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## **Master's thesis**

Subject: Analytical and comparative study of Decision making Methods and Tools for SME Digitalization

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## Declaration

I hereby declare that this thesis is my own work, that I have not presented it elsewhere for examination purposes and that I have not used any sources or aids other than those stated. I have marked verbatim and indirect quotations as such.

Nuremberg, 18.08.2021



Vikas Kodangala, Bhat

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## List of Abbreviations

IoT	Internet of things
AI	Artificial Intelligence
SMEs	Small and medium Enterprises
KfW	Kreditanstalt Wiederaufbau
IT	Information Technology
CEO	Chief Executive Officer
FCM	Fuzzy cognitive mapping
MCDM	Multicriteria decision making
MCDA	Multicriteria decision analysis
INFORMS	Institute for Operational Research and the Management Sciences
MODM	Multiple objective decision making
AHP	Analytic Hierarchy Process
TOPSIS	Technique for Order of Preference by Similarity to Ideal Solution
CRITIC	Criteria Importance Through Inter criteria Correlation
EDAS	Evaluation Based on Distance from Average Solution
SDM	Strategic Decision making

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# 1 Introduction

With the development of the digital economy and the current and future chances of public health crises, the future of the global economy will have a lot to do with digitalization. Technologies such as blockchain, IoT, AI etc. along with the emergence of new digitalized business and working models will bring about a new face to the global economy (Othman Abanmai, 2020). And Small and medium enterprises (SME), being the heartbeat for economic development of most of the regions of the world, should overcome the lack of resources and experience in implementing new technologies to become successful and reach a wider market (World Bank).

Statistics show only one in four SMEs has invested in modern technologies in recent years. Which is clearly too less, considering the numerous opportunity it brings in terms of value creation. It is also seen that most money flows into buildings and machines and very little into modern software and technologies. Majority of these organizations still have major deficits when it comes to digitization. Almost only one-fifth of German SMEs pursue a complete digitization strategy. Even though many companies are expanding their digitization, most of them are doing so in very small and vague steps. One reason for this is financing problems. Even if the costs for digitization projects are within the limits, the impression remains that the costs are far higher than the benefits which are initially perceived. This is a deterrent. (ARTS, 2021)

Digitalization also brings a lot of challenges to SMEs. A study conducted by KfW bank in 2019 shows that one-third of the European SMEs think digitalization is their biggest challenges for the future. The four biggest challenge identified for SMEs to integrate a digital business model are (i) Leadership and error culture (ii) Lack of innovative capacity (iii) Inert structure and steep hierarchies (iv) Selecting appropriate technology. (Philipp Noack).

The first three challenges are related to organizational and management structure and focus on innovation, which can be overcome with structural changes more easily than the fourth challenge of Selecting the appropriate Digital technology. Unlike large firms, SMEs also face challenges with limitations in their resources (Dilber Ulas).

The main objective of this thesis is to build on the fourth challenge, i.e. Researching on different decision making methods, tools and support systems that can be used in an SME environment to help the decision maker make a better decision when it comes to Digitalization. These environments are highly dynamic with limited resource and information (Bryant, 2007). Also, SMEs contribute to 90 per cent of the world business and 50 per cent of employment worldwide (World Bank), hence making them important to every economy.

It's also a proven fact that when compared with large firms, the owners of SMEs taking decisions for themselves and there is a proneness to business failure due to the lack of decision making and management skills. (B.E.A. Jayasekara et al., 2020)

Past research has focused a lot on decision making in large firms and little is known about the decision making processes by the people in charge in a small firm (Heron de jong et al.). There are however some decision making methods that suit the SME environment better than others, and this thesis adds to this currently important research area by answering the following research questions and by bridging the research gap in Decision support for SMEs with decisions on adopting and Implementing Digitalization:

RQ1: Which decision making tool is best suited for SME digitalization Decisions? Or which suits what situation?

RQ2: Is Heuristics really an advantage in SME digitalization decisions?

To answer this question, the following chapter 'State of Knowledge' consolidates all the literature and the present knowledge available in the areas of decision making in an SME environment such as decision making tools and methods, SME digitalization and associated challenges and finally, the role of heuristic-based decision making in these dynamic decision environments.

After the Literature Review, the Methodologies used in this research are introduced which is followed by the Result chapter, where the findings of the research are presented. And finally, the summary of the results and recommendations for future work are discussed.

## 2 State of Knowledge

This chapter gives more details on the current status of the works of literatures following the systematic literature review and extracts from it the important knowledge that is crucial for this research such as SME digitalization, decision making situations in SMEs and the factors that are important for it. Also, the suitable decision making methods and tools for this type of dynamic SME decision making environment.

Digitalization can reduce the gaps between the small and medium companies and the big ones, but most SMEs are traditionally run and are family-owned. They might face challenges and struggle to compete in the fourth industrial revolution (Orzes et al., 2020). SMEs in reality, will be able to undergo the digital transformation much faster than the large companies, as from the IT standpoint it is faster and easier to implement new IT solutions from scratch than changing the existing one.

Digitalization, if implemented successfully in an SME, can bring with it a lot of opportunities (Jan Stentoft et al., 2019). SMEs are slowly integrating digital lean management into their corporate strategy. As an outcome of this lean has been implemented in several SMEs already (Azevedo and Almeida, 2021). This according to (Azevedo and Almeida, 2021) is very important and helps increase the success rate of industry 4.0 in SME manufacturing by developing SME customized implementation strategies and concepts and technologically feasible solutions. This will help show the expected success in the results and the effort for sensitization and awareness building among SMEs for industrial 4.0 will be a success.

### 2.1 Challenges faced by SMEs in Digitalization decisions

Small and medium enterprises face a lot of challenges from securing finances to attracting new customers. But now with the focus on digitalization and Industry 4.0, embracing new technologies is a modern-day challenge almost all SMEs face. (Simon Willmetts, 2019). Digitalization or digital transformation can be defined as the processes to restructure economies, institutions and society on a system level (Gregory Unruh and David Kiron, 2017). This includes customer interaction through social media, integration of IT systems and extensive use of big data not just for marketing but also for data-driven revenue models and preventive maintenance (Bouwman et al., 2019). Therefore

digitalization is not just about internal process changes by incorporating new technologies but a fundamental change in business model (Loebbecke and Picot, 2015).

This business model change is not an easy decision to make for an SME as it is a complex phenomenon. Business model change brings with it complicated investment decisions, acquisition of resources and competencies (Sosna et al., 2010) and dealing with and resolving conflicts between old and new business models (Chesbrough, 2010). At the same time, SMEs need to profit from a new business model to save themselves from their competitors (Ibarra et al., 2020).

Decisions regarding the implementation of digital technologies come under strategic decision making, which requires modification or a complete change of the business model and also business restructuring (Nuijten et al., 2020). This coupled with other challenges of digitalization such as the cost vs benefit dilemma, concerns about data protection and security, additional personnel costs etc. (ARTS, 2021) make it a difficult decision to select and implement the digital right digital technology as per plan.

## **2.2 Decision making in SME environment**

In general terms, decision making may be defined as the process of making choices from among alternatives (J.G. March, 2009). In an organization, it is important and hence is complicated process with considerably high stakes and widespread impact (J. Greenberg, Robert A. Brown, 2010). Therefore, decision making plays an important part in deciding the future outcomes for the organization. Presently, most decisions in an organization are made in groups, teams and committees which benefits from more knowledge and expertise (Fred C. Lunenburg, 2011) but expertise is something that most SMEs lack (Rohana Ngah, 2009), hence more focus is needed on Decision making methods, tools and aspects in an SME environment.

Khatri et. al says that the aspect where smaller firms differ from the larger ones are in the use of intuition. Here there is a strong influence of the idiosyncrasies of the decision maker, who in most cases is the Manager/business owner (Said Elbanna, 2006) and lesser influence on collecting comprehensive information (Gilmore et al.). In a 2004 study, it was found that external factors did not play a significant role in SME managerial

decision making as compared to internal factors, organizational structure and profile of the manager (G Jocumsen).

The larger corporations also take a larger time span in decision making while SMEs consider a shorter horizon. Big companies also prefer to use a process driven approach, SMEs adopt informal intuitive processes into decision making. (SASCHA KRAUS, B. SEBASTIAN REICHE AND CARL HENNING RESCHKE, 2008)

However, there is also decision making methods and tools which fit perfectly into the dynamic decision making environment such as that found in SMEs. These methods in combination with quick decision making possibilities in SMEs due to the lack of hierarchies can prove to be a strong tool for SME decision makers to avoid catastrophic decision failures by rushing into decisions.

Before we can consider decision support methods and tools for a SME environment, it is important to know what factors or what features are important in this dynamic environment. Then based on this the suitable methods can be analysed, evaluated and compared.

Information, knowledge, data, experience etc. are key to decision making. "for small firms, comprehensive information becomes a luxury that they cannot afford" says (Keith D.Brouthers et al., 1998). Also, small companies are focused on the CEO's interests and confidence in processing the information (Rob J.G. Jansen et al., 2011). This means in terms of information SME decision makers mostly use Intuition or heuristics (Jean Richard et al., 2019) and hence in this respect the ability to use gut feeling and experience in the decision making process is an important factor and along with this, the use of any data and statistics that readily available will only enhance the outcome. Large companies traditionally use logical and statistical based decision making methods. These, however, heavily depend on the information input in the form of data, the more the better. And to acquire such a volume of data each time a decision needs to be made is too costly for SMEs (Muhammad Iqbal et al., 2018).

This brings us to the accuracy of outcomes, which is very critical for the survival of SMEs as the cost of a bad decision can mean a complete business failure and almost 20% of small businesses fail within the first year and by the fifth year about half would have

failed (Melissa Horton, 2021). And 90 per cent of the business failures are due to bad decisions (Clark, 2000). In the case where a decision on digitalization has to be made, accuracy is highly important as the decision to digitalize is often accompanied by heavy investment. And a poor decision means bankruptcy.

Ibarra et al. also point out that SMEs have limited time (Ibarra et al., 2020) and from this point of view the time to arrive at a decision is also an important factor. As they are not just competing with the large companies but with other SMEs too.

Another important factor that goes hand in hand is effort, less effort means more time and other resources the decision maker saves, and can be used in other important activities. As in most cases the decision maker in SMEs is a key figure in the company (Rob J.G. Jansen et al., 2011).

And finally Ibarra et al., (World Bank) and from several other papers and surveys and as a fact we know that SMEs are stressed for money and face a lot of financial challenges and hence it is important that the decision making method be as cost-effective as possible and not divert excessive valuable financial resources into it.

So to list out the important factors identified and which will be used to evaluate the decision making methods in this research are:

- i. *Cost effectiveness*: The cost that is incurred for using a particular decision making method, including license cost, acquisition cost, training cost if any
- ii. *Time for decision arrival*: The total time required from gathering all the inputs and data required for decision making, till the final decision arrival
- iii. *Effort*: The overall effort that a decision making method requires to execute
- iv. *Able to use gut feeling/experience*: The extent to which the decision making method relies on gut feeling and intuition based on experience as input to arrive at the decision
- v. *Making use of statistics/ logic/ data*: The extent to which the decision making method relies on statistics, logic and data as input to arrive at the decision

vi. Accuracy of the decision: How correct the outcome of decision are

## 2.3 Decision Tools and Methods

This section discusses in detail the suitable decision making methods and tools for an SME environment and why and how they can contribute to the goal.

### 2.3.1 Fuzzy Logic

Fuzzy logic is a discipline in mathematics, first mentioned in the article “Fuzzy Sets – Information and Control” by L. A. Zadeh back in 1965 (Zadeh, 1965). Since then there have been a variety of set theories based on this original idea. Fuzzy logic is a logical system that resembles Human thinking and perception as close as possible. It's based on the idea that humans are not always thinking in precise values like ‘Yes’ and ‘No’, but within this closed boundary like for example: ‘rather yes’, ‘much yes’, ‘maybe no’ and ‘no’ (Katarína Valášková, Tomas Kliestik, Mária Mišanková, 2014). Mathematically, instead of a value in  $\{0,1\} \in X$ , they accept values in a closed Interval  $[0,1]$ .

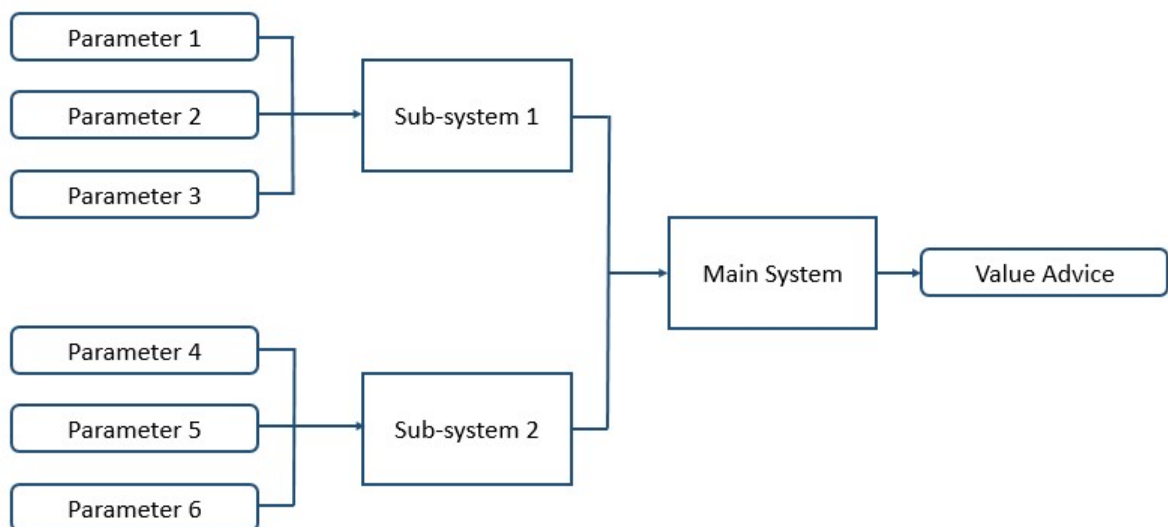


Figure 1: Basic Fuzzy Logic Decision making Architecture (Achanga et al., 2012)

Fuzzy logic has been adopted as a means to resolve problems of data imprecision, achieving desirable outcomes with limited or incomplete data. The fuzzy logic subsystem is based on heuristic rules. The main system is designed with the input parameter necessary for the decision, the output parameter is the valuable advice. As shown in figure 1 The input of the main system is obtained as a form of outputs of the subsystem and then a number of heuristic rules were then generated using different combinations (Achanga et al., 2012).

The algorithm or procedure for fuzzy decision making comprises of the following steps: problem identification, fuzzification, fuzzy interference and rule base, defuzzification, interpretation and verification (Dostál, 2008).

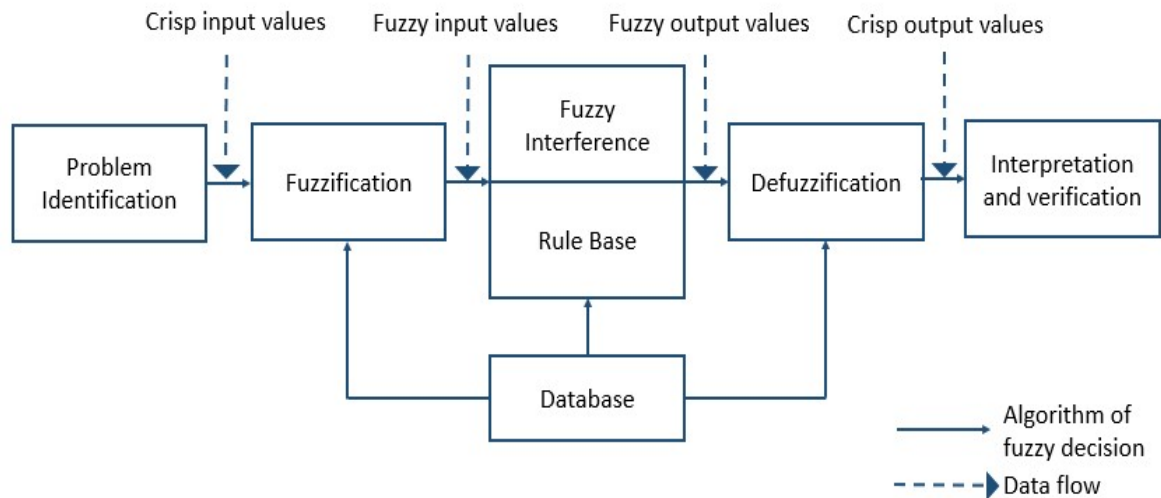


Figure 2: Algorithm of fuzzy decision (Dostál, 2008)

Fuzzy logic in decision making has evolved a lot since its first mention in 1965. In recent years there has been a lot of research in the fuzzy logic system based decision making, across different fields, and has proven to be effective in situations with incomplete and missing data to make a precise decision as possible with the data in hand. This is also pretty much the situation in an SME environment, where the decision maker lacks all the necessary data and could be a vital decision making tool. However, Achanga et al. also point of that this process is extensive and might require some technical expertise to execute it. Nevertheless, its potential for decision making for digitalization based decisions in SME use cases will be studied in this research.



*Cognitive maps or fuzzy cognitive maps* is one such well-known method to capture and clarify people's perceptions and ideas (Ferretti, 2016). They are recognized as an interactive visual tool that allows structuring and clarification of complex decision problems (Ferreira et al., 2016). The figure below is an example of a basic fuzzy cognitive map. Each node in the Fuzzy cognitive map represents a concept and each arc  $C_i, C_j$  is directed as well as weighted and represents the linking between the concepts showing how concept  $C_i$  causes  $C_j$ . (Vijay Mago, 2011)

The weights  $E$  can have the following relations:

$E_{ij} > 0$  expresses positive causality (excitement)

$E_{ij} = 0$  express no causality

$E_{ij} < 0$  expresses negative causality (Inhibition)

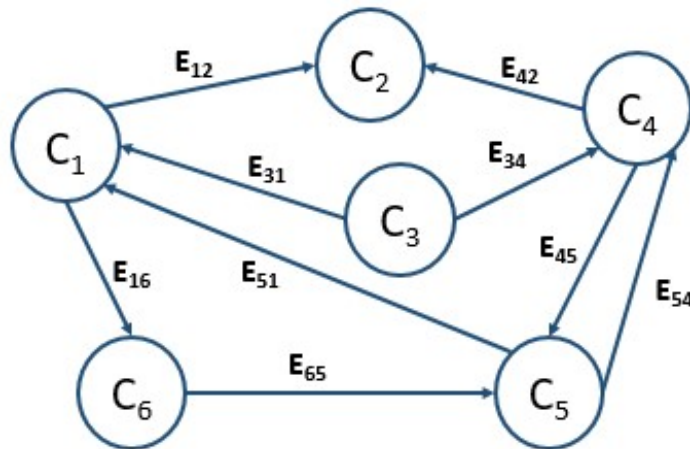


Figure 3: Basic structure of FCM (Vijay Mago, 2011)

This can be used to model decision systems even very complex ones to arrive at a decision. Easy and cheap software's make the process simple. Below is an example from FCM software.

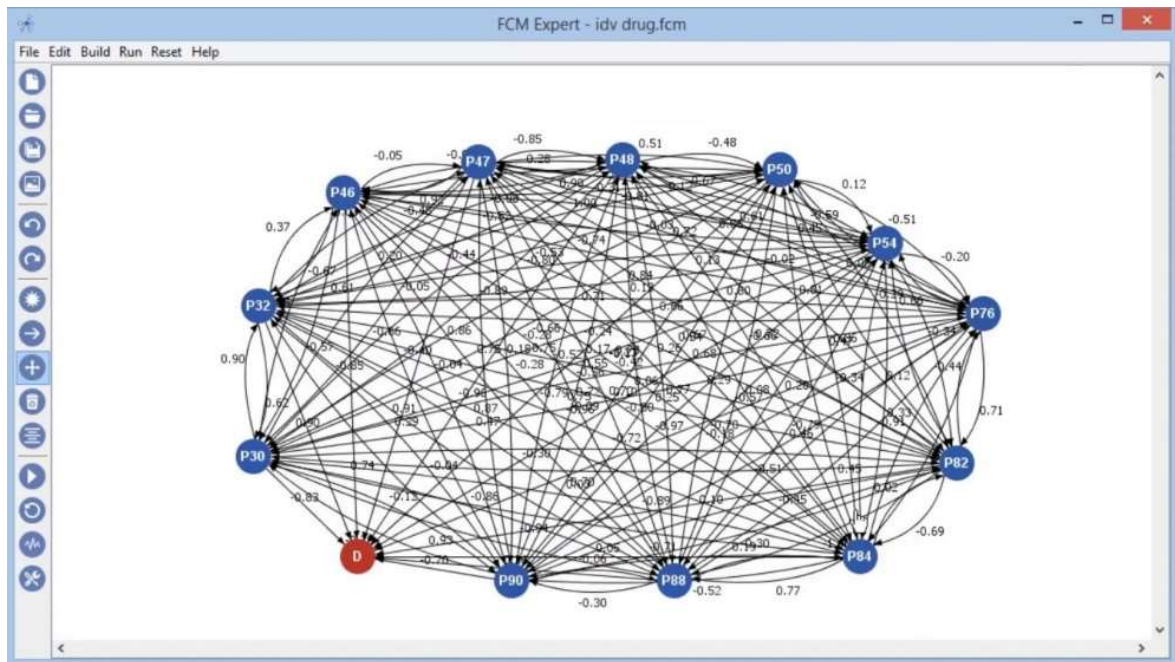


Figure 4: Software's to solve complex FCM (Nápoles et al., 2018)

Other than this, FCM Software's also can help with building an FCM from raw data or data sets, perform What-If simulations, combine multiple FCMs, estimate weights using AI, topology optimization, improve convergence and classify new instances (Nápoles et al., 2018).

“Eliciting the different views and belief sets as individual cognitive maps, drawing together this expert opinion in the form of a composite map and, using the composite map in a work-shop setting to explore the policy arena and the possible policy options” (Eden, 2004). This sequence of mapping procedures allows decision makers, first, to deal with both qualitative and quantitative factors, reducing the number of omitted criteria in the framework, increasing transparency and providing a fuller understanding of the decision problem at hand (MARTINS et al., 2015). Second, decision makers can structure complex decision problems. Lastly, decision makers can provide support for the development and implementation of strategic directions. This structuring tool can, therefore, be of great use in assessing SME innovation capability (Castela et al., 2018).

### 2.3.2 Multiple criteria decision making

Multiple criteria decision making (MCDM) also referred to as multiple criteria decision analysis (MCDA) is a method to arrive at decisions by evaluating multiple conflicting criteria's. The purpose of this method is to support the decision maker when faced with

multiple conflicting criteria's. 'Solving' the decision problem when it comes to MCDM involves choosing the 'best' from the available alternatives. The concept of optimal solution is often replaced by a non-dominated solution, which means it is not possible to improve in any criteria without sacrificing the other, so in a situation where there are many critical criteria's the preferred solution will be a solution that maximizes all criteria as much as possible without sacrificing the other. (Wikipedia, 2021)

This is the main advantage of this MCDA when comparing with other decision making methods (Siksnyte-Butkiene et al., 2020). Hence, this could be a very powerful tool for SME decision makers for whom every criterion is critical and a compromise somewhere is unaffordable.

Therefore, one needs tools to help the decision maker focus on the preferred solution he wants to arrive at. Active research in MCDM began in 1970, there are several organizations overlooking this including the Society on Multi-criteria decision making, Euro working group on MCDA and INFORMS Section on MCDM. MCDM comprises knowledge from many different fields including mathematics, Decision Analysis, Economics, Computer Technology, Software Engineering, Information systems. (Wikipedia, 2021)

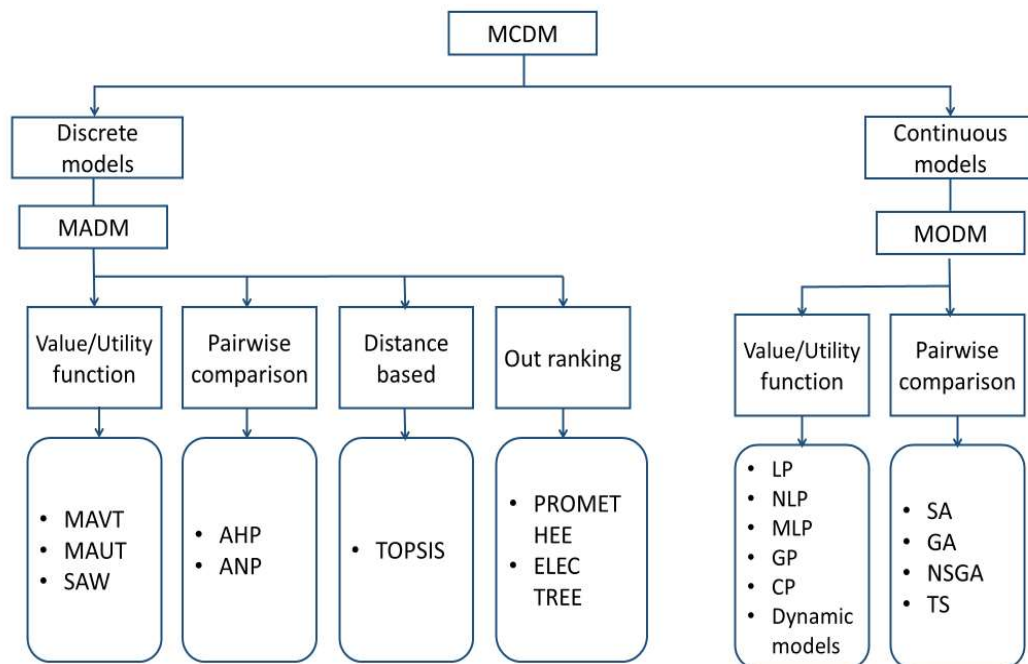


Figure 5: Classification of MCDM methods

There are a lot of MCDM methods and as per (Justin Amoyal, 2018) there are 42 different MCDM methods for which specialized decision making software's are available, both licensed and free versions (Wikipedia, 2021). The MCDA methods are categorized into two categories: Multiple attribute decision making (MADM) and multiple objective decision making (MODM) (Renatus and Geldermann, 2016).

Both these methods require different approaches. MODM selects the optimal solution using mathematical models that are based on goal functions and several side constraints. MADM on the other hand allows the decision maker to select the optimal action from a given set of discrete alternatives. (Renatus and Geldermann, 2016) in their similar research say that this is suitable when the business actions are finite and known beforehand. This is also the case most of the time with SME digitalization, they know the technologies, the machines and business actions in different scenarios. Decision makers has to select one option from the available set. Large companies here hire outside analysts who are experts in Multi-criteria decision problems who will contribute as moderators during the decision making processes. SMEs due to their lack of finances and personal mostly cannot.

Since hiring an external expert is not a feasible option for SMEs, three things have to be assured: Firstly, the method should be easily understood. Secondly, the decision maker trusts the decision of the software in the absence of a human expert (McIntosh et al., 2011) and finally Time. SME Decision makers expect reliable results in the least time spent (Renatus and Geldermann, 2016).

The following figure shows the nine steps for the multi-criteria decision support model.

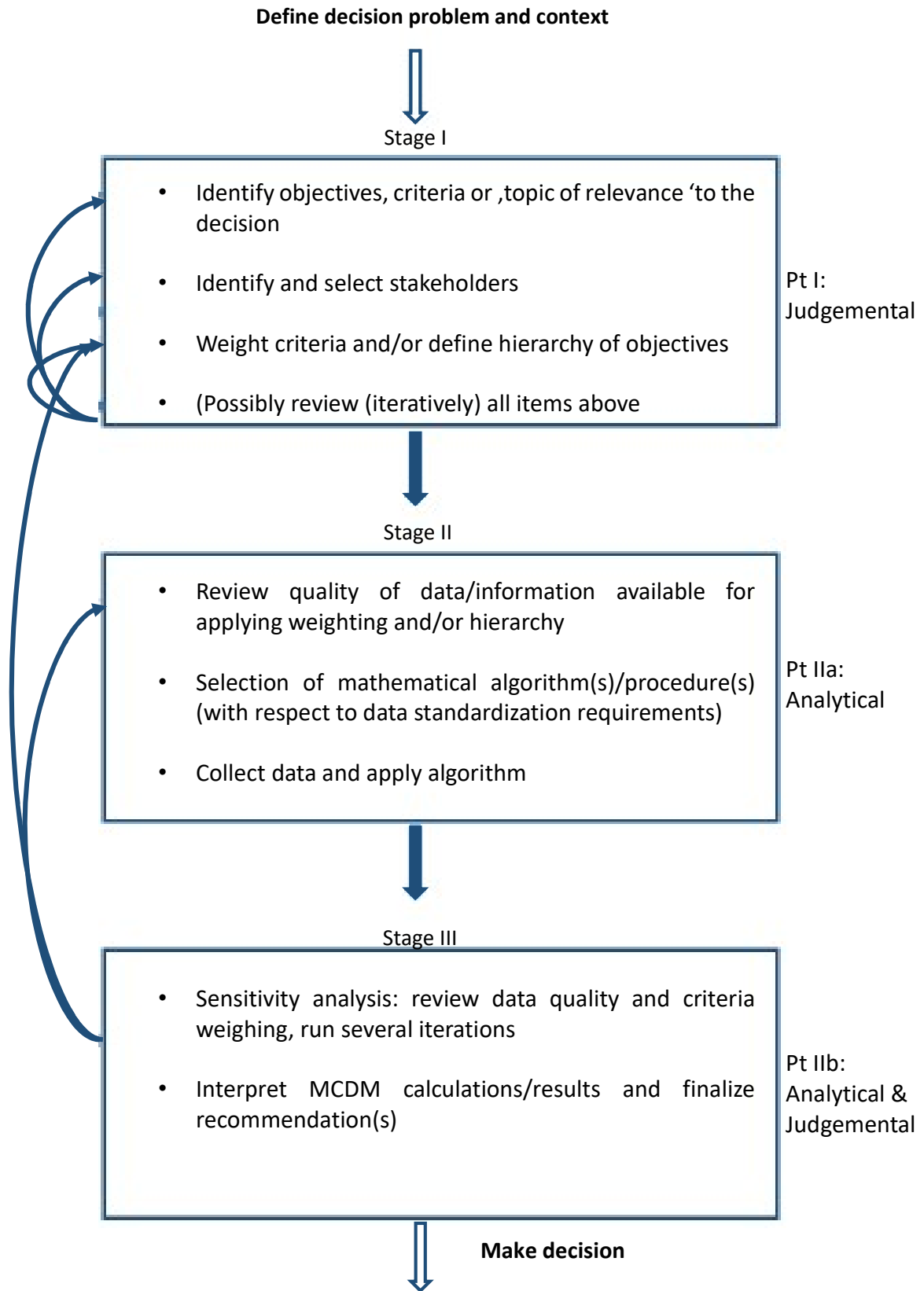


Figure 6: The overall processes of MCDM model (Mosadeghi et al., 2013)

### 2.3.3 Third person de-biasing

(Nuijten et al., 2020) published their journal article titled 'Cognitive biases in critical decision facing SME entrepreneurs: An external Accountants perspective', where a third person, an accountant, in this case, oversees the decision maker for biases during critical decision making. In the previous section of MCDM where it's not feasible to hire external advisors. This method overcomes this challenge by using someone who is already in the company, and just oversees that the decision maker does not get blinded by obvious biases because of his emotional connection to the company or because of the need to make a decision in a hurry. The advantage here is unlike the MCDM advisor, the advisor for de-biasing does not need to have any methodical knowledge or any additional knowledge, just the ability to be a neutral observer is utilized in this method.

(Herbert A Simon, 1947) first introduced this idea, where he described the role of 'administrative man'. The administrative man or woman is a person who helps to provide the organizations with objective and unbiased information to support decision making. Simon also explains the background by taking two systems in a dynamic decision making environment. In such a decision making environment, the rational decision making processes, referred to as system 2 (Stanovich and West, 2000) gets overwhelmed the decisions are dominated by experimental and intuitive decision making processes, referred to as system one.

Before going to de-biasing it is important to understand bias properly. A bias can be defined as a systematic deviation from rational choice theory when people choose actions and estimate probabilities (Tversky and Kahneman, 1974). Heuristics as we know are shortcuts or principles that one can use for problem solving and information processing. As heuristics simplify information processing, they are associated with biases. (Nuijten et al., 2020) through their literature survey, lists various domains where SME decision makers seek advice and they have classified them as follows:

- I. Strategic decision making
- II. Regulatory compliance decisions
- III. Human resources domain
- IV. Information technology
- V. Succession planning (Nuijten et al., 2020)

Decisions for SME digitalization comes under both Strategic decisions and information Technology. They also bring out 12 different biases across 5 decision domains which are shortly described below: (Nuijten et al., 2020)

1. *Anchoring*: Influences one's intuitive judgement. Subconsciously decisions are anchored to a reference point and subsequently make an adjustment to this initial anchor to come to their judgement, however, these anchors are often insufficient causing the outcome to be biased towards the initial anchor and thereby limiting rational decision making (Tversky and Kahneman, 1974).
2. *Availability Heuristic*: here the prior examples that easily come to mind can receive disproportionate weight in decision making (Tversky and Kahneman, 1974). The stronger the positive or negative experience the more it can influence. Recent experiences generally come to mind more easily.
3. *Confirmation Bias*: It is when the decision maker looks for information that supports their decision while disregarding the information that is contradicting. It is said to occur when decision makers have not faced failures before and overestimate their previous success and focus only on the positives (Nuijten et al., 2020).
4. *Regret and counterfactual Thinking*: "What could have happened if..." kind of thoughts is associated with this type of bias, i.e. thoughts that form an alternative to past events or situations. This can lead to forming alternative strategies for the future and hence can influence decision making processes. (Baron, 2013)
5. *Escalation of commitment*: This is when the decision maker over commits to an already chosen course of action, despite having feedback that it will not lead to a desired outcome. (Staw, 1976)
6. *Illusion of control*: As the name suggests, this bias occurs when decision makers overestimate the amount of control they have over a situation. It's an illusion where someone feels that they still have control over those outcomes which are objectively outside of their control. (Langer, 1975)

7. *Overconfidence*: This is one of the most studied biases when it comes to SME/Entrepreneur decision making. This is a bit different from the previous illusion of control, where it's the false belief of having control over a situation outside one's control. Overconfidence on the other hand relates to overestimation of one's personal chance of success in any situation. Entrepreneurs have been found to show more overconfidence than managers in a large organization. (Busenitz and Jay B. Barney, 1997)
8. *Planning Fallacy*: As the name suggests, it is associated with over-optimism in estimation regarding the amount of work and the time in which it can be completed. This also includes not adding risks (Baron, 1998; Kahneman and Dan Lovallo, 1993).
9. *Representative bias*: It is based on the fact that decision maker assumes falsely that limited experience can be generalized and hence can be applied in all instances. (Nuijten et al., 2020)
10. *Status Quo bias*: Status Quo is more about being adamant and unwilling to deviate from the past decisions made by the same or different person, even if it is no longer rational. (Burmeister and Christian Schade, 2007). (Burmeister and Christian Schade, 2007) also, say in their paper on the status-quo bias that SME/Entrepreneur decision makers are not more prone to status quo bias as others but the possibility to encounter is more in such a decision making environment.
11. *The Affect heuristic*: This is when the decision maker weights the pros and cons and then makes the decision based on what they 'like', this 'effects' eventually the decision outcome. This is also more popular in SME/Entrepreneur environments, as they passionately follow their emotions. (Baron, 2008)
12. *Groupthink*: This bias unlike the previous 11 biases is for decision making in a group. In simple terms, it's the human tendency to not want to go against the group. (Nuijten et al., 2020)



The research by (Nuijten et al., 2020) concludes that out of all these biases, the ones that play a major role in strategic decisions are overconfidence, planning fallacy and status quo bias. A strategic decision is also the domain that showed to have the most bias than the other decision domains in SME. IT domain is one other domain that together with the strategic domain contribute towards SME digitalization decisions. The major biases in IT domain decisions are planning fallacy, escalation of commitment and overconfidence. Note: overconfidence and planning fallacy are common for both domains. The administrative man can additional be trained in identifying these specific biases.

(Nuijten et al., 2020) also mentions four ways to de-bias the decision by having a third person overlook the decision maker and the decision making processes. Namely: De-biasing by giving warnings, De-biasing by giving information to help recognize or reduce the impact of Biases, de-biasing by intervening when an SME decision maker falls victim to a bias and finally de-biasing by coaching and mentoring.

De-biasing by a giving warning is when the third person or 'administrative person' as we call from here on, give warnings in advance about the bias that may play a role. This may prevent the decision maker from falling victim to the bias when the warning is given by the right person, in the right way at the right time. Might happen that the warning might go into deaf ears depending on the person giving the warning. An accountant is a good example for the right person, as they are someone who is deal with finances are play an important role in a firm. (Nuijten et al., 2020)

De-biasing by giving information to help Recognize or reduce the impact of Biases can be an example of when the administrative person gives the symptoms of the bias to the decision maker which lets them know they are heading towards a decision with bias, and also help them recognize the bias in the future because of similar symptoms. This method is said to be more effective if the administrative man also provides business support and can provide insights into the impact of choice. (Nuijten et al., 2020)

De-biasing by intervening when SME decision maker falls victim to bias is an approach where the 'administrative person' responds when that have a strong feeling that the SME decision maker has fallen victim to bias. They could react by trying to make the decision maker aware of the bias they fell prey to, warning them of the potential negative

consequence of the bias and advising them on activities that can take to reduce the impact of the bias (Nuijten et al., 2020).

And finally, de-biasing by coaching and Mentoring, a more extensive and holistic approach. Like the first method, this can be done before the decision making processes by explaining every bias and its symptoms in detail also with examples. This also makes it easier to give a warning (second method) and intervene (third method) later on. (Nuijten et al., 2020)

#### **2.3.4 Metacognitive Model**

Metacognition or “ thinking about thinking” in simple terms (Flavell, 1979) has seen some research interest in the last decade on how it can be used in a dynamic decision making environment, such as in most SMEs (Vanderstraeten et al., 2020).

Haynie et al. differentiate between cognition, the heuristic or knowledge structure that people use to make assessments, judgements, that is a decision involving opportunity evaluation, venture creation or growth (Mitchell et al., 2002) and finally metacognition, a higher order process that reflects one’s awareness and control over knowledge structure that are employed to make assessments, judgements or decision. And also convinces how cognition is the process of formulating from available cognitive mechanisms, which are suitable in a flexible and dynamic environment. (Haynie et al., 2010). More importantly, a person can be trained to enhance metacognition (SCHMIDT and FORD, 2003). So a metacognitively aware person is highly likely to formulate and evaluate multiple alternatives for a given task and are also sensitive and receptive to environmental feedback which can be subsequently incorporated into the decision making framework (Melot, 1998).

The figure below of the metacognitive model for entrepreneurial mind-set by Haynie et al. shows its five major elements. These elements are interrelated and together represent a metacognitive function.

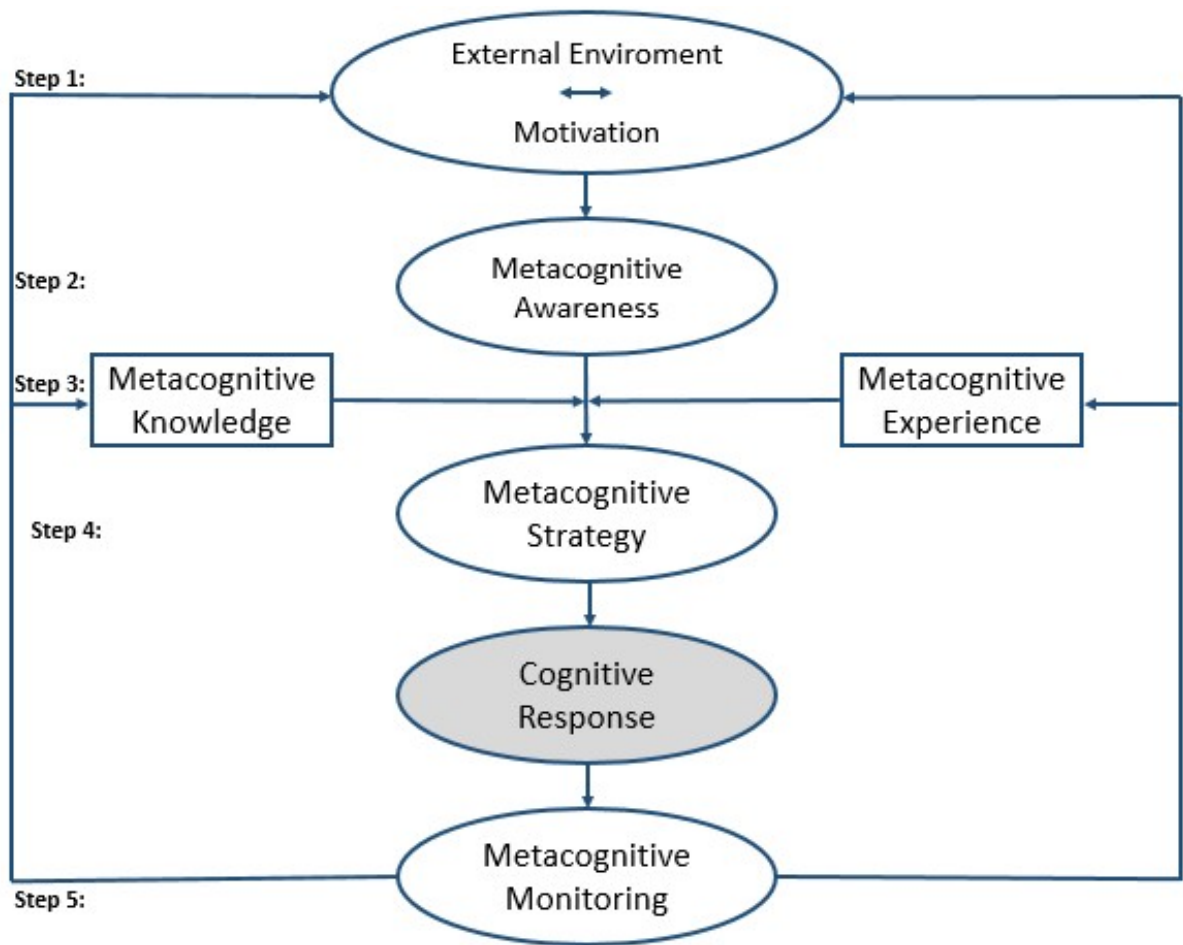


Figure 7: A Metacognitive model of the entrepreneurial mind-set (Haynie et al., 2010)

The entrepreneur's or decision maker's motivational and environment activates metacognitive processing, focused on developing and evaluating alternative cognitive strategies appropriate to achieve desirable entrepreneurial outcomes. The greater the novelty, uncertainty and dynamism the higher the metacognitive awareness, and higher metacognitive awareness greater reliance on metacognitive knowledge and experience and more desirable the outcome of the metacognitive task. Also, the greater the user's metacognitive strategies and metacognitive monitoring the more desirable the outcome (Haynie et al., 2010).

After their extensive study, Haynie et al. points out that Metacognition has a very good application in opportunity recognition decisions. This makes metacognition a compelling

model to look into when an SME decision maker has to recognize and identify the opportunity for digitalization.

The research focus has now shifted from „What decision to make“ to „how decisions are made“ (Arash Najmaei and Z. Sadeghinejad, 2016). As figure 6 shows metacognition is a tool that enhances cognitive decision making processes. Cognition refers to activates such as thinking, knowing and processing of information (Armstrong and Hird, 2009). Different individuals have different cognitive structures due to the extent of their life trajectories differ (Nooteboom, 2009). How managers or decision makers use their cognitive resources i.e. their experience and knowledge is still unclear despite extensive research (Arash Najmaei and Z. Sadeghinejad, 2016). These cognitive resources are what they apply when making decisions. Now, in situations like in SMEs where the decision makers do not have the required knowledge or experience and have only part of these resources, they need to be able to control their knowledge and experience, such abilities are driven by their metacognition (Perfect and Schwartz, 2009)

(Flavell, 1979) also defines metacognition as one’s knowledge and experience about one’s cognition. That is being aware and in control of one’s decision making and with a knowledge of how one’s decision making process works. This metacognition knowledge can be further subdivided into (i) knowledge of person variable (ii) knowledge of task variable and (iii) knowledge of strategy variable (Flavell, 1979). In other words, it is ones conscious and cognitive understanding of people, tasks and strategy (Haynie et al., 2010).

When a person is metacognitively aware, they can feel and experience when he or she engages in a cognitive task such as retrieval (Perfect and Schwartz, 2009). This person can distinguish that he or she is not very good at certain kinds of cognitive tasks but poor at others (Nambisan and Baron, 2013). Flavell also concludes in 1987 that when an individual’s cognitive is in difficulty, his metacognition goes up, this might have caused as a reason of high risk and uncertainty involved in the situation. Also, on the contrary, when memory resources are hindered by other urgent mental occurrences such as pain, anxiety or depression, metacognition is less likely to occur or to be applied (Flavell, 1979).

Haynie and Shepard in 2009 developed a 31-item scale for measuring metacognition knowledge, metacognitive experience, metacognitive controlling and metacognitive monitoring. This, along with the fact that metacognition could be developed by training (several techniques could be used to enhance managers metacognition) (Nambisan and Baron, 2013) can serve as an important tool for preparing the DME decision makers of the future. Large firms are already studying how consumers use metacognition to determine the product they decide to shop and also universities have started to incorporate metacognitive skill training for management students to prepare the entrepreneurs for the future (Arash Najmaei and Z. Sadeghinejad, 2016).

From this literature research it can be concluded that metacognition in itself cannot be treated as a decision making method, however, serves as an important tool to help the accuracy of cognitive and heuristic (cognitive shortcuts) (Arash Najmaei and Z. Sadeghinejad, 2016) decisions which we will discuss in the next subsection.

### **2.3.5 Heuristic based decision making**

Heuristics is a method of problem solving or self-discovery that uses a practical method that is not guaranteed to be optimal, perfect or rational, but is sufficient for reaching an intermediate short term goal or approximation. When one finds themselves, in a situation where it is almost impossible or impractical to find an optimal solution, heuristics can be used to speed up the processes of finding a satisfactory solution. In short, heuristics is a mental shortcut that eases the cognitive load. (Myers, 2010) Because of this approximate nature in heuristic and being irrational has made it a little unpopular among the 20<sup>th</sup> century research community, which later changed with the important contribution in the 1970s. Some of the widespread misconceptions were/are: (Gigerenzer and Brighton, 2009)

- Heuristics are always second best
- We use heuristics only because of our cognitive limitation
- More information, more computation and more time would always be better

These misconceptions are called accuracy-effort trade off (general law of cognition). If less effort and cost is invested, then the accuracy is lower. Efforts can be searching for information and doing computation etc. Since the principle behind the heuristic is 'fast

and frugal' it is considered as the second best, as it is faster and is based on approximation when compared with computation based decision making. Keeney and Raiffa in 1993 claimed that heuristics are rarely appropriate. (Gigerenzer and Brighton, 2009) and their team put this in the test. They found out less information and computation lead to more accuracy and in these situations the mind does not need to make trade-offs. Here a less is more effect holds.

Simple heuristics can be more accurate than complex procedures is one of the major discoveries of the last decades (Gigerenzer, 2008). successfully exploiting evolved mental abilities and environmental structures. Since this many studies have followed in the field of heuristics. The following table lists six common beliefs about heuristics that are erroneous.

Misconceptions	Clarification
1. Heuristics produce second-best results; optimization is always better	In many situations, optimization is impossible (computationally intractable) or less accurate because of estimation errors (i.e. Less robust)
2. Our minds rely on heuristics only because of our cognitive limitations	Characteristics of the environment (e.g. Computational Intractability) and of the mind make us rely on heuristics
3. People rely on heuristics only in routine decisions of little importance	People rely on heuristics for decisions of both low and high importance
4. People with higher cognitive capacities employ complex weighing and integration of information; those with lesser capacities use simpler heuristics(related to misconception 1)	Not supported by experimental evidence(e.g. Börder,2003). Cognitive capacities seem to be linked to the adaptive selection of heuristics and seem less linked to the execution of a heuristic
5. Affect, availability, causality and representativeness models of heuristics	These terms are mere labels, not formal models of heuristics. A model makes precise prediction cad can be tested such as in computer simulations
6. More information and computation is always better	Good decision in a partly uncertain world requires ignoring part of the available information (e.g. To transfer robustness)

Table 1: Common beliefs of heuristics that are false (Gigerenzer, 2008)

The Less-is more effect explains why the accuracy-effort trade-off is not always valid. As per the Less-is-more effect: More information or computation can decrease accuracy; therefore, minds rely on simple heuristics in order to be more accurate than strategies that use more information and time. It has to be noted that the term less-is-more does not mean that the less information a person uses, the better the performance. Rather, it refers to the existence of a point at which more information or computation becomes detrimental, independent of costs. (Gigerenzer and Brighton, 2009)

Heuristics unlike its logical and probabilistic counterparts focus on situations in which people need to act very quickly, which is almost opposite to the logical way of decision

making. Also in situations where probabilities and utilities are unknown, the goals are not clear where conditions prevent the use of logic or probability theory. Gigerenzer says the mind resembles an adaptive toolbox with various heuristics tailored for specific classes of problems, much like the tools in a worker's toolbox.

Heuristic	Defenition	Ecologically rational if:	Bold Predictions
Recognition Heuristic (Goldstein & Gigerenzer, 2002)	If one of two alternatives is recognized, infer that it has the higher value on the criterion	Recognition validity >.5	Contradicting information about recognized object is ignored, less is more effect if a>b, forgetting is beneficial.
Fluency heuristic (Schooler & Hertwig, 2005)	If one alternative is recognized faster than another, infer that it has the higher value on the criterion	Fluency validity >.5	Less-is-more effect, forgetting is beneficial
Tit-for-tat (Axelrod, 1984)	Cooperate first, keep a memory of Size 1, and then imitate your partner's last behavior	If other players also play tit-for-tat; if the rules of the game allow only defection or cooperation, but not Divorce	Can earn more money than optimization (backward induction)
Imitate the majority (Boyd & Richerson, 2005)	Look at a majority of people in your peer group, and imitate their behavior	Environment is not or only slowly changing, info search is costly or time-consuming	Mass phenomena, cultural evolution
Imitate the successful (Boyd & Richerson, 2005)	Look for the most successful person and imitate his or her behavior	Individual learning slow, info search costly and time-consuming	Cultural evolution
Take the best (Gigerenzer & Goldstein, 1996)	Infer which of two alternatives has the higher value by (a) searching through cues in order of validity, (b) stopping the search as soon as a cue discriminates, (c) choosing the alternative this cue favors	Cue validities vary highly, moderate to high redundancy, scarce information (Hogarth & Karelaia, 2005, 2006; Martignon & Hoffrage, 1999, 2002)	Can predict as accurately as or more than multiple regression (Czerlinski et al. 1999), neural networks, exemplar models, and classification and regression trees (Brighton, 2006)
Tallying (unit weight linear model; Dawes, 1979)	To estimate a criterion, do not estimate weights but simply count the number of favoring cues	Cue validities vary little, low redundancy (Hogarth & Karelaia, 2005, 2006)	Can predict as accurately as or more than multiple regression
Satisficing (Simon, 1955; Todd & Miller, 1999)	Search through alternatives, and choose the first one that exceeds your aspiration level	Decreasing populations, such as those in seasonal mating pools (Dudey & Todd, 2002)	Unknown
1/N; equality heuristic (DeMiguel et al., 2006)	Allocate resources equally to each of N alternatives	High unpredictability, small learning sample, large N	Can outperform optimal asset allocation models
Default heuristic (Johnson & Goldstein, 2003)	If there is a default, do nothing about it	Values of those who set defaults match with those of decision maker, consequences of choice hard to predict	Can predict behavior when trait and preference theories fail

Table 2: Heuristics that are likely in the Adaptive Toolbox (Gigerenzer, 2008)

Heuristics is formed out of several building blocks, and by adjusting these blocks the heuristics can be adapted to new situations. (Gigerenzer and Goldstein, 1996) explains this with the example of take the best heuristic, which is comprised of three building blocks: (i) Search rule – lookup cues in order of validity (ii) Stopping rule- stop the search

after the first cue discriminates between the alternatives and (iii) Decision rule- choose the alternative that this cue favours. The stopping rule employs extremely limited search but the search rule adjusts for that by ordering the cues according to their validity. It may not guarantee the best but is robust. Take the best heuristics is designed to help one choose between two alternatives, but its building blocks can be adjusted for classification tasks in which one objects has to be assigned into one of the several classes, for example, assigning patients to one of several treatments as shown in the figure.

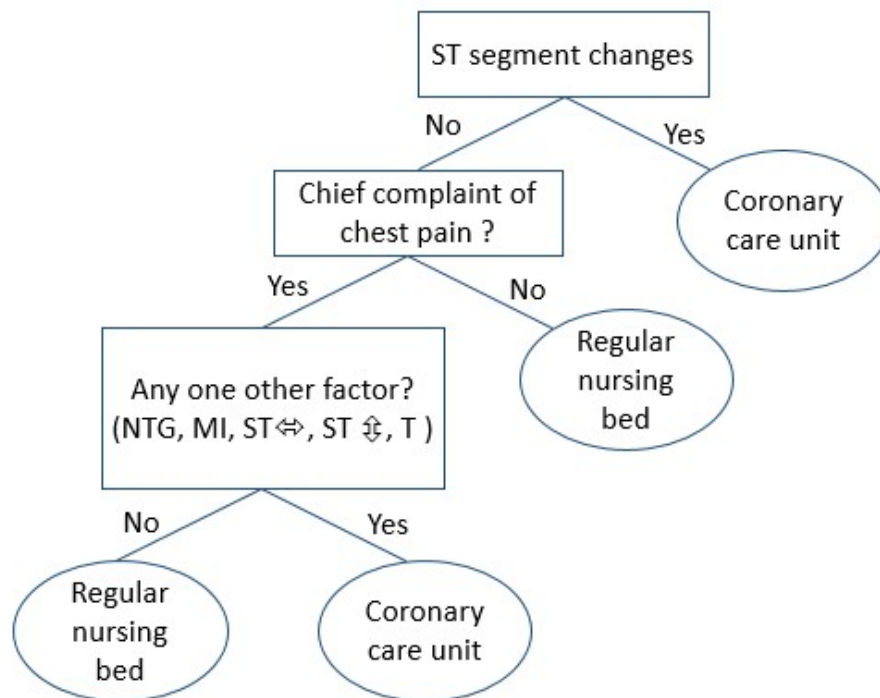


Figure 8: Fast and Frugal trees for coronary unit care (Gigerenzer, 2008)

Why do heuristics work? As per (Gigerenzer, 2008) heuristics exploit evolved capacities that come for free, and thus they can provide solutions to problems that are different from strategies of logic and probability. Moreover, they are tools that are customized to solve diverse problems. We can also predict when the heuristic will succeed and when it will fail by understanding its ecological rationality.

Behaviour is often called rational if it follows the laws of logic or probability theory, but from a Darwinian perspective, the goal of an organism to peruse its objective in its environment does not follow logic. Therefore, the rationality of the Heuristic adaptive toolbox is not logical but ecological. The study of ecological rationality analyses which



heuristic matches which environment structure. The tools that were used for this are mathematical analysis and computer simulation. And results are represented as “Heuristic A is more frugal or accurate than is heuristic B in environment X”, as in the above table. (Gigerenzer, 2008)

Payne et al. in their book *The Adaptive Decision Maker* makes an interesting claim that, ignoring information is necessary because the cost involved in acquiring it produces an accuracy effort trade off (Payne et al., 1993). Later more research contributed to this (Gigerenzer, 2008).

But how far can heuristics be used in management decisions, where usually using logic and or statistics are regarded as a hallmark for good decision making (Artinger et al., 2015). (Artinger et al., 2015) says uncertainty is a characteristic of managerial decision making, where one does not know the possible options with their probabilities of occurrences and consequences that there might bring. Yet, what management science teaches is where the probabilities are known and optimal decision choices can be calculated. This is also known as the ‘Risk’ situation in the literature. So there is a mismatch between theory and practice.

There are already some managerial tools that are used during uncertain situations. For example, decision trees (VROOM and YETTON, 1973). But using a decision tree can easily and quickly become hard to compute and prone to errors because with ‘n’ binary cues, there are ‘ $2^n$ ’ leaves. On the contrary, the fast and frugal tree of heuristic has ‘ $n+1$ ’ leaves making it a robust tool for such a managerial situation. An example of this is the fast and frugal tree as in Figure 8. This model has also been used by the magistrates at the London court to determine bail (Dhami, 2003).

Most managerial decision making environments are uncertain with limited information and time constraints owing to competitive pressure, more so in small and medium size businesses. There are a number of psychological science based literature that discusses heuristics in such situations and environments where a normal complex decision algorithm incurs error as most of them are sensitive to variance in data. The only place where error can influence is due to the biases, but this is much less sensitive to fluctuation in the environment making it more effective and robust. (Artinger et al., 2015)

An adaptive toolbox with wide arrays of heuristics instead of just one helps managerial decision making in an organization. All this makes a strong case for heuristics to be a dominant decision making method for managerial decision making in general in an environment similar to that of an SME. This makes it a strong contender also for a strategic decision such as digitalization, which will be analysed in the coming chapters.

### **3 Methodology**

This chapter gives a detailed description of the methods used for data collection (section 3.1), data analysis (Section 3.2.1) and data representation (Section 3.2.2) in the Thesis.

#### **3.1 Systematic Literature Review**

The data collecting process in this research follows a systematic literature review method which provides a reproducible and also trustworthy and explicit method that reduces bias, thus providing reliable Manuscripts for evaluation and interpretation (Anderson P et al., 2004). The practices recommended by Denyer and Tranfield for conducting systematic literature review are used in this thesis. Denyer and Tranfield developed four key principles for systematic literature review: Transparency, Inclusivity, explanatory and Heuristic (Buchanan and Bryman, 2011). In terms of transparency, this section describes the process and methods employed in this research. For inclusivity, this research places importance on reviewed articles from different fields in this domain, including Technical, Business and Psychological. The thesis also explains individual studies and integrates them into a holistic view on the Decision making methods for digitalization in SME environment. And the thesis can be said to be heuristic in a way that it offers suggestions on mixed findings regarding the impact of Decision making on SME Digitalization.

To ensure thoroughness of the literature search, specialists in the field of Small and Medium Enterprise research and industry experts with decades of experience in decision making were consulted in identifying relevant keywords and searching them in the selected database. The search was conducted in EBSCO with both Business Source Elite and Academic Search Elite as Databases. The following keywords were used to identify relevant keywords: '(decision making or decision-making or decision making process or decision making tools) AND (sme or small and medium sized enterprises or SME or entrepreneur) AND (digitalisation or Digitalization or INDUSTRY 4.0) OR (heuristics in decision making or Heuristics) OR (Adaptive toolbox OR cognitive heuristics)'

For the selection processes in a systematic literature review, there are two main steps, (i) using inclusion and exclusion criteria for filtering the results and (ii) assessing the

quality of the study to be included (Briner and Walshe, 2014). The preliminary search result was sorted into four categories based on their domain and then narrowed down to relevant theoretical, conceptual or empirical article with inclusion and exclusion criteria as shown in Table 3 and figure 9.

	DM tools/mtds for SME	SME & Digitalization	SME & Heuristics	Adaptive toolbox
Priliminary Database	4273	376	48	40
Scholarly Journals	2854	230	47	38
Academic journals & Languages	542	89	24	16
Keywords in Title	52	20	11	7
Selected (After Abstract reading)	27	5	2	7

Table 3: Selected literatures after applying Inclusion-exclusion criteria

Once the final list of the manuscript was obtained, their abstracts were read to find articles with explicit focus on Decision making methods, SMEs, Digitalization and heuristics. And the manuscripts thus selected were read fully.

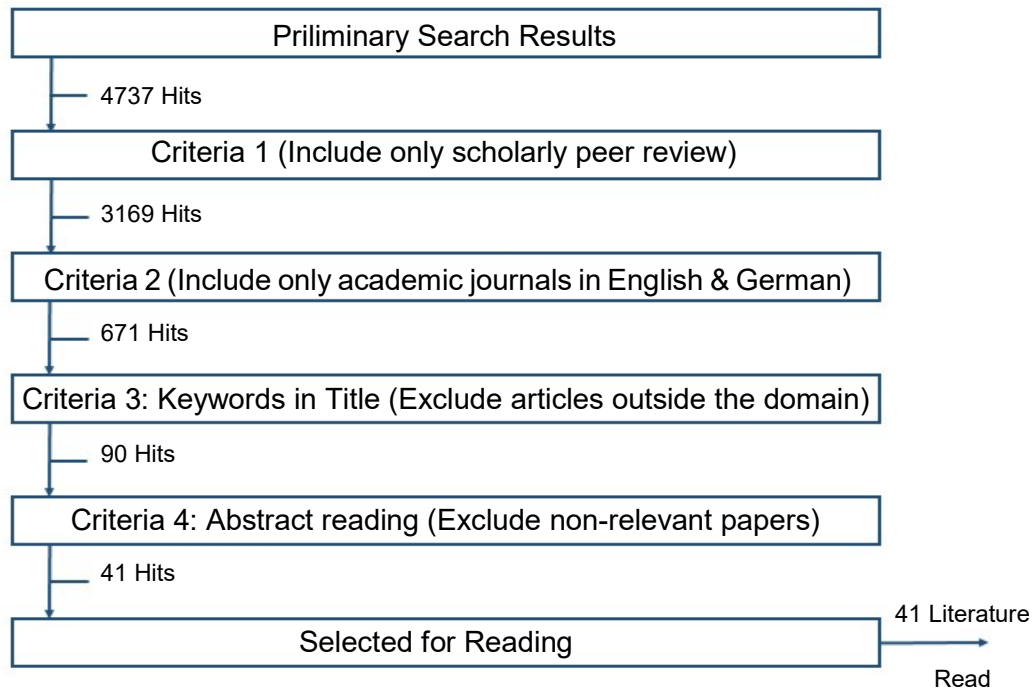


Figure 9: Inclusion/exclusion criteria for systematic literature selection

## 3.2 Data Analysis and Representation

After a systematic literature review, the data analysis step supports decision making and suggest a conclusion. It is a process to inspect, clean, transform raw literature and a model to retrieve important information (Anupama Pal, 2017). And then represent the conclusion in an easily understandable but accurate way. This research uses Analytical Hierarchy Process (AHP) for analysis and a bubble chart for representation.

### 3.2.1 Analytical Hierarchy Process

Developed in the 1970s by Thomas L. Saaty and based on “a theory of relative measurement based on paired comparisons used to derive normalized absolute scales of numbers whose numbers are then used as priorities” (Saaty, 2007). It is characterized by its simplicity, ease of use and ability to analyse elements of quantitative and qualitative nature, whether they are tangible or intangible (Theodor Stewart and Valerie Belton, 2002). As Goepel puts it, “The steps of AHP are quite simple”- First, define the goal of the decision: what to decide, for what purpose and the alternatives? Then, Structure the decision into a hierarchy: what criteria and category that figure into my decision? Thirdly, pairwise comparison of each category. And then, calculate the priorities and consistency index: were the comparisons logical and consistent? And finally, evaluate the alternatives according to the priorities identified: what is the optimum solution to the decision problem. (Goepel, 2018)

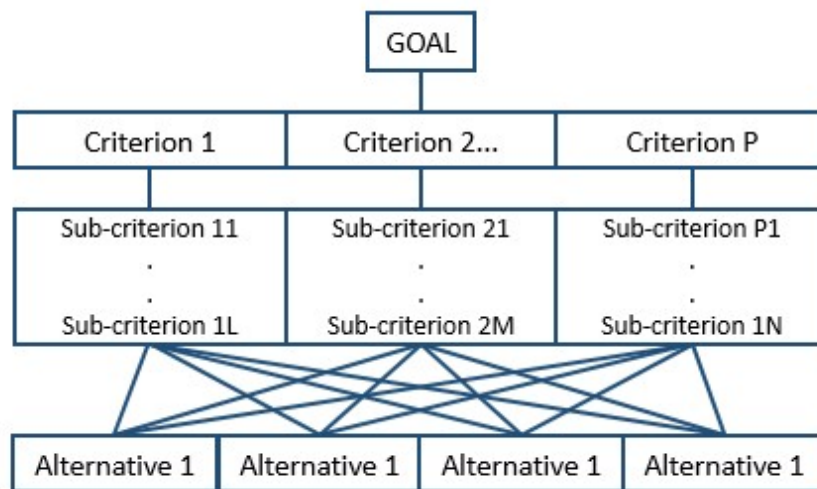


Figure 10: Conceptual Structure of AHP (Bhushan and Rai, 2004)

To model a problem, one needs a hierarchic or a network structure to represent that problem, as well as pairwise comparisons to establish relations within the structure. These analyses are based on a measurement scale known as “Saaty’s fundamental scale,” which varies between 1 and 9. Table 4 shows the definitions of the scale, where “1” reflects a variable’s lack of importance in relation to others and “9” reflects extreme importance.

This thesis uses online software from *bpmsg.com* to perform the analysis. Once the goal and criteria are defined, the software returns the weights for the criteria in percentage for the particular goal defined, also highlighting the inconsistent judgement if any for reassessing the weights. The weights for the Pairwise comparison is got from experts in SME digitalization and Decision making, hence making the analysis as robust as possible. And finally, these weights can be compared with that of the decision making methods obtained from literature research to arrive at the result.

Intensity	Definition	Explanation
1	Equal Importance	Two activities contributing equally to the objective
3	Moderate Importance	Expirence and judgement slightly favor one activity over another
5	Strong Importance	Expirence and judgement Strongly favor one activity over another
7	Very strong Importance	An activity is favoured very strongly over another; its dominance is demonstrated in practice
9	Extreme Importance	The evidence favouring one activity over another adds up to the highest possible level of confirmation
2,4,6,8		Values in between
Reciprocal of above non zero numbers		If activity i has one of the above non-zero numbers assigned to it when compared to activity j, then j has the reciprocal value when compared with i

Table 4: Saaty's fundamental scale of absolute numbers) (Saaty, 2008)

### 3.2.2 Bubble chart

A bubble chart is a variation of scatter chat that can represent three variables in a two dimensional plane. Other than the two axes, the size of the bubble makes up the third dimension (Microsoft, 2021). This type of chart is popular in representing results after the decision as they are concise and easy to understand, hence they are also used to represent portfolio decisions. This thesis also uses this chart with appropriate scaling

after the data analysis to represent the findings of AHP, as the numerical result of AHP alone can be difficult to interpret for someone foreign to the method.

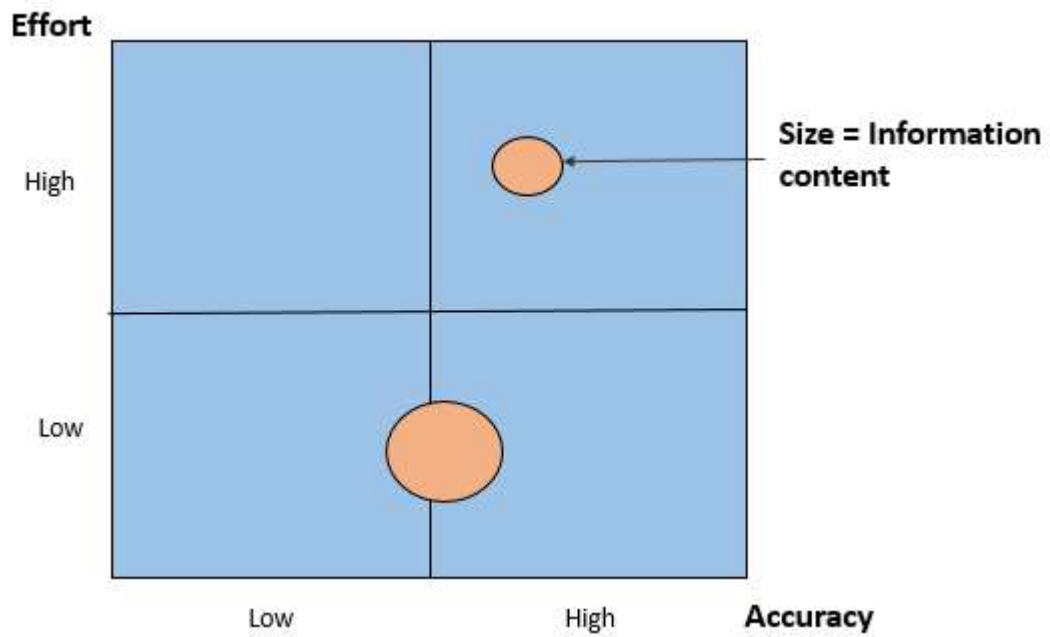


Figure 11: Example of Bubble Chart (Source: Prof Dr Bernhard Axmann, Technische Hochschule Ingolstadt )

## 4 Results

We first look at 'heuristics in SME decision making', especially in a strategic decision making situations, such as a decision on digitalization, entering new markets etc. Such decisions have a big impact on SMEs as there are no much room for mistakes in a dynamic and volatile environment. This also helps us find answers to our second research question on the advantage of heuristic decision making and its applicability in this situation.

There is a lot of literature nowadays in heuristics and entrepreneurship, but nothing concrete relating to the use of Heuristics in cases of strategic decision making such as digitalization decisions in SMEs. Therefore, in the course of this research, Dr Gerd Gigerenzer, the expert in bounded rationality and heuristics, and also the person behind the adaptive toolbox was contacted for an informational interview and the following question was asked:

Question 1: *"What is your opinion about SME Decision makers completely relying on gut feeling for Strategic decisions like for example investing in new Digitalization Technology (money is a curial resource for SMEs, wrong investment can lead to business failure)?"*

Response: *"In my experience, venture capitalists and start-ups rely on gut feelings, but never completely. You always need to check some facts and then rely on your intuition. There is no algorithm that can predict better then experienced entrepreneurs"*

Question 2: *"What's your thought on training the decision makers with the Adaptive toolbox & its building blocks with examples for Search, Stop and decision rule, do you think this will help them make better decisions?"*

Response: *"I am a partner of a start-up, Simply Rational, and we train decision makers using smart heuristics in the right situation"*

The responses from Dr Gigerenzer makes it clear that completely relying on gut feeling is not recommended as some facts and details have to be cross checked and then make the final decision based on intuition. However, at the same, time he emphasizes that there is no model algorithm that can 'predict' the outcome better than experience. And



the second response confirms our previous understanding that decision makers can be trained in heuristics decision making (additional reference: (Artinger et al., 2015)). Hence, it makes sense to see heuristic decision making combined with metacognition as a single decision making method, as from our literature study and expert interview this makes more sense for the situation of Digitalization decision in SME environment.

To answer our question “Is Heuristics really an advantage for SME digitalization decision?”, there is no single Yes or No answer. What can be said is that the benefit that Heuristics brings with respect to the time of decision arrival and the use of financial resources is incomparable with other decision making methods. At the same time, there is a high risk of business failure if the decision maker is compromised in terms of lack of experience and also the negative influence of biases (ClockShark, 2018). As an owner of a project or a business, it’s the job of the decision maker to critically evaluate their heuristics. And from the previous section it is clear that this can be achieved through training, either training self in methods like metacognition to cross check one’s heuristics or by undertaking external training or taking time to cross check the heuristic outputs with fact.

So in conclusion, if any of the training methods have been undertaken by the decision maker or has explicitly crosschecked intuition with facts, then heuristic is definitely an advantage when compared to other methods. Computation and analysis based methods take more time for each decision. Whereas with heuristics, training is a one-time effort and then decisions are arrived in a relatively very high speed, which is an important factor in SME (Radu Ogarcă, 2010). The same can be said about the cost. While software-based decision making methods carry a recurring license fee, heuristic needs just a one-time training fee.

This important conclusion will be taken into consideration when answering the first research question. Figure 12 is a flowchart that summarizes the second research question.

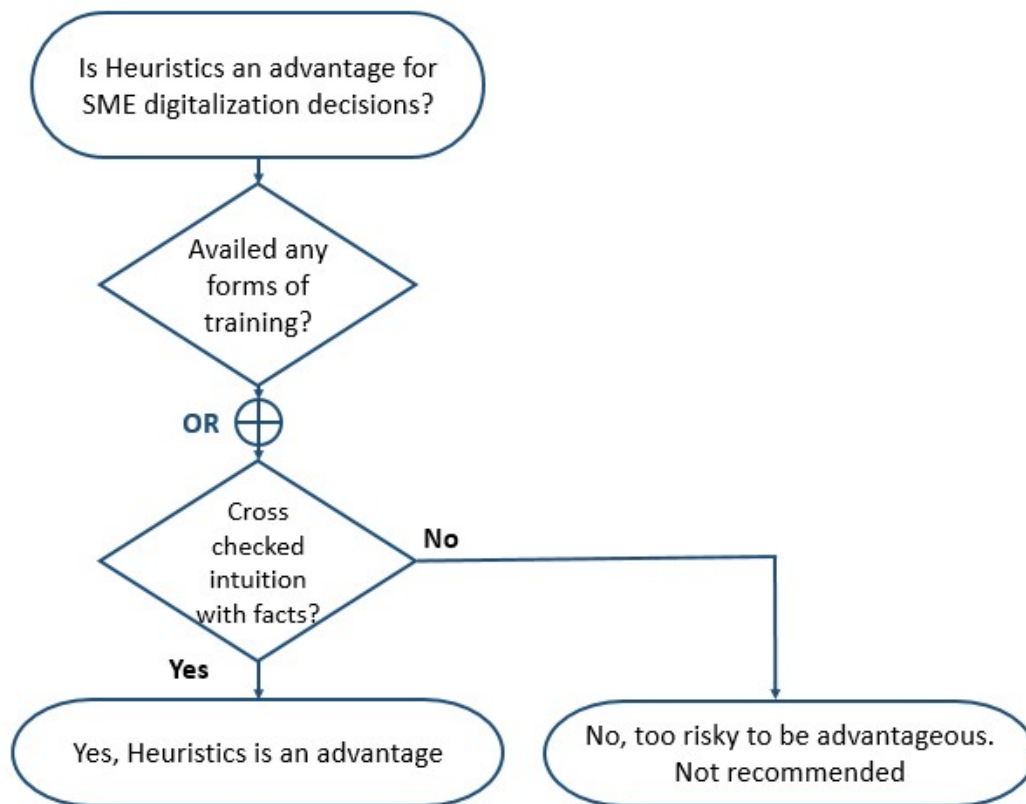


Figure 12: Flowchart summarizing research question 2

Before starting the Analysis through analytical hierarchical processes it is important to develop a model, with our focus or goal and the alternatives (figure 13). Then the next step is a pairwise comparison of these factors. The idea here is to find out the importance of each factor with regards to SME digitalization decisions. The weights for the pairwise comparison is also based on the Saaty's fundamental scale and has been performed with inputs from a Netherland based expert in behavioural decision making in IT projects, Dr. Arno Nuijten. He has interacted with more than three hundred SMEs managers and employees.

The third step is assigning the local priorities (or preferences) of alternatives with respect to each criterion (Ho W, 2008) i.e. deriving priorities (weights) for the criteria's (Ho W, 2008). It is important to assign weights to the different decision making methods we have selected in terms of the factors mentioned in the previous section based on the literature study, the ones that are important and which influence the SME digitalization decision. For each factor, weights are assigned according to Saaty's Fundamental scale (Saaty T.L., 1980), as in table 4.

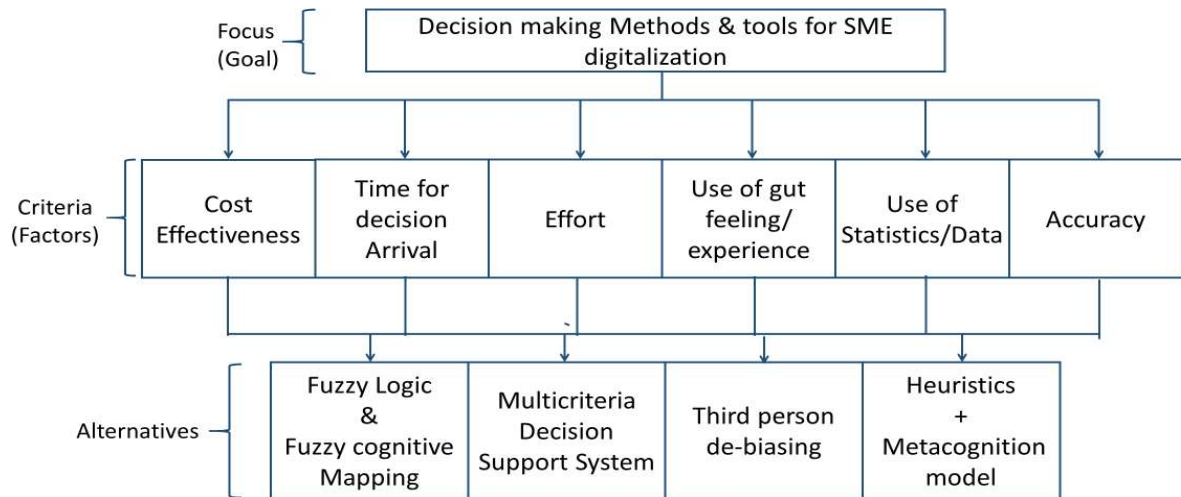


Figure 13: Model of Research with focus and goal

So the second step determines how important are in turn these factors in comparison with each other for an SME digitalization decision. And the third step helps determine how strong this decision making factor is for each of the decision making methods using a literature review.

The final step is to correlate and arrive at the result. This is done by adding up the product of weights of factors and ideal weight returned by pairwise comparison, also known as model synthesis (Ho W, 2008). The decision making method with the highest rating is the optimum solution to our first research question.

#### 4.1 Pair-wise comparison

The AHP pair-wise comparison is performed using an online software tool by Klaus .D Goepel, called: 'BPMSG's AHP Online System'-Rational decision made easy (Goepel, 2018). This thesis uses this software to perform the pair-wise comparison step of AHP.

Mathematically, in the backend, the software is based on the solution of the Eigen value problem. The result of the ' $n$ ' pair-wise comparisons are formed into a matrix. The first dominant normalized right Eigen vector of the matrix gives the weights. And the corresponding Eigen values gives the consistency ratio. (Goepel, 2018)

After creating and starting a new project, the first step is to define a hierarchy. It is done by typing in the syntax in the input field. Each branch in the hierarchy is defined by its

node (the category/the factor) and the nodes leaf (the subcategories). The node is followed by a colon, and a branch is closed by a semicolon as seen in the figure below.

## Input/Edit Hierarchy

Input or edit text in the text area below, then submit. (See [examples](#))

```
SME Digitalization Decisions:Cost effectiveness, Time for decision arrival,
Effort, Use of Gut feeling/Experience, Use of Statistics/Logic/Data, Decision
Accuracy;
```

Figure 14: Inputs for AHP node generation

This gives a preview of the output window, with all the factors but with equal weights as shown in the figure below. In the following steps to get the actual weights, a series of pair-wise comparisons need to be carried out by the software. The iteration continues till the first normalized matrix is received.

Decision Hierarchy		
Level 0	Level 1	Glb Prio.
SME Digitalization Decisions	Cost effectiveness <input type="text" value="0.167"/>	16.7%
	Time for decision arrival <input type="text" value="0.167"/>	16.7%
	Effort <input type="text" value="0.167"/>	16.7%
	Use of Gut feeling/Experience <input type="text" value="0.167"/>	16.7%
	Use of Statistics/Logic/Data <input type="text" value="0.167"/>	16.7%
	Decision Accuracy <input type="text" value="0.167"/>	16.7%
		1.0

Figure 15: Output preview before pair-wise comparison

The next step is to give inputs to undertake the pair-wise comparison. Here the inputs are from the expert as mentioned before. It is based on how these factors should compare against each other to get the best result in an SME decision on digitalization.

The following image shows the experts input in the AHP format with the Saaty's fundamental scale rating.

A - wrt SME Digitalization Decisions - or B?		Equal	How much more?
1	<input checked="" type="radio"/> Cost effectiveness	<input type="radio"/> Time for decision arrival	<input type="radio"/> 1 <input type="radio"/> 2 <input type="radio"/> 3 <input type="radio"/> 4 <input type="radio"/> 5 <input type="radio"/> 6 <input checked="" type="radio"/> 7 <input type="radio"/> 8 <input type="radio"/> 9
2	<input checked="" type="radio"/> Cost effectiveness	<input type="radio"/> Effort	<input type="radio"/> 1 <input type="radio"/> 2 <input type="radio"/> 3 <input type="radio"/> 4 <input type="radio"/> 5 <input checked="" type="radio"/> 6 <input type="radio"/> 7 <input type="radio"/> 8 <input type="radio"/> 9
3	<input checked="" type="radio"/> Cost effectiveness	<input type="radio"/> Use of Gut feeling/Experience	<input type="radio"/> 1 <input type="radio"/> 2 <input checked="" type="radio"/> 3 <input type="radio"/> 4 <input type="radio"/> 5 <input type="radio"/> 6 <input type="radio"/> 7 <input type="radio"/> 8 <input type="radio"/> 9
4	<input checked="" type="radio"/> Cost effectiveness	<input type="radio"/> Use of Statistics/Logic/Data	<input checked="" type="radio"/> 1 <input type="radio"/> 2 <input type="radio"/> 3 <input type="radio"/> 4 <input type="radio"/> 5 <input type="radio"/> 6 <input type="radio"/> 7 <input type="radio"/> 8 <input type="radio"/> 9
5	<input type="radio"/> Cost effectiveness	<input checked="" type="radio"/> Decision Accuracy	<input type="radio"/> 1 <input type="radio"/> 2 <input type="radio"/> 3 <input type="radio"/> 4 <input type="radio"/> 5 <input type="radio"/> 6 <input type="radio"/> 7 <input checked="" type="radio"/> 8 <input type="radio"/> 9
6	<input checked="" type="radio"/> Time for decision arrival	<input type="radio"/> Effort	<input type="radio"/> 1 <input type="radio"/> 2 <input type="radio"/> 3 <input type="radio"/> 4 <input type="radio"/> 5 <input type="radio"/> 6 <input checked="" type="radio"/> 7 <input type="radio"/> 8 <input type="radio"/> 9
7	<input type="radio"/> Time for decision arrival	<input checked="" type="radio"/> Use of Gut feeling/Experience	<input type="radio"/> 1 <input type="radio"/> 2 <input type="radio"/> 3 <input type="radio"/> 4 <input type="radio"/> 5 <input checked="" type="radio"/> 6 <input type="radio"/> 7 <input type="radio"/> 8 <input type="radio"/> 9
8	<input type="radio"/> Time for decision arrival	<input checked="" type="radio"/> Use of Statistics/Logic/Data	<input type="radio"/> 1 <input type="radio"/> 2 <input type="radio"/> 3 <input checked="" type="radio"/> 4 <input type="radio"/> 5 <input type="radio"/> 6 <input type="radio"/> 7 <input type="radio"/> 8 <input type="radio"/> 9
9	<input type="radio"/> Time for decision arrival	<input checked="" type="radio"/> Decision Accuracy	<input type="radio"/> 1 <input type="radio"/> 2 <input type="radio"/> 3 <input type="radio"/> 4 <input type="radio"/> 5 <input type="radio"/> 6 <input type="radio"/> 7 <input checked="" type="radio"/> 8 <input type="radio"/> 9
10	<input type="radio"/> Effort	<input checked="" type="radio"/> Use of Gut feeling/Experience	<input type="radio"/> 1 <input type="radio"/> 2 <input type="radio"/> 3 <input type="radio"/> 4 <input checked="" type="radio"/> 5 <input type="radio"/> 6 <input type="radio"/> 7 <input type="radio"/> 8 <input type="radio"/> 9
11	<input type="radio"/> Effort	<input checked="" type="radio"/> Use of Statistics/Logic/Data	<input type="radio"/> 1 <input type="radio"/> 2 <input type="radio"/> 3 <input type="radio"/> 4 <input checked="" type="radio"/> 5 <input type="radio"/> 6 <input type="radio"/> 7 <input type="radio"/> 8 <input type="radio"/> 9
12	<input type="radio"/> Effort	<input checked="" type="radio"/> Decision Accuracy	<input type="radio"/> 1 <input type="radio"/> 2 <input type="radio"/> 3 <input type="radio"/> 4 <input type="radio"/> 5 <input type="radio"/> 6 <input type="radio"/> 7 <input checked="" type="radio"/> 8 <input type="radio"/> 9
13	<input checked="" type="radio"/> Use of Gut feeling/Experience	<input type="radio"/> Use of Statistics/Logic/Data	<input checked="" type="radio"/> 1 <input type="radio"/> 2 <input type="radio"/> 3 <input type="radio"/> 4 <input type="radio"/> 5 <input type="radio"/> 6 <input type="radio"/> 7 <input type="radio"/> 8 <input type="radio"/> 9
14	<input type="radio"/> Use of Gut feeling/Experience	<input checked="" type="radio"/> Decision Accuracy	<input type="radio"/> 1 <input type="radio"/> 2 <input type="radio"/> 3 <input type="radio"/> 4 <input checked="" type="radio"/> 5 <input type="radio"/> 6 <input type="radio"/> 7 <input type="radio"/> 8 <input type="radio"/> 9
15	<input type="radio"/> Use of Statistics/Logic/Data	<input checked="" type="radio"/> Decision Accuracy	<input type="radio"/> 1 <input type="radio"/> 2 <input type="radio"/> 3 <input type="radio"/> 4 <input type="radio"/> 5 <input checked="" type="radio"/> 6 <input type="radio"/> 7 <input type="radio"/> 8 <input type="radio"/> 9

Figure 16: Input for AHP pairwise comparison

For example, in the first row, the expert has chosen 'Cost effectiveness' as more important than the factor next to it i.e. 'Time for decision arrival'. And the number scale that follows it on the right is the Saaty's fundamental scale (table 4). In this case, the expert has chosen '7', meaning 'Cost effectiveness' has very strong importance when compared with the 'Time for decision arrival'. Similarly, all the other 15 combinations are rated.

In this case 'n=15', so 15 pair-wise comparisons will be undertaken, when the 'Calculate' button is clicked. On doing this along with the pair-wise comparison a consistency check is also performed. This is to check and indicate inconsistent inputs. Consider three criteria or factors A, B and C. if factor A is preferred twice as much as B, and B twice as much as C. Then mathematically, the preference between A and C should be 4 ( $=2 \times 2$ ). But when a human is assigning preferences to a large number of factors amongst

each other there may be some deviations unintentionally. For the above example, instead of a preference of '4' between A and C, a value of '3' or '5' may be assigned unintentionally. This causes inconsistency in the system. To overcome this Saaty included this consistency check step during the pair-wise comparison. This eliminates any human error that comes in, if at all any.

To look for the most inconsistent comparison, we look for the pair  $i,j$  with

$$\max ( \epsilon_{ij} = a_{ij} \frac{p_i}{p_j} )$$

where  $p_i$  and  $p_j$  are priorities in the input side, with an  $N \times N$  pair-wise comparison matrix  $A = a_{ij}$ , the calculated principle eigenvalue  $\lambda_{max}$ . The consistency index  $CI$  is given as:

$$CI = \frac{(\lambda_{max} - N)}{N - 1}$$

Then consistency ratio  $CR$  is calculated using:

$$CR = \frac{CI}{RI}$$

Where Random Index,  $RI$  is predefined for a given order of matrix  $n$ .

$n$	1	2	3	4	5	6	7	8	9	10
$RI$	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

Figure 17: Random Index(RI) values for a 'n' dimension matrix (Saaty T.L., 1980)

To avoid inconsistent results, the consistency ratio should be below 10% or less than 0.1. On running the pair-wise comparison on the software as per the user input as in figure 18 an output is generated with 17.2 % inconsistency, i.e. 7.2% above the recommended 10 per cent.

CR = 17.2% Adjust highlighted judgments to improve consistency

Calculate Submit

Figure 18: Consistency ratio of Initial run

The software not only prompts the exact nodes or the location of the inconsistent input but also give the proper value to correct this inconsistency. Such fields are highlighted by green marks as seen in the following figure. The user can adjust these suggested values and run the calculation again. In our calculations, three inconsistencies were highlighted. First one between time for decision arrival and effort, '7' instead of '2'. Then '2' instead of '6' between time for decision arrival and use of gut feeling and experience. And finally, '8' instead of '9' between effort and decision accuracy.

A - wrt SME Digitalization Decisions - or B?		Equal	How much more?
1	<input checked="" type="radio"/> Cost effectiveness	<input type="radio"/> Time for decision arrival	<input type="radio"/> 1 <input type="radio"/> 2 <input type="radio"/> 3 <input type="radio"/> 4 <input type="radio"/> 5 <input type="radio"/> 6 <input checked="" type="radio"/> 7 <input type="radio"/> 8 <input type="radio"/> 9
2	<input checked="" type="radio"/> Cost effectiveness	<input type="radio"/> Effort	<input type="radio"/> 1 <input type="radio"/> 2 <input type="radio"/> 3 <input type="radio"/> 4 <input type="radio"/> 5 <input checked="" type="radio"/> 6 <input type="radio"/> 7 <input type="radio"/> 8 <input type="radio"/> 9
3	<input checked="" type="radio"/> Cost effectiveness	<input type="radio"/> Use of Gut feeling/Experience	<input type="radio"/> 1 <input type="radio"/> 2 <input checked="" type="radio"/> 3 <input type="radio"/> 4 <input type="radio"/> 5 <input type="radio"/> 6 <input type="radio"/> 7 <input type="radio"/> 8 <input type="radio"/> 9
4	<input checked="" type="radio"/> Cost effectiveness	<input type="radio"/> Use of Statistics/Logic/Data	<input checked="" type="radio"/> 1 <input type="radio"/> 2 <input type="radio"/> 3 <input type="radio"/> 4 <input type="radio"/> 5 <input type="radio"/> 6 <input type="radio"/> 7 <input type="radio"/> 8 <input type="radio"/> 9
5	<input type="radio"/> Cost effectiveness	<input checked="" type="radio"/> Decision Accuracy	<input type="radio"/> 1 <input type="radio"/> 2 <input type="radio"/> 3 <input type="radio"/> 4 <input type="radio"/> 5 <input type="radio"/> 6 <input type="radio"/> 7 <input checked="" type="radio"/> 8 <input type="radio"/> 9
6	<input checked="" type="radio"/> Time for decision arrival	<input type="radio"/> Effort	<input checked="" type="radio"/> 2 <input type="radio"/> 3 <input type="radio"/> 4 <input type="radio"/> 5 <input type="radio"/> 6 <input checked="" type="radio"/> 7 <input type="radio"/> 8 <input type="radio"/> 9
7	<input type="radio"/> Time for decision arrival	<input checked="" type="radio"/> Use of Gut feeling/Experience	<input checked="" type="radio"/> 2 <input type="radio"/> 3 <input type="radio"/> 4 <input type="radio"/> 5 <input checked="" type="radio"/> 6 <input type="radio"/> 7 <input type="radio"/> 8 <input type="radio"/> 9
8	<input type="radio"/> Time for decision arrival	<input checked="" type="radio"/> Use of Statistics/Logic/Data	<input type="radio"/> 1 <input type="radio"/> 2 <input type="radio"/> 3 <input checked="" type="radio"/> 4 <input type="radio"/> 5 <input type="radio"/> 6 <input type="radio"/> 7 <input type="radio"/> 8 <input type="radio"/> 9
9	<input type="radio"/> Time for decision arrival	<input checked="" type="radio"/> Decision Accuracy	<input type="radio"/> 1 <input type="radio"/> 2 <input type="radio"/> 3 <input type="radio"/> 4 <input type="radio"/> 5 <input type="radio"/> 6 <input type="radio"/> 7 <input checked="" type="radio"/> 8 <input type="radio"/> 9
10	<input type="radio"/> Effort	<input checked="" type="radio"/> Use of Gut feeling/Experience	<input type="radio"/> 1 <input type="radio"/> 2 <input type="radio"/> 3 <input type="radio"/> 4 <input checked="" type="radio"/> 5 <input type="radio"/> 6 <input type="radio"/> 7 <input type="radio"/> 8 <input type="radio"/> 9
11	<input type="radio"/> Effort	<input checked="" type="radio"/> Use of Statistics/Logic/Data	<input type="radio"/> 1 <input type="radio"/> 2 <input type="radio"/> 3 <input type="radio"/> 4 <input checked="" type="radio"/> 5 <input type="radio"/> 6 <input type="radio"/> 7 <input type="radio"/> 8 <input type="radio"/> 9
12	<input type="radio"/> Effort	<input checked="" type="radio"/> Decision Accuracy	<input type="radio"/> 1 <input type="radio"/> 2 <input type="radio"/> 3 <input type="radio"/> 4 <input type="radio"/> 5 <input type="radio"/> 6 <input type="radio"/> 7 <input checked="" type="radio"/> 8 <input checked="" type="radio"/> 9
13	<input checked="" type="radio"/> Use of Gut feeling/Experience	<input type="radio"/> Use of Statistics/Logic/Data	<input checked="" type="radio"/> 1 <input type="radio"/> 2 <input type="radio"/> 3 <input type="radio"/> 4 <input type="radio"/> 5 <input type="radio"/> 6 <input type="radio"/> 7 <input type="radio"/> 8 <input type="radio"/> 9
14	<input type="radio"/> Use of Gut feeling/Experience	<input checked="" type="radio"/> Decision Accuracy	<input type="radio"/> 1 <input type="radio"/> 2 <input type="radio"/> 3 <input type="radio"/> 4 <input checked="" type="radio"/> 5 <input type="radio"/> 6 <input type="radio"/> 7 <input type="radio"/> 8 <input type="radio"/> 9
15	<input type="radio"/> Use of Statistics/Logic/Data	<input checked="" type="radio"/> Decision Accuracy	<input type="radio"/> 1 <input type="radio"/> 2 <input type="radio"/> 3 <input type="radio"/> 4 <input type="radio"/> 5 <input checked="" type="radio"/> 6 <input type="radio"/> 7 <input type="radio"/> 8 <input type="radio"/> 9

Figure 19: Inconsistency marked in green

After correcting for the inconsistencies, the second run gave a result out consistency ratio of 8.1%, inside the 10% limit.

CR = 8.1% OK

Figure 20: Acceptable consistency ratio after correcting

Since the result is within the consistency limit, the resulting priorities are returned and ranked as shown in the following figure.

### Resulting Priorities

Cat		Priority	Rank
1	Cost effectiveness	16.6%	2
2	Time for decision arrival	4.1%	5
3	Effort	2.8%	6
4	Use of Gut feeling/Experience	9.1%	4
5	Use of Statistics/Logic/Data	11.8%	3
6	Decision Accuracy	55.7%	1

Figure 21: Priorities after pair-wise comparison

The first rank goes to decision accuracy with a weight of 55.7%, more than 50 per cent. All other factors combined have less than 50% weight. This means the accuracy of the decision is so important and plays a huge role in the success of the decision outcome and eventually, the business than the other lower rated factors like effort and time for decision arrival. In other words, its signalling that it is okay to take the time and extra effort in the decision making processes for an SME especially in a critical strategic decision like digitalization. And a mistake or inconsistency in this factor will be less hurtful to the business than compromising the decision accuracy, turning a blind eye to the cost and also the other two factors pertaining to data input strategies.

The next important factor is the cost effectiveness at 16.6%, also not surprising as cost is an important factor for SME's. But, at the same time getting the decision right or decision accuracy is 39.1% more important.



The third and the fourth rank goes to the information that is used for the decision making. Interestingly both gut feeling and experience and Statistics/Logic/Data are pretty closely weighed at 9.11% and 11.8% respectively. Moreover, the use of Statistics, Logic or data based method is preferred slightly more than gut feeling and experience, by 2.69%. In retrospection, even though it's just a small 2.69% increase, it is in accordance with what was previously discussed, when answering the second research question on Heuristics. That is, even though heuristic is very good or arguably the best method for decision making in the uncertain environment as per Dr Gigerenzer. The heuristics instincts need to be cross checked with facts. As for an SME or entrepreneur strategic decisions the stakes are high and also the risk. A mistake in an important strategic decision might cause the end of the business. Therefore, it makes sense to see here also in the pair-wise comparison the weight of both the different types of input information source to be close to each other but factual information source having a slight edge over heuristic.

Decision Hierarchy		
Level 0	Level 1	Glb Prio.
SME Digitalization Decisions <span style="border: 1px solid green; padding: 2px;">AHP</span>	Cost effectiveness <span style="border: 1px solid green; padding: 2px;">0.166</span>	16.6%
	Time for decision arrival <span style="border: 1px solid green; padding: 2px;">0.041</span>	4.1%
	Effort <span style="border: 1px solid green; padding: 2px;">0.028</span>	2.8%
	Use of Gut feeling/Experience <span style="border: 1px solid green; padding: 2px;">0.091</span>	9.1%
	Use of Statistics/Logic/Data <span style="border: 1px solid green; padding: 2px;">0.118</span>	11.8%
	Decision Accuracy <span style="border: 1px solid green; padding: 2px;">0.557</span>	55.7%
		1.0

Figure 22: Weights of the factors after Pair-wise comparison

## 4.2 Assigning local priorities

From the literature research, each decision making method are compared against each other based on the different factors that are important for SME digitalization decisions. They are summarized in the paragraphs below:

Fuzzy Logic and Fuzzy cognitive mapping: Assessing these decision making methods through the defined factors - (i) Cost effectiveness: There are free software's available online and also low cost options (Nápoles et al., 2018). (ii) In terms of time for decision arrival the method is rated for low decision arrival times (Papageorgiou, 2011). "the main reasons to use FCM is for its ease of use, ease to construct and parametrize, flexibility in representation (van Vliet et al., 2010) and easily understandable and transparent to non-experts and laypeople" (Rodriguez-Repiso et al., 2007). Which depicts the ease of the method or (iii) low effort requirements. In terms of knowledge requirement, the use of (iv) existing knowledge and experience and expertise (Papageorgiou, 2011) is sufficient and can be strengthened using (v) data (approximate values also suffice) that is available, if at all (Achanga et al., 2012). (vi) The results have high accuracy even in an environment with limited and incomplete information like in SMEs(Achanga et al., 2012).

Multiple criteria decision making : Assessing this from the factors defined: from the cost effectiveness the method is quite cost efficient as the software's used are available for free and also licensed versions are cheaper than methods that require hiring external analysts (Goepel, 2018). In terms of time for decision arrival (Renatus and Geldermann, 2016) points out in their research that the third factor 'Time', that this method is suitable for SME decision makers need for quick decisions. When it comes to ease of use, WHP is known for its simple evaluation method, methods like AHP does not involve sophisticated calculations and methods like TOPSIS, CRITIC and EDAS all involve single computation and most MCDM methods have software's that can do the computation. When it comes to the use of gut feelings and experience methods like AHP uses experiences to assign weights but not so much of gut feeling, at the same time some methods such as CRITIC need data to form weights(Siksnyte-Butkiene et al., 2020). So other than gut feeling both use of data and experience is characteristic of MCDM. And finally, when it comes to the accuracy with MCDM, the decisions are pretty accurate but however the necessity is the representation (Heli Saarikoski et al., 2016). Sometimes the interdependency of attributes might give inaccuracies (Siksnyte-Butkiene et al., 2020).

Third Person de-biasing: Assessing third person de-biasing from the factor defined. (i) when it comes to cost-effectiveness this method can be seen as one with zero investment as the idea is to get someone working in the same company to be an

observer in the decision making processes and indicate when a bias occurs with one of the four methods as seen before. (ii) Time of decision making can also be pretty fast as it does not require any calculations like MCDM or fuzzy logic, but just giving signals to the decision maker so that he or she corrects themselves away from biases. (iii) The same can be said about the effort, its quiet effortless decision making processes (iv) and being able to use gut feeling and experience is not necessary or required but every bit of experience improves the quality and effectiveness of the methods as the administrative man would be able to identify even the hidden biases quickly. (v) on the other hand when it comes to making use of existing data this method requires the administrative person to have knowledge about the different biases and their characteristics so that it can be identified when it occurs, (vi) and this fact is very much influences the accuracy of the decision, the more knowledgeable and neutral the administrative person is the better the accuracy of the decision (Nuijten et al., 2020).

Heuristic and metacognition: Analysing Heuristic in comparison with other three methods with the factors defined. (i) In terms of cost, the heuristic is also a method itself that does not require any investment for decision making. (ii) When it comes to speed of decision making, the heuristic is the fastest method in this research, also called 'fast and frugal' (Gigerenzer and Brighton, 2009). (iii) (Gigerenzer and Goldstein, 1996) also explains how effortless this method is, and in comparison to the other methods in this research again this is the most effortless. (iv)/(v) when it comes to the type of information required, heuristics is completely base on gut feeling and experience and does not theoretically use Probabilistic, statistical or logical data into consideration. (vi) Finally, the accuracy of the decision with heuristic is certainly not the best solution but a good enough solution with the shortest time with limited information. Hence in comparison to other methods it definitely cannot be said to be the most accurate decision making method, but should be noted that "with limited information and time", no doubt heuristic is the strongest (Gigerenzer, 2008).

For analysing and comparing among the above decision making methods we need to translate the qualitative to quantitative values which are done by rating the methods for every factor using Saaty's fundamental scale. The Saaty's fundamental scale uses a score from 1 to 9. With 1 having the least score and 9 the best among the methods compared.

**Cost Effectiveness:** here a score of '1' corresponds to expensive or least cost effective and '9' is the most cost effective among the considered options.

Both FCM and MCDM are software-based methods. There are free online tools and software available, but the licensed version would be recommended for flexibility in case of complex strategic decision making. Hence both these methods are rated at '5'. Third person de-biasing receives a score of '9' as the administrative man is the only requirement for this method and is already working in the company and can be trained with the information available freely. And finally, heuristics theoretically should also be very cost effective, but after the literature review and the inputs from the expert, it was found that for strategic decision making the heuristic inputs need to be crossed check and might require training from experts in using Heuristic in SDM, but in case training is usually performed by external trainers and only once. In this case, it's not very cost effective as third person de-biasing so will be rated as '7' for this analysis.

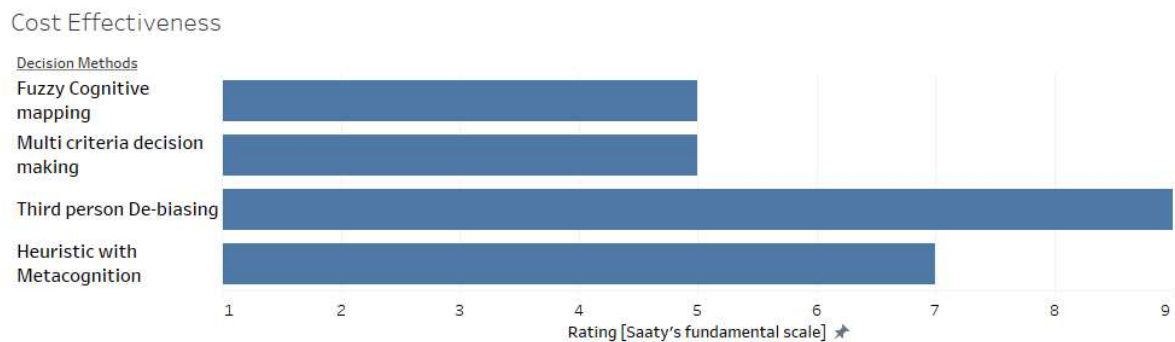


Figure 23: Decision making methods rated according to Cost effectiveness

**Time for decision arrival:** The fastest method here would be '9' on the fundamental scale and the slowest a '1'. The faster a decision can be made the better in an SME environment.

When it comes to arriving at decisions both FCM and MCDM requires some preparation before the analysis can be started. Such as defining objective and model creation, identifying alternatives and influencing factors, weighing them etc., and the analysis itself also takes time. The analysis is then mostly performed with software and MCDM analysis has extra steps of pairwise comparison as compared to FCM, so for the same decision problem FCM can be a bit faster. Hence FCM is rated at '5' and MCDM at '4'. Third person de-biasing is a bit faster than the software based method but in practice

will need discussion between the administrative man and the decision maker whenever a bias is encountered as compared to heuristic which is the fastest of the four methods, However, for SDM decisions with Heuristic might require a bit of crosschecking. Hence, both are equally rated at '7'.

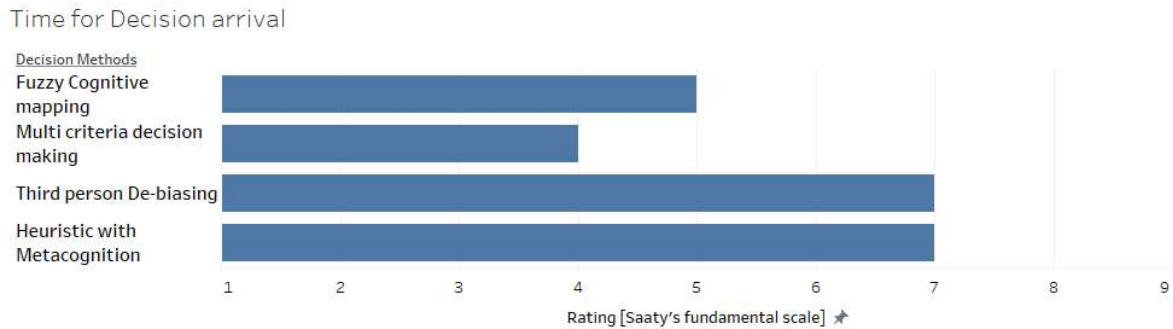


Figure 24: Decision making methods rated with respect to time needed to arrive at a decision

**Effort:** In terms of effort a score of 1 means high effort and 9 is almost effortless

The two software methods have more effort including some preparation before the analysis can be started such as defining objective and model creation, identifying alternatives and influencing factors, weighing them and then analysing and arriving at conclusion. Hence, both are rated at '4'. Heuristic and third person de-biasing is comparatively effortless. Also, both require training effort, but only once in the beginning and not every time a decision needs to be made and hence that effort is not considered here. And in the case of the heuristic training effort is external and another extra effort heuristic has is cross checking effort. So, in conclusion, third person de-biasing is more effortless than Heuristic. Hence de-biasing is rated at '9' and heuristics at '7'.

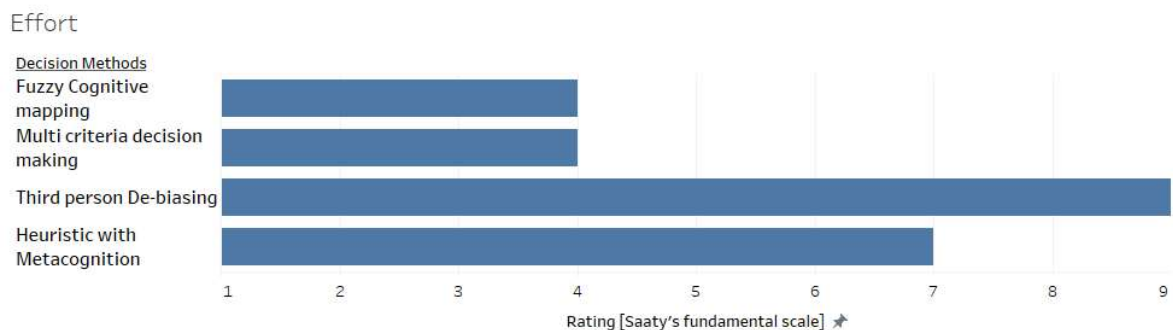


Figure 25: Decision making methods rated with respect to the needed Effort

**Use of Gut feeling and experience:** Complete use of gut feeling is rated at '9' as complete use of gut feeling has benefits in SME environment by influencing other factors like time, cost and effort. A case when it has no influence on the method can also be rated as 9, as it does not bring any of the disadvantages with it and rating it 9 will ensure mathematical neutrality. And accuracy has not much influence on gut feeling based method or logical/ statistical methods as per the Literature study, as accuracy is dependent on the amount of error that is induced and not on the method used itself.

Here Both FCM and MCDM are predominantly logic-based decision making methods and should not involve much gut feeling. However, in practice, the decision maker tends to use gut feelings based experience when weighing the factors and therefore this factor is rated at '5', as the weights form the basis for the result calculation but do not fully influence the decision as consistency checks during analysis can correct this up to a certain extent. Third person de-biasing is based on facts and knowledge-based training with little influence on gut feeling from experience, but at the same time this fact based training is done before hand and not during the decision making and has no influence on time, cost or effort on the method hence can be rated at '9'. And finally, heuristic, even tough is based on gut feeling during SDM decision needs a bit of crosschecking the gut feeling with facts hence is rated at '7'.

Able to use Gut feeling/Experience



Figure 26: Decision making methods rated with respect to the ability to use Gut feeling & Experience

**Use of Statistics/logic/data:** this can be argued to be opposite to gut feeling, as the use of statistics or data can take away time and cost money to source the required data and requires more effort from the decision maker's point of view. It is true in a general isolated situation. In our research for SME digitalization decisions, we found out the importance of cross checking instincts from gut feelings and experiences with facts and data is very important. A situation where spending other resources like effort, time and

money might not be ideal in an SME decision making environment. Hence the decision making methods that use up a lot of time, effort and money for information based on Statistics/Logic and data will be rated less compared to the ones that don't. But, the factor 'Use of Statistics/Logic/Data' will be rated as a favourable factor in the model synthesis step, to take into the importance of supplementing gut feeling with Factual data and logic when it comes to SME strategic decision applications.

Even though FCM and MCDS are predominantly logic based decision making methods, it has the influence of gut feeling especially, when assigning weights. And since the analysis is dependent on this weight it can be said that these methods can be rated at '4'. The method of third person de-biasing is based on the knowledge of the administrative man trained with facts and information on biases in decision making, however, gut feeling can influence experienced persons in this role and therefore is rated at '3', slightly less influential than FCM and MCDS. Heuristics is mostly completely gut feeling based, but as we learned in SDM the instincts need to be cross checked, hence receives a score of '7'

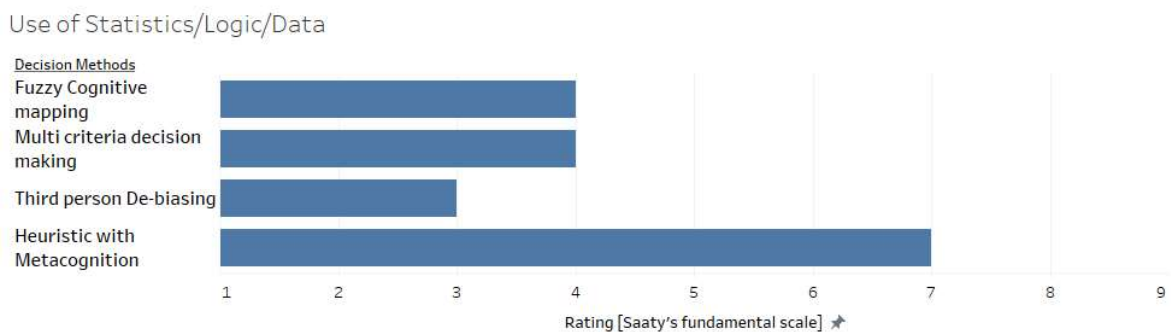


Figure 27: Decision making methods rated with respect to the dependency on Statistics, Logic and factual data

**Accuracy of decision:** Accuracy is something that is very difficult to rate as it is dynamically dependent on different situations, for a general situation of a dynamic SME decision making environment a rating between 1- low accuracy and 9- highly accurate can be assigned as by studying the disadvantages and limitation of each of them.

FCM is pretty accurate in an SME decision making environment as long as the person assigning the weights has sufficient knowledge (Wojciech Stach et al.) otherwise it can result in inaccuracy the same applies to MCDM (Siksnylyte-Butkiene et al., 2020), but since of the decision makers in SMEs may not always have all the information the

tendency of error incursion is higher in FCM and MCDM in general. Third person de-biasing is definitely better in accuracy than FCM and MCDM. The limitation here is that it might be difficult for the administrative man to familiarize the characteristic, symptoms and suggestive actions for all the biases as there are so many of them, and also at the same time there might be some undiscovered biases (Nuijten et al., 2020). But having said that they can be trained in the most common biases and a guidebook or a handout for reference to overcoming this issue to the most extent. Finally, Heuristic decision making as per the literature is the best suited for SME decision environment supported by the fast and frugal concept, the adaptive toolbox and less is more concept etc. (Gigerenzer, 2008; Gigerenzer and Brighton, 2009; Gigerenzer and Goldstein, 1996), however, as brought up the expert interaction that in a strategic decision in SMEs this method cannot be completely utilized on its own without cross checking the intuitions. The literature review found that heuristic in combination with metacognition can act as a cross check to blind intuition or undergoing a training in heuristic strategic decision making for SMEs. When this is ensured it can be taken as the most accurate decision making method out of the four options. Heuristics for SME SDM can be rated as '8', the third person de-biasing a '6' and FCM and MCDM in an environment with decision makers who predominantly are not experts in all aspects and factors that a complex strategic decision brings with, can be rated at '4'.



Figure 28: Decision making methods in terms of accuracy in SME strategic decisions

The local priorities of factors for the different decision methods can be summarized in the following table



	Fuzzy Cognitive Mapping	Multicriteria Decision Making	Third person De-biasing	Heuristic with Meta cognition
Cost Effectiveness	5	5	9	7
Time for decision arrival	5	4	7	7
Effort	4	4	9	7
Use of Gut feeling/Experience	5	5	9	7
Use of Statistics/Logic/Data	4	4	3	7
Decision Accuracy	4	4	6	8

Table 5: Summary of Local priorities of the factors for the different decision making methods

### 4.3 Deriving overall priorities and final solution: Model Synthesis

In model synthesis, we combine the ideal weights from section 4.1 and the local priorities derived in section 4.2 to arrive at the best decision making method for SME digitalization.

The first step here is to normalize the local priority values obtained. That is dividing each column value with the preferred value in that column. The idea here is to have the values between 0 and 1 so that the final results can be compared easily. For our six factors the preferred value for each of the factors will be:

1. Cost effectiveness: Preferred value is the one with the highest rating as that is the most cost effective one
2. Time for decision arrival: The highest value is preferred here as faster decision making is favourable for SME strategic decisions
3. Effort: Effort is not a deal breaker but, less effort is preferred. Hence, the highest rating is preferred as it signifies the lower effort
4. Use of Gut feeling/ Experience: Also has a positive relationship as explained in the previous sections and therefore highest value is preferred
5. Statistic/Logic/Data: As discussed in section 4.2, this factor here will be preferred with a higher value for its importance in assisting gut feeling and instincts in strategic decision making for SMEs.

6. Decision accuracy: For accuracy also the highest rating is the preferred one.

The following table shows this, with preferred values being marked in red

	Cost Effectiveness	Time for decision arrival	Effort	Use of Gut feeling/ Experience	Use of Statistics/ Logic/Data	Decision accuracy
Fuzzy Cognitive Mapping	5	5	4	5	4	4
Multicriteria Decision Making	5	4	4	5	4	4
Third person De-biasing	9	7	9	9	3	6
Heuristic with Meta-cognition	7	7	7	7	7	8

Table 6: The preferred value for each factor

For normalization, we now divide each column with its highest values to get a ratio between 0 and 1, since all our preferred values are the highest. In situations where the lowest is preferred then that lowest number is divided with each column value. The idea remains the same.

	Cost Effectiveness	Time for decision arrival	Effort	Use of Gut feeling/ Experience	Use of Statistics/ Logic/Data	Decision accuracy
Fuzzy Cognitive Mapping	$5/9 = 0.556$	$5/7 = 0.714$	$4/9 = 0.445$	$5/9 = 0.556$	$4/7 = 0.571$	$4/8 = 0.500$
Multicriteria Decision Making	$5/9 = 0.556$	$4/7 = 0.571$	$4/9 = 0.445$	$5/9 = 0.556$	$4/7 = 0.571$	$4/8 = 0.500$
Third person De-biasing	$9/9 = 1.000$	$7/7 = 1.000$	$9/9 = 1.000$	$9/9 = 1.000$	$3/7 = 0.428$	$6/8 = 0.750$
Heuristic with Meta-cognition	$7/9 = 0.778$	$7/7 = 1.000$	$7/9 = 0.778$	$7/9 = 0.778$	$7/7 = 1.000$	$8/8 = 1.000$

Table 7: Values after normalization

Now the next step is the model synthesis. Here the weights obtained by the pairwise comparison are correlated with the normalized matrix of the local priorities. In this step for each decision making method, the priority value of a factor is multiplied with its corresponding ideal weight obtained from the pair-wise comparison. And the six products so obtained from the six factors are summed to obtain a value that is the overall priority of that decision making method. This step is repeated for all the decision making methods to obtain their corresponding overall priorities. The method with the highest

overall preference will be the best decision making method based on the factors considered in an SME environment for a Strategic decision on digitalization.

	Cost Effectiveness	Time for decision arrival	Effort	Use of Gut feeling/ Experience	Use of Statistics/ Logic/Data	Decision accuracy
<b>Weights</b>	<b>0.166</b>	<b>0.041</b>	<b>0.028</b>	<b>0.091</b>	<b>0.118</b>	<b>0.557</b>
Fuzzy Cognitive Mapping	0.556	0.714	0.445	0.556	0.571	0.500
Multicriteria Decision Making	0.556	0.571	0.445	0.556	0.571	0.500
Third person De-biasing	1.000	1.000	1.000	1.000	0.428	0.750
Heuristic with Meta-cognition	0.778	1.000	0.778	0.778	1.000	1.000

Table 8: Table of normalized local priorities with their weights

Overall priority for 'Fuzzy Cognitive Mapping':

$$\rightarrow (0.556 \times 0.166) + (0.714 \times 0.041) + (0.445 \times 0.028) + (0.556 \times 0.091) + (0.571 \times 0.118) + (0.500 \times 0.557) = \mathbf{0.530504}$$

Overall priority for 'Multicriteria Decision making':

$$\rightarrow (0.556 \times 0.166) + (0.571 \times 0.041) + (0.445 \times 0.028) + (0.556 \times 0.091) + (0.571 \times 0.118) + (0.500 \times 0.557) = \mathbf{0.524641}$$

Overall priority for 'Third person De-biasing':

$$\rightarrow (1.000 \times 0.166) + (1.000 \times 0.041) + (1.000 \times 0.028) + (1.000 \times 0.091) + (0.428 \times 0.118) + (0.750 \times 0.557) = \mathbf{0.794254}$$

Overall priority for 'Heuristics with metacognition':

$$\rightarrow (0.778 \times 0.166) + (1.000 \times 0.041) + (0.778 \times 0.028) + (0.778 \times 0.091) + (1.000 \times 0.118) + (1.000 \times 0.557) = \mathbf{0.93773}$$

Decision making methods	Overall priority
Heuristics with metacognition	<b>0.93773</b>
Third person de-biasing	<b>0.794254</b>
Fuzzy cognitive mapping	<b>0.530504</b>
Multicriteria decision making	<b>0.524641</b>

Figure 29: Overall priority for each decision making method

The results of model synthesis give us the solution for our first research question of which is the best decision making method or tool for SME digitalization decisions. Clearly, the best method to come out of the analysis is Heuristics with metacognition. Not far behind is Third person de-biasing. Analytical methods like Fuzzy cognitive mapping and Multicriteria decision making ended up with lower priority in our research case. The following figure shows them relative to each other.

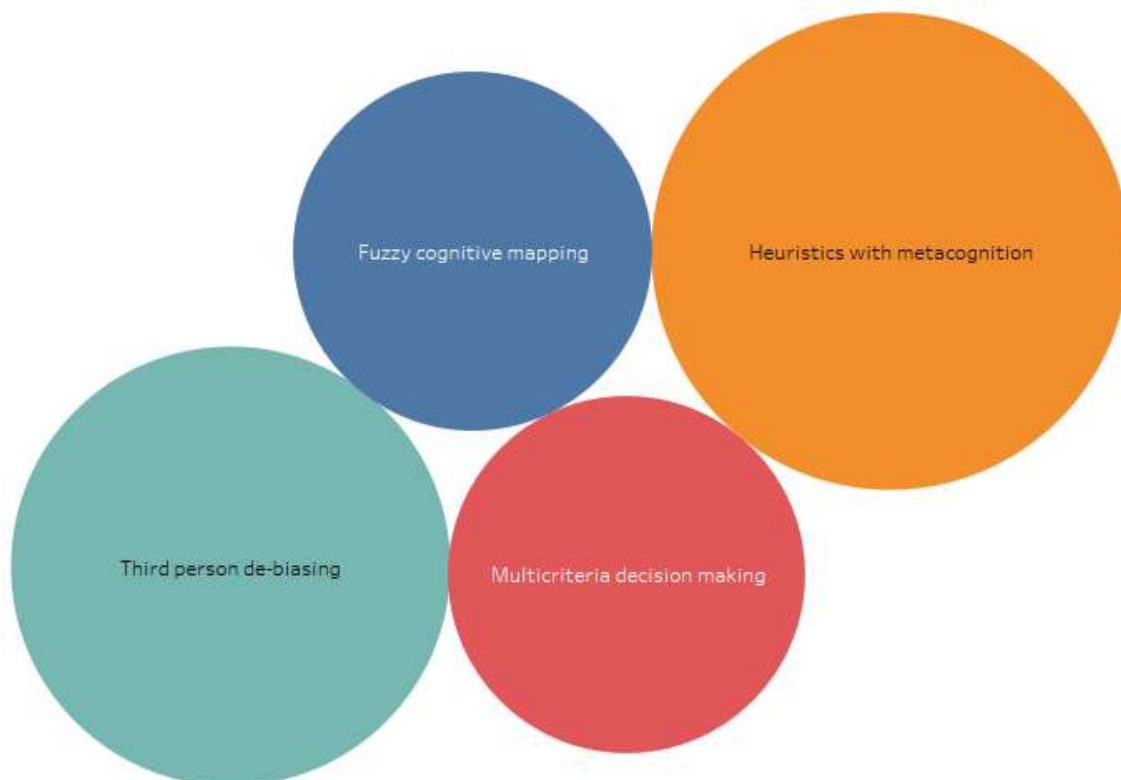


Figure 30: Overall priority relative to one another

## 4.4 Analysis and Discussion

The computational methods are relatively close to each other, and is also expected so, as both of them are similar in the processes of execution. The intuition based methods are prioritized much better in comparison. And among them, Heuristics with metacognition is the overall best with Third person de-biasing coming slightly behind in the second place. The obvious conclusion here is that in the decision situation considered and the factors thus evaluated, intuition-based methods are more suited for an SME digitalization decision than the computation based methods.

Another thing that can be noted here is that even though third person de-biasing has more '9's in its local priorities than heuristic with metacognition, heuristic has higher overall priority due to the significance of the weight of the 'decision accuracy' factor.

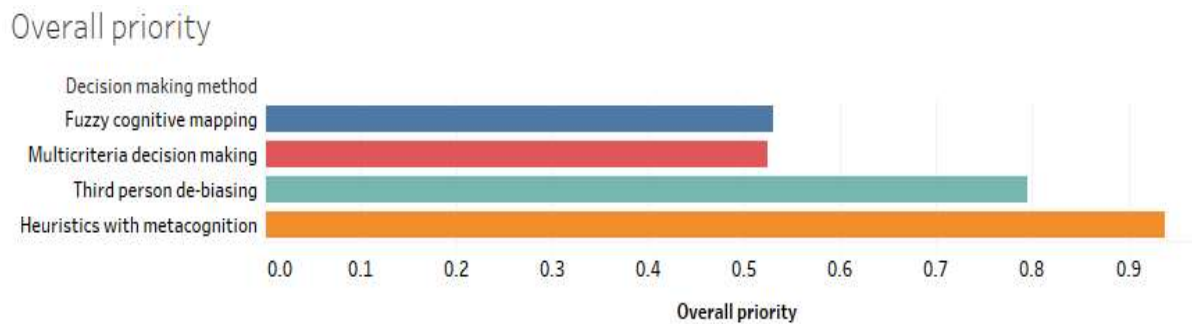


Figure 31: Overall priority values relative to each other

The two most important factors for a decision making method are cost effectiveness and accuracy of the decision, as found out in section 4.1. These two dimensions can be combined with the third dimensions of overall priority using a three dimensional bubble chart as shown in the figure below. It also makes sense to analyse these two factors separately as in this study, as they weigh far more than the other factors. The sum of the top two factors consists of 72.3% of the total weight, compared to only 27.7% for the remaining four factors

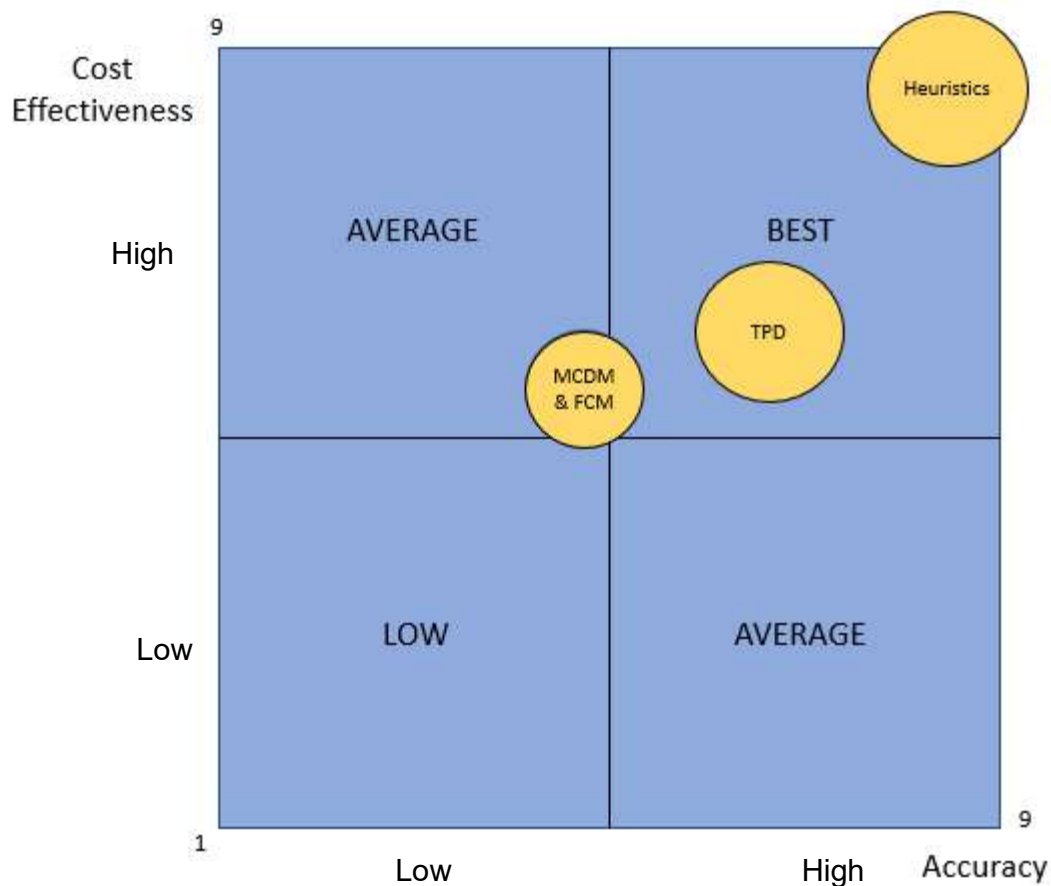


Figure 32: Bubble diagram with respect to the top two factors

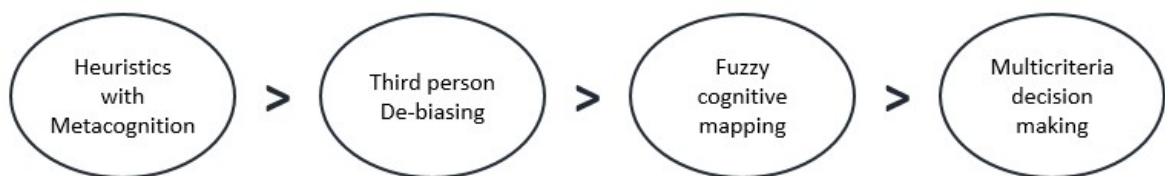
The three bubbles represent the four decision making methods, their sizes correspond to their overall priorities. The 'x' axis represent the most important factor of 'Decision Accuracy' and the 'y' axis represents the second most important factor, 'Cost effectiveness'. It must be noted that the bubbles for Fuzzy cognitive mapping and Multicriteria decision making overlap as both of them have the same score for both the factors and radius also being quite similar owing to the almost similar overall priority. MCDM is ever so slightly smaller than that of FCM. However, here the sizes of the bubbles are just to compare the final overall priority, which includes all six factors. This should not be confused as a priority with just the two factors and is also not of much importance for the following analysis.

It is interesting to observe from this bubble diagram that when only the most two important factors are considered, then none of the decision making methods falls in the 'LOW' zone. A LOW region in the bubble diagram represents that particular method has a low weight for two factors considered on axes. The region 'AVERAGE' corresponds

to where one factor is low and 'BEST' where both the factors have high weight and hence, the decision making methods that fall in this region are better suited.

The analytical methods of FCM and MCDM clearly fall in the AVERAGE section, whereas intuition-based methods of Third Person De-biasing and Heuristic with Metacognition are in the BEST section. Also, Heuristic doing much better than De-biasing.

From the two observations and analysis, we can conclude that definitely out of the four decision making methods for a strategic decision involving digitalization, the most favourable one is Heuristic with Metacognition. When these are ranked against one another, the optimal method to the least optimal methods are as seen in the following figure.



*Figure 33: Order of preference of Decision making methods for SME digitalization decisions*

The second part of the first research question 'which decision making suits what situation' was added into this research to see if there are any situation where one decision making method fits the best. Through literature study and the analysis, this research did not find a clear situation where any one of the four considered decision making methods explicitly fits the best. Each method has its own advantages and disadvantages. The order of priority as seen in figure 32, describes the priority of decision making for an environment that this research focused on.

## 5 Conclusion

This research aimed at studying deeply and thoroughly the two challenges faced by SMEs, namely Digitalization and Strategic Decision making. For the ease of research, the vast topic was broken down into two research questions: *Which decision making tool is best suited for SME digitalization decisions? Or which suits what situation?* And gave additional focus on Heuristics, the current hot topic in SME decision making, by asking the question *Is heuristics really an advantage in SME digitalization decisions?*

The underlying purpose was that SMEs cannot directly use any decision making methods like a big company as they have like financial and intellectual constraints and also lack of manpower. Out of all the available decision making methods available, it was necessary to find out through literature research which of these decision making methods or support tools are suitable for a dynamic decision making environment like in an SME. And as the next step through analytical and comparative study find out which of these methods suits best or rate them according to their suitability, in the use case of a decision regarding SME digitalization.

The approach of systematic literature review helped not only to collect the information but also study them systematically, which is a more effective way. The outcomes of the systematic literature review facilitated in finding out some decision making methods that were suitable for a dynamic SME digitalization situation: Fuzzy cognitive mapping, Multicriteria decision making, Third person De-biasing and Heuristic with metacognition. Similarly, it also helped to identify the six main factors, with which that these decision making methods should be analysed to rate them according to the digitalization use case. The factors were: Cost effectiveness, Time for decision arrival, Effort, Ability to use gut feeling/ intuition/ experience, Use of Statistics/ Logic/ data and decision Accuracy.

In the result section, the second research question was answered as Heuristic is a key player in SME decision making and the findings from this could be used to get a clearer idea when answering the first research question. Here, the opinion of the leading heuristic expert and the person behind the heuristic toolbox himself was also consulted. In the second section, Analytic Hierarchy Process was used to compare the four



decision making methods with respect to the six factors to rate them according to their suitability for an SME digitalization decision.

During the research and in completion of this thesis a few challenges were Identified. These are listed below and can be used as motivation to form the basis of recommendations for future studies:

- This research did not go deep into the subcategories of decision making methods but took the general characteristics of them. For example, there are more than forty different decision making methods under Multicriteria decision making itself. A recommendation here is to look into also subcategories, maybe there are some methods, where the factors suit SME digitalization decision situation way better than when factors are considered for the general group.
- Similarly, there can be a better method than metacognition that goes well with the heuristic. The scope of this study's literature review was focused on main methods. The second recommendation for future research is to look into the '*Smart heuristics*' training methods for SME decision makers, similar to the one proposed by Dr Gigerenzer.
- The ideal weights for this study were obtained from one expert. A recommendation here would be to collect it from more experts, if possible from different regions and take the average weight. This would make the weights more generalized and universal.

This research tries to fill the gap linking strategic decision making methods and Digitalization in SMEs, also explores how the emerging concept of heuristics help bridge this gap. There are still many opportunities for future research in the area of Strategic decision making involving SME digitalization, and also slowly the research on heuristics is picking up day by day. The continuation of this research could help bridge the gap between SMEs and large companies in terms of the extent of digitalization and also make decision making for SME decision making easier, effective and accurate and thus also preventing the business failure of the economic backbone on many nations, the small and the medium sized enterprises.

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