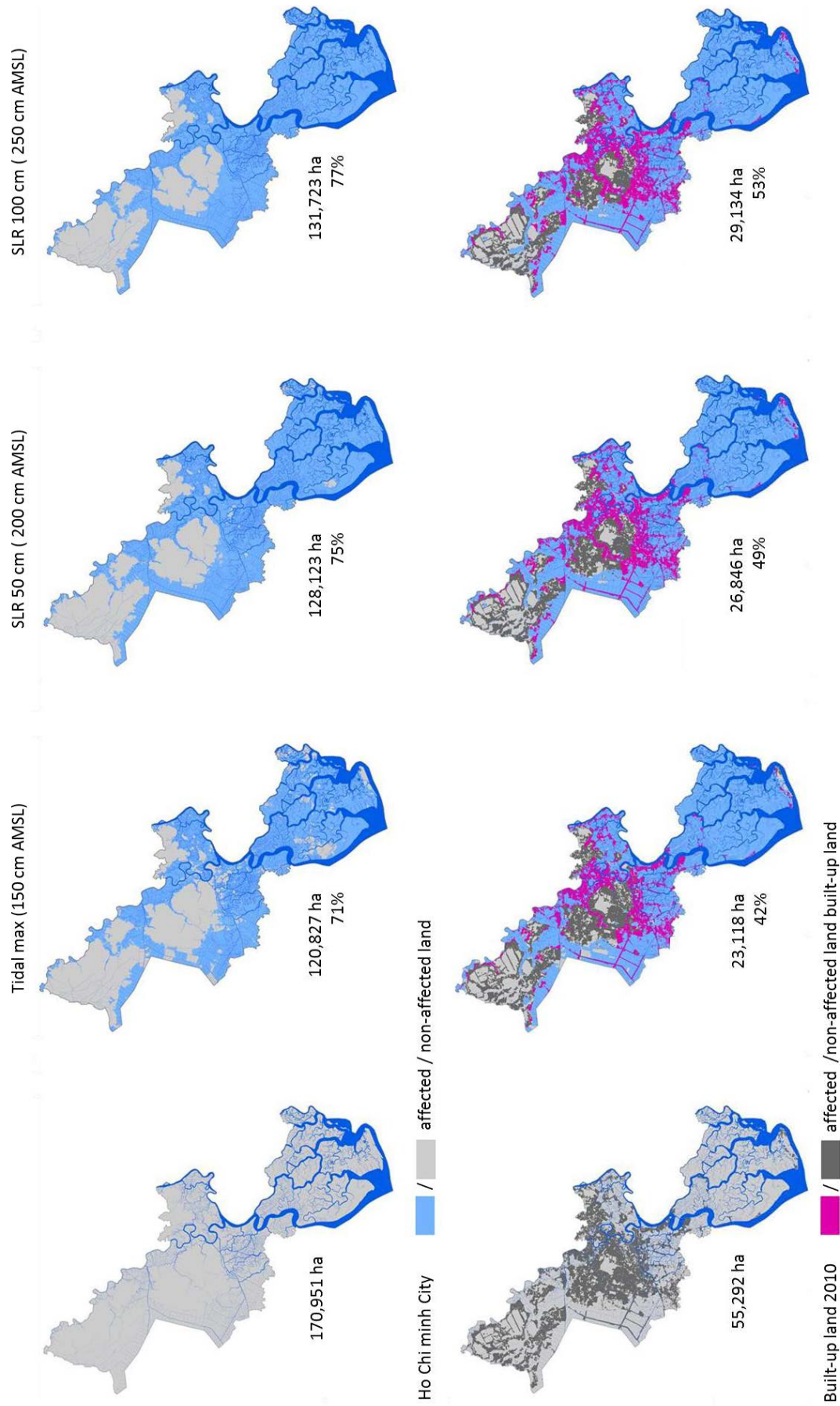


Figure 7-2 Sea-level rise and exposure matrix (source: author's own)

In terms of built-up land, the results of the assessment also demonstrate that a significant proportion of the current built-up area (defined in this assessment as land classified with residential, public and industrial USTs) displays a high degree of exposure to flood risk (Figure 7–2). Approximately 23,118 ha or 42% of the current total 55,292 ha of built-up land is exposed to flooding following a 150 cm event above mean sea-level, *i.e.* a current maximum tide event. The majority of this current exposure is seen concentrated in a few hotspots located in the low-lying areas to the south of the historic centre. These comprise of developments from mainly between the years 2000 and 2010. Disregarding any future urban development but taking into account the maximum tide event of 150 cm occurring simultaneously in conjunction with future climate change scenarios, a 50 cm rise in sea-level, (*i.e.* a combined water level of 200 cm above current mean sea-level) would give rise to 49% or 26,846 ha of the current total built-up area of HCMC being exposed to flood risk. While a 100 cm rise in sea-level (*i.e.* a combined water level of 250 cm above current mean sea-level) would equate to 53% or 29,134 ha of the total built-up area of HCMC becoming exposed to flood risk respectively.

Table 7–2 shows the overview of the total-built up area exposed for the individual districts of HCMC. In conjunction with Figure 7–2, it can be seen that already for the maximum tide water level of 150 cm, high percentages of the total built up areas of many districts are exposed to flood risks. The urban districts of district 8, and Binh Thanh, the peri-urban district of district 7 and the rural districts of Binh Chanh and Nha Be and Can Gio all for example exhibit over 80% of their total built-up areas being exposed to flood risks. At a water level of 150 cm 29.6% or 3,251 ha of the total built up area of the urban districts are seen to be exposed to flood risk, whereas this figure is 57.2% or 9,236 ha for the peri-urban districts and 37.8% or 10,626 ha for the rural districts.

At a combined water level or 200 cm, *i.e.* a sea-level rise of 50 cm coinciding with the occurrence of a maximum tide event, the peri-urban district of district 7 and the rural districts of Nha Be and Can Gio all show 100% of their total built-up areas being exposed to flood risks. Overall, at this water level 41.4% or 4,545 ha the built-up area of urban districts is exposed, while 64.9% or 10,484 ha of the built-up area of peri-urban districts and 42% or 11,815 ha of the built-up area of the rural districts are exposed to flood risk.

At a combined water level of 250 cm, *i.e.* a sea-level rise of 100 cm and a maximum tide event, the districts of Binh Thanh, Binh Tan and Binh Chanh all show over 80% of their total built areas are exposed to flood risk, while the districts of district 6, 4, 8 and 2 all show over 90% exposure rates. The highest rates of exposure at this water level were seen in districts 7, Nha and Can Gio with 100% exposure. In contrast, the northern urban districts of Go Vap, Tan Binh and Tan Phu, and the two northern rural districts of Cu Chi and Hoc Mon show the lowest levels of built-up exposure at a 250 cm water level, all below 30% exposure. Furthermore, the urban district of district 10 shows no exposure of built-up land to flood risks for any of the assessed water levels. In total at a 250 cm water level, 45.2% or 4,964 ha of the built up land in urban districts is exposed to flood risk, whereas a substantial 68.9% or 11,139 ha of built up land in peri-urban districts and a moderate 46.3% or 13,030 ha of built up land in rural districts is exposed to flood risk. Interestingly, district 10 showed no flood exposure at the three water levels to its 496 ha of built-up land.

Table 7–2 Built-up area exposed per district

Districts	Total built-up area (ha)	Built-up area exposed (ha)			Built-up area exposed (%)		
		Tidal max (150 cm)	SLR 50 cm (200 cm)	SLR 100 cm (250 cm)	Tidal max (150 cm)	SLR 50 cm (200 cm)	SLR 100 cm (250 cm)
<b>Urban districts</b>							
1	543.0	51.4	295.9	338.2	9.5	54.5	62.3
3	415.7	0.0	113.0	143.3	0.0	27.2	34.5
4	282.2	180.8	281.9	282.0	64.1	99.9	99.9
5	317.7	8.4	172.3	200.3	2.6	54.2	63.0
6	633.5	445.4	577.4	577.4	70.3	91.1	91.1
10	495.6	0.0	0.0	0.0	0.0	0.0	0.0
11	468.4	34.7	110.5	165.3	7.4	23.6	35.3
Phu Nhuan	427.8	0.0	67.0	117.3	0.0	15.7	27.4
8	1,060.7	881.4	1,005.6	1,005.7	83.1	94.8	94.8
Binh Thanh	1,325.0	1,061.5	1,135.6	1,136.7	80.1	85.7	85.8
Go Vap	2,487.5	491.1	536.9	606.0	19.7	21.6	24.4
Tan Binh	1,204.2	43.0	84.4	132.4	3.6	7.0	11.0
Tan Phu	1,314.9	54.2	165.1	259.4	4.1	12.6	19.7
<i>Total</i>	<i>10,976.1</i>	<i>3,251.8</i>	<i>4,545.8</i>	<i>4,964.0</i>	<i>29.6</i>	<i>41.4</i>	<i>45.2</i>
<b>Peri-urban districts</b>							
Thu Thiem 2	1,365.9	1,030.7	1,182.0	1,252.5	75.5	86.5	91.7
7	1,509.9	1,312.4	1,509.9	1,509.9	86.9	100.0	100.0
9	3,414.4	1,847.6	1,985.5	2,146.5	54.1	58.2	62.9
12	3,707.0	2,021.5	2,091.1	2,164.8	54.5	56.4	58.4
Binh Tan	3,015.8	1,605.1	2,218.4	2,457.5	53.2	73.6	81.5
Thu Duc	3,144.8	1,419.4	1,497.4	1,607.9	45.1	47.6	51.1
<i>Total</i>	<i>16,157.8</i>	<i>9,236.8</i>	<i>10,484.4</i>	<i>11,139.1</i>	<i>57.2</i>	<i>64.9</i>	<i>68.9</i>
<b>Rural districts</b>							
Cu Chi	15,160.7	2,499.2	3,167.2	3,913.0	16.5	20.9	25.8
Hoc Mon	4,524.6	855.6	998.6	1,289.2	18.9	22.1	28.5
Binh Chanh	5,399.0	4,401.5	4,576.1	4,755.0	81.5	84.8	88.1
Nha Be	2,109.9	2,093.5	2,109.8	2,109.9	99.2	100.0	100.0
Can Gio	963.7	780.1	963.7	963.7	80.9	100.0	100.0
<i>Total</i>	<i>28,158.0</i>	<i>10,626.9</i>	<i>11,815.4</i>	<i>13,030.9</i>	<i>37.8</i>	<i>42.0</i>	<i>46.3</i>
<b>Whole City</b>	<b>55,291.9</b>	<b>23,118.5</b>	<b>26,845.6</b>	<b>29,133.9</b>	<b>42.1</b>	<b>48.6</b>	<b>52.7</b>



## 7.4 Exposed population

Table 7–3 shows an overview of the absolute total and percentage of population exposed in the individual districts of HCMC. In total, according to the distribution of population over the classified USTs, at a water level of 150 cm, corresponding to the current maximum tide event, 2.7 million or 36.6% of the entire population of HCMC resides on built up land potentially exposed to flood risk and therefore can be assumed to be affected by the risks a flood event would pose. For a water level of 200 cm, *i.e.* a current maximum event and a 50 cm sea-level rise, 3.6 million or 49.3% of HCMC's population would be affected. While at a water level of 250 cm, *i.e.* a current maximum tide event and a 100 cm sea-level rise, 4 million or 54.1% of HCMC population resides in built-up land exposed to flood risk.

Table 7–3 Population exposed per district

Districts	Population	Population exposed (ha)			Population exposed (%)		
		Tidal max (150 cm)	SLR 50 cm (200 cm)	SLR 100 cm (250 cm)	Tidal max (150 cm)	SLR 50 cm (200 cm)	SLR 100 cm (250 cm)
<b>Urban districts</b>							
1	189,781	19,558	139,851	149,971	10.3	73.7	79.0
3	196,217	0	70,741	83,084	0.0	36.1	42.3
4	186,127	127,904	185,699	186,127	68.7	99.8	100.0
5	176,627	3,917	104,379	119,636	2.2	59.1	67.7
6	246,875	183,907	246,875	246,875	74.5	100.0	100.0
10	235,608	0	0	0	0.0	0.0	0.0
11	232,858	7,471	62,896	101,392	3.2	27.0	43.5
Phu Nhuan	200,581	0	24,577	59,077	0.0	12.3	29.5
8	432,757	365,925	424,593	424,593	84.6	98.1	98.1
Binh Thanh	495,554	337,443	383,790	384,155	68.1	77.4	77.5
Go Vap	567,824	126,180	144,046	159,876	22.2	25.4	28.2
Tan Binh	430,405	8,466	32,973	62,348	2.0	7.7	14.5
Tan Phu	420,301	4,659	19,259	42,820	1.1	4.6	10.2
<b>Total</b>	<b>4,011,515</b>	<b>1,185,430</b>	<b>1,839,679</b>	<b>2,019,954</b>	<b>29.6</b>	<b>45.9</b>	<b>50.4</b>
<b>Peri-urban districts</b>							
Thu Thiem 2	142,113	105,316	120,360	128,979	74.1	84.7	90.8
7	177,207	153,453	177,207	177,207	86.6	100.0	100.0
9	267,289	118,797	133,674	145,878	44.4	50.0	54.6
12	432,750	132,875	144,426	161,118	30.7	33.4	37.2
Binh Tan	631,468	246,874	398,313	460,086	39.1	63.1	72.9
Thu Duc	462,095	166,132	180,106	197,820	36.0	39.0	42.8
<b>Total</b>	<b>2,112,922</b>	<b>923,447</b>	<b>1,154,086</b>	<b>1,271,088</b>	<b>43.7</b>	<b>54.6</b>	<b>60.2</b>
<b>Rural districts</b>							
Cu Chi	360,171	67,352	85,169	98,837	18.7	23.6	27.4
Hoc Mon	364,170	53,046	63,941	87,662	14.6	17.6	24.1
Binh Chanh	448,271	341,260	361,579	387,413	76.1	80.7	86.4
Nha Be	105,141	103,076	105,141	105,141	98.0	100.0	100.0
Can Gio	71,523	63,787	71,523	71,523	89.2	100.0	100.0
<b>Total</b>	<b>1,811,371</b>	<b>628,521</b>	<b>687,353</b>	<b>750,576</b>	<b>34.7</b>	<b>37.9</b>	<b>41.4</b>
<b>Whole City</b>	<b>7,473,713</b>	<b>2,737,398</b>	<b>3,681,118</b>	<b>4,041,618</b>	<b>36.6</b>	<b>49.3</b>	<b>54.1</b>

As to be expected, the exposure of population over the HCMC districts corresponds heavily with the exposure of built up land seen in Table 7–2. Observable in Table 7–3, that at water levels of 150 cm, 200 cm and 250 cm, it was calculated that 1.1 million

(29.6%), 1.8 million (45.9%) and 2.0 million (50.4%) residents of the 13 urban districts resided on land exposed to flood risk. Overall, the urban districts of district 4, 6 and 8 showed the highest exposure at all water-levels. Within the 5 rural districts of HCMC, at water levels of 150 cm, 200 cm and 250 cm, 0.6 million (34.7%), 0.7 million (37.9%) and 0.8 million (41.4%) of their population reside on land exposed to flood risks respectively. The southern rural districts of Nha Be, Can Gio exhibit the highest exposure while the northern rural districts of Cu Chi and Hoc Mon showed the least. The highest relative levels of exposed population were seen in the peri-urban districts of HCMC. It was calculated that for the water levels of 150 cm, 200 cm and 250 cm, 0.9 million (43.7%) 1.2 million (54.6%), and 1.3 million (60.2%) of the total 2.1 million population in peri-urban districts reside on built-up land exposed to flooding. The highest exposure among the peri-urban districts of HCMC was seen to the south and east of the current city centre in district 7 and district 2.

### **7.5 Exposed residential USTs**

Knowledge of the nature of the USTs exposed is important as populations and assets in multi-storey structures will not be placed at the same risk and will have very different adaptation options as those in single-storey structures (Deilmann, 2007). Additionally, the buildings, which make up the USTs are usually one of the highest value assets of residents. Table 7–4 shows an overview of the exposure of the main classes and groupings of USTs, as well as the individual USTs related to the assessed water levels of 150 cm, 200 cm and 250 cm above current mean sea-level. The Table shows flood risk exposure in terms of absolute area and population exposed to the different water levels and in the percentage of the total area exposed for each individual UST, classes or groups. It can be seen from Table 7–4 that for a current maximum tide event of 150 cm AMSL, 17,800 ha or 42% of all shophouse based USTs to potential flood risks. At this same water level, 684 ha or 81% of all villa based USTs, 247 ha or 49% of all apartment based USTs and 26 ha or 4% of all central business district based USTs are exposed. At a water level of 200 cm AMSL (*i.e.* a sea-level rise of 50 cm and a maximum tide event occurring), 20,326 ha or 48% of all shophouse based USTs, 739 ha or 88% of all villa based USTs, 306 ha or 615 of all apartment based USTs and 236 ha or 35% of all central business district based USTs are exposed to flooding.

With an increase to a water-level to 250 cm AMSL (*i.e.* a sea-level rise of 100 cm and a maximum tide event occurring), 22,149 ha or 52% of all shophouse based USTs are exposed to flooding. Furthermore, at this water-level the exposure of villa-based USTs constant at 739 ha or 88%, while apartment based USTs increased exposure to 341 ha or 68% and central business district based USTs to 294 ha or 40%.

In regards to the residential USTs subdivision into groups, the highest exposure in terms of percentage of group to flood risk at the current maximum tide water level of 150 cm AMSL was seen in the regular villa group with 602 ha or 90%, the mixed shophouse group with 937 ha or 57% and the new apartment group with 180 ha or 53% total exposure. The mixed villa group showed 82 ha or 46% exposure at this water level and the peri-urban shophouse group exhibited 13,134 ha or 44%.

At a water level of 200 cm AMSL, 626 ha or 94% of regular villa and 937 ha or 64% of mixed shophouses, 82 ha or 64% of mixed villas, and 232 ha or 64% of new apartments are seen to be exposed to flood risks. From the old apartment group, 74 ha or 58% is exposed and 14216 ha or 48% of the peri-urban shophouses and 2,938 ha or 48% irregular shophouse group.

At the final assessed water level of 250 cm AMSL, 626 ha or 94% of the regular villa group was seen to be exposed to flood waters. This was followed with exposure levels of 90 ha or 70% of the old apartment group, 251 ha or 68% of the new apartment group, 1055 ha or 64% of mixed shophouses and 113 ha or 63% of the mixed villa group. Interestingly, the regular shophouse, irregular shophouse and peri-urban shophouse groups showed comparable exposure rates at this water level in percentages term with 51%, 54% and 52% respectively. However in absolute terms, 15,325 ha of peri-urban shophouse USTs were exposed and only 3,266 ha and 2,503 ha of irregular shophouse and regular shophouse USTs respectively.

In terms of individual urban structure types, at the current maximum tide water level of 150 cm AMSL, the highest exposure levels in percentage terms was seen in the American apartment UST with 41 ha or 100% of classified structures exposed.

Table 7-4 USTs and flood exposure in terms of population exposed and UST

UST	Total coverage (ha)		Area exposed (ha)		Population affected		Percentage of total UST type exposed (%)		
	Tidal max (150 cm)	SLR 50 cm (200 cm)	SLR 50 cm (200 cm)	SLR 100 cm (250 cm)	Tidal max (150 cm)	SLR 50 cm (200 cm)	Tidal max (150 cm)	SLR 50 cm (200 cm)	
<b>All Shophouse based-</b>	42,315.3	17,880.0	20,326.7	22,149.4	2,120,318	2,805,925	3,119,571	42.3	48.0
Regular shophouse	4,923.4	1,423.9	2,134.0	2,502.7	316,225	612,954	727,870	28.9	43.3
Shophouse reg. new	449.1	162.2	240.4	262.1	32,575	59,291	60,788	36.1	53.5
Shophouse reg. new comm.	391.9	188.1	253.3	350.4	23,980	40,441	67,809	48.0	65.1
-Shophouse reg. narrow	2,062.8	459.4	761.9	840.8	163,163	348,226	398,235	22.3	36.9
-Shophouse reg. w/yards	2,019.6	614.2	876.3	1,049.4	96,507	164,996	201,038	30.4	43.4
Irregular shophouse	6,131.5	2,384.8	2,938.0	3,266.4	915,510	1,205,012	1,330,794	38.9	47.9
Shophouse irreg. high-dense	1,602.4	792.0	1,087.7	1,203.0	442,460	646,736	719,380	49.4	67.9
Shophouse irreg. w/yards	4,443.9	1,523.4	1,768.4	1,981.4	442,767	523,134	576,272	34.3	39.8
Shophouse irreg. temp.	83.2	69.4	81.9	82.0	30,283	35,142	35,142	81.5	96.2
Peri-urban shophouse	29,613.5	13,134.9	14,215.8	15,324.9	714,300	774,740	845,026	44.4	48.0
Shophouse irreg. scattered	6,989.4	2,547.8	2,830.6	3,320.1	216,238	245,065	295,047	36.5	40.5
Shophouse irreg. clustered	5,490.9	3,732.7	3,860.8	3,937.6	268,311	280,847	287,724	68.0	70.3
Shophouse irreg. w/fields	17,133.2	6,854.4	7,524.4	8,067.2	229,751	248,828	262,255	40.0	43.9
Mixed shophouse	1,646.9	936.5	1,038.9	1,055.4	174,283	213,219	215,881	56.9	63.1
Shophouse w/ industry	1,292.5	707.7	780.4	795.7	135,596	171,830	173,514	54.8	60.4
Shophouse irreg/reg.	354.4	228.8	239.4	259.7	38,687	41,389	42,367	64.6	72.9
All villa based-	844.7	684.1	739.4	739.4	48,563	55,581	55,581	81.0	87.5
Regular villa	665.7	601.8	626.2	626.2	32,721	34,654	34,654	90.4	94.1
villa	274.8	251.0	268.7	268.7	12,358	12,358	12,358	91.3	97.8
Luxury villa	390.9	350.8	357.6	357.6	21,908	22,296	22,296	89.7	91.5
Mixed villa	179.0	82.3	113.2	113.2	15,842	20,927	20,927	46.0	63.2
Villa in est. UST	150.7	82.3	113.2	113.2	15,842	20,927	20,927	54.6	75.1
Colonial villa	28.3	0.0	0.0	0.0	0	0	0	0.0	0.0
All Apartments-	500.0	247.2	306.4	341.1	47,122	69,252	77,108	49.4	61.3
Apartment new	370.8	197.9	232.1	251.1	23,414	37,006	42,247	53.4	62.6
Low-rise apartment	152.5	98.8	121.6	134.5	12,413	21,989	24,054	64.8	79.7
High-rise apartment	218.3	99.1	110.5	116.6	11,001	15,017	18,193	45.4	50.6
Apartment old	129.2	49.3	74.3	90.0	23,708	32,246	34,861	38.2	57.5
Chinese apartment	56.0	8.6	33.6	49.3	2,853	11,391	14,006	15.3	60.1
American apartment	40.7	40.7	40.7	40.7	20,855	20,855	20,855	100.0	100.0
Social apartment	32.5	0.0	0.0	0.0	0	0	0	0.0	0.0
All CBD based-	744.5	26.9	263.0	294.4	8,871	142,208	157,136	3.6	35.3
CBD	531.5	20.9	189.9	214.8	6,804	123,496	136,462	3.9	35.7
CBD w/high dense	213.0	6.1	73.1	79.6	2,067	18,712	20,674	2.8	34.3
All residential	44,404.6	18,838.3	21,635.5	23,524.4	2,224,874	3,072,966	3,409,396	42.4	48.7
Additional built up UST	10,887.2	4,280.2	5,210.1	5,609.5	152,779	226,628	242,596	39.3	47.9
Green & Open UST	115,659.2	977,08.9	101,277.1	102,589.0	359,745	381,524	389,626	84.5	87.6
<b>Total UST</b>	<b>170,951</b>	<b>120,827.4</b>	<b>128,122.68</b>	<b>131,722.881</b>	<b>2,737,398</b>	<b>3,681,118</b>	<b>4,041,618</b>	<b>70.7</b>	<b>74.9</b>

Furthermore, at this water level 251 ha 91% of villa, 351 ha 90% luxury villa and 69 ha 82% of shophouse irregular temporary UST were calculated to be exposed. At a water level of 200 cm above AMSL, 269 ha or 97% of villas, 82 ha or 96% of shophouse irregular temporary and 358 ha or 92% of luxury villas UST were seen to become exposed. Also noteworthy at this water level is the exposure of 122 ha or 80% of low rise apartments, 113 ha or 75% of villa in established UST, 258 ha or 73% of shophouse irregular and regular mix, and 3,861 ha or 70% of shophouse irregular clustered. Examination of the results for a water level of 250 cm above AMSL shows that 98% of villa, 96% of shophouse irregular temporary, 92% of luxury villa, 89% of shophouse regular new community and 88% of both low-rise and Chinese apartments are exposed to flood risk. Also interestingly at this water level, 1,203 ha or 75% of shophouse irregular high-dense, 258 ha or 73% of shophouse irregular/regular mixed and 3,937 ha or 72% of shophouse irregular clustered are exposed to flood risks. The highest exposure in absolute terms at the three water levels was seen in the peri-urban structure type, shophouse irregular with fields. This UST displayed 6,854 ha or 40%, 7,524 ha or 44% and 8,067 ha or 47% exposure rates at the three assessed water levels. Furthermore, both Colonial villa and social apartment USTs showed no exposure at any of the assessed water levels.

## **7.6 Exposed population over residential USTs**

Brief mention should be given to the exposure of population disturbed over the classified USTs. As discussed in Chapter 4, USTs influence the environment of the population and act as shelter for protection in times of hazards. Table 7–4 shows that the most exposed population to flood risks in absolute terms at all assessed water levels was in the irregular shophouse development group, namely the individual shophouse high-dense and shophouse irregular with yards USTs. Overall, at the highest water level, the group of irregular shophouses accounts for 1.3 million or 33% of the total population exposed of 4.4 million. Furthermore, the exposure of population at the highest water level in this UST group is 18% of the total 7.4 million population of HCMC. Individually at a water level of 250 cm AMSL, 0.7 million residents residing in shophouse irregular high-dense and 0.6 million in shophouse irregular with yards USTs are exposed, accounting for 18% and 14% of the overall total population exposed respectively.

At the current maximum tide water level of 150 cm AMSL, the peri-urban shophouse group showed the second highest total population exposed with 0.7 million and the regular shophouse group contained 0.3 million exposed residents. However as the water levels were increased to the highest water level of 250 cm AMSL, the gap between the two UST groups was seen to decrease and finally, 0.8 million residents were assessed to be exposed in peri-urban shophouse based USTs and 0.7 million in regular shophouse based USTs.

### **7.7 Exposed public, industrial and green and open space based USTs**

In addition to the exposure of residential USTs, knowledge relating to the exposure of public, industrial and green and open space based USTs is important for decision-makers. To give an example, a hospital has a very high vulnerability to urban flooding since this function is indispensable in a state of emergency. On the other hand, flooding of marginal regions of residential areas such as peri-urban USTs is a considerable catastrophe for individuals, but does not have a significant impact on the entire city; hence those areas could be defined as less vulnerable. The industrial sector is a significant and growing part of the HCMC economy. The siting of industry in flood-prone areas is highly problematic as the loading of flood waters with pollution needs to be considered, as well as other indirect impacts.

In order to gain an understanding of the exposure of critical infrastructure to flood risks, Table 7–5 provides an overview of the flood exposure of public, industrial and green and open space based USTs. It can be seen that at a water level of 150 cm, 1,370 ha or 26% of the classified public and special use based USTs are exposed. As the water level increases by 50 cm and 100 cm, the exposure rate increases to 32% and 34% respectively. At the highest water level, it was assessed that 85% of all energy and communication based USTs were exposed to floods, 79% of trade and commerce based USTs, and 36% of hospitals and health centres and 29% of educational sites. Overall at the three water levels of 150 cm, 200 cm and 250cm AMSL, 52%, 63% and 68% of all industrial based USTs were seen exposed to flood risk. Here, the UST group of industry low-dense exhibited a slightly higher exposure rate than high-dense industrial UST. For green and open classified USTs, the rate of exposure overall was 85% at a water level of 150 cm AMSL, 88% for a water level of 200 cm AMSL and 89% for a water level of 250 cm AMSL.

Table 7–5 Flood exposure risk to public, industrial and green and open space based USTs

UST groups & classes	Total UST area (ha)	UST area exposed (ha)			UST area exposed (%)		
		Tidal max (150 cm)	SLR 50 cm (200 cm)	SLR 100 cm (250 cm)	Tidal max (150 cm)	SLR 50 cm (200 cm)	SLR 100 cm (250 cm)
<b>Public &amp; special use</b>	<b>5,249.7</b>	<b>1,370.8</b>	<b>1,661.5</b>	<b>1,759.7</b>	<b>26.1</b>	<b>31.6</b>	<b>33.5</b>
<i>Educational sites</i>	670.6	139.0	183.0	192.6	20.7	27.3	28.7
<i>Trade &amp; commerce</i>	68.3	45.8	53.8	53.8	67.1	78.8	78.8
<i>Sites of worship</i>	181.7	58.5	79.2	92.7	32.2	43.6	51.0
<i>Hospital/health</i>	167.5	19.7	47.1	59.5	11.7	28.1	35.5
<i>Public offices</i>	255.3	93.2	120.1	122.0	36.5	47.0	47.8
<i>Transportation nodes</i>	1,410.2	551.7	566.7	570.4	39.1	40.2	40.4
<i>Cultural sites</i>	436.0	177.4	288.7	294.0	40.7	66.2	67.4
<i>Energy/communications</i>	48.4	36.2	41.2	41.2	74.8	85.1	85.1
<i>Security &amp; military</i>	2,011.7	249.2	281.9	333.6	12.4	14.0	16.6
<b>Industrial</b>	<b>5,637.5</b>	<b>2,909.4</b>	<b>3,548.6</b>	<b>3,849.8</b>	<b>51.6</b>	<b>62.9</b>	<b>68.3</b>
<i>Industry high dense</i>	2,191.2	930.8	1,351.7	1,419.6	42.5	61.7	64.8
<i>Industry low dense</i>	3,446.2	1,978.6	2,196.9	2,430.2	57.4	63.7	70.5
<b>Green &amp; open space</b>	<b>115,659.2</b>	<b>97,708.9</b>	<b>101,277.1</b>	<b>102,589.0</b>	<b>84.5</b>	<b>87.6</b>	<b>88.7</b>
<i>Park</i>	595.8	102.1	118.3	140.8	17.1	19.9	23.6
<i>Harvested crops</i>	57,705.4	42,642.3	42,642.3	45,742.1	73.9	73.9	79.3
<i>Aquaculture</i>	10,955.3	10,560.7	10,560.7	10,812.0	96.4	96.4	98.7
<i>Forest</i>	38,042.5	37,377.5	37,377.5	37,777.4	98.3	98.3	99.3
<i>Grasslands</i>	2,453.4	2,150.9	2,698.7	2,747.9	58.2	66.2	67.4
<i>Under construction</i>	5,399.6	4,566.5	4,860.7	5,006.6	84.6	90.0	92.7
<i>Disposal &amp; treatment</i>	299.7	269.5	297.2	298.3	89.9	99.2	99.5
<i>sports site</i>	207.5	39.4	63.9	63.9	19.0	30.8	30.8

Note: Green and open space excludes surface water bodies

At a water level of 250 cm AMSL, approximately 100% of all classified disposal and treatment sites are exposed to flooding. Interestingly, out of the entire land-use blocks classified as under construction, 85% or 4,566 ha out of a total of 5,400 ha are assessed to be already exposed to flood risk at the current maximum tide level of 150 cm AMSL. At a water level of 200 cm and 250 cm AMSL, the total exposure of identified under construction sites increases to 90% or 4,861 ha and 93% or 5,007 ha accordingly.

## 7.8 General discussion—what and who is exposed

The results from the sea-level rise and current exposure assessment provide interesting insights into current vulnerabilities on a city-wide scale. The UST based assessment results enables the communication of both the location and extent of current exposure to flood risk for the whole administrative area of HCMC. The results mapped at the same spatial scale as the official land-use map, revealed that the city currently experiences high exposure to flood risks.

The approach also allows questions of “what is” and “what if” to be asked in relation to flood risk exposure for the city. For instance, the UST approach shows the detailed spatial distribution of exposure results for specific USTs and critical urban land-uses. This can provide an indication of the key sectors and social groups exposed and accurately determine the population and structural assets potentially affected by floods.

Resultantly, hotspots and the city-districts and neighbourhoods most at risk can be identified. This can greatly improve emergency management and current disaster planning for the city. The exposure levels of planned areas for future urban growth with the greatest need of further, more in-depth studies can also be highlighted.

Many studies have stated that it is often the poor that are most affected by climate change, and weather related disasters (Balk *et al.*, 2009b; Baker, 2012; Laukkonen *et al.*, 2009; McGranahan *et al.*, 2007; Satterthwaite, 2007; 2008; Moser and Scatterthwaite, 2010; Banks *et al.*, 2011). Studies investigating cities and urban areas in India (Revi, 2008; Chatterjee, 2010), Latin America (Hardoy and Pandiella, 2009), Africa (Douglas *et al.*, 2008), and Asia (Tanner *et al.*, 2009; Kovats and Akhtar, 2008), all suggest that it is the poor that will be more exposed, more vulnerable and have less capacity to adapt. To prepare for current and future climate-related risks, protection measures for flooding are typically constructed to protect the most vulnerable and those at greatest risk of flooding. In fact, both risk adaptation and mitigation measures need to focus on the particular population and elements at risk in the urban environment to be effective in responding to a heterogeneous array of constraints and opportunities, which each UST provides. Table 7–6 shows the ranking of the top five residential USTs in terms of absolute total land exposed, percentage of total UST area and in terms of the absolute population exposed.

In absolute terms of total area exposure, the peri-urban and irregular shophouse groups are seen to be most exposed. Here the peri-urban UST Shophouse irregular with fields is ranked first followed by UST Shophouse irregular clustered. However, this is just one measure of exposure to the current maximum tide water level. If the total population exposed per UST is considered the shophouse irregular with yards UST is ranked first, followed by the UST Shophouse irregular high-dense.

Another measure of exposure is to consider the percentage of the classified UST which is exposed. In percentage terms, the highest exposure levels to a current maximum tide event with a water level of 150 cm were seen for the five USTs American apartment, Villa, Luxury Villa, Shophouse irregular temporary and Shophouse irregular clustered. At a 150 cm water level, 100% of the American apartments, 91% of the Villa, 90% of the Luxury Villa 82% Shophouse irregular temporary and 68.0% of the Shophouse irregular clustered USTs are exposed.



Table 7–6 Top 5 residential USTs exposed to a current maximum tide water level (150 cm)

Ranking	Area exposed (ha)	Percentage exposed (%)	Population exposed (persons)
1	Shophouse irregular with fields (6,854.4 ha)	American apartment (100%)	Shophouse irregular with yards (442,767)
2	Shophouse irregular clustered (3,732.7 ha)	Villa (91.3%)	Shophouse irregular high-dense (442,767)
3	Shophouse irregular scattered (2,547.8 ha)	Luxury Villa (89.7%)	Shophouse irregular clustered (268,311)
4	Shophouse irregular with yards (1,523.4 ha)	Shophouse irregular temporary (81.5%)	Shophouse irregular with fields (229,751)
5	Shophouse irregular high-dense (792.0 ha)	Shophouse irregular clustered (68.0%)	Shophouse irregular scattered (216,238)

Interestingly, at the same water level, 268,311 people were assessed to be exposed in the Shophouse irregular Clustered UST, 30,283 people were assessed to be exposed in the Shophouse irregular temporary UST, 20,855 people in the American apartment UST, 21,908 people in the Luxury villa UST and only 10,813 people in the Villa UST respectively.

Both Villa and Luxury villa USTs can be taken as new high end-real estate additions to the urban landscape of HCMC. They were found mainly in Districts 2 and 9 and to lesser extends in other peri-urban and rural districts of the city, often along the banks of the Saigon River. In stark contrast, the UST American apartment was seen solely in Binh Thanh district and was seen to cover only 41 ha in total. This UST was seen to be populated by low income families.

The high exposure in terms of both land area and population of the three peri-urban USTs shophouse irregular with fields, shophouse irregular clustered and shophouse irregular scattered is to be expected, considering they are located exclusively in the often low-lying peri-urban and rural districts of HCMC, and due to the fact that they were classified to make up 66% of total residential area.

The UST shophouse irregular high-dense, is a common high dense irregular development with narrow streets. It was found to occur in the vast majority of HCMC districts. While the UST shophouse irregular temporary was typically found along canals and drainage ditches or near industries predominately in districts, 8, 7 and Binh Chanh districts. The buildings, which comprise this UST are rudimental and makeshift in nature, and are lived in by very low income migrant populations. At the block level,

the buildings that make up this UST are very basic, informal and often located in the most vulnerable locations, often lacking basic infrastructure provision. These areas are not just exposed to flood risk but also likely to be one of the most vulnerable in part due to underdeveloped infrastructure, often one story nature of the buildings, poor drainage and sanitation, but also due to the low adaptive capacity of the residents. It is worth noting that the colonial villa UST, found exclusively in the historical city centre and the social apartment UST, were the only classified USTs seen to be immune to flood exposure at the current maximum tide flood level.

The results of the exposure to sea-level rise and current flood risk highlight that the UST method could be also usefully applied to estimating populations and assets exposed and potentially impacted by hazards other than flood risk, for example UHI. The UST dataset could be advanced for a more detailed or comprehensive assessment of flood risk, to include the additional parameters of building height, size, and relation to built and open spaces relevant for flood damage and vulnerability assessments.

## **7.9 Policy responses**

Generally speaking, there are three main flood risk management approaches for urban areas (Klein *et al.*, 2001; Vis *et al.*, 2003; Hooijer *et al.*, 2004; Nicholls *et al.*, 2007). The first is hazard reduction, which aims to keep floodwaters out from populated and built areas by either hard technical protection measures such as dikes, dams, storm surge barriers, or spatial measures such as creating more space for water to be retained and detained. The second is vulnerability reduction, which aims in its simplest sense to prepare populations and assets for floods. This can comprise of risk communication, warning and evacuation schemes, as well as structural adjustments to buildings and infrastructure. For example, flood proofing or elevating housing structures. Whereas, the third is exposure reduction, which attempts to keep population and assets away from floods. This can be achieved by prohibiting vulnerable land-uses in flood prone areas or relocating existing settlements. The decision on which approach is most suitable is dependent on location, assets and density. The Vietnamese Government has traditionally placed strong emphasis on structural measures, such as river and sea dykes. Table 7–7 overleaf, provides an overview of structural and non-structural measures to respond to flood risks. The specific structural and non-structural measures and their relationship to risk adapted land-use planning are outlined in Table 3–2 (Page 64).

Table 7–7 Structural and non-structural flood related measures (Petry, 2002)

Structural	Non-structural
Extensive <ul style="list-style-type: none"> <li>– Reshaping of land surface</li> <li>– Protection from erosion</li> <li>– Delay of runoff processes</li> <li>– Increase of infiltration</li> <li>– Urban works</li> </ul>	Regulation <ul style="list-style-type: none"> <li>– Zoning</li> <li>– Coding</li> </ul>
Intensive <ul style="list-style-type: none"> <li>– Levees, dykes, floodwalls</li> <li>– Dams and reservoirs</li> <li>– Floodways and diversion works</li> <li>– Polders and fills</li> <li>– Drainage works</li> </ul>	Flood defence <ul style="list-style-type: none"> <li>– Forecasting</li> <li>– Warning</li> <li>– Flood proofing</li> <li>– Evaluation</li> <li>– Relation</li> </ul> Insurance <ul style="list-style-type: none"> <li>– Governmental</li> <li>– Private</li> <li>– mixed</li> </ul>

In the case of HCMC, while development increases the severity of disasters placing more people and assets at risk, it is impossible to halt all development in areas exposed to flooding. It would however seem sensible for the city to consider a prevention policy, which limits the development of exposure by limiting the development in exposed areas, while protecting what is already there. Development in areas exposed to flooding should only be allowed if certain standards designed to limit the potential risks and so reduce vulnerability are fulfilled. This could include retrofitting, increasing building standards and reorganisation of uses in ground floors, zoning with no-construction zones, and insure constructing new buildings with higher floor heights, high foundation walls, stilts, avoiding merely one story buildings that do not permit populations to take refuge on an upper floor in times of flooding, setbacks, minimum plot sizes, placing services such as electricity above buildings so that they are not interrupted by floodwaters, using building materials that are more waterproof and flood resistant, or elevating floors and buildings.

As a general rule, such policies would require density indicators and effective monitoring to be effective in controlling the number of people, homes and properties at risk of flooding. To this effect, planning regulations in less exposed, safe areas will have an impact on the risk of flooding, as encouraging greater density in safer areas avoids placing populations and assets in flood exposed areas. Additional regulations controlling soil sealing in less exposed, higher elevation areas would help to control the quantity of run-off waters, to adjacent lower elevated areas, which has an influence on flood risk.

For HCMC, given its already high population density and its large concentration of assets, any further delay to develop and integrate effective adaptation strategies into the current spatial planning system would inevitably have far-reaching regional and national repercussions.

When evaluating an array of future adaptation responses to flood risk, it is important to remember that the assessed exposure within this study will not necessarily translate directly into future impacts. The relation between the exposure to rising sea-levels and the future risk of impacts is complex and will depend upon the presence flood protection measures, plans and structural flood proofing strategies, as well as overall improvements in the current drainage conveyance (Gersonius *et al.*, 2008). However, Storch and Downes (2011), discuss that even with drainage improvements, in the event of a maximum tide water level of 150 cm, the occurrence of localised pluvial flooding may be exacerbated through an increased time period if such drainage systems remain tide locked. While not taking into consideration the effects of potential sea-level rise or changes in the intensity or frequency of extreme events, this alone highlights the need for future planning in HCMC to create or reserve a degree of space for resilience to future water. Currently HCMC exhibits minimal protection standards from the drainage system and the flood defences that exist. This also assumes that they are adequately maintained. While the forecasting of future protection levels is naturally difficult, it can be envisaged that future protection levels will increase over time following continued foreign investment and economic growth to the city. However to avoid false reassurances, planned adaptation strategies should not lose sight of the consequences, should adaptation or particularly flood defences fail or be breached.

### **7.10 Broader conclusions**

The flood risks to HCMC are foreseen to continue to increase under impending urban growth and a climate change unless appropriate actions are taken. Many authors have acknowledged that socio-economic changes, in particular urbanisation play a larger role in growing exposure and vulnerability than the anticipated increases in both the frequency and magnitude of extreme events due to climate change (Dawson *et al.*, 2011; Storch and Downes, 2011; de Moel *et al.*, 2011; Güneralp *et al.*, 2013). The recent flood events in cities of Southeast Asia have brought into sharp belief, how important anticipating and managing extreme events can be (*i.e.* the floods of Bangkok in 2011

and Jakarta in 2013). Managing risks and exposure to flooding in HCMC will be a crucial component of climate change adaptation and disaster risk reduction. The results of this assessment warrant serious consideration on how best to control growth in low lying regions. The results from the sea-level rise and current exposure assessment help the quantification and better understanding of these risks and more importantly, the benefits of timely adaptation.

The results from the assessment show that the historical centre of HCMC is situated away from areas at risk. The supply of land for development in HCMC has historically been restricted due to the adjacent low-lying areas, which the assessment highlights are at current flood risk from a maximum tide event. The recent trends towards the increased development of these low-lying and flood exposed areas will have serious implications for emergency management and disaster planning. New urban dwellers know very little about the flood risk in these areas due to their short duration of residence. With the onset of future rises in sea-level, these recent development areas will likely become less inhabitable and the areas which are not protected yet exposed to flooding will be unavailable for new development.

The 2007 UN-Sigma Xi Climate Change Report entitled “Confronting climate change: Avoiding the unimaginable and managing the unavoidable” outlines responses to both mitigate and adapt to the effects of climate change (Sigma Xi, 2007). The report suggests in its executive summary “To avoid new development on coastal land that is less than one meter above present high tide, as well as within high-risk areas such as floodplains” (Sigma Xi, 2007, p. 4).

In the recent literature, traditional flood control measures are increasingly recognised as inadequate to dealing with growing flood risks (Vis *et al.*, 2003; Hooijer *et al.*, 2004; Schanze, 2006). A shift in flood policy from the traditional notion of “flood protection” towards “flood risk management” can be recognised. Hard structural protection measures, for example dikes, are generally not considered to be sufficient for dealing with high exposure to flood risk, if they are not undertaken in combination with comprehensive, appropriate and adequate land-use policies. While structural measures may fulfil their defensive role well at specific locations, they may aggravate or create problems elsewhere. In this sense, the solution to the problems for some at one location becomes a problem for others at a different location. As mentioned in section 7.2, the construction of structural protection measures may also lead to an increase in overall

vulnerability as they influence risk-taking behaviour. This can occur when the structural protection measures create a false sense of security and new residential, industrial and public developments are constructed in the protected areas. However even with structural protection measures, risk is never zero, high losses can occur if there is a severe climatic event. It can therefore lead to an increased vulnerability, as was the case in the Bangkok floods of 2011.

The assessment highlights the importance of planning future urban development on the basis of solid assessments of future climate risks. The results provide an initial assessment of exposure to the current land-use and can assist the formulation of alternative policy paths for land-use planning. In the future the types maps compiled in this study will become increasingly relevant for not only awareness-raising among planners and inhabitants, but also for creating adaptive responses (Goschalk, 2003; Woltjer and Al 2007; Zevenbergen *et al.*, 2008).

## **8 Discussion**

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This Chapter is guided by the research objectives as outlined in Chapter 1 and draws together the key findings of the study to build the overall research picture. The selected UST classification method is critically discussed, as well as the achieved results. The utilisation and potential of USTs to characterise, map and monitor with high thematic detail, the spatial structural and functional environment of HCMC is addressed. Furthermore, the potential for placement of USTs within a framework for both climate change adaptation and disaster risk reduction to suit the needs of local planners is demonstrated on hand the deduction of density indicators and flood risk exposure mapping. The experience and the applicability of the developed conceptual framework and risk based indicators for the development of planning recommendations is documented and evaluated. Finally, research constraints, lessons learnt, and suggestions for future research and transferability of the results are subsequently presented.

### **8.1 The UST approach for monitoring**

Information on the current climate and changes in climate alone cannot be sufficient for anticipating and reducing climate impacts and disaster risks. The continual monitoring of emerging megacities is essential to evaluate and address the negative problems associated with urbanisation. Reliable information on how Vietnamese cities are changing will become of greater importance as populations become increasingly urban and against the backdrop of climate change and heightened disaster risks. Climate change, disaster risks and urbanisation have increased the demand for monitoring, controlling and modelling urban environments. Urbanisation itself involves simultaneous economic, demographic and land cover changes: economic concentration and clustering of population in urban areas, loss of natural ecological systems to the built environment and increasing building density within existing urban areas. Important for monitoring is the consistent processing of reliable core indicators as planning information, as well as their exchange between the different actors and the administrative bodies of development and environmental standards in spatial planning.

In HCMC, land-use and land cover patterns have undergone a fundamental change due to rapid urbanisation. The urban area of HCMC has been constantly changing, it has sprawled with new developments, and parts of it have changed in form, horizontally, as well as vertically, functionality and demographic structure. Sustainable management and governance of HCMC requires reliable, up-to-date, area-wide intermittent and detailed monitoring. While some data of the urban environment exists, it rapidly becomes outdated due to the strong dynamics and is only available at different spatial resolutions.

While the urban area of HCMC consists of various heterogeneous areas, structurally homogenous areas were distinguishable. The UST classification as developed and applied in this study is one way to divide urban areas into homogeneous units with similar characteristics. The frequent changes require a method for continual monitoring, essential to evaluate spatial urban information. The classification was the first such UST study in Vietnam and has shown the potential to rationally characterise and monitor the current status and changes to the urban environment of HCMC. The USTs of HCMC were distinguished according to their physical and functional characteristics. This in turn required an understanding of form, scale (building, commune and district) and historical context. The main conditions were that USTs should reflect the characteristics of their building archetypes, green and open spaces, and the USTs should represent significant features and differences. The classification involved the manual interpretation of high resolution satellite image and groundtruthing on hand various research stays from 2009–2011, for the division and differentiation of the city into homogeneous characteristic configurations of building archetypes, green and open space. As was expected, the urban fabric of HCMC was seen to be incredibly complex.

A significant step for the creation of the UST classification was the initial survey and understanding of 19 observed building archetypes for the city (Chapter 5). The dominant building typologies provided the foundation for the UST classification. They were based in part on the official Vietnamese building code, which distinguishes three main archetype classes, (i) adjoining houses (shophouses), (ii) separate discrete houses (villas, etc.) and (iii) apartment buildings (MoC, 2008). The observed building archetypes defined in the study, although offering a higher differentiation, and defined for a different research question, correspond well with other classifications of Vietnamese residential buildings. The World Bank utilised five generalised housing



typologies (i) temporary shelters (ii) old town houses (iii) new town houses (vi) apartments and (v) villas, on individual plots for their review of Vietnamese urbanisation (World Bank, 2011). More recently both UN-Habitat (2014) and World Bank (2015) developed for their housing studies in Vietnam a classification system of ten building archetypes based on five main classes (i) shophouses, (ii) alley houses (informal/formal), (iii) apartment blocks, (vi) villas and (v) small single story houses (informal) (Samad *et al.*, 2015; UN-Habitat, 2014).

In HCMC credible baseline information is rarely available at a high enough resolution to be useful for policy analysis and decision making. The classification scheme is presented in Chapter 5. A total of 80 differentiated USTs were developed and assigned to the common spatial geometry of the 16,292 blocks used for land-use planning in the city in line with the requirements of the research objectives. The USTs accurately defined the current land-use and urban extent, the current urban component and their characteristics. As such, the USTs can be taken to represent the actual land-use, depicting physical and environmental structures and social characteristics in a direct and indirect way. Chapter 5 also offers a short description of the main characteristic of each UST.

The UST classification allowed for a higher differentiation of the urban environment than that of the official land-use map 2010, where categories are nationally set and focus strongly on agricultural land-uses. Here urban areas were seen to be particularly undifferentiated and displayed built-up land-use designations of solely urban residential, rural residential and industrial areas (compare Figure 5–2 (Page 114), and Figure 5–3 (Page 125)). The developed UST classification allowed for the further differentiation of residential developments into one of 23 distinct residential USTs, public, commercial and special use areas into 20 separate USTs, and industrial areas into 4 distinct USTs. The remaining green and open spaces were divided into one of 33 possible USTs. The land-use map itself displays only the pure designation of land-use, but did not illustrate the actual utilisation of land in reality. It also did not illustrate the inherent qualities, *i.e.* environmental significance or the exposure or resilience of areas or structures. Knowledge of the distribution of USTs in HCMC allowed for the first time a comparison of the actual land-use to the planned vision. This enabled the assessment of land-use compliance and adherence to land-use designation and the complication of an actual land-use map (see Figure 5–21 (Page 151)).

The ease with which HCMC could be categorised, mapped and interpreted, as well as the accuracy of the final classification suggests that USTs may offer direct benefits to the local urban managers for monitoring the urban environment. The current land-use map compiled from an UST approach to classify the current urban landscape provides context specific information for the assessment of current and future risks and adaptation options. Furthermore, the classified USTs as shown in this study have the capability to support the process of an independent and up-to-date source of urban planning considerations. The study highlights the real potential and advantages of using synoptic spatially distributed USTs in urban environmental and climatic hazard assessments to support risk adapted land-use planning and for the realisation and siting of both mitigation and adaptation responses.

The use of USTs as a conceptual common spatial framework, to enable analysis of UST derived indicators allows for the use of one single spatial unit of analysis- the official land-use block geometry. In this sense, the USTs are used as an aggregation of data, simplifying the detailed real world information. Here, the developed classification structures displays the real complexity and promotes recognition and a spatial overview.

The USTs offer a number of opportunities to assess the urban environment of HCMC. The manual interpretation of remote sense data to classify the USTs of HCMC provides a novel efficient, cost effective and very feasible method for high resolution block-based relevant urban-wide observation of the structural status of the city. This is important for monitoring effects. The results, if repeated, would allow for the continued monitoring of spatial-temporal changes to the HCMC urban environment.

## **8.2 The UST approach for deriving density information**

As was discussed in Chapter 4, in a wider sense, sustainable cities, resilient and low carbon cities are a matter of density. When combined with the official building footprint data, the urban structural densities of each UST at the planning relevant block scale could be calculated. This information is diagnostic of urban change and can be used to examine development trajectories in the context of land-use controls. Furthermore, as a decision-support tool, density indicators, and the measurable changes derived from them, can enable more informed decision-making during the policy formulation process. This enables the interactions between different urban parameters, as well as the interdependency, synergies and conflicts, of various urban policy objectives to be

analysed. This study has shown that building density, building height, ground coverage ratio, and gross floor area, building volume, floor area ratio could all be calculated and measured in an accurate direct manner.

The representation of socioeconomic and sociodemographic information by USTs was demonstrated for HCMC. Population density and gross floorspace per person could also be mapped at block scale in an indirect way using USTs as a proxy indicator. This provided spatially disaggregated information at a higher resolution than census information. While the official census data is only updated every 10 years in Vietnam, USTs have the potential to provide intermittent proxy population estimations based on built structural indicators. However, for further socioeconomic indicators for example the population structure or individual characteristics or behaviour of UST residents, additional supplementary data would be needed.

Differences between USTs and their heterogeneity could be demonstrated. Statistical measures for each UST derived indicator, *i.e.* mean, medium, standard deviation were used to describe the representation quality. For certain USTs, several indicators showed large standard deviations. While this makes the task of objective UST classification more difficult, a large standard deviation of density indicator values can also be seen as an additional feature, assist to characterise specific USTs. The manual assigning of total soil sealing was found to be a highly subjective task, for which at first sealed percentage values differed greatly among interpreters.

The UST derived spatially explicit indicators play an important role in describing the urban area of HCMC for planning and monitoring purposes *i.e.* by characterising the urban environment. Figure 8–1 shows in detail for comparison the ten selected density indicators for the core area of HCMC. It highlights first and foremost, similar to many other historic city centres of Southeast Asian cities, large parts of HCMC’s inner city districts are characterised by very high building and population densities. The maps generally depict a concentric staggered degree of structural use in the municipal area. Yet, Figure 8–1 also illustrates the need for multiple measures of density. Whilst the UST in the CBD (district 1) of HCMC indicate low per block building density values, the actual built-up density in terms of gross floor area, FAR and building volumes are relatively higher. Building density does not give an indication of the third dimension, FAR or other density values. Furthermore, population density is seen to be higher in the “dense” shophouse based UST around the CBD. Generally, population was seen to

correlate with gross floor area and FAR, however there are vast population and building density variations depending on dwelling and household size. Comparing building densities over USTs can be also misleading given the large differences between dwelling size and household size between inner city areas and peri-urban areas and between USTs.

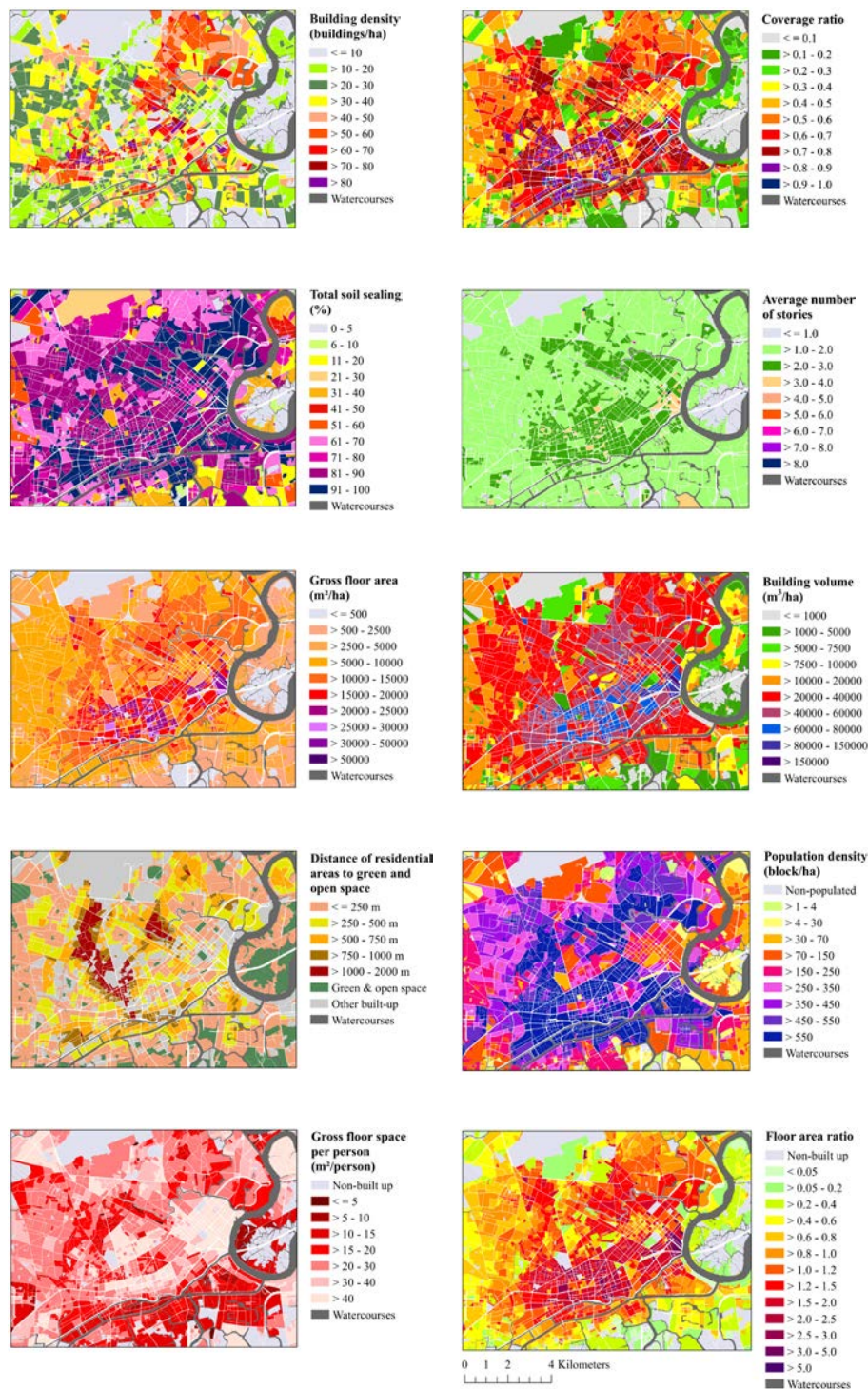


Figure 8-1 Compiled density indicators for Ho Chi Minh City (source: author's own)

The results highlight the challenges in measuring urban density and indicate that several measures are required for a good understanding of urbanisation processes. There is nothing gained from just one measurement of density. For example, solely the number of buildings per ha is not a sufficient measure of density for urban monitoring in core areas as it will underestimate the densities of both use and population. Similarly high-rise apartment UST found in many of the peri-urban areas displaying greater FAR and greater built volumes result in lower gross floorspace per person values than more densely spaced shophouse developments *i.e.* lower planimetric and horizontal building densities.

The density results show on the whole, a very high intensity of development in the inner core of HCMC expressed as high FAR values and substantial coverage ratios and soil sealing rates. This kind of urban form achieves many of the classic goals of sustainable urbanism such as reduced land consumption, variety of uses and the “city of short distances” (Storch *et al.*, 2008). However, as outlined in Chapter 6, high building density, high building volumes and high coverage and sealing influence climatic hazards, most notably urban flooding and UHI.

These spatial density indicators assigned to each land-use block are all familiar to the urban planning authorities in HCMC and are considered relevant for both monitoring urban development and hazard risk assessments. The findings emphasise the potential of UST, to derive and display climatic hazard relevant urban density information. Risk adapted land-use planning for climate change adaptation and disaster risk reduction requires proactive planning and informed decision making based on evidence. The selected and mapped density indicators for HCMC are not tied to hazards, yet some are more relevant to one hazard than to another. The significance of these indicators for hazard risk assessment is illustrated by the extensive number of urban water balance, flood risk assessment and urban climate assessment studies that use them, as well as their sought-after application in HCMC’s existing planning activities and role they play in producing planning recommendations. As such, the derived density indicators can bridge the gap between risk thematic disciplines, the analysis of risk and spatial planning of HCMC. The density indicators can provide a means to describe the characteristics influencing urban climate, urban flood and overall risk in a manner that is both suitable and comprehensible to spatial planning in HCMC.

### 8.3 The UST approach to assess hazard exposure

The application and subsequent use of the UST classification for hazard assessments was proved possible by the application of USTs for a flood hazard exposure as demonstrated in Chapter 7. The Chapter described the scale of the physical exposure in terms of land area (ha) and population and USTs that are likely to be affected at different flood water levels. The potential of the UST-based indicator framework for spatial analysis and the spatial representation of hazard risks allowed for a comprehensive overview of the prevailing conditions within the complex urban landscape of HCMC.

The spatial detailing of hazard exposure of buildings, population and land was determined depending on their location. In terms of exposure, the USTs and the number of buildings, and people affected were derived using the relationship between census information, USTs and floorspace and building footprints. Crucially however, these should not be taken as exact numbers, as they are fraught with uncertainty. Yet at worst, the results provide a good approximate estimation of the likely elements affected. The exposure to environmental hazards, the mapping of public infrastructure, and official plans and demographic data came to life when visualised and mapped. Not only USTs, but general high risk areas became apparent when mapped, revealing patterns and hotspots across geographic locations (Downes and Storch, 2016).

As such, the USTs can be an essential data source at a small spatial scale. This information is of high relevance for disaster management. The results show concrete information to support decision-makers in advance or during an event. Furthermore, the indicator framework can help improve the understanding of the interactions between development and the exposure to climatic hazards. This allows for a spatially explicit view of the consequences of development and (climate) change, which is highly attractive to stakeholders, as it provides a readily interpretable image of the potential consequences at the same scale as the official land-use map (Storch and Downes, 2011; 2012).

Furthermore, in terms of USTs and hazards, the classification can be used not solely for terms of hazard exposure but also in terms of hazard generation, *i.e.* surface runoff or extreme heat. Urban climatic and hydrographic relevant information, as well as, socioeconomic data are represented by USTs. The analysis shows the potential of USTs

to identify the starting points for measures to be taken in an integrated urban water management or urban climate management context.

The hazard exposure mapping at the block scale means the indicators are scaled uniformly and thus can be compared both temporally and spatially. As such, the representation is finer than that of the larger administrative units flood risk mapping commonly used, where asserts and populations are aggregated and evenly distributed over larger administrative units. With socioeconomic information such as population density disaggregated at the level of land-use blocks, the representation of census information is much finer.

Awareness of risk is the first step towards initiating the rethinking of the response to climate change and disasters based on preventive measures. As the scenario assessment revealed, HCMC will experience increased exposure to flooding, the results warrant serious consideration on how best to control growth in low lying regions. The results have the potential to influence political decision-making. However a main constrain is the political will to invest in precautionary adaptation and risk reduction measures. A number of authors have concluded that more information concerning the most vulnerable areas and populations is needed than ever before (Birkmann, 2007). It is important to remember that the derived UST density indicators do not correlate linearly with risk or vulnerability, therefore a quantitative estimate of vulnerability is hard to calculate and contains often large uncertainties, dependent upon location and sensitivity. The measure of vulnerability is absent in this study. However, in planning the potential number of buildings, area and people affected determine decisions and not necessarily the vulnerability of these elements. Important however, is the availability of these results for policy makers.

To fit into the Vietnamese spatial planning system, information needs to be made available for policy-makers and decision-makers both at national and local levels. More research is needed in Vietnam at the local level on how to measure risk and how to improve existing indicators approaches at different scales. Urban monitoring based on a UST classification offers an intermittent and on-going hazard assessment and would provide information in direct temporal and spatial scales relevant for decision-making. Moreover, the results are presentable in understandable and self-explicable risk maps for planners, decision-makers or citizens.

## 8.4 Planning recommendations

Emerging megacities like HCMC are required to understand their risks to make the necessary investments, but the hurdle is risk information. Here, guidance and spatially explicit recommendations are often lacking. Good quality prior information is critical for accurate planning in response to climate and disaster risk. Undoubtedly, adaptation and disaster risk reduction have to be prioritised in the HCMC development agenda. By providing access to more information about risk, the local urban administration can implement management systems that include adaptation and disaster risk reduction solutions. These will not only have environmental benefits but will allow the more focused placement of scarce funds.

### 8.4.1 Target end-users

Most importantly, the UST classification and density indicators, subsequent thematic risk analysis and planning recommendation compilation have been developed to support the ongoing discussions undertaken in Vietnam, and locally in HCMC. Adaptation is recognised by the Government of Vietnam at national and local levels as a valid response to the challenge of climate change. Various high level national policies and strategies identify climate change and disaster risk as important challenges to national development including the National Target Programme to Respond to Climate Change (2008) and the National Strategy for Natural Disaster Prevention, Response and Mitigation to 2020 (2007). If spatial planning activities involving indicator-driven spatial databases are not coordinated with the local administrative planning bodies, the indicator-specific data generated at various levels for urban planning and management purposes remains uncoordinated and limited in its use to support decision-making.

The direct target group (*i.e.* the persons directly addressed by this research), are the local policymakers of HCMC. This also include decision- and policy-makers within DoNRE, as well as other researchers, programme managers and operational staff of the DoNRE, DPA, SIHYMETE and Sub-NIAPP. Figure 8–2 shows extracts from the final documentation of HCMC’s USTs, which details the mapping criteria, spatial distributions and densities of each classified UST (Downes and Storch, 2015). The handbook has been made available to the city administration in both English and Vietnamese. In order to meet the needs of spatial planners, the UST classification has been undertaken with DoNRE, the real user group (wanting to solve a real problem) to



prevent it from becoming solely an academic exercise. In regard to adaptation strategies for climate change in HCMC, DoNRE has a key position (as outlined in Chapter 3). Other end-users indirectly interested in these results include both governmental and non-governmental organisations working in settlement development planning at international, national, municipal and/or local levels. The UST results are intended to generate discussion and innovation based on new understandings of urban development patterns, climate change, risk and uncertainties.

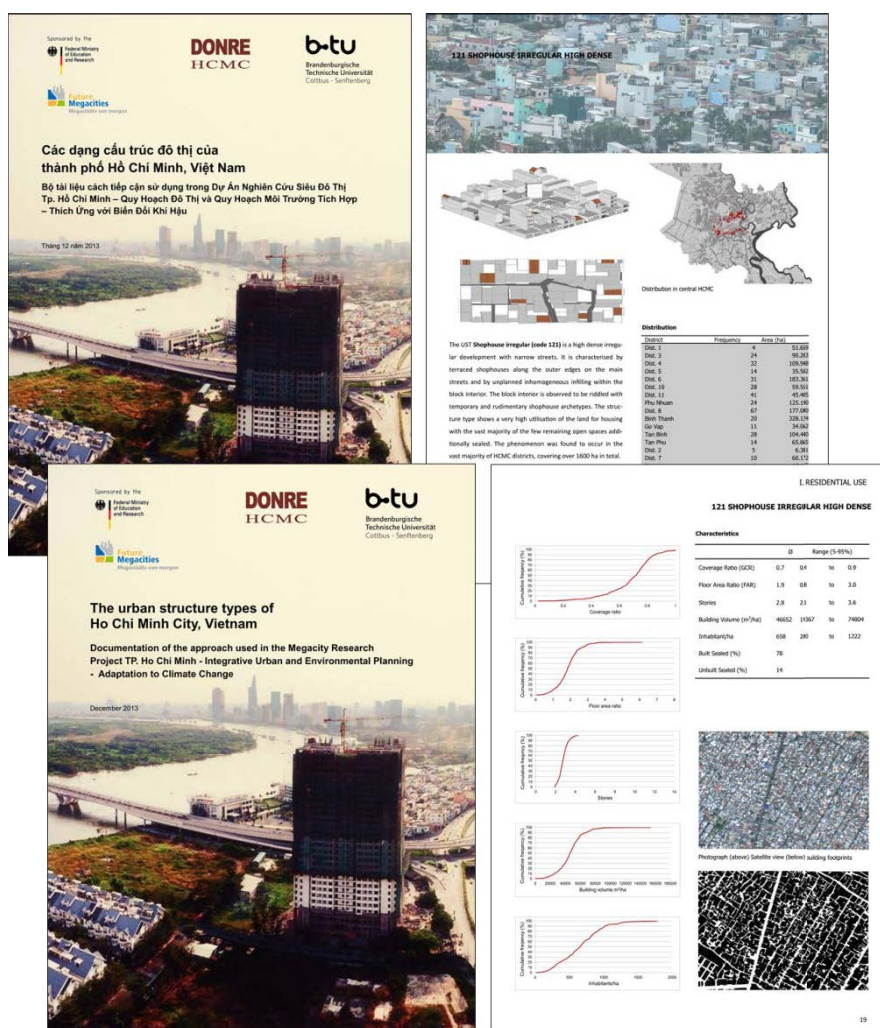


Figure 8–2 Handbook documentation of HCMC’s USTs detailing the mapping criteria, spatial distributions and densities of each classified UST (Downes and Storch, 2015a; 2015b)

#### 8.4.2 Land-use planning recommendations

An important objective for the development of the conceptual framework was to consider the needs and requirements of urban land-use planners. Recommendations should be simple to interpret, and presented spatially to make them easily

understandable for decision-making. Because of their suitable scale for both urban planning and adaptation planning, street blocks were used as the unit to present the results of the characterisation. The spatial scale of land-use blocks for the analysis is selected in such a way that it fits to the official land-use zoning plans, furthermore influencing both urban hydrographic and urban micro climate effects. Most micro climatic and hydrographic effects are related to building block densities of development. Urban risk management needs a multi-disciplinary approach and data from various sources used in this study can be easily aggregated to this spatial level. The UST classification and the density indicator results as presented in this study provide a powerful information source for monitoring, investigating and understanding the properties of HCMC and constitute important input data for further analysis and processing. Combining and merging these spatial data with a DTM and other types of information allowed for the generation of higher value information products.

An existing categorising system, such as that of USTs, is preferable for the use in urban spatial planning for the characterisation of the urban water balance and urban climate. The UST approach as presented in this study generated density information that shows how the urban water balance or urban climate in different USTs can be characterised. This allows planners to gain an insight into the difference in urban water and climate parameters in land-use blocks of varying USTs and at the same time, facilitates the analysis of the heterogeneity of urban water and climate parameters within blocks of the same UST. Such knowledge is highly valuable for the development of risk mitigating and adaptation planning activities.

The authors of the land-use planning recommendations take into account that adapting to climate change and reducing disaster risks involves a broad spectrum of measures directed towards reducing exposure to a series of climatic stimuli (changes in environments, variability and extreme climatic events). Of the classified USTs with more homogeneous urban water or climatic characteristics, one main recommendation response may be appropriate. Whereas, for more heterogeneous USTs with varied characteristics, a variety of recommendations will be required.

Rujner and Goedecke (2016), used the classified USTs of HCMC developed in this study to investigate the rainfall-runoff regime of the city. They used the German water balance model ABIMO to calculate the long-term annual means of individual water balance components for the entire administrative area of the city. They studied the

current conditions and the further time series of the future urban development scenarios as set out in the draft Land-use Plan up to the year 2020/25. Results were mapped for every land-use block and highlighted that urbanisation is one of the main causes for increased flooding. Finally, on the basis of modelled results, the authors compiled a planning recommendation map displaying zones as planning priorities, targets and measures (Figure 8–3). The integration of flooding concerns into land-use planning can be observed in the German Flood Act, as well as in the planning regulations in England and Wales (Jha *et al.*, 2011). In the HCMC recommendation map, significant zones were designated on the basis of modelled hydrological values, while differentiated areas were assigned to focal planning targets.

Furthermore, the relationship between USTs and the urban micro climate can increase the understanding of the micro climate system among urban planners. Katzschner *et al.* (2016) developed an urban climate map with planning strategies and general recommendations for HCMC. They showed that the classified USTs of HCMC can be used to identify climate functions (heat stress, areas of bioclimatic risk, ventilation, and cold air generation in open spaces) and provided a series of recommendations to solve spatially explicit problems (*i.e.* on the distinction of local comfort areas, improvement of ventilation, deficiency of urban greenery) and for the effective zoning of HCMC into areas with differing degrees of climatic characteristics (Figure 8–4). Their study showed that urban density and shadow effects are the two most significant factors that should be observed in future development.

Both of the aforementioned studies highlight the UST concept in relation to urban flooding and urban climate. At the same time, heat stress and flooding tend to concentrate mainly in high built up areas for which impacts are higher because of population and asset concentration. Unsurprisingly, spatial planners need to be supported by urban climatologist and hydrologists for the correct interpretation of the results in the context of the urban micro climate and urban flooding.

The rapid growing nature of HCMC naturally presents obstacles for implementation of adaptation and disaster risk reduction measures. However, where adaptation planning is concerned, the failure or inability to act can ultimately be costly. Storch and Downes (2011), assessing the exposure of HCMC to flooding by coupling urban development and sea-level rise scenarios, successfully used the UST classification of HCMC overlain with a DTM to quantify current and future city-wide flood risks (Figure 8–5).

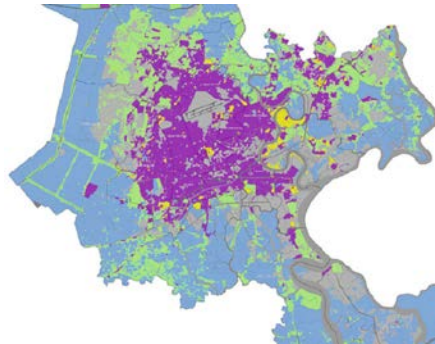


Figure 8–3 Urban water balance planning recommendation map—blue areas highlight priority areas to maintain (agricultural land, green and open spaces with high evaporation and low run-off potentials) (Rujner and Goedecke, 2016)

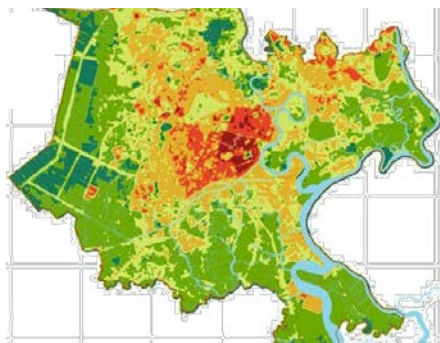


Figure 8–4 Urban climate map of HCMC—green areas highlight fresh and cold air product zones (Katzschner et al., 2016)

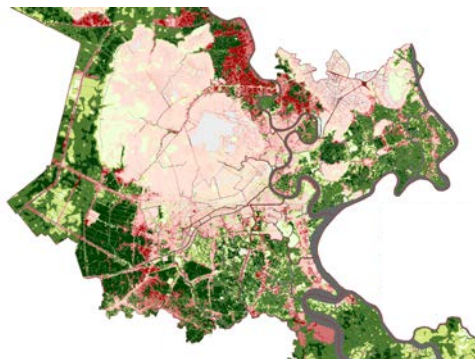


Figure 8–5 Low-lying built up areas—dark red depicts built up areas below 0.5 m AMSL (Storch and Downes, 2011)

Storch and Downes (2011), concluded that socio-economic development and resultant urban expansion into low-lying areas up to the year 2025, as non-climatic drivers of future risk are significantly more important than changes in sea-level rise up to the year 2010. They showed that, 160 km<sup>2</sup> or 32% of the current built-up area is exposed to flooding. This is likely increased up to 360 km<sup>2</sup> or 48% when solely considering planned urban development up until the year 2025. The results assisted local stakeholders (and inhabitants) to better understand the nature of future climate change risks and to identify the main drivers of current and future urban exposure (Storch *et al.*, 2016).

The achieved UST derived urban density indicators, the urban water balance planning recommendation map (Rujner and Geodecke, 2016) and the urban climate map (Katzschner *et al.*, 2016), as well as analysis of non-built up and built-up areas at flood-risk (Storch and Downes, 2011) where compiled to a standalone document and provided to DoNRE and Sub-NIAPP to assist in the revision for the HCMC Land-use Plan up to the year 2010 (Figures 8–6 and 8–7). Eleven specific focus areas were selected in combination with DoNRE and for each area the current situation was described, with detailed planning recommendations given. The overall aim of the approach was the interlocking of planning recommendation maps and to demonstrate the multi-functionality of areas. The joint significance of spatial areas for both the water balance and climate was emphasised. Many areas also shared a common risk profile and as such, should not only be individually represented in a plan.

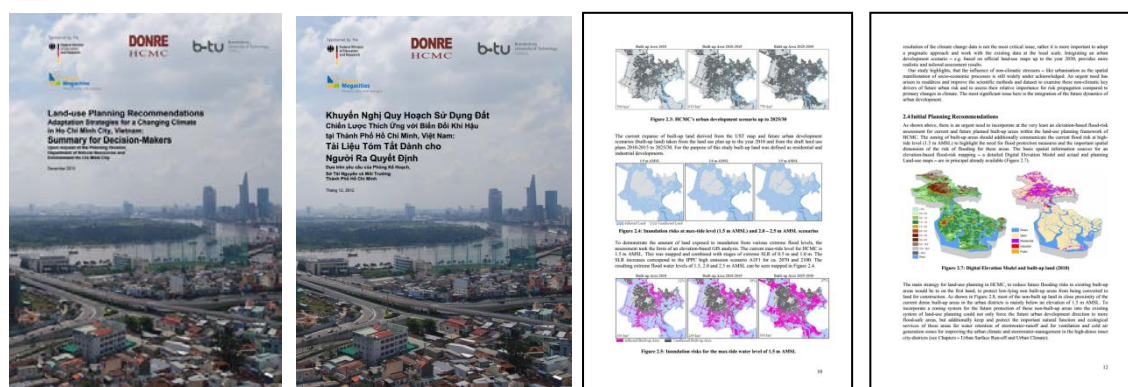


Figure 8–6 Handbook land-use planning recommendations (Storch and Downes, 2013b; 2013c)

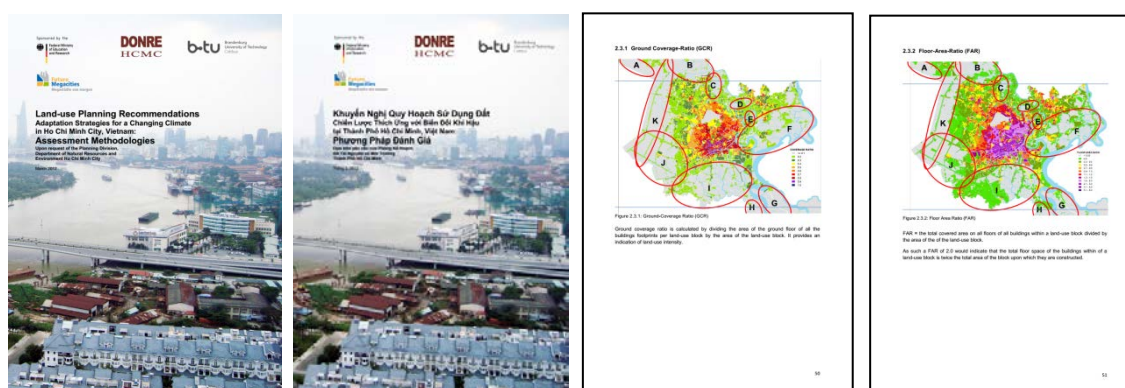


Figure 8–7 Handbook assessment methodologies (Storch and Downes, 2013d;2013e)

The land-use planning recommendations, advocated specific adaptation measures in order to steer adaptation, proof development plans and to proactively combat potential growths in risk exposure. These compiled recommendations aided the understanding of the most appropriate locations for (re)development as a primary means to reduce future impacts. Even if risks from climate change are not imminent, the handbook highlighted and communicated the importance and necessity to plan development in a forward-thinking and long-term adaptive manner. As such, the formulated recommendations compiled by the authors Runjner and Goedecke (2016), Katzschner *et al.* (2016), and Storch and Downes (2012; 2013f), should be considered as being part of an adaptation toolbox, and the choice of measures remains a political decision deserving of a large deliberation. The instruments compiled together provided the possibility of influencing the form and function of land in a positive way.

Policy recommendations can promote adaptation measures and their inclusion in the early stages of decision making. The process itself also strengthens the capacity of stakeholders and the voice of DoNRE to understand and communicate the challenges and the need to take action (Storch *et al.*, 2016; Downes *et al.*, 2014; 2013). The time span of this research was not long enough to evaluate the use of the derived UST information into the local HCMC planning praxis. This can easily take several years, since the development of spatial plans is a slow process. However the results were integrated into the official Land-use report of the Land-use Plan up to 2020 by DoNRE for submission to the People’s Committee (Figure 8–8).

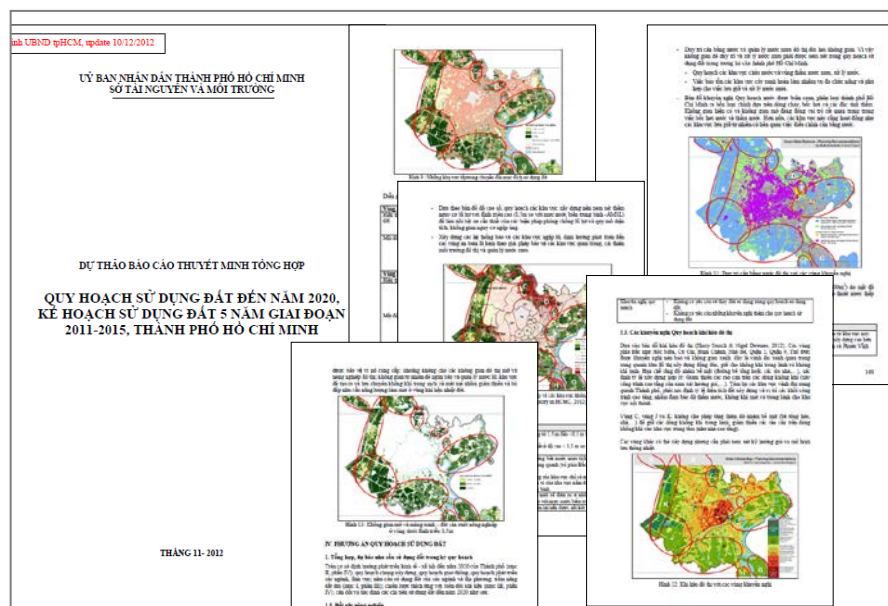


Figure 8–8 Integration of developed planning recommendations into the official report by DoNRE for submission to the Peoples Committee in December 2012 (*DoNRE, 2012*)

Moreover, the planning recommendations will facilitate the greater understanding of current uncertainties regarding the causal drivers and impacts of climate change, lead to a broader consensus for actions, and aid informed decision-making from the integration of these considerations into the spatial planning framework.

### 8.4.3 Risk-adapted land-use planning

In the emerging mega-urban regions of Southeast Asia, both planned and unplanned urbanisation into flood prone-areas appears to be an unavoidable consequence of socio-economic development, presenting an important challenge to both sustainability and adaptation planning (Bulkeley and Betsill, 2005; Bicknell *et al.*, 2009; Hara *et al.*, 2008; Adikari *et al.*, 2010; Fünfgeld, 2010; 2011; Storch and Downes, 2011; Chan *et al.*, 2012; McGranahan *et al.*, 2007). These risks occur, often not solely due to a lack of risk awareness, but seem to be an accepted consequence of maintaining current economic success and social progress (Downes and Storch, 2014). Hence, in dealing with climate change and disaster risks in conjunction with rapid transformations, urban planning is often reactive (Garschagen, 2013; Garschagen and Kraas, 2010). The rapid growing nature of HCMC naturally presents obstacles for implementation; however where adaptation planning is concerned, in-actions or in-ability can be ultimately costly (Storch and Downes, 2011).

Following disaster, rebuilding of the city has the highest priority, but leaves little room to create an environment which is able to deal with future events of climate change. Flood risk protection and implementation of costly mitigation measures, as well as, the abatement of urban heat are often shifted to a future development cycle, where implementation is not seen to constrain the economic and social goals. This is especially the case with slower onset impacts such as sea-level rise and urban heat island development.

Land-use planning and land-use policy is a crucial component of adaptation and risk management policies. Yet in Vietnam, previously when dealing with climate change and disaster risks, there has often a miss-match of scientific style solutions to a policy style problem. If the response is not fit for purpose, then the solutions will ultimately not work. There is rarely an optimal adaptation and disaster risk reduction option. Often the most appropriate strategy is dependant heavily upon other political and social policies and the local vision HCMC has of its own future. From a review of the literature, it is clear that spatial planning can make a positive contribution to adapting to and mitigating climate change, however the planning or absence of planning in the past in HCMC has delivered results which are detrimental for climate change.

To truly embed climate change considerations into land-use planning in HCMC is inherently a complex decision-making problem, which requires a response to the information deficit and the careful assessment of the current decision-making situation, related to place and space. While the developed UST classification goes some way to address this, the case of HCMC, demonstrates the challenges in applying and embedding adaptation into an existing land-use planning and policy framework. HCMC is at a crossroads; the rapid and vigorous development of the city during the last 20 years has rendered many previous plans quickly obsolete by the rapid changes in population and higher income lifestyles, as well as, unexpected patterns of development.

The process of planned adaptation, as well as disaster risk reduction requires the prerequisite of a sound adaptation planning framework for incorporating the vulnerability and resilience of land-uses, populations and assets into HCMC's urban policy and decision-making. Adaptation and risk-based planning frameworks are commonly founded on specifically selected sustainability indicators, data resources and are linked to available planning and assessment instruments including Strategic



Environmental Assessment (SEA). SEA is strongly associated with land-use planning and is the process of preliminary consideration of any plan, programme, or other strategic document in terms of possible negative impacts on the environment and human health. It is envisaged that the developed density indicators, UST based risk assessments and planning recommendations within an SEA-based adaptation planning framework can be utilised in all steps of assessment and management processes, namely (i) Identifying the objectives of the spatial plan; (ii) Assessing current and future climate impacts on HCMC to achieving these objectives; (iii) Evaluating the effectiveness of adaptation policies and risk reductions measures to manage the potential impacts to acceptable levels; (iv) Deciding on which adaptation policies and measures to adopt in the land-use and urban development plan; (v) Communicating to stakeholders the consequences of adaptation policies and risk reductions measures and explaining the consequences.

For HCMC, effective proactive planning policies are required to stem the tide of increasing land consumption into the high-risk flood-prone areas surrounding the city to the east and southeast. Here, without delay, urban containment policies should be considered as a promising swift adaptation approach to address the current and unfolding patterns of spatial risk; this may even be necessary in the face of a short-term cost to economic growth. Effective control of planning is needed, *i.e.* planning restrictions (as well as, to some extent building regulations) and the integration of adaptation measures into urban development pathways and land-use planning is essential for managing risks. HCMC's urbanisation over the last 20 years is an extreme case of land-use change. The geographical pattern of the expansion of city during this period has had a direct impact on the city's overall environmental quality, particularly water flows, flooding and urban thermal stress and ultimately urban resilience. Land-use planning designations can influence the location, type, design, quality, and timing of development. This can be by the maintenance of protective features of the natural environment that lessen or absorb the potential impacts of climate change. Water retention areas, protective mangrove forests, and cold air generation areas should be protected as far as possible. Whilst, resilience against the episodic and regular risks prevalent in HCMC can be created by zoning instruments that designate development in both safe and suitable locations. Utilising the existing flood-prone areas as greenbelts for current and future flood protection measures would additionally provide significant

urban environmental benefits including recreational value, protection of open space, agricultural land, natural resources, all in addition to the vital reinforcement of ecosystem services for storm- and floodwater management and their important function as fresh and cold air production zones to mitigate the urban heat island effect. To this affect, successful land-use planning depends heavily on how well the current and probable future risks are understood. For HCMC, the inherent complexity of risks and vulnerabilities requires improvements in the use of spatial information, in order to identify hazard patterns, vulnerabilities and risks at a scale that can provide guidance for urban land-use and development planning. In the future, HCMC's land-use planners will play an increasingly important role through risk-adapted land-use planning to review existing plans and policies, control development in high-risk areas, initiate climate conscience urban regeneration and climate conscious new development, as well as the provision of building standards, early warning systems, and emergency response plans. The spatial planning framework and subsequent urban planning decisions, as currently applied, do not attach ample importance to the physical exposure and the rate of urban growth associated with the risk of disaster losses. Land-use planning in HCMC has to shift towards the evaluation of land conditions and urban development potentials in a more spatially explicit manner.

This emerging megacity, with its concentration of population and economic assets, highlights the two-way link required between urban development and exposure to climate related risks and the need for more effective urban governance in the integration of climate change adaptation into spatial planning. The reorientation of land-use planning, by focusing new developments away from the low-lying areas, identifying where current developments should be removed or exchanged for less flood-sensitive land-uses and safeguarding natural mitigating functions, will require a much more spatially focused effort and explicit zoning and protection. New development should be located on land appropriate for building and avoiding low-lying wetlands. Managing the risks associated with sea-level and increased surface-runoff will be a crucial component of adaptation planning. The urban fabric of HCMC was built with due consideration of the prevailing conditions of flood-risks and as the city has grown, partial "hard solutions" have been frequently implemented. As a result, the past developments have often interrupted natural flooding processes, removed buffering ecosystem components, covered large areas with sealed surfaces and increased runoff and reduced natural

storage capacities and interrupted potential flow paths. The current and future city will ultimately require a combination of ‘soft’ (spatial planning) and ‘hard’ measures (flood defences) to manage the increasing risks of sea-level rise (Storch *et al.*, 2009; MoNRE, 2009).

### **8.5 Limitations of the developed UST approach**

While many of the potentials of the UST approach have already been discussed in the appropriate sections above, it is worth reviewing the main weakness of using an UST approach to monitor the urban environment, and to produce risk maps and planning recommendations. The key advantage of the UST method over other methods for urban monitoring is the simplicity it provides. However, the UST approach does suffer from a number of limitations and constraints that cannot be neglected as they may restrict its application in further contexts and potentially influence the outcome and the validity of its results.

The first and most important step is the visual interpretation of land-use block characteristics and the development of a representative UST hierarchical classification system (Chapter 5). The developed classification systems aimed to facilitate information transfer through a simple and logical partition of the urban environment. Homogeneity was an ideal condition, which is almost impossible for the development of building archetypes and the UST classification system. In reality there was often a lack of heterogeneity caused by a variety of building types and slight variations at block level. HCMC’s urban layout and the geometry of land-use block polygons made it extremely difficult, if not impossible, to identify fully homogenous built-up areas in terms of urban structure. While care was taken not to change the geometry of the official land-use map, inconsistencies between boundaries of administrative units at different levels, districts, wards and communes (*Thành Phố, Quận, Huyện, Phường, Xã*) were eliminated in cooperation with Vietnamese partners. However, the position of the land-use boundaries and the nature of mixed uses within each block made the classification of fully homogeneous USTs challenging.

In this case, it is important to scrutinise the density indicator results. Some of the specific density values for classification USTs showed large variation. A portion of this deviation can be explained, as land-use polygons didn’t in all cases contain solely just the building archetypes associated with specific USTs.

While the assigned UST may not be fully homogenous, they were the dominate structure in each block and as such, the predominate activity and structure corresponds to the UST, which it represents. Here it is worth remembering that the classification of USTs based on visual interpretation of remotely sensed imagery is additionally highly prone to subjective interpretation by the interpreter. Meaningful subdivisions of each UST category were examined in the context of the research question and the communicability of the typologies was observed. The identification and delineation of USTs by visual interpretation of remote sensing images was supplemented with additionally spatial and contextual information gathered during research stays.

Most of the characteristics of USTs are additionally modified by the size of the mapping scale. This is particularly true for density indicators, which are highly dependent upon where the exact boundaries are set. Figure 8–9 shows the relationship between classified residential USTs and land-use block size. It can be seen that the actual size of the land-use blocks varied widely and did not follow a regular grid structure.

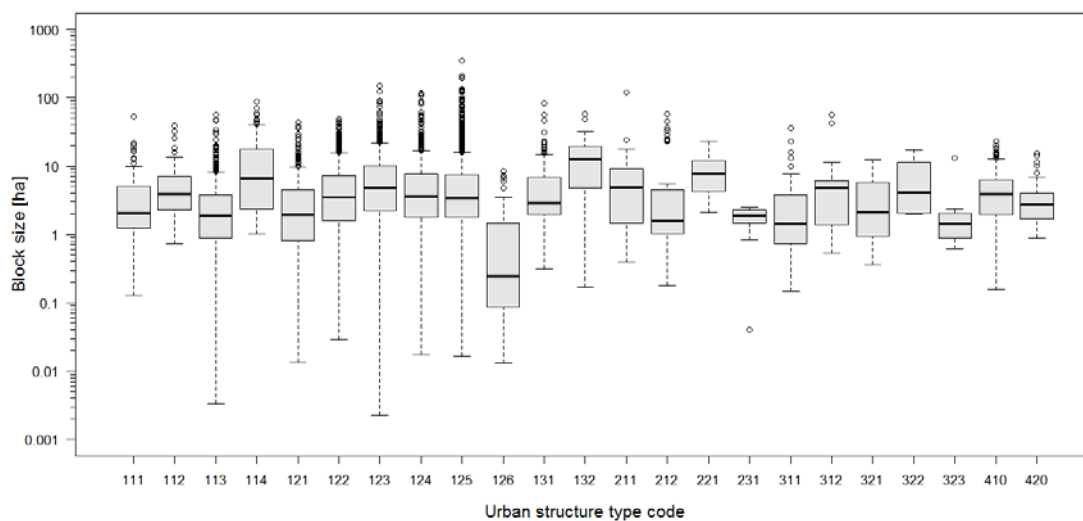


Figure 8–9 Relationship between block size and USTs

The largest land-use blocks were seen in the UST shophouse irregular with regular (*code 132*), here blocks exhibited a medium size of 14.4 ha. The Shophouse with yards (*code 114*) UST, displayed medium block size of 6.6 ha, while the UST Villa (*code 211*), had medium block sizes of 4.9 ha. The peri-urban scatted (*code 123*), clustered (*code 124*) and large field (*code 125*) USTs all displayed relative similar medium block sizes of 4.7 ha, 3.5 ha and 3.6 ha respectively. Larger block sizes showed a higher degree of heterogeneity within blocks. Here the building distributions were often

disrupted by large green and open areas or agricultural fields or development was seen solely linear one or two units wide along traffic axis with agricultural areas on either side. Often these polygons were designated as agricultural areas in the official Land-use Plan. In such areas, future studies using the same data should consider the sub-division of these polygons into built and specific agricultural-use. The smallest block sizes were seen in the shophouse irregular temporary UST (*code 126*) with a medium size of only 0.2 ha. Overall, the land-use blocks in the urban districts of HCMC had a medium size of 0.1 ha, in the peri-urban districts 0.6 ha and in the rural district 2.9 ha.

Due to the fact that in HCMC, no central spatial data infrastructure for planning-related government information exists, a large portion of the data acquired during the course of the research was inaccurate. Because the responsibility for spatial information management is distributed over many administrative departments, data sets received from different sources did not match, thus complicating the processing and analysis. Errors were detected, *i.e.* wrong or missing administrative boundaries. Furthermore, some necessary input data was either not available on the necessary spatial scale or not available at all. Another important aspect, which must not be underestimated, is that large portions of the data are available only in Vietnamese without any descriptive meta-data.

Comparisons of the official building cadastral footprint data, and the satellite imagery also revealed a number of problems. The “footprint” of the building was taken to correspond to the polygon (gross) floor plan of a building. However, it was seen for closely spaced adjacent building structures, digitalisation errors and the merging of a number of buildings into single polygon structures occurred. This resulted in one complex building polygon rather than several separate neighbouring buildings. This was seen to occur predominately in the shophouse irregular temporary UST (*code 126*) and may have led to inaccurate calculation of density indicators. For future analysis, the segmentation to generate sub-partitions of the merged building polygons should be considered.

Dealing with data of different temporal resolutions can also be a cause of uncertainty, as changes may have occurred between datasets. However, in this study, where the temporal difference may have influenced the results, care was taken: The acquisition time of satellite imagery and census information for HCMC could be used without any

change as the temporal difference was less than 1 year between census information and satellite images.

A further weakness of the UST approach was in the identification of new developments, which are still under construction. While these blocks were noted as under construction, little information could be acquired as to the nature of the development. In total, 5,400 ha of land area were classified as under construction in HCMC. This equates to an additional 10% of the already existing built-up area. While this highlights the pace of change, little can be said about the risk trends, yet the development of this size will have direct impacts to the city.

## **9 Transferability: Application testing to Da Nang**

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### **9.1 Motivation**

Adaptation and disaster risk reduction are place-specific actions. The findings from HCMC provide useful lessons for future actions in both Vietnamese and other Southeast Asian cities. However, as noted earlier, the building archetypes and the manual deduction of USTs of a city and the subsequent relation of USTs to built-up density information and socioeconomic data depend heavily on the case study area. The subdivision of the urban environment into UST classes is furthermore heavily dependent on the objective of the research. Consequently, methods may not always be standardised, comparable or transferable. How much complexity is warranted in a UST classification is dependent upon the location and research question. In the approach applied to HCMC, an understanding of the local area was needed to differentiate between land-use and the land cover characteristics seen visually. Furthermore, the quality of the UST classification depends heavily on the quality of the classification of the building archetypes.

To test if the UST classification developed for HCMC could be adapted to the local conditions of another Vietnamese city; the scheme was applied to the city of Da Nang. The work was undertaken within the framework of the BMBF funded action-orientated research project “Rapid Planning –Sustainable infrastructure, environmental and resource management for highly dynamic metropolises”. The objective of the overall project is to develop a rapid trans-sectoral urban planning methodology, which specifically targets sustainable supply and disposal infrastructure. A basis for the development of this methodology was the UST classification of the city in relation to socio-economic classes, and to assess excess urban basic services, which are in turn, then to be coupled with supply and consumption patterns.

### **9.2 Urban context**

Da Nang city is an important port city, strategically located at the coast of the South China Sea, and at the mouth of the Han River (15°550' N, 107°180' E). It is the third

most populated city in Vietnam and the largest city in central Vietnam. The city in total covers an administrative area of 1,284.8 km<sup>2</sup> (GSO-DN, 2016).

The city borders Thừa Thiên-Huế Province to the north and Quảng Nam Province to the south and west. Surrounded by mountains to one side and the South China Sea on the other, the city is important as the Central Key Economic Zone and lies at the end of an East-West Economic Corridor (EWEC), which connects Laos, Myanmar and Thailand to the commercial Tien Sa Seaport and the South China Sea. The city is also recognised as a centre for culture and sport, education, science and technology for the entire central region, as well as, also being of strategic importance for national defence and security.

The city was founded in 192 AD. By the middle of the 16<sup>th</sup> century, the town of Hoi An, about 30 km south of present-day Da Nang was the busier trade centre, whereas Da Nang was only a small port for goods in transit and ship repair. However, Da Nang gradually grew in importance, and developed into a commercial port, replacing Hoi An by the early 18th century, as the main regional port.

French colonists separated Da Nang from Quang Nam as a concession and renamed the city Tourane, transforming it into a Western-style urban centre by the late 19<sup>th</sup> and early 20<sup>th</sup> century. While, the original location and structure of the city centre, on the western shore of the Han River, has remained, the city's morphology has changed over time. Periods of expansion and (re)development have been influenced by and based on a synthesis of both culture and inherent geography. The initial city planning comprised of a rudimentary street layout and three urban blocks undertaken during the French colonial period (Figure 9–1). These blocks continue to be the site of the administrative centre of the city.

During the Vietnamese War, Da Nang was known as a “military urban metropolitan” due to the intensification of basic infrastructure provided in order to serve both logistical and other military purposes. During this time Da Nang airport, the Tien Sa Seaport, Naval ports, petroleum terminals, additional roads, waterways, harbours, and cargo storage systems were all developed. The development of these fundamental infrastructure systems was later utilised for the city's recovery following liberation in 1975, and for the further urban development in the years directly following the war.



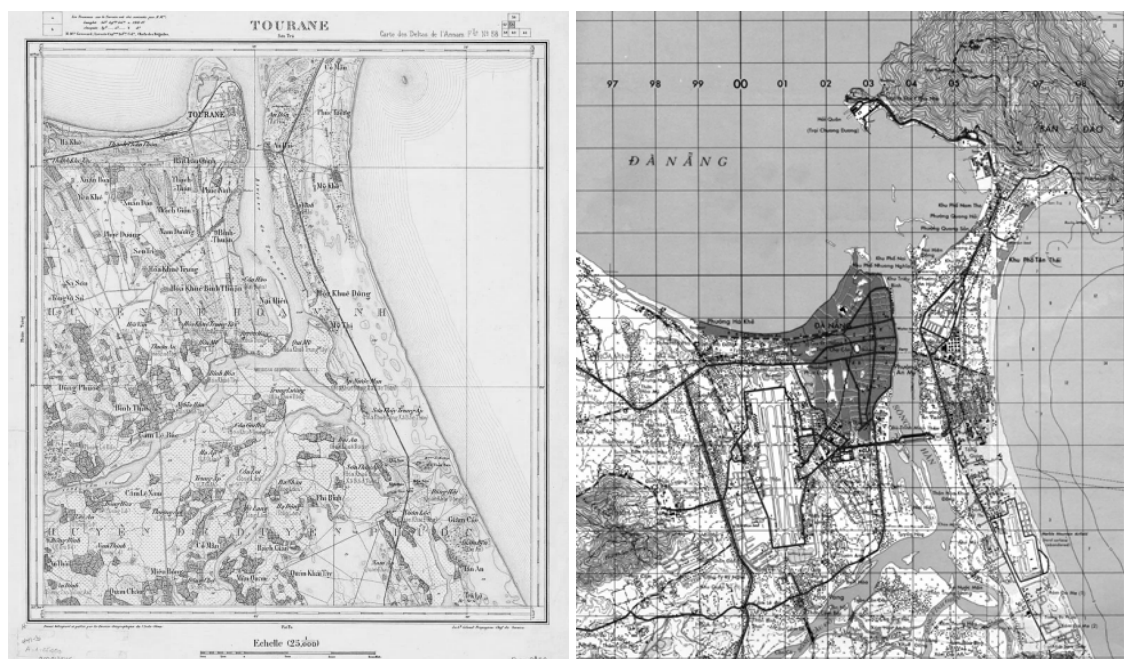


Figure 9–1 Historical maps of Da Nang showing expansion over time (a) A city map after 1889 derived from Atlas général de l'Indochine française Atlas) under French colonial rule. (b) Da Nang at the time of the American War (with permission from Mr. Vo Van Hoang, Da Nang Institute for Socio-Economic Development (DISED))

The city gained independence, entering a new era of reform, development and remedial phase, overcoming the consequences left by the war and focusing more on economic recovery and social stabilisation. However, it was not until the 1990's that Da Nang witnessed sustained, positive and stable economic growth. In 1996, the National Assembly approved the separation of Da Nang and Quang Nam Province from the existing Quang Nam – Da Nang Province. This made the city a separate centrally controlled municipality. On 1<sup>st</sup> January, the following year, Da Nang became a new administrative unit and socio-economic development and change followed rapidly. At this time the city began to focus on strengthening production and business, while initiating infrastructure upgrades and renovation to its urban core.

In July 2003, Da Nang was recognised as a Class I city, while on 16<sup>th</sup> October, the same year, the Political Bureau of the Communist Party of Vietnam released Resolution No. 33-NQ/TW outlining plans for further industrialisation and modernisation, providing the city with more opportunities for development. At this time the exact development orientation of Da Nang was set as “building Da Nang into a major city, a socio-economic, industrial, trade, tourism, service, scientific and technological, banking and financial, sport and cultural, education and training centre in Central Vietnam”. Subsequently, Da Nang underwent quick and robust modernisation processes and

emerged as a dynamic city, expanding urban space and intensifying infrastructure. Da Nang experienced steady economic growth from the period 1997 to 2016, with an annual mean growth rate of 10.3% between 1997–2000, 11.7 % between 2001–2010 and 9% between 2011–2016. This was 1.9% higher than the overall growth rate of the whole country in the same period (GSO-DN, 2016). These growth rates helped narrow the development gap between the Central Region of Vietnam and the major economic centres of HCMC and Hanoi respectively. As comparable to the trend of the whole country, the city's economic structure has shifted in the last 30 years increasingly towards the service and industry sectors. Simultaneously, the share of agriculture production has significantly reduced. In 2015, the GDP generated from the industry sector accounted for 53.9% of the city's total GDP, while those for the service and agriculture sectors were 43.9% and 2.2%, respectively (GSO-DN, 2016). The main driver for the recent socioeconomic development in the service sector has been both private and state sector investment in the tourism industry.

Recent growth of the city has seen it expand its industrial parks, export-processing zones, such as Son Tra Export Processing Zone, and implement a series of projects to renovate and establish new urban areas, such as Thac Gian - Vinh Trung, Bach Dang Dong, Lien Chieu - Thuan Phuoc, Khue Trung - Hoa Cuong. Phases of urban expansion, the conversion of agricultural land into urban, and densification, however, have either often followed short-term plans, or been somewhat unplanned. The dominate residential shophouse building typology, in both planned and unplanned assemblages, has led to the over-exploitation of land resources, limiting space for green, public or open land (Do *et al.*, 2018). The spatial extent of the city has tripled from a mere 5,000 ha in the early 2000's to over 15,000 ha by 2015 (GSO-DN, 2016). At the same time, density has also been lowered in some areas of the inner core districts of Hai Chau and Thanh Khe.

The current urban area is situated along both banks of the Han River and is officially subdivided into 8 districts, 6 of these are urban districts (Cam Le, Hai Chau, Thanh Khe, Lien Chieu, Ngu Hanh Son, and Son Tra), and 2 rural districts (Hoa Vang and Hoang Sa) with proportionate infrastructure for a Class I urban area. They are further subdivided into 1 commune-level town, 14 communes, and 45 wards. In 2016, the city had a population of 1,046,252, with the highest urbanisation rate of any city in Vietnam. An urban population of 915,200 inhabitants accounts for over 90% of the city's

population (GSO-DN, 2017). Between the years 1995–2016, the population of Da Nang increased by approximately 400,000, growing on average by 20,000 annually (GSO-DN, 2017). A large majority of new residents are migrant workers from rural areas. The population is predicted to reach over 1.6 million in 2020, of which 1.3 million are predicted to live in urban areas (81.3%); while reaching over 2.5 million inhabitants in 2030 with 2.3 million (92%) living in urban areas.

### **9.3 Planning up to 2030 and climatic challenges**

Da Nang has a number of approved plans which guide the development and management of the city. These plans, in line with the objectivities of the Socio-Economic Development Plan (SEDP) 2016–2020, regulate land-use scenarios and orientate the population density distribution around the city. The current Master Plan (2000–2020) with development orientation to 2030 and a vision to 2050 comprises of a general plan for the urban area and detailed district, as well as, local plans. The plan aims to limit population growth in the inner city districts such as Hai Chau and Thanh Khe, where the population density is currently highest and direct future urban expansion towards the south, south-west, south-east and north-west into the outlying districts of the city such as Lien Chien, Cam Le and Ngu Hanh. Figures 9–2 and 9–3 overleaf show shades of this urbanisation.

Urban expansion, infrastructure, and traffic investments have been prioritised. The overall plan puts forward suggestions for improving, upgrading areas of the old inner city districts, relocating unsuitable functions, and developing new satellite urban areas. It reconfirms the development orientation goals for the city of becoming a nationally modern city and a major city which contributes to the socio-economic development in the Western Highlands and Central Region. The overall vision is the construction and sustainable development of Da Nang city towards an international standard urban centre. The Master Plan not only delivers the orientation for spatial urban planning, but it also sets out a wide range of criterion, index and indices for key sectors in Da Nang: population size, land-use, transportation system, energy supply, water access and waste management. The Land-use Plan of Da Nang until 2020 was prepared by the central government (Resolution No. 105/NQ-CP), requesting the Da Nang People’s Committee to organise, manage and monitor the land conversion on-site which meets the requirements and developments objectives of the city urban planning.



Figure 9–2 Photograph of high dense shophouse developments in Thanh Khe District looking towards Hai Chau District (CBD) (source: author's own photograph)



Figure 9–3 Photograph of high-rise and multi-story development along the coast of Son Tra District (source: author's own photograph)

Da Nang has also set the ambitious objective of becoming an “Environmental City” by 2020. Based on the adopted “Environmental City” concept, the vision statement for Da Nang proposes thus: “Da Nang to be an internationally competitive environmental city beyond being pollution-free”. This vision for Da Nang, which is fully supported by the stakeholders of the city, connotes the following ideas and intentions (i) for Da Nang not only to become free from pollution, but also to ensure broader environmental

sustainability by preserving ecosystems and cultural assets, (ii) for Da Nang to develop a distinct identity and an appealing image as a significant urban core in the Asia-Pacific region with a key role of connecting economic zone with the world, and (iii) for Da Nang to become a national centre for developing new industries. To realise this vision for the city, a set of goals is elaborated, as follows; (i) manage growth effectively, (ii) develop a competitive economy, (iii) ensure an inclusive social development, (iv) manage the environment effectively, and (v) strengthen governance (JICA, 2010).

With a tropical monsoon climate, Da Nang is also exposed to a variety of water-related risks. With steep mountains to the west, short and sloping rivers, flooding is a recurring problem, both in poorly-drained inner city districts, as well as, in the peri-urban floodplain districts undergoing rapid land conversion. Flash flooding has caused sizable damage to houses and crops as well as severe surface soil erosion (JICA, 2010). Recent urban development and encroachment into the low-lying areas of the city have been promoted with no consideration for adaptation needs, creating a significant hazard-landscape. Furthermore, tropical cyclones also have caused severe damage to vulnerable coastal areas in the past, leading to landslides and erosion and the resettlement of many vulnerable households.



Figure 9–4 Photograph of tree lined streets of Hải Châu District. With the objective of becoming an “Environmental City”, the reality is that Da Nang currently suffers from a lack of open and green space (source: author's own photograph)

During the dry months, Da Nang can also experience prolonged heatwaves and droughts that significantly impact upon agriculture production and city water supply, and is often accompanied by serious salt water intrusion. This is increasingly impacting the city's ability to meet water demand. Water shortages are then felt in turn, in the important tourism, environmental, sanitation and public health sectors. While the impacts to the city remain unpredictable, climate change scenarios suggest that Da Nang is likely to experience an increased intensity of severe rain events leading to an increase in flood events in both magnitude and frequency (Reed, 2013).

#### **9.4 UST classification of Da Nang**

USTs were classified and assigned to the digital version of the official cadastral map of Da Nang for the year 2018. This base map was kindly supplied by the Da Nang Department of Planning and Investment (DPI), and comprised of 46,194 polygons in total. Following, the same visual manual interpretation approach utilised for HCMC, each polygon was taken to represent an urban block and assigned a specific UST code. However, instead of commercially available satellite imagery, for Da Nang, free, publicly available images in high spatial resolution from the Google Earth tool were utilised for the interpretation of each block. Over the last decade the Google Earth tool has developed rapidly and has been widely applied in a number of sectors. As a free and open data source, the high spatial resolution imagery provided by this tool has supported land use and land cover mapping (Mering *et al.*, 2010; Dulh *et al.*, 2012; Taylor and Lovell 2012; Hu *et al.*, 2013; Malarvizhi *et al.*, 2016).

In total, 39 differentiated USTs were classified to the polygons of Da Nang. These USTs were divided into main five utilisation categories based on their predominant function. Hence, they were classified as being of either of residential, commercial and tourism services, public and special use, industrial, or green and open space use. Figure 9–5 shows the classified main UST utilisation groups and Figure 9–6 shows all the UST mapped for the core area of Da Nang. Table 9–1 additionally, provides an overview of the classified UST for Da Nang. As with the HCMC classification scheme, the individual USTs were predominately arranged into classes based on the dominant housing typologies they contained, the observed level of planning, their densities and age. Overall just 6.5% of the total Da Nang administrative area was classified as residential.

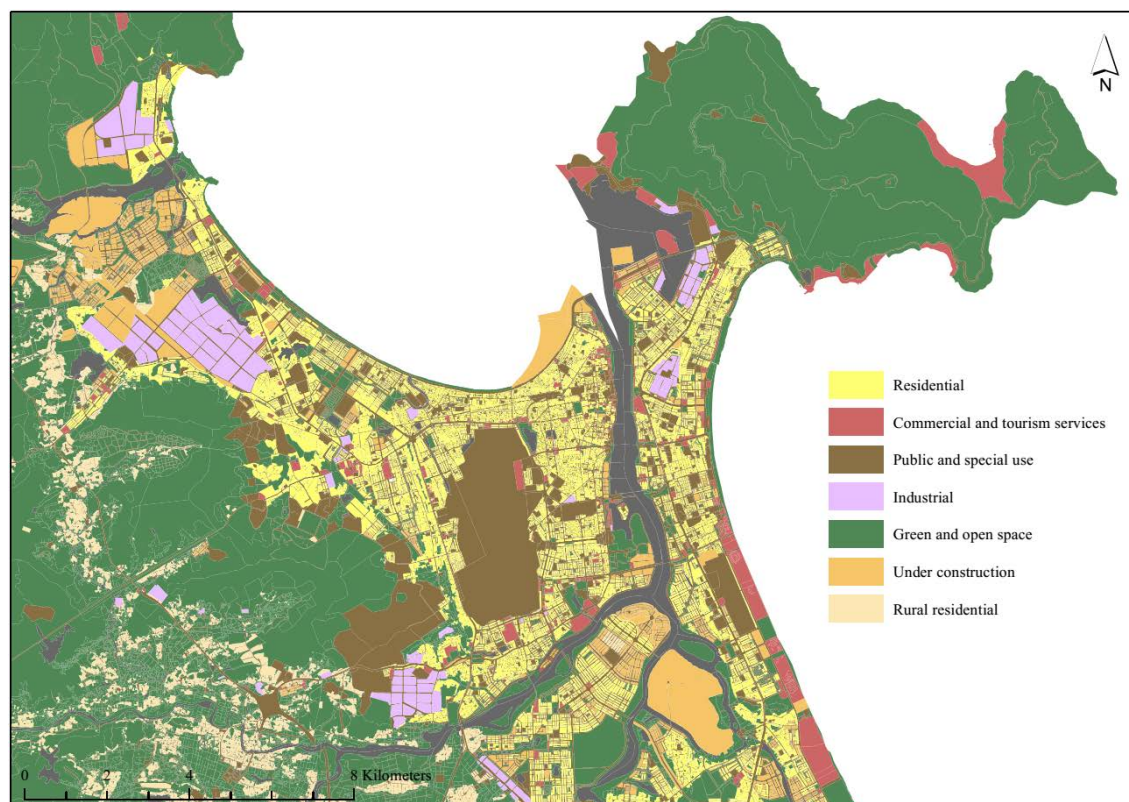
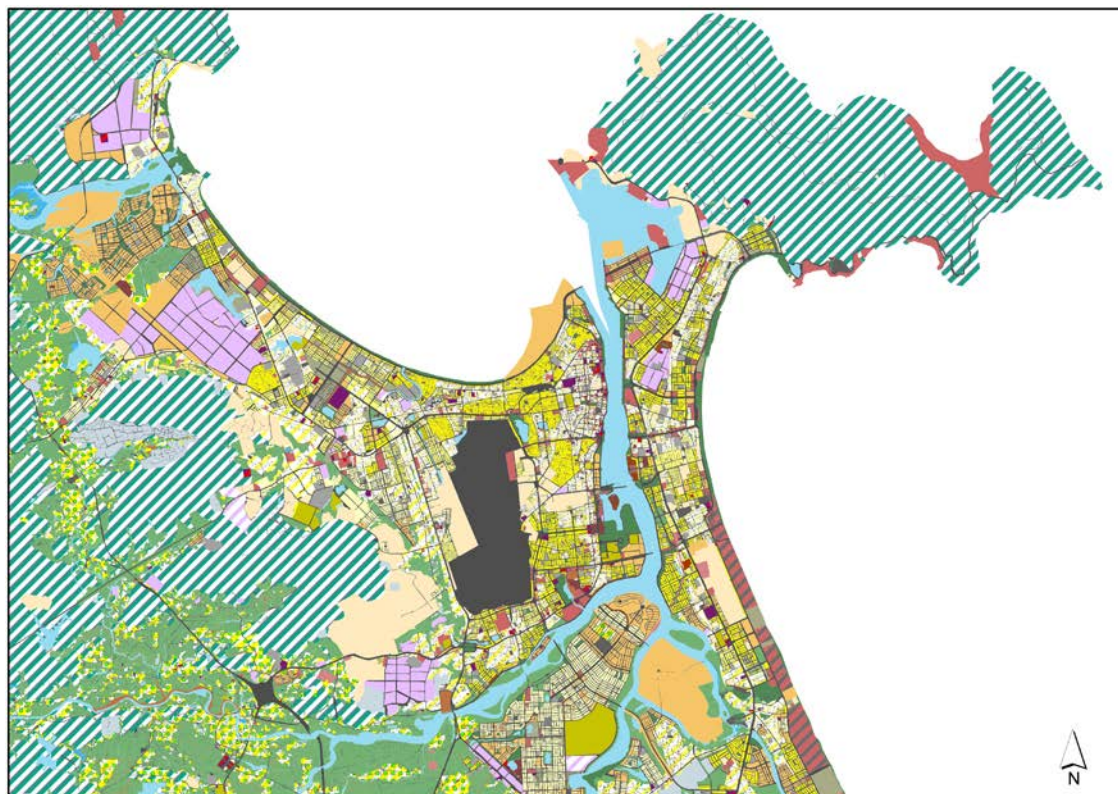


Figure 9–5 UST utilisation categories of Da Nang (*Note: Rural residential and construction sites USTs are shown separately to highlight the urban boundary, and the current direction urban development respectively*) (source: author's own)

Residential USTs varied from the dense planned and unplanned developments around the historic urban core, to more rural open settlement structures in the peri-urban parts of the city. The residential USTs were subdivided into four classes of shophouse based USTs (6 types), villa based UST (1 type), apartment (1 type), and rural residential (1 type) USTs.

The 6 shophouse based residential USTs were the dominant structures seen in Da Nang, accounting for more than 70% of all residential designated blocks and over 55% of the total residential area. In total, 3 shophouse based USTs were classed in the regular shophouse class, 3 under the irregular shophouses, and due to a large number of rural villages within the administrative area of Da Nang, a new UST was incorporated into the classification termed rural residential<sup>15</sup>. This UST represents rural areas, where the houses do not follow the general design structure of shophouses, and are surrounded by yards, gardens and fields.

<sup>15</sup> For this UST, the term Nhà ở nông thôn is applied in Vietnamese, which literally means rural houses.



0 2 4 8 Kilometers

#### Urban structure types of Da Nang 2018

111 Shophouse regular	511 Education and training	711 Recreational areas, parks and scenic land
112 Shophouse regular new	521 Traditional market	730 Aquaculture
113 Shophouse regular w/ narrow street	531 Religious and worship site	751 Unused land
121 Shophouse irregular highdense	532 Site of traditional beliefs	752 Under construction
122 Shophouse irregular	540 Hospital and health centre	761 Municipal solid waste site
123 Irregular shophouse w/ yards	550 Administration / Public Offices	762 Irrigation works
130 Rural residential	560 Transportation	770 Sport site
200 Villa	570 Cultural arts theatre/Museum	780 Cemetery
300 Apartments	580 Energy and comm. infrastructure	721-723 Agriculture
400 Commercial and tourism services	590 Military and security	741-743 Agroforest and forest
410 Villa resort	600 Industry	791-792 Surface water

Figure 9–6 USTs of Da Nang (source: author's own)

The rural residential UST covered most of the residential buildings in land zoned as rural and located in the less densely populated areas, which was observed to be rural in character, *i.e.* adjacent to agricultural, farming or forest areas. No blocks in Da Nang were designated as belonging to either of the peri-urban shophouse and the mixed shophouse UST groups.



Table 9–1 Classified USTs of Da Nang

Utilisation Category/class	No. urban structure types	No. of blocks	Surface Area (ha)	Percentage utilisation category (%)	Percentage of total Da Nang surface area (%)
Total urban structure types	39	46,194	103,758	-	100
Residential (4 classes)	9	19,209	6,773	100	6.5
<i>Shophouse based-</i>	6	13,492	3,754	70.2	3.6
<i>Villa based-</i>	1	44	22.9	0.2	0.02
<i>Apartments based-</i>	1	70	51.9	0.4	0.05
<i>Rural residential</i>	1	5,603	2,943	29.2	2.8
Commercial land and tourism services	2	775	2,182	100	2.1
Public	9	2,632	2,618	100	2.5
Industrial	1	208	887.7	100	0.8
Green and open space	15	21,417	83,266	100	80.2
Remaining transport and surface water	3	1,953	8,030	100	7.7

This is in part due to the clearer distinction between the observed urban and rural residential blocks, which made designations of peri-urban UST superfluous. Furthermore, blocks containing villa and apartment structures were not further subdivided due to their relatively low occurrence. As such the blocks which contained villa structures were grouped solely as the UST Villa and those which contained apartments simply as UST Apartment.

Numerous individual UST characteristic for HCMC were not observed (or not observed in sufficient quantities) in Da Nang to warrant their inclusion in the adapted classification scheme (see Annex VII). This is particularly true for the apartment UST group. Here high rise apartments, low rise apartments and social apartments were seen, but the Chinese apartment and American apartments of HCMC were not. Figures 9–7, 9–8 and 9–9 overleaf provide overviews of each individual classified residential UST of Da Nang.

**Shophouse regular**



Surface area: 689.5 ha      Percentage of residential area: 10.1%

Districts (wards): Cẩm Lệ (Khuê Trung, Hòa Thọ Đông), Hải Châu (Hòa Cường, Thuận Phước, Hòa Thuận Tây), Thanh Khê (Thạc Gián), Ngũ Hành Sơn (Khuê Mỹ, Hoà Hải), Sơn Trà (Nại Hiên Đông, An Hải Bắc, Thọ Quang, Mân Thái, An Hải Đông), Liên Chiểu (Hòa Hiệp Nam)

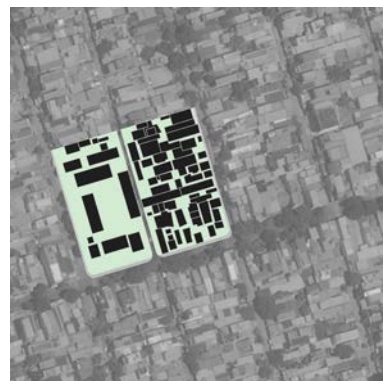
**Shophouse regular new**



Surface area: 486.7 ha      Percentage of residential area: 7.2%

Districts (wards): Cẩm Lệ (Hoà Xuân), Hòa Vang (Hoà Sơn), Sơn Trà (Nại Hiên Đông), Ngũ Hành Sơn (Hoà Hải)

**Shophouse regular narrow streets**



Surface area: 352.2 ha      Percentage of residential area: 5.2%

Districts (wards): Liên Chiểu (Hoa minh, Hoà Khánh Bắc), Thanh Khê (Hòa Khê, Hoà An), Cẩm Lệ (Hoa Phát, Khuê Trung), Sơn Trà (An Hải Đông), Ngũ Hành Sơn (Hoà Hải, Bắc Mỹ An)

Figure 9–7 Regular USTs observed in Da Nang (source: maps author's own and background image GoogleEarth®)

**Shophouse irregular high-dense**

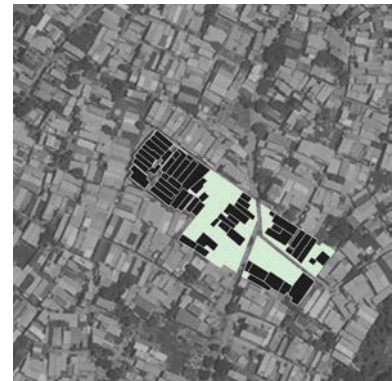
Surface area: 282.5 ha      Percentage of residential area: 4.2%



Districts (wards): Hải Châu (Thuận Phước, Bình Hiên) Liên Chiểu (Hoà Khánh Bắc) Thanh Khê (Tân Chính, Tam Thuận, Chính Gián, Hòa Thuận Đông, Thạch Gián, Vĩnh Trung, Hòa Khê)

**Shophouse irregular**

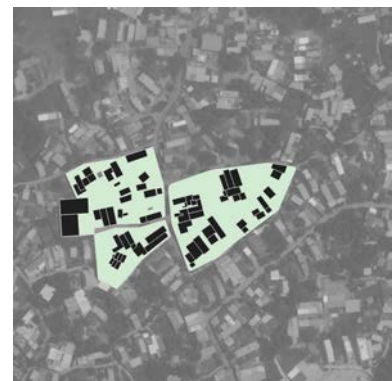
Surface area: 1069.8 ha      Percentage of residential area: 15.8%,



Districts (wards): Sơn Trà (Thọ Quang, An Hải Bắc, Phước Mỹ), Ngũ Hành Sơn (Bắc Mỹ An, Khuê Mỹ), Hải Châu (Hoà Cường Nam, Hòa Thuận Tây, Hòa Cường Bắc, Hải Châu 2, Thạch Thang, Thanh Bình) Thanh Khê (Xuan Ha), Cẩm Lệ: (Khuê Trung, Hòa Thọ Đông, Hoà An), Liên Chiểu (Hoà Khánh Bắc, Hoà Minh, Hòa Hiệp Nam, Hoà Hiệp Bắc)

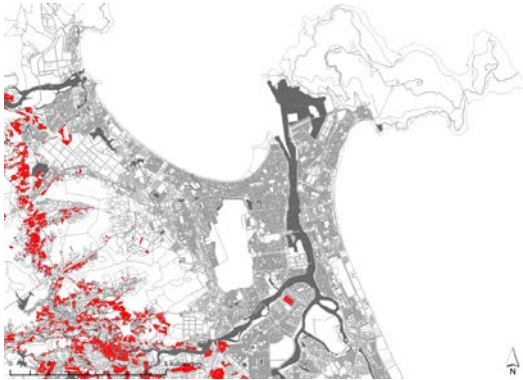
**Shophouse irregular with yards**

Surface area: 874.1 ha      Percentage of residential area: 12.9 %



Districts (wards): Liên Chiểu (Hoà Hiệp Bắc, Hòa Khánh Nam, Hoà Khánh Bắc), Hòa Vang (Hoà Liên), Hòa Vang (Hòa Sơn), Cẩm Lệ (Hòa An, Hòa Thọ Tây, Hòa Thọ Đông, Khuê Trung), Ngũ Hành Sơn (Hoà Quý, Hoà Hà)

Figure 9–8 Irregular USTs observed in Da Nang (source: maps author's own and background image GoogleEarth®)

**Rural residential**

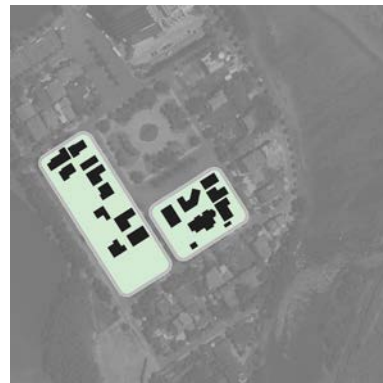
Surface area: 2943.8 ha      Percentage of residential area: 43.5%

Districts (wards): Hòa Vang (Hòa Tiến, Lê Văn Hoan, Hoà Sơn, Hoà Ninh, Hoà Nhơn, Hoà Liên)

**Villa**

Surface area: 22.6 ha      Percentage of residential area: 0.3%

Districts (wards): Sơn Trà (Hải Bắc, An Hải Tây), Hải Châu (Đảo Xanh, Hoà Cường Bắc, Hoà Cường Nam), Cẩm Lệ (Hoà Xuân), Ngũ Hành Sơn (Khuê Mỹ)

**Apartment**

Surface area: 51.9 ha      Percentage of residential area: 0.8%

Districts (wards): Sơn Trà (Nại Hiên Đông, Thọ Quang, An Hải Đông), Ngũ Hành Sơn (Bắc Mỹ An), Cẩm Lệ (Hoà Xuân, Hòa Thọ Đông, Hoà An), Liên Chiểu (Hoà Hiệp Nam), Thanh Khê (Thanh Khê Tây)

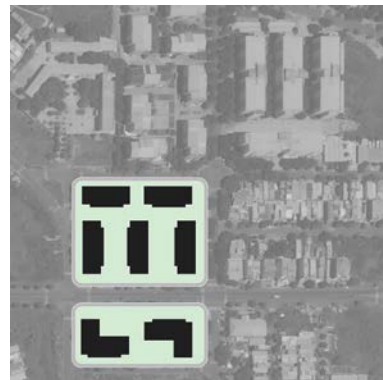


Figure 9–9 Rural, villa and apartment USTs observed in Da Nang (source: maps author's own and background image GoogleEarth®)

Due to an observed clearer distinction between residential areas and the much smaller central business district in Da Nang, the CBD based residential class types were not utilised for the city. Another major difference is that in Da Nang, with its fast-growing tourism sector, an additional utilisation category termed commercial and tourism services was included, specifically as the name suggests for the classification of a large amount of commercial land and tourism services. In total, 2.1% of the total surface area of Da Nang was classified as commercial and tourism services. In Da Nang, a total 9 of USTs were assigned to the utilisation category Public and Special use. In comparison, 21 individual USTs comprised this group for HCMC. Overall, 2.5% of Da Nang's administrative area was classified as public and special use. In Da Nang, only one UST was designated as Industry. Here, the industrial group was not further subdivided into 4 separate USTs in terms of observed sealing and density parameters as in HCMC. In total, only 0.8% of Da Nang was classified as industrial. Another distinction between the two classification schemes was in the utilisation category of green and open spaces.

For HCMC, 33 individual USTs were assigned to the utilisation category, but for Da Nang in the year 2018, only 15 individual USTs were utilised. This was due to the difference in land-use designations in the official databases of the two cities, which were subsequently visibly verified. Overall, 80.2% of the administrative area of Da Nang was classified as to belonging to this group. Interestingly, within this category, the blocks mapped as under construction accounted for 2.2% of the total area.

## **9.5 Linking USTs to urban infrastructure**

In terms of recent urban growth, providing infrastructure has become fundamental. Continued infrastructure development, stretching existing and creating new infrastructures are all critical in addressing the socio-economic development goals for Da Nang and to allow the city to function. The current lack of infrastructure provision undermines the current living standards and the city's aspirations. Managing the urban infrastructure challenges in the coming years will require an integrated strategy for overall improvement, which foresees and responds to both the framing global mega- and regional socio-economic trends (*i.e.* climate change, demographics), and combines specific local level information and hindsight.

This, in turn, will require an understanding of the interlinkages between both the basic physical urban form, and function, and also the organisational public service provision (i.e. roads, energy supply, waste disposal and canalisation). For traditional infrastructure planning, the local block scale represents the spatial unit of the physical and tangible connection between the supplier and service provider and that of the consumer or producer. This is the level where energy and water are consumed and waste and wastewater are typically generated. Local information is important and values of both consumption and generation should ideally feed into planning.

The UST classification of Da Nang deals with the configuration of urban form and space, and the spatial patterns of supporting infrastructure. The work demonstrates the applicability of the UST method to investigate the relationship between the urban block scale and the four infrastructure domains of energy, water and wastewater, solid waste and urban agriculture. The spatial patterns of UST and their built features and densities have an impact on the modalities for infrastructure service provision and consumption trends. As such, an in-depth study of each of the classified residential USTs allowed for the compilation of typical infrastructure assemblages and sustainable infrastructure potentials to each defined residential UST. Comparative statements about UST and their infrastructure groupings, together with the accurate, detailed and up-to-date mapped spatial distribution of UST provides a vital high-level overview of the general needs of the city for policy-making. Whilst, at the downscaled level, it can understand, predict and illustrate at a fine-grained graphic and sectoral domain scale effective interventions for planning and monitoring.

### **9.5.1 Energy**

Urbanisation and industrialisation of Da Nang in recent years has led to a consequent rise in energy demand. To analyse the overall energy relationship and performance of Da Nang, the spatial patterns of both energy consumption and generation potentials need to be well understood. The relationship between the classified residential USTs and energy is complex. While it can be expected that residential energy consumption, efficiency patterns, and transport related-energy varies over USTs.

Da Nang currently has no significant energy resources of its own. All energy is imported and the local planning and implementation of electricity overhead transmission lines reactive to development. In terms of overall sustainable energy

infrastructure provision, the potential to generate and embed renewable energy and diversify the energy mix within the administrative area, close to where it is needed is an interesting research topic. The city exhibits significant solar energy potential and may be able to benefit from local coastal wind resources. An accurate estimation of the potential of renewable energy technologies is essential for planning and promotion of technological systems. The UST classification can aid and explore the link between individual UST and spatial potentials for the integration of robust, decentralised and renewable energy generation at this scale. This is because the layout, density, geometry and orientation of buildings within a block, as well as, structural stability, greatly affects the potential for using renewable energy sources such as solar or wind for electricity production.

Throughout the last decades there have been numerous studies, investigating the small-scale micro-generation and solar potential of cities. While limited installed rooftop or façade photovoltaic (PV) installations for the generation of electricity were observed in Da Nang, the potentials for incorporating them are more technically and economically feasible for certain classified UST than for others. USTs are not always suitable for solar energy applications, due to limited available rooftop areas or shadow and sky-view obstructions limiting incoming sunlight. The greatest potential for their utilisation would be on the USTs shophouse regular new, and villa (see Table 9–2). These USTs offer favourable conditions as low-rise single family-houses, where residents have clear ownership of a sufficient roof area for the installation of photovoltaic systems. The apartment UST also offers favourable conditions for installation with typical large flat roofs. In all the other USTs, apprehension about the feasibility of rooftop photovoltaic installations is linked to structural challenges, which would need to be overcome.

The use of micro-wind turbines mounted on rooftops or surrounding areas additionally offers a potential low-cost renewable source of energy for the city. Despite their potential, roof-top or façade mounted turbines are at present not common in Vietnam. No wind turbines were observed in the city of Da Nang. This may be in part due to issues of wind speeds, turbulence and relatively high noise levels generated by turbines. As wind resources are greatly affected by UST themselves, the placement of wind turbines mounted on building rooftops requires the complete assessment of local wind flows to maximise energy harvesting. Here further studies of wind flow within and above the classified UST would be needed.

Table 9–2 Relationship between observed USTs and energy infrastructure solutions

UST	Potential integration of renewable energy generation solutions
Shophouse regular	<ul style="list-style-type: none"> <li>– Rooftop mounted photovoltaic installations.</li> <li>– Limited options for small scale wind turbines.</li> <li>– Widespread solar water heater system use.</li> </ul>
Shophouse regular new	<ul style="list-style-type: none"> <li>– Potential rooftop and façade mounted photovoltaic installations.</li> <li>– Rooftop and faced mounted small scale wind turbines.</li> <li>– Widespread solar water heater system use.</li> </ul>
Shophouse regular narrow streets	<ul style="list-style-type: none"> <li>– Limited integration potential of photovoltaic installations.</li> <li>– Limited integration potential of rooftop small scale wind turbines.</li> <li>– Potential to expand solar water heater system use.</li> </ul>
Shophouse irregular high-dense	<ul style="list-style-type: none"> <li>– Limited integration potential of photovoltaic installations.</li> <li>– Limited integration potential of rooftop small scale wind turbines.</li> <li>– Potential to expand solar water heater system use.</li> </ul>
Shophouse irregular	<ul style="list-style-type: none"> <li>– Limited integration potential of photovoltaic installations.</li> <li>– Limited integration potential of rooftop small scale wind turbines.</li> <li>– Potential to expand solar water heater system use.</li> </ul>
Shophouse irregular with yards	<ul style="list-style-type: none"> <li>– High potential for rooftop, façade or yard based photovoltaic installations.</li> <li>– High potential for rooftop, façade or yard based small scale wind turbines.</li> <li>– Potential to expand solar water heater system use.</li> </ul>
Rural residential	<ul style="list-style-type: none"> <li>– High potential for rooftop, façade or adjacent land based photovoltaic installations.</li> <li>– High potential for rooftop, façade or adjacent land based wind turbines.</li> <li>– Potential to expand solar water heater system use.</li> </ul>
Villa	<ul style="list-style-type: none"> <li>– High potential for rooftop or façade mounted photovoltaic installations.</li> <li>– High potential rooftop and faced mounted small scale wind turbines.</li> <li>– Widespread solar water heater system use.</li> </ul>
Apartment	<ul style="list-style-type: none"> <li>– High potential for rooftop or façade mounted photovoltaic installations.</li> <li>– High potential rooftop and faced mounted small scale wind turbines.</li> <li>– Widespread solar water heater system use.</li> </ul>

Furthermore, as the centres of cities typically experience lower wind speeds, small wind turbines typically perform better towards the outskirts of the city, along rivers and coastal areas, and are particularly well suited for use in peri-urban and rural areas. Both rural residential and shophouse irregular with yards USTs offer space for the integration of wind energy systems adjacent to buildings in the peri-urban and rural areas of the city.

Furthermore, considering structural safety and stability of installation, as well as the distance from the city centre of Da Nang, rooftop or façade mounted small wind turbines present a high potential to be integrated into the USTs shophouse regular new, villa and apartments. Solar water heating (SWH) systems, which harvest solar energy to heat water, and associated storage tanks are widely available in Vietnam and were observed to be widely utilised in Da Nang (Figure 9–10).





Figure 9–10 Photograph of a typical solar water heating (SWH) system with solar water collectors and storage tank on a rooftop in Da Nang (*source: author's own photograph*)

Solar water heating systems generally meet all the water heating needs of the residents. They were commonly seen on the roofs of USTs shophouse regular, shophouse regular new and villas. Unfortunately, the downside of their widespread use is that the systems reduce the limited roof space for additional photovoltaic or turbine installations. Nevertheless, some households have overcome this by optimising their roof space and by mounting SWH and tanks on iron frames.

### 9.5.2 Water and wastewater

The provision of water is essential for the socio-economic development of Da Nang. As the city has grown and spatially expanded, so have the need for and the associated expansion of water and wastewater utilities. Water is supplied from the Vu Gia – Thu Bon River Basin in neighbouring Quang Nam Province. Larger piped distances means higher economic costs of connection, while at the same time, an absence of wastewater utility provision, means higher environmental costs. Linear piped infrastructures such as water require medium- to long-term planning and are often inflexibility to short-term changes. This means that the long-term consequences of improper planning can be costly. Therefore, an integration of urban planning and both water and wastewater infrastructure planning is essential.

Da Nang is supplied with fresh water from the urban water supply system operated by Da Nang Water Supply Service Co., Ltd (DAWACO). The dominating factor typically affecting connection to the water supply grid is the location. The vast majority of residential USTs in the city are connected to the water supply network. The network was seen to cover up to 90% of the urban area in the year 2016, while according to the water supply planning undertaken by UPI, 100% coverage for urban areas and 65% coverage for rural areas is planned for the year 2020 (UPI, 2016). In the more peri-urban and rural areas, it is not uncommon for households to have small private wells as the main water source or to supplement the main water supply (Table 9–3). In some rural areas, bottled water is also used for drinking purposes or connection is shared among neighbours. Wells must be registered with the local government but there are no restrictions on withdrawal rates. Wells were seen mostly to occur in rural residential UST and the peri-urban USTs of shophouse irregular with yards and to some extent of shophouse irregular. In addition to being connected to the water supply network, the Apartment UST was also seen to contain large volume water storage tanks.

Rainwater harvesting and greywater recycling systems have the potential to reduce reliance on the current water supply system. While the exact design of such systems has to be adapted to the UST-specific conditions, their utilisation and incorporation depend both on the location and UST specific characteristics. The Villa UST, Apartment UST, shophouse irregular with yards, as well as, rural residential UST are the only UST where the built structure and the amount of open space would allow for rainwater harvesting and greywater recycling systems for the collection and storage for domestic reuse on-site and to reduce the demand from other sources, namely water supply and wastewater systems. For Da Nang, rainwater harvesting systems would also help mitigate flooding in the low-lying areas of the city, and be a benefit for the city in terms of reducing stormwater runoff from entering the drainage system.

In comparison to the water supply grid coverage, the service coverage of sewage and wastewater treatment infrastructure is low. Wastewater containment and disposal systems were seen to vary widely between USTs. The majority of households collect and treat black water in individual on-site septic tanks. In fact, the Vietnamese Building Code (No. 682/1996/BXD-CSXD) dictates that all houses built in urban districts since the year 1996 install a septic tank. However, less than 10% of these septic tanks release effluent overflow directly to the city's limited combined sewage and drainage system,

which gathers both rainwater and wastewater in Da Nang, via a pipeline collection network and further drainage canals.

The majority of the remaining effluent is allowed to infiltrate into the ground and cause groundwater contamination as the tanks are commonly under-maintained and have an unsealed base (Pham *et al.*, 2012). Septic tanks are not emptied regularly, and no technical guidance notes or design, operational or maintenance regulations exist (Pham, 2014). Moreover, the uncontrolled release of methane gas also causes air pollution and bad odours. When full, tanks are typically pumped empty by motorised vacuum trucks from the city's urban environment company (URENCO) or by private companies, based on the homeowner's request. In theory the pumped septage from the tanks should be transported to landfills or treatment facilities, however, it is often not further treated and illegally discharge directly into the environment. While wastewater is increasingly seen as a renewable resource in many cities from which water and energy, as well as, compost can be derived, collected septage and conveyed effluents in Da Nang are not further utilised (Guest *et al.*, 2009). This is alarming, considering, Da Nang is likely to become increasingly dependent on wastewater utilisation for meeting some of its future water needs.

In the shophouse building typology, generally, septic tanks are built to the back of the house and concealed underground. In the UST shophouse regular with narrow streets for example, with this can present accessibility issues for maintenance, connection and pumping as septic tanks are often connected to drainage systems under the typically 1.4 m wide alleyways.

In the denser built shophouse USTs, this can present connection and accessibility issues, making it difficult to access the septic tanks directly, as well as, position the vacuum truck closely. This is particularly the case with the irregular shophouse USTs with internal irregular building orientations and narrow internal alleyways, with small drainage channels located under the alleyways. While the drainage channels can provide a runway for rodents and an infection risk due to pathogens contained in effluent overflow, the septage needs to be pumped out of the front of the house. Typically, in these older urban areas, the sewage and drainage systems are in poor condition and have inadequately sized pipes and even the inner city location does not guarantee connection to the sewage system for the households (Figure 9–11).



Figure 9–11 Photograph of an open sewer in a peri-urban location (Hòa Khánh Nam/Liên Chiêu District)  
(source: author's own photograph)

Moreover, most regular shophouse based USTs directly discharge greywater into the combined sewage and rainwater drainage system which runs along the streets, while in the irregular shophouse based UST, it is more common for greywater to be directly discharged into the immediate environment and either into the adjacent drainage network or ground.

Recent additions to the urban fabric of Da Nang, including the USTs, shophouse regular new, villas, as well as, construction land prepared for development are characterised by in-situ site and service infrastructure. This typically includes separate or combined sewer and drainage systems. Note, however, for Da Nang, this does not necessarily mean that both the stormwater and domestic waster are in any way treated and more often than not, unfortunately they are discharged together untreated into nearby water bodies. The Vietnamese technical regulation on domestic wastewater (QCVN 14:2008/BTNMT), requires the owners of apartments to treat domestic wastewater discharged into combined drains to meet certain effluent quality standards. This has led to an increasing trend of private sector investment into wastewater collection and treatment for new developments in Da Nang. While a large septic tank, discharging into the drainage system, is still the most common type of on-site sanitation facility utilised for apartment UST, a select number of newer and larger apartment developments have included small-scale sewage treatment plants as primary treatment.

Table 9–3 Relationship between observed USTs and water and wastewater

UST	Water and wastewater
Shophouse regular	<ul style="list-style-type: none"> <li>– Water grid connection.</li> <li>– Septic tanks located at back of house, with tanks discharging effluent and greywater into existing combined sewage and drainage system.</li> </ul>
Shophouse regular new	<ul style="list-style-type: none"> <li>– Water grid connection.</li> <li>– Septic tanks located at back of house, areas may contain separate or combined systems. Greywater maybe discharged directly to drainage system.</li> </ul>
Shophouse regular narrow streets	<ul style="list-style-type: none"> <li>– Water grid connection.</li> <li>– Septic tanks located at back of house. Vary degrees of connection of septic tanks to discharge effluent overflow to back alley sewers or drainage systems. Greywater discharged into drainage systems.</li> </ul>
Shophouse irregular high-dense	<ul style="list-style-type: none"> <li>– Water grid connection.</li> <li>– Septic tanks located at back of house. Inner city location does not guarantee effluent connection to sewage system as accessibility issues due to building orientations and narrow alleyways. Greywater often discharged directly into drainage system.</li> </ul>
Shophouse irregular	<ul style="list-style-type: none"> <li>– Water grid connection.</li> <li>– Septic tanks located at back of house. Accessibility and connection issues relating to internal narrow alleyways. Greywater often discharged directly into drainage system.</li> </ul>
Shophouse irregular with yards	<ul style="list-style-type: none"> <li>– Water grid connection and some private wells.</li> <li>– Individual septic tanks, with limited connection to sewage system. Greywater maybe discharged directly to drainage system, or adjacent environment.</li> </ul>
Rural residential	<ul style="list-style-type: none"> <li>– Water grid connection or private wells and bottled water for drinking.</li> <li>– Individual septic tanks, pit latrines or double vault composting toilets. Greywater maybe discharged directly to drainage system, or adjacent environment.</li> </ul>
Villa	<ul style="list-style-type: none"> <li>– Water grid connection.</li> <li>– Septic tanks located at back of house, sewers and drainage designed as site and service. Areas may contain separate or combined systems. Greywater maybe discharged directly to drainage system.</li> </ul>
Apartment	<ul style="list-style-type: none"> <li>– Water grid connection and large capacity storage tanks.</li> <li>– Septic tank, discharging to the drainage system with large diameter sewer connections. Limited small-scale sewage treatment plants. Greywater maybe discharged directly to drainage system.</li> </ul>

The UST rural residential was seen to exhibit a greater number of pit latrines, these are typically not emptied but simply covered with soil and abandoned when full. Since no centralised treatment facility exists, they may also utilise traditional double vault composting toilets. In the rural residential UST and irregular shophouse with yards UST, individual household septic tanks were also seen to be connected to a soak pit.

Individual household septic tanks are not considered an adequate sustainable long-term solution for Da Nang. Owing to the limited coverage of the current conventional drainage and sewage systems, and the high costs associated with expansion and the introduction of further wastewater treatment facilities, Da Nang's infrastructure planners and policymakers increasingly need to consider and implement decentralised and semi-decentralised wastewater treatment and on-site systems.

Future potential treatment systems will undoubtedly be dictated by both the minimum legal treatment standards, as well as, the UST-specific conditions. The selection of the

most appropriate and most sustainable decentralised wastewater management systems for particular USTs will depend on population density, land requirements, the share of connected households and the costs associated with construction, operations and maintenance. Socially acceptable norms and practices, *i.e.* acceptance by stakeholders and the residents, are also an important aspect. Decentralised wastewater management systems in Da Nang would be particularly suitable for the low-density peri-urban areas of the city. In particular, areas classified as UST irregular with yards can be deemed suitable.

However, a decentralised approach in the existing densely developed and populated inner city areas of the city with an existing sewage collection system would not be a viable alternative to centralised treatment solutions (Libralato *et al.*, 2012). Such is the case in the older and denser urban structures classified, such as the irregular shophouse and irregular shophouse high dense UST, which are unsuitable for most decentralised system solutions due to the land requirements. These areas typically require the use or continued use of centralised treatment systems, or innovative engineering solutions. The German Corporation for International Cooperation (GIZ) has suggested the integration of vacuum wastewater systems, also known as pneumatic sewer systems, to connect households directly to sewage lines and promoted biogas production as a decentralized waste water treatment solution in such areas (World Bank, 2013; 2014). By-products of the biogas production, irrigation water and fertilizer from the bio plant could then be used for urban agriculture. The main argument is that such a system would require less space, be minimum invasive and construction, operation and maintenance costs low.

### **9.5.3 Solid waste management**

In contrast to both the previously outlined sectors, the solid waste sector is not dependent on fixed pipe conveyance or transmission lines for service provision. Waste collection typically follows transportation routes and the main determinant is accessibility. Furthermore, while waste disposal and transfer facilities require space, the urgency to be integrated into urban and infrastructural development has traditionally often been deemed secondary. The expansion of urban space, rapid population growth and high urbanisation rates have placed high pressures on the waste collection, transportation and disposal systems of Da Nang. The solid waste sector is in a current state of overload and not keeping pace with the development of the city. The is facing

problems such as unstable collection and transportation, lack of facilities and outdated treatment technologies, which also causes soil, water and air pollution, severe changes in natural habitats and ecological areas, and public health issues. The state-owned Da Nang Urban Environment Company Limited (URENCO) is in charge of the solid waste collection and treatment for the city. In 2016, the municipal solid waste generation in Da Nang averaged 730 tons/day (GSO-DN, 2017). Solid waste generation amounts differ due to variations in consumption between locality, while consumption, in turn, is affected by socio-economic, environmental and demographic factors. Depending on the location and local characteristics, solid waste is collected from households via a combination of hand carts, tricycles, waste bins placed at fixed positions, hourly collection and collection by open trucks and compactor trucks (Figures 9–12 and 9–13).

Solid waste from residential areas is collected by workers and transported to transfer stations. Here it is compressed into containers and transported to the Khanh Son Landfill in Lien Chieu District for disposal. Currently, 100% of the collected solid waste is landfilled. Waste is collected mainly unseparated, while, separation of recyclable elements at source is undertaken, it remains undocumented and no official figures are available. Typically residents or local woman unions separate and recover the most valuable fractions, paper, cardboard metal and plastics elements at source or informal sector “waste pickers” at the landfill, for sale to scrap dealers or processing before they are finally sold to manufacturing enterprises.

A five-year study undertaken between 2010–2015, on the deficit between the annual amounts of solid waste generated and solid waste collected in Da Nang showed that collection rates varied between the inner urban districts and the sub-urban districts, with 83.7% and 59.5% collection rates respectively (Thanh, 2018). It is also should be noted here that the inferred figure for the sub-urban area might be influenced as part of the induced solid waste is directly self-treated by the locals, for instance, burying or incineration. For their services, URENCO charges the maximum monthly collection fee for household waste collection and transportation in accordance with Decision No.33/2017/QĐ-UBND dated 18<sup>th</sup> November 18, 2017. Table 9–4 shows that the maximum waste fee is determined based on the width of the road on which the house is located. The waste fee for households located on alleys is lower than those on larger streets. Furthermore, the waste fee is dependent upon whether business activity occurs on the premises.



Figure 9–12 Photograph of solid waste collection by tricycle (Cẩm Lệ District)



Figure 9–13 Photograph of solid waste collection by compactor truck (Ngũ Hành Sơn, District) (source: author's own photograph)

Table 9–5 highlights the typical waste management conditions in relation to the classified UST of Da Nang. In terms of collection, collection by compactor or older waste trucks is only possible in UST shophouse regular, shophouse regular new, villa and apartments. Due to the presence of large streets in the UST structure, all households are accessible for truck collection.



Table 9–4 Municipal solid waste household collection fee (extract from: Decision No.33/2017/QĐ-UBND dated 18/11/2017 of the People’s Committee of Da Nang city)

No.	Subjects of application	Unit	Price (USD)
1	Household		
1.1	Households with no business activities at home		
1.1.1	Apartments, tenements, rented housing	hh/month	0.65
1.1.2	Alleys	hh/month	1.09
1.1.3	Large streets	hh/month	1.3
1.2	Households with business activities, disposing not more than 1 m <sup>3</sup> of waste/month		
1.2.1	Alleys		
1.2.1.1	Group 1: construction materials; F&B, groceries; appliance; automobile and motorbike fixing; hostels	hh/month	2.17
1.2.1.2	Group 2: Tailoring, jewelleries, car/motorbike wash, convenience store and others	hh/month	1.96
1.2.2	Large streets		
1.2.2.1	Group 1: construction materials; F&B, groceries; appliance; automobile and motorbike fixing; hostels	hh/month	4.35
1.2.2.2	Group 2: Tailoring, jewelleries, car/motorbike wash, convenience store and others	hh/month	3.48

The inner city street space in the residential areas allows for the placement of collection bins along the main streets. The waste bins are emptied at least once daily. Accordingly, URENCO uses small waste trucks to transport and position standard waste bins along the main streets/routes, allowing households to discharge their domestic waste. After a specific amount of time, trucks return to pick up the bins and transfer them directly to the Khanh Son landfill.

Due to limited space for fixed bins, URENCO often operates a collection by hour scheme in the shophouse based USTs -regular with narrow streets, -irregular high-dense and -irregular high-dense areas of the city. This involves daily generated solid waste being placed on the street in small plastic bags by residents and being collected during a specific period during the day usually in the early morning. In these USTs, the collection takes place by tricycles (pedi-carts) or hand cart only due to limited access to the households located along the small internal alleyways. In the peri-urban UST shophouse irregular with yards and the UST rural residential, the amount of collected solid waste is significantly reduced. While these areas are typically assessable by compactor waste trucks, waste generation and collection rates vary considerably depending on location. In areas far from the centre of the city, trucks will use their horn to signal to residents to bring and discharge their waste directly into the truck, or workers will gather the plastic waste bags left on the street and transport the waste directly to Khanh Son landfill. Often residents of these areas undertake self-treatment of waste via burying, direct animal feed application or composting of the organic fraction, incineration or illegal dumping.

Table 9–5 Typical relationship between solid waste and observed USTs

UST	Solid waste management
Shophouse regular	<ul style="list-style-type: none"> <li>– Primary collection by compactor or older trucks.</li> <li>– Transfer directly to Khanh Son treatment complex.</li> <li>– Space for fixed collection bins.</li> </ul>
Shophouse regular new	<ul style="list-style-type: none"> <li>– Primary collection by compactor or older trucks.</li> <li>– Transfer directly to Khanh Son treatment complex.</li> <li>– Space for fixed collection bins.</li> </ul>
Shophouse regular narrow streets	<ul style="list-style-type: none"> <li>– Primary collection by hour scheme by trucks, tricycles (pedi-carts) or hand carts.</li> <li>– Transfer to transfer station and secondary transport to Khanh Son treatment complex.</li> <li>– No space for fixed collection bins.</li> </ul>
Shophouse irregular high-dense	<ul style="list-style-type: none"> <li>– Limited primary collection access. Collection by hour by pedi-cart or hand cart only.</li> <li>– Transfer to transfer station and secondary transport to Khanh Son treatment complex.</li> <li>– No space for collection bins.</li> </ul>
Shophouse irregular	<ul style="list-style-type: none"> <li>– Primary collection by hour scheme by trucks, tricycles (pedi-carts) or hand carts.</li> <li>– Transfer to transfer station and secondary transport to Khanh Son treatment complex.</li> <li>– No space for collection bins.</li> </ul>
Shophouse irregular with yards	<ul style="list-style-type: none"> <li>– Primary collection by hand carts, pedi carts and trucks.</li> <li>– Transfer to transfer station or direct to Khanh Son treatment complex.</li> <li>– Self-treatment via burying, compost, incineration or illegal dumping, animal feed.</li> </ul>
Rural residential	<ul style="list-style-type: none"> <li>– Primary collection rates vary considerable depending on location.</li> <li>– Direct to Khanh Son treatment complex.</li> <li>– Self-treatment via burying, compost, incineration illegal dumping, animal feed.</li> </ul>
Villa	<ul style="list-style-type: none"> <li>– Primary collection by compactor or older trucks.</li> <li>– Transfer directly to Khanh Son treatment complex.</li> <li>– Space for fixed collection bins.</li> </ul>
Apartment	<ul style="list-style-type: none"> <li>– Primary collection by compactor or older trucks.</li> <li>– Transfer directly to Khanh Son treatment complex.</li> <li>– Space for fixed collection bins.</li> </ul>

By weight, a large share of Da Nang household municipal solid waste consists of organic material (Thanh, 2018). While currently the vast majority of collected organic waste is deposited in Khanh Son landfill, the material is increasingly viewed as a valuable resource. While centralised composting and anaerobic digestion, as well as, incineration are viable options for energy and fertiliser production, they are cost-intensive (Pleissner, 2016). This is due to the transport and treatment costs and high moisture content of the waste.

Waste management in Da Nang needs to evolve from the simple collection and transportation of waste to the Khanh Son Landfill, to include waste prevention and recycling, as well as other potential waste treatment and landfill technologies. For Da Nang, decentralised waste management strategies are an interesting cost-efficient alternative to the current unsorted collection and landfill practice. From a waste

management perspective, decentralisation can be understood as undertaking waste treatment processes on-site or close to where the organic material is generated.

While the peri-urban and rural residential USTs of Da Nang can be considered predestinate for decentralised waste treatment solutions undertaken already for resource utilisation, as a traditional coping mechanism in the absence of service provision, and while the low dense existing structures allow for easy future integration. However, decentralised treatment of waste is likely to be more problematic and challenging in inner city UST areas characteristic of limited space. Furthermore, larger-scale decentralised solutions, dependent upon the amount of waste are unlikely to succeed without public willingness and acceptance of waste treatment due to odour pollution which may negatively affect the quality of life of residents. There would also need to be a relaxation of current governmental regulations banning waste treatment in residential areas. While individual household composting should be encouraged independent to UST, several USTs such as apartments or villa, however offer possible locations.

#### **9.5.4 Urban agriculture**

Urban agriculture can be defined as undertaking agricultural practices in and around cities (Zezza and Tasciotti, 2010; Kasper *et al.*, 2017). This can include both crop cultivation and animal husbandry on urban and peri-urban lands and maybe be initiated by bottom-up community-led or top-down institutionally-led actions.

For Da Nang, urbanisation has inevitably resulted in the loss of officially designated agricultural land. Urban agriculture and food production in Da Nang is an increasing challenge as land is taken out of production or only made available to a limited extent (Figure 9–14). Land is often prepared for construction or left vacant as the owners anticipate the gains to be made from selling it or using it for non-agricultural purposes. Although agriculture, only makes up a small decreasing share of the city's GDP, it still plays an important role in food security for the city. Around 23% of all agricultural products and 30% of all vegetables and fruits consumed in Da Nang are produced within the city's administrative borders (Dinh *et al.*, 2013). According to Linh (2013), who undertook a detailed study of land use change over 30 years, the agricultural area of Da Nang has since 1995 decreased in size by 60%. This can be attributed as a direct result of land take for urban development. The current amount of land designated as agricultural land and under cultivation is currently around 8000 ha (GSO-DN, 2016).



Figure 9–14 Photograph of a large scale safe vegetable (*Rau an toàn*) farm in Cẩm Lệ District. The farm is located on the floodplain of the Cẩm Lệ River and experiences seasonal flooding (source: author's own photograph)

The majority of cultivated land lies in the peri-urban district of Hoa Vang. Agricultural practices are also, however, undertaken on land not officially designated for agricultural production. The exact figures on urban agriculture are hard to calculate or even estimate and statistical data in Da Nang does not capture the practice.

Linking on-site observed urban agriculture practices to the classified UST aids the identification of the unmonitored level agriculture activities and the multiple functions of urban areas. Direct observation is needed to identify the finer-scale urban agriculture and internal heterogeneity often overlooked (Figure 9–15). Furthermore, the spatial presentation of urban agriculture potentials provides insights, accurate mapping and inventory results, into the different types of private and public productive uses of the different spatial structures that make up the city. In a further step, crop yield values for the main agricultural crops could be used to estimate the city's food protection potential. Table 9–6 demonstrates the existing and potential relationships between the classified UST of Da Nang and urban agriculture practices. The difference in street and block spatial patterns, building typologies, land parcel patterns and the arrangement of buildings within the parcels, create very different environments for urban agriculture practices. Due to their flat roof structure, all shophouse based USTs offer opportunities for the implementation of household rooftop gardens.



Figure 9–15 Photograph of fine scale urban farming practices observed in Da Nang (*source: author's own photograph*)

Rooftop gardening, balcony and windowsill growing were observed to occur in both the UST shophouse regular and UST shophouse with narrow streets. Small square box gardens often made from polystyrene boxes were also seen to exist in these USTs. Additionally, the interim use of adjacent vacant small parcels of land for a vegetable garden was seen in these USTs characterised by their geometric regularity and rectilinear structure, as well as, in the shophouse irregular UST. These areas are typically vacant private land rented from the owners or empty public land, which has no other function, rented from the local ward authority. In such areas, however, care should be taken in regards to soil quality and not farm on areas with a high pollution load. Nevertheless, rooftop gardens and interim gardening on vacant land parcels increase the green areas of the city and can beneficially influence both the urban microclimate and help manage stormwater, buffering or detaining run-off following rainfall.

The buildings that comprise UST shophouse regular new and villa are often designed with a set-back to the road in front. This setback is often used as a front garden and often ornamental in design where flowers or selected fruit trees (*i.e.* mango, papaya, avocado, kumquat, guava) are grown. Rooftop farming in the villa UST is impractical due to the pitched or complex structures. Land and space availability is very critical for urban farming.

Table 9–6 Existing and potential relationship between urban agriculture and observed USTs

UST	Existing and potential urban agricultural practices
Shophouse regular	<ul style="list-style-type: none"> <li>– Rooftop gardens, balcony and windowsill vegetable growing.</li> <li>– Small box gardens for salad and herbs.</li> <li>– Vacant land parcels farmed.</li> </ul>
Shophouse regular new	<ul style="list-style-type: none"> <li>– Front garden for ornament flowers and fruit trees.</li> <li>– Adjacent vacant land parcels in peri-urban locations.</li> <li>– Potential for rooftop gardening and community gardening activities.</li> </ul>
Shophouse regular narrow streets	<ul style="list-style-type: none"> <li>– Rooftop gardens, balcony and windowsill vegetable growing.</li> <li>– Small box gardens for salad and herbs.</li> <li>– Vacant land parcels farmed.</li> </ul>
Shophouse irregular high-dense	<ul style="list-style-type: none"> <li>– Lack of space presents challenge for integrating urban farming.</li> <li>– No urban farming observed.</li> <li>– Potential for balcony and windowsill vegetable growing, shade allowing.</li> </ul>
Shophouse irregular	<ul style="list-style-type: none"> <li>– Rooftop gardens, balcony and windowsill vegetable growing.</li> <li>– Small box gardens for salad and herbs.</li> <li>– Vacant land parcels farmed.</li> </ul>
Shophouse irregular with yards	<ul style="list-style-type: none"> <li>– Yard areas provide small areas of land suitable for agriculture</li> <li>– Adjacent plots, marginal lands in peri urban locations</li> <li>– Yards used as small-intensive urban farms or salad gardens.</li> </ul>
Rural residential	<ul style="list-style-type: none"> <li>– Intensive farming undertaken on adjacent land.</li> <li>– Rice, cassava, maize, sweet potato, peanut and sesame.</li> <li>– Additionally small scale horticulture and aquaculture.</li> </ul>
Villa	<ul style="list-style-type: none"> <li>– Front garden generally for ornament flowers, fruit trees and vegetables.</li> <li>– Potential for community vegetable gardening activities within structure.</li> <li>– Rooftop gardening requires innovative solutions.</li> </ul>
Apartment	<ul style="list-style-type: none"> <li>– Balcony and windowsill vegetable growing.</li> <li>– Court yards sometimes planted with decorative flower-beds or single trees.</li> <li>– Potential for vertical gardening, rooftop or farming vacant land parcels.</li> </ul>

In the shophouse irregular UST high dense an acute shortage of space for urban agriculture is the main constraint. No urban farming practices were observed in this UST. Finding innovative farming solutions in this spatial structure would require community willingness and acceptance.

While innovative farming system such as hydroponics and vertical farming exist, the only practical opportunities for farming in this UST would be limited to rooftop farming or hanging vertical gardens along the sides of buildings and or alleyways. However, this is also not without limitation and it remains uncertain if adequate natural sunlight would be available for a large part of the day in the 1.4 m wide alleyways.

Within the apartment UST, only small amounts of urban agriculture were seen on selected balconies and the rarely on the ground level surrounding the main buildings. This UST also has the potential for a more comprehensive vertical gardening or rooftop gardening solutions. The set-back and often underutilised land directly surrounding

individual apartment towers have large potential for agriculture. In such settings, community gardens could be developed, providing spaces where people can socialise and orient their behaviours towards achieving community-building goals. Furthermore, the interim use of adjacent underutilised parcels of land which are either unused, left fallow or abandoned or awaiting construction after initial clearance could be used. There is no doubt that urban farming has societal significance in community development, especially in areas in which vacant land exists.

In the peri-urban UST Shophouse irregular with yards, a variety of grown crops were observed included leafy and root vegetables, mushrooms, fruit trees, flowers and other ornamental plants. Finally, the rural residential UST, agricultural activities are extensively undertaken. The main crop grown here is rice, which is planted intensively and harvested twice a year, while other annual crops observed cultivated were cassava, maize, sweet potato, peanut and sesame.

## **9.6 Lessons learnt for a generic UST classification scheme**

Chapter 4 outlined previously undertaken UST studies (see Table 4–1 (Page 95) and Table 4–2 (Page 96)). It shows that the vast majority of these studies focus solely on the classification of a single city. Only a handful of studies investigate the transfer of UST approaches to other cities or other regions.

This Chapter has outlined how the developed HCMC UST classification was adjusted to suit the observed built, socioeconomic conditions of an additional Vietnamese city. This adjustment was not solely concerned with a new geographic and urban setting, but also a new research question. The HCMC classification scheme contained 23 distinct residential USTs, while for the central Vietnamese city of Da Nang, 9 residential USTs were utilised. Both allowed for a higher level of differentiation than seen in the HCMC Land-use Plan or that of the cadastral map of Da Nang. Furthermore, for the predominant observed shophouse building archetype, 12 shophouse based USTs were classified for HCMC, while only 7 UST were classified for Da Nang. This was undertaken on the basis of their distinct configurations characteristic open spaces, built-up densities, building alignments, and associated infrastructure or absence of infrastructure (Table 9–7).

Table 9–7 Comparison of UST classifications for both HCMC and Da Nang

	HCMC (2010)		DA NANG (2018)	
	No. UST	Surface area (%)	No. UST	Surface area (%)
Total USTs	80	81.7	39	100
Residential	23	21.1	9	6.5
<i>Shophouse based</i>	12	20.1	7	3.6
<i>Villa based</i>	4	0.4	1	0.02
<i>Apartment based</i>	5	0.24	1	0.05
<i>Central business district based</i>	2	0.35	0	0
<i>Rural residential</i>	0	0	1	2.8
Public, commercial (tourism)	20	2.43	11	4.6
Industrial	4	2.67	1	0.8
Green & open space	33	55.5	15	80.2
<i>Remaining transport &amp; surface water</i>	-	18.3	3	7.7

The results of classifying and mapping the USTs of Da Nang demonstrate that the classification scheme could be further adapted with minor alterations to the local conditions of another city with the same socioeconomic and historical characteristics and climatic contexts. The classification also allowed for the compilation of typical infrastructure assemblages and sustainable infrastructure potentials to each defined residential UST of Da Nang. Therefore, the conceptual framework and its implementation as presented in this study can be assumed not to be solely limited to HCMC, and beside Da Nang, it is likely transferable further to other Vietnamese cities without any problems. Yet as can be seen by the results for Da Nang, even within Vietnam, each city would be expected to exhibit individual features and unique characteristics, despite apparent structural similarities.

Chapter 4 has shown that there is an increasing number of studies utilising UST approaches in the international literature. However in the absence of a widely standardised and accepted UST framework, distinct differences between the applied classification systems can be stated, especially regarding different geographical regions, economic, historical and cultural development. Both, the number of classified USTs and classification depth varies widely, while the vast majority of UST approaches have focused solely on individual cities. Only five studies were seen to apply their developed UST scheme to more than one city, with one study addressing only two cities (Steiniger *et al.*, 2008; Wurm *et al.*, 2009; Puissant *et al.*, 2012; Geiß, 2015; Bochow *et al.*, 2016).

A straightforward transfer to cities outside of Vietnam has not been tested. However, the classification system developed cannot be considered as generic. Considerable



changes to the scheme need to be considered. A generic classification scheme widely transferable needs to be flexible enough to provide hierarchically consistent classifications applicable for a broad array of research questions, while detailed enough to allow for consistent replicability, and for the same question to be asked in different regional and geographical contexts. Additionally, it is important to safeguard the use of terms and if the vocabulary and nomenclature of the developed UST are understandable and transferable to the end-users or target groups in a different city, regional or professional context (Bechtel *et al.*, 2016; Bechtel *et al.*, 2018; Lehner and Blaschke, 2019). Based on the results from HCMC and Da Nang, Figure 9–16 demonstrates an attempt to include the recognised USTs of both cities into a generic and robust classification scheme.

The generic classification was developed solely for the residential land-use functions but could be easily expanded to include other functions. The first four levels of the classification have been designed as generically as possible to allow for a wide range of applications, *i.e.* transferability and understanding in a wide range of sectors and to a wide range of cities. Resultantly, the first part of the classification scheme is broad, general and comprehensive. At the first level, the differentiation between single-family and a multi-family structure is made. At the second level, the differentiation between linear terraced houses (also termed “row houses” in the literature), detached, apartments and semi-detached housing types is made. This division is clear, easy to understand for a range of stakeholders, and corresponds well to general building codes categories, including those of the official Vietnamese building code. It is important to note, that semi-detached housing is currently seen to a very limited extent in Vietnam and therefore was not further considered, and only included in the classification for generic purposes. The next level differentiates dominant building archetype. Urban blocks can be differentiated from shophouse, villa, to low-, mid- or high-rise apartments and rural houses. At the fifth hierarchical level, specific local contextual knowledge is utilised to divide the UST into groups reflective of urban development phases and real urban planning occurrence. At this level, considerable effort is needed to understand the all-important local context, where, form and functions may differ from that of other contexts. This scheme allows for the subjective inclusion of relevant information at this level.

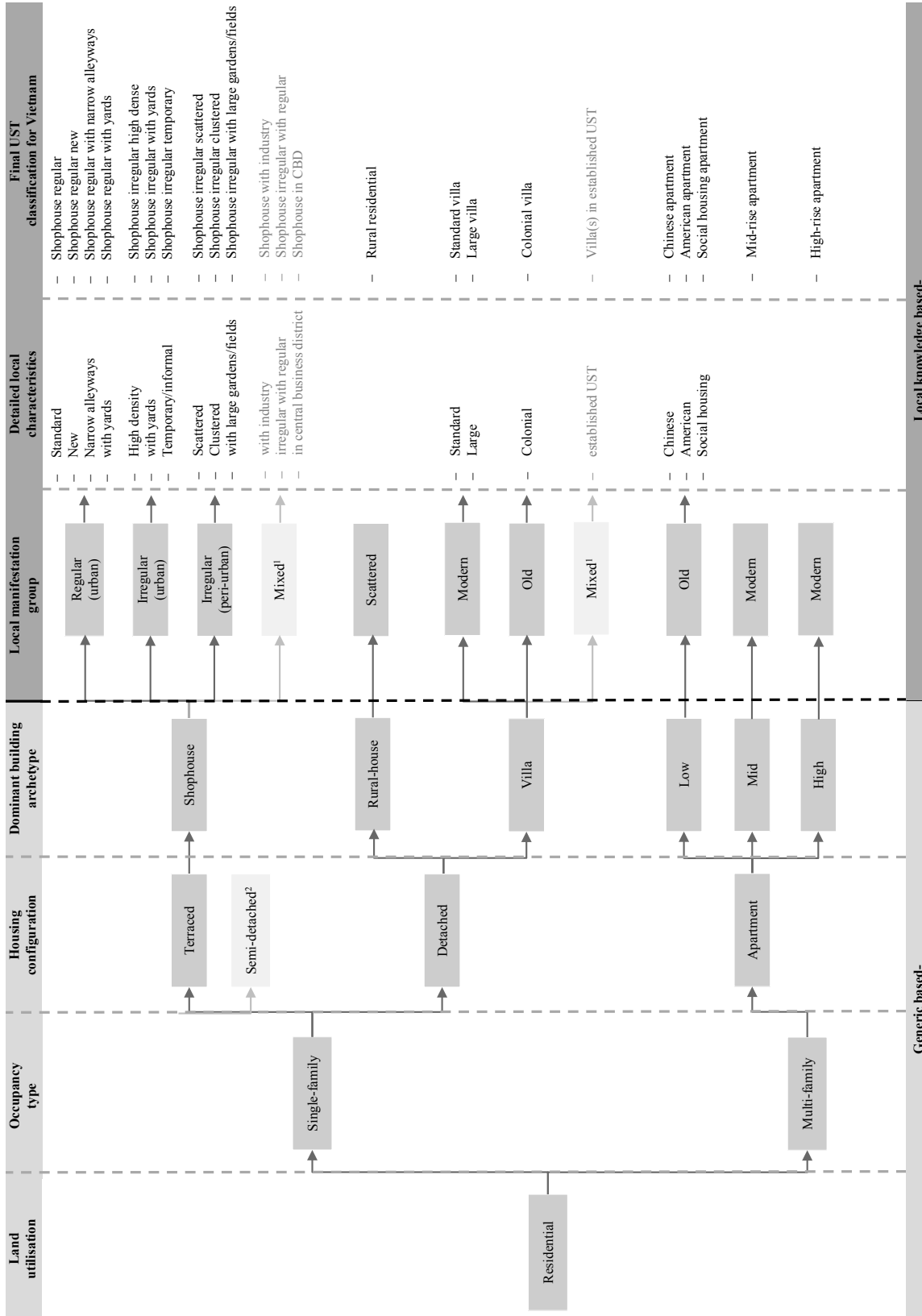


Figure 9–16 Proposed generic UST scheme with the final robust UST classification for Vietnamese cities (1semi-detached housing structures are currently only sporadically seen in Vietnam and were rarely observed to cover an entire block; 2The inclusion of mixed groupings is not ideal, their classification was often the result of the inherent limitations of block size, as discussed in Chapter 8) (source: author's own)

Consequently, at this level, USTs can be adapted to the regional and local characteristics as a reflection of the research motivation, for example, to better understand the links between structures and socioeconomic, as well as, climatic hazards, planning traditions and practices. At this level of the developed classification, the shophouse archetype group is further subdivided based on physical form, level of planning and location, into regular planned, irregular unplanned and irregular peri-urban. Moreover, at this level, the apartment USTs are further differentiated on the basis of temporal dimensions. Here the term “new” previously used in both the HCMC and Da Nang classifications is replaced with the term “modern” to allow for greater understanding and to reflect the amenities that both “modern” apartments or villas contain. For both apartments and villas, the term “old” is continued to be used and denotes buildings of a certain historical period, but does not necessarily reflect the real-life built conditions. At this level the “mixed groupings” USTs used in the HCMC classification due to the known limitations of block size are also incorporated.

At the sixth hierarchical level, the local observed variations of building archetypes, their densities, arrangements, settings and additional contextual information are used to guide the final level of division into individual USTs. This final division is heavily contested and knowledge-based, and as such the high level of detailed local understanding is needed at this final level which may hinder direct transferability to other regions. For example, the USTs Chinese, American and social housing apartments, as well as colonial villa, have very different regional interpretations and understandings.

## **9.7 Scope of further research**

This section addresses the remaining demand for further research in the area of USTs and the scope for further research. The descriptive view of an urban area offered by the application of spatially differentiated USTs for urban monitoring, risk mapping and infrastructure planning and recommendation development shows the broad functionality of the spatial units for effective urban management. It also demonstrates that they can be adapted to different research objectives. At the same time, the acquiring of new knowledge always leaves unanswered questions, some uncertainties, and opens up new questions. The results of this study thus have implications for subsequent research. The application of UST indicators in practices will be carried out under the great uncertainty surrounding the future spatial effects of global megatrends and climate change to

HCMC and to Da Nang and under the consideration of the time delay in implementation and roll-out times of adaptation and risk reduction measures and infrastructure provision. Further analysis should be undertaken to analyse the full potential of the classified UST schemes for both HCMC and Da Nang in regards to their ability to represent both socioeconomic and sociodemographic information and to enhance the application of USTs. The developed generic classification scheme attempts to make the first four levels generically applicable to all cities, while the last two are a speciality for Vietnamese cities. As such, the framework provides a coordinated structure for future urban mapping and monitoring in Vietnam.

For HCMC, in a further step, the developed framework could incorporate and link risk reduction policies in a more direct manner to the classified USTs. This could offer tailored adaptation and risk reduction solutions for particular USTs and encompass adaptation relevant building techniques for new developments, as well as, altering or retrofitting existing USTs to address risks. The framework would also allow for the development of flood damage potentials to be linked to USTs. While different climate change and disaster risk parameters can be linked to USTs, further information is needed on the individual characteristics of residents within the USTs. Hence, USTs should be seen as a starting point for the further analysis of urban flood or climatic hazard analysis. In this study, the compiled density related UST derived indicators were used in isolation. In further research, multiple indicators can be used to generate holistic spatial maps of exposure and sensitivity. These maps should then be combined to generate net maps of vulnerability. Additionally, the framework can link possible vulnerability weightage and asset value potentials to USTs to provide an estimate of possible damages that might arise to the urban system and its assets from climatic stimuli. This would, however, be subject to certain subjectivity.

For Da Nang, UST characterisation of the city demonstrated the suitability of USTs to investigate the relationship between the urban block and the four infrastructure domains of energy, water and wastewater, solid waste management and urban agriculture. Aimed towards managing and planning sustainable supply and disposal infrastructures, the design allows for additional consumption and demand indicators to be incorporated. This presents a mechanism for the city to monitor and address the infrastructure challenges at a finer scale and assess the varied planning targets and goals in a more holistic and spatially appropriate manner.

## 10 Conclusions

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Based upon the overall findings from the study, a number of conclusions can be drawn. For HCMC, the rapid pace of urbanisation over the past two decades has undoubtedly placed a large burden on the local authorities. The result has been that planning decisions have not always been made with sufficient attention to hazard exposure. At the same time, planners have had to contend with simultaneously planning for new developments, carrying out urban up-grading and making improvements to existing areas.

In HCMC, exposure to hazard events results mainly from economic and demographic pressures on land-use. Ultimately, urban resilience and exposure are dependent upon the decisions on how to use land and the choices that are made regarding which structures are built, their location and at which densities. The exposure and sensitivity pattern of each individual development, therefore, determines the ultimate risk to climatic hazards for the whole city. Hence subsequent rapid urbanisation and a continuation of the haphazard planning practices seen over the past decades, particularly in the absence of effective spatial planning, will likely only lead to overall increased risk for HCMC. This will also limit the flexibility of the city to adapt in the future, leading to costly mal-adaptation.

Land-use planning is one of the most influential instruments for climate change adaptation and disaster risk reduction. DoNRE has a critical role to play in adapting HCMC to climate variability and change. In HCMC, land is a highly sought after resource. To strengthen the capacity and successfully fulfil the mandate of DoNRE to undertake risk-adapted land-use planning, justifiable land-use decisions must increasingly be undertaken on the back of science-based information. Critically, this information needs to bridge the science-policy interface and support decision-making. Accepting that planning action can only be as good as the analysis and strategic considerations that guide the action, detailed scientific information at a planning policy-relevant scale is urgently required.

Previous advancements and growth in the use of urban remote sensing techniques have not always been coupled with increased knowledge to support decision-making. On the contrary, the UST classification for HCMC produced an analytical instrument and planning tool to facilitate cooperation between various thematic disciplines. Due to the defining characteristics of the function- and structural- orientated UST classification, there was a direct relationship between the developed indicator framework and the land-use planning instrument of urban planning. The approach permitted the integration of climate change adaptation and disaster risk reduction considerations into the existing planning framework via the drafting of spatially explicit planning recommendations and zoning.

While several methods based on indicators and other information have been proposed to evaluate climatic risk issues, the UST framework proved successful in spatially representing core density indicators. The classification provided a means to make spatially explicit renders and analyse relevant parameters at the urban block scale. Features of built-up areas, impervious surfaces, real or actual land use, housing types, building density, population density and the social status of urban areas were assigned to every block. In this manner, the classification demonstrated good potential for providing an area-wide data basis for future urban monitoring programmes. This allows the evaluation and comparison of the underlying USTs, and the relationship among UST properties and risk across a range of urban settlement types and geographies. The classification can also be appreciated as a first screening step before detailed modelling and analysis is undertaken to help further understand the role of built structures within the urban climate change policy discourse. The density findings can be readily converted into administrative, political and legislation documents, which become the basis for actions.

For decision-makers, the maps and graphics were produced at a scale suitable for planning and are even understandable for non-scientists. The visualisation of USTs and indicators at the block scale places information in its appropriate spatial context and therefore reflects the need for local responses. This aids in better interpretation and internalisation of the complexity of UST patterns and risk. Which may, in turn, contribute to a greater urgency than would otherwise arise in response to more generic statements about potential climatic risks, also allowing the determinants of risks (and the locally relevant consequences), to be considered in their local context. The density

indicators were selected to represent both the biophysical and socio-economic determinants of climatic risk. This is seen as crucial to highlight and communicate the role of development and land-use planning. But also to understand the drivers, opportunities and barriers affecting change and the implementation of mitigation and adaptation measures at the local level.

The classification of USTs upon the official HCMC land-use block geometry and the review process involving DoNRE, among other local stakeholders, facilitated their direct involvement in the process, leading to a shared product. In this way, the framework acted as a tool to promote engagement between researchers and the local administrative stakeholders. Moreover, the UST classification has shown the potential to yield new ways to identify and categorise previously undocumented types of urbanisation and spatiotemporal changes. Additionally, it provides a link between environmental planning, environmental sciences and urban planning, expediting and easing the visual communication between different scientific disciplines.

The formulation of the UST classification of HCMC, as well as the incorporation of ancillary data, also assisted DoNRE to identify other useful sources of information that may exist for future risk-adapted land-use planning. The flooding exposure mapping results and the implementation of UST data for the development of planning recommendations display the feasibility of USTs in the context of urban climatic risks, and can be strengthened by the further analysis of the relation of USTs to different data sets. The results of assessments can then be communicated with wider stakeholders, illustrating the potential tangible outcomes of climate change, development interactions, and the challenges thereafter.

It could be argued on the basis of the results, that the spatial distribution of built-up land must be optimised to create more green and open space within existing settlements. Focusing on a patchwork of greening along transportation routes and floodplains (ribbons and corridors) is emphasized, rather than large expanses solely at the urban periphery. These open spaces must be designed and distributed thoughtfully to achieve multiple goals like agricultural production, stormwater management, and flood protection. Currently, the larger blocks of green space are limited to the low-lying flood-prone urban periphery, where they act as a natural greenbelt or food belt. These have essentially been able to reinforce the seen internal settlement containment.

To evaluate both transferability and functionality, the developed UST approach was applied to the central Vietnamese city of Da Nang to investigate the relationship between urban structures and the four infrastructure sectors of energy, water and wastewater, solid waste and urban agriculture. Essentially, this study demonstrated that USTs are compatible for many applications. On the basis of lessons learnt, a flexible and easy to use generic classification scheme, which can be applied to a variety of urban planning and management problems, is presented. This generic classification has high potential applicability to both research and policy understanding of the urban environment. Due to its ability to model complex urban phenomena and provide policy-relevant information, the developed framework used in this study holds high promise for future work that is, in particular, more specifically tailored towards the strategic policy.

This study introduced a number of new and relevant findings that both promote the existing risk-adapted land-use planning research in general and supplement the current state of research in the field of Vietnamese urban adaptation and disaster risk reduction. Finally, it is important to bear in mind; it will ultimately depend on the political willingness of HCMC officials whether to use the developed UST framework for adaptation and disaster risk reduction.

Over the coming decades, in light of the underlying demographic structure of Vietnam, the strong rural-urban pull of HCMC, Da Nang and the government's own development targets, a significant amount of further urban development will be required. As the built environment has a design life of over 80 years, with settlement patterns and urban formations often having even greater longevity, the legacy of these developments will continue to impact the environment and ultimately shape the spatial pattern and long-term risks to the urban system for decades to come. Hence, there is a need for anticipatory decisions to be undertaken, steering cities towards low-risk sustainable development which would have potentially high benefits over the coming decades.

In conclusion, adaptation is unrealisable without improvements in the usability of scientific results for decision-making and their integration into the planning process. By identifying and estimating the local risks arising from climate change, the findings of this study in the development of planning recommendations have supported the HCMC's administration to establish a well-founded database with reliable information. This significantly expands the existing evidence base to assist a shift in both policy and



practice within the land-use planning, climate change adaptation and disaster risk reduction domains. On this basis, spatially explicit planning strategies and recommendations that anticipate climate change risks and development scenarios were formed to contribute to the development of resilient settlements within HCMC. Spatial indicators and planning recommendations based on a UST approach aimed to advance and disseminate knowledge, thus informing decision-makers about climate change risks to increase their capacity to implement necessary adaptation measures and to strengthen the resilience of the HCMC's urban system. A challenge going forward is to provide a more comprehensive and integrated platform that is widely shared and updated by the administrative stakeholders and importantly, the public.

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## Annex I National & HCMC building codes reviewed

No.	Document		Content	
	Vietnamese	English	Vietnamese	English
<b>I GENERAL</b>				
1	QĐ 45 /2009/QĐ-UBND ngày 3 tháng 7 năm 2009	Decision No. 45/2009 dated on July 3rd 2009 by HCM People's Committee	Về sửa đổi bổ sung một số điều của quyết định số QĐ 135 /2007/QĐ-UBND ngày 8 tháng 12 năm 2007 của Ủy Ban Nhân dân Thành phố quy định về kiến trúc nhà liền kề trong khu đô thị hiện hữu trên địa bàn thành phố Hồ Chí Minh	On amending and supplementing a number of articles of the Decision No. 135 /2007/QĐ-UBND dated on December 8th 2007 by City People's Committee about the architecture of detached houses in existing urban areas of Ho Chi Minh city
2	QCXDVN 01: 2008/BXD	Vietnam Building Code No. 01: 2008 by Ministry of Construction	Quy chuẩn xây dựng Việt Nam - Quy hoạch vùng và đô thị, và quy hoạch khu dân cư nông thôn	Vietnam Building Code. Regional and Urban Planning and Rural Residential Planning
3	TCXDVN 4319-2012	Vietnam building standard No. 4319-2012 by Ministry of Construction	Nhà và công trình công cộng - Nguyên tắc cơ bản để thiết kế	Public buildings - Basic principles for design
<b>II INDUSTRIAL WORKS</b>				
4	TCVN 4514:2012	Vietnam standard No. 4514:2012 by Ministry of Construction	Xí nghiệp công nghiệp - Tổng mặt bằng - Tiêu chuẩn thiết kế	Industrial enterprises - General - Design standards
<b>III HOUSING</b>				
5.1	TCXDVN 323-2004	Vietnam building standard No. 323 - 2004 by Ministry of Construction	Nhà ở cao tầng - tiêu chuẩn thiết kế	High rise apartment building-design standard
5.2	Công Văn 1245/BXD-KHCN	10.1.1 Document/Official Dispatch No. 1245/BXD-KHCN dated on June 24th 2013 by Ministry of Construction	Hướng dẫn chi tiêu kiến trúc áp dụng cho nhà ở cao tầng	Guiding on architectural criteria applied for high-rise apartment
5.3	QĐ 212-QĐ-BXD	Decision No. 212-QĐ-BXD dated on February 25th 2013 by Ministry of Construction	Hủy bỏ tiêu chuẩn ngành xây dựng	Cancelling some of construction standards (Including TCXDVN 323-2004)
6	TCVN 4451:2012	Vietnam standard No. 4451:2012 by Ministry of Construction	Nhà ở. Nguyên tắc cơ bản để thiết kế	Housing -Basic principles for design
7	TCVN 9411:2012	Vietnam standard No. 9411:2012 by Ministry of Construction	Nhà ở liền kề- Tiêu chuẩn thiết kế	Row houses - Design standards
<b>IV TOURISM WORKS</b>				
8	TCVN 9211-2012	Vietnam standard No. 9211 - 2012 by Ministry of Construction	Khách sạn - Tiêu chuẩn thiết kế	Hotel - Design standards
<b>V EDUCATION WORKS</b>				
9	TCVN 3907:2011	Vietnam standard No. 3907:2011 by Ministry of Construction	Trường mầm non. Yêu cầu thiết kế	Kindergarten - Design Requirements
10	TCVN 3981 - 1985	Vietnam standard No. 3981 - 1985 by Ministry of Construction	Trường đại học - tiêu chuẩn thiết kế	Universities - Design Standards
11	TCVN 4602:2012	Vietnam standard No. 4602:2012 by Ministry of Construction	Trường trung cấp chuyên nghiệp - Tiêu chuẩn thiết kế	Technical Colleges - Design Standards
12	TCVN 8793:2011	Vietnam standard No. 8793:2011 by Ministry of Construction	Trường tiểu học - Yêu cầu thiết kế	Primary School - Design Requirements
13	TCVN 8794 : 2011	Vietnam standard No. 8794 - 2011 by Ministry of Construction	Trường Trung học - Yêu cầu thiết kế	Secondary school - Design Requirements
14	TCVN 9210:2012	Vietnam standard No. 9210:2012 by Ministry of Construction	Trường dạy nghề - Tiêu chuẩn thiết kế	Vocational School - Design Standards

<b>VI SPORTING WORKS</b>					
15.1	TCXDVN 287: 2004	Vietnam building standard No. 287:2004 by Ministry of Construction	No.	Công trình thể thao - Sân thể thao - Tiêu chuẩn thiết kế	Sporting facilities - Stadium - Design Standards
15.2	TCVN 4205:2012 (replacement for TCXDVN 287: 2004)	Vietnam building standard No. 4205:2012 by Ministry of Construction	No.	Công trình thể thao - Sân thể thao - Tiêu chuẩn thiết kế	Sporting facilities - Stadium - Design Standards
16.1	TCVN 288 : 2004	Vietnam standard No. 288:2004 by Ministry of Construction	No.	Công trình Thể thao - Bể bơi - Tiêu chuẩn thiết kế	Sporting facilities - Swimming pool - Design Standards
16.2	TCVN 4260:2012 (replacement for TCXDVN 288 : 2004)	Vietnam standard No. 4260:2012 by Ministry of Construction	No.	Công trình Thể thao - Bể bơi - Tiêu chuẩn thiết kế	Sporting facilities - Swimming pool - Design Standards
17.1	TCVN 4529 : 1988	Vietnam standard No. 4529 : 1988 by Ministry of Construction	No.	Công trình thể thao - Nhà thể thao - Tiêu chuẩn thiết kế	Sporting works - Sporting buildings - Design Standards
17.2	TCVN 4529:2012 (replacement for TCXDVN 4529:2012)	Vietnam standard No. 4529:2012 by Ministry of Construction	No.	Công trình thể thao - Nhà thể thao - Tiêu chuẩn thiết kế	Sporting works - Sporting buildings - Design Standards
<b>VII MEDICAL WORKS</b>					
18.1	TCXDVN 365 : 2007	Vietnam building standard No. 287 - 2004 by Ministry of Construction	No.	Bệnh viện Đa khoa - Hướng dẫn thiết kế	General hospital - Guideline
18.2	TCVN 4470:2012 (replacement for TCXDVN 365 : 2007)	Vietnam standard No. 4470:2012 by Ministry of Construction	No.	Bệnh viện đa khoa - Tiêu chuẩn thiết kế	General hospital - Design Standards
19	TCVN 7022:2002	Vietnam standard No. 7022:2002 by Ministry of Construction	No.	Trạm y tế cơ sở. Yêu cầu thiết kế	Local Medical Care - Design Requirements
20	TCVN 9212:2012	Vietnam standard No. 9212:2012 by Ministry of Construction	No.	Bệnh viện đa khoa khu vực - Tiêu chuẩn thiết kế	Local General Hospital - Design Standards
21	TCVN 9213:2012	Vietnam standard No. 9213:2012 by Ministry of Construction	No.	Bệnh viện quận huyện - Tiêu chuẩn thiết kế	District/Communal hospital - Design Standards
22	TCVN 9214:2012	Vietnam standard No. 9214:2012 by Ministry of Construction	No.	Phòng khám đa khoa khu vực - Tiêu chuẩn thiết kế	Local General Center - Design Requirements
<b>VIII CEMETERY WORKS</b>					
23	TCVN 7956: 2008	Vietnam standard No. 7956: 2008 by Ministry of Construction	No.	Nghĩa trang đô thị - Tiêu chuẩn thiết kế	Urban cemetery - Design Standards
<b>IX AIRPORT</b>					
24	TCVN 8753:2011	Vietnam standard No. 8753:2011 by Ministry of Construction	No.	Sân bay dân dụng - Yêu cầu chung về thiết kế và khai thác	Aerodrome – General Requirements for Design and Operations
<b>X COMMERCIAL BUILDINGS</b>					
25	TCVN 4530:2011	Vietnam standard No. 4530:2011 by Ministry of Construction	No.	Cửa hàng xăng dầu- Yêu cầu thiết kế	Filling station – Specifications for design
26	TCVN 9211-2012	Vietnam standard No. 9211 - 2012 by Ministry of Construction	No.	Chợ - tiêu chuẩn thiết kế	Markets - Design Standards
<b>XI AGENCY OFFICES</b>					
27	TCVN 4601:2012	Vietnam standard No. 4601:2012 by Ministry of Construction	No.	Công sở cơ quan hành chính nhà nước - Yêu cầu thiết kế	State Administrative Agency Offices - Design Requirements
<b>XII CULTURAL BUILDINGS</b>					
28	TCVN 5577:2012	Vietnam standard No. 5577:2012 by Ministry of Construction	No.	Rạp chiếu phim - Tiêu chuẩn thiết kế	Cinema - Design Standards
29.1	TCXDVN 281: 2004	Vietnam building standard No. 281 - 2004 by Ministry of Construction	No.	Nhà Văn hóa Thể thao - Nguyên tắc cơ bản thiết kế	Building for sports-Cultural-Basic principle for design
29.2	TCVN 9365:2012 (replacement for TCXDVN 281: 2004)	Vietnam building standard No. 9365:2012 by Ministry of Construction	No.	Nhà Văn hóa Thể thao - Nguyên tắc cơ bản thiết kế	Building for sports-Cultural-Basic principle for design
30	TCVN 9369:2012	Vietnam building standard No. 9369:2012 by Ministry of Construction	No.	Nhà hát - Tiêu chuẩn thiết kế	Theatre - Design Standards
<b>XIII PLANNING</b>					
31	TCVN 4449:1987	Vietnam building standard No.	No.	Quy hoạch xây dựng đô	Urban planning - Design

		4449:1987 by Ministry of Construction	thị - Tiêu chuẩn thiết kế	Standards
32	TCVN 4454:2012	Vietnam building standard No. 4454:2012 by Ministry of Construction	Quy hoạch xây dựng nông thôn. Tiêu chuẩn thiết kế	Rural Planning - Design Standards
33	TCVN 4616:1988	Vietnam building standard No. 4616:1988 by Ministry of Construction	Quy hoạch mặt bằng tổng thể cụm công nghiệp. Tiêu chuẩn thiết kế	Planning of general plan for industrial zones - Design Standards
34	TCVN 8270:2009	Vietnam building standard No. 8270:2009 by Ministry of Construction	Quy hoạch cây xanh sử dụng hạn chế và chuyên dụng trong đô thị. Tiêu chuẩn thiết kế	Greenery planning for functional and specific areas in urban - Design Standards
35	TCVN 9257 : 2012	Vietnam building standard No. 9257 : 2012 by Ministry of Construction	Quy hoạch cây xanh sử dụng công cộng trong các đô thị- Tiêu chuẩn thiết kế	Greenery planning for public areas in urban - Design Standards
36	TCXDVN 104:2007	Vietnam building standard No. 104:2007 by Ministry of Construction	Đường đô thị. Yêu cầu thiết kế	Urban roads - Specification for Design
37	Thông tư số 49/2012/TT-BGTVT (kèm theo QCVN 45 : 2012/BGTVT)	Circular No. 49/2012 dated on December 12th 2012 by Ministry of Transportation (attached with Vietnam Code QCVN 45 : 2012/BGTVT)	Ban hành Quy chuẩn kỹ thuật quốc gia về bến xe khách	Promulgating National technical regulation on Bus station

## Annex II Illustration material for observed residential building archetypes in HCMC

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*(source: author's own photographs)*



Temporary shophouse



Ally shophouse



Detached shophouse



Semi-detached shophouse



Terrace shophouse



Colonial villa



Villa



Luxury villa





Mid-rise apartments



High rise apartments



Social apartments

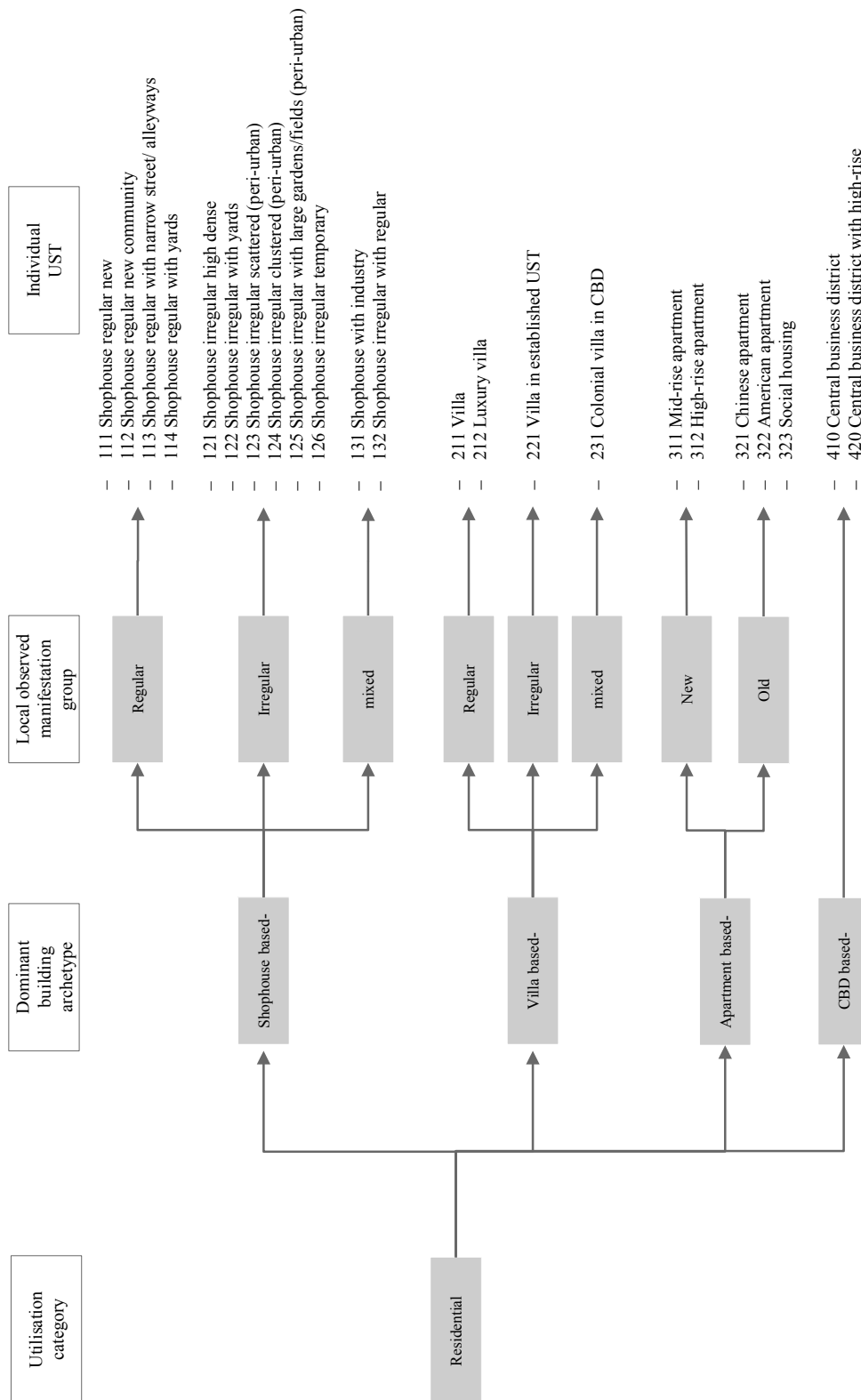


Old Chinese apartments



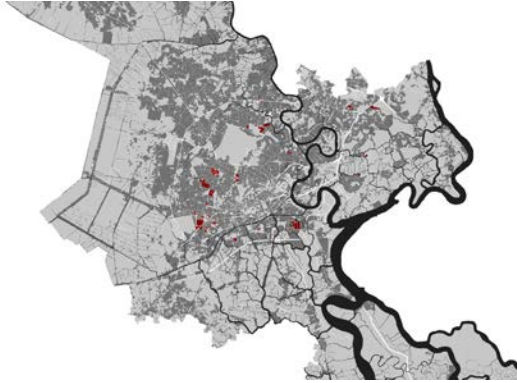
American apartments

# Annex III Division of residential USTs: HCMC



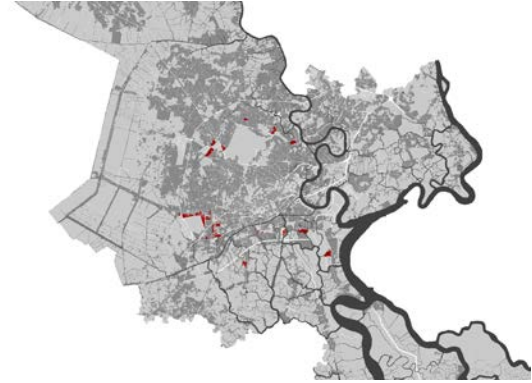
## Annex IV HCMC residential UST distribution

111 Shophouse regular new



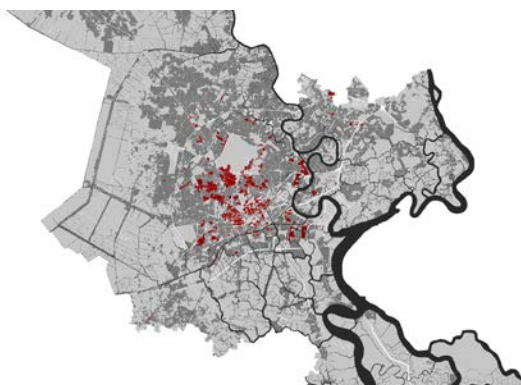
District	Frequency	Area (ha)
Dist. 1	-	-
Dist. 3	-	-
Dist. 4	1	0.795
Dist. 5	-	-
Dist. 6	10	32.866
Dist. 10	-	-
Dist. 11	11	76.878
Phu Nhuan	-	-
Dist. 8	3	6.693
Binh Thanh	1	7.489
Go Vap	7	55.537
Tan Binh	4	19.294
Tan Phu	34	122.904
Dist. 2	1	5.092
Dist. 7	12	57.718
Dist. 9	2	23.703
Dist. 12	5	8.793
Binh Tan	-	-
Thu Duc	1	12.828
Cu Chi	-	-
Hoc Mon	1	2.503
Binh Chanh	7	15.988
Nha Be	-	-
Can Gio	-	-
<b>Whole City</b>	<b>100</b>	<b>449.081</b>

112 Shophouse community new



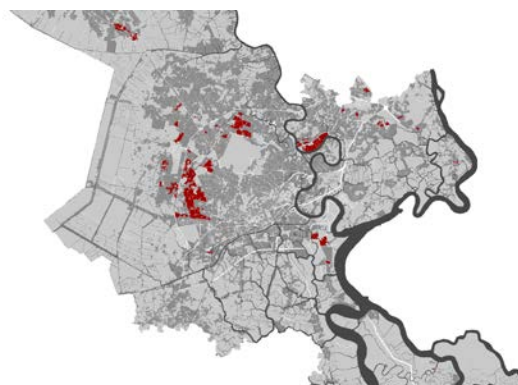
District	Frequency	Area (ha)
Dist. 1	-	-
Dist. 3	-	-
Dist. 4	-	-
Dist. 5	-	-
Dist. 6	8	50.504
Dist. 10	-	-
Dist. 11	-	-
Phu Nhuan	-	-
Dist. 8	4	11.021
Binh Thanh	1	18.446
Go Vap	4	31.587
Tan Binh	2	14.501
Tan Phu	1	38.446
Dist. 2	-	-
Dist. 7	3	61.091
Dist. 9	1	2.97
Dist. 12	2	18.002
Binh Tan	25	112.727
Thu Duc	-	-
Cu Chi	-	-
Hoc Mon	-	-
Binh Chanh	11	32.638
Nha Be	-	-
Can Gio	-	-
<b>Whole City</b>	<b>62</b>	<b>391.933</b>

113 Shopehouse narrow street/alleyways



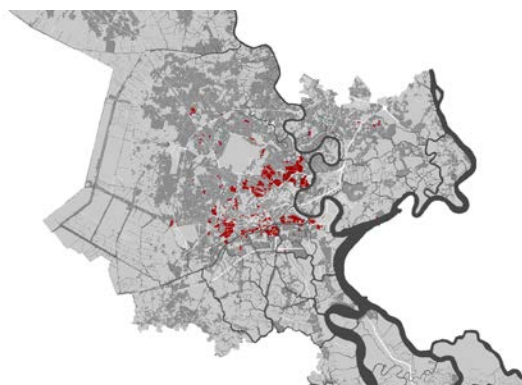
District	Frequency	Area (ha)
Dist. 1	-	-
Dist. 3	48	79.251
Dist. 4	15	49.404
Dist. 5	34	109.474
Dist. 6	28	122.071
Dist. 10	71	163.689
Dist. 11	119	164.915
Phu Nhuan	17	47.561
Dist. 8	21	45.467
Binh Thanh	7	138.321
Go Vap	25	121.551
Tan Binh	103	399.702
Tan Phu	29	297.168
Dist. 2	4	19.501
Dist. 7	8	109.052
Dist. 9	2	7.126
Dist. 12	18	50.554
Binh Tan	22	65.999
Thu Duc	12	46.484
Cu Chi	-	-
Hoc Mon	2	1.886
Binh Chanh	6	23.607
Nha Be	-	-
Can Gio	-	-
Whole City	591	2,062.783

114 Shopehouse with yards



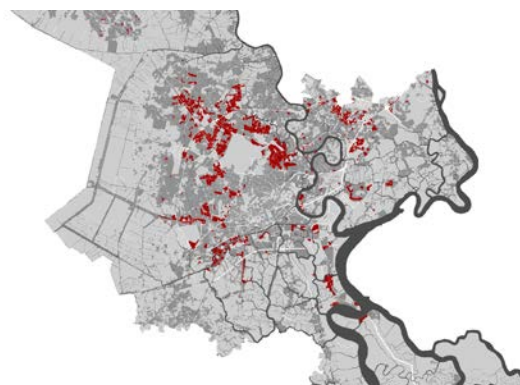
District	Frequency	Area (ha)
Dist. 1	-	-
Dist. 3	-	-
Dist. 4	-	-
Dist. 5	-	-
Dist. 6	-	-
Dist. 10	-	-
Dist. 11	-	-
Phu Nhuan	-	-
Dist. 8	2	9.867
Binh Thanh	-	-
Go Vap	18	248.048
Tan Binh	-	-
Tan Phu	2	80.341
Dist. 2	-	-
Dist. 7	4	107.810
Dist. 9	7	51.450
Dist. 12	4	15.224
Binh Tan	36	717.046
Thu Duc	9	238.636
Cu Chi	55	327.820
Hoc Mon	5	77.351
Binh Chanh	6	91.876
Nha Be	-	-
Can Gio	5	54.087
Whole City	153	2,019.555

121 Shophouse irregular high dense



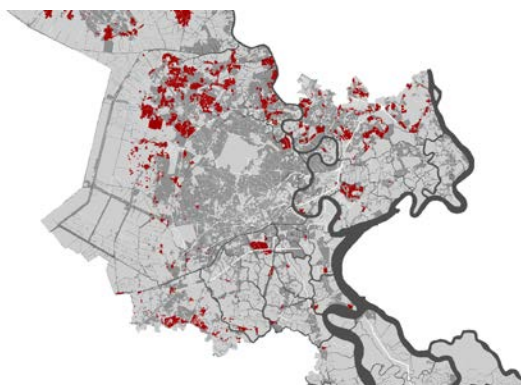
District	Frequency	Area (ha)
Dist. 1	4	51.659
Dist. 3	24	90.283
Dist. 4	32	109.948
Dist. 5	14	35.502
Dist. 6	31	183.361
Dist. 10	28	59.551
Dist. 11	41	45.405
Phu Nhuan	24	125.190
Dist. 8	67	177.080
Binh Thanh	20	328.124
Go Vap	11	34.062
Tan Binh	28	104.440
Tan Phu	14	65.865
Dist. 2	5	6.381
Dist. 7	10	60.172
Dist. 9	4	16.443
Dist. 12	27	29.823
Binh Tan	9	23.541
Thu Duc	13	22.637
Cu Chi	-	-
Hoc Mon	5	17.004
Binh Chanh	2	10.386
Nha Be	2	1.379
Can Gio	10	4.128
Whole City	425	1,602.365

122 Shophouse irregular with yards



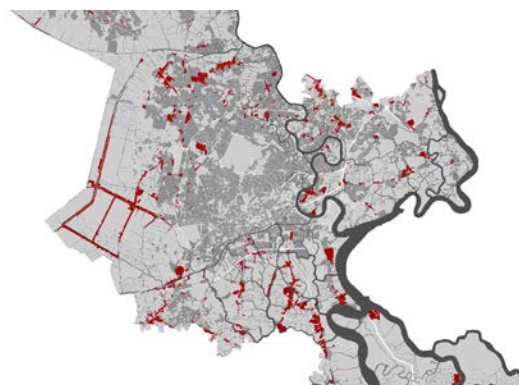
District	Frequency	Area (ha)
Dist. 1	-	-
Dist. 3	-	-
Dist. 4	3	2.522
Dist. 5	-	-
Dist. 6	11	73.373
Dist. 10	-	-
Dist. 11	15	22.434
Phu Nhuan	1	5.021
Dist. 8	78	247.586
Binh Thanh	30	258.881
Go Vap	60	700.901
Tan Binh	31	163.748
Tan Phu	18	249.945
Dist. 2	25	153.321
Dist. 7	15	130.754
Dist. 9	41	229.050
Dist. 12	151	705.695
Binh Tan	45	356.867
Thu Duc	81	336.202
Cu Chi	37	105.800
Hoc Mon	80	382.815
Binh Chanh	15	94.133
Nha Be	25	156.878
Can Gio	32	67.997
Whole City	794	4,443.923

123 Shophouse irregular scattered (Peri-urban)



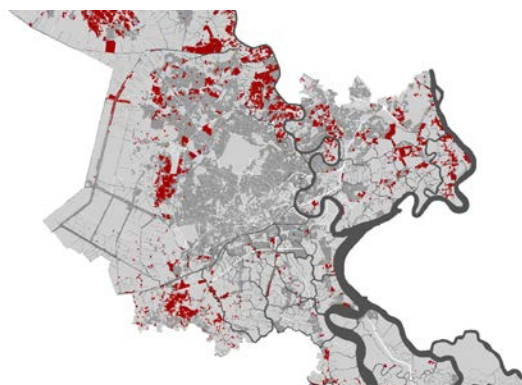
District	Frequency	Area (ha)
Dist. 1	-	-
Dist. 3	-	-
Dist. 4	-	-
Dist. 5	-	-
Dist. 6	-	-
Dist. 10	-	-
Dist. 11	-	-
Phu Nhuan	-	-
Dist. 8	7	13.102
Binh Thanh	5	95.684
Go Vap	4	12.668
Tan Binh	-	-
Tan Phu	2	11.779
Dist. 2	25	212.846
Dist. 7	2	27.323
Dist. 9	57	473.314
Dist. 12	108	702.743
Binh Tan	24	144.788
Thu Duc	76	634.263
Cu Chi	139	1,723.975
Hoc Mon	218	1,827.238
Binh Chanh	124	952.805
Nha Be	14	93.272
Can Gio	9	63.646
Whole City	814	6,989.448

124 Shophouse irregular clustered (Peri-urban)



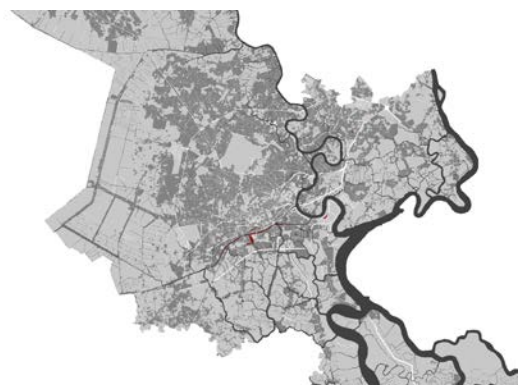
District	Frequency	Area (ha)
Dist. 1	-	-
Dist. 3	1	1.280
Dist. 4	-	-
Dist. 5	-	-
Dist. 6	-	-
Dist. 10	-	-
Dist. 11	-	-
Phu Nhuan	-	-
Dist. 8	7	26.727
Binh Thanh	4	13.640
Go Vap	5	19.193
Tan Binh	-	-
Tan Phu	2	13.694
Dist. 2	23	188.495
Dist. 7	5	145.877
Dist. 9	34	257.009
Dist. 12	35	239.169
Binh Tan	30	98.313
Thu Duc	60	378.557
Cu Chi	155	654.841
Hoc Mon	111	695.156
Binh Chanh	153	1,684.074
Nha Be	83	744.821
Can Gio	34	330.016
Whole City	742	5,490.861

125 Shophouse irregular w. garden (Peri-urban)



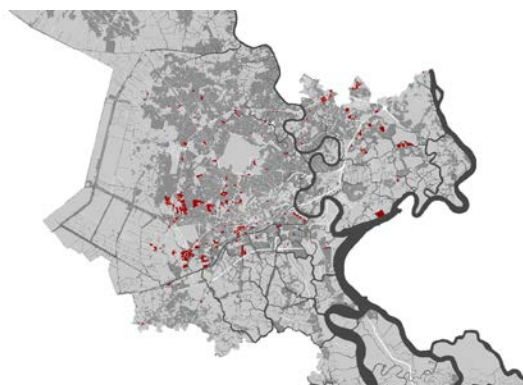
District	Frequency	Area (ha)
Dist. 1	-	-
Dist. 3	-	-
Dist. 4	-	-
Dist. 5	-	-
Dist. 6	-	-
Dist. 10	-	-
Dist. 11	-	-
Phu Nhuan	-	-
Dist. 8	12	59.557
Binh Thanh	16	84.898
Go Vap	1	3.377
Tan Binh	-	-
Tan Phu	-	-
Dist. 2	20	89.666
Dist. 7	5	39.383
Dist. 9	182	1,193.464
Dist. 12	169	1,161.464
Binh Tan	25	226.384
Thu Duc	66	350.460
Cu Chi	1272	10,509.602
Hoc Mon	198	1,139.929
Binh Chanh	252	1,659.253
Nha Be	63	258.151
Can Gio	60	357.614
Whole City	2341	17,133.20174

126 Shophouse irregular w. temporary



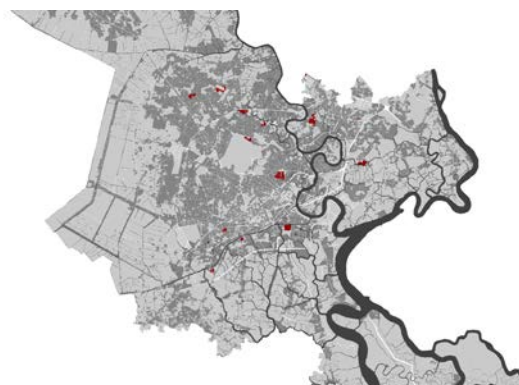
District	Frequency	Area (ha)
Dist. 1	-	-
Dist. 3	-	-
Dist. 4	5	3.980
Dist. 5	-	-
Dist. 6	3	1.150
Dist. 10	-	-
Dist. 11	-	-
Phu Nhuan	-	-
Dist. 8	52	52.878
Binh Thanh	-	-
Go Vap	1	0.498
Tan Binh	-	-
Tan Phu	-	-
Dist. 2	6	3.627
Dist. 7	8	10.184
Dist. 9	1	1.283
Dist. 12	-	-
Binh Tan	-	-
Thu Duc	2	2.926
Cu Chi	1	1.564
Hoc Mon	-	-
Binh Chanh	1	7.152
Nha Be	-	-
Can Gio	-	-
Whole City	80	85.24323

126 Shophouse with industry



District	Frequency	Area (ha)
Dist. 1	2	2.956
Dist. 3	1	2.202
Dist. 4	7	29.966
Dist. 5	9	27.048
Dist. 6	15	42.345
Dist. 10	1	0.724
Dist. 11	7	30.651
Phu Nhuan	1	5.334
Dist. 8	23	72.217
Binh Thanh	2	9.036
Go Vap	5	18.211
Tan Binh	10	39.969
Tan Phu	17	105.585
Dist. 2	1	46.698
Dist. 7	3	19.676
Dist. 9	14	124.084
Dist. 12	13	34.086
Binh Tan	31	328.079
Thu Duc	24	118.317
Cu Chi	4	43.751
Hoc Mon	9	38.412
Binh Chanh	22	151.207
Nha Be	1	1.983
Can Gio	-	-
Whole City	222	1,292.539

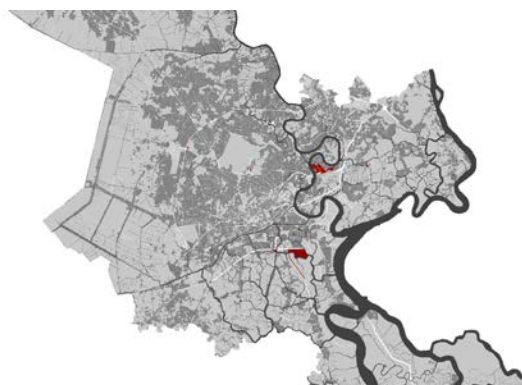
127 Shophouse irregular with regular



District	Frequency	Area (ha)
Dist. 1	-	-
Dist. 3	-	-
Dist. 4	-	-
Dist. 5	1	1.304
Dist. 6	2	18.231
Dist. 10	-	-
Dist. 11	-	-
Phu Nhuan	1	57.322
Dist. 8	3	20.905
Binh Thanh	-	-
Go Vap	3	35.425
Tan Binh	-	-
Tan Phu	-	-
Dist. 2	-	-
Dist. 7	2	37.891
Dist. 9	1	31.733
Dist. 12	5	58.095
Binh Tan	-	-
Thu Duc	3	57.013
Cu Chi	1	13.118
Hoc Mon	1	23.375
Binh Chanh	-	-
Nha Be	-	-
Can Gio	-	-
Whole City	23	354.4103



211 Villa



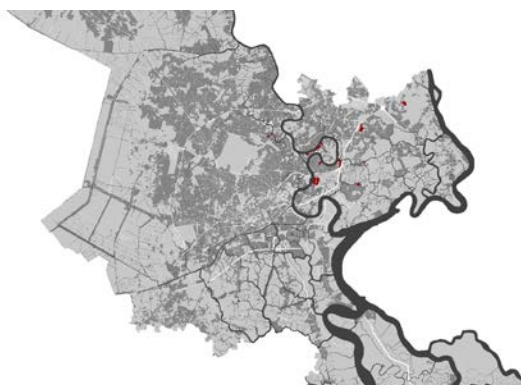
District	Frequency	Area (ha)
Dist. 1	-	-
Dist. 3	-	-
Dist. 4	-	-
Dist. 5	-	-
Dist. 6	-	-
Dist. 10	-	-
Dist. 11	-	-
Phu Nhuan	-	-
Dist. 8	-	-
Binh Thanh	-	-
Go Vap	-	-
Tan Binh	1	3.658
Tan Phu	-	-
Dist. 2	14	107.325
Dist. 7	1	119.093
Dist. 9	3	8.095
Dist. 12	1	3.155
Binh Tan	-	-
Thu Duc	3	2.467
Cu Chi	-	-
Hoc Mon	-	-
Binh Chanh	2	6.692
Nha Be	1	24.299
Can Gio	-	-
Whole City	26	274.783

212 Luxury villa



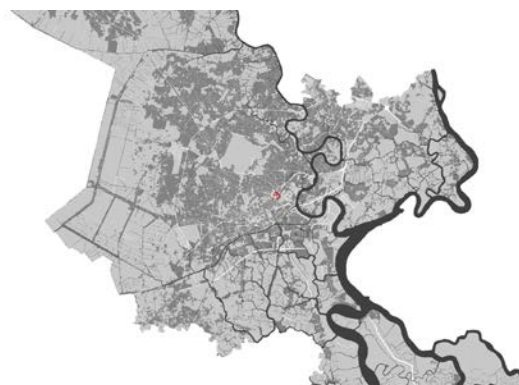
District	Frequency	Area (ha)
Dist. 1	-	-
Dist. 3	-	-
Dist. 4	-	-
Dist. 5	-	-
Dist. 6	-	-
Dist. 10	-	-
Dist. 11	-	-
Phu Nhuan	-	-
Dist. 8	1	45.256
Binh Thanh	-	-
Go Vap	-	-
Tan Binh	-	-
Tan Phu	-	-
Dist. 2	15	178.525
Dist. 7	1	35.342
Dist. 9	1	2.253
Dist. 12	2	37.671
Binh Tan	3	58.526
Thu Duc	26	33.359
Cu Chi	-	-
Hoc Mon	-	-
Binh Chanh	-	-
Nha Be	-	-
Can Gio	-	-
Whole City	49	390.9317

221 Villa in est. UST



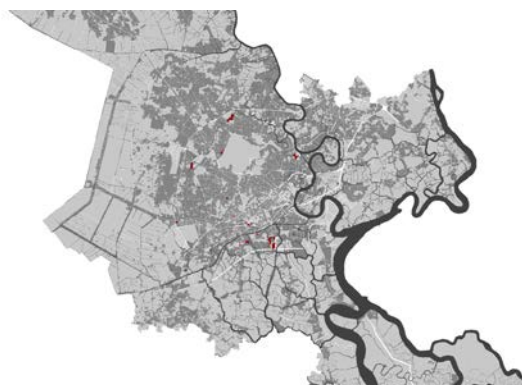
District	Frequency	Area (ha)
Dist. 1	-	-
Dist. 3	1	2.086
Dist. 4	-	-
Dist. 5	-	-
Dist. 6	-	-
Dist. 10	-	-
Dist. 11	-	-
Phu Nhuan	-	-
Dist. 8	-	-
Binh Thanh	2	24.999
Go Vap	2	7.534
Tan Binh	-	-
Tan Phu	-	-
Dist. 2	8	74.579
Dist. 7	-	-
Dist. 9	3	41.503
Dist. 12	-	-
Binh Tan	-	-
Thu Duc	-	-
Cu Chi	-	-
Hoc Mon	-	-
Binh Chanh	-	-
Nha Be	-	-
Can Gio	-	-
Whole City	16	150.701

231 Colonial villa in CBD



District	Frequency	Area (ha)
Dist. 1	-	-
Dist. 3	15	28.239
Dist. 4	-	-
Dist. 5	-	-
Dist. 6	-	-
Dist. 10	-	-
Dist. 11	-	-
Phu Nhuan	-	-
Dist. 8	-	-
Binh Thanh	-	-
Go Vap	-	-
Tan Binh	1	0.040
Tan Phu	-	-
Dist. 2	-	-
Dist. 7	-	-
Dist. 9	-	-
Dist. 12	-	-
Binh Tan	-	-
Thu Duc	-	-
Cu Chi	-	-
Hoc Mon	-	-
Binh Chanh	-	-
Nha Be	-	-
Can Gio	-	-
Whole City	16	28.279

## 311 Mid-rise apartment



District	Frequency	Area (ha)
Dist. 1	-	-
Dist. 3	-	-
Dist. 4	2	1.721
Dist. 5	4	11.056
Dist. 6	3	1.625
Dist. 10	-	-
Dist. 11	2	2.799
Phu Nhuan	-	-
Dist. 8	11	17.487
Binh Thanh	1	16.050
Go Vap	1	22.586
Tan Binh	1	7.754
Tan Phu	1	4.017
Dist. 2	-	-
Dist. 7	-	-
Dist. 9	-	-
Dist. 12	1	1.415
Binh Tan	3	18.435
Thu Duc	1	0.959
Cu Chi	-	-
Hoc Mon	-	-
Binh Chanh	4	42.453
Nha Be	2	4.168
Can Gio	-	-
Whole City	37	152.5245

## 312 High-rise apartment



District	Frequency	Area (ha)
Dist. 1	-	-
Dist. 3	-	-
Dist. 4	2	12.971
Dist. 5	5	14.956
Dist. 6	-	-
Dist. 10	3	2.725
Dist. 11	3	12.333
Phu Nhuan	2	7.147
Dist. 8	1	4.331
Binh Thanh	2	2.749
Go Vap	-	-
Tan Binh	3	17.314
Tan Phu	2	13.203
Dist. 2	-	-
Dist. 7	1	56.088
Dist. 9	-	-
Dist. 12	3	57.653
Binh Tan	1	5.375
Thu Duc	-	-
Cu Chi	-	-
Hoc Mon	-	-
Binh Chanh	-	-
Nha Be	1	11.449
Can Gio	-	-
Whole City	29	218.2937

## 311 Chinese apartment



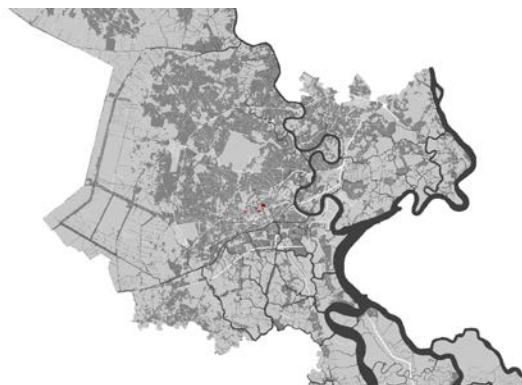
District	Frequency	Area (ha)
Dist. 1	-	-
Dist. 3	-	-
Dist. 4	3	3.780
Dist. 5	-	-
Dist. 6	-	-
Dist. 10	2	2.070
Dist. 11	-	-
Phu Nhuan	-	-
Dist. 8	1	3.158
Binh Thanh	-	-
Go Vap	-	-
Tan Binh	-	-
Tan Phu	-	-
Dist. 2	-	-
Dist. 7	1	8.571
Dist. 9	9	38.402
Dist. 12	-	-
Binh Tan	-	-
Thu Duc	-	-
Cu Chi	-	-
Hoc Mon	-	-
Binh Chanh	-	-
Nha Be	-	-
Can Gio	-	-
Whole City	16	55.98167

## 322 American apartment



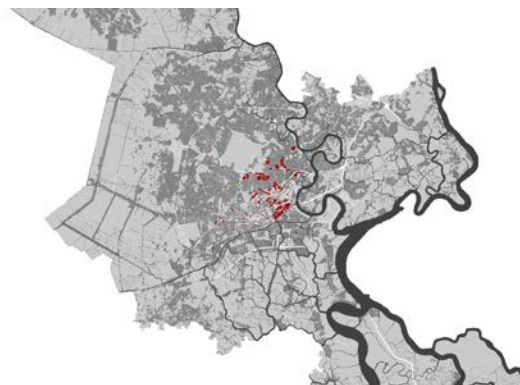
District	Frequency	Area (ha)
Dist. 1	-	-
Dist. 3	-	-
Dist. 4	-	-
Dist. 5	-	-
Dist. 6	-	-
Dist. 10	-	-
Dist. 11	-	-
Phu Nhuan	-	-
Dist. 8	-	-
Binh Thanh	6	40.720
Go Vap	-	-
Tan Binh	-	-
Tan Phu	-	-
Dist. 2	-	-
Dist. 7	-	-
Dist. 9	-	-
Dist. 12	-	-
Binh Tan	-	-
Thu Duc	-	-
Cu Chi	-	-
Hoc Mon	-	-
Binh Chanh	-	-
Nha Be	-	-
Can Gio	-	-
Whole City	6	40.72037

## 323 Social housing



District	Frequency	Area (ha)
Dist. 1	-	-
Dist. 3	1	13.180
Dist. 4	-	-
Dist. 5	-	-
Dist. 6	-	-
Dist. 10	12	16.346
Dist. 11	2	3.011
Phu Nhuan	-	-
Dist. 8	-	-
Binh Thanh	-	-
Go Vap	-	-
Tan Binh	-	-
Tan Phu	-	-
Dist. 2	-	-
Dist. 7	-	-
Dist. 9	-	-
Dist. 12	-	-
Binh Tan	-	-
Thu Duc	-	-
Cu Chi	-	-
Hoc Mon	-	-
Binh Chanh	-	-
Nha Be	-	-
Can Gio	-	-
Whole City	15	32.53631

## 411 Central business district (CBD)



District	Frequency	Area (ha)
Dist. 1	26	152.928
Dist. 3	23	97.281
Dist. 4	-	-
Dist. 5	3	3.076
Dist. 6	3	8.502
Dist. 10	13	44.403
Dist. 11	4	9.810
Phu Nhuan	14	77.708
Dist. 8	-	-
Binh Thanh	10	91.831
Go Vap	1	17.587
Tan Binh	6	28.393
Tan Phu	-	-
Dist. 2	-	-
Dist. 7	-	-
Dist. 9	-	-
Dist. 12	-	-
Binh Tan	-	-
Thu Duc	-	-
Cu Chi	-	-
Hoc Mon	-	-
Binh Chanh	-	-
Nha Be	-	-
Can Gio	-	-
Whole City	103	531.518

## 420 Central business district w. high-rise



District	Frequency	Area (ha)
Dist. 1	37	163.166
Dist. 3	12	29.017
Dist. 4	-	-
Dist. 5	-	-
Dist. 6	2	6.060
Dist. 10	1	0.915
Dist. 11	3	9.685
Phu Nhuan	2	4.147
Dist. 8	-	-
Binh Thanh	-	-
Go Vap	-	-
Tan Binh	-	-
Tan Phu	-	-
Dist. 2	-	-
Dist. 7	-	-
Dist. 9	-	-
Dist. 12	-	-
Binh Tan	-	-
Thu Duc	-	-
Cu Chi	-	-
Hoc Mon	-	-
Binh Chanh	-	-
Nha Be	-	-
Can Gio	-	-
Whole City	57	212.989

## Annex V HCMC median block-level density values per district

District	Building density (buildings/ha)	Ground coverage ratio (GCR)	Total soil sealing	Building height (stories)	Tallest building (stories)
<b>Urban districts</b>					
1	25.07	0.58	83.72	2.50	8.58
3	46.28	0.62	86.78	1.93	5.26
4	38.37	0.64	86.20	1.68	3.65
5	32.55	0.69	86.25	2.46	6.46
6	26.67	0.60	83.49	1.69	3.88
10	39.01	0.66	85.31	2.27	4.94
11	56.80	0.74	86.19	2.12	4.73
Phu Nhuan	45.43	0.60	84.67	1.99	4.93
8	21.61	0.38	63.50	1.28	2.06
Binh Thanh	22.48	0.32	57.51	1.37	3.18
Go Vap	26.13	0.38	60.78	1.45	2.81
Tan Binh	23.71	0.49	81.68	1.77	3.75
Tan Phu	24.84	0.52	75.72	1.49	3.46
<i>Total</i>	26.67	0.60	83.72	1.77	3.88
<b>Peri-urban districts</b>					
Thu Thiem 2	7.43	0.10	28.43	0.89	0.56
7	14.49	0.22	55.73	1.08	1.78
9	5.44	0.07	22.11	0.85	0.39
12	10.59	0.17	36.89	1.02	1.35
Binh Tan	12.80	0.23	48.79	1.20	1.57
Thu Duc	13.16	0.22	43.12	1.07	1.58
<i>Total</i>	11.70	0.20	40.0	1.04	1.46
<b>Rural districts</b>					
Cu Chi	2.77	0.03	13.30	0.73	0.21
Hoc Mon	7.95	0.11	20.92	1.01	0.63
Binh Chanh	4.86	0.06	17.96	0.88	0.16
Nha Be	3.37	0.03	15.88	0.75	0.16
Can Gio	1.92	0.02	7.70	0.47	0.13
<i>Total</i>	3.37	0.03	15.88	0.75	0.16
<b>Whole City</b>	<b>22.05</b>	<b>0.35</b>	<b>59.15</b>	<b>1.33</b>	<b>2.44</b>

District	Gross floor area (GFA) (m <sup>2</sup> /ha)	Floor Area Ratio (FAR)	Building Volume (m <sup>3</sup> /ha)	Population density (ha)	Gross floorspace per person (m <sup>2</sup> /ha)
<b>Urban districts</b>					
1	17,033.46	1.64	57,596.48	299.66	68.33
3	13,275.33	1.33	42,277.92	485.33	39.14
4	10,337.50	0.98	30,829.28	677.22	16.42
5	18,510.97	1.82	55,854.65	593.12	35.29
6	10,186.53	0.99	30,786.40	463.84	24.87
10	15,683.35	1.55	48,255.78	620.16	33.91
11	15,063.35	1.48	45,541.01	652.76	26.47
Phu Nhuan	12,379.13	1.17	38,971.34	453.74	27.61
8	5,610.80	0.35	16,613.06	360.56	22.71
Binh Thanh	5,397.34	0.34	16,842.69	249.53	26.88
Go Vap	5,557.64	0.37	16,761.71	261.74	21.69
Tan Binh	8,928.85	0.85	26,968.30	385.92	24.74
Tan Phu	7,314.20	0.64	22,500.41	327.86	26.89
<b>Total</b>	<b>10,337.50</b>	<b>0.99</b>	<b>30,829.28</b>	<b>453.74</b>	<b>30.38</b>
<b>Peri-urban districts</b>					
Thu Thiem 2	1,212.31	0.45	3,809.45	53.13	32.93
7	2,849.06	0.01	8,658.42	157.37	39.09
9	823.34	0.48	2,471.35	37.88	22.83
12	1,968.28	0.09	5,906.67	103.67	21.88
Binh Tan	2,936.53	0.01	8,820.96	141.14	24.97
Thu Duc	2,748.16	0.01	8,348.70	125.47	23.62
<b>Total</b>	<b>2,358.22</b>	<b>0.0</b>	<b>7,127.69</b>	<b>114.57</b>	<b>27.55</b>
<b>Rural districts</b>					
Cu Chi	356.73	0.01	1,069.06	12.17	27.64
Hoc Mon	1,591.81	0.01	4,769.42	44.75	35.46
Binh Chanh	688.21	0.01	2,064.09	30.87	22.72
Nha Be	333.65	0.01	1,004.11	18.12	18.14
Can Gio	198.48	0.01	594.95	8.15	23.71
<b>Total</b>	<b>356.73</b>	<b>0.01</b>	<b>1,069.06</b>	<b>18.12</b>	<b>25.53</b>
<b>Whole City</b>	<b>5,477.49</b>	<b>0.41</b>	<b>16,687.39</b>	<b>255.63</b>	<b>28.71</b>



## Annex VI HCMC median block-level density values per UST

UST	Building density (buildings/ha)	Ground coverage ratio (GCR)	Total soil sealing	Building height (stories)	Tallest building (stories)
All Shophouse based-	13.3	0.15	40	1.1	2
Regular shophouse	33.7	0.62	90	1.8	4
Shophouse reg. new	32.7	0.54	81	1.8	4
Shophouse reg. new comm.	16.25	0.22	76	1.9	4
-Shophouse reg. narrow	42.15	0.72	90	2.0	4
-Shophouse reg. w/yards	17.55	0.22	59	1.2	2.5
Irregular shophouse	31.65	0.48	67	1.4	3
Shophouse irreg. high-dense	46.5	0.72	92	1.8	4
Shophouse irreg. w/yards	27.85	0.38	67	1.2	3
Shophouse irreg. temp.	32.85	0.70	85	1.3	2
Peri-urban shophouse	7.4	0.07	10	1.0	1
Shophouse irreg. scattered	14.4	0.15	36	1.1	2
Shophouse irreg. clustered	12.2	0.13	40	1.0	2
Shophouse irreg. w/fields	5	0.04	10	1.0	1
Mixed shophouse	20.1	0.39	89	1.3	3
Shophouse w/ industry	20	0.42	89	1.3	3
Shophouse irreg/reg.	22.5	0.22	83	1.2	3
All villa based-	18	0.26	44	1.4	3
Regular villa	16.55	0.22	37	1.3	3
villa	14.7	0.23	44	1.5	3
Luxury villa	16.7	0.22	37	1.3	2
Mixed villa	21.8	0.42	75	1.6	4
Villa in est. UST	17.85	0.24	75	1.3	3.5
Colonial villa	27.4	0.49	78	1.7	5
All Apartments-	16.2	0.58	85	2.0	4
Apartment new	14.5	0.51	92	2.0	5
Low-rise apartment	18.35	0.58	92	2.0	4
High-rise apartment	14.5	0.50	81	1.9	6
Apartment old	17.3	0.67	83	2.0	4
Chinese apartment	14.55	0.67	85	1.7	3
American apartment	15.9	0.42	72	1.6	5
Social apartment	23.3	0.69	83	3.0	5
All CBD based-	36.1	0.64	82	2.2	6
CBD	42.3	0.65	82	2.1	6
CBD w/high dense	29	0.63	93	2.6	10
All residential	13.8	0.17	40	1.1	2

UST	Gross floor area (GFA) (m <sup>2</sup> /ha)	Floor Area Ratio (FAR)	Building Volume (m <sup>3</sup> /ha)	Population density (ha)	Gross floorspace per person (m <sup>2</sup> /ha)
All Shophouse based-	1,699	0.17	5,088	67	24.0
Regular shophouse	10,349	1.03	32,401	434	23.7
Shophouse reg. new	8,897	0.89	29,673	408	23.1
Shophouse reg. new comm.	4,849	0.485	16,076	154	29.9
-Shophouse reg. narrow	13,314	1.33	39,943	579	23.1
-Shophouse reg. w/yards	2,549	0.255	7,648	99	27.1
Irregular shophouse	5,965	0.6	17,723	311	21.2
Shophouse irreg. high-dense	11,367	1.135	34,101	620	20.7
Shophouse irreg. w/yards	4,523	0.45	13,568	211	22.2
Shophouse irreg. temp.	8,128	0.815	21,134	507	14.5
Peri-urban shophouse	734	0.07	2,201	30	24.9
Shophouse irreg. scattered	1,656	0.17	4,969	65	25.5
Shophouse irreg. clustered	1,432	0.14	4,296	60	24.6
Shophouse irreg. w/fields	453	0.05	1,360	19	24.7
Mixed shophouse	5,031	0.5	13,164	212	34.2
Shophouse w/ industry	5,205	0.52	13,534	219	34.5
Shophouse irreg/reg.	2,884	0.29	8,652	115	25.2
All villa based-	3,715	0.37	13,980	119	34.6
Regular villa	3,308	0.33	13,287	89	29.6
villa	3,687	0.37	13,758	70	50.5
Luxury villa	3,162	0.32	12,847	132	21.0
Mixed villa	6,674	0.67	23,961	175	36.9
Villa in est. UST	3,392	0.34	10,176	110	27.7
Colonial villa	8806	0.88	30,507	196	47.7
All Apartments-	12,088	1.21	42,184	526	24.6
Apartment new	11,651	1.165	42,166	344	30.8
Low-rise apartment	14,202	1.42	46,878	446	31.4
High-rise apartment	9,463	0.945	31,632	315	29.6
Apartment old	14,332	1.43	45,436	697	19.5
Chinese apartment	8,106	0.81	26,623	594	12.4
American apartment	9,261	0.93	29,922	522	21.8
Social apartment	24,344	2.43	77,047	1084	22.4
All CBD based-	14,413	1.44	53,490	398	33.2
CBD	13,385	1.34	50,473	494	27.7
CBD w/high dense	19,308	1.93	69,164	241	58.5
All residential	1,930	0.19	5,768	73	24.2

## Annex VII Division of residential USTs: Da Nang

