



Analysis of errors during the construction of large press tools and development of a lessons learned process

by

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Thesis submitted to the Faculty of Engineering and Management,
in partial fulfilment of the requirements for the
degree of Master of Engineering in the study program
Automotive Production Engineering (M.Eng.)

Issued on: 16.10.2020

Submitted on 24.03.2021

Matriculation no. 00103863

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Abstract

Thesis topic:	Analysis of errors during the construction of large press tools and development of a lessons learned process
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Submitted on:	24.03.2021
First Examiner:	Prof. Dr.-Ing. Martin Bednarz

“Every process can be improved further and there is no upper limit to an improvement” as rightly pointed out by Mr Alexander Smith shares a broad insight into not just a manufacturing company but life in general. The concept of continual improvement not only plays a vital role in our lives an individual but also the processes followed by an organisation to develop a product or provide a service in a very cost-competitive market. Among the various areas of organisational development, a key area is business process improvement as stated in research by Tony et al. [1]. The construction of large press tools is a resources intensive, time-consuming and expensive process which in the scope of an automotive manufacturer requires an immense collaboration of a large number of internal and external departments, external companies and other stakeholders. Since any deviation in the prescribed process costs time and money for modification to ensure quality, it is important to develop a process to analyse the typical errors which rise during the construction, classify them and find out the improvement potentials in the internal and external working. Keeping this goal in mind a structured approach is taken to study the process of construction of large press tools in BMW, develop tools to automate the analysis process and finally a lessons learned process is described to cascade the learnings from the results intra and inter department.

Statutory Declaration

I declare that I have authored this thesis independently, that I have not used other than the declared sources/resources, and that I have explicitly marked all material that has been quoted either literally or by content from the used sources.

This thesis was not previously presented to another examination board and has not been published.

Ingolstadt, 24.03.2021



First and last name

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III List of Abbreviations

BMW	Bayerische Motoren Werke AG
PDCA	Plan Do Check Act
SE	Simultaneous Engineering
PMPA	Project Management Performance Analyser
APM	Association for Project Managers
EWS	Early Warning System
Le Le	Lessons Learned
OEE	Operative Equipment Efficiency
BBA	BMW Brilliance Automotive
EPE	Einpresselemente
BPM	Business Process Management

1 Introduction

“Every process can be improved further and there is no upper limit to an improvement” as rightly pointed out by Mr Alexander Smith shares a broad insight into not just a manufacturing company but life in general. The concept of continual improvement not only plays a vital role in our lives of an individual but also the processes followed by an organisation to develop a product or provide a service in a very cost-competitive market. Among the various areas of organisational development, a key area is business process improvement as stated in research by Tony et al. [1]. With high number of well-established automakers in the market and innovative upcoming newcomers, there is a need to be competitive. With a competitive environment, there is a focus on effective management systems as found by Pinto et al. [2]. The need arises to find the value-added process and the non-value added in a development process arise from this ideology. While the value-added processes add value in a product there is no benefit for the existence of steps which does not add value and hence there should be eliminated. Value stream mapping has gained importance over the years and has a high reputation of uncovering waste in manufacturing, production and business processes. The ideology helps in identifying, removing or streamlining value-added steps and non-value-added steps thus increasing the efficiency of the whole process [3]. One case study by Nallusamy [4] reported an increase of 10% process cycle efficiency and non-value-added time reduced by 13% by using lean tools such as 5S, VSM, line balancing in a major automotive manufacturing assembly line.

While the German automakers such as Daimler, Volkswagen Group, Porsche implement various internal methods to optimise processes on the shop floor and beyond, BMW Group is no exception. The final product as a vehicle in BMW starts from the first steps of top car design (identifying trends, hand-drawn sketches, tape drawings, digital models, clay models, realisation) at which point the design is revealed to the internal departments which then start working at least a year or more before the start of production of the vehicle. Each department has its responsibilities and goals set in the development process. Each goal or responsibility is carried with strict adherence to a defined process plan. With the help of the master thesis in the department of TP-110 (responsible for the Die and Tooling Design, Press Simulation and Standards) a process optimisation goal is set. By setting goals to find the effects and analyse the usual design errors, level of collaborative work of internal and external stake holders in the company and at the end to suggest a lesson learned process description, the department hopes to eliminate the non-value added activities in the process plan and improve the working of the department internally and externally with the stake holders. Because of the work with suppliers, there is a need to evaluate them, uncover potential for improvements on their side

and the working with BMW. A lesson learned is of no use if it is not shared with colleagues horizontally and vertically in an organisation. As stated by Duffield in his research, knowledge and project management literature indicate that in practice lessons learned processes rarely happen in organisations. When it does the organisation fails to go beyond lessons identification and move to organisational learning. Duffield finds out over 67% of the general management from the top Fortune 500 companies globally fail to implement the right methods from the limited practical models available and hence fails to use to conceptualise what organisational learning is and therefore enable it [4]. Tapping into the already existing practices in BMW, an Obeya approach is finalised. Lindlof et al. explain the benefits and limitations of visual planning and knowledge sharing and how it is gaining traction over the years. The benefits of such a system as mentioned by him are efficient communication, shared understanding, ability to prioritise tasks and efficient levelling of workloads [5]. With the help of a few tools, a few of which conceptualised during the work and some which are already existing, act as a source of inputs for the Obeya methodology to work.

1.1 Background

BMW Group, an acronym for Bayerische Motoren Werke AG, is a German multinational and one of the largest automobile manufacturers of luxury vehicles and motorcycles. Founded in 1916 originally as a manufacturer of aircraft engines, it now has brands such as BMW, Mini, Roll-Royce under its name.

The development vehicles are distributed among the departments. Responsibilities are divided internally in BMW. Each department has its functions and responsibilities. The TP segment falls under the Production umbrella of the complete organisation. TP stands for Production System, Technical Planning, Tool Shop, Plant Construction. The category is further subdivided into different sub-segments among which TP-1 is responsible for Forming and Hang-on Parts and in turn TP-110 is responsible for the Die and Tooling Design, Press Simulation and Standards.

1.2 Thesis outline

The functioning of the department is critical to the development of the backbone of the vehicles. Despite the arrival of carbon fibre sheet metal forming is still of great importance to BMW and the automotive industry in general. The complexities of designing, optimising and developing a press tool to form sheet metal into various parts of an automobile and ensuring that it

functions, and forms parts as expected for the lifetime of the production of the specific model or even more. Several specialists work in tandem to develop the press tools.

This process brings the need to be monitored and improved with the PDCA approach. There is a need to evaluate the process and quantify the results in order to improve it at regular periods. Starting from the project kick-off the project moves in one direction with the constant collaboration of the Design Reviewers from TP - 110, Project Integrators, Suppliers, Sub Suppliers, and Tool Shop Colleagues. There is a possibility of communication gap, responsibility mismatch and technical errors in design, review and development. The tasks in the thesis are in line with the topic of the analysis of big press tools and develop a lesson learned process. The tasks can be classified as in the following diagram. The tasks are divided in the form of finding a method to collect the process deviations in the existing process, developing a tool to bring to the surface the deviations, a way to analyse them and compare certain data. The lessons learned process enables the flow of information vertically as well as horizontally.



Figure 1.1: Project task overview

The overview of the project tasks as shown in above picture percolate down to minor detailed tasks which are described in Section 3. The individual tasks are taken as the goal or objective to start the thesis.

1.3 Motivation

A business process is a routine within which an individual or management follows to attain business goals. The flow of the processes in a business influences its efficiency. Most companies use the same approach to achieve their goals over the years. As long as they make profits, they don't see the need to refine their business processes. Streamlining processes aims to optimise operational tasks. It involves eliminating unnecessary steps, employing new technology, and implementing alternative methodologies. The intended results of business optimisation are maximum profits, motivated employees, and satisfied stakeholders.

No matter what, processes should always function at their peak efficiency. Efficiency has a direct impact on the productivity of employees who use these processes. In a regular situation, what happens if an employee has a faulty device and it takes two days for the IT team to respond? The employee is forced not to work the entire time. Companies that have been around for a while don't have the liberty to scrape off everything and rebuild their processes from scratch. These companies nail down detailed processes the first time and continue to use them for a long time. The easiest and best option is to optimize processes constantly.



Figure 1.2: Process improvement areas

Process optimization is the discipline of adjusting a process to optimize a specified set of parameters without violating a few constraints. The most common goals are minimizing cost and maximizing throughput and/or efficiency. This is one of the major quantitative tools in

industrial decision making. Business process optimization is the practice of increasing organizational efficiency by improving processes. It's a part of the discipline of business process management (BPM). Optimized processes lead to optimized business goals. Steps to implement business process optimization. Planning is essential to make the most out of the business process optimization effort. Here's a brief step-by-step guide to help carry out a process optimization plan.

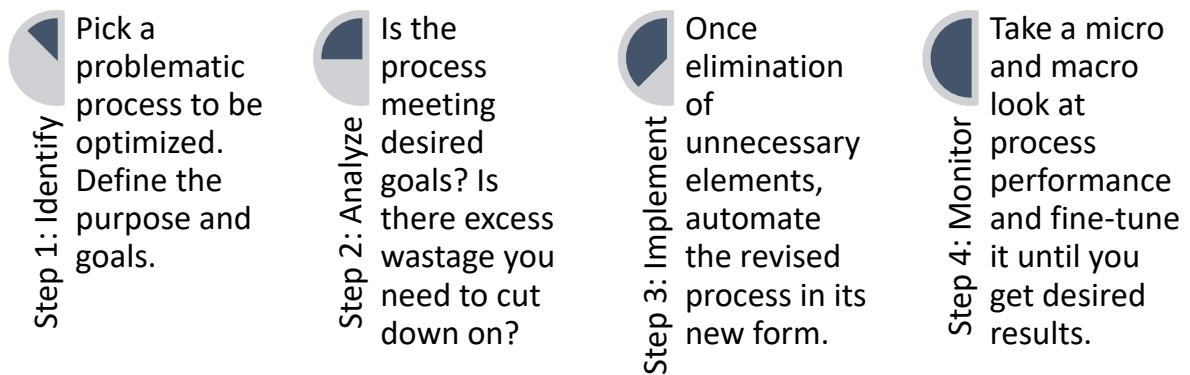


Figure 1.3: Process optimisation steps

With the help of the study, there is a goal to optimise the big press tool development process in TP-110.

2 Literature review

Despite the arrival and a high rise in demand for carbon fibre, sheet metal forming is still of great significance to the automotive industry. Sheet metal is used for the production of most high-volume production cars. The go-to material in the automotive industry is still metal. Metals being able to undergo plastic deformation is the sole reason why it is favoured among others. Most shapes can be achieved with sheet metal.

The fundamental principle behind the sheet metal process is its plastic deformation. Materials without this property or with a lower ability to deform will fail to be moulded to different shapes. Metals without this property will break and tear.

This chapter discusses and provides an overview of aluminium, sheet metal, the forming techniques and the various tools required for the forming processes. The press tool development process is elaborated and various types of defects encountered in the forming processes. A comprehensive discussion about the BMW forming processes and techniques is also provided later.

2.1 Forming in the automotive industry

Sheet metal forming technology comprises of the ways behind obtaining useful products required in the automotive industry, manufacturing of computers, electronics, appliances and other devices by structured methods such as blanking, punching, drawing and bending. Usage of dies, mechanical and hydraulic presses, jigs and fixtures and the recent computer and numerically controlled machines form an integral part of these methods. Any part constructed out of metal or contains metal will have most probably gone through one or the other forming processes.

2.1.1 Significance of forming in the automotive industry

A sketch depicting a rolling mill drawn by Leonardo da Vinci, suggest that sheet metal forming was prevalent around 1485. A surfeit of opportunities for sheet metal work arose because of the Industrial Revolution which led to the inventions such as assembly lines, rudimentary clutch system and brakes used in presses. Joseph Bramah, an English industrialist was accredited for the design of the first hydraulic press [10].

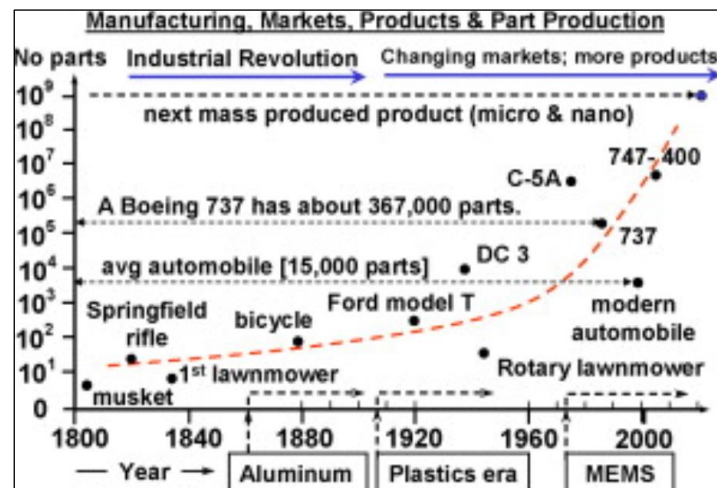


Figure 2.1: Increase in complexity of parts from the industrial revolution [9]

With the increase in the trend of the complexity of products over the years, observed in Figure 2.1, the focus has been on efficient, robust and innovative manufacturing processes [9]. A lot is owed to sheet metal forming for the development of light weight products. Parts of good dimensional accuracy is a need for the automotive industry and that is achieved with help of sheet metal. High volumes are achieved due to the availability of sheet metal in sheets of various thicknesses. World Steel Association estimates that the automotive sector consumes roughly 12% of the overall steel consumption. One of the largest global steel producer, Arcelor Mittal, which accounts for around 16.7% of the world's automotive steel sheet market in 2014. Steel accounts for roughly 60% of the weight of an average automobile [12].

2.1.2 Aluminium as a manufacturing material

“Aluminium plays a crucial role in the automotive industry and aluminium is most likely to play a more important role in future car generations. Its material properties give it some advantages and open the way for new applications in the automotive industry. As car bodies contribute to approximately 20% of the total weight of a car they offer a promising way to reduce the weight of cars considerably.” Gordon et al [44] mention that aluminium contribution weighs from 6% to and go more than 10% soon. Aluminium has some properties that make it interesting for bodies in white applications. The strength of aluminium sheet panels and extruded sections is approximately the same as that of steel body. “That means to achieve a certain permanent distortion or a break of the panel the same force must be applied. However, the rigidity of aluminium is lower than that of steel. That is partly due to the modulus of elasticity of aluminium that is just one-third that of steel. The effect is that aluminium has a higher elastic distortion when exposed to the same force as steel. This can be compensated by increased wall thicknesses, the great variety of forming and shaping and optimised cross-

sections of the parts since the geometry of the panels also influences deformation behaviour and consequently the ability to absorb energy when a car body is subject to impacts.” Therefor the author concludes that aluminium is not yet a simple replacement for steel as the advantages do not completely outweigh the disadvantages.

2.1.3 Steel as a manufacturing material

Steel is graded as a way of classification and is often categorized into the following groups.

Carbon Steels	Alloy Steels	Stainless Steels	Tool Steels
<ul style="list-style-type: none"> • contain trace amounts of elements besides carbon and iron. • Accounting for 90% of steel production. • Low Carbon Steels/Mild Steels (up to 0.3% carbon), Medium Carbon Steels (0.3–0.6% carbon), and High Carbon Steels (more than 0.6% carbon). 	<ul style="list-style-type: none"> • contain alloying elements like nickel, copper, chromium, and/or aluminum. • Additional elements are used to influence the metal’s strength, ductility, corrosion resistance, and machinability. 	<ul style="list-style-type: none"> • contain 10–20% chromium as their alloying element and are valued for their high corrosion resistance. • Commonly used in medical equipment, piping, cutting tools, and food processing equipment. 	<ul style="list-style-type: none"> • make excellent cutting and drilling equipment • contain tungsten, molybdenum, cobalt, and vanadium • increased heat resistance and durability.

Figure 2.2: Steel Grades

Sheet metal is metal formed by an industrial process into thin, flat pieces. Sheet metal is one of the fundamental forms used in metalworking, and it can be cut and bent into a variety of shapes. Varied metals and metal alloys can be formed into sheets and used to fabricate sheet metal parts. Various metals can be made into flat sheets with calendaring units.



Figure 2.3: Different types of sheet metal, Nalin et al. [14]

For sheet metal the ability to be shaped in a given process is focused on. This is called formability. To calculate the formability of a material and estimate the behaviour of a sheet, mathematical calculations are made for prediction.

From blocks of metal sheet metal is channelised through calendaring units and flat sheets of various thicknesses are formed. Figure 2.4 below shoes the steps in sheets formation.

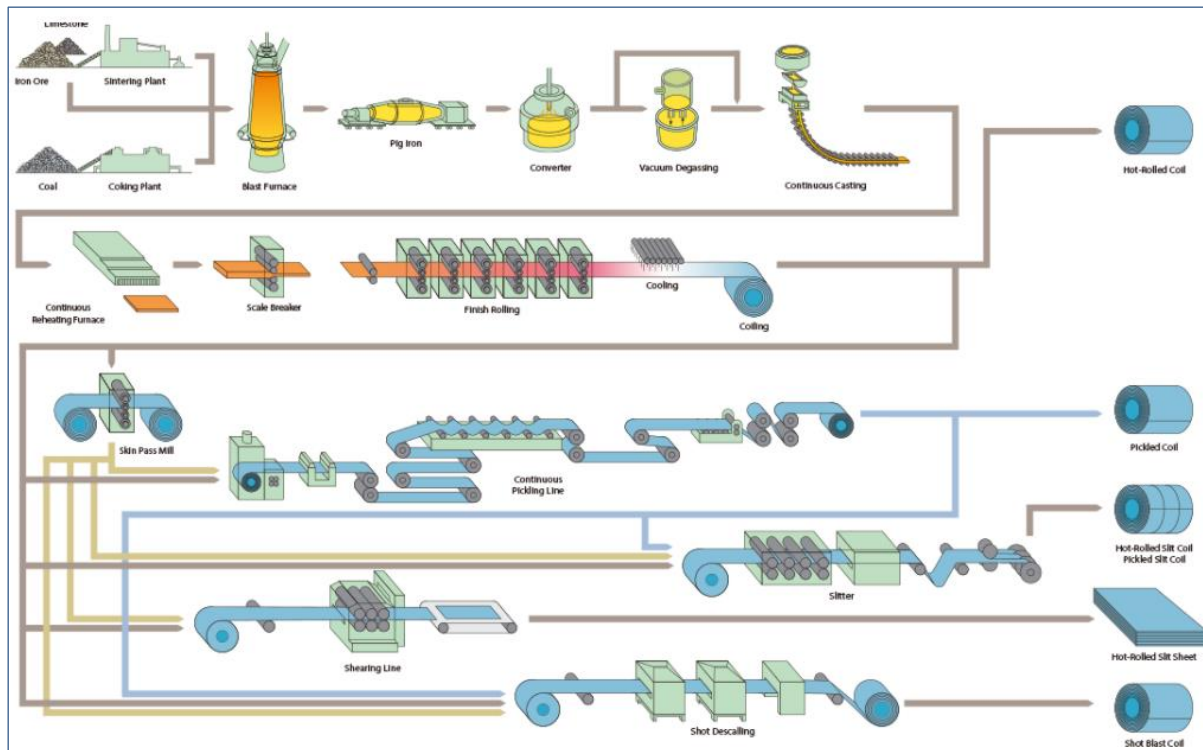


Figure 2.4: Manufacturing process of hot rolled steel sheets, Nalin et al. [14]

2.1.4 Criteria for selection

The criteria to select a material has been briefly touched on in the previous section. The most important property of sheet selection is its ability to be shaped in a given process as mentioned in the literature. The assessment of formability is a matter of high importance and creates the foundation of the ongoing work. The discussion about the various defects encountered while forming sheet metal leads back to the material properties of sheet metal. Not only there is a need to understand the mechanical tests carried out to assess the properties of the sheet, but the knowledge of the mathematical forms to define the properties is a topic of immense research. The area to define and express each and every property in its fundamental form is out of the scope of this report but it is of utmost importance to discuss the two fundamental regimes of interest in sheet metal forming. The regimes are namely the elastic and plastic

deformation. Forming a sheet to a definite shape involves the permanent “plastic flow”. With the advent of the plastic flow, there is an emergence of strains in the sheet which are quite large in cases. With the introduction of stress on sheet metal, there will also be an elastic strain. The value is typically small but has an important effect, for example, when the panels are removed from a die and forming forces unloaded, elastic shape changes or “spring back” occurs.

The choice of materials depends on the requirements of the application and factors in material selection include :



Figure 2.5: Criteria for selection of sheet metal type

2.1.5 Metal forming principles

As discussed in the previous section there is a continuous production of sheet metal at a low cost with a substantial fraction of metals being produced is hot-rolled strip and cold-rolled strip. With the help of the secondary processes, the parts are formed into parts of automobiles among various other uses. As mentioned in the previous section the properties of high elastic modulus, high yield strength ensures that parts can be produced with good strength to weight ratio. The following sections give an overview of the basic mechanics to form parts. The basic forming techniques are combined to make complex operations used in large scale production in the automotive industry [14].

DIN 8580 describes the manufacturing processes and classifies them into six main groups: primary shaping, material forming, dividing, joining, modifying material property and coating. From a molten, gaseous or formless state of matter to the creation of an initial shape is called Primary Shaping. Locally separating the material is called Dividing and assembly of individual work pieces to creating sub-assemblies and also the process of filling and saturation of porous work pieces is termed as Joining. When thin layers are applied to components, by processes such as galvanising, painting or foil wrapping it is termed as Coating. Many a time the material property of a work piece needs to be altered to achieve some desired results or achieve some certain useful properties. The processes such as heat treatment, hardening, recrystallization and annealing all fall under this category. These processes are termed Modifying.

As defined by DIN 8580 Forming is manufacturing through the three dimensional or plastic deformation of a shape while retaining its mass and material cohesion. It is the modification of shape with controlled geometry. Chip less or non-material removal process is what Forming process is categorised under.

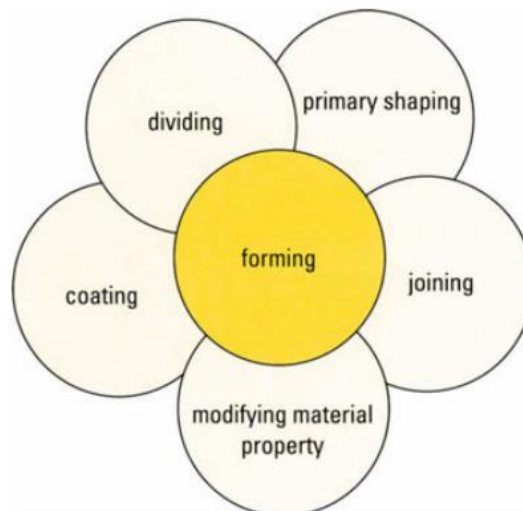


Figure 2.6: Overview of production processes, Metal Forming Handbook, Schuler GmbH [40]

As per DIN 8582, the forming techniques are classified under the following categories:

- Forming under compressive conditions
- Forming under combined tensile and compressive conditions
- Forming under tensile conditions
- Forming by bending
- Forming under shearing conditions

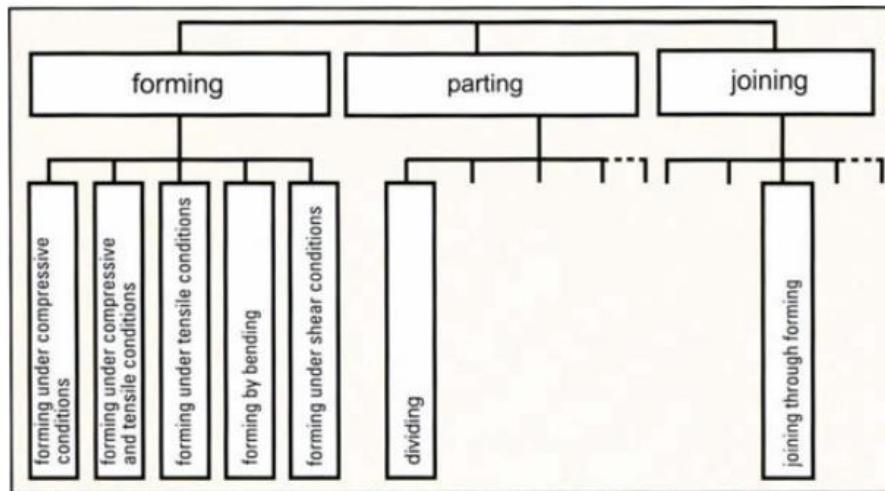


Figure 2.7: Production processes used in the field of forming technology, Metal Forming Handbook, Schuler GmbH [40]

The DIN standards from 8583 – 8587 go on to differentiate between the 17 distinct forming processes. The differentiation takes into account the relative movement between die and work piece, die geometry and work piece geometry.

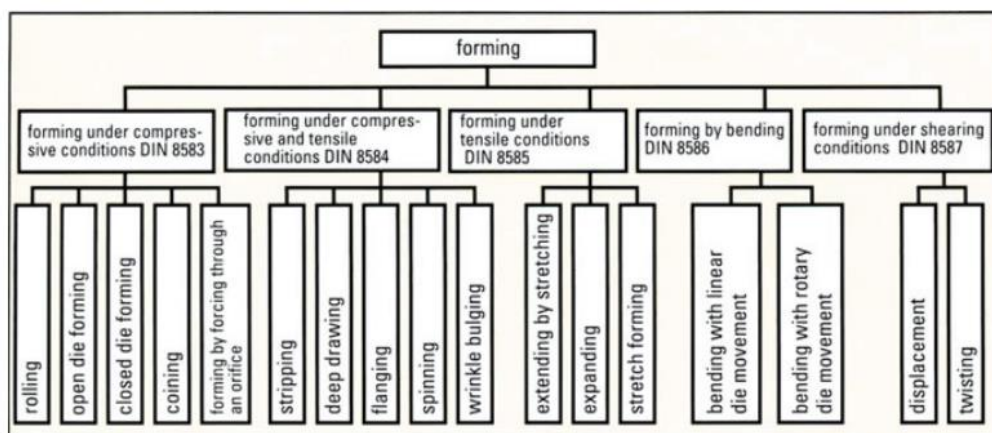


Figure 2.8: Production processes used in Forming per DIN 8582, Metal Forming Handbook, Schuler GmbH [40]

2.1.6 Sheet metal forming presses and press tool fundamentals

In the previous sections, it has been described how sheet metal is an important commodity in the manufacturing sector. It has his use spread out in the automotive industry, home

appliances industry, electronics and electrical industry and many others. However, it is of utmost importance to describe a short overview of how a flat sheet metal sheet of a certain thickness is formed into a final product. The machinery, equipment, tools and various other important resources play a vital role in providing the right shape and form to a metal sheet. There are stages to the forming process depending on the complexity of the geometry of the part. There are varieties of machinery that are working in tandem to facilitate the operations required to realise a geometry. Among the machinery involved, presses and press tools are the most important resources involved in the journey of a part from a flat sheet to a formed part.

The reader needs to get an idea about the fundamental building blocks of a press at first. “The function of the press is to transfer one or more forces and movements to a tool or a die with the purpose of forming or blanking a workpiece” as stated by the Metal Forming Handbook, Schuler GmbH [40]. Based on production techniques, the classifications of presses are:

- “Sheet Metal forming presses
- Blanking presses
- Presses for solid forming, such as forging, extrusion and coining presses
- Presses for internal high-pressure forming
- Pressure forming, stretching and stamping presses”.

Figure 2.9 describes the parts of a conventional double-action mechanical press.

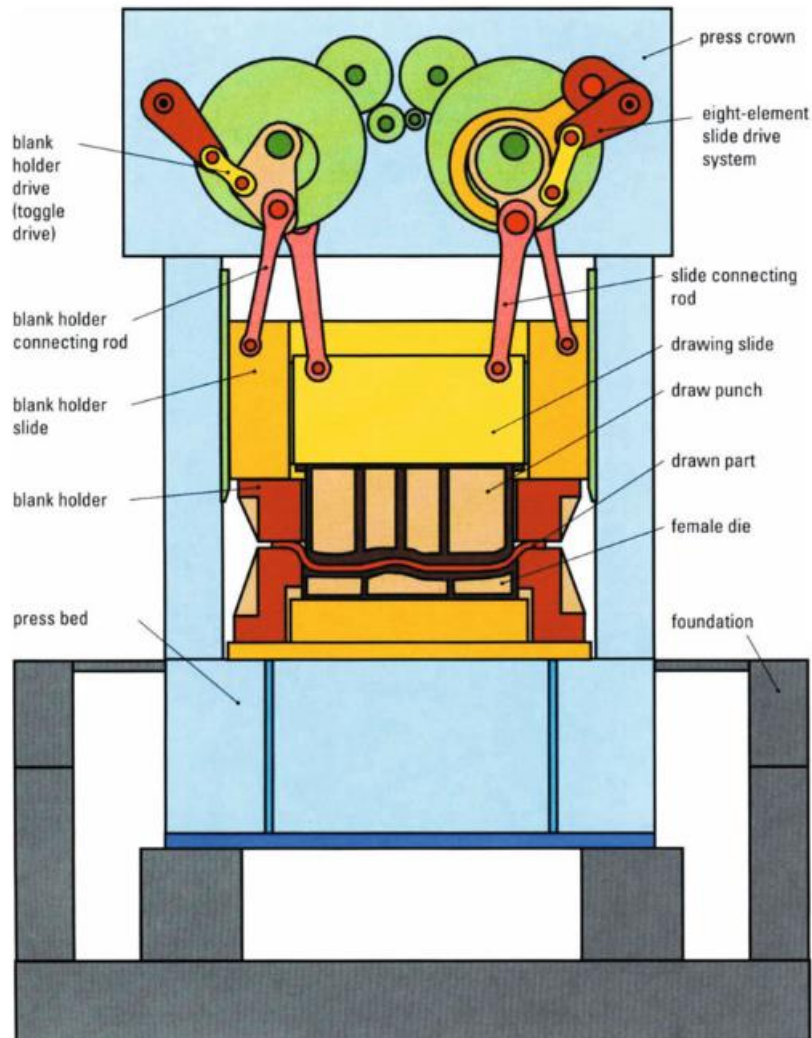


Figure 2.9: Parts of a double-action mechanical press, *Metal Forming Handbook*, Schuler GmbH [40]

In the automotive industry where a series of presses are required to carry out a series of operations and where parts need to move sequentially, for the sake of automation and high productivity, crossbar feeders are required. The crossbar feeders work in tandem with the forming operations and are responsible for carrying the formed part from one stage to the other and feeding it into the die opening before the forming operation takes place. A series of mechanical presses with a drive system and crossbar feeders are shown below in Figure 2.10.

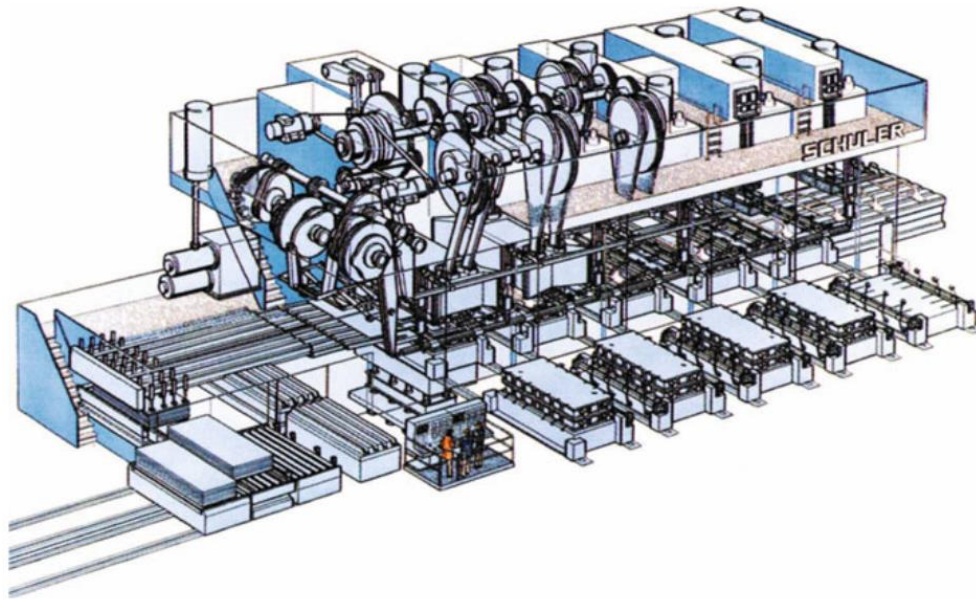


Figure 2.10: Drive system of a transfer press with crossbar transfer, Metal Forming Handbook, Schuler GmbH [40]

Even though the mechanical presses are the first of their kind, there are now hydraulic presses and servo presses. A hydraulic press works on the principle of Pascal's law, which states that when pressure is applied to a confined fluid, the pressure change occurs throughout the entire fluid. Within the hydraulic press, there is a piston that works as a pump, that provides a modest mechanical force to a small area of the sample.



Figure 2.11: Gigant Hydraulic Press, Metal Forming Handbook, Schuler GmbH [40]

The newest forms of presses are the electro servo presses. Electro servo press is mainly composed of a servo motor drive system, digital control system, one-button operation panel, safety protection system and intelligent lubrication system. Electro servo presses using servo motor drive system enables the use of setting the slider stroke, speed, pressure and other technical parameters and strength. Electro servo press mostly has touch screens that can display real-time working status, monitoring the production process and hence ensure control the stability of product quality.



Figure 2.12: Servo press line with blank holder and crossbar feeder, Metal Forming Handbook, Schuler GmbH [40]

2.1.7 Press tool development

Metal forming fundamental is that the geometry of the workpiece is established entirely or partially by the geometry of the die. Compared to machining processes, much higher forces are required in metal forming. The geometry of the part dictates the number of operational steps in the production process. In the time of the design phase, the required manufacturing methods, sequence and number of production steps are established. The aim is always to reduce the number of operations and hence reduce the number of dies to be used while keeping a high level of operational reliability and productivity. During this process, the number of machines requirement, type and volume along with other boundary conditions are calculated.

The type of die and the connected topic of transportation of the part between dies is determined in accordance with the forming procedure. A single set of dies are usually used for forming large parts typically in the automotive industry, the domestic appliance industry. Transfer presses which have for example vacuum suction systems allow the installation of a double-

action tool in a sufficiently large mounting area. Large size dies are used in large presses, while transfer dies are used for high volume smaller parts. Progressive or progressive blanking dies blank sheet metal in several stages. The development of a die usually starts simultaneously. “As a result of simultaneous engineering (SE), the die maker is often involved in the initial development phase of the metal part as well as in the planning phase for the production process. Therefore, a much broader involvement is established well before the actual die development is initiated.”

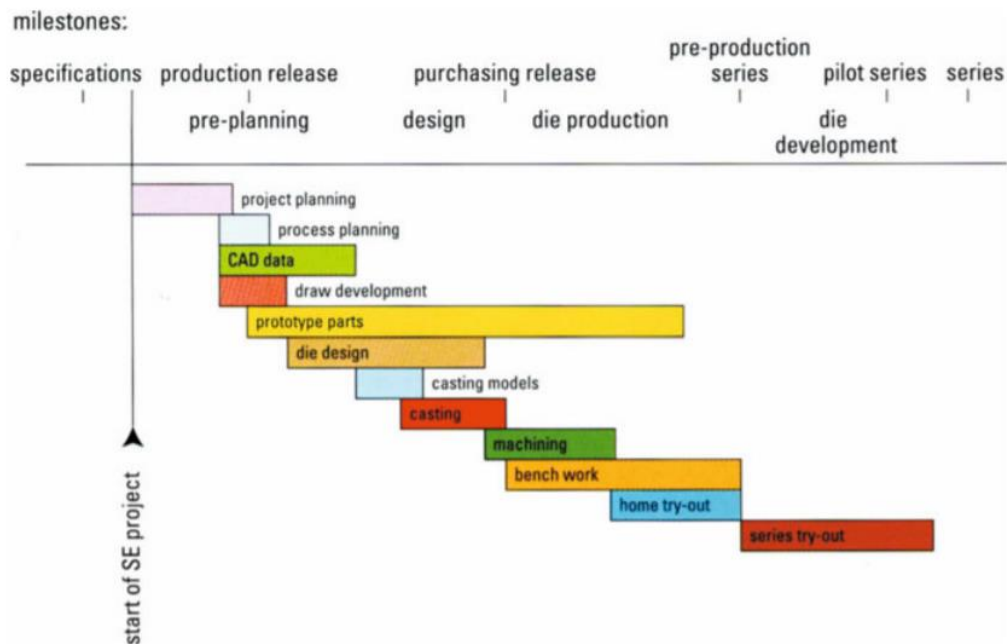


Figure 2.13: Timeline of a SE (Simultaneous Engineering) project, *Metal Forming Handbook*, Schuler GmbH [40]

2.1.8 Effects of tool design error

The automotive industry does not have much scope to allow defects in the forming of parts. The errors in tool design lead to many issues such as defects in the formed parts, problems with the longevity of the tool or problems in tool commissioning.

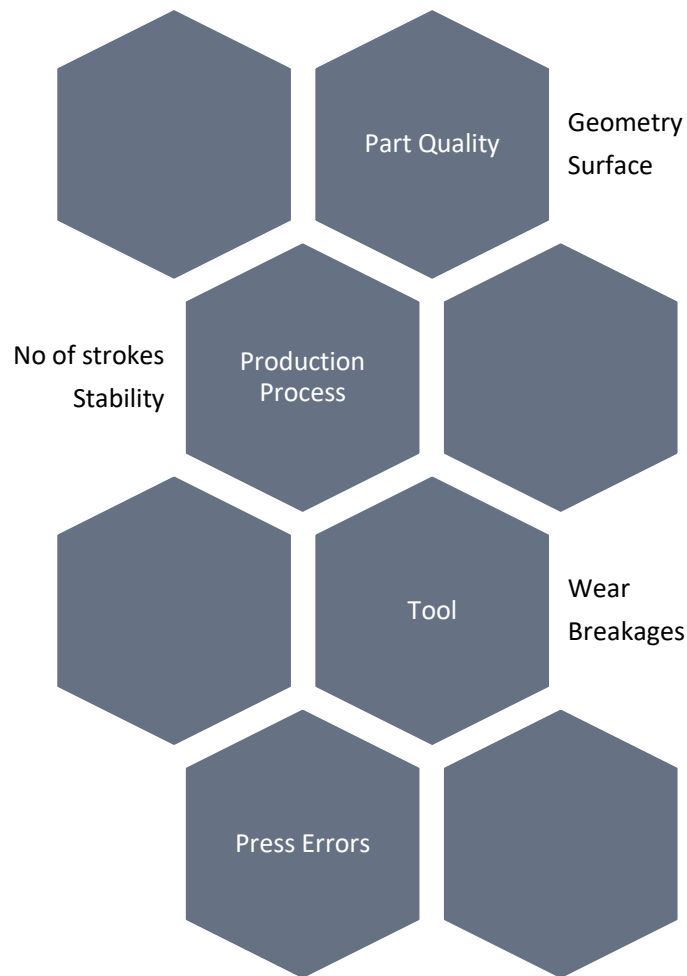


Figure 2.14: Usual effects of errors in tool design

The development process of tools take time and consume a lot of resources. The effects of design errors are caught at the final stages and it consumes more resources to rectify the errors. Hence it is of utmost importance that the designs are reviewed during the design phase thoroughly to avoid expensive modifications at the end.

2.2 BMW forming technology

The production of a car starts in the press shop. Every day, BMW produce over 32,000 car body parts in a single press shop. In the press lines, sheet steel passes through several process steps to receive its final shape. At the heart of the press shop, is a state-of-the-art high-speed servo press line.



Figure 2.15: BMW Press shop Munich, BMW Press Release



Figure 2.16: BMW Press shops around the globe

The steps involved in part production starts from the coils of sheet being uncoiled and blanked into pieces. The blanks are cut in dimensions that are excess of the final material. The blanks will go through the process of drawing, trimming, punching extra and there is a portion of the blank that will be scrap. The following image shows the work steps for the journey from the coil to the final part. The steps vary from part to part resulting in more or less number of operations.

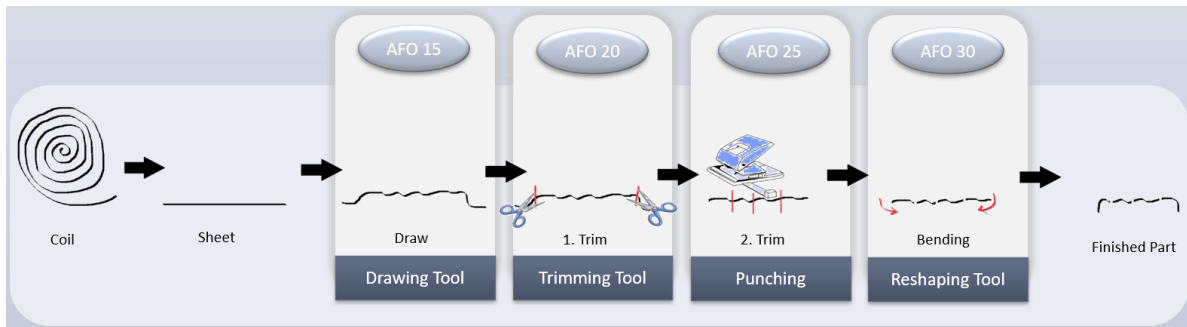


Figure 2.17: Usual steps in press shop part production



Figure 2.18: Pictorial representation of steps to the final part

Our study is concentrated on the press tools that are being used in the presses in the press line located on the bottom centre of Figure 2.18. As discussed in the last section the dies have the responsibility in bringing the final shape to the part. With the complexity of the part, the number of dies/tools vary. If the geometry of the part is complex it is not sufficient to form the blank with the number of dies shown above. The operation starts with a drawing tool. The dies with different functions have different components to it. The building blocks of the press tool has different roles to play in forming of the part and a very important topic for maintenance as well. The working sequence of an automotive part (front flap inner panel) is shown in Figure 2.19.

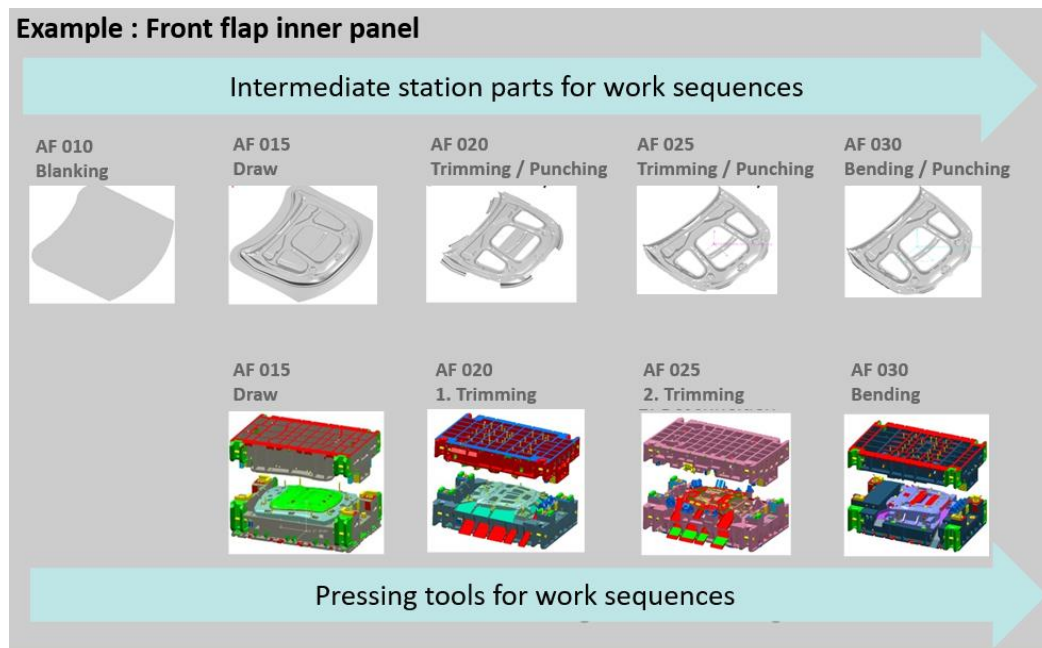


Figure 2.19: Press tools for working sequences

2.3 Project evaluation methods

The project evaluation methods are an essential part of any organisation. There is always a need to find out the techniques to evaluate the success of any project. Derek et al. [23] write “projects comprise of many processes and tasks that transform initial decisions and assumptions into specifications: resources are allocated, solutions developed, and the necessary elements acquired and implemented”. In this process, management contracts and communication processes are the glue that binds the complete development together and progress is made. This results in a goal coordinated performance but the results are often not meeting the expectations. Because of this expectation and reality mismatch in all goal-oriented projects, it is of utmost importance to have a method to evaluate the project and find out how good it ran, what were the deviations and causes of it. Finally, the lessons can be reviewed and learned by colleagues.

2.3.1 Significance of project evaluation

Worldwide project managers and their teams are working hard to evaluate the projects well and eventually improve the project evaluation methods. The project evaluation methods are implemented worldwide and project assessments are carried out worldwide. The terms used all over the world vary from project reviews, audits and health checks. The significance of the

steps is to evaluate the extent to which a project is aligned to the laid out process. It is there to support decision making and make sure that the projects are successful. The most important significance is to learn from previous experiences. Assessments are very important in understanding the success of the project. Klagegg et al. [24] recognise that an effective project assessment “should be systematic and well adapted to the purpose and context of the deliverables, as well as anchored in a governance framework established by the project owner/ sponsoring organisation”. Warraich et al. [25] have an interesting take on the understanding of the model which can be used for a study of this domain to identify the project evaluation chain. The authors propose a typical Project Management Performance Analyser (PMPA) chain as mentioned in Figure 2.20 which takes into account most of the project resources in account to enable a comprehensive assessment of any project.

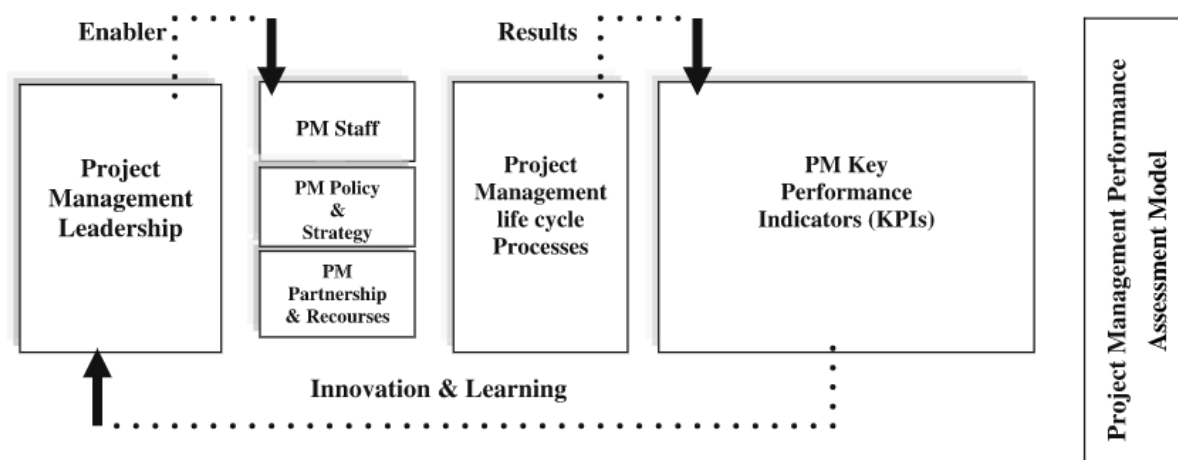


Figure 2.20: Project performance model, Warraich et al. [25]

Donald et al. [26] have studied some of the largest “Fortune 500” companies to determine the feasibility and profitability of a project. In their research, the authors states that the importance and significance of a project evaluation depend on how the corporate decision-makers use both quantitative and qualitative evaluation methods when evaluation projects. As per the authors, as qualitative methods vary from project to project, quantitative have a more common basis. Christopher et al. [27] stress in their article that the underlying concept of any project evaluation technique should be thoroughly reviewed for each project. Age-old value-based, matrix evaluations, etc are considered but usually does not consider all the dimensions of a project. Even though the author highlights that no specific project evaluation technique can be termed as the best, the author suggests that a good evaluation technique should a) In general

reflect individual preferences, b) be publicly accountable c) be operational; and d) be cognizant of systems' effects. In the book titled "The ABCs of Evaluation: ...", John et al. [28] successfully give the readers a concrete definition of what evaluation stands for in a project. The authors mention that there is no one definition of evaluation but in both profit and non-profit organisations, managers have with them data (information) that could help evaluate a program or a project. All evaluations have in common is the data that is in question here. Henceforth the authors try to define evaluation "as the systematic process of collecting data that help identify the strengths and weaknesses of a program or project". The data can have a varied level of complexities. The definitions of evaluation defined by the authors are :

- Evaluation is the systematic approach of collecting and analysing data to determine whether and to what degree objectives have been or are being achieved.
- Evaluation is the systematic process of collecting and analysing data in order to make a decision.

The authors state that the definitions have the first common words in the first phase of the definition while the philosophies change in the second part of the sentence.

2.3.2 Project attributes

For a successful evaluation, the parameters to evaluate a project should be rightly taken. The parameters and their values are the building blocks of the project evaluation. As mentioned in the last section each project needs to be evaluated with different parameters. Sometimes the parameters such as length of a project, errors in a project or simply the deviations in a project. Each different parameter in a project plays a different role in project evaluation.

2.4 Lessons learned processes

Flyjberg [29] mentions in his research that project management and mega project management (similar to the BMW tool development projects) are emerging and costly field of study. The author notes that even though the projects are hard to manage, and take longer times to complete, the project overruns remain quite high. Meredith et al [30] explains that the lessons learned process has an objective to capture the results and experiences "from successes, failures and near-misses, and absorb them into the organisational structure for future use". The authors determined the project leader's role as a crucial role in enabling the learning from each other's experience, utilising lessons-learned for early warning signs (EWS). Even though as per the authors' findings many organisations try to implement a lessons

learned process, few of them get it right. To go into the depth of a lessons learned process one need to understand the fundamental concepts behind the lessons learned processes.

2.4.1 Organisational knowledge loop

The introduction to organisational knowledge should definitely start with the definition of what is knowledge and learning. While Jonson et al [31] say “Knowledge is what we perceive to be real and true”, Walker et al. [24] states “learning is a relatively permanent change due to experience”. Knowledge is a subjective term and depends upon the perception and social context for an individual. Therefore the authors continue that organisation knowledge must be contained in the form of company perimeters as regulations, files, records of actions and decisions, maps or physical objects, is subject “to the individual’s or team’s perception during the formation and update process of those artefacts”

The APM (Association of Project Managers) [32] defines knowledge management. The process of converting personal information and experiences into collective knowledge, with the help of a structured approach of information and learning flow and enabling it to be shared within the organisation is what knowledge management stands for. The literature focuses on the need to capture the right knowledge and experience in order to improve decision making. However it also highlights the need of a format of recording the lessons learned, the process of which is quite difficult for others to everyone to use. The key steps defined in the articles for efficient and successful knowledge management include: Ownership, Responsibility, Extraction of the right information. The whole process of knowledge gaining and sharing can be demonstrated with the figure representing an organisational knowledge loop.

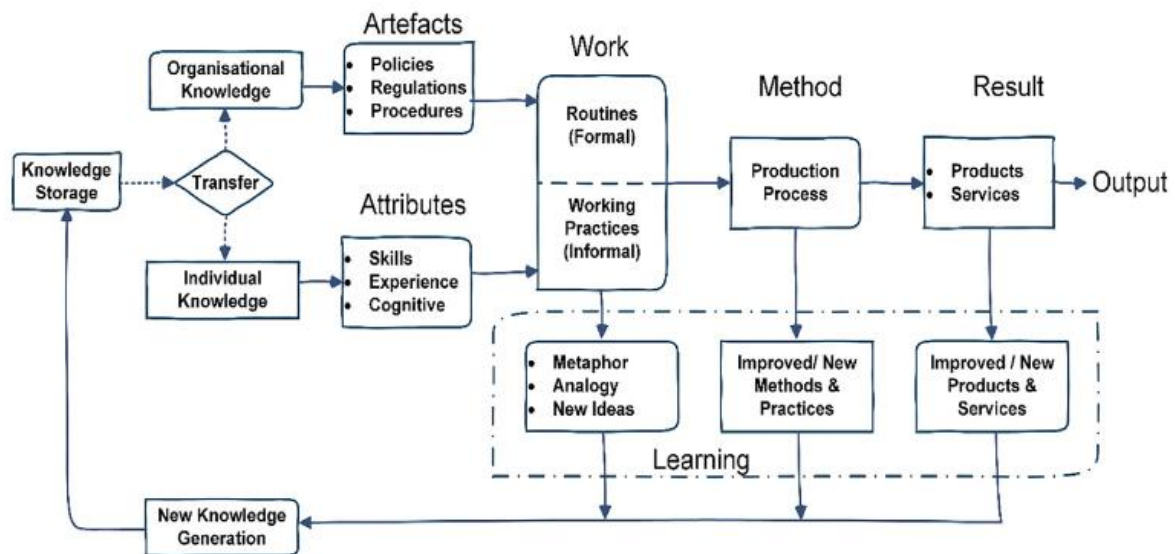


Figure 2.21: Organisation Knowledge Loop [32]

The major terms involved in the functioning of the organisational knowledge loop and the stages of the knowledge management can be defined as mentioned in the article published by Ranjbarfard et al. [34].

- Generation- also called creation, production and development. New knowledge gained by innovation, experimentation, creative thinking, or acquisition.
- Storage- the selective retention of existing, acquired and created knowledge consisting of information, documents and experiments, in a properly indexed knowledge repository with search and retrieval functions.
- Transfer- also called sharing, integration, distribution and dissemination. The spreading of existing knowledge within the organisation, between a source and recipient. Methods include teaching, searching and social activities.
- Application- or utilisation. Retrieving and using knowledge to support decisions, actions, problem-solving and training. Activities to ensure that existing knowledge is productively applied.

The organisation knowledge loop is triggered in two specific conditions. Argyris et al [33] go on to explain the two situations when a possibility of learning can take place:

- The situation where an organisation has achieved what it planned; that is there is a match between the design and the outcome
- The position where there is a mismatch between the intended and the outcome.

With the help of the organisational loop once can understand the different levels of organisation knowledge transfer. In a big organisation like BMW it is important that a person understands the criticality and levels of knowledge bridging. Crossan et al. [35] mention the multilevel issues of an individual, group and organisation. They authors discuss about the significance of links between knowledge transfer between the levels of an individual, group and organisation. The links of an organisation level are well explained by Hall et al [36] which is taken as a foundation to create the lessons learned loop. The authors unassembled the social learning paradigm and suggested “orders” of learning:

- “Third-order – the overarching goals that guide the policy in a particular theme
- Second-order – the techniques or constructs used to achieve the goals
- First-order – the settings of the instruments”

With the orders of the learning, the author proposes three types of learning project learning which can be implemented in an organisation.

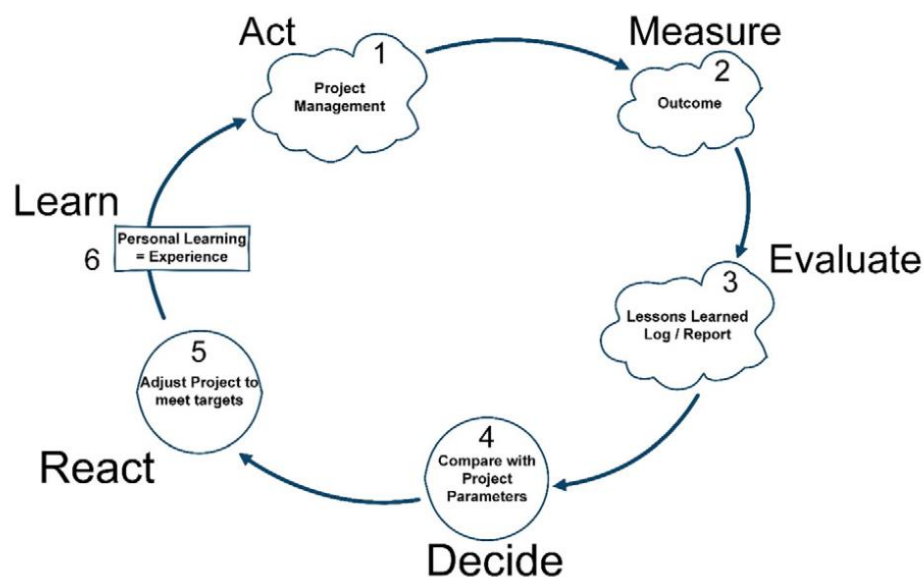


Figure 2.22: Single-loop project learning, Ashrafe et al [37]

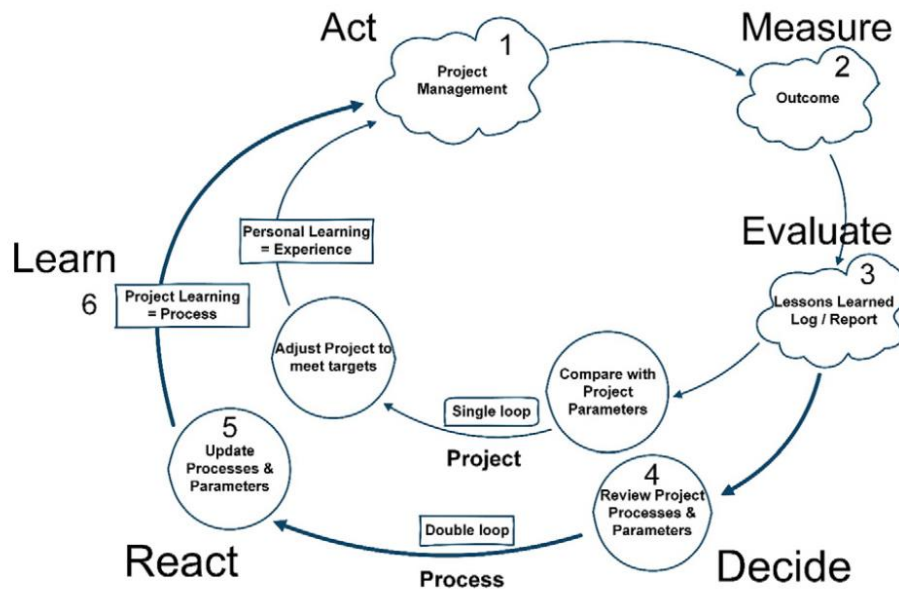


Figure 2.23: Double-loop project learning, Ashrafe et al [37]

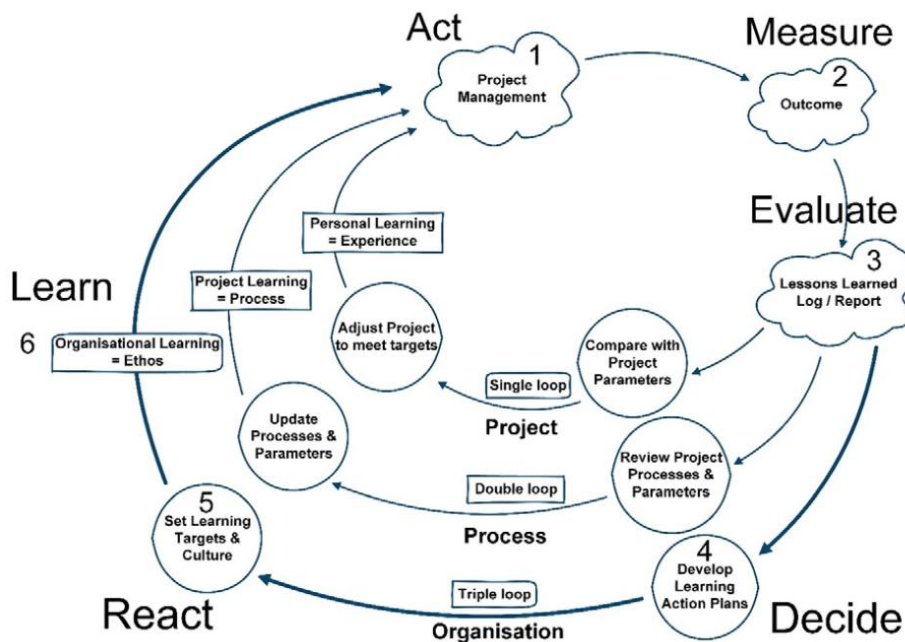


Figure 2.24: Triple-loop project learning, Ashrafe et al [37]

The main difference between the three loops of project learning is that with each increase in a loop there is the importance given to the continuous revision of the learning construct with each project. The project management revises the objectives, parameters that need to be evaluated

concerning each project. It is beyond the scope to select three-loop learning in our study and hence the aim was to achieve single-loop learning.

2.4.2 Lean management overview

The respective tools help the colleagues to accumulate various process deviations and learnings from projects. But the learnings are not as good as lessons if they are not spread across the department and beyond. With quite a few deliberations an Obeya methodology was found which is made the base for the lessons learned description. The lessons learned descriptions are taken from the principles of Obeya which is already practised in the BMW Brilliance China, Tool Shop department. Before touching Obeya there is a need to touch on the lean management philosophy that roots from the Toyota Production System as developed by Taiichi Ohno, Shigeo Shingo since the late 1940s. Lean management is about continuously improving work processes, purposes, and people. With the aim to maximize customer value while minimizing waste. Lean can be applied in any business and process, be it production or service. In essence, Lean is a way of thinking and acting, not a cost reduction programme or a mere set of tools.

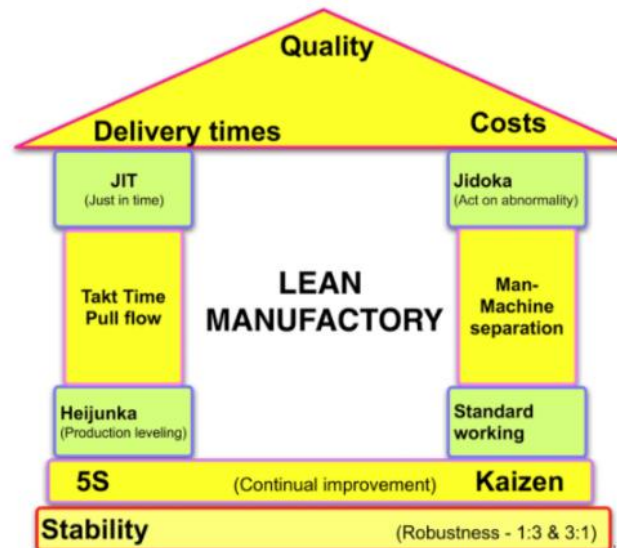


Figure 2.25: House of Lean

Even though lean has become a “buzz word” nowadays, the underlying concept remains the same. The principle of maximizing the customer value with minimum waste, that is “manufacturing/ delivering more with less”. Since the principle is about eliminating waste (the non-value added components in a process), the topic is of high importance in this study which strives to find the inefficiencies in a process and eliminate them. The customer can be taken

as internal stakeholders. To achieve this Konstantinos et al [39] proposes the shortened lean principles which are “value”, “value stream”, “flow”, “pull”, “perfection”.

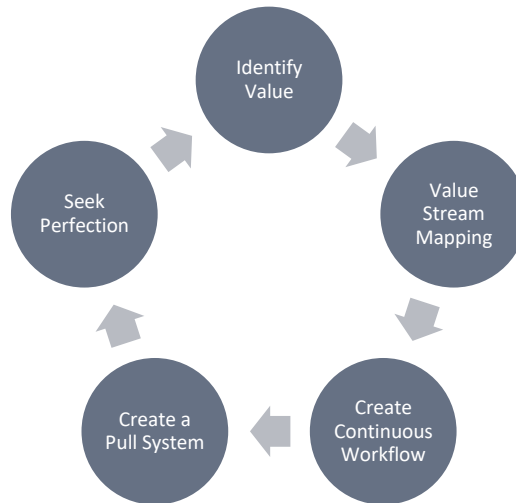


Figure 2.26: Lean Principles

This lean principle is taken as the foundation in creating the study approach because it aligns with the objectives of the study.

2.4.3 Agile Techniques

Agile is a stepwise approach to project management and software development (both of which is very much required in this study) that helps teams reach goals faster. Instead of a final milestone, the agile methodologies are built on a construct of step milestones. Agile teams deliver in small steps and the steps accumulate for a result.

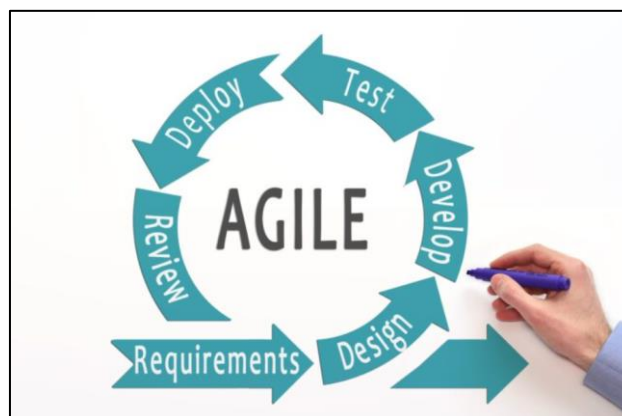


Figure 2.27: Agile Working

2.4.4 Obeya as a methodology

As mentioned in the last section Obeya is very much relevant in BBA, China plant and needs to be explained thoroughly. As per the Obeya association [38] “Obeya or Oobeya (from Japanese 大 部屋) literally means “large room” or “war room”. Toyota put Obeya into practice back in 1993 launching their first Prius as a part of the Toyota Lean Manufacturing System. Takeshi Uchiyamada, a Toyota Chief Engineer, was given a difficult challenge: designing the car of the 21st century, with very aggressive fuel consumption targets. In less than three years, the first hybrid car, the Prius, was brought to market – 15 years ahead of the competition.

An Obeya is a room set up to get employees out of their offices and cubicles and into a central location where they can meet, discuss key information, and solve pressing problems. The idea behind an Obeya is to break down the barriers that prevent employees from collaborating and sharing information to make efficient decisions. Obeyas are most effective when established and outfitted to solve singular problems or work on specific projects. Ideally, they host an array of visual information to make the process smoother and more efficient, as well. Obeya rooms fuel creativity, break down silo barriers and increase collaboration on all levels while developing problem-solving skills. An Obeya room can be intended to shorten the Plan-Do-Check-Act (PDCA) cycle. There even is a physical Obeya method where the walls are structured according to PDCA principles. However, the Obeya is not just about the room only or the visual representation of information. Ultimately Obeya rooms are about installing routines (‘Kata’) to collaborate, manage the business and solve problems more effectively.”

The principles of the Obeya is elaborated illustrated below will be used in the later sections of the methodology.

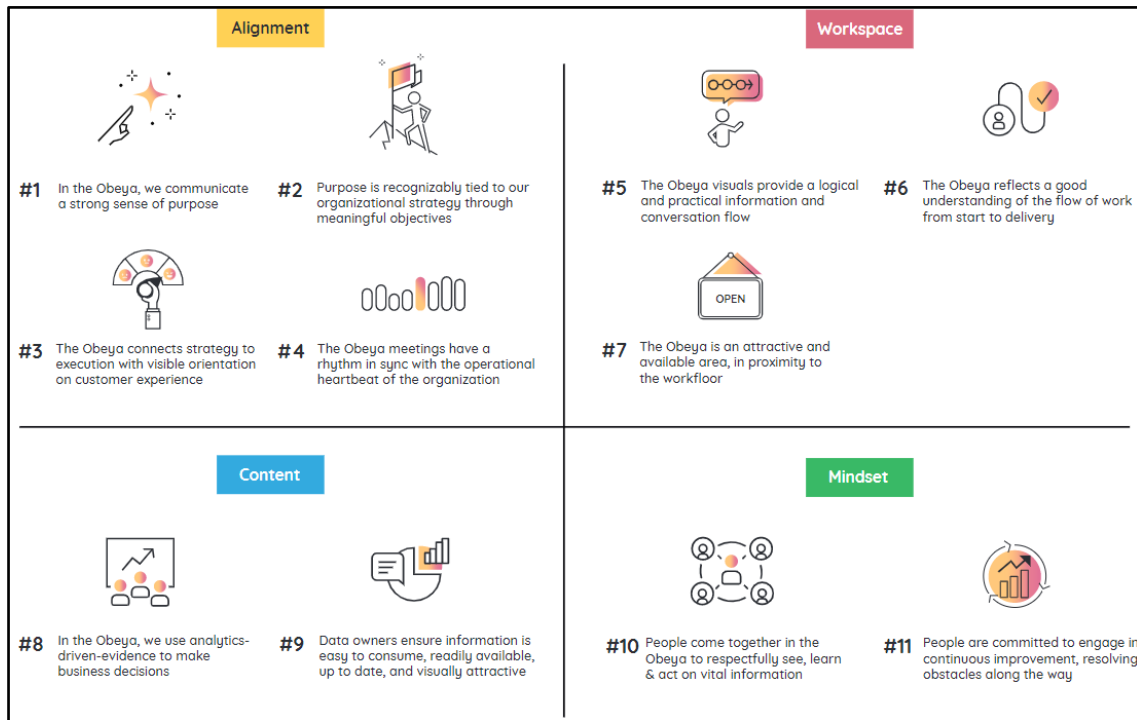


Figure 2.28: Principles of Obeya, Obeya Association [38]

2.4.5 Combining Agile, Lean and Obeya as a methodology

Obeya is ideal to combine Lean and Agile, with Big Room Planning and Agile Portfolio Management. All resources help organizations to translate their strategy into all projects and activities in the organization and to prioritize them. The lessons learned methodology will be created in the combination of the three systems. The readers need to get an introduction to the technique so that they can get a flavour of the methodologies combined to produce a customised effort. The methodology is powerful and is a proven potential in bringing employees together in order to accelerate learning. A typical Obeya room is shown below.



Figure 2.29: A typical Obeya meeting, Obeya Association [38]



Figure 2.30: Visual representation in Obeya, Obeya Asociation [38]

3 Methodology for the analysis of design errors and lessons learned process creation

The motivation of the extensive research and analysis of the design and development errors of big press tools and the need for a lessons learnt process is described in Chapter 1. The three main objectives of the complete study were defined and described while Chapter 2 presented the underlying theoretical concepts from various books, publications, projects, articles in the form of a literature review. With the merged motivation, goal, requirements of the project and the underlying literature behind it, this chapter develops systematically a required methodology. The purpose and requirements were first identified to construct the framework of the methodology. More concepts, ideas and methods were referred to create a holistic analysis model to evaluate the development of press tools in the automotive industry and construct ways to put the analysis into practice.

The purpose of the thesis is to contribute to the area development of big press tools and develop a process to capture the learnings from each project, analyse them and implement it in future projects. The area of development of big press tools is a vast domain as discussed in the previous chapters. The domain has been a topic of extensive study over the years and there is no scarcity of publications, articles and books on the same. The technical know-how needed to carry out a successful tool development is of utmost importance. With respect to the process of development in an industry level, there are many parties involved in it. This makes the process even more complex in nature and demands high level of communication, understanding between the parties, adherence to set process plans, milestones and standards. The analysis of such an intricate process needs an understanding of what needs to be analysed and how can it be done. Reviewing of the right literature to understand the foundations of each process is necessary. In parallel a separate study was carried out on ways to store the analysed data and in turn analyse the data to get useful information to be taken as lessons learned. Moving forward a development of a systematic approach to capturing the various elements of lessons learned from past and ongoing projects is needed.

The research demanded a methodology to evaluate the effects of typical design errors in the development of big press tools which is a segment of forming technology in the scale of the automotive manufacturer. The research demanded a methodology to evaluate the internal processes and the process with external suppliers in the development of a big press tool. The research demanded a methodology to develop a way to capture the lessons and use them to improve the running and future projects. And finally, the research demanded a methodology to create a tool to combine all the above evaluations and automate the whole process as much as possible. The objectives set in the first chapter could be summarised as: **The methodology**

must be able to evaluate a typical big press tool development, enable a creation of a tool to do the same and propose a lessons learned process to capture the evaluations.

Technical know-how will ensure the foundation to typical design errors and its effects in the development of a big press tool. A modelling technique would act as a foundation to visualise and improve the existing internal system and system with the external suppliers in the development of a press tool. The development of a tool required significant IT knowledge which coupled with the technical knowledge was a great fit.

3.1 Overall approach

It was necessary to break down the study into a few essential elements to get a better idea in the approach taken to reach the goals of the study. This would not only give the people involved in the study a bird's eye view on the approach chosen but the readers as well. This chapter would describe in detail some of the already mentioned points in the last chapters and go on to show a path chosen to reach the end goal. The steps were essential to prevent the study from meandering and created a detailed objective for the study. The objectives were broken down into questions which this study wants to answer. A major part of the objectives such as the classification and effects of typical design errors were straight forward objectives which can be met by the collaboration of experienced personnel with little help from the outside knowledge bank. While objectives such as proposing an improvement potential for the internal process required referring already published articles, fulfilling the objective of describing a lessons learned process in the department involved more or less equal knowledge gathering from inside resources as outside. The objectives dictated the amount and type of data required to carry out a reasonable analysis. Immense care had been taken to look at the objectives from different angle and decide whether qualitative type of data was suited for it or quantitative type of data or a mixture of both. The amount and type of data dictated the sources the data can be obtained from. Quantitative type of data such as number of typical errors in a tool design was easy to obtain considering the well-kept database for present and past projects, qualitative data such as criticality of design errors, was established by creating different elements to judge them and eventually adding numbers to it. While some sources of data were already present in the knowledge of the organisation as project files, good amount of data also had to be obtained from literature outside the confines of the company.

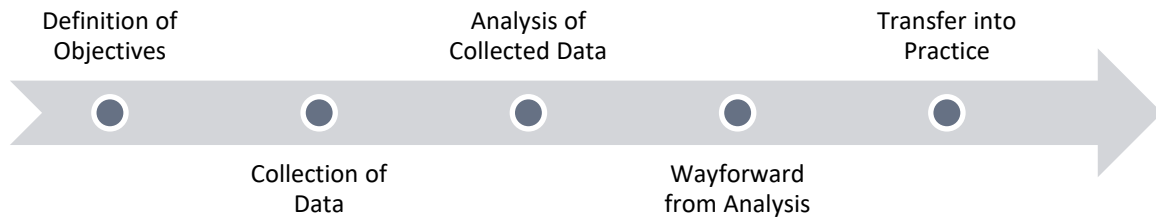


Figure 3.1: Overview of steps taken to conduct study

3.1.1 Research objectives and questions

The methodology was constructed after a detailed understanding of the objectives and what questions were needed to be answered with the help of the research. Each task of the study had already been defined at the start which is mentioned in Chapter 1. As mentioned in the last paragraph it was important to derive definite objectives for each tasks. The objectives created would then serve as the foundation for an approach that needs to be taken and the resources required to reach the goals. A preliminary road map was established at the very early stages of the study. A tabular format is included to provide the readers with a compact summary of the objectives and questions for each task.

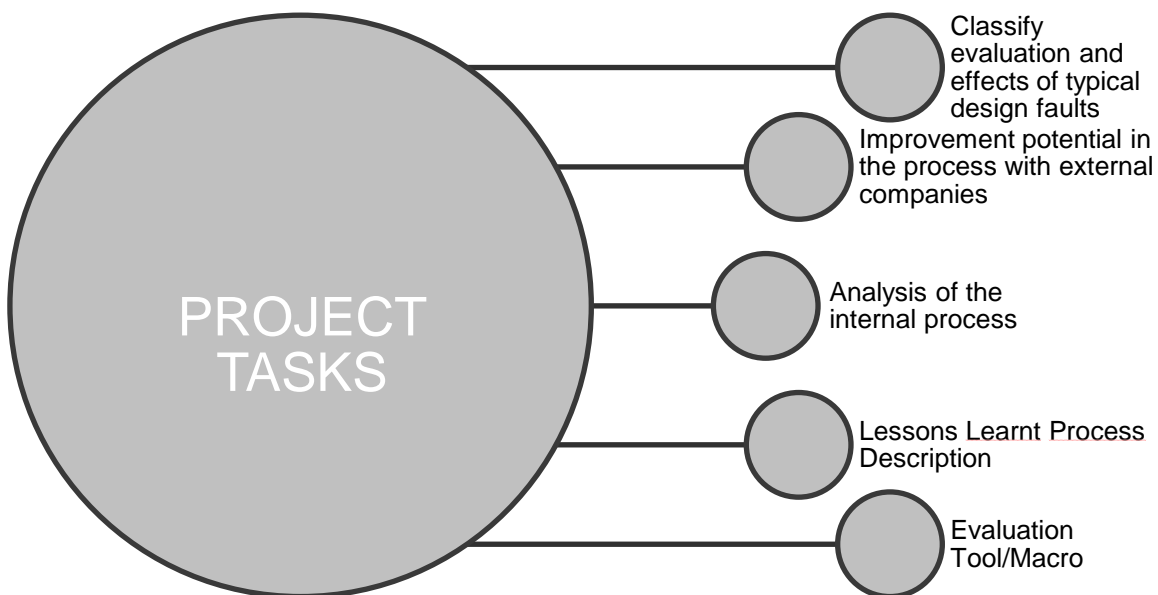


Figure 3.2: Study Tasks

3 Methodology for the analysis of design errors and lessons learned process creation

Objectives	Questions
<p>Classify evaluation and effects of typical design faults</p> <ul style="list-style-type: none"> • Component quality (e.g. geometry, surface, process capability) • Production process (number of strokes, useful degree (OEE), stability) • Wear, tool breakages • Can be installed in the press or other "No Goes" • Less relevant errors • Cluster examination points can be automated/not automated with suggested solutions 	<p>What are typical design faults and how can they be classified?</p> <ul style="list-style-type: none"> • How is component quality defined? • What are the types of component quality? • How does a tool design affect production processes? • What are the key performance indexes related to production processes in this case? • How does a tool design contribute to tool wear and breakages? • Why and what contributes to the tool installation problems? • What are cluster examination points and how can clustering be automated?

Table 3.1: Detailed objective and question analysis

Objectives	Questions
<p>Description of improvement potential in the cooperation/process with external companies, such as</p>	<p>What is the cooperation/process with external companies? What are the internal standards for evaluation?</p>
<ul style="list-style-type: none"> • Adherence to delivery dates 	<ul style="list-style-type: none"> • How can the delivery dates be analysed?
<ul style="list-style-type: none"> • Error processing of the external companies 	<ul style="list-style-type: none"> • What is error processing of the external companies?
<ul style="list-style-type: none"> • Frequency of acceptance 	<ul style="list-style-type: none"> • What is the volume of businesses with external companies?

Table 3.2: Detailed objective and question analysis

3 Methodology for the analysis of design errors and lessons learned process creation

Objectives	Questions
Analysis of the internal process	What is the internal process flow?
<ul style="list-style-type: none"> Interaction TP-110 internally in the design process (construction, flow chart, press simulation) 	<ul style="list-style-type: none"> How can the internal design process be evaluated?
<ul style="list-style-type: none"> With process integration and new parts planner 	<ul style="list-style-type: none"> How can the coordination process be evaluated?

Table 3.3: Detailed objective and question analysis

Objectives	Questions
Lessons Learned Process Description	What is the internal process flow?
<ul style="list-style-type: none"> Process description for a future Le Le process 	<ul style="list-style-type: none"> How can the internal design process be evaluated?
<ul style="list-style-type: none"> Transparency about vehicle projects or external companies 	<ul style="list-style-type: none"> How can the coordination process be evaluated?
Evaluation Tool/Macro	What is the easiest way to create a tool/macro?
<ul style="list-style-type: none"> Evaluation tool for future construction projects, if possible with the connection to construction checklist 	<ul style="list-style-type: none"> What is the purpose of the tool? How can it be built?

Table 3.4: Detailed objective and question analysis

After the objectives were broken down into definite research problems or questions it paved the way for constructing a correct methodology. The overview of the research objectives and questions provided a clear understanding of the steps involved in answering them.

3.1.2 Quantitative and qualitative data

There was a need to understand the type of data needed to be accumulated to enable a clear understanding of the questions and work on answering them. No amount of data was enough until the right type of data was chosen and collected. It was deemed a very important step to clearly understand the differences between the types of research data in general. Not all types

of data are relevant for the specific study being carried out and it was deemed even more important to focus on the right type of data and ignore the irrelevant ones. Once the general types of data were defined it was important to classify the already existing data in these type and find out what else could be collected to improve the research. There had been an extensive effort to include both the elements of a typical research. The two elements of quality and quantity are defined and included in the ways of carrying out the research. The proliferation of qualitative methods in educational research has led to considerable controversy about standards for the design and conduct of research. This controversy has been playing itself out over the last several decades largely in terms of the quantitative-qualitative arguments as mentioned by Kenneth et al. [8]. The need to have a balance in the elements is derived from the diverse results of various research papers.

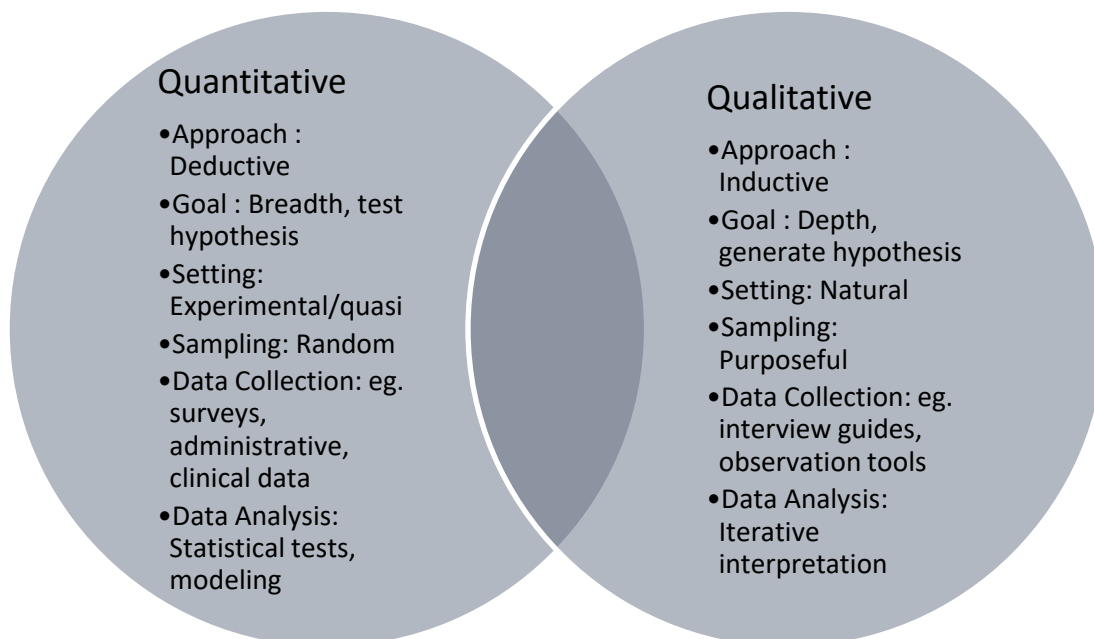


Figure 3.3: Qualitative and Quantitative Research Criteria

In the book “Analysing qualitative data” Bryman et al. [15] focused on the methods of performing a data analysis keeping in mind both the types of data. The authors mentioned that it is a very important factor in conducting research and suggested that researchers should take extra precaution in first understanding what the type means in their respective researches and what kind of data can be classified in the two types. A failure to do so would result in serious analysis error and sometimes data collection error. The authors mentioned that the step of linking the two types of data within each other can be of significant priority as well.

In this study, care had been taken to create a data list requirement to start the process of answering the questions. The data list would then act as a stepping stone for the resources

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required to collect such data. The following chart would provide the people involved in the study and the reader a clear understanding of what kind of information was necessary to answer the questions in order to evaluate the tasks.

	Quantitative	Qualitative
Classify evaluation and effects of typical design faults	<ul style="list-style-type: none"> • Types of design faults • Number of design faults 	<ul style="list-style-type: none"> • Effects of design faults • Criticality of design faults
Description of improvement potential in the cooperation/process with external companies	<ul style="list-style-type: none"> • Duration of projects • Duration of reviews • Number of reviews 	<ul style="list-style-type: none"> • Punctuality • Innovativeness • Company maturity
Analysis of the internal process	<ul style="list-style-type: none"> • Number of interdependencies 	<ul style="list-style-type: none"> • Communication between colleagues
Lessons learned process description	These tasks combined the analysis from the other tasks	
Evaluation tool/macro		

Table 3.5: Types of research data

While conducting a detailed cost estimation in the automotive industry Shehab et al. [16] discussed in details in their research paper about the approach to their study in the automotive industry which echoes the methodologies used in this study. They described how the research methodology was divided into three broad sections which are: research strategy, data collection along with idea formation and data analysis along with validation. In the first phase of their methodology, they have detailed an appropriate research strategy to conclude that a qualitative research strategy was chosen. Later in the discussion related to the shortcoming of the study they had shifted their focus to the fact that narrowing down the research strategy to just a qualitative approach has axed a lot of elements from the study. They had gone further to suggest that in future studies on specific or related topics, a need of investigation in the quantitative elements is required as well.

3.1.3 Data collection techniques

The data points needed to carry out analysis was discussed and laid out in the last sections. However, there was a need to include a part in the study to achieve the best possible analysis from the data. The part was a detailed understanding of the terms. When shared with the people involved in the study there was always a different understanding of the terms. As clearly elaborated by Delbridge et al [17] in their study of the process of benchmarking in the automotive industry, misinterpretation of the terms played a crucial role in data collection methods. The data points were generated with the help of industry experts. After the initial process of setting up the data collection methods, it was found out that the interpretation of data points was different for different people. The need for defining the data points with care was observed early in the research phase and addressed quickly. Once it was addressed and the data points were clearly defined there was a uniformity in the data collected. Taking inspiration from the concept in this study, the data points were clearly defined at the very beginning of the data collection procedure. Once the data points were defined it was easier for the people taking part in the study to be providing quality and relevant data. Some of the data point definitions are laid out in the following table.

Data Points	Definitions
Design faults	Design not confirming to the BMW B2 standards of press tool design
Duration of projects	Number of business weeks between the start date and commissioning of a press tool
Punctuality	Adherence to the pre-decided and confirmed delivery dates of individual stages of the tool design review
Maturity of an external company	Confirming to the golden rules mentioned in the BMW B2 standards and inclusion of innovation and out of the box thinking by ext. companies

Table 3.6: Data points and their definition

Not all the data points had been shown in this section because of the low relevance for the reader. The data points which have a qualitative element to it are defined to provide the reader with a crisp understanding of what the study was trying to capture through the data points.

There were several methods used to collect the data against the data points. Some of the data collected were even dictated by the type of data it was categorised under. Quantitative data

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would generally be collected by reading existing numbers pertaining to the data point. Whereas data points falling under the qualitative category would be dealt in a much more understanding form. Direct numbers would then be not effective in collecting such data. The data collection techniques used were:

- Interdepartmental interviews: Knowledge from the existing colleagues in the department
- Existing project attribute sheets: A project attribute excel file was the most important source of data points for this study.

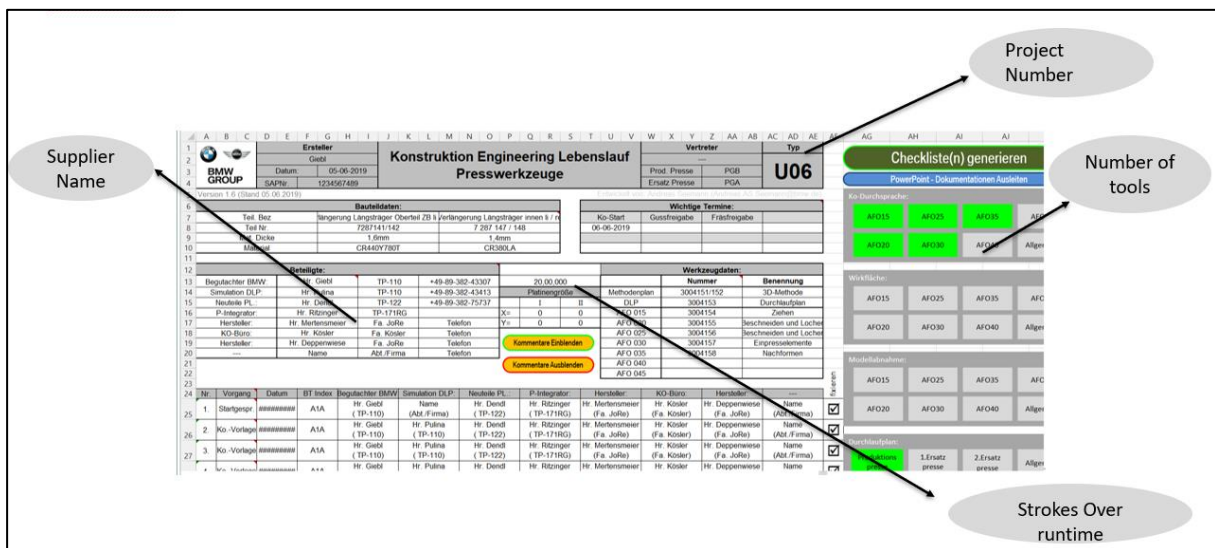


Figure 3.4: Project Attribute Sheet

- Existing audit systems in BMW: Supplier audit systems to ensure the highest standards of the parts received by BMW.

3.1.4 Data analysis and usage of results

In the last sections, it was described what kind of data was needed to be collected and what was the data collection techniques that were deployed to collect the data. As described in the last section the data collected is maintained in a predefined format for the benefit of analysis. This section would give the reader an overview of the analysis that was carried out on the data

3.2 Methods of data collection and foundation build-up

3.2.1 Existing data

BMW is one of the most reputed automobile manufacturers in the world had a bank of resources to offer. The existing resources came in the form of existing data. Existing data contained valuable information which would prove to be of great importance in the study.

B2 Standards	<ul style="list-style-type: none"> • Predefined standards created to ensure the quality of manufacturing • Standards followed by external manufacturers as a guide line
Knowledge base	<ul style="list-style-type: none"> • Experience from colleagues
Previous publications	<ul style="list-style-type: none"> • Various research articles published by colleagues in collaboration with Technical Universities
Previous reports	<ul style="list-style-type: none"> • Knowledge gathered from student thesis • Knowledge from internal study reports

Table 3.7: Existing knowledge internally

3.2.2 Research demand

The vast majority of the literature review concentrates on the underlying concepts of sheet metal forming. The literature concentrates on the properties of the material and how that affects the final formed piece. Because of the importance and history of the forming technology most literature focuses either on the process of manufacturing sheet metal from ores, or the process of forming sheet metal into usable parts, or the most common defects in the formed part and ways to improve the forming process or about the various tools required to enable the forming the metal into usable parts. In the vast ocean of literature of forming technology, a person will find only a handful of good literature in the form of books, articles or publications where the author has concentrated on the required timeframe of sheet metal forming into usable automotive parts in the scale of a large multinational automotive company which involves many internal stakeholders, external stakeholders, complex resources in the form of machinery and people working all together to reach a certain goal. Consequently, there has been extensive research on each individual process cycle of sheet metal operations over the years, but authors have failed to interconnect these processes in relation to different industries. This creates the need to understand the underlying concepts in individual time frames of the process and

somehow interconnect them in the context of this study. Even though industry-leading equipment manufacturers that cater to this industry, such as Schuler GmbH has tried to publish literature in the form of books which has the best possible view on this specific thesis, it is still an ignorant step to rely on just one. The broad objective of the thesis is to evaluate the development of the big press tools and sheet metal forming is just a part of it. Knowledge on how to evaluate the interdependencies of internal colleagues, stakeholders, external suppliers play a major role in fulfilling the objectives of the study. Knowledge on how to capture the evaluation, analyse them and use them to improve the same process is of high importance. This broad overview leads us to finalise the three most important demands of research for this study to be concluded.



Figure 3.5: Broad topics which demand research for a successful study

3.2.3 Collaboration with internal colleagues and external departments

Intradepartmental Collaboration

There had been a lot of data collection from inside the department of TP-110 because BMW is a vault of knowledge. It would be impossible for an organisation to reach the pinnacle of technology without good knowledge. The base of the study was created with the help of the colleagues who are responsible for the review of the design of the press tools. The first task in the study was to classify the various press tool design errors. Because of the strong experience of BMW in press tool manufacturing as discussed in the previous chapters, there was already a sense of how to classify the design errors.

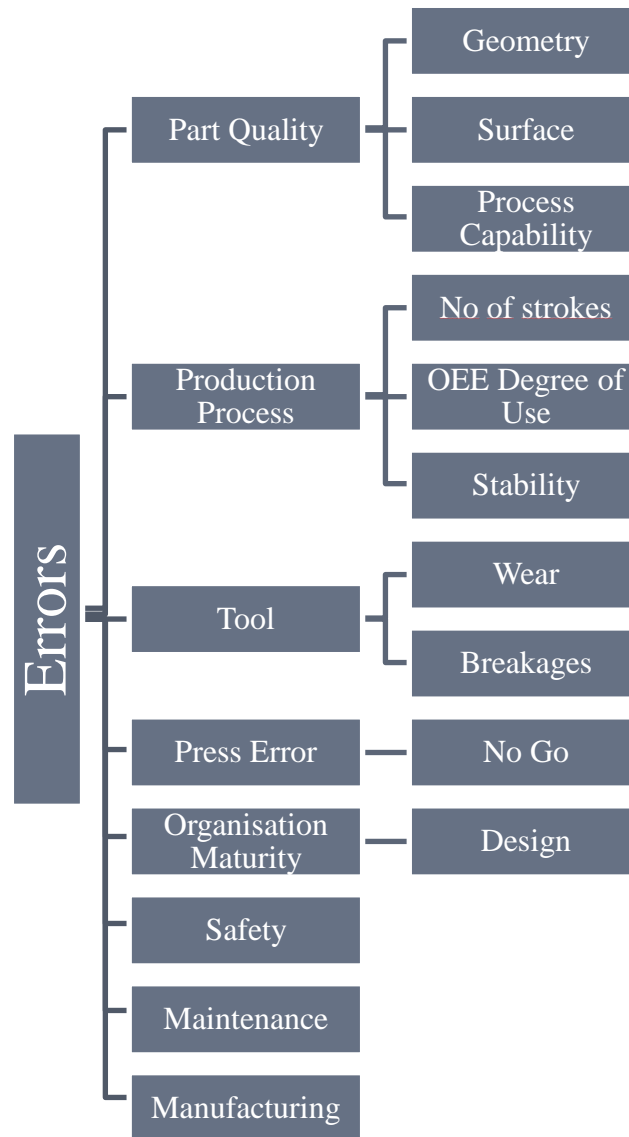


Figure 3.6: Press Tool Design Errors

The press tool design errors did not necessarily mean errors issues on the tool but an error in tool design which leads to these kinds of errors. Some of the errors classified above are found on pressed parts while others arise during the commissioning of the press tools. There was a need to elaborate on the meaning of each error to make sure the classifications were right. For the benefit of the readers and the colleagues, it was decided to create a small table to explain what each design error meant.

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Part Quality	Geometry	<ul style="list-style-type: none"> • Errors concerning dimensions of a pressed part
	Surface	<ul style="list-style-type: none"> • Concerns regarding surface roughness • Scratches and marks
	Process Capability	<ul style="list-style-type: none"> • Errors causing erratic process capability values
Production Process	No. Of Strokes	<ul style="list-style-type: none"> • Predefined no. of strokes cannot be achieved
	OEE Degree of Use	<ul style="list-style-type: none"> • Predefined Operative Equipment Efficiency cannot be achieved with error
	Stability	<ul style="list-style-type: none"> • Errors resulting in an unstable process • Errors leading to vibrations
Tool	Wear	<ul style="list-style-type: none"> • Design error leading to wear and tear of tool • Frequent part changes required
	Breakages	<ul style="list-style-type: none"> • Design error results in tool breakage • Design with not enough support structures
Press Error	No Go	<ul style="list-style-type: none"> • The tool does not fit in selected press
Organisation Maturity	Design	<ul style="list-style-type: none"> • Tool design not as per BMW B2 design standards • Design with more material, resource usage than required • Design with a low level of innovation
Safety		<ul style="list-style-type: none"> • Tool design error can lead to safety issues
Maintenance		<ul style="list-style-type: none"> • Design error makes it difficult for regular maintenance • Nonstandard parts used.
Manufacturing		<ul style="list-style-type: none"> • Design error leads to difficulty in manufacturing

Table 3.8: Design errors encountered in press tool construction

Once the errors were defined it was easy to classify them with the construction process. As mentioned in the previous chapter BMW designers use a Design Checklist to review the press tool design of suppliers working on a project. The checklist contained over 600 questions to review all the parts of a press tool. The parts included all levels of a tool design which could affect the processes connected with the tool in the topics such as part quality, production processes, installation in presses, maintenance etc. The approach provided the design

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reviewers a 360-degree overview of the complete journey of the tool from the manufacturer to a BMW press shop and processes connected with that certain press tool. The questions in the checklist were a guiding step to initiate the classification process. The process of tool review mentioned in the previous chapter contained simple steps.

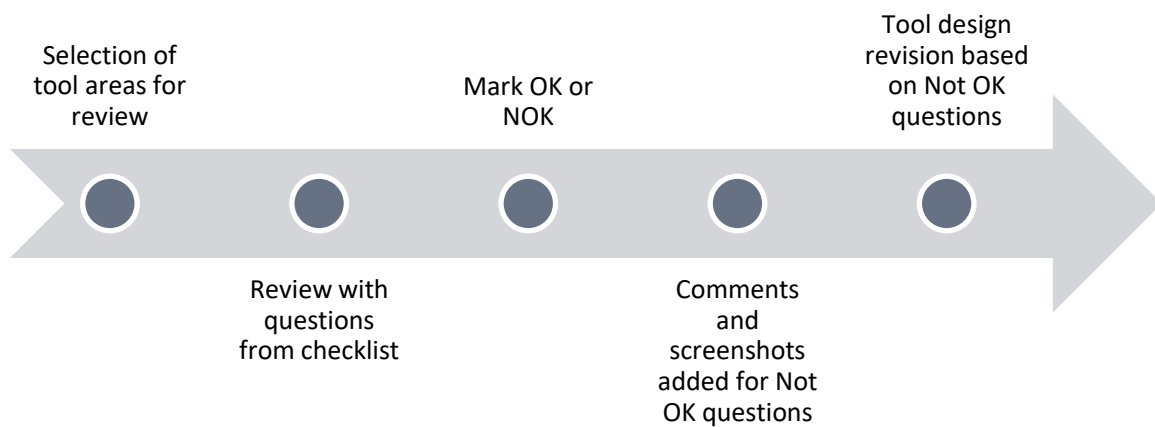


Figure 3.7: Tool Design Review Checklist usage process

Bauteil / Panel: _						
Afo / Op AFO15:						
				begutachtet:	6	von 364
Nr. No.	Großwerkzeuge Allgemein General Tools	i.O. O.K.	n.i.O. n.O.K.	entf. NA	Action	
B001	Gusstruktur, Auskernung, Verrippung, Gestaltung. Casted structure, coring, ribbing and geometry.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	+	
B002	Alle Werkzeuge für das Presswerk Swindon benötigen Jacking Areas (Abstand 170+20 mm) All tools for Press Shop Swindon to be provided with Jacking Areas (distance 170mm + 20mm)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	+	
B003	Sind die Jacking Areas durch Rippen ganz unterstützt? Are all Jacking Areas fully supported with ribs?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	+	
B004	Sind Flansch-, Rippen- und Wanddicken nach Bauvorschrift bzw. Werkzeug-Konstruktions-Richtlinien hochfeste Bleche / Aluminium ausgelegt und die Werkstoffvereinbarungen aus der Konzeptfestlegung eingehalten? Is the thickness of flanges, ribs and walls correct according standard, design guidelines for high strength steels / aluminium and are the choosen tool materials according the concept sheets?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	+	
B005	Ist die Freigängigkeit der Unterluftbolzen gewährleistet betreffend Produktion-, Alternativ- und Try out - Presse? (metr. and inch) Is the clearance for the marquette pins been given? (Production-, alternative- and try-out press)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	+	
B006	Wurden Materialanhäufungen vermieden? (Lunker Gefahr) Have hot spots been avoided?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	+	
B007	Keine Hinterschnitte und unzugängliche Kammern und Kerne. Have undercut areas and non accessible cores been avoided?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	+	

Figure 3.8: Excerpt of questions from the press tool design checklist

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All possible questions in the checklist were taken and they were reviewed and classified to the design errors defined in the previous table. The aim was to create a classification which was unanimously accepted. For that purpose a simple tool was developed to unanimously classify each question to a type of error defined previously. The sheet was accessible to all the design reviewers in the department and provisions were created so that each person had a say on what question should be classified to what design error as per their understanding and experience. With the help of regular and periodic discussion, all the deviations in the classifications were unanimously set straight. An excerpt of the tool used for the above process is shown below and a comprehensive review of it included in the tool section.

1	Werkzeug Die	Part Quality						Production Process	
		Geometry	Surface	Process Capability	No. of strokes	DEE Degree of Use	Stability	Wear	
1.1	Allgemein General								
	Ante Todorovski	A	A	A	A	A	A	A	A
	Josef Giebl	J	J	J	J	J	J	J	J
	Stefan Brenner	S	S	S	S	S	S	S	S
	Thomas Bieber	T	T	T	T	T	T	T	T
	Ingo Wumb								
	Arpan Das								
8	Ziehen // Drawing								
H001	Sind die theoretische und die eingezogene Platine dargestellt? Is the blank shape before and after the draw process been shown?	J			J	X			
H002	Ist eine Platinenunterstützung erforderlich? Is a blank support necessary?	J	X		J	X			
H003	Ist ein Platinen-Bedrukker erforderlich? Is a blank pusher necessary?	J	X		J	X			
H004	Sind bei Zerteilen ohne ausreichende Formkontur Aufnahme-Möglichkeiten für nachfolgende Arbeitsgänge geschaffen? Is a correct panel locating in the following operations after drawing possible?	J	X		J	X			
H005	Sind Stahleinsätze richtig dimensioniert und gestaltet? Are steel inserts from correct shape and correct size?					X		X	X
H006	Sind die Trennungen von Ober- / Unterteileinsätze zueinander versetzt? Are the butt lines of the lower and upper steels staggered?		J	X		X			
H007	Sind die Trennungen ca. 5° schräg zur Laufrichtung der Platine? Are the butt lines 5° angled to the blank flow direction?		X	J		X			
H008	Sind Enddruckmarkierungsstempel gemäss Konzept Ziehwerkzeug eingebracht?		X	X	J	X			

Figure 3.9: Classification of each question with an error

Each design reviewers were allotted a letter that they could put beside question and linking it to the error on the top. Once the regular meetings took place the deviations between each classification were discussed.

The classification of the questions with the design errors successfully completed the objective of the first task. The classification would provide a foundation to fulfil the next objectives later in the study. However, it was visible that there was a lack of qualitative analysis in the design errors. Just classification of the design errors showed the quantitative aspect of evaluating the external companies. However the design errors were not equally balanced in the aspect of criticality. Some of the design errors did not lead to a halt in the project review while some design errors seriously derailed the project off its course. The criticality of design errors were linked with the quality aspect of the design errors and a chart was created to weigh the design errors.

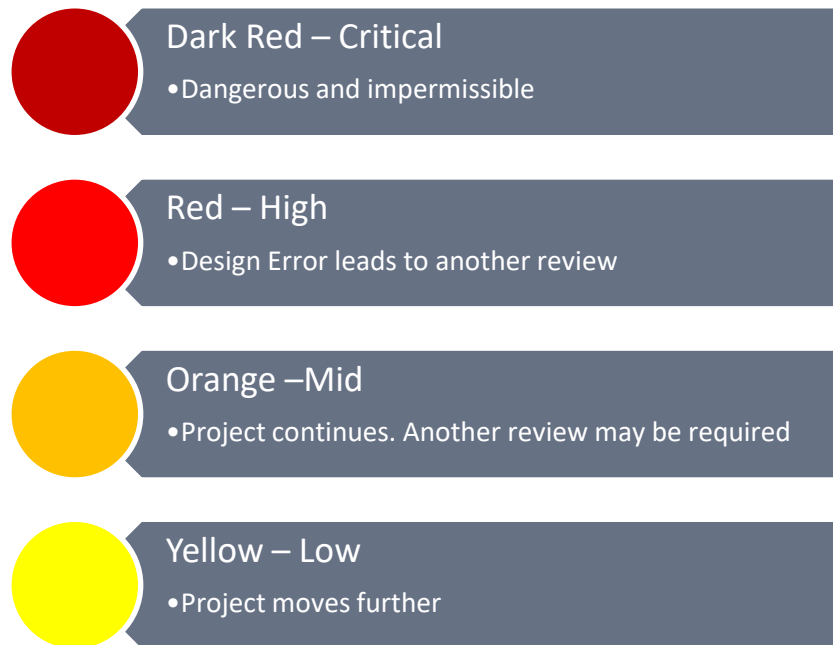


Figure 3.10: Quality of design errors with respect to criticality

The qualitative classification of the design errors helped provide the study another dimension to the research work. The quality aspect of each design error was matched in the same way the questions in the checklist were matched with all the design reviewers. The sections of the tool that would be reviewed through the help of the checklist was reviewed a colour were assigned to them. That meant any question from that section of the tool to be reviewed would fall in the same category as the section.

Werkzeugspannung und Zentrierung	Ziehen	Biege- / Nachformaufsatz
Transport	Beschneiden	Schneidaufsatz
Werkzeugführung	Nachformen	Schneidmesser
Grundgestell	Bauteilaufnahme und Lagekontrolle	Trennmesser
Pressenspezifische Punkte	Ziehstempel	Lochen
CBF-Pressen	Blechhalter / Luftboden	Abfallableitung
Werkstoffe	Ziehmatrize	Schieber
Instandhaltung	Beweglicher Matrizeneinsatz	Einpresselemente
Bearbeitung	Niederhalter	Heber
Stückliste	Biege- / Nachformbacken	Federn

Table 3.9: Criticality of design error table of sections of the tool

The design error criticality would help us determine later in the study about the qualitative aspect of the work of external companies. Too many errors from the dark red category would mean there is a fundamental knowledge gap of the working of the external companies which needed to be addressed immediately before awarding further businesses. More design errors from the yellow category would mean the external companies are creating a BMW standard press tool design and don't need any immediate training.

Interdepartmental Collaboration

The research required communication with colleagues from several domains. The communication was mostly in the form of interviews. The interviews consisted of face to face

3 Methodology for the analysis of design errors and lessons learned process creation

meetings and over internet platforms. The departments that were consulted and the topics discussed in the course of the study is shown in the figure below.

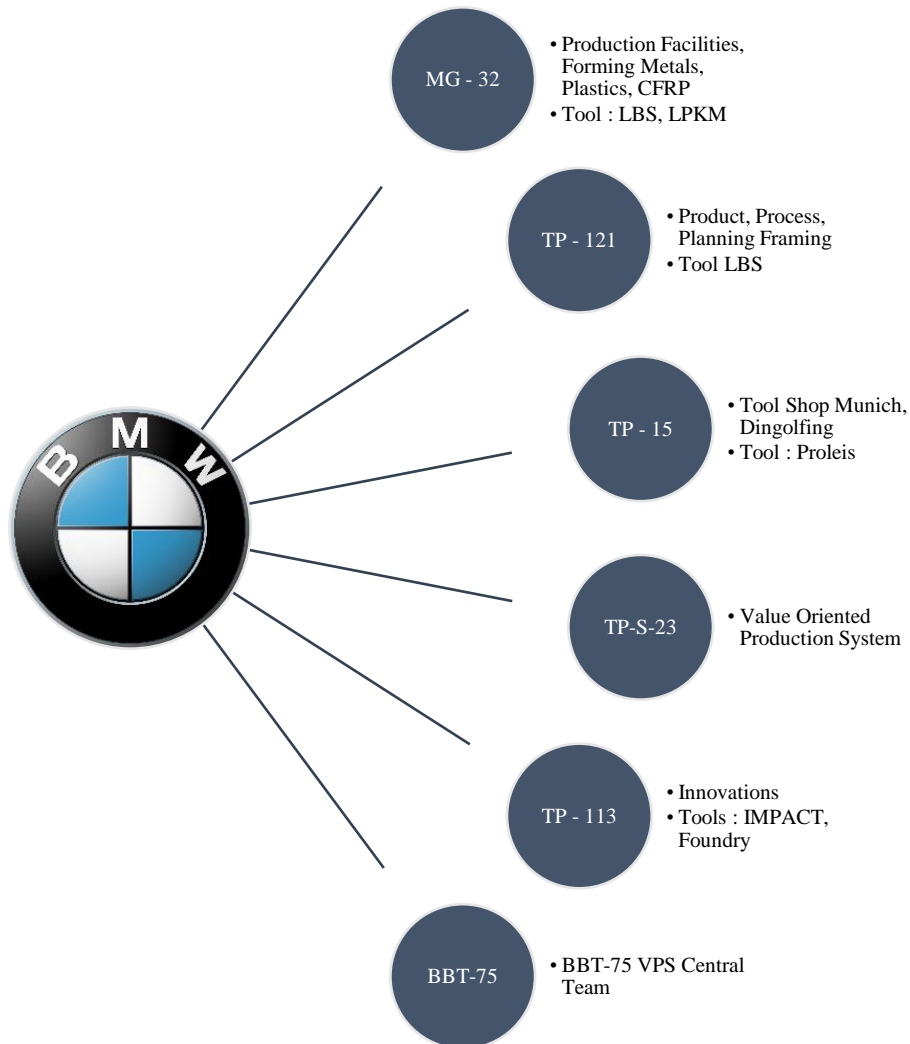


Figure 3.11: Collaboration with internal and external resources

❖ Interviews

It was necessary to create a summary of the information exchanged between domains and describe how it helped in the study.

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Dept.	Dept. Name and Tools Used	Discussion Topics	Objective Requirement
MG - 32	Production Facilities, Forming Metals, Plastics, CFRP Tool : LBS, LPKM	How are external companies evaluated through LBS (Lieferanten-bewertungs - system) for indirect parts.	Find the parameters and design the process to evaluate external companies in the final tool.
TP - 121	Product, Process, Planning Framing Tool: LBS	Coordination with external companies for direct parts used in the vehicles.	In-depth understanding of the evaluation of external companies and evaluation of internal process
TP - 15	Tool Shop Munich, Dingolfing Tool : PROLEIS	Departmental method of a Lessons Learned Process. How lessons are stored, categorised, tracked and implemented in future projects.	Understanding how a traditional Lessons Learned Process works in BMW.
TP – S -23	Value Oriented Production System	Ways to combine the different BMW methods of Lessons Learned Process. Customisation possibilities	Visualisation of the working of the Lessons Learned Process Parameters
TP - 113	Innovations Tools : IMPACT, Foundry	Possibilities to include the developed tool in Foundry software system.	Excel tool to Foundry system
BBT - 75	BBT-75 VPS Central Team	The functional and robust lessons learned system in BMW China plant.	In-depth information about the development of the Lessons Learned Process.

Table 3.10: Overview of interviews : Topics of discussion and usage in objectives

The interviews took place over several sessions and consisted of important exchange of data. In some of the interviews the philosophies were explained by the responsible colleagues from

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the respective department while in other discussions possibilities of customisation of the data collected was discussed. The most important aspects of the interviews and discussions elaborated below would give the reader a comprehensive understanding about the key takeaways.

- ❖ MG – 32 and TP – 121 (BMW Indirect and Direct Purchasing) : The goal of the discussion was to understand the LBS or LPKM (stands for Supplier Evaluation System and Supplier Management System) in BMW.

The following points and figures were the key takeaways from the discussions:

- Suppliers would be evaluated on parameters such as : Innovation, Quality, Flexibility, Cost and Risk Management
- Two departments would carry out the analysis: Specialist Dept. and Purchase
- Unbiased evaluator would use numbers for each parameter
- The numbers would be in the form of a traffic signal

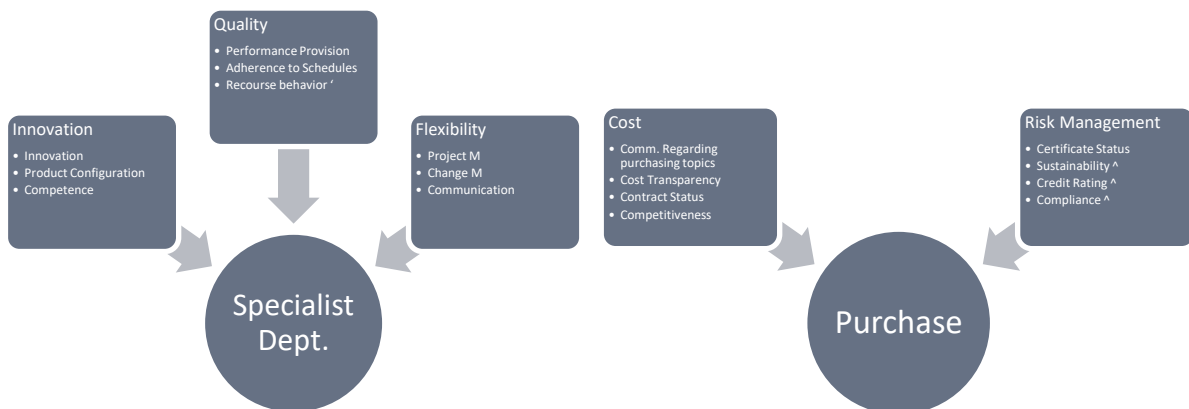


Figure 3.12: Departments in BMW responsible for evaluation of external companies

SUPPLIER EVALUATION INDIRECT MATERIAL. TRAFFIC LIGHT LOGIC.

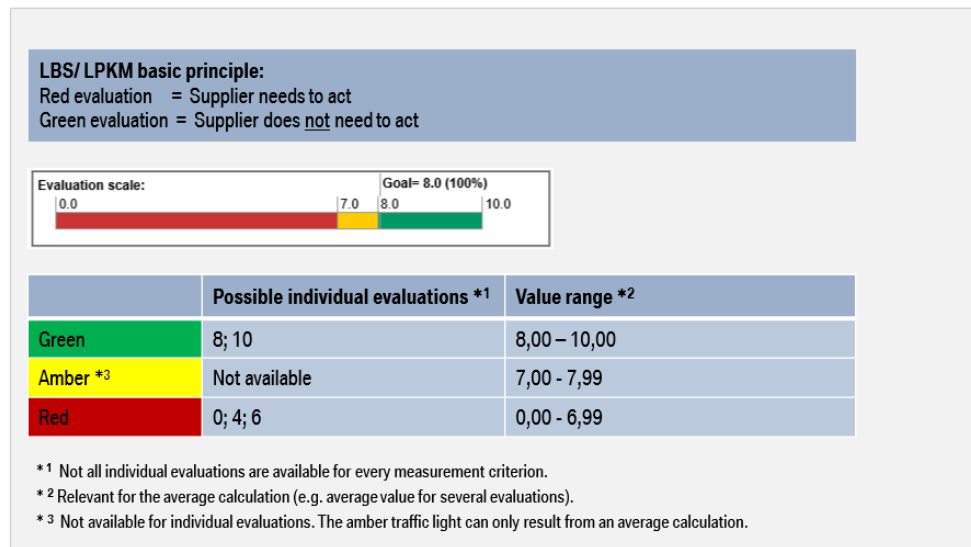


Figure 3.13: Supplier evaluation traffic logic control (BMW LBS/LPKM principle)

- ❖ TP – 15 (BMW Tool Shop Munich, Dingolfing): The goal of the discussion was to understand the lessons learned process carried out in the department. The discussion was in the form of an interview where the colleague was aware of the topics to be discussed.

The following points and figures were the key takeaways from the discussions which will be dealt in greater detail in the next chapters:

- PROLEIS Software was a platform being used by the department to store the lessons learned in projects and implement them in the next projects.
 - Discussed ideas were to customise the PROLEIS software into an easily implementable EXCEL tool.
- ❖ TP – S-23 (Value-Oriented Production System): The department was responsible for infusing value into the departments at BMW. The discussions were in the form of an interview with the topic already shared with the responsible colleague. More information is provided in the next chapters.
 - The ideas discussed were to improve the existing tool to evaluate the internal process and working of the external companies.

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- The discussion revolved around developing a method that can be tracked over a period of time.
- ❖ TP – 113 (Innovations in Press Tool Design) : The goal of the discussion was to understand the existing data mining software existing in BMW and how to incorporate that in the automation of the process being suggested.
- The discussion was in the form of regular meetings to see the scope of taking a part of the FOUNDRY software and using it to automate the process in TP – 121.
 - Steps were taken to create some files and see the extent to which the automation can be implemented.
- ❖ BBT – 75 (Value-Oriented Production System, BMW Brilliance Automotive Ltd.) : The goal of the discussion was to understand the existing process of capturing the lessons learned. The department already had an existing process created to capture lessons from ongoing projects and percolate the learnings to departments horizontally and vertically in the organisation.
- The discussion was in the form of pre-decided meetings where the colleague were aware of the topic to be discussed which was the creation of a lessons learned process.
 - Through the discussion, the goal was to understand the present process existing in the department in BBA, China.
 - The second goal was to understand the possibility to replicate a similar process in the department. The information received from the appointments would be shown and analysed in the next chapters.

3.2.4 Construction of tools for data collection

The collection of data was an important part of the study. Data-collection techniques allowed us to systematically collect information about our defined objectives. Although as mentioned in the beginning usually there is already a repository of data available, but not analysed properly. The location of the sources was a good starting point for data collection.

- ❖ EXCEL Tool to classify the design errors with checklist questions: As mentioned in the last section classification of the errors would have consumed time to process and incorporate

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if it would have been done individually. The excel tool made the way for the collaborative working as described below :

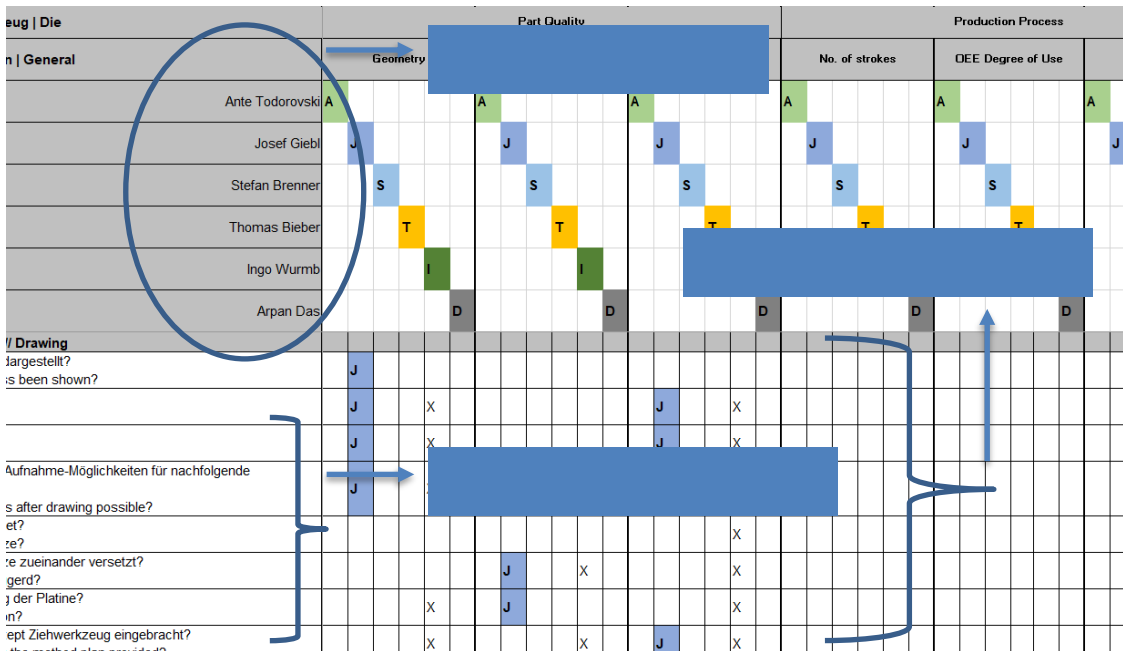


Figure 3.14: EXCEL Tool for collaborative classification

- ❖ **MACRO Enabled Tool:** The automated tool developed to extract data out of the various project checklists was to fulfil two objectives of the study. The automated tool enabled the colleagues to run a MACRO to accumulate the required data from the various design checklists of various projects. The tool discussed in details in the next Chapter Transfer to Practice was beneficial for evaluating the performances of the external companies in pre-decided parameters as mentioned below.

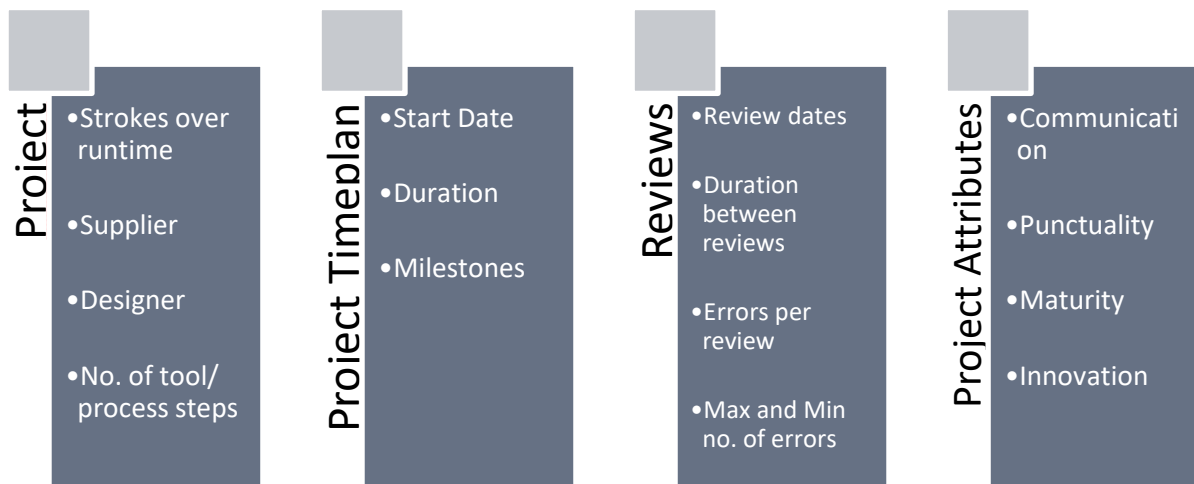


Figure 3.15: MACRO enabled tool functionality

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- ❖ Project study to evaluate internal and external processes: An excel tool was created to map out four live projects and four finished projects to create a comparison between the running of individual projects and the set project flow. The tool gave an overview on which phases of the project it deviated from the set process plan, accumulate the possible reasons for the deviations and the effects.

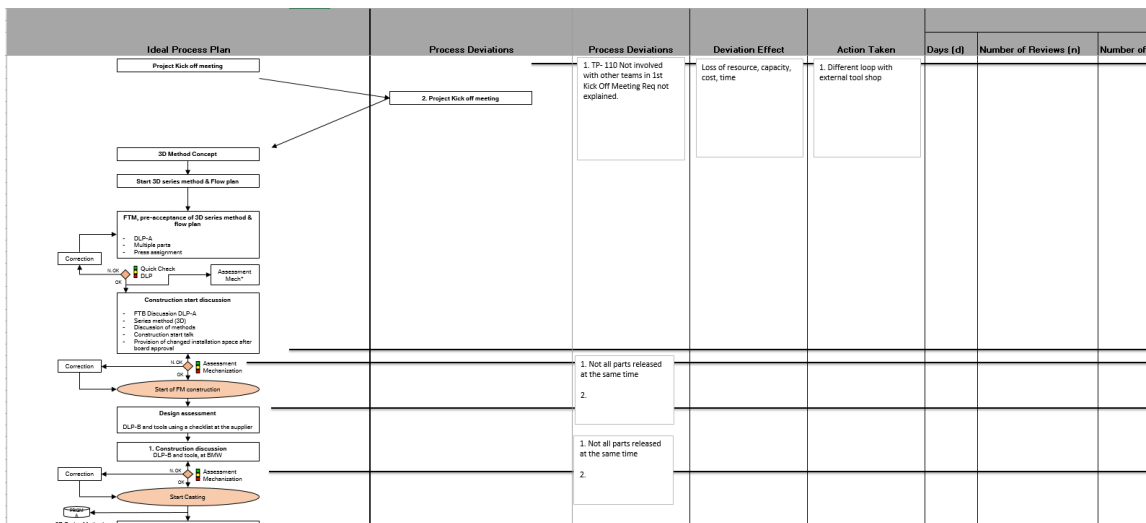


Figure 3.16: EXCEL tool to capture ideal process plan vs actual process plan

- ❖ FOUNDRY: Another data mining tool was used to collect some initial data through machine learning in order to see the validity of the MACRO enabled EXCEL tool. The tool was already established in TP-113 and limited access was provided in order to see the probability of including it in the study.

3.3 Analysis

The analysis was one of the most important part of the study. As data experts mentioned years back, the data is good as their analysis techniques. With several information exchanged between intradepartmental resources and interdepartmental resources, there was a need to properly analyze to fulfil the next objectives.

3.3.1 Content analyses

The analyses carried out to understand the data and conclude useful information was a fundamental part of the research as mentioned above. The carried out processes are mentioned below:

❖ Data Preparation for the complete study:

- Before the data could be worked on a thorough preparation was necessary to find conclusive material. A thorough compilation of the various types of design errors was necessary to conclude which design errors need to be concentrated on. There were over 600 questions in the design checklist and it required a thorough examination of what questions were still valid. Some of the questions were strike-off because of the obsolescence of certain type of press lines.
- Four live projects and four finished projects were followed through the course of the study to gain insight into the working of the internal stakeholders and external companies. Several projects showed signs of erratic time fluctuations for some study parameters. They were either focused on or removed in most cases to prevent the study from becoming extremely complex.
- FOUNDRY data mining software the data to be prepared to the easiest possible level for it to be fed into and conclusive results to be obtained.

❖ Analysis of the data for the completion of the study:

- The data obtained by the collaborative efforts of the colleagues internally in the department to classify the various questions with the typical design errors, were analysed in the usual manner. The sheet which contained the classification was made available to all the colleagues from the beginning for their comments.
- The live and finished projects which were followed were tracked on a customised the tool mentioned in the previous section. Easy analysis was possible by just looking at the overview page. The deviations were marked and reasons, effects and lessons learned for/from the deviations were added in their own columns.
- The main tool that was created for this study would collect all the data and initially would show in the form of a tabular column making it difficult to analyse it in a short period of time as shown in the figure below. However, after serious consideration, the MACRO code was altered to create easily understandable graphs for quick analysis of the most

3 Methodology for the analysis of design errors and lessons learned process creation

important data. This was the most important improvement in the whole study and would benefit the people using it in future.

					Part Quality				Production Process				Tool		Press Error Organisation Maturity					
					Geometry	Surface	Process C	No. of strc	OEE	Degre	Stability	Wear	Breakages	No Go	Design	Safety	Maintenar	Manufacturing		
G70	Fa. Gestan	Radhaus h	AFO 15	Review 1	0	1	1	0	0	0	7	1	7	5	7	0	0	4	33	33
G70	Fa. Gestan	Radhaus h	AFO 15	Review 2	0	0	0	0	0	1	0	0	0	2	0	0	0	3	3	
G70	Fa. Gestan	Radhaus h	AFO 25	Review 1	0	0	0	0	0	1	3	3	2	3	2	0	2	16	23	
G70	Fa. Gestan	Radhaus h	AFO 25	Review 2	0	0	0	0	0	0	0	0	0	1	0	0	0	1	2	
G70	Fa. Gestan	Radhaus h	AFO 30	Review 1	1	1	1	1	0	1	4	7	3	8	2	1	2	32	23	
G70	Fa. Gestan	Radhaus h	AFO 30	Review 2	0	0	0	0	0	1	0	1	1	0	0	0	0	3	1	
G70	Fa. Gestan	Radhaus h	AFO 35	Review 1	2	1	2	0	1	4	1	10	8	15	1	1	2	48	35	
G70	Fa. Gestan	Radhaus h	AFO 35	Review 2	0	0	0	0	0	0	0	0	0	1	0	1	0	2	2	
G70	Fa. Gestan	Radhaus h	AFO 40	Review 1	0	0	1	1	0	3	3	8	5	9	1	1	2	34	33	
G70	Fa. Gestan	Radhaus h	AFO 40	Review 2	0	0	0	0	0	0	0	0	0	2	0	0	0	2	4	
G70	Fa. Gestan	Radhaus h	AFO 40	Review 3	0	0	0	0	0	0	0	1	0	0	0	0	0	1	2	
G70	Fa. Gestan	Schliessble	AFO 15	Review 1	1	0	1	0	0	7	1	12	4	8	0	0	7	41	32	
G70	Fa. Gestan	Schliessble	AFO 15	Review 2	0	0	0	0	0	1	0	1	0	0	0	0	0	2	1	
G70	Fa. Gestan	Schliessble	AFO 20	Review 1	0	0	0	0	0	4	1	7	5	5	0	0	1	23	25	
G70	Fa. Gestan	Schliessble	AFO 20	Review 2	0	0	0	0	0	0	0	2	2	1	0	1	0	6	5	
G70	Fa. Gestan	Schliessble	AFO 25	Review 1	1	0	1	1	0	3	3	10	6	9	0	3	2	39	37	
G70	Fa. Gestan	Schliessble	AFO 25	Review 2	1	0	1	1	0	2	0	0	0	4	0	2	0	11	10	
G70	Fa. Gestan	Schliessble	AFO 25	Review 3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	
G70	Fa. Gestan	Schliessble	AFO 35	Review 1	2	1	1	0	0	5	1	8	7	7	0	1	1	34	24	
G70	Fa. Gestan	Schliessble	AFO 35	Review 2	0	0	0	0	0	0	0	1	1	2	0	0	0	4	3	
U06	Fa. JoRe	Verlänger	AFO 15	Review 1	0	0	0	0	0	0	2	1	1	6	2	1	1	14	12	
U06	Fa. JoRe	Verlänger	AFO 15	Review 2	0	0	0	0	0	0	0	0	0	1	0	0	0	1	2	
U06	Fa. JoRe	Verlänger	AFO 20	Review 1	0	0	0	0	0	0	1	3	2	7	1	3	0	17	14	
U06	Fa. JoRe	Verlänger	AFO 20	Review 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
U06	Fa. JoRe	Verlänger	AFO 20	Review 3	0	0	0	0	0	0	0	0	0	2	0	0	0	2	3	
U06	Fa. JoRe	Verlänger	AFO 25	Review 1	0	0	0	0	0	0	0	0	1	5	1	2	0	9	10	
U06	Fa. JoRe	Verlänger	AFO 25	Review 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
U06	Fa. JoRe	Verlänger	AFO 25	Review 3	0	0	0	0	0	0	0	1	0	2	0	0	0	3	4	
U06	Fa. JoRe	Verlänger	AFO 30	Review 1	0	0	0	0	0	0	0	1	1	5	0	2	1	10	9	
U06	Fa. JoRe	Verlänger	AFO 35	Review 1	0	0	0	0	0	0	1	1	3	6	1	1	0	13	14	

Figure 3.17: Data representation through developed tool V1

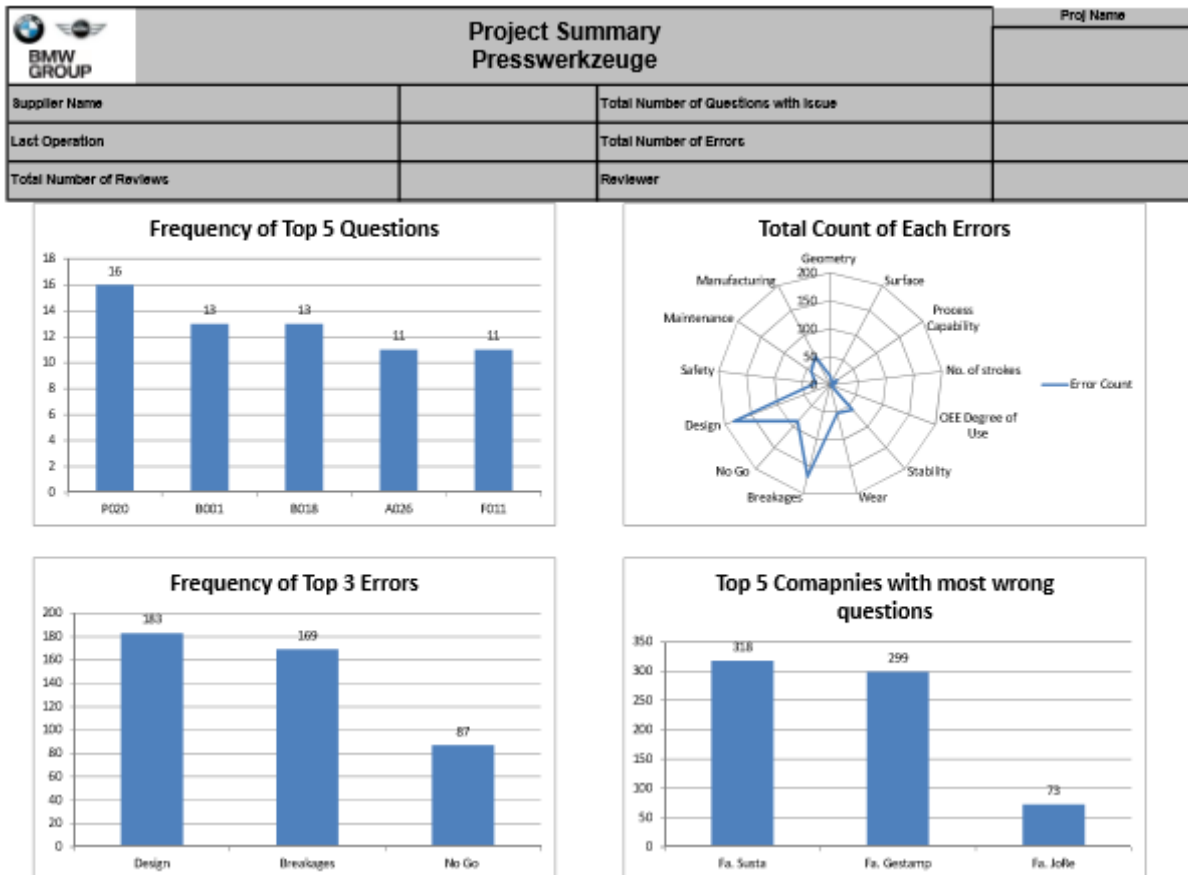


Figure 3.18: Data representation for easy analysis through tool V2

3.4 Evaluation and justification of the methodological choices

There was a strong foundation of understanding on which the methodology was established. It should be noted that with the amount of complexity and differences in each task, there was a need to create a robust, flexible yet definitive methodological approach. As described by Dejana Zlatanovic [18] the methodological approach to solving a complex research is always breaking down the tasks into smaller individual goals. The authors mentioned that in the process of breaking down the goals there is a clarity on the bigger picture. While their research struggled to combine the interdependences of each objective, this research was successful in combining the tasks together to create a coherent study. The conclusion went on to highlight that there was an imminent issue in the research because the authors failed to consider the two sides of any study: qualitative and quantitative aspects. In this research, we were successful in bringing the two elements as early as the first steps in the study.

4 Transfer to practice

The research demand for a methodology to transfer the knowledge gained into practices based on their importance was identified. The respective research work required a combination of concepts and methods from different areas of expertise. The methodology was created to address the objectives. With the help of the methodology, it was understood what kind of data was required to start the study and how it can be collected. The methodology defined several study attributes and a foundation was created to reach the objectives. With the definitions defined it was easier to understand what level and type of data were needed to conduct a thorough study on the topics. In Chapter 3, the methodology was summarised as “The methodology must be able to evaluate a typical big press tool development, enable a creation of a tool to do the same and propose a lessons learned process to capture the evaluations.” As the methodology was successfully created, there was a need to create a way to transfer the theory into practice. The transfer would ensure the continuity of the study in the regular working of the department. The overall goal of the study had as a part of the description of a lessons learned process. The methods required to create a lessons learned process would involve a holistic approach in combining the objectives of the study and delivering the results. However, the transfer required a need for an IT solution with a consistent and standardised data management element. Chapter 4 could be summarised as **“The practice should be able to incorporate varied complexity and can be performed regularly with limited knowledge and time”**.

4.1 Overall Approach

The technological knowledge gathered systematically from various sources and organised within an IT solution consistent with standard data management techniques. VDI 3633 Part 1 defined knowledge building as an important task.: “Tools such as simulation tools are developed from the experience of experts and thus contain the knowledge acquired through diverse experience. The simulation models form a knowledge reservoir which serves as an efficient basis for decision-making” as mentioned in VDI 3633 Part 1. It was required to meet certain requirements to develop a comprehensive tool.

Flexibility: As per the VDI 3633 models could be put to place if they are flexible and could be for different tasks with different complexity with a reasonable effort and knowledge. Input and output data of the model must therefore be able to be varied.

Transparency & Usability: To provide simple handling, both methods and tools must be chosen and implemented with a high focus on clarity. Dependencies and influencing factors must be

recognizable in the processes and calculations. Bottom-up approaches are preferred. The tool must provide user-friendly visualization and user interfaces.

Holistic: Information sources must be chosen accurately to provide the highest validity possible

Less redundancy: The tool needed the ability to be transferred for other types of data. The tool should be easy to comprehend and does not hold any redundant features which can slow it.

Validity: The tool should be able to validate the results on its own. The tool must have two or more techniques to validate the data it is representing at the end. In this case, it is the project attribute sheet.

Scalability: There should be enough room for scalability. Sustainable development is the motto for any development. There should be enough space for adding other features to the tool.

4.2 Automated tool and process deployments

With the help of the foundations established in the last section, the work on the automated tool was started. Some of the attributes of a tool collected from the VDI 3633 Part 1 can be used for the deployment of the lesson learned process.

4.2.1 Project process comparison tool

The functioning of the department was elaborated in the form of a process flow chart. The process flow chart defined the functioning of a project and the various interdependencies of the internal and external colleagues. The chart was taken as a foundation to build an editable excel sheet to follow the projects and accumulate the process deviations in reality. Along with the process deviations, the reasons for the deviations and effects were also noted. The excel tool was created to create a holistic overview of the running of the project and if possible create a side by side comparison of the various projects. The learnings from the sheet would be taken as a source of open point for the lessons learned process.

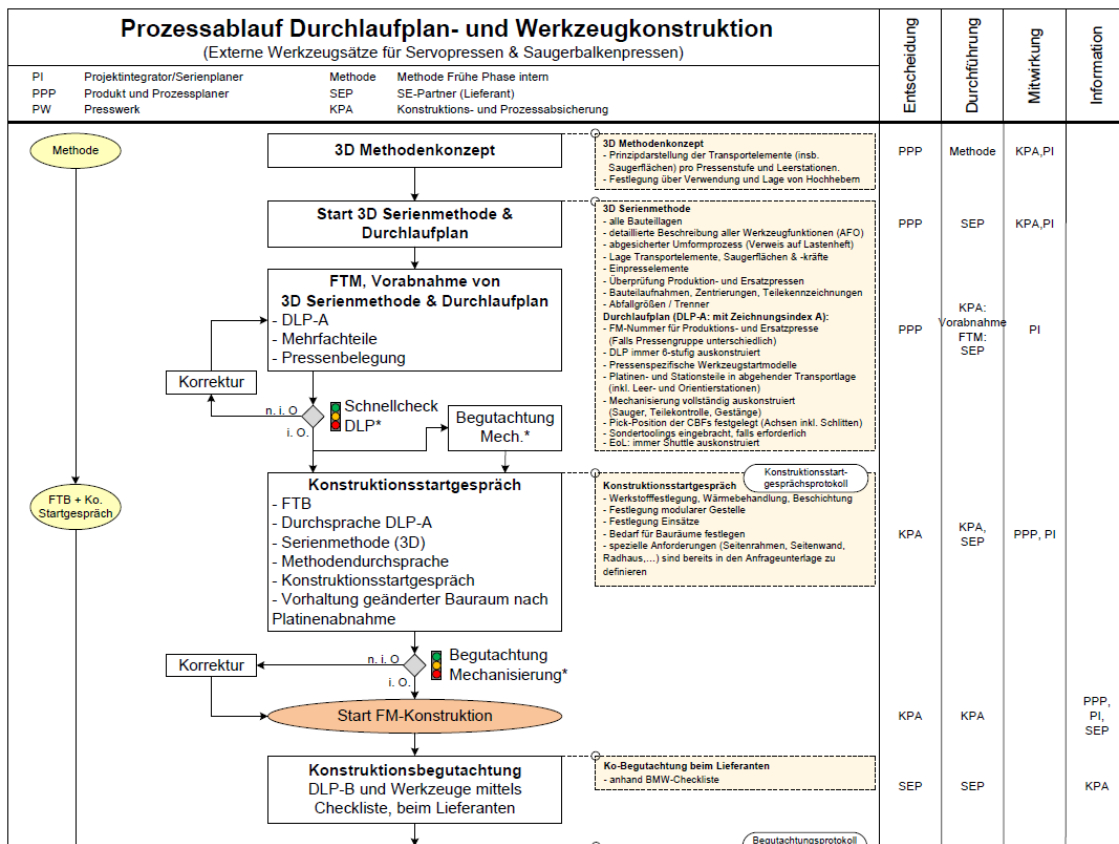


Figure 4.1: Ideal process plan of the department

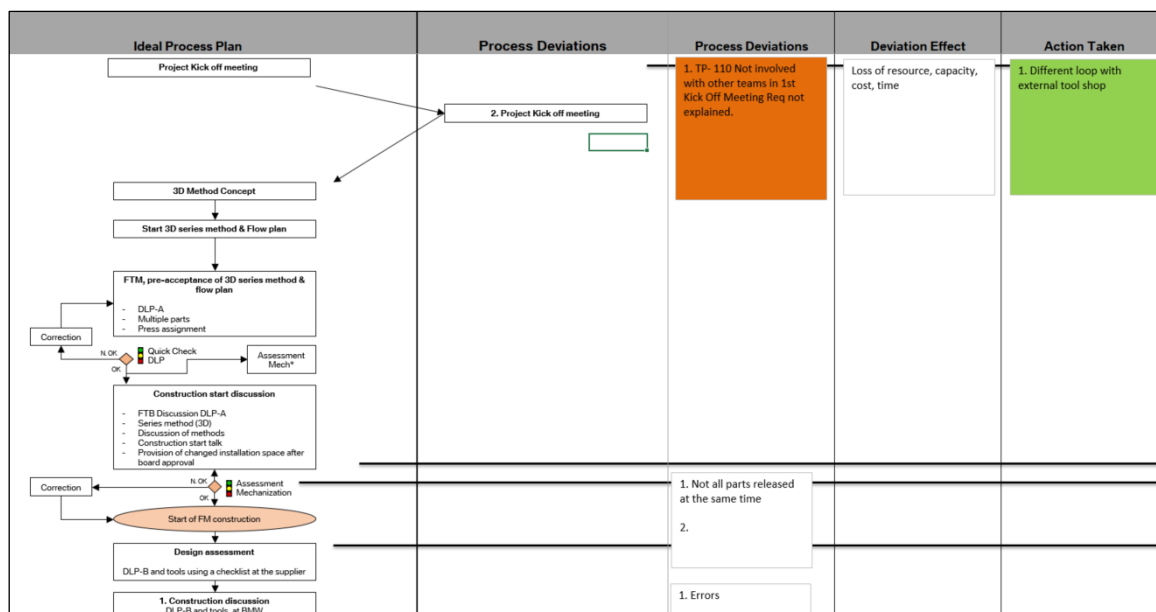


Figure 4.2: Editable sheet to track project steps against ideal process steps

4.2.2 Clustering tool

An essential part of the study was the development of an automated tool to carry out the processes. To fulfil the requirement care had been taken to understand the basis of tool selection and the development process. Both of these factors played an important role in the study of already developed tools. A portion of the study article “Excel as a qualitative data analysis tool” by Meyer et al. [18] gave a clear understanding of the need for a good data analysis tool. It comprehensively described the predicament researchers often face in the sea of data. Even though researchers find the richness and interconnectedness of the data fascinating, it can definitely be overwhelming. It went on to say that some sense must be made while preserving their complexity. Conceptualising tracking was the central hurdle as per their research. In the case of qualitative data, there was often a need to connect a bit of data to another. Hence over the years, this need led to the development of a market for quality data analysis tools that depend on modern computing power to enhance our human senses. The authors argued that even though Excel is often viewed as just a number cruncher it is therefore associated with quantitative data analysis. However, they concluded that Excel has proven to be useful in the qualitative data analysis segment as well. The article mentioned that Excel can handle a large amount of data, provide multiple attributes and allow for a variety of display techniques. The authors further explained how Excel has proven to be successful as a qualitative and quantitative analysis tool. This provided a good foundation to choose Excel as the platform to build a tool.

The obvious choices was using VBA Macro to create the tool. However, it was necessary to provide the colleagues in the study and the reader a comprehensive introduction to VBA and the general tool development steps to develop a tool. A good definition for the word Macro was taken from the book “Programming Excel with VBA” by Falvio Morgado [19] which stated “there was a time in computer usage that if you needed to accomplish a series of successive commands in software, you could use the appropriate program syntax to type the menu commands to follow, one command per row, and then make the program execute them, row by row. In the DOS age of the early 1980s, the spreadsheet program called Lotus 123 called this method a macro , and since then, every time a program tries to allow the user to implement such a resource to execute any desired number of successive menu commands, the convention is to say that the program is following a macro code.” The chapter 1 of the publication and its summary at the end described in details how a VBA code works.

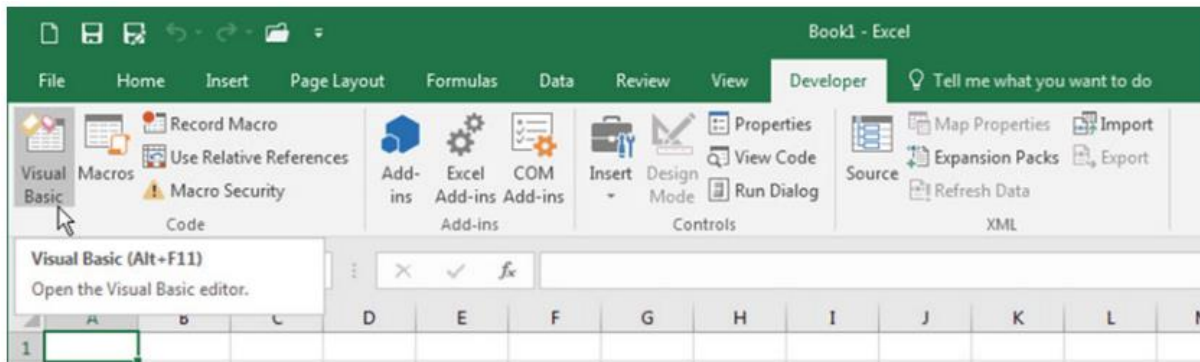


Figure 4.3: VBA Excel Developer tab

The developer tab in Excel would lead the user to VBA code module associated with the excel workbook file. By default, the Excel workbook file is called “ThisWorkbook”. Every excel file has just one of them.

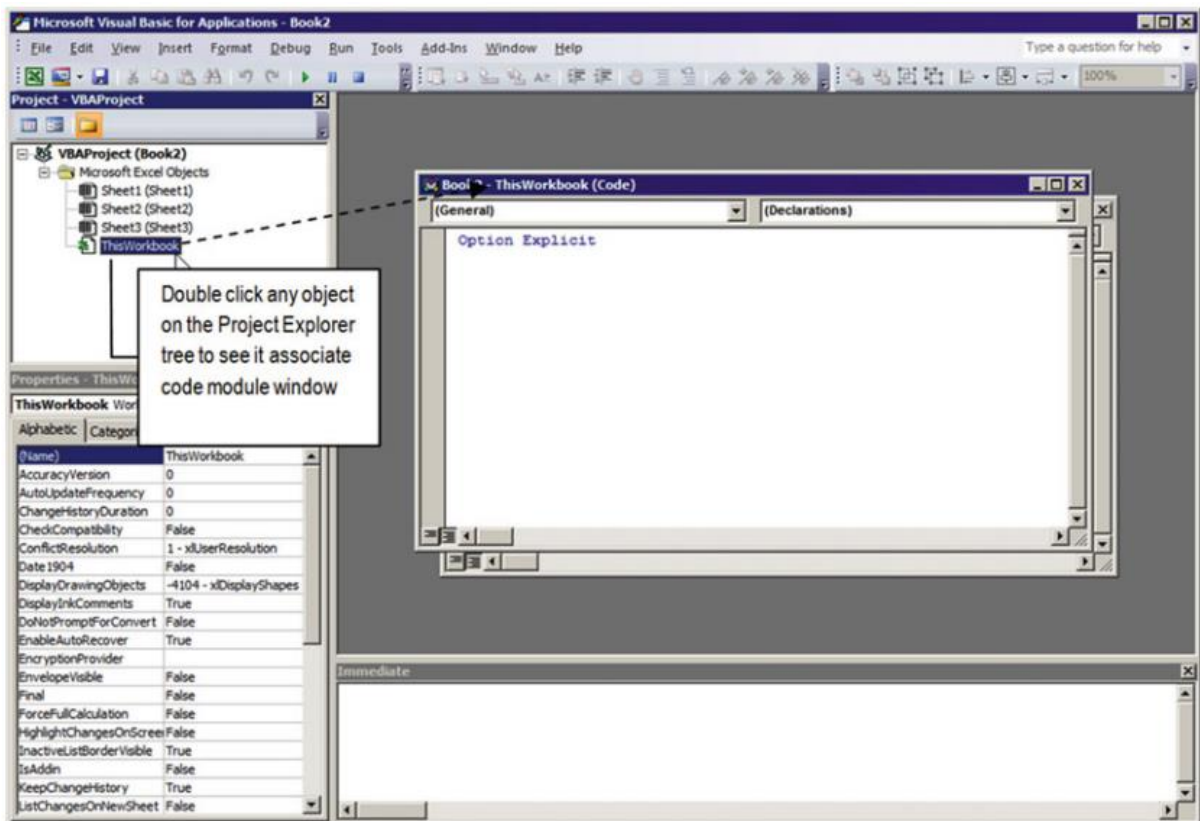


Figure 4.4: VBA Code module with the excel workbook file Favio Morgaod [29]

As discussed earlier a tool must have the following characteristics. It should be flexible, easy to use with a good visual representation. A simple yet definitive structure to develop a tool was taken as the basis of the tool creation. In the book “Essentials of Excel, Excel VBA, SAS....”

Lee et al. [20] elaborated on the three-step approach to designing any VBA tool: Visual prototype, feature building and modification, finalisation. Most of the Macro based excel applications created in the last few years followed this process. Coincidentally the approach took into consideration a reverse engineering technique compared to the usual build from scratch techniques. The visual prototyping, which might be a hand-drawn display or an MS Paint sketch, gave a view of the end result to work backwards. The libraries and functions created can be traced back to the initial visual prototype. Once the second step of feature building was taken, a comparison with the visual prototype and built feature would give rise to finesse modifications. The three-step methodology combined all intermediate and small processes under one big umbrella. A brief description of each step along with an example of it in relation to this study was deemed necessary to give the reader a broader view.

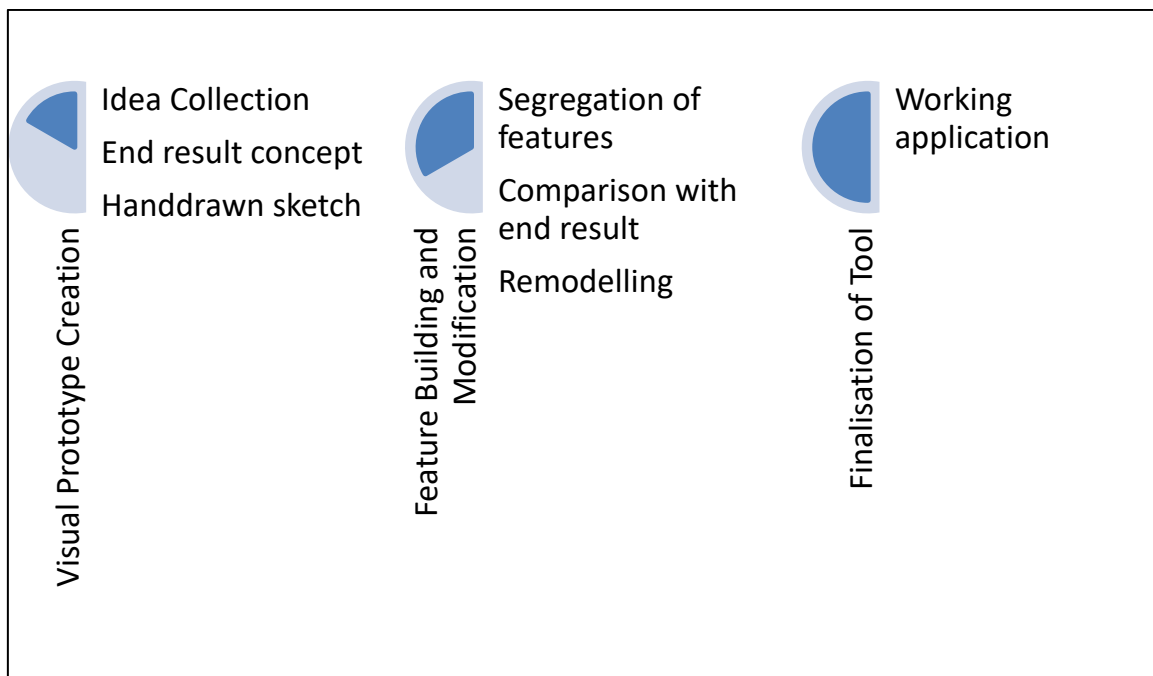


Figure 4.5: Three step approach to design a VBA tool

A brief description of each step along with an example of it in relation to this study was deemed necessary to give the reader a broader view.

- Visual Prototype Creation: With the help of a thorough understanding of the objective pertaining to this tool, an initial requirement was drawn out for the VBA tool. The tool should be able to take in the selected data points mentioned in the previous sections. The tool should be able to provide the user with an easy to understand visual representation of the project in terms of objective:

- Number of design errors per project
- Number of design errors
- Which design error has occurred the maximum number of times

A representation of the final display page was created as a visual prototype.



Figure 4.6: Visual prototype representation of the final display page of the tool

- Segregation of features and comparison with end results: The final display was segregated into individual blocks for better understanding. The individual blocks were constructed in tandem to improve the overall process. Some of the intermediate final display pages as shown below for the benefit of the reader.

					Part Quality		Production Process				Tool		Press Error		Organisation Maturity				
					Geometry	Surface	Process Ca	No. of strc	OEE	Degre	Stability	Wear	Breakages	No Go	Design	Safety	Maintenar		
G70	Fa. Gestan Radhaus h	AFO 15	Review 1	0	1	1	0	0	7	1	7	5	7	0	0	0	4	33	33
G70	Fa. Gestan Radhaus h	AFO 15	Review 2	0	0	0	0	0	1	0	0	0	2	0	0	0	0	3	3
G70	Fa. Gestan Radhaus h	AFO 25	Review 1	0	0	0	0	0	1	3	3	2	3	2	0	0	2	16	23
G70	Fa. Gestan Radhaus h	AFO 25	Review 2	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	2
G70	Fa. Gestan Radhaus h	AFO 30	Review 1	1	1	1	1	0	1	4	7	3	8	2	1	2	32	23	
G70	Fa. Gestan Radhaus h	AFO 30	Review 2	0	0	0	0	0	1	0	1	1	0	0	0	0	0	3	1
G70	Fa. Gestan Radhaus h	AFO 35	Review 1	2	1	2	0	1	4	1	10	8	15	1	1	2	48	35	
G70	Fa. Gestan Radhaus h	AFO 35	Review 2	0	0	0	0	0	0	0	0	0	1	0	1	0	2	2	
G70	Fa. Gestan Radhaus h	AFO 40	Review 1	0	0	1	1	0	3	3	8	5	9	1	1	2	34	33	
G70	Fa. Gestan Radhaus h	AFO 40	Review 2	0	0	0	0	0	0	0	0	0	2	0	0	0	2	4	
G70	Fa. Gestan Radhaus h	AFO 40	Review 3	0	0	0	0	0	0	0	1	0	0	0	0	0	1	2	
G70	Fa. Gestan Schliessble	AFO 15	Review 1	1	0	1	0	0	7	1	12	4	8	0	0	7	41	32	
G70	Fa. Gestan Schliessble	AFO 15	Review 2	0	0	0	0	0	1	0	1	0	0	0	0	0	2	1	
G70	Fa. Gestan Schliessble	AFO 20	Review 1	0	0	0	0	0	4	1	7	5	5	0	0	1	23	25	
G70	Fa. Gestan Schliessble	AFO 20	Review 2	0	0	0	0	0	0	0	2	2	1	0	1	0	6	5	
G70	Fa. Gestan Schliessble	AFO 25	Review 1	1	0	1	1	0	3	3	10	6	9	0	3	2	39	37	
G70	Fa. Gestan Schliessble	AFO 25	Review 2	1	0	1	1	0	2	0	0	0	4	0	2	0	11	10	
G70	Fa. Gestan Schliessble	AFO 25	Review 3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	
G70	Fa. Gestan Schliessble	AFO 35	Review 1	2	1	1	0	0	5	1	8	7	7	0	1	1	34	24	
G70	Fa. Gestan Schliessble	AFO 35	Review 2	0	0	0	0	0	0	0	1	1	2	0	0	0	4	3	
U06	Fa. JoRe Verlängeru	AFO 15	Review 1	0	0	0	0	0	0	2	1	1	6	2	1	1	14	12	
U06	Fa. JoRe Verlängeru	AFO 15	Review 2	0	0	0	0	0	0	0	0	0	1	0	0	0	1	2	
U06	Fa. JoRe Verlängeru	AFO 20	Review 1	0	0	0	0	0	0	1	3	2	7	1	3	0	17	14	
U06	Fa. JoRe Verlängeru	AFO 20	Review 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
U06	Fa. JoRe Verlängeru	AFO 20	Review 3	0	0	0	0	0	0	0	0	0	2	0	0	0	2	3	
U06	Fa. JoRe Verlängeru	AFO 25	Review 1	0	0	0	0	0	0	0	0	1	5	1	2	0	9	10	
U06	Fa. JoRe Verlängeru	AFO 25	Review 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
U06	Fa. JoRe Verlängeru	AFO 25	Review 3	0	0	0	0	0	0	0	1	0	2	0	0	0	3	4	
U06	Fa. JoRe Verlängeru	AFO 30	Review 1	0	0	0	0	0	0	0	1	1	5	0	2	1	10	9	
U06	Fa. JoRe Verlängeru	AFO 35	Review 1	0	0	0	0	0	0	1	1	3	6	1	1	0	13	14	

Figure 4.7: Intermediate displays of the tool

- Finalisation of the tool: The intermediate displays went through several changes to accommodate the need of the end-users. Excessive data as a display was not an option. It was decided to add more visual to the end page for better understanding and clarity.

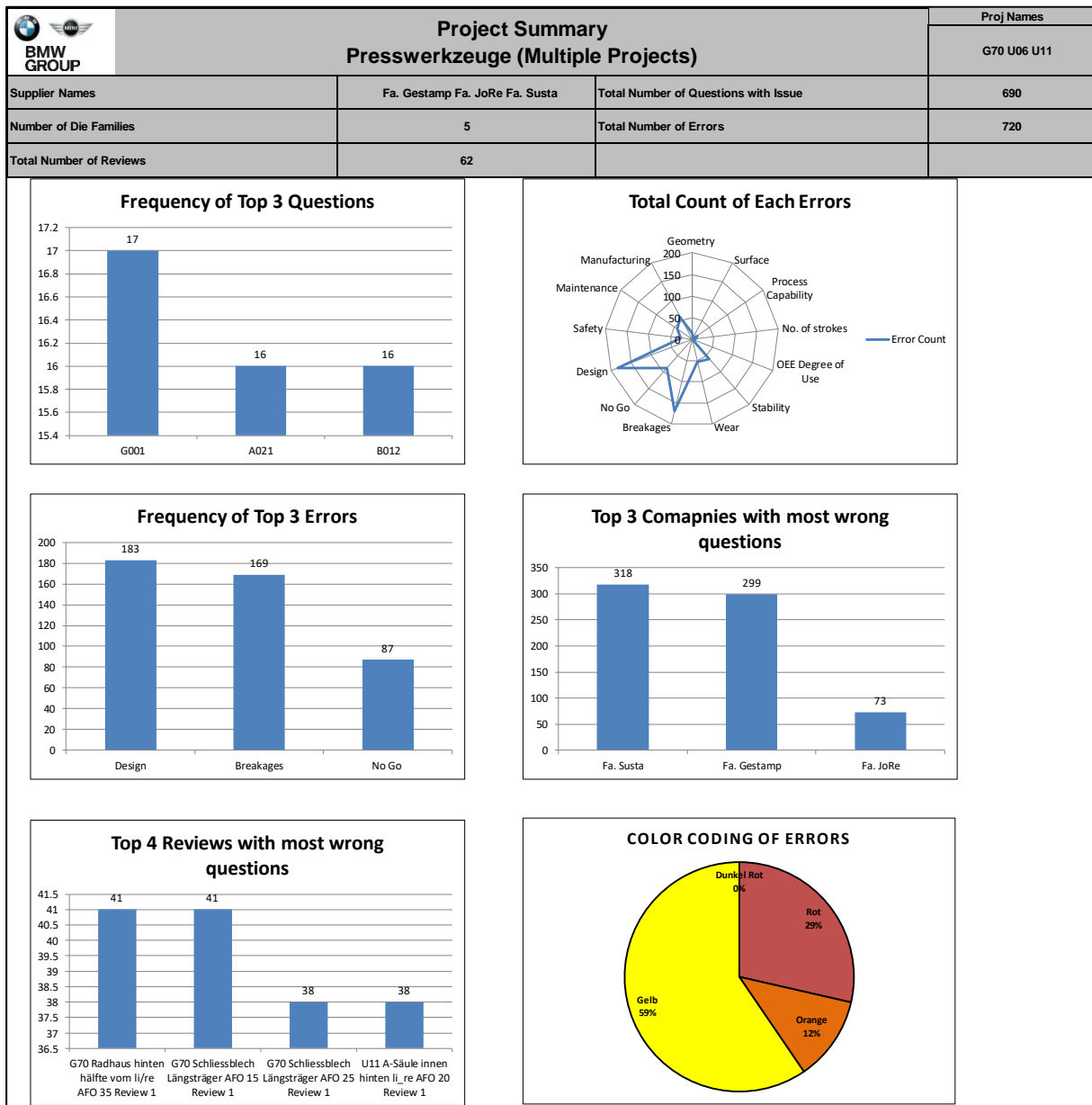


Figure 4.8: Finalisation

Even though VBA Excel proved to be a versatile tool it had quite a few drawbacks for this amount of data handling. From the views mentioned in the book “Practical Data Analysis in Chemistry” Rutan et al. [42] it was clearly visible the limitations of using excel to analyse data of this size. In their research, the authors had to initially plan to take the functions of Excel in building a tool. However, the problems that they faced were slow processing of data, less cope of data stored in memory and its usage and a not so counter-intuitive user interface. The drawbacks of the tool would be discussed in details in the later sections.

4.2.3 Process deployments

One of the tasks was the describing of a lessons learned process as mentioned in the list of objectives. Flyvbjerg et al. [21] in his research mentioned that over a length of a project cost overrun has remained high. Often these costs were fuelled by benefit shortfalls ranging from 20% to 50%. He had tried to define the relevance of the success of a project with the well-known 'iron triangle' measures. But long ago that had been fading out and the well-known 'iron triangle' measures are obsolete and Project Management success can no longer be determined by the measures of time cost and quality. Williams et al. [22] described that research and practice are moving towards a "multi-dimensional definitions involving objective and subjective criteria". Other authors described in their articles that the ultimate criteria to judge project success has not been found yet and the success of a project depended on many factors. The factors shifted from project to project as described by Ballard et al. [23] (Conceptualising..... articles). As discussed in the introduction to the lessons learned process in a project in Chapter 2, the process should capture the results and experiences from successes, failures, and near-misses and absorb them into a predefined method into the organisational structure for future use. This study included research steps to first identify the already existing methodologies available in this department and other departments. The results from the research were then accumulated, studies and customised lessons learned process was described. The process could be divided into four steps.

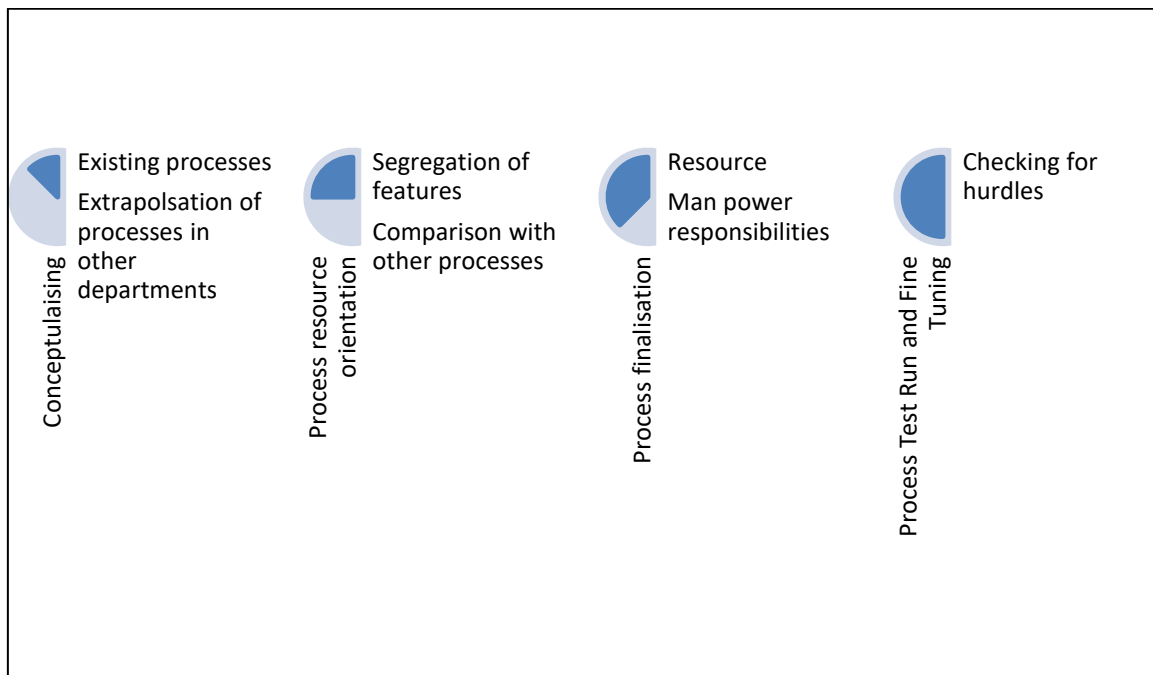


Figure 4.9: Steps to deploy the suggested process

The steps were taken to create a customised lessons learned process for the department.

- **Conceptualising:** This stage was to develop a visual display of the process to be implemented in the department. The department was already using a basic lessons learned process as described below. The open points from the lessons learned process came from one source: LOP/COC (Points from online commissioning). Interdepartmental colleagues would join a weekly meeting to collect the points from other departments. The open points would then go into a premade open points format. The points would be then worked on and then lessons would be learned for the next project. In this case, two more sources of open points were taken. The tool developed to find crucial information from the project data was also a source of open point now.

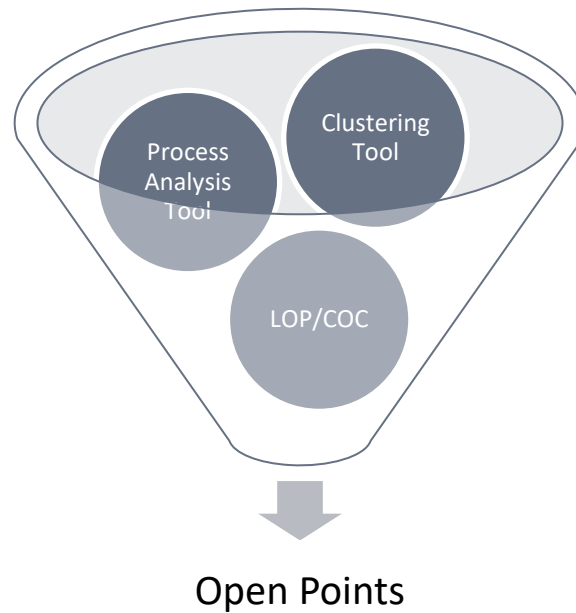


Figure 4.10: Source of open points

Process Analysis Tool	Clustering Tool	Online Commissioning
Process Deviations	Maximum Errors	Issues with die commissioning
Responsibility Mismatch	Repetitive Mistakes	Analysis to figure out why it was not captured during review and how to avoid it in the next project
Time	Number of Reviews	
Communication of Suppliers and Internal Colleagues	Supplier Attributes And other topics	

Table 4.1: Sources of open points with descriptions

- Process resource orientation: The features were quite well received from the BMW China Press Shop. With several appointments were able to understand the process. The BBA China plant had several resources at its disposal. The following images would give the reader an in-depth overview of the process being followed :

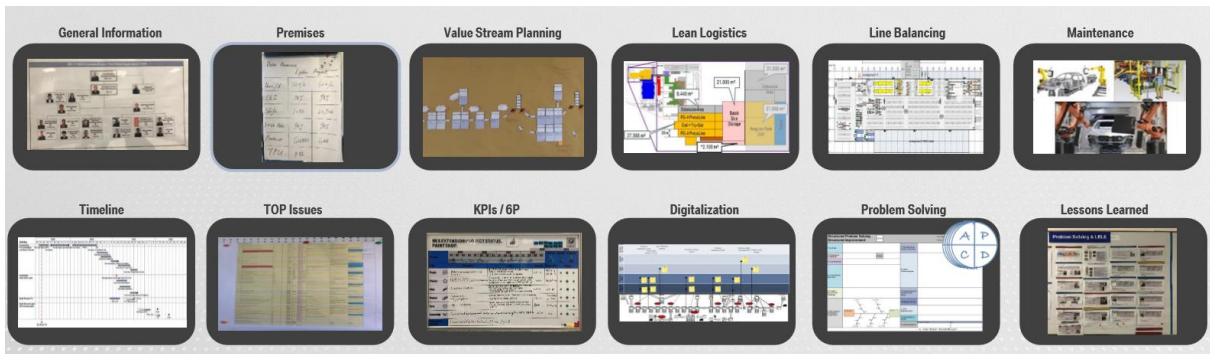


Figure 4.11: Information on a LeLe Board

The LeLe board would contain all the information required to get an overview of the department, KPIs, Timeline of projects, Problems Solved and a list of lessons learned. The topics which were found relevant for the LeLe process in the department in concern was the General Information about the department, Timeline of projects, Top Issues and a Lessons Learned Board. A digital image was created to visualise the LeLe area already existing in the BMW Brilliance Automotive. That would provide the reader with an idea of how the LeLe process worked.



Figure 4.12: BBA press shop lessons learned area (virtual)

However, with the space constraints in the department, it was decided to use the only available visual display available in the department.



Figure 4.13: Visual display chosen to implement the Le Le process

- Process Finalisation: The most important point decided was the type of data to be stored. As per experience, a digital file does not necessarily enable the process of storing and learning lessons. What was decided was a combination of a digital and a physical system to create the lessons learned process. Once the open points are collected through the tools mentioned in the first point, they were written down in the format mentioned below. There would be regular meetings to update the weekly charts.

Sl No	Date	Source	Project Name Part	Open Point	Description with Photo	Raised By	Criticality	Responsibility	Status	Remarks with Before/After
1	27.08.2020	Excel Tool	G70 9879117	Training to reduce design error for Supplier Susta : Gusstruktur, Auskernung, Verrippung, Gestaltung.		Arpan	5	Stefan	One Time Learn Rejected	Training

Figure 4.14: Digital file chosen for a LeLe Process

The digital file was accessible to all and it was decided that there will be responsibilities defined to update the sheet on a weekly basis. The person who had the responsibility for updating the digital file would do the same digitally while the person who was assigned the

responsibility for taking a regular print of the file to put it up on the visual display would do that. For the ease of the reader, a responsibility chart had been added which is in the next section.

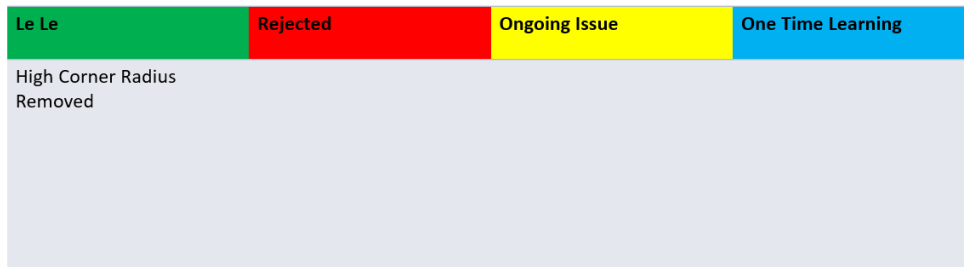


Figure 4.15: Segregation of open points in LeLe display

It was always necessary to define the roles of the people working in the system to have a clear understanding of the responsibilities one has to fulfil in order for the Le Le process to function properly. The responsibilities of each person were defined and mentioned below.

Facilitator	<ul style="list-style-type: none"> • Focus solely on the process and not get caught in content discussions • Ensuring the MT can provide clarity on the WHAT and the Team Reps can align on the HOW • Facilitating the Obeya meeting in alignment with the agenda and work agreements • Adherence to the work agreements during the meeting as needed • Help the Obeya Action writer in capturing action points during the Obeya meeting
Actions Writer	<ul style="list-style-type: none"> • Capturing action points during Obeya meetings – action, owner and deadline – on post-its and put on the action wall • Recapping action points collected at the end of the Obeya meeting to make sure that actions are clear for all participants
Time Keeper	<ul style="list-style-type: none"> • Keep track of the group progress during the given agenda timebox & timely notify the facilitator
Guidance developer	<ul style="list-style-type: none"> • Obeya guidance consist of living documents that display best practices in Obeya use: • Capturing group learnings & best practices via improvements in the guidance docs • Pro-actively suggest improvements • Stick up-to-date guidance documents on the wall after the meeting
MT member	<ul style="list-style-type: none"> • Updated priority wall • Adherence to priority milestone definition • Adherence to priority milestone narrative manual (output & outcome) • Adherence to priority milestone template • Adherence to priority setting agreements • Making sure you understand the team approach without interference on the HOW • (KPI) Target setting
Team Representative	<ul style="list-style-type: none"> • Updated Portfolio Wall • Adherence to Portfolio Milestone Definition and Porfolio Alignment agreements • Always have a team represented in Obeya meeting • Understanding the Priorities without interfering on the WHAT • In-time alignment with other teams on the HOW related to set priorities • Ability to make decisions on behalf of your team (planning) • In depth knowledge on team capacity, workload and planning • Provide status update on priority milestones according to the Priority Status Definition • Keeping the team/area fully updated after Obeya meeting
Obeya Room Maintenance	<ul style="list-style-type: none"> • All physical elements of the Obeya (walls, posters, etc) are fit for use • Ensuring room is tidy and ready to use • Ensuring all materials (pens, post-its, etc) are sufficiently available • Continuous improvement of physical obeya room • Checking users on relevance and effectiveness current setup • Proactively driving/discussing room innovation
Digital Obeya maintenance	<ul style="list-style-type: none"> • Ensuring all information in the physical Obeya is reflected in the digital space • Governance on user rights • Ascertain ISO governance/decision processes are captured • Ascertain back-ups • Use user knowledge to answer questions and guide other users • Drive Digital innovation

Figure 4.16: Responsibilities of people in Le Le process

It was always necessary to define the roles of the people working in the system to have a clear understanding of the responsibilities one has to fulfil in order for the Le Le process to function properly. The responsibilities of each person was defined and mentioned below.

4.3 Obstacles in transferring into practice

Any process or tool implementation would be hurdled with obstacles in spite of careful planning. Most of the hurdles could be predicted at the start of the project. However in the best of planning sometimes leads to unexpected issues. In a research article named

“Implementation obstacles for a work development-oriented TQM strategy” Martin et al. [41] talked about the main obstacles, a company faces when implementing a new process are limited resources, lack of knowledge and unclear management directive. In the implementation procedure of the tool and the lessons learned the following was observed.

❖ Classification of design errors

- There were no obstacles as such but the classification took a considerable amount of time.

❖ Clustering tool

- Resources: The resources that was available for the tool development was chosen as Excel it being a freeware and widely used in the industry. Even though there were other robust data analysis tools available in other departments, the time and manpower was not sufficient to implement it.
- Knowledge: The knowhow to implement a tool of this scale was limited. The tool was to be made part of a larger process.

❖ Lessons learned process deployment

- The deployment was hurdled with space restrictions
- Resources were not as much as required for a typical lessons learned process Obeya room.

A detailed discussion about the limitations faced would be continued in Section 5.2.3

5 Results, discussion and recommendations

Chapter 3 described the methodology created to steer through the study while Chapter 4 described the process of transferring the study into practice. This chapter talks about the quantitative and qualitative results obtained from the study. The quantitative results would be some of the output of the tools or processes which were tried to be implemented with the help of the study while qualitative results would be the observations in the tool and process usage.

5.1 Preliminary results

5.1.1 Classification results of design errors with questions in the checklist

Design Error	Sub error	Number of classifications
Part Quality	Geometry	84
	Surface	48
	Process Capability	103
Production Process	No. Of Strokes	8
	OEE Degree of Use	30
	Stability	44
Tool	Wear	45
	Breakages	108
Press Error	No Go	52
Organisation Maturity	Design	87
Safety		31
Maintenance		35
Manufacturing		68

Table 5.1: Number of design errors in a complete design checklist after classification

An excerpt from the page which shows the number of classifications is shown below.

5 Results, discussion and recommendations

1		Werkzeug Die						Part Quality												
1.1		Allgemein General						Geometry		Surface		Process Capability								
		Ante Todorovski	A					A		A										
		Josef Giebl	J					J		J		J								
		Stefan Brenner		S					S		S		S							
		Thomas Bieber			T						T		T							
		Ingo Wurm				F					F		F							
		Arpan Das					D						D							
26		Heber // Lifter																		
Z001		Ist das Teil auf den Teilanhebern ausreichend aufgenommen? (Formaufnahme, Grobeinweiser, Aufnahmestifte, Magnete) Is the panel position on the lifters sufficient? (form, nauages, pins, magnets)																		
Z002		Sind gedämpfte und richtig dimensionierte Sicherungselemente und Anschläge für Teilanheber vorhanden? Are damped and correct designed retainers and stop blocks for the lifters provided?																		
Z003		Sind die Teilanheber richtig gesteuert? (Dauerluft bzw. gesteuerte Luft) Is the control of pneumatic lifters correct?																		
Z004		Weitere? Others?																		
27		Federn // Springs																		
AA01		Werden Gasdruckfedern verwendet? Gummi- und Stahlfedern nur nach Rücksprache mit BMW verwenden Gas springs to be preferred, rubber and steel springs only as an exception?																		
AA02		Sind die erforderlichen Federkräfte und -wege richtig berechnet? Are all springs concerning travel and tonnage designed correctly?											T							
AA03		Sind die Federn so angeordnet, dass möglichst kein Kippmoment entsteht Are springs correctly positioned without generating rocking of the spring loaded parts?																		
AA04		Ist sicher gestellt, dass beim Aufwärtshub der Presse das Bauteil im Werkzeug nicht beschädigt wird? (Abstreifer, Faltenhalter) Are all spring loaded parts designed for anti bouncing?			T				T				T							
AA05		Ist eine Ringleitung für die Gasdruckfedern erforderlich? Is a ring line for gas springs necessary?																		
AA06		Federkräfte dürfen nicht auf Sicherungselemente wirken Are all retainer cleared from spring tonnage?																		
AA07		Sind die Einbauvorschriften für Gasdruckfedern beachtet worden? Are all gas springs attached according to the B2 4001																		
AA08		Sind Schutzbleche für freiliegende Federn und Federböden vorgesehen? Are all accessible springs covered with debris guards?																		
AA09		Weitere? Others?																		
			5.00	30.00	38.00	11.00	0.00	0.00	1.00	17.00	25.00	5.00	0.00	0.00	5.00	44.00	38.00	16.00	0.00	0.00
						84.00					48.00					103.00				

Figure 5.1: Total number of design errors in the design checklist

5.1.2 Results from the process analysis tool

The process analysis tool compared four running projects and four finished projects. As discussed in the last chapters the ideal process flow plan was taken and put on an editable excel sheet. The steps of the projects to be followed were then compared with the ideal process steps and the deviations were noted down. Along with the deviations, the probable causes and effects were also discussed, though the observation was solely taken from the design reviewer. From the impact of the deviations on the flow of the project, some deviations were marked orange to notify the severity to the observers. Finally, in the column of lessons learned, some lessons that could be taken for the next project were noted down. Lessons were distributed to all the departments involved in the project. Although eight projects were followed, the two projects with the most project deviations are shown below in Table 5.2.

5 Results, discussion and recommendations

Project Name	U12
Part Name	Roof Frame Inner Left/Right, Side frame inner front
Design Reviewer Name	Thomas Bieber
Supplier Name	HIT Automotive
Start Date	Apr-20
Number of Processes	OP 15, 20, 25, 30, 35, 40
Special Remarks	1. OP 30 Plate Underneath Die known from the beginning. Die size and safety issues
	2. 2 die with in-press elements. OP30/40. OP 30 2 feeding machines. 40 1 feeding machine

Table 5.2: U12 project details (one tool family)

5 Results, discussion and recommendations

Project Name		U12									
Part Name		Roof Frame Inner Left/Right, Side frame inner front									
Design Reviewer Name		Thomas Bieber									
Supplier Name		HIT Automotive									
Start Date		Apr-20									
Number of Processes		OP 15, 20, 25, 30, 35, 40									
Special Remarks		1. OP 30 Plate Underneath Die known from beginning. Die size and safety issues 2. 2 die with inpress elements. OP30/40. OP 30 2 feeding machines. 40 1 feeding machine									
Step	Dates	Problems	Effects	Action Take	Proposals	Lessons	Lessons for Department				
							TP-101 Capacity Planning	TP-12 New Part Planner	TP-17 Project Integration	TP 110	
	Project Kick off meeting	0 01 April 2020									
	3D Methodenkon	3D Method Concept	1 01 May 2020								
	Start 3D series method										
	Start 3D Serienme		2 01 July 2020	OP 30 delay. Dimension of the plate. With the plate underneath the die, how to mount the feeding machines? Possibility to bring plate under. Safety Issues	Die set held for delay, how to run in China? Process inside China...	Several meetings with colleagues in China to resolve issue.	* When the requirements are available, discussion in the beginning of project. * 2 feeding machines	Clarify the project specific constraints in the beginning of the project. Heavy dimension restrictions, can it be run in the press.	Discussion with other departments about design constraints and plant specific constraints at the beginning of the project.		Integrate the project team members for better information flow
	FTM, Vorabnahme von 3D Serienmethode & Durchlaufplan - DLP-A - Mehrfachteile - Pressenbelegung	FTM, pre-acceptance of 3D series method & flow plan - DLP-A - Multiple parts - Press assignment	3 10 July 2020								
	Schnellcheck DLP*	Quick Check	4 12 July 2020								
	Correction		5	94 sheets in the PPT. To be corrected : 49 flow sheet.							
	Design Review Mechanic		6			How to handle the design model of the flow. Knowing the flow model.					
	Konstruktionsstar	Construction start discussion FTB Discussion DLP-A Series method (3D) Discussion of methods Construction start talk Provision of changed installation space after board approval	7 16 July 2020								
	Review Mechanisation		8								
	Correction		9				Checklist should be used at Supplier. Colleagues send the checklist for the 1 st rev and then do the 1 st rev. 80% guaranteed. Lessons Learned. Must in the beginning of the project.				Supplier Training request. Checklist to be sent before project start. Supplier self checklist review required

Figure 5.2: Process Analysis of Project U12 (one tool family)

5 Results, discussion and recommendations

On the left hand side of this excel sheet is the ideal process plan followed by the department while on the right-hand side the deviations are collected. The probable causes of the deviation, effects of the deviation and proposals by the design reviewer were noted. Lessons were formulated and placed under columns of the department representatives. All the above are highlighted in Figure 5.3 below. A detail discussion about the preliminary results is in the 5.2 Discussion section

Dates	Problems	Effects	Action Taken	Proposals	Lessons	Lessons for Department			
						TP-101 Capacity Planning	TP-12 New Part Planner	TP-17 Project Integration	TP 110
01 April 2020									
01 May 2020									
01 July 2020	OP 30 delay. Dimension of the plate. With the plate underneath the die, how to mount the feeding machines? Possibility to bring plate under. Safety Issues	Die set held for delay, how to run in China? Process inside China...	Several meetings with colleagues in China to resolve issue.	* When the requirements are available, discussion in the beginning of project. * 2 feeding machines	Clarify the project specific constraints in the beginning of the project. Heavy dimension restrictions, can it be run in the press.	Discussion with other departments about design constraints and plant specific constraints at the beginning of the project.		Integrate the project team members for better information flow	

Figure 5.3: Process deviation data captured in Project U12 (one tool family)

The details of the second project where high number of deviations are mentioned below.

5 Results, discussion and recommendations

Project Name	G 12/20 to U06 (minor changes in tools from the first project)
Part Name	Double Tooling
Design Reviewer Name	Thomas Bieber
Supplier Name	Matrici
Start Date	Jan-19
Number of Processes	OP 15, 20, 25, 30, 35
Special Remarks	1. Already stable flow, inside production, strokes achieved, design alright
	2. One change in OP for holes
	3. Matric changed the operation flow from the previous project

Table 5.3: U06 project details (one tool family)

The snippet of the captured process deviations below.

Project Name	G 12/20 to U06										
Part Name	Double Tooling										
Design Reviewer Name	Thomas Bieber										
Supplier Name	Matrici										
Start Date	Jan-19										
Number of Processes	15 - 35										
Special Remarks	1. Already stable flow, inside production, strokes achieved, design alright 2. Matric flow of design change. One change in OP for holes										
Step	Dates	Remarks	Problems	Effects	Action Tak	Proposals	Lessons	Lessons for Department			
								TP-101 Capacity Planning	TP-12 New Part Planner	TP-17 Project Integration	TP 110
Project Kick off meeting	0	Jan-19									
3D Methodenkon	3D Method Concept	1									
Start 3D series method											
Start 3D Serienm	2	Feb-19	Unoptimise d Flow from Supplier, Unnecessa ry change from original flow	Time Consumpti on of reviews			Clarification from the beginning of thr project about the constraints and demands		Highlighting and fixing the important aspects of tool design such as the process flow.	Ensuring the process flow remains same.	

Figure 5.4: Process Analysis of Project U12 (one tool family)

The excel page was created to collect the data from the projects and give the colleagues a complete overview of the process deviations in the project. The discussion will contain an understanding of the results in detail.

Project Name	U06
Part Name	Double Tooling
Design Reviewer Name	Thomas Bieber
Special Remarks	Problems with EPE (Einpresselemente) Machines; design, placement

Figure 5.5: Project issues with EPE (Einpresselemente) machines alignment with tool design

EPE or “Einpresselemente” are various types of self-piercing and riveting fasteners that need to be aligned with the press tool design to ensure flow of the elements during the forming operation. The tool design process was stalled for inaccurate and faulty placement and alignment of such tools. External companies such as PROFIL who are responsible for providing the machines for the elements were brought into the tool design process at a later stage causing collaboration issues.



Figure 5.6: EPE (Einpresselemente), Techfast.de

5 Results, discussion and recommendations

Project Name	U12
Design Reviewer Name	Ante Todorovski
Ext. Manufacturer	HIT Automotive
Special Remarks	<ol style="list-style-type: none"> 1. Go ahead for casting all tools for 5 operations one month before the schedule 2. Quick check step skipped because U11 lead

Table 5.4: U12 Tool family observations

The project details mentioned in Table 5.4 resulted in a tool family cast release one month before time.

Project Name	U12
Part Name	B Pillar
Design Reviewer Name	Josef Giebel
Supplier Name	HIT Automotive
Start Date	Apr-20
Number of Processes	OP 15, 20, 25, 30, 35
Special Remarks	<ol style="list-style-type: none"> 1. Colleagues responsible for creating process flow did not complete process flow documentation on time. Colleagues from design review created the process flow 2. OP 15, 30 were signed off for casting without the other Ops.

Table 5.5: U12 B Pillar tool family process analysis observations

5.1.3 Results from the clustering tool

The clustering tool that was created to automatically extract data out of the design checklists used for each individual tool family. An introduction about the design checklist which was used by the design reviewers was described in 3.1.3 Data collection techniques. We have discussed here one such result from the clustering tool. Even though we can take one tool family and use

5 Results, discussion and recommendations

the clustering tool to evaluate results, here we have taken quite a few tool families and tried to find a combined analysis of all the tool families. Not all the tool families were being manufactured by the same external company. The table shows the projects that were taken to use the clustering tool.

Sl.	Project Type	Part Number	No of processes	Start Date	Manufacturer
1	U06	7 287 147 / 148	OP 15, 20, 25, 30, 35	06.06.2019	Fa. JoRe
2	G70	9879121 / 122	OP 15, 20, 25, 30, 35	17.02.2020	Fa. Gestamp
3	G70	9879117/18/19/20	OP 15, 20, 25, 30, 35, 40	17.02.2020	Fa. Gestamp
4	U11	9479325_326 9479358_359	OP 15, 20, 25, 30, 35, 40	12.12.2019	Fa. Susta
5	U11	9479311_312 9479395_396	OP 15, 20, 25, 30, 35	12.12.2019	Fa. Susta

Table 5.6: Project checklists selected for clustering tool results

Even though there are more details to a checklist but the most important details are shown in the above Table 5.6. For the benefit of understanding a screenshot of the first page (containing information about the tool family) of the U06 tool family is shown below in Figure 5.7.


 BMW GROUP	Ersteller		Konstruktion Engineering Lebenslauf Presswerkzeuge				Vertreter		U06			
	Giebl						Datum: 05-06-2019			Prod. Presse		PGB
	SAPNr. 1234567489									Ersatz Presse		PGA
Version 1.6 (Stand 05.06.2019) Entwickelt von: Andreas Seemann (Andreas.AS.Seemann@bmw.de)												
Bauteildaten:						Wichtige Termine:						
Teil. Bez		längerung Längsträger Oberteil ZB li / verlängerung Längsträger innen li / re				Ko-Start	Gussfreigabe	Fräsfreigabe				
Teil Nr.		7287141/142		7 287 147 / 148		06-06-2019						
Mat. Dicke		1,6mm		1,4mm								
Material		CR440Y780T		CR380LA								
Beteiligte:				Hübe über Laufzeit		Werkzeugdaten:						
Begutachter BMW:	Hr. Giebl	TP-110	+49-89-382-43307	20,00,000			Nummer	Benennung				
Simulation DLP:	Hr. Pulina	TP-110	+49-89-382-43413	Platinengröße		Methodenplan	3004151/152	3D-Methode				
Neuteile PL:	Hr. Dendl	TP-122	+49-89-382-75737		I	DLP	3004153	Durchlaufplan				
P-Integrator:	Hr. Ritzinger	TP-171RG		X=	0	AFO 015	3004154	Ziehen				
Hersteller:	Hr. Mertensmeier	Fa. JoRe	Telefon	Y=	0	AFO 020	3004155	Beschneiden und Locher				
KO-Büro:	Hr. Kössler	Fa. Kössler	Telefon	<div style="border: 1px solid orange; border-radius: 10px; padding: 2px; display: inline-block;">Kommentare</div>		AFO 025	3004156	Beschneiden und Locher				
Hersteller:	Hr. Deppenwiese	Fa. JoRe	Telefon			AFO 030	3004157	Einpresselemente				
---	Name	Abt./Firma	Telefon	<div style="border: 1px solid orange; border-radius: 10px; padding: 2px; display: inline-block;">Kommentare</div>		AFO 035	3004158	Nachformen				
						AFO 040						
						AFO 045						

Figure 5.7: Design checklist information page of U06 tool family 7 287 147 / 148

5 Results, discussion and recommendations

All the design checklists were put together in one folder and the clustering tool was used to find a summary from the design checklists. The result page which combined a summary of all the tool families is shown below in Figure 5.8.

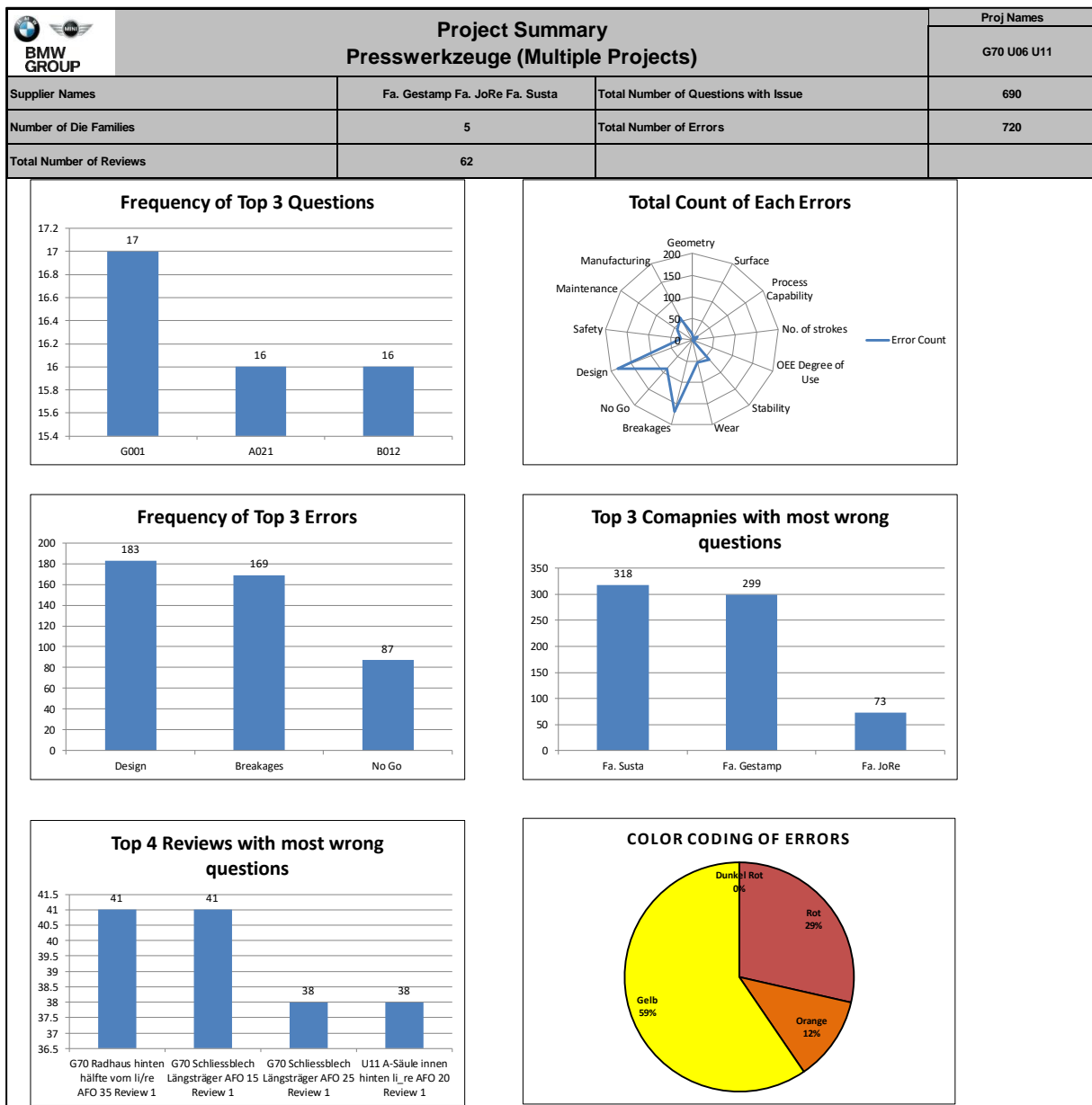


Figure 5.8: Clustering tool combined summary of all selected tool families

The most important results shown in the summary page of the clustering tool would reveal the following points to the user:

- Supplier/Manufacturer Names: Which are the manufacturers responsible for the design and manufacturing of the tools under study.

- Project Types: This data shows the types of projects the die family falls under.
- No of die families: The number of tool families that have been taken for analysis with the help of the clustering tool.
- The total number of errors: What are the total number of design errors combining all the tool design checklist for all the tool families.
- The total number of reviews: What was the total number of reviews for each tool family.
- Graphs and visual representation: The reviewer would get to know the most wrong questions. Which company had the most number of errors in a project and other vital information?

The clustering tool could also be focused on just one supplier and find out its performance. The image below Figure 5.9 shows that.

5 Results, discussion and recommendations

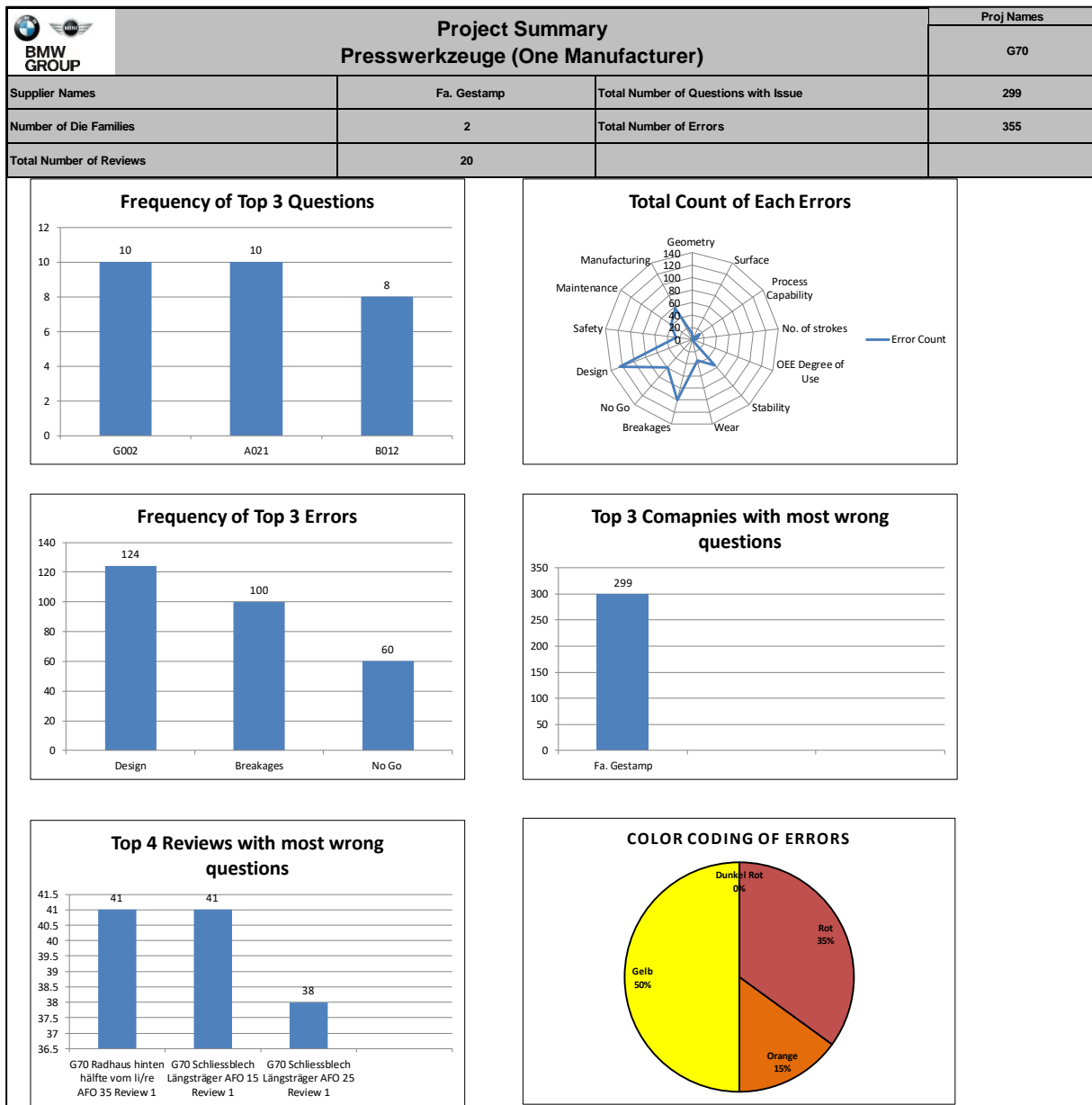


Figure 5.9: Clustering tool summary tool families of one manufacturer (Fa. Gestamp)

The discussion about the summary would be carried out in the discussion section.

5.1.4 Results from lesson learned process implementation

The lessons learned process was defined and discussed in the regular team meeting. The components of the lessons learned process as discussed in 4.2.3 Process deployments was clear and self-explanatory. The initial results of the implementation were that the colleagues took handwritten notes and used the available board for displaying the lessons learned. The colleagues discussed about the open points in the meeting.

5.2 Discussion

A detailed discussion would be necessary to understand the study carried out and the impact it has on the functioning of the department. From the Chapter 1 Introduction where we have defined the motivation and objective of the study to Chapter 2 Literature review where we had put together a variety of knowledge that will be the foundation of the study to Chapter 3 where we have defined the methodology to carry out this task to Chapter 4 where we had described how the process transfer took place now we are ready to discuss about the results from this study.

5.2.1 Key findings of the study

- Process Comparisons

The main findings from the results (Section 5.1.1) of the comparison of the actual process to develop the tool and the ideal process to develop the tool were:

Project	Challenges	Lessons
U12	Tool design not within constraints	<ol style="list-style-type: none"> 1. TP-17 Project Integrator should integrate team members and share constraints better at the start of project. 2. TP-101 Capacity planning should conduct discussion with the manufacturer and team about constraints at start
	Excessive design reviews	<ol style="list-style-type: none"> 1. TP-110 Design Reviewers should train manufacturers about BMW design training 2. Manufacturers should conduct self-design reviews which will has potential to guarantee 80% correct tool design.
U06	Unnecessary process flow change	<ol style="list-style-type: none"> 1. TP-117 should clarify that the process flow from the bring over tool family should remain same.
	Tool design not within constraints	<ol style="list-style-type: none"> 1. TP-17 Project Integrator should integrate team members and share constraints better at the start of project. 2. TP-101 Capacity planning should conduct discussion with manufacturer and team about constraints at start 3. TP-101 should define the plant constraints at the start of project.

Table 5.7: Observations and lessons learned from process deviation results

5 Results, discussion and recommendations

Project	Challenges	Lessons
U06	EPE Machines alignment required from start	<ol style="list-style-type: none"> 1. Involve EPE machine suppliers from initial design reviews 2. Project integrators should involve experience from tool shop to understand the alignment of EPE machines (left or right), decide whether to use existing machines or not.
U12	Observe positives	<ol style="list-style-type: none"> 1. Ext. supplier HIT Automotive performance was good and project was running one month earlier for one tool family 2. All tools from the family was given go ahead for cast.
	Responsibility mismatch	<ol style="list-style-type: none"> 1. Colleagues responsible for process flow creation did not complete documentation on time. Capacity analysis to be performed at start of project. 2. Multiskilling practices to ensure colleagues can perform multiple jobs.
	Go ahead of casting	<ol style="list-style-type: none"> 1. Project reviews should take place in a way that all tools in a family could be given go ahead together.

Table 5.8: Observations and lessons learned from process deviation results part 2

The process deviations were captured in the excel sheet and probable causes and effects were noted down. Possible lessons learned were formulated with the help of the experience of the design reviewers.

- Clustering tool results

The clustering tool was deployed to analyse some of the projects carried out before. Valuable information could be retrieved from the densely packed design checklists. Valuable information such as in a group of die families which were the highest number of errors, the highest number of types of errors and the company with the highest issues with the design.

5 Results, discussion and recommendations

Project(s)	Data Point	Observation
G70, U06, U11	External Manufacturers	Fa. Gestamp, Fa. JoRe, Fa. Susta
	# of die families	5
	Total numbers	690 (questions), 720 (design errors)
	Top three wrong questions	G001: Is a BMW- bill of material (FM-Stüli) available? A021: Are accident prevention regulations given? (debris guards, finger traps) B012: Casted structure, coring, ribbing and geometry.
	Design errors seen from spider web	Design (183), Breakages(169) and Tool No-Go(87) are the three most design errors in these projects
	Manufacturer with most errors	Fa. Susta had the maximum number of errors
	Criticality of errors	Yellow (not critical errors) were the highest.
G70 <i>(analysis with only one company)</i>	External Manufacturers	Fa. Gestamp
	# of die families	2
	Total numbers	299 (questions), 355 (design errors)
	Top three wrong questions	G002: Is the heat treatment of all forming steels / trim steels stated in the bill of material? A021: Are accident prevention regulations given? (debris guards, finger traps) B012: Casted structure, coring, ribbing and geometry.
	Design errors seen from spider web	Design (124), Breakages(100) and Tool No-Go(60) are the three most design errors in these projects

Table 5.9: Observations from the clustering tool (multiple and single manufacturers)

The clustering tool successfully extracted a lot of valuable data from the design checklists and presented the user with improvement points for the next project.

5.2.2 Interpretations of findings

In simple terms the most important lesson taken was the external manufacturers need to adhere to the various BMW standards during the design phase of the tool. The observation was that the external manufacturers were not using the design checklist questions to self-review their design and hence the BMW design reviewers needed several discussion to review the design and modify them. The lessons learned was that the external manufacturers needed regular training on the BMW design standards and mandatory self-reviews. The constraints of the project should be identified and communicated to all the team members at the start of the project to prevent unnecessary tool design changes in the middle of the project.

The most important indication from the clustering tool was that in none of the five-tool families taken for the study, there were any dark red design errors which indicate that no company made a design error that could potentially pose to be a threat on the safety on human beings. However, the total number of reviews resulted in design errors out of which 29% of the design errors were in the red category which meant that the design review process had to be halted in some point of the course of the project to give time for tool modification. The open points which could be taken from the findings were that the manufacturer with the highest design issues needed training and if the design issues continued to arise in projects, less business could be provided till there were visible improvements in the performance.

Project Stage	TP-101 (Capacity Planning)	TP-12 (New Part Planner)	TP-17 (Project Integration)	Tool Shop
Before Project Kick Off	Share constraints of tool design, plant availability	Take feedback from TP-110 about supplier performances in last projects.	Integration of all colleagues	Exchange ideas about EPE machines
Design reviews	Ext. suppliers should perform self-design review before review with BMW New part planner must involve all departments during reviews			
Release for milling	TP-110 design reviewers should release all tools at once for casting Obeya lessons learned should be tracked at every stage of project.			

Table 5.10: Few lessons learned interpretations from results

5.2.3 Limitations of the study

Even the best research has some limitations. There is no end to improvement and anything can be improved over time. Even though the study was quite extensive and elaborate there were always areas that can be improved. The study was carried out in a very limited amount of time and even though it was ensured that all resources are available to take information, still it was not enough to make it a complete study. The limitations of the study can be listed down in points for a better understanding.

❖ Classification of design errors:

- The design errors were classified with all the questions in the design checklist. However, the design checklist was the version from the time of the thesis. There was no scope of including an option to actualise the classifications if some new questions were added in the checklist or some questions became obsolete. The classification needs to be carried out every time the content of the checklist changes.
- The classification was carried out with the colleagues present at that point in the department. Not all the arguments for the classifications were recorded. When all the colleagues agreed before a discussion on whether a question in the checklist should be classified with a typical design error, there were no needs for clarifications and the arguments for such a classification was not stored.

❖ Clustering tool:

- The robustness of tools posed a serious limitation. As per Walsch et al. [43] MS Excel tool has an extra feature called Solver to store data in temporarily for data analysis. Even though MS Excel is a robust tool it does have many limitations such as having a permanent pool of data that can be used for analysis.
- The classification of the design errors by the collaboration of the colleagues was the master data for the clustering tool. There is no easy option to actualise this data when the design checklist changes.

❖ Process analysis tool:

- The duration of the study posed a serious limitation for all the analysis, especially the process analysis tool. Even though all deviations were meant to be captured, major information was skipped because of the not fixed format. In some way, the excel page to record the data was slightly difficult to understand for some colleagues.

❖ Obeya lessons learned process:

- Obeya methodology for a lessons learned process is a resource extensive process and the department was not equipped with such big space and separate rooms to conduct meetings. Otherwise more results on the implementation of the lessons learned process could have been added in the study.
- Even though several other important sources of open points for a lessons learned process available, only three major sources were taken for the sake of simplicity. However, the department has many interdependencies and hence many other sources of open points.

5.3 Recommendations

The study was a very important part of the regular functioning of the department and improving the interdependencies and collaborative work of other departments and external colleagues. There exists a high improvement potential for all the objectives laid out at the beginning of the study and the results from this study should be taken as a start point for further study. The overall recommendations would be stated first and then the detailed recommendations for each task would be provided.

❖ Overall recommendations:

- The study could be improved by structuring a future study with sufficient resources in the form of time and expertise. Time would be beneficial to conduct a thorough analysis of the data to find a more holistic result, while expertise would help in tackling the obstacles in design error analysis, tool development and process implementation
- A futuristic study should ensure a robust tool structuring for better understanding and benefit of the users

❖ Recommendations for the classification of design errors:

- The classification should be carried out with options of revising the classifications when there is a change in questions in the checklists. The possibility to easily update/modify classifications should be added to the tool.
- The arguments behind each classification should be stored for future reference. The stored data should be easily accessible.

❖ Recommendations for clustering tool:

- The clustering tool has the classification as the basis of functioning. The tool should have an easy function to update the classifications.

- A better and robust tool suitable for this analysis should be selected at first. The tool should have the capability to store data if required.
 - More projects should be selected for analysis under the clustering tool. This will help the readers to get a much even result. In this study, only six design checklists were taken for analysis.
- ❖ Recommendations for process comparison tool:
- The process comparison tool could be made more simpler and easy to use. The features in the present tool make it harder for other colleagues to use.
- ❖ Recommendations for Obeya lessons learned process:
- The department TP-110 went through an organisational change right at the end of the study. Recommendations for a department neutral lessons learned process would be beneficial.
 - The lessons learned process failed to incorporate many other sources of open points in the department such as tool standardization weekly meetings. In this meeting, the observations regarding developed tools running for years would be discussed and lessons learned points would be noted.
 - Open points from parallel studies should be incorporated into the lessons. Studies such as improvement in filler CAMs in dies were carried out in parallel and the lessons learned should take the lessons from these studies as well in future.
 - The Obeya lessons learned process should be able to provide information about external companies to other departments responsible for external company selection. If an external company needs training before businesses can be awarded, the Purchase department should be aware of the reasons (results from clustering tool) and business should not be awarded to the external companies before improvements.

6 Summary

This research aimed for a thorough “**analysis of errors during the construction of large press tools and development of a lessons learned process**”. In terms with the objectives set for the sub-tasks of the thesis, a holistic view of the whole process was achieved.

The classification of the typical design faults was successfully completed with the collaboration of the experienced design reviewers in the department. The classification was taken as a basis to develop a tool that can evaluate the working of external companies with BMW. The tool developed was in a series of steps taking into account qualitative and quantitative data points such as criticality of design errors as qualitative and the number of design errors, questions, etc as quantitative. The development of the tool took place in several steps and MS Excel was considered as the optimum choice for the tool. The internal processes and working of the other departments were studied with the help of a process analysis tool where the process was compared with the ideal process plan. Process deviations, their possible causes and effects were accumulated and possible lessons learned for all the people involved in the project was set. An Obeya lesson learned process was described with the help of external research and collaboration with internal departments which already followed some sort of a lessons learned process. Process roles and resources were created and described and a preliminary test to check the functionality of it was created. The results of the clustering tool revealed valuable information about the functioning of the external companies and their defined performance. The clustering tool gave the user a broad idea about which external company was reliable, less prone to errors and infused innovativeness. In future, the tool can show data about the punctuality of an external company and its maturity. The clustering tool revealed the most error-prone questions and the most common design errors being made by the manufacturers. These were considered as open points for the lessons learned process where the responsible people would take measures in improving the working potential of manufacturers. The design reviewers and colleagues from the purchase department can with the help of the results estimate a good strategy to conduct training for some external companies to improve their performance. The process analysis tool revealed areas where the department can increase capacity. Especially at some instances, it was discovered that multi-skill will be better at easing the load on departments. Recommendations were made at the end of the study to improve further research. A good tool selection and better implementation would be necessary for the future study. A good and thorough implementation would require definitely more time with extensive tool developing knowledge. Through the study, it was possible to get an important insight into the construction of big press tools and ways to improve the process further.

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8 Appendices

1 Werkzeug Die		Part Quality			Production Process			Tool	
1.1 Allgemein General		Geometry	Surface	Process Capability	No. of strokes	QEE Degree of Use	Stability	Wear	Drainages
	Arie Todorovsk	A	A	A	A	A	A	A	A
	Josef Gebi	J	J	J	J	J	J	J	J
	Stefan Brenner	S	S	S	S	S	S	S	S
	Thomas Biebler	T	T	T	T	T	T	T	T
	Ingo Wurmb	W	W	W	W	W	W	W	W
	Arpan Das	D	D	D	D	D	D	D	D
A001	Ist die Reife des Konstruktionsstandes zur Abnahme geeignet? Is the design suitable for a review?								
A002	Kommt beim Öffnen des Modells eine Fehlermeldung? Do you get an error message when opening the model?								
A003	Ist die Werkzeugkonstruktion mit dem zum Konstruktionsstarttermin gültigen CatiaV5-Startmodell ausgeführt? Is the tool design made with the CatiaV5-Startmodel which is valid from the date of the kickoff meeting?								
A004	Sind gültige reduzierte Pressenmodelle eingebracht und entsprechen diese den BMW-Namenskonventionen? Are valid reduced press models integrated according to the BMW naming convention?								
A005	BMW-Normteile dürfen NUR nach Rücksprache mit BMW verändert werden. BMW-Standardparts must not be modified - only by BMW consultation.								
A006	BMW-Konstruktionsnormteile dürfen nur mit den freigegebenen FP_xx-Parametern verändert werden. BMW-design standard parts must only be modified with the released FP_xx-parameters.								
A007	Entspricht der Methodenplan dem letzten Änderungsstand des Bauteils? Does the process plan comply with the latest issue level of the part?	A							
A008	Ist eine Methodenplanänderung nötig? Is a modification of the method plan necessary?								
A009	Sind die Werkzeugmaße korrekt? Breite/width: 3180 Tiefe/depth: 2180 Höhe/height: 1200 Are the dimensions correct?								
A010	Sind Ober- und Werkzeuggesamtgewichte innerhalb der zul. max. Belastung der jeweiligen Pressen? OT-Gewichte/OT weight: 9,30 Gesamtgewichte/total weight: 21,80 Are the upper / lower die weights feasible for the production and alternative press?								
A011	Sind OT-, UT-, Niederhalter und Federboden gegen falsches Zusammensetzen gesichert? Are upper die / lower die and pressure pad / floater tool proved?								X
A012	Ist eine werkzeuginterne Kollisionsprüfung durchgeführt worden und kollisionsfrei? (dynamic/static) Is a die internal clash control available and okay? (dynamic/static)								X
A013	Ist eine Federentlastung notwendig und richtig dimensioniert? Hub und Gasdruckfederkraft (Mindestens OT-Gewicht + 10%). Is a die parking with gas springs and parking blocks provided and of correct design? Stroke and gas spring force (to be minimum upper die weight + 10%).							X	X
A014	Sind Rückkaldistanzen für Niederhalter, Blechhalter und Luftboden vorgesehen? Are the setting blocks for pressure pads, floaters and blankholders correct designed?							A	X
A015	Wird Niederhalter bzw. Luftboden auf Enddruck gefahren? (bei Form-Werkzeug) Does pressure pad or floater bottoming?	A	X						
A016	Distanzblöcke zwischen beweglichen Werkzeugeteilen müssen mit mindestens 2 Schrauben befestigt sein. Distance blocks between moveable tool elements must be fixed with minimum 2 screws.								X
A017	Kann das Werkzeug ohne Bauteile ohne Beschädigung gefahren werden? Can the die be run in the press without part and without danger of damaging?	A						X	A
A018	Bei Verwendung von Taylor Rolled (welded) Blankes müssen im Bereich des Dickensprunges Einsätze verwendet werden. If Taylor Rolled or Taylor welded blanks: Provide steel inserts along the transition.	A						A	X
A019	Wird vermieden, dass die Stabilisatoren auf schräge Fläche >3° auftreffen und über Hebern sitzen? Stabilisatoren müssen nicht auf geneigte Flächen (> 3°) und auf Hebern sitzen. Use controlled stabilizers? Stabilizers must not hit angled faces (> 3°) and sit above lifters. Use controlled stabilizers?						A	X	A
A020	Sind die richtige Art der Nennschraube- und Enddruckstempel vorhanden und ist die Funktion gewährleistet? (Bei Formgebenden Werkzeugen: Perforierungskontrollstempel) Are correct die check buttons designed and is their function given? (At all forming dies, perforations check stamp)	A	X	X			A		
A021	Wurde die UVV beachtet? (z. B. Fingerschutz) Are accident prevention regulations given? (debris guards, finger traps)								
A022	Ist die elektrische und pneumatische Installation nach B2 2002.001 ausgeführt (spiegelbildliche Werkzeuge beachten)? Pressenblätter für spezifische Elemente checken. Are all electrical and pneumatic components designed according to the standard (B2 2002.001) and positioned correctly? Check also press sheets for specific elements.								
A023	Ist bei komplexen Werkzeugen eine Montageanleitung vorhanden? Are sequence plates needed at complicated tool? Is the tool feasible for a easy strip down?							A	X
A024	Weitere?								

Figure 8.1: Design checklist questions and errors classification sheet (Part 1)

1	Werkzeug Die	Press Errors		Organisation Maturity		Safety		Maintenance		Manufacturing	
		No Go	Design								
1.1	Allgemein General										
	Ante Todorovski	A		A		A		A		A	
	Josef Glebl	J		J		J		J		J	
	Stefan Brenner	S		S		S		S		S	
	Thomas Bieber	T		T		T		T		T	
	Ingo Wurmb	I		I		I		I		I	
	Arpan Das		D		D		D		D		D
A001	Ist die Reife des Konstruktionsstandes zur Abnahme geeignet? Is the design suitable for a review?			A	X	D					
A002	Kommt beim Öffnen des Modells eine Fehlermeldung? Do you get an error message when opening the model?			A	X	D					
A003	Ist die Werkzeugkonstruktion mit dem zum Konstruktionsstarttermin gültigen CataV5-Startmodell ausgeführt? Is the tool design made with the CataV5-Startmodell which is valid from the date of the kickoff meeting?			A	X	D					
A004	Sind gültige reduzierte Pressenmodelle eingebracht und entsprechen diese den BMW-Namenskonventionen? Are valid reduced press models integrated according to the BMW naming convention?			A	X	D					
A005	BMW-Normteile dürfen NUR nach Rücksprache mit BMW verändert werden. BMW-Standardparts must not be modified - only by BMW consultation.			A	X	D					
A006	BMW-Konstruktionsnormteile dürfen nur mit den freigegebenen FP_xx-Parametern verändert werden. BMW-design standard parts must only be modified with the released FP_xx-parameters.			A	X	D					
A007	Entspricht der Methodenplan dem letzten Änderungsstand des Bauteils? Does the process plan comply with the latest issue level of the panel?			A	X	D					
A008	Ist eine Methodenplanänderung nötig? Is a modification of the method plan necessary?			A	X	D					
A009	Sind die Werkzeugmaße korrekt? Breite/width: 3180 Tiefe/depth: 2180 Höhe/height: 1200 Are the die dimensions correct?	A	X		X	D					
A010	Sind Oberteil- und Werkzeugesamtwerte innerhalb der zul. max. Belastung der jeweiligen Pressen? OT-Gewicht/DU weight: 9,3to Gesamtgewicht/total weight: 21,8to Are the upper / lower die weights feasible for the production and alternative press?	A	X								
A011	Sind OT, . UT, . Niederhalter und Federboden gegen falsches Zusammensetzen gesichert? Are upper die / lower die and pressure pad / floater tool proved?										
A012	Ist eine werkzeuginterne Kollisionsprüfung durchgeführt worden und kollisionsfrei? (dynamisch/statisch) Is a die internal clash control available and okay? (dynamic/static)			A							
A013	Ist eine Federentlastung notwendig und richtig dimensioniert? Hub und Gasdruckfederkraft (Mindestens OT-Gewicht + 10%). Is a die parking with gas springs and parking blocks provided and of correct design? Stroke and gas spring force (to be minimum upper die weight + 10%).										
A014	Sind Rückfaldabstände für Niederhalter, Blechhalter und Luftboden vorgesehen? Are the setting blocks for pressure pads, floaters and blankholders correct designed?									A	
A015	Wird Niederhalter bzw. Luftboden auf Enddruck gefahren? (bei Form-Werkzeug) Does pressure pad or floater bottoming?									A	
A016	Distanzblöcke zwischen beweglichen Werkzeulementen müssen mit mindestens 2 Schrauben befestigt sein. Distance blocks between moveable tool elements must be fixed with minimum 2 screws.									A	
A017	Kann das Werkzeug ohne Bauteil ohne Beschädigung gefahren werden? Can the die be run in the press without panel and without danger of damaging?										
A018	Bei Verwendung von Taylor Rolled (welded) Blanks müssen im Bereich des Dickensprunges Einsätze verwendet werden. If Taylor Rolled or Taylor welded blanks: Provide steel inserts along the transition.										
A019	Wird vermieden, dass die Stabilisatoren auf schräge Fläche >3° auftreffen und über Hebern sitzen? Gesteuerte Stabilisatoren verwenden? Stabilizers must not hit angled faces (> 3°) and sit above lifters. Use controlled stabilizers?										
A020	Sind die richtige Art der Kennzeichnungs- und Enddruckstempel vorhanden und ist die Funktion gewährleistet? (Alle Formgebenden Werkzeuge; Perforierungskontrollstempel) Are correct die check buttons designed and is their function given? (At all forming dies, perforations check stamp)										
A021	Wurde die UVV beachtet? (z. B. Fingerschutz) Are accident prevention regulations given? (debris guards, finger traps)					A	X				
A022	Ist die elektrische und pneumatische Installation nach B2 2002.001 ausgeführt (spiegelbildliche Werkzeuge beachten)? Pressenblätter für spezifische Elemente checken. Are all electrical and pneumatic components designed according to the standard (B2 2002.001) and positioned correctly? Check also press sheets for specific elements.	A	X								
A023	Ist bei komplexen Werkzeugen eine Montageanleitung vorhanden? Are sequence plates needed at complicated tool? Is the tool feasible for a easy strip down?	A	X					A	X		
A024	Weitere? Others?										

Figure 8.2: Design checklist questions and errors classification sheet (Part 2)

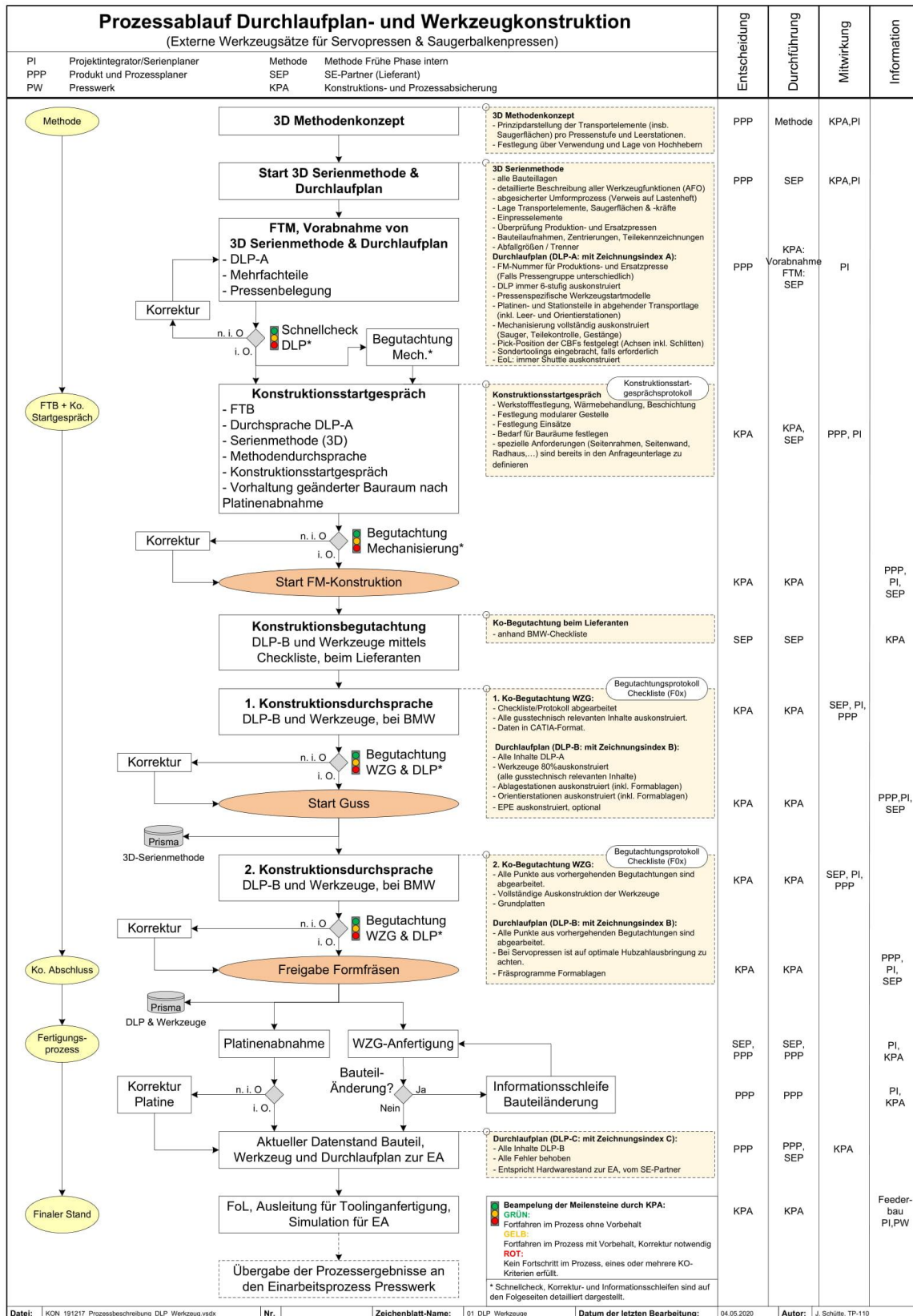


Figure 8.3: Press tool construction process plan

INHALT DES ORDNERNS

TP-org (\Europe.bmw.corp\WINFS) (C:) > TP-1 > TP-11 > TP-110 > 020_Intern > 14_Mitarbeiter

Name	Date modified	Type	Size
Ante	09-09-2020 12:36	File folder	
Ingo	09-09-2020 12:36	File folder	
Joseph	09-09-2020 12:36	File folder	
Stefan	09-09-2020 12:36	File folder	
Thomas	09-09-2020 12:36	File folder	
Intructions.pptx	09-09-2020 12:38	Microsoft PowerPo...	
Lebenslauf Folder	09-09-2020 12:36	File folder	
Summary Sheet loophrough 2020.09.08,...	08-09-2020 16:35	Microsoft Excel M...	
Copy of LIST_9479311_Konstruktion_Engi...	23-07-2020 10:07	Microsoft Excel W...	
Copy of LIST_9479325_Konstruktion_Engi...	23-07-2020 10:08	Microsoft Excel W...	
Copy of LIST_9879117_18_19_20_Konstru...	23-07-2020 10:09	Microsoft Excel W...	
Copy of LIST_9879121_122_Konstruktion_...	23-07-2020 10:10	Microsoft Excel W...	
LIST_7287141_Konstruktion_Engineering_...	02-07-2020 11:01	Microsoft Excel W...	

Individuelle Ordner für jeden Kollegen

Ordner mit Checklisten zu verschiedenen Projekten. Automatisiertes Excel-Tool

Checklisten früherer Projekte

Figure 8.4: User manual for clustering tool (Page 1)

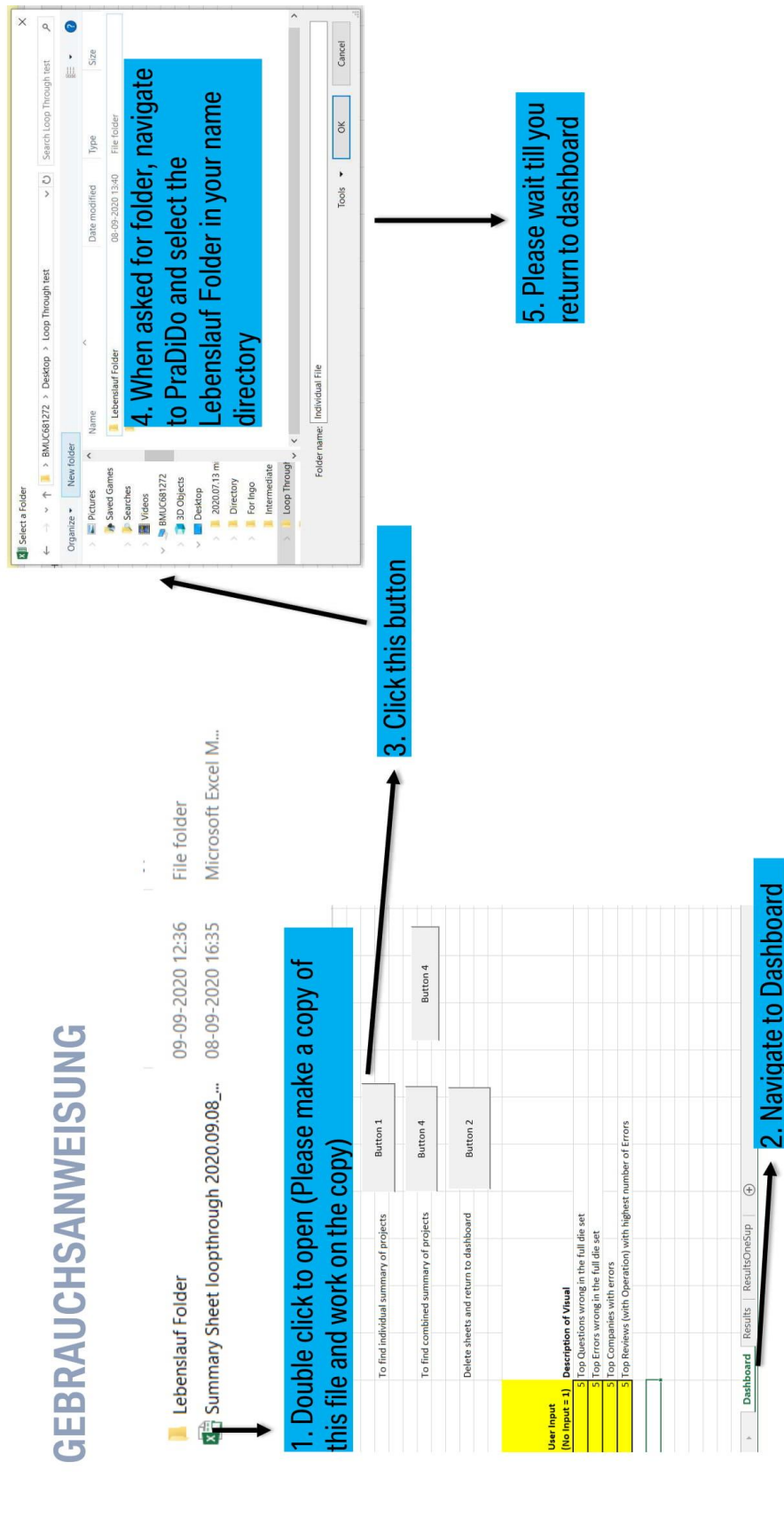


Figure 8.5: User manual for clustering tool (Page 2)

GEBRAUCHSANWEISUNG

To find individual summary of projects	Burton 1
To find combined summary of projects	Burton 4
Delete sheets and return to dashboard	Burton 2

User Input (No Input = 1)

5	Top Questions wrong in the full file set
5	Top Errors wrong in the full file set
5	Top Companies with errors
5	Top Reviews (with Operation) with highest number of Errors

Dashboard | Results | ResultsOneSup | +

6. Input values. Please do not keep it blank. The first 3 tasks work as of now

7. Click this button

8. When asked for folder, navigate to PraDiDo and select the Individual File Folder

9. Please wait till you see the results (Results involving all Design checklists in the folder)

> TP-org (\europe.bmw.corp\WINFS) (C:) > TP-1 > TP-11 > TP-110 > 020_Intern > 14_Mitarbeiterordner > PraDiDo > Das_Arpan > Tes'

Name	Date modified	Type	Size
Individual File	09-09-2020 13:22	File folder	
Letztslauf Folder	09-09-2020 13:22	File folder	
Summary Sheet loopthrough 2020.09.08_4.xlsm	09-09-2020 13:19	Microsoft Excel M...	253 KB

Frequency of Top 5 Questions

PO2	1.5
PO3	1.3
PO1	1.3
PO4	1.1
PO5	1.1

Frequency of Top 5 Errors

Design	185
Breakages	168
No. GS	87
Stability	60
Manufacturing	37

Total Count of Each Errors

Top 5 Companies with most wrong questions

Fi. Luft	71
Fi. Gump	299
Fi. Luft	342
Fi. Luft	342
Fi. Luft	342

Project Summary Presswerkzeuge (Multiple Projects)		Proj Names
Supplier Names	Total Number of Questions with Issue	
Number of Die Families	Total Number of Errors	
Total Number of Reviews	Reviews	

Figure 8.6: User manual for clustering tool (Page 3)

GEBRAUCHSANWEISUNG

Button 1	Button 4	Button 2
To find individual summary of projects		
To find combined summary of projects		
Delete sheets and return to dashboard		

User Input
(No Input = 1)

Description of Visual

- 5 Top Questions wrong in the full die set
- 5 Top Errors wrong in the full die set
- 5 Top Companies with errors
- 5 Top Reviews (with Operation) with highest number of Errors

1 Fa. Gestamp
Fa. JoRe
Fa. Susta

Dashboard Results

10. Navigate to dashboard page again

11. Type 1 beside the supplier name you want to filter out. Now the results will be only focused with this supplier.

12. Click this button to generate results

13. Select the Individual File folder again

14. In ResultsOneSup page you will see only the result of one supplier for all the projects

Figure 8.7: User manual for clustering tool (Page 4)