Berker Kantar, BSc

Agile Factory Planning Approach

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Graz, June 2019

Affidavit

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Abstract

In today’s dynamic and turbulent environment, factory planners face a variety of challenges. Classical factory planning approaches are not capable of coping with challenges caused by uncertain changes. In addition, the main reason for the emergence of the agile methods is to respond quickly and effectively to the changes. Therefore, it is necessary to develop a new factory planning approach that takes more agility into account.

For this reason, different factory planning approaches were analysed to understand the main procedure of planning a factory. After each phase, the advantages and disadvantages of these phases were mentioned. Significantly, challenges arisen while planning a factory were identified from the literature research.

Afterwards, the main difference between agility, flexibility, and responsiveness was described. Agile Manifesto and its four values and twelve principles were explained. Moreover, six different agile methods and their phases and practices were described. This part was completed by determining the characteristics and advantages of agile methods.

Furthermore, a brownfield factory planning project was conducted to apply the phases mentioned in the first part and to identify the real-life challenges. In this project, current state analysis and rough planning phases were carried out. After these phases, challenges were identified and matched with the challenges identified in the literature.

Last but not least, a new agile factory planning approach was developed in order to overcome the challenges by putting less effort. This approach was developed based on the classical factory planning approach with considering agile perspective. For this reason, some procedures and practices of agile methods and essential factory planning procedures have been harmonised.

Kurzfassung

In dem dynamischen und turbulenten Umfeld von heute stehen Fabrikplaner vor unterschiedlichen Herausforderungen. Die klassischen Fabrikplanungsansätze sind nicht in der Lage, die durch Unsicherheiten und Veränderungen hervorgerufenen Herausforderungen zu bewältigen. Die sowohl schnelle, als auch effektive Reaktion auf diese Veränderungen ist der Hauptgrund für die Entstehung der agilen Methoden. Aus diesen Grund ist es notwendig, einen neuen Fabrikplanungsansatz zu entwickeln, welcher den Faktor Agilität berücksichtigt.

Zu diesem Zweck wurden verschiedene Ansätze der Fabrikplanung analysiert, um das Hauptverfahren der Fabrikplanung genauer zu verstehen. Nach jeder Phase wurden die Vor- und Nachteile der jeweiligen Phasen angeführt. Aus der Literaturrecherche wurden insbesondere die auftretenden Herausforderungen bei der Planung einer Fabrik identifiziert.

Anschließend wurde der Hauptunterschied zwischen Agilität, Flexibilität und Reaktionsfähigkeit beschrieben. Das Agile Manifest mit seinen vier Werten und zwölf Prinzipien wurde erläutert, da dieses die Grundlage der agilen Methoden darstellt. Darüber hinaus wurden sechs verschiedene, aus der Literatur bekannte, agile Methoden sowie deren Phasen und Praktiken beschrieben. Dieser Teil wurde durch die Bestimmung der Eigenschaften und Vorteile dieser Methoden ergänzt.

Ein Brownfield-Fabrikplanungsprojekt wurde durchgeführt, um einerseits die im ersten Teil genannten Phasen anzuwenden und andererseits um die Herausforderungen, welche im Rahmen eines realen Projekts auftreten können, zu identifizieren. In diesem Projekt wurde nach der Analyse des Ist-Zustandes die Grobplanungsphase durchgeführt. Nach diesen Phasen wurden Herausforderungen identifiziert und mit den aus der Literatur bekannten Herausforderungen abgeglichen.

Zum Abschluss dieser Arbeit wurde ein neuer, agiler Fabrikplanungsansatz entwickelt, um die Herausforderungen mit weniger Aufwand zu bewältigen. Dieser Ansatz wurde auf Basis des klassischen Fabrikplanungsansatzes unter Berücksichtigung der agilen Perspektive entwickelt. Aus diesem Grund wurden einige Vorgehensweisen und Praktiken agiler Methoden und wesentlicher Fabrikplanungsverfahren harmonisiert.

Table of Content

1 Introduction

Factory planners face a variety of challenges in today's dynamic and turbulent environment. Classical factory planning approaches are unable to cope with the challenges caused by uncertain changes.[1] The fast and effective response to these changes is the main reason for agile methods to emerge.[2] For this reason, a new approach to factory planning needs to be developed that takes agility into account. In this chapter, the task, objectives, and the structure of the thesis are mentioned.

1.1 Task and Objectives

In factory planning, planners deal with different issues in every project. However, these problems cannot be solved with classical factory planning approaches. Before finding a solution, it is necessary to define the challenges encountered while planning a factory. To make these definitions more straightforward, the challenges in the literature should be supported by the challenges encountered in an industrial project. That is the reason that the brownfield project was carried out, and challenges out of the project were taken into consideration.

Furthermore, linear project management approach is sometimes inadequate to be adaptive. Particularly in software development, many project managers try to figure out the best way to overcome uncertainties. Therefore, it leads to the emergence of agile methods. The primary purpose of agile methods is to keep pace with the changes that occur. To be more flexible and adaptive, the characteristics of the agile methods should be identified primarily. In order to overcome the challenges emerged while planning a factory, new factory planning approach needs to be developed, and it should be based on characteristics of agile methods.

The main objectives of this thesis can be summarised as:

- Analysis of different factory planning approaches
- Determination of challenges in factory planning
- Analysis of different agile methods
- Determination of characteristics and advantages of agile methods
- Identification the challenges from brownfield factory planning project
- Development of an agile factory planning approach

[1] Cf. Kampker / Meckelnborg / Burggräf / Netz (2013), p. 1
[2] Cf. Bernardes / Hanna (2008), p. 36

1.2 Thesis' Structure

The main structure and the steps of the thesis are shown in Figure 1. First of all, the research question was determined as "How can classical factory planning approaches getting more agile in order to cope with uncertain changes". Then, the approach for the literature review was structured. For the literature review, some keywords were used for some purpose. Also, there was a year criterion as well. After determining the research question and literature review approach, the main parts of the thesis structured in the figure below.

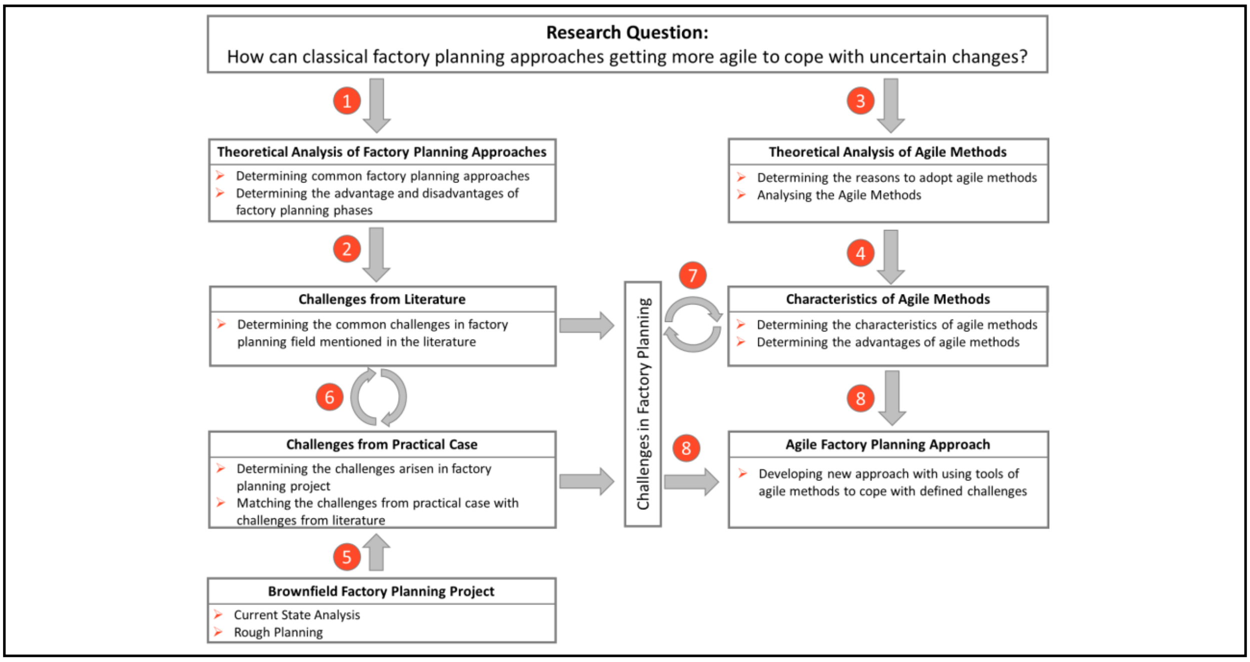

Figure 1: Structure of the Thesis

In the first part of the thesis, a theoretical analysis of factory planning models takes place. There are several factory planning approaches in the literature. Therefore, in this part, the five conventional factory planning approaches are determined. While determining those approach, the focal point is that each approach should comprise of different structure. Moreover, while investigating each phase of general factory planning approaches, advantages and disadvantages are mentioned at the end of each phase. The main outcome of this phase is challenges in factory planning. Challenges while planning a factory are determined from the literature.

In the second part of the thesis, after defining the agility, flexibility, and responsiveness, agile manifesto and its four values and twelve principles are mentioned. Then, six agile methods are explained. Because there are several agile methods in the literature, however, mainly project management oriented agile methods are explained. Besides four project management oriented agile methods, one software development oriented and one hybrid agile methods are described as well. This phase is concluded by describing the characteristics and advantages of agile methods.

In the third part of the thesis, a real factory planning project is explained. In this brownfield factory planning project, current state analysis, and rough planning were conducted. The procedure and the outcomes of these phases are described. As the last step of this project, the challenges encountered in this project are mentioned and matched with the challenges taken out of the literature.

In the fourth part of the thesis, a new agile factory planning approach is developed. This approach is developed to cope with the challenges found in the literature and practical case study. It also uses some of the tools and practices of explained agile methods. This approach also reflects the characteristics of agility.

1.3 Approach of Literature Research

In order to find the answer to this question, a literature review is necessary. In the literature, there are several articles, journals, and books about both fields of factory planning and agility. Therefore, the research scope should be narrowed down. First of all, “Google Scholar” was selected as a search engine to reach the literature because it is the most comprehensive website that contains the articles, journals, and book from other sources. Also, the year criterion was selected as from 2009 to 2019 in order to reach recent sources.

Then, there are some keywords used to reach the relevant sources about factory planning and agility. Firstly, the whole concept was searched with using the keywords as “Agile Factory Planning” and “Agile Fabrikplanung”. However, there are not a sufficient amount of sources. Therefore, the keyword “Factory Planning” and “Agile” was searched together in separate quotes in order to reach the articles that they consider factory planning approaches and agility all together. After selecting the factory planning approaches to investigate, “Factory Planning” and “Challenges” keywords were searched to determine the challenges in the factory planning.

Afterwards, for the Agility field, keywords “Agility” and “Literature Review” keywords were searched for explaining the definition of agility and related concepts. For Agile Manifesto, it has an original website that was published by the alliance. However, for explaining the values and principles, some hardcopy doctoral theses were used. Moreover, “Agile Method” and “Comparison” keywords were used to find proper agile methods and to determine their characteristics and advantages.

2 Factory Planning

In this chapter, firstly the basics of factory planning are mentioned, and then five different factory planning approaches are described. Finally, challenges in factory planning projects were identified in the literature and are described as the last section of this chapter.

2.1 Basics of Factory Planning

Before starting to describe factory planning, beginning with a definition of terms of “factory” and “planning” will be helpful to understand better what factory planning is.

The term "factory" is derived from the Latin "fabrica - the workshop, the manufacture" and refers to an industrial production plant, whose aim is the extraction and processing of substances that are used for the production of consumer goods or means of production.[3]

VDI defines the term of planning as a rational expectation of a targeted outcome, including the sequence of actions deemed necessary. The relevant decision-making points should be drawn up based on the pre-specified of periods and costs while taking into account all significant influencing variables.[4]

Association of German Engineers (VDI) defines factory planning as:

“Systematic, objective-oriented process for planning a factory, structured into a sequence of phases, each of which is dependent on the preceding phase, and makes use of particular methods and tools, and extending from the setting of objectives to the start of production”.[5]

For all real estate as buildings and movables such as equipment and machinery, the life cycle forms the basis of modern management.[6] The changes in factory life cycles are shown in Figure 2.

[3] Cf. Kettner / Schmidt / Greim, p. 3
[4] Cf. VDI 5200 (2011), p. 4
[5] Cf. VDI 5200 (2011), p. 3
[6] Cf. Wirth / Müller (2004), p. 117

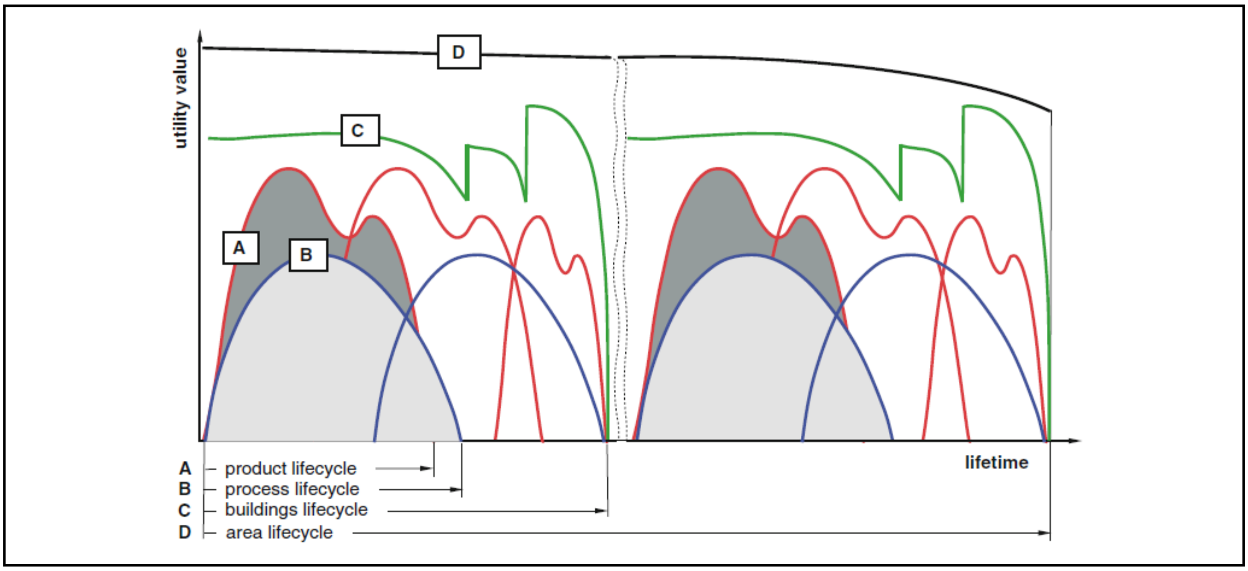

Figure 2: Lifecycle of Factory[7]

These changes are based on the relationships between the different life cycles of product, process, plant and area[8]:

- **A) Product:** The product life cycle is becoming shorter and shorter, and it depends on customer request, product, and industry.
- **B) Process:** Process life cycle is designed for one or more product life cycles and adapts to the product life cycle. Production lifecycle includes the lifecycles of machines, plants, and work systems that adapt to the process lifecycles.
- **C) Buildings:** The life cycle of the technical building equipment is designed according to the process and production system life cycle and partly according to the building life cycle. The life cycle of buildings varies according to the type of building, such as lightweight construction and reinforced concrete, partly based on initial technologies, and has to adapt to changes in the production system life cycle.
- **D) Area:** The area use cycle is oriented towards the recycling of rehabilitated land on existing infrastructure, which means land recycling.

Industrial enterprises belong to the group of enterprises providing services in kind, which, together with service enterprises, are subdivided into the superordinate area of production management and form part of an economic system. The task of factory planning is to create the prerequisites for fulfilling the operational goals of a factory, including its social and economic functions, taking into account various framework and boundary conditions. Thus, planning must enable a technically flawless economic course of the production process under the right working conditions.[9]

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[7] Cf. Wiendahl / Reichardt / Nyhuis (2015), p. 5
[8] Cf. Wirth / Müller (2004), p. 117
[9] Cf. Kettner et al. (1984), p. 1 ff

With a holistic approach to factory planning and logistics, isolated solutions can be avoided. This makes it possible to design value-added processes, material and information flow as the company's overall objective. Figure 3 shows the influences and objectives of factory planning.[10]

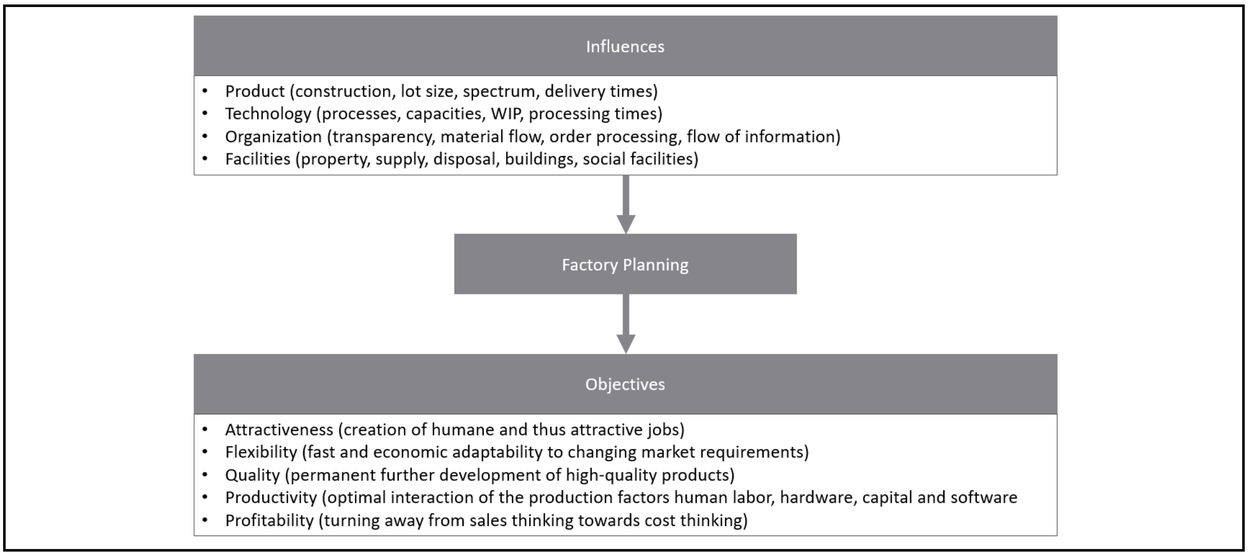

Figure 3: Influences and Objectives of Factory Planning[11]

The classification of factory planning in business planning is shown in Figure 4. The content components of the factory are referred to as effective systems. These have an effect on the execution and on the process result, which is why they must be integrated into an integrated factory planning. Factory planning forms the bridge between corporate planning and the operation of the company across all planning levels.[12]

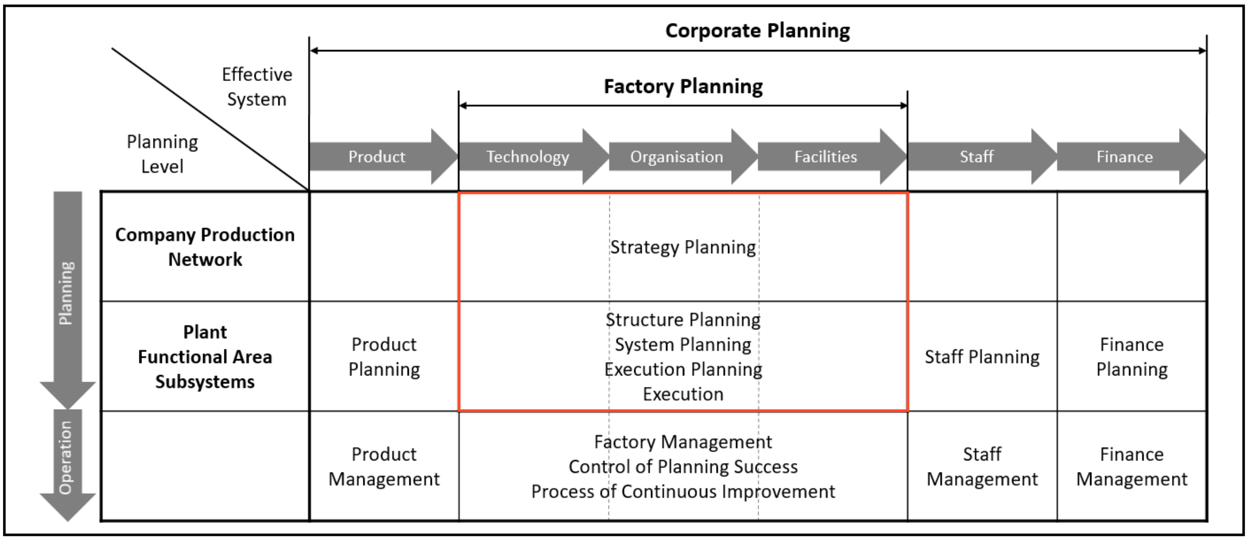

Figure 4: Classification of Factory Planning in Business Planning[13]

[10] Cf. Pawellek (2014), p. 9 ff.
[11] Based on Pawellek (2014), p. 9 own representation
[12] Cf. Pawellek (2014), p. 19
[13] Based on Pawellek (2014), p. 19 own representation

2.2 Reasons for Factory Planning

Generally, the reason for planning the plant lies in a discrepancy between the current state of the plant and the applicable requirements. REFA divides the reasons for factory planning into internally and externally. At the same time, REFA claims that there are different reasons for new planning and re-planning of factories. For instance, products for market niches, products with new technologies, and relocation of markets can be examples for external occasions for new factory planning. Improvement of material flow, technical characteristics of the existing building, and lack of space for extensions can be examples for internal reasons for new planning of factories. External reasons for re-planning of factories are capacity adjustment to sales changes, an adaptation of technical equipment to the state of art and economic, fashion, and seasonal influences. Last but not least, internal reasons for re-planning of the factory can be a change in production methods, bottlenecks, and change in the organisational structure.[14]

According to VDI, changes are the triggers for factory planning processes, and these changes arise from changes within the factory, changes within the company, and changes outside the company.[15] To put it another way, there are three different clusters of reasons which cause initiating factory planning processes. Firstly, changes within the factory lead to planning the factory. Organisational changes, new production technologies, or fraying out of existing factory equipment and machinery, which leads to planning the replacement investments, are the reasons for factory planning that originates in the plant. Secondly, the reasons for a factory's planning can be changes in corporate strategy and new product development. Moreover, changes in other corporate parts such as factory purchase and closure can be the reason that leads to factory planning. Thirdly, reasons outside the company can cause factory planning, and these reasons may involve changes in the market situation, customers' specific preferences, labour market changes, or statutory requirements. Requirements and regulations for environmental protection may be an example of reasons outside of the company.[16] Last but not least, one of the reasons does not always lead to one particular type of planning.[17] In other words, choosing a suitable type of planning is depending on the corporate decision.

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[14] Cf. REFA (1985), p. 152f
[15] Cf. VDI 5200 (2011), p.4 ff
[16] Cf. VDI 5200 (2011), p. 5
[17] ibidem

2.3 Basic Planning Cases

According to Grundig, the tasks in factory planning can be divided into five primary cases which differ in their task character, their scope of problems and degree of difficulty, their solution concepts and solution spaces as well as particular contents of the planning methodology.[18]

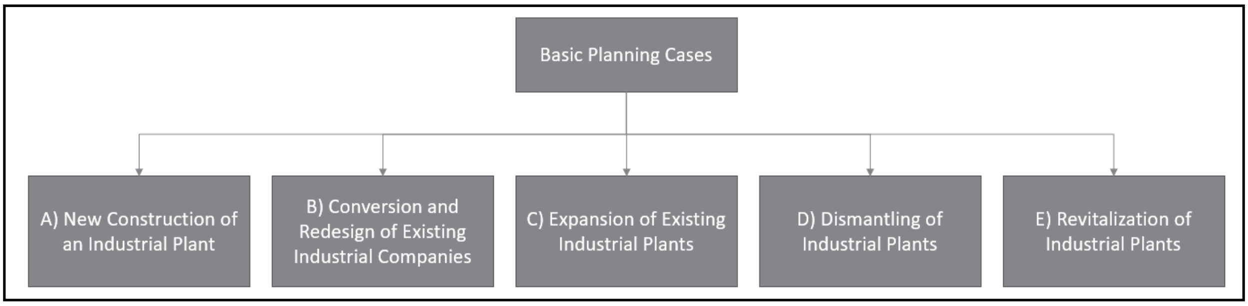

Figure 5: Basic Planning Cases According to Grundig[19]

A) New construction of an industrial plant:

The classic primary case in factory planning is the new construction of an industrial plant on an undeveloped site. This is referred to in the literature as "greenfield planning". Characteristics are a long planning lead time and a high degree of design freedom in the process. Furthermore, an optimal location is determined, and a general development plan is drawn up.[20]

B) Restructuring and redesign of existing industrial enterprises:

This most frequently occurring primary case is characterized by a constant adaptation of the manufacturing processes to the changing production program. The objectives are the rationalisation and modernisation of given production complexes.[21]

C) Extension of existing industrial plants:

In this basic case, capacity must be expanded due to order and sales growth. As a rule, the actual location is expanded. Relatively exact specifications for the production program are possible. In extreme cases, the expansion can call the location into question and lead to a spin-off to a new location.[22]

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[18] Cf. Grundig (2018), p. 17 ff
[19] Based on Grundig (2018), p. 17 ff own representation
[20] Cf. Grundig (2018), p. 17
[21] Cf. Grundig (2018), p. 18
[22] ibidem

D) Dismantling of industrial plants:

This basic case can occur, for example, due to a drop in sales, a reduction in the vertical range of manufacture or the outsourcing of production stages. This process leads to re-dimensioning of structures and capacities in production areas, secondary areas and indirect production areas.[23]

E) The revitalisation of industrial plants:

The revitalisation will bring decommissioned factories to a new industrial use. The feature of this rehabilitation process is the achievement of optimal process solutions due to high degrees of freedom, restructuring/redesign of the production complexes, and exact specifications of the production program.[24]

2.4 Planning Principles

In order to fulfil complex factory planning tasks and their objectives, compliance with general planning principles is of great importance. The essential principles are listed below:[25]

1. Value Creation Analysis

Planning is linked to the value chain. The value-adding process elements are to be designed flexibly and non-value-adding process steps are to be minimized/avoided as far as possible.[26]

2. Holistic Planning

This is to be understood as the linking of solutions to sub-tasks as the overall objective of factory planning. The solutions of subtasks must not be viewed in isolation since optimal partial solutions do not necessarily lead to an optimal overall solution.[27]

3. Step-by-step procedure

The step-by-step procedure is defined on the one hand by the gradation "from coarse to fine" and on the other hand, from "ideal to real". Sub-steps are designed to be as unambiguous as possible and divided into a sequence of steps. In the real planning process, smooth transitions, iterative returns, and time overlaps are created for the subtasks.[28]

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[23] Cf. Grundig (2018), p. 18
[24] ibidem
[25] Cf. Kettner et al. (1984), p. 4
[26] Cf. Grundig (2018), p. 23 ff
[27] Cf. Kettner et al. (1984), p. 4
[28] Cf. Kettner et al. (1984), p. 5

4. Visualisation

The visualisation of results using 2D and 3D representations is of great interest to ensure the coordinated, consistent, and distributed cooperation of different specialist groups.[29]

5. Ideal Planning

Ideal planning conveys the objective standard for subsequent real planning. Therefore uncompromising ideal planning should not be renounced.[30]

6. Production-Oriented Planning

When planning a new factory, the starting point should be the product or a known production program from which the planning principles are derived.[31]

7. Variant Principle

As a rule, there are several solution variants for each factory planning task. The creation of variants must be understood and carried out as a consciously desired procedure so that a discussion between solution, alternatives and influences can be forced and a preferred variant can be derived.[32]

8. Economic Efficiency

In order to demonstrate attractive profitability, the scope of planning must be limited and overplanning and under planning must be avoided.[33]

9. Interdisciplinary

Factory planning is to be regarded as teamwork. For this reason, the interdisciplinary teams must work together from the outset and must be strengthened depending on the planning phase.[34]

10. Flexibility

The flexibility and versatility of the planning result are of great interest, as the service life of products and processes is continuously decreasing. By consciously designing flexibility, the factory can be adapted to changing production conditions.[35]

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[29] Cf. Grundig (2018), p. 24
[30] Cf. Kettner et al. (1984), p. 6
[31] ibidem
[32] Cf. Grundig (2018), p. 24 ff
[33] Cf. Grundig (2018), p. 24
[34] Cf. Kettner et al. (1984), p. 7
[35] Cf. Kettner et al. (1984), p. 8

Methods of Model Planning: Bottom-up and Top-down

For the step-by-step planning of a model, top-down and bottom-up models can be considered. With the bottom-up method, small, simple partial models are modeled at the beginning and these are joined step by step to form a complex overall model. The top-down method describes, in greater detail, a procedure that is continued step by step until the desired accuracy is achieved. It has been proven that the combination of both approaches makes sense. A model can first be divided into independent submodels, which can be considered individually as top-down, and then these submodels can be merged by "bottom-up".[36]

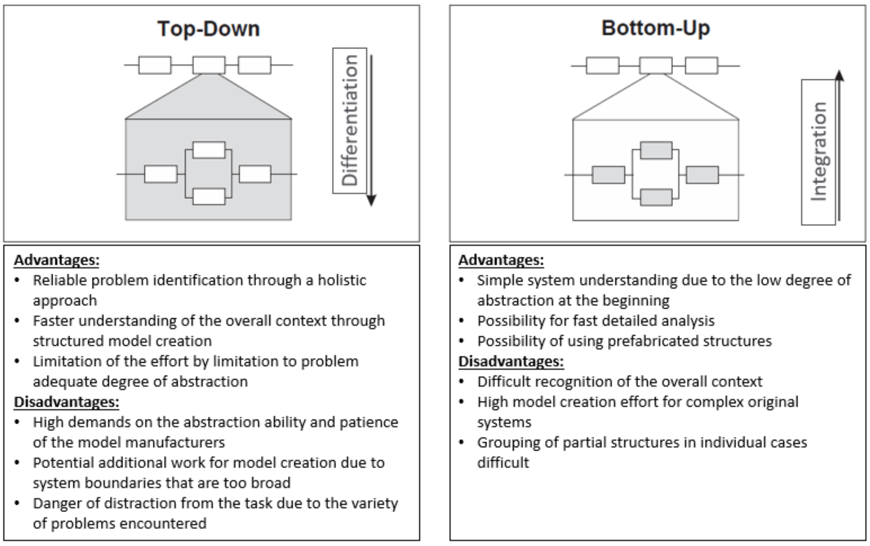

Figure 6: Top-Down and Bottom-Up[37]

2.5 Factory Planning Approaches

In the literature, the factory planning process can be divided into different planning phases depending on the respective author, whereby a generalising, generalizable planning system can be represented concerning the procedure. The individual planning phases consist of defined planning contents. As a rule, each subsequent planning phase builds on the results of the previous planning phase.[38]

Figure 7 indicates the different factory planning approaches existing in the literature. As shown in the figure, each planning approach has a different structure. However, their phases can be clustered under five general phases as preparation, structural planning,

[36] Cf. Schenk / Wirth / Müller (2014), p. 221
[37] Cf. Schenk et al. (2014), p. 221
[38] Cf. Grundig (2018), p. 37

detail planning, implementation planning and implementation. These steps will also constitute Section 2.6, which describes the factory planning phases.

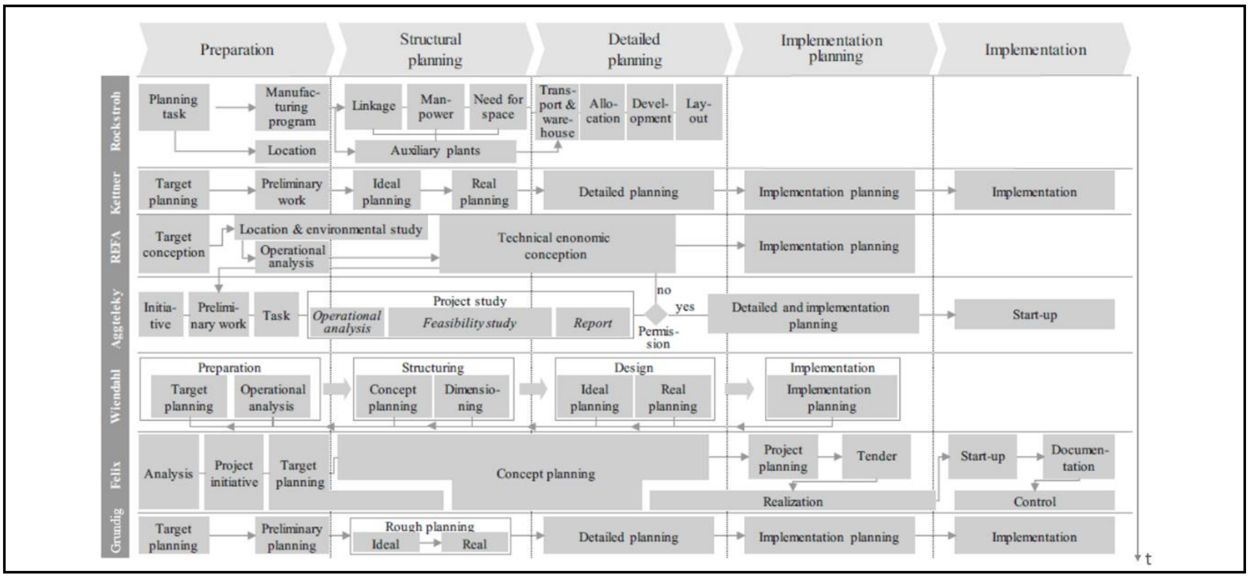

Figure 7: Comparison of Factory Planning Approaches[39]

2.5.1 Grundig

Grundig builds on Kettner's 6-step model and Aggteleky's pyramid model and adds planning complexes and planning activities that show the primary activities within the individual planning phases in abstract form. Figure 8 shows six phases of planning processes from target planning to execution. [40]

It only describes the interim results as outgoing information for some of the activities. The planning activities are divided into three basic planning fields: Location planning, general development planning and factory structure planning.[41] The planning procedure is strongly application-oriented, i.e. it includes a detailed description of the required tools and methods per planning across all phases. It also subdivides the process into four planning complexes.[42]

Initiation, analysis and conception take place in the first planning complex of the planning basis, which covers the planning phases target and preliminary planning. The rough planning phase is assigned to the planning complex Factory Structure Planning, within which a planning report is prepared that summarizes the solution concepts developed. The logically following planning complex execution planning is equated with the planning phase detailed planning, at the end of which the factory planning project is defined. Both

[39] Cf. Bertling / Caroli / Dannapfel / Burggräf (2018), p.28
[40] Cf. Grundig (2012), p. 40ff
[41] Cf. Grundig (2012), p. 15
[42] Cf. Grundig (2012), p. 52ff

the execution planning and execution phases are assigned to the project implementation planning complex and cover the preparation of the planning basis for a commissioning concept as well as the actual implementation of the factory.[43]

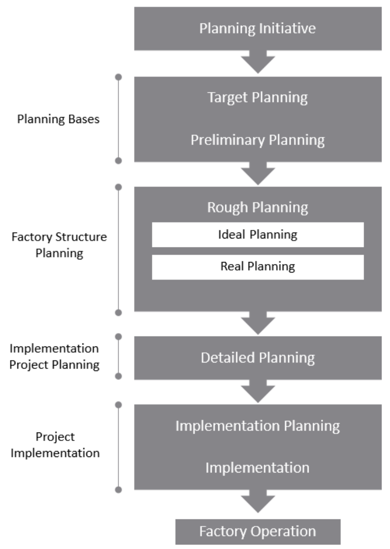

Figure 8: Grundig's 6 Phases Model[44]

2.5.2 Aggteleky

Basically, according to Aggteleky, the three phases of target planning, concept planning and execution planning, which are followed by factory operation, can be distinguished in a simplified way. To map these phases, Aggteleky chooses a planning pyramid consisting of three levels. While most phase models are constructed two-dimensionally in the dimensions planning time and planning progress, Aggteleky uses the three-dimensional shape of a pyramid to represent the planning process, with the third dimension representing the planning effort. The pyramid structure of the representation illustrates the increasing planning effort in later planning phases as well as higher project processing costs and an increasing interdisciplinary, whereby earlier planning steps have a higher importance.[45]

Based on the planning initiative, the preliminary work is followed by the first planning phase as the top of the pyramid. The result of the preliminary work is a concrete, formulated task. On this basis a planning study takes place as a second planning phase, which according to Aggteleky is to be regarded as the core of every factory planning. In this step, an operational analysis is first carried out, followed by an optimization study. The management then decides on the project so that the execution planning can then

[43] Cf. Grundig (2012), p. 41ff
[44] Based on Grundig (2012), p. 47 own representation
[45] Cf. Aggteleky (1987), p. 31 ff

begin as the third planning phase. This includes "all planning activities of a technical, commercial and organisational nature which are necessary for the realisation of the investment project".[46] The entire factory planning process ultimately ends with commissioning and is partly iterated due to approval procedures.[47]

For the implementation of a successful factory planning Aggteleky underlines the importance of project management and lists methods and principles for application.[48] The project management principles have to be adapted to the planning case at hand.[49] Aggtekely emphasises a reference to construction planning in the implementation planning phase and points out a cooperation between the disciplines.[50] However, a content representation of the intersections is not developed. The individual planning steps have dependencies and are run through iteratively due to a continuous development of the planning contents.[51]

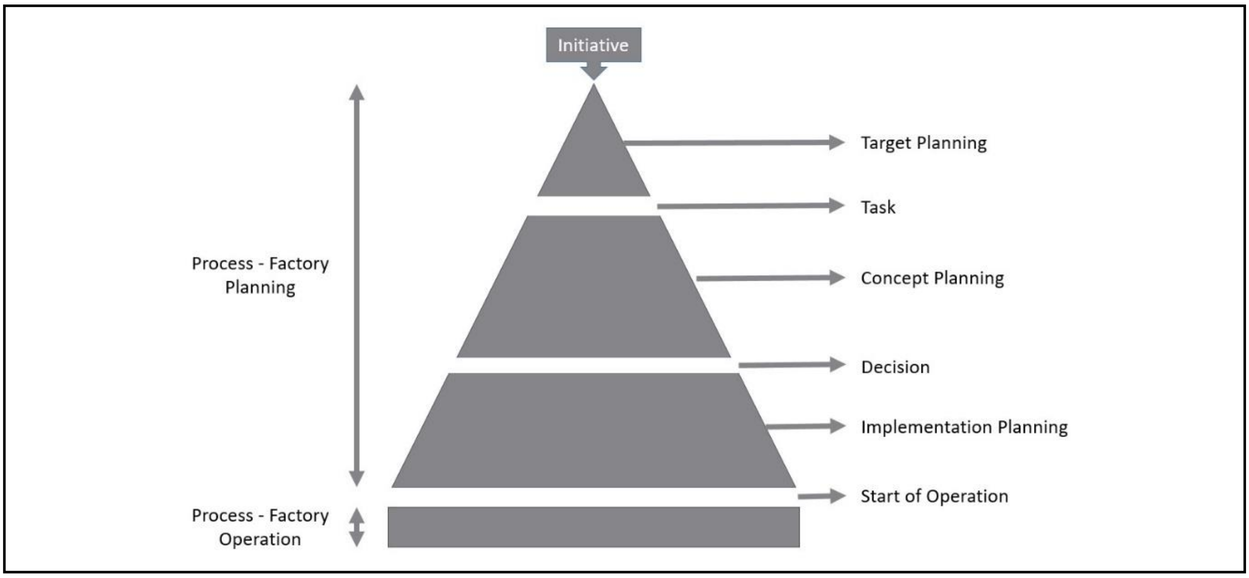

Figure 9: Planning Pyramid of Aggteleky[52]

2.5.3 Felix

Felix develops a reference process that extends over ten phases. It also defines concrete tasks, results, consequences of non-fulfilment of tasks and responsibilities for the individual planning steps, so that it can be seen in close relation to the phase-oriented approaches.[53] Due to a modular composition of the planning process, the factory planning

[46] Cf. Aggteleky (1987), p. 32
[47] Cf. Aggteleky (1987), p. 31ff
[48] Cf. Aggteleky (1990), p. 95
[49] Cf. Aggteleky (1990), p. 116
[50] Cf. Aggteleky (1990), p. 522
[51] Cf. Aggteleky (1987), p. 36 ff
[52] Based on Aggteleky (1987), p. 33 own representation
[53] Cf. Felix (1998), p. 87 ff

procedure according to Felix is a "generally valid system of factory planning", which allows a project-specific configuration of the factory planning project.[54] The procedure is based on the step model according to Aggteleky, to the three steps of which Felix adds a fourth with the management of the building. Spread over these four stages, ten planning phases with a total of 25 phase sections are sought.[55] The modular structure of the factory planning process is reflected in the distribution of tasks across 40 planning fields. These planning fields are structured both according to subject areas and system aspects and refer to separate systems (e.g. production system or plant structure planning), to individual elements (e.g. personnel, construction or plant planning), to individual processes (e.g. production or warehouse planning) and to special structures (e.g. layout planning). This means that every organizational unit involved in factory planning is taken into account and allows each individual project to be mapped.[56] The planning services are arranged in a matrix, consisting of the individual planning phases and the planning fields mentioned. Accordingly, a field in the matrix, a so-called service package, contains the individual services that occur in a planning field in the corresponding planning phase. Felix describes a total of 238 packages of elements that are functionally delimited and have specific input and output information.[57] Nine attributes are described for each service package (input, output, influencing factors, conditions, laws, factory planner, main person responsible, HOAI, computer system), whereby the interfaces to other service packages are defined. In addition, the implementation and dissemination of the information are evaluated with regard to possible computer support.[58]

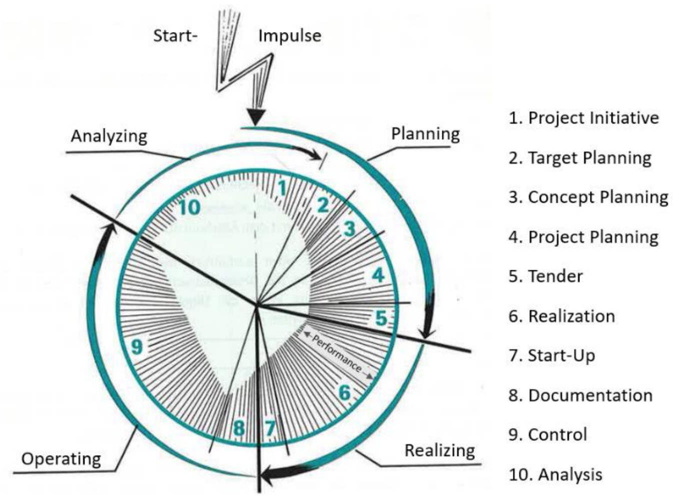

Figure 10: Planning Approach of Felix[59]

[54] Cf. Felix (1998), p. 13
[55] Cf. Felix (1998), p. 37ff
[56] Cf. Felix (1998), p. 46 ff
[57] Cf. Felix (1998), p. 76ff
[58] Cf. Felix (1998), p. 297 ff
[59] Based on Felix (1998), p. 42 ff own representation

2.5.4 Schuh

Factory planning using the counterflow method goes back to Schuh, who in this approach combines a top-down approach with a bottom-up approach. In this way, factory planning does justice to the tasks of spatial, functional and temporal design and structuring of the "factory" system.[60]

The top-down perspective follows a classic greenfield approach and aims to create an ideal concept. This planning is based on an analysis of the current and future product range as well as the market, so that required core competencies can be derived and planning requirements identified. Based on this, the process design is carried out, which focuses on structuring, technology planning and capacity determination. Complemented by benchmarking comparisons, an ideal concept is created which answers relevant questions regarding order and material flow control as well as work organization. It is also possible to evaluate defined measurement and parameters, so that the orientation of the top-down procedure can be classified as strategic.[61]

In contrast, planning takes place in parallel from a bottom-up perspective. Here, the existing concept is examined with the help of a strengths and weaknesses analysis, in the context of which the knowledge and experience of the employees are particularly included. The strengths and weaknesses profile of the existing work structure can be used to determine the need for change and thus design alternatives, the implementation of which is evaluated both qualitatively and financially.[62] The planning of processes within the bottom-up approach takes place "from the small to the big", starting with the micro level via the macro level to the meso level.[63]

The combination of the two perspectives takes place in the roll-out phase. The analytical ideal concept represents the guiding principle of the planning, while the target concept from the synthetic approach provides the basis for a profitability analysis, so that a real concept is created. In this context, Schuh points to the detailing of several alternative design scenarios (two to three) in order to be able to reflect concept requirements differently, in some cases in the opposite direction. After selecting a concept, a detailed analysis, investment calculation and implementation planning are carried out.[64]

The concept of factory planning using the countercurrent method enables a practice-oriented design of the project, which creates greater acceptance among the employees.

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[60] Cf. Schuh / Gottschalk / Lösch / Wesch (2007), p. 196
[61] Cf. Schuh et al. (2007), p. 197
[62] Cf. Schuh et al. (2007), p. 197ff
[63] Cf. Schuh et al. (2007), p. 199
[64] Cf. Schuh et al. (2007), p. 197ff

In addition, the actual need for change corresponds to the strategic goals and an overall optimum is achieved instead of individual optima.[65] The procedure is thus suitable for countering dynamics and turbulence, even though integration of construction planning with the required interfaces is not taken into account.

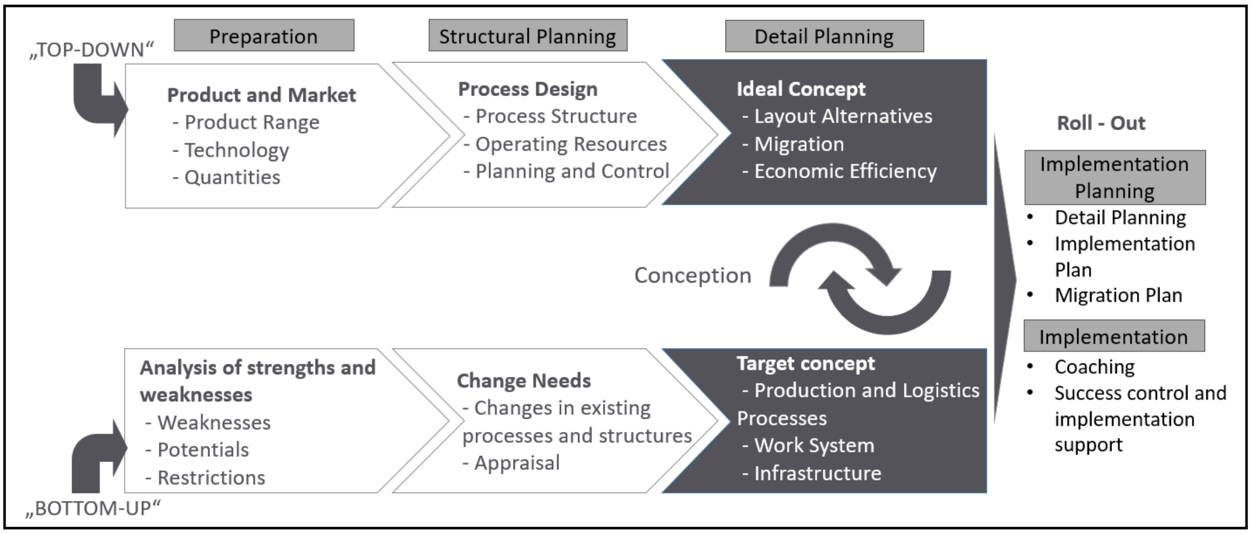

Figure 11: Counter Flow Method of Schuh[66]

2.5.5 Condition Based Factory Planning

The presented classical approaches with their phase-related approach follow the assumption that the definition of the project objectives does not change throughout the project. In practice, however, factory planning projects are subject to a high degree of dynamics, subjectivity, and interaction between those involved in planning. Configuration and ongoing adaptation to the current target system take place in the project during ongoing operational planning. Traditional approaches with their rigid phase model do not do justice to this particular adaptation of goals and planning procedures. This makes it all the more urgent to have freely configurable factory planning processes that enable real planning processes and variable decision-making situations.[67]

In response to the deficits mentioned in practice, the methodology of condition-based factory planning was developed. In this approach, the planning activities are clustered with a high degree of content-related coherence to planning modules and defines corresponding interfaces to other modules so that in total a planning map is created which maps all tasks within the framework of factory planning projects. The interfaces are created via a corresponding specification of input and output information. Due to the relative independence of the planning modules, a configurable planning process is

[65] Cf. Schuh et al. (2007), p. 199
[66] Based on Schuh et al. (2007), p. 23 own representation
[67] Cf. Schuh / Kampker / Wesch (2011), p. 89

possible, which can be adapted according to the scope of planning in the project. Depending on the project, the modules can be arranged in a logical and structured sequence so that the project plan can be developed. The aim is to parallelize activities as far as possible in order to shorten the overall project time. The scope of planning can be continuously adapted to the current planning situation during the project. In this way, the procedure does justice to the iterative character, subjectivity, and dynamics of real factory planning projects.[68]

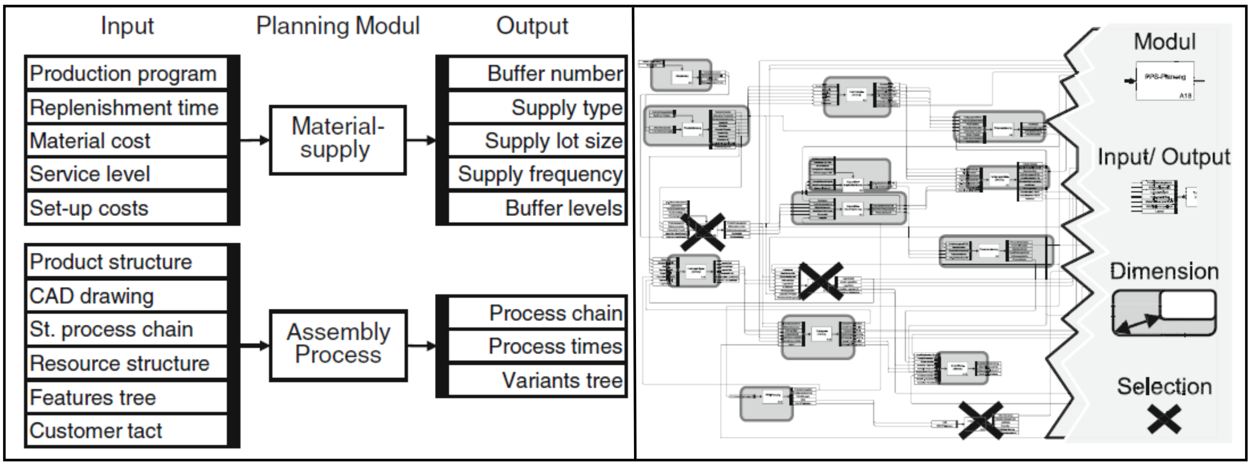

Figure 12: Planning Modules and Their Interconnectivity in Condition Based Factory Planning[69]

2.6 Phases of Factory Planning

The quality of the decisions made in the planning phases of preparation and structural planning is of great importance for the overall project, because at the beginning the total investment costs are influenced by fundamental decisions (e.g. construction of an additional factory). These early occurring costs influence the effects of the cost structure in the company much more than decisions in later phases (e.g. construction). Thus the majority of the investment is determined by fixed costs in the early planning phases. The cost-time course of the individual planning phases is described in Figure 13.[70]

[68] Cf. Schuh et al. (2011), p. 91 ff
[69] Cf. Schuh et al. (2011), p. 92
[70] Cf. Pawellek (2014), p. 63 ff

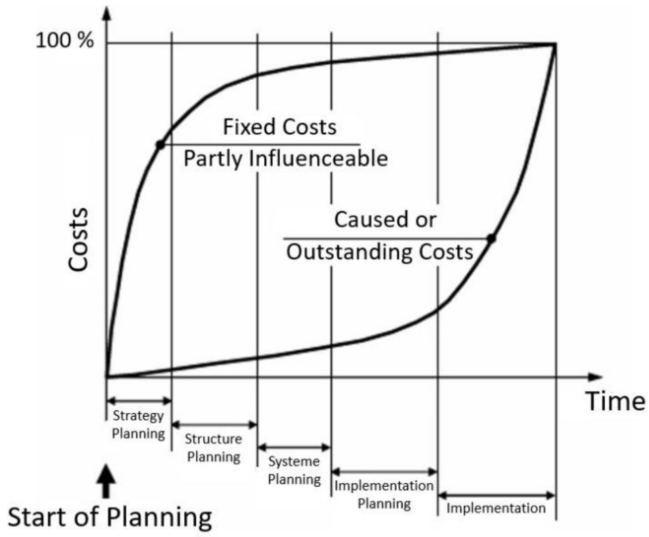

Figure 13: Costs in Planning Phases[71]

2.6.1 Preparation

According to Grundig, the generic term "preparation" is divided into the two phases of target planning and preliminary planning. Target planning is usually decided by upper management. Goals can be strategic considerations, new requirements on the part of the sales market or identified deficits.[72]

The result in the target planning provides a defined task list with the following possible topics:[73]

- Problem description
- Objectives of the project (short, medium, long term)
- Rough concepts/alternatives
- Financial and cost framework
- Schedules (planning, realization, etc.)
- Specifications Versatility
- Project management and project organization

The preliminary planning is based on the first definitions of the objectives and should result in the tasks and planning bases being concretized.[74]

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[71] Based on Pawellek (2014), p. 64 own representation
[72] Cf. Grundig (2018), p. 55
[73] ibidem
[74] Cf. Kettner et al. (1984), p. 17

Essential planning contents in this phase are:[75]

- Analysis of the current status/potential of the factory
- Defining the production program
- Demand planning and investment expenditure
- Feasibility studies
- Design of solution concepts

Most of the works of planning consist of the fundamental cases of reorganization, expansion and modernization. The processes that have to be changed are generally due to the first developments over the years. In these fundamental cases, the first step is to analyze the production potential. This allows a "distance detection" based on practice between the target and the actual state. The principal purpose of the potential analysis is for the further planning process to show the initial situation. Product data, process data and building data are fundamental to this. This data should be formatted to make the object valuable in a structured manner. Methods of data collection are divided into direct and indirect methods in principle. These methods are also called as primary and secondary[76]

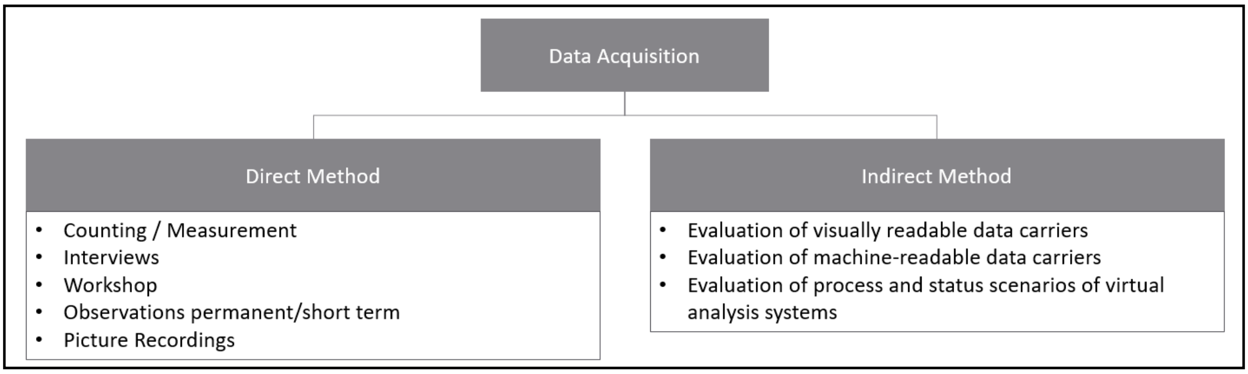

Figure 14: Data Acquisition Methods[77]

Direct method of data acquisition:

The direct data collection is very complicated as specific surveys need to be carried out. If the data are not available or of poor quality, this is the case. In the current process the data recovery is performed.[78] This data collection form is called as primary or direct data collection.[79] In most cases, it is expensive to perform direct data collection.[80]

[75] Cf. Grundig (2018), p. 56
[76] Cf. Grundig (2018), p. 56 ff
[77] Based on Grundig (2018), p. 59 own representation
[78] Cf. Grundig (2018), p. 59
[79] Cf. Arnold / Furmans (2009), p. 237
[80] Cf. Grundig (2018), p. 59

Interviews:

Oral interviews, written surveys or self-writing are performed in the survey. Combinations of these methods may also be carried out in practice. In order to ensure that the wording is objective and objective, care must be taken during the oral and the written questioning; the information value of the questioning shall be increased if it is conducted in parallel with several people. The bright, easily understood and objective wording of the questions should be given particular importance in both written and oral surveys. In order to produce usable results and thus limit the scope of interpretation of notices, the entry forms should be straightforward, unambiguous in structure. Continuous surveillance and thorough guidance must be ensured.[81]

Self-writing is a particular type of written questioning. The information required is directly entered and stored in a ready-to-use form by the employee. As with all written forms, this procedure benefits from the simultaneous feasibility of collecting data for a number of employees / working places. One of the disadvantages of self-registration is that it usually depends heavily on the employee who carries out it.[82]

Observations:

There is a distinction between continuous observations and statistical observations of samples. The choice of the observation depends strongly on the object or process that is to be seen. Sample observations provide binding statements in any desired accuracy about the percentage frequency or duration of the processes and amounts.[83]

Workshop:

Workshops are particularly appropriate to develop ideas efficiently and to propose solutions for selected staff. The selection of workshop participants is of particular importance, as the quality of the workshop results usually depends strongly on the persons involved. The number of participants should be manageable in order to give each participant the chance to express his or her opinion and make a contribution to the solution process. If the group is too large, individual creativity and willingness to cooperate can suffer. At the end of a workshop, a result or final report must be prepared. This report is intended to summarize the ideas and document significant interim results.[84]

[81] Cf. Kettner et al. (1984), p. 38
[82] Cf. Gonschorrek / Hoffmeister (2006), p. 152
[83] Cf. Kettner et al. (1984), p. 38
[84] Cf. Herrmann / Huber (2009), p. 130ff

Indirect method of data collection:

The data is evaluated indirectly using existing company documents, plans, files or data carriers. The effort is much more efficient than direct data acquisition. The data shall here be guaranteed to be available, complete and timely.[85] Existing data are reworked and evaluated for the study during the secondary data collection.[86] Therefore no new data is recorded for the research, which usually reduces effort, as opposed to the primary data collection.[87] However, it is necessary to ensure that the information is up-to-date, complete, plausible, redundant and consistent.[88]

The evaluation of optically readable data media includes:[89]

- Machine files and allocation plans
- Production documents
- Layout representations
- Warehouse and production statistics
- Transport and personnel statistics

To evaluate machine-readable data carriers, software and hardware systems are used. The statistical modules are used to evaluate the data. Process and condition scenarios are considered in the evaluation of virtual analysis systems.[90]

All data obtained from the analysis should be examined and verified critically. Weak points and failures can already be detected early in future phases to identify significant improvement potential and to avoid planning errors.[91]

A distinction is drawn between internal and external documents in the case of existing documents. Internal documents include, but are not limited to:[92]

- Location and building plans
- Production program
- Parts lists
- Work and production plans

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[85] Cf. Grundig (2018), p. 59
[86] Cf. Arnold / Furmans (2009), p. 237
[87] ibidem
[88] Cf. Grundig (2018), p. 59
[89] ibidem
[90] ibidem
[91] Cf. Kettner et al. (1984), p. 42
[92] Cf. Arnold / Furmans (2009), p. 238

The following are examples of documents outside the company:[93]

- Professional journals
- Market researches
- Annual reports

Undetected errors in the data can escalate and cause dramatic planning errors through extrapolations. This makes it necessary to examine and verify all data collected from the actual state. Important information and improvement potential can be collected for the next phases by identifying weak points.[94]

Requirement Quantity Estimation

The objective of the estimated demand quantity is to be able to make fundamental statements concerning areas, staff, capital, time and resources. The main basis for estimating demand quantities is the production program. A rough estimate of the operational resources requirement, which forms the basis of a personal need assessment can be made by determining the type and amount of the products as well as the production processes. Due to the needs of operating resources or personnel a first rough estimate of the area is possible and provides an essential starting point for considering the location.[95]

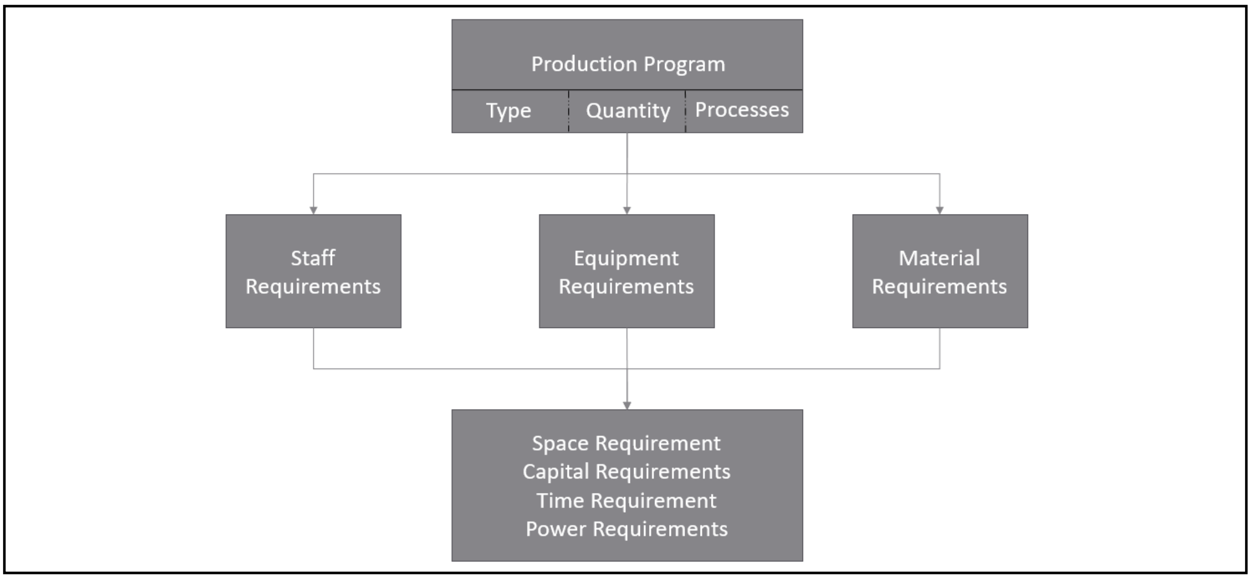

Figure 15: Basic Scheme of Needs Assessment[96]

[93] Cf. Arnold / Furmans (2009), p. 238
[94] Cf. Kettner et al. (1984), p. 42
[95] Cf. Kettner et al. (1984), p. 18
[96] Based on Kettner et al. (1984), p. 18 own representation

There are a number of different methods for recording and evaluating the current situation, which can be used depending on the objectives and data basis:[97]

- Plant comparison by means of key figure analysis
- Material flow analysis
- Plausibility checks
- Value stream analyses
- Process sequence analyses
- ABC and XYZ analysis
- PQ analysis

The ABC and PQ analyzes are ideally suited for product or area recording, limiting analysis efforts and for the targeted, comparative data assessment or analysis of weak points.[98]

In this phase, clear specifications are produced for further planning steps. This phase is also a foundation for further planning phases.[99]

There are several deficiencies in this phase as every phase. For instance, since this phase is very flexible and applicable, special requirements are not taken into account. Less time is spent on data analysis, and there is little or no evaluation of data analysis. The requirement is based exclusively on a business or logistics system's vision or approach. In the preliminary planning phase, customers will be less or not involved. It is unclear whether the plan can be based only on corporate and logistical strategies and visions. There is no explicit declaration as to the techniques of planning. The dimensions of the products are not taken into account. The consistency of the products is not taken into account.[100]

Furthermore, use the improper planning technique because of a misinterpretation or because customer demands are not fully informed. The customers have no uniform opinion. Wrong procedures are planned; clients want other production procedures. The clients can not identify with the processes envisaged.[101]

The clients can be involved in the preparation phase. Customer engagement might assist in conveying know-how from competitors.[102]

[97] Cf. Grundig (2018), p. 60
[98] ibidem
[99] Cf. Straub (2014), p. 87
[100] Cf. Straub (2014), p. 87 ff
[101] Cf. Straub (2014), p. 88
[102] ibidem

With clients involved in the early planning phase, they can consider their input on the target preparation. In the case of real, practical analysis and evaluation of the demands, explicit attention can be placed on the planning stage of structural planning and detailed planning.[103]

2.6.2 Structural Planning

Structural planning is expressed in the literature as “rough planning”, and in smaller or broader context, depending on the fundamental planning situation. The differentiation between planning in the narrower and extended sense depends on the scope of the planning. Planning of factories in the narrowest sense describes internal planning for the location and is described as layout design. Their main task is to arrange organizational units at the best possible location. In the broad sense, factory planning also encompasses the management of problems as location or construction in general.[104]

Last, like a company site, is assumed to be spatially confined. The organizational groups at each location shall be arranged in the best way possible. Extended planning also includes the planning and operational positioning of the operating facilities, where different criteria such as the available infrastructure as well as supplier and customer locations are taken into account.[105]

In this planning phase the data already determined during the preliminary planning will be monitored and refined, regardless of the scope of the facility planning. Two stages usually involve structural planning. Ideal planning is the first step. Ideally planned, the ideal concept should be adapted to actual conditions.[106]

The conceptualized solution concepts are analyzed, tested and evaluated at the end of this phase. In the elaborate detailed planification, the best variant is transferred. Only with tremendous effort in detailed planning can future conceptual changes be implemented. Therefore, the transition constitutes a "no return point."[107]

The planning data already determined are checked, supplemented and refined at the beginning of this planning phase. Then the rough plan is split into two phases. Ideal planning is performed in the first phase. It seeks to develop an ideal concept as a benchmark for the second stage of the planning of the real estate. Real planning adaptations to the real conditions that are not taken into consideration in the ideal planning. A number of solutions in the form of actual designs, including technical and

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[103] Cf. Straub (2014), p. 88
[104] Cf. Grundig (2018), p. 43
[105] Cf. Scholz (2010), p. 3
[106] Cf. Kettner et al. (1984), p. 19
[107] Cf. Grundig (2018), p. 42

economic considerations, are available at the end of its rough planning phase and are analysed, examined and evaluated. A layout variant is selected, transferred and subject to detailed planning for the subsequent detailed planning. The transition is a "no return" point and must be approved by the management of the enterprise. Furthermore, short, medium and long-term planning objectives must be established and the final task set.[108]

The structure planning phase is divided in four parts: determination of functions, dimensioning, structuring, and design. In the following, these parts are described in detail.

2.6.2.1 Determination of Functions

In this step of the structure planning phase, all functions are determined within the production system of the organisation. A functional plan of manufacturing procedures is developed in combination with the determination of tasks, necessary procedures, and machines. It visualises the functional units and their qualitative connections.[109] This allows the production flow in the plant is visualised. Also, for the entire plant or in single places, the functional scheme can be established. While the machinery and workstations are included in the workplace scheme, whereas the design of separate facilities, such as pre-assemblies, storage, and final assemblies, is included for the entire plant.[110] In addition, the functional scheme not only results from the material flow but also the processes and processes.[111]

There can be different levels of detail in the scheme. The availability of information depends on it. Unable to derive detailed processes, only a rather rough scheme is possible. A detailed functional scheme is nevertheless possible if the production program, materials, processes and equipment are available. Figure 16 illustrates the steps to derive a functional system.[112]

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[108] Cf. Kettner et al. (1984), p. 19 ff.
[109] Cf. Grundig (2018), p. 76 ff
[110] Cf. Kettner et al. (1984), p. 19 ff
[111] Cf. Schenk /Wirth / Müller (2010), p. 59 ff
[112] Cf. Grundig (2018), p. 77

Step	Contents	
A Analysis of **production program / bill of material**	Product Elements - Main assemblies - Subassemblies - Single parts - Internal/external production	Manufacturing Stages - Prefabrication - Pre-assembly - Final assembly
B Analysis of **work procedures and areas / process flows**	- Work processes - Workplaces (equipment) - Process flows	
C Development of **working procedure schemes**	- Material flow analysis - Separation into Units	

D
Derivation of **functional scheme**
	- Allocating functional units
	  - Functional-oriented
	  - Material flow oriented	

E Derivation of **functional scheme (area true to scale)**	- Determination of space requirements per function unit - Area of functional units true to scale	

Figure 16: Derivation Steps of the Functional Scheme[113]

In the first step, the scope of each product is defined. Use of the material bill helps identify the various levels of production and elements of the product.[114] In the second step, each element has all processes and process flows analysed. For the entire factory, the process flows between the units are detected. A detailed material flow analysis is performed in the third step, containing qualitative information. An example of qualitative information is the sequence of material flow, whereas the amount of annual products and items, for example, is quantitative information. In addition, in this step units are grouped. For grouping units, the principles are, for example, allocation of cost centres, the analogy of procedures and equipment, and the storage structure.[115]

By visualising the processing logic in the fourth step, better understanding and knowledge of the production flow will be achieved. The functions and units are related and are illustrated in a structure which shows the linkage between each function. The first unit-oriented functional scheme is this visualisation without taking into account areas that are true to scale.[116] A rough estimate or calculation of space demands is carried out in the next step. It is necessary to show a truly functional system. This is necessary. This functional system, however, concerns only functional units and not their arrangement. It shows that the scheme is not similar to a layout because only the process logic and the estimated spatial need per unit are displayed – not where the units are located. [117]

[113] Based on Grundig (2018), p. 77 own representation
[114] Cf. Schenk et al. (2010), p. 60 ff
[115] Cf. Grundig (2018), p. 79 ff
[116] Cf. Kettner et al. (1984), p. 100 ff
[117] Cf. Grundig (2018), p. 82 ff

2.6.2.2 Dimensioning

The dimensioning of equipment, staffs, spaces, and the media is part of structural planning.[118] The site is split into various fields, which are used for various reasons by VDI 3644.[119] Figure 17 provides an overview of the areas.

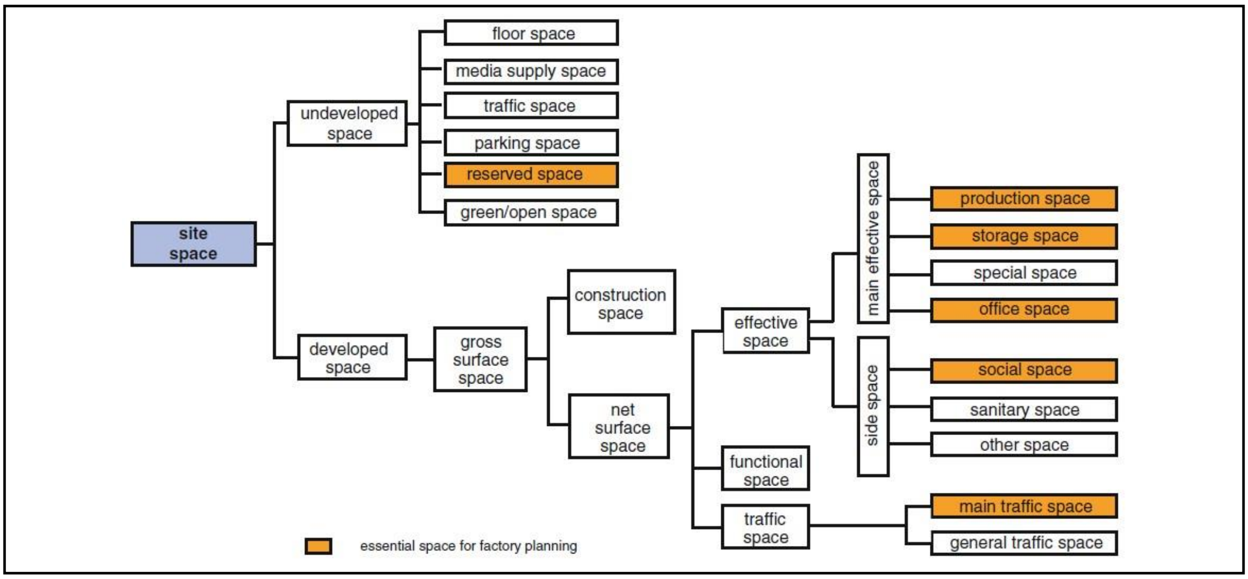

Figure 17: Division of the Site Area[120]

The orange painted areas are very crucial significance in layout planning based on the area of the property. With the growing future of the factory, the facilities can be extended by reserved areas. The area of production includes all the rooms needed for material production, assembly, inspection and handling.[121] Production areas contain areas that are required for assembling, manufacturing, handling and testing workpieces. The storage areas are used for the supply and delivery, provision and intermediate storage of workpieces for the production process. Office areas are regarded as administrative areas, and social areas are mainly used for the health and care of employees. Main traffic areas are exclusively used for the transport of workpieces and personnel. Undeveloped reserve areas are designed for the growth of the factory.[122]

The production spaces can be estimated in various ways. The estimate can be made based on absolute or relative factors in the early phases of factory planning. When detailed information on the equipment is provided, space requirements can be more precisely calculated. For determining the necessary space, there are various methods such as bottom-up and top-down methods. The top-down approach begins with the site

[118] Cf. Grundig (2018), p. 83
[119] Cf. VDI 3644 (2010), p. 7
[120] Cf. Wiendahl et al. (2015), p. 402
[121] Cf. Wiendahl et al. (2015), p. 403
[122] Cf. Wiendahl / Reichardt / Nyhuis (2009), p. 468

space calculation and then divides the space into departments, and finally, the spaces required per place of work. For the bottom-up strategy, the space calculation for each place of work at the start is typical. The space for the department is calculated based on the workplace area.[123]

2.6.2.3 Structuring

The structural planning is a component of the factory's ideal planning. The results of the previous steps shape the foundation for aligning all units in the layout. The system operation is based on the distinct structure layouts that can be defined.[124]

Structure planning can concentrate on the overall plant structure. The manufacturing, logistics, and management fields are linked here.[125] The design and determination of the following concentrations can be another focal point: workplace, area, and building. This is shown in Figure 18.[126]

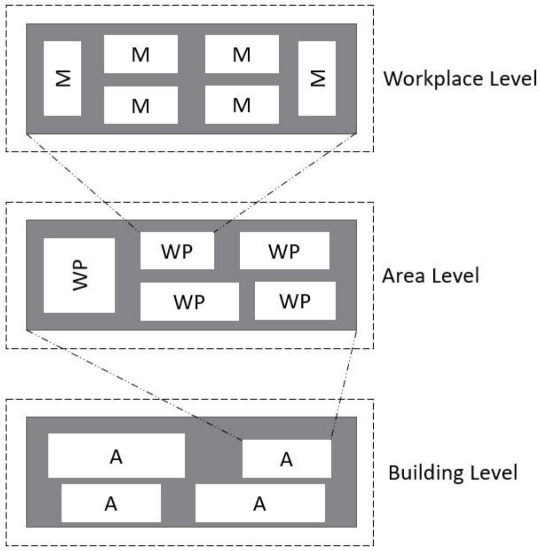

Figure 18: Structuring Levels[127]

The structuring of areas and processes is part of the building level. Workplace, production cell, or handling equipment alignment is a component of the area level, whereas the workplace level involves the construction of all workplace components and their appliances.[128]

Material flows are described in terms of qualitatively and quantitatively. The series of manufacturing procedures is determined as a qualitative trait. Whether the direction of

[123] Cf. Schenk et al. (2010), p. 96ff
[124] Cf. Grundig (2018), p. 106
[125] Cf. Grundig (2018), p. 103
[126] Cf. Grundig (2018), p. 104
[127] Based on Grundig (2018), p. 104 own representation
[128] Cf. Grundig (2018), p. 111 ff

flow and a flow of goods exists between two production operations or not is described. Quantitative features describe the quantitative material flow over some time. For instance, the number of units per year and the intensity of material flow between production processes.[129]

The individual matrices in the material flow analysis are outlined in more detail below:[130]

Material Flow Matrix:

In the second stage of the material flow analysis, the material flow matrix is an accurate depiction of the procedures of material flow. A flow orientation is available when recording the movements “from” and “to”. For matrices, the machinery in rows and columns must be matched carefully. The material flow matrix is usually produced in piece basis.

Transport Matrix:

The real transport activity is shown in transport units in the transport matrix. This matrix is similar to the matrix of the material flow.

Distance Matrix:

The distances between each item of the operating and transport equipment are used for creating the distance matrix from the layout. The transport matrix can be used to take relevant positions because it is only of interest the distances at which the material flows prevail. The lines and columns should be accurately matched within the transportation matrix. The distances from the middle to the middle of assets in a straight row or through the genuinely covered transportation path are regarded, depending on the selected literature. Usually, the unit of the distance matrix is a meter.

Transport Intensity Matrix:

By multiplying the transport matrix with the distance matrix, the transport intensity matrix is calculated with the unit.

The cost of transportation can also be calculated by multiplying expenses or capacities using the matrix acquired.[131]

Figure 19 shows the general procedure for generating a matrix of transport intensity.

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[129] Cf. Grundig (2018), p. 111 ff
[130] Cf. Arnold / Isermann / Kuhn / Tempelmeier / Furmans (2008), p. 395 ff
[131] Cf. Liebetruth (2016), p. 41

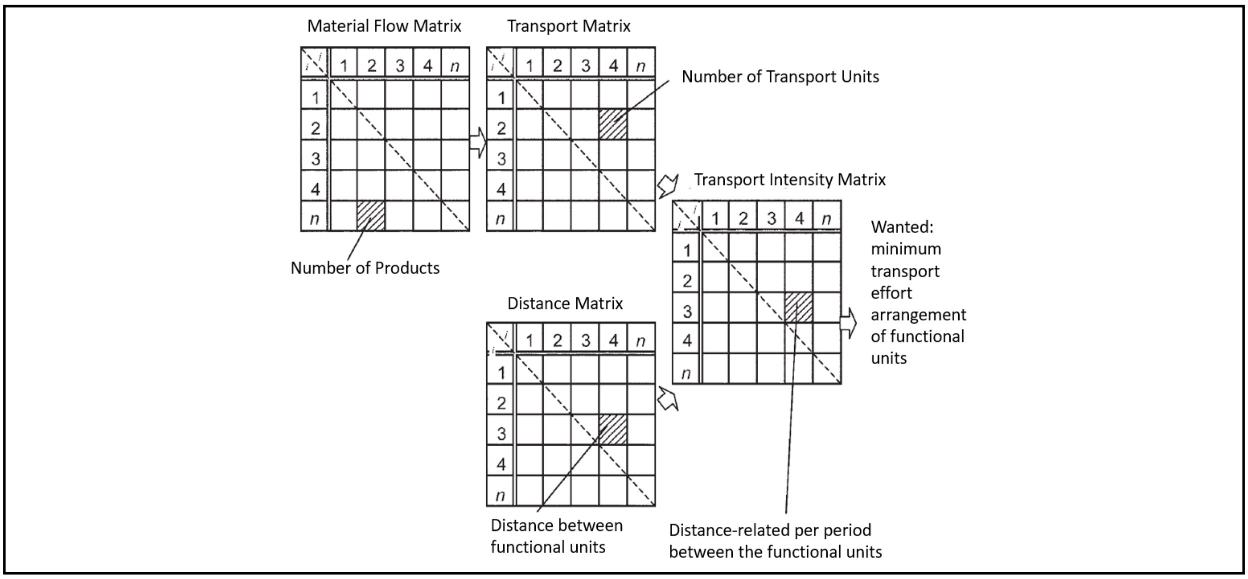

Figure 19: Material Flow Matrixes[132]

The transport matrix is arranged for an optimised series of individual assets in the last phase of the material flow analysis. The goal of the sorting is to minimise the reverse flow by swapping columns and rows beneath the diagonal. That is achieved by gradually optimising the row and column sums for each matrix element by quotient formation. At every step, the largest quotient is checked. When this is identified, it is removed from the transport matrix and displayed in a new order. The number of iteration steps is equivalent to the number of matrix components. In this process, the material flow behaviour is optimised in the direction of the flow.[133]

A quantitative material flow scheme, which is called as a Sankey Diagram, or a position-related material flow scheme, which is called a quantity path diagram, can be used to display the material flow graphically:

Sankey Diagram:

Sankey diagram can be created based on material flow direction and transport relationships. Besides the direction of flow, the intensity of flow by period is also shown in this diagram. Wider arrows mean higher transportation volume. The Sankey diagram offers a streamlined representation of the material flow in comparison with the matrix representation.[134]

[132] Based on Grundig (2018), p. 116 own representation
[133] Cf. VDI 2498 (2011), p. 3
[134] Cf. Dickmann (2015), p. 399

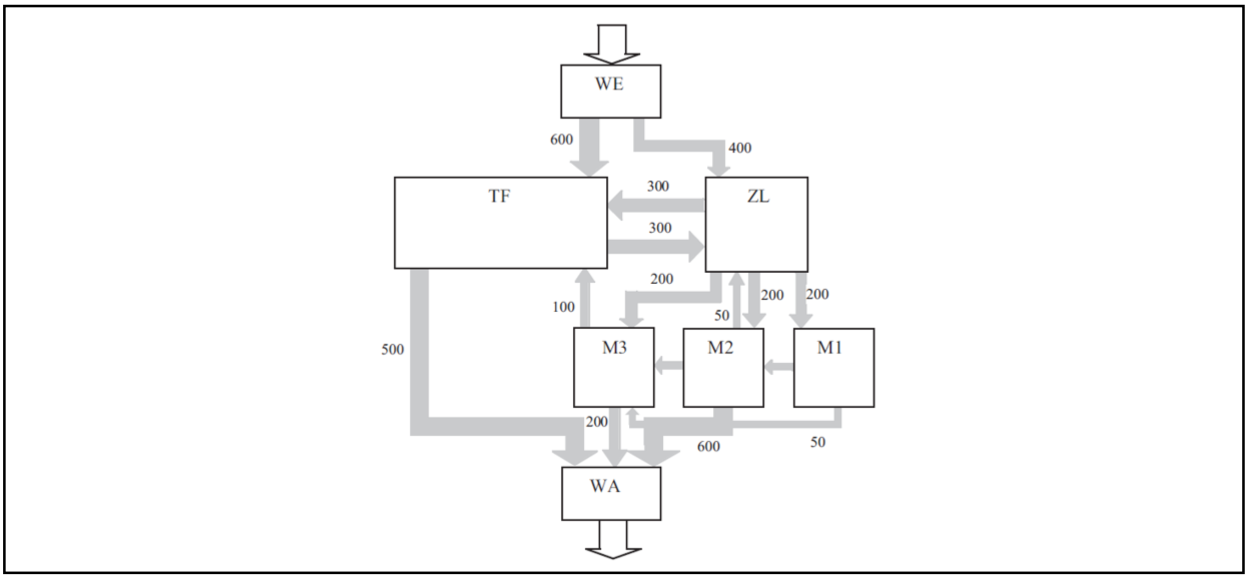

Figure 20: Sankey Diagram[135]

Transport Route Related Material Flow Diagram:

The analysed material flow is displayed accurately depending on the defined transport routes of the analysed item. A distinction is made in the literature between the representation of the direct and transport route-related materials. The transport route related material flow diagram is shown in Figure 21.[136]

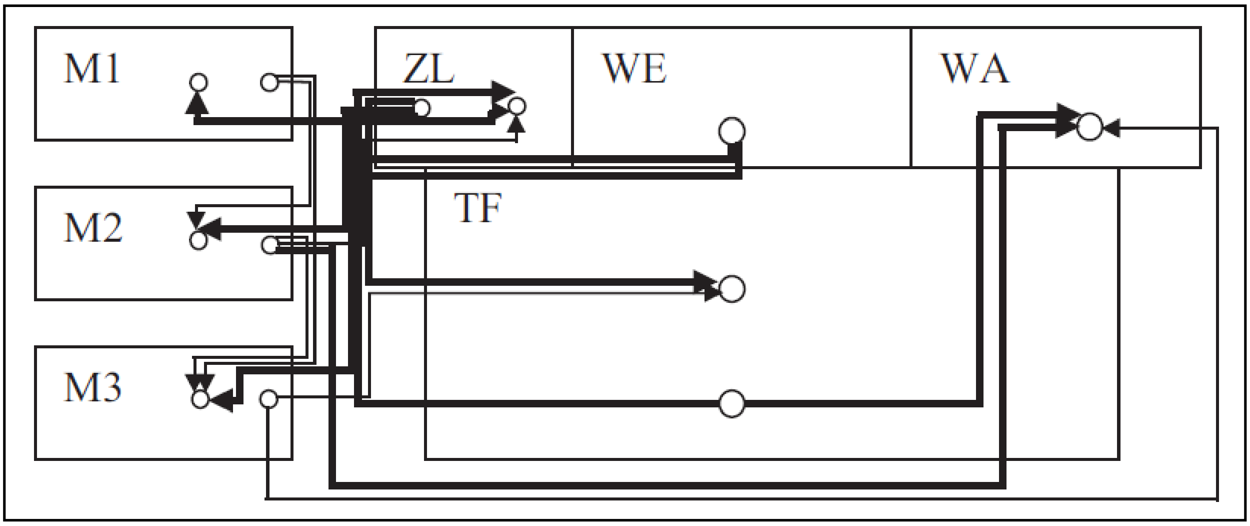

Figure 21: Transport Route-Related Material Flow Display[137]

[135] Cf. Grundig (2018), p. 117
[136] Cf. Grundig (2018), p. 117ff
[137] Cf. Grundig (2018), p. 118

Triangular Method According to Schmigalla:

A heuretic technique that constitutes a template for planning the layout is the Schmigalla triangle approach. This method is based on the transport matrix as defined in the current state analysis. The triangle trial and the triangle calculation methods are distinguished.[138]

Three interconnected resources, if they are triangulated with each other, will make the minimum effort in transport. The transport intensities, compared to the Sankey diagram, are taken into consideration instead of the direction of material flow.[139]

The one-sided transport matrix is developed in the first phase with the triangle calculation technique. To that end, the lower side of the diagonal contains all the values in the transportation matrix that lie over the diagonal Amount of transports are summed up if there are transportation in both directions. In the second step, two objects with the highest relation between them are searched and placed on the square or triangle grid. The objects are selected in the following steps based on their intensity of transport and best assigned to the objects already placed. Objects are always placed with the least effort to transport.[140]

Transport Intensity Matrix

	1	2	3	4	5	6	7	8	9
1	0	0	0	0	0	0	0	0	0
2	90	0	0	0	0	0	0	0	0
3	170	90	0	0	0	0	0	0	0
4	140	0	180	0	0	0	0	0	0
5	0	0	100	210	0	0	0	0	0
6	10	0	0	10	90	0	0	0	0
7	0	0	40	30	80	0	0	0	0
8	0	0	30	0	180	110	0	0	0
9	0	0	0	0	0	0	0	40	0

1. Step — search 2 points with maximum transport intensity — Max {I_{ij}} = 210, i⇔j: 4⇔5

2. Step — search next intensive point

	1	2	3	6	7	8	9
*4	140	0	180	10	30	0	0
*5	0	0	100	90	80	180	0
	140	0	280	100	110	180	0

3. Step — as 2. step

	1	2	6	7	8	9
*3	170	90	0	40	30	0
*4	140	0	10	30	0	0
5	0	0	90	80	180	0
	310	90	100	150	210	0

.
.
.

8. Step

	9
1	0
2	0
3	0
4	0
5	0
6	0
7	0
*8	40
	40

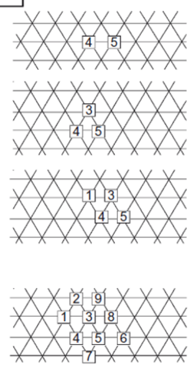

Figure 22: Triangular Method According to Schmigalla[141]

[138] Cf. Pawellek (2014), p. 203
[139] ibidem
[140] Cf. Pawellek (2014), p. 203 ff
[141] Cf. Pawellek (2014), p. 203

2.6.2.4 Design

The overhaul of the ideal layout is discussed in this chapter of factory planning. In other words, ideal layouts are revised, selected, and transmitted to real layouts.[142] A real layout is called a spatial and feasible arrangement of units that take into account feature, material flow, room, practice, and formal influence variables.[143] In other words, ideal layouts are put into reality. It means that this step relies on the sub-phases within the structural planning described previously. Different layouts are firstly designed regarding the real areas. Afterwards, the multiple logistic components are selected and arranged.[144]

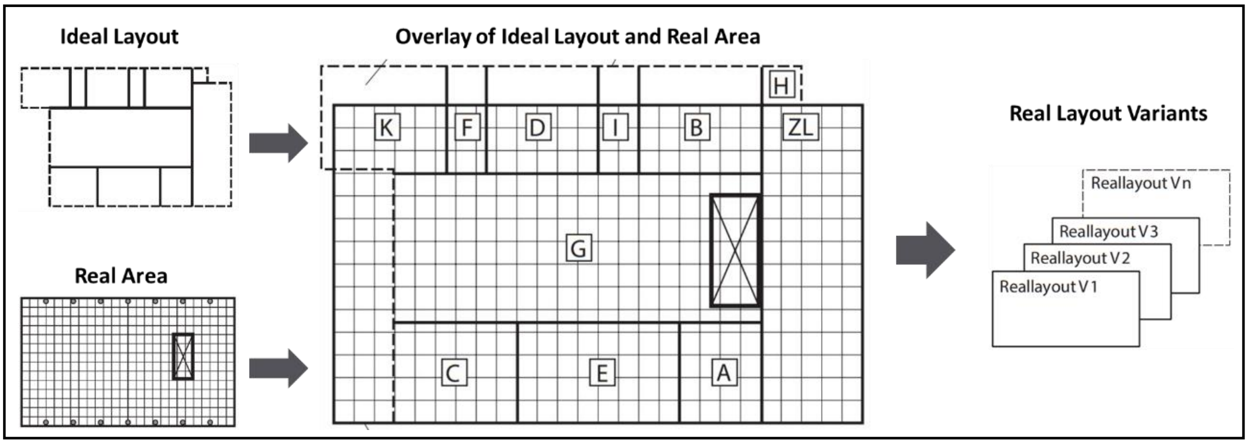

Figure 23: From Ideal Layout to Real Layout[145]

Then, the variants are evaluated by comparison. The main objective of comparing different variants is finding optimal and productive layout. This comparison should be made by a group of experts because of uncertainties.[146]

There are several advantages of structural planning. Firstly, it is a creative process that offers an opportunity to look at fresh concepts. New equipment and processes can be identified, tested, and evaluated in this phase. New alternatives can be adopted and promoted.[147]

However, there are also several downsides of this phase as well. This is a complicated method, as various variants are planned in conjunction. Moreover, various project stakeholders may have different ideas and not act in agreement. This planning phase is not involving customers immediately. Process, product and customer specific

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[142] Cf. Grundig (2018), p. 151
[143] Cf. Schenk et al. (2014), p. 341
[144] Cf. Grundig (2018), p. 151
[145] Based on Grundig (2018), p. 154 own representation
[146] Cf. Grundig (2018), 182
[147] Cf. Straub (2014), p. 91 ff

specifications are generalised. No consideration is given to the size of the products. There is no regard to the consistency of the products.[148]

Furthermore, if there are participants in the planning team, it makes it harder to find an agreement about the structure of the variants. There is no correct depth at which the variants are created. Consistent consensus on one variant may be hard to reach. A planer seems to use the existing framework easily, but particular know-how is required in order for others to use it.[149]

2.6.3 Detail Planning

The chosen real layout and all prior planning bases will be examined, added, and comprehensively detailed during this planning phase. The rough planning methods and tools are used for this purpose. The focus is on designing an overall solution that is technically and economically convincing. In this refinement of the original layout, the individual operating areas are presented, and the following important information is provided[150]:

- Position and dimensions of all machines, plants, and equipment
- Building floor plans with the most critical dimensions and arrangements of doors, gates, windows, staircases, paths, etc.
- Traffic routes
- Safety-relevant objects and energy supply
- Supply and disposal lines

For a better overview, various task lists depending on their intended use are derived from the detailed layout. Among other things, these include the main circuit layout for energy supply and security plans which are needed to initiate approvals.[151]

In this phase, CAD systems are generally used. For instance, the computer-aided design in 2D/3D models based on measuring and geometry libraries can illustrate the detailed design. AutoCAD or FactoryCAD is a frequently used program.[152] CAD programs are often employed when creating fine layouts to allow 3D viewing of the layouts.[153] Errors like a machine or line collisions can, therefore, be detected and prevented early.[154] Detailed planning also involves the design of the workplace and the creation of data or drawings for specifications for businesses to be handed over to suppliers and

[148] Cf. Straub (2014), p. 92
[149] ibidem
[150] Cf. Kettner et al. (1984), p. 26 ff
[151] Cf. Kettner et al. (1984), p. 28
[152] Cf. Grundig (2018), p. 160 ff
[153] Cf. Schenk et al. (2014) p. 266
[154] Cf. Schenk et al. (2014) p. 343

subcontractors. Detailed planning results are planning documents ready to be executed. Finally, in the detailed planning phase, the project is released, the project documentation is prepared, and the transition to implementation planning takes place. [155]

The detail planning phase has several advantages. In detail planning phase, tasks and the focus are clear. If a single real layout is not selected in the previous phase, variations can be evaluated in parallel because the base data has already been evaluated in the previous planning phase.[156]

Straub argues that new information may overload the system users. One of the critical deficiencies is that the new system cannot be adopted by users because they have a bias. If planners encounter with the problem as the first time in the later stages of structural planning, a large loop is required to fix it.[157]

There is a risk that the chosen variant in the previous phase, which is structure planning, is not applicable. Also, unnecessary iteration may cause the motivation of the planning group to decrease. It is not easy in this phase to share the information between the customers and planners as soon as possible.[158]

In this phase, particular requirements from customers can be considered, and this is the last step that the flexibility and adaptability features of the system can be added on the planning object. In the end, in brownfield projects, planning systems should be compatible with the already installed system.[159]

In a nutshell, the main advantage of this phase is the clear focus because only one variant is being planned, so this also helps to work parallel. Customers and users can be integrated more actively in this phase.[160]

2.6.4 Implementation Planning

In the implementation planning phase, all the preparatory and planning operations are carried out for the organisational, technical, and constructional implementation of the desired planning object. This includes all necessary measures and decisions that must guarantee a smooth implementation phase after that. The rough and detailed planning results form the basis of the implementation plan.[161]

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[155] Cf. Grundig (2018), p. 51
[156] Cf. Straub (2014), p. 94
[157] Cf. Straub (2014), p. 95
[158] ibidem
[159] ibidem
[160] ibidem
[161] Cf. Grundig (2018), p. 195 ff

In practice, the implementation planning frequently overlaps with the detailed planning and structural planning if necessary due to the short implementation deadlines.[162] Project postponements can also occur, which lead to more extended periods between the structural or detailed planning and the implementation planning and thus frequently bring about a change in the initial situation and the given boundary conditions.[163] For this reason, it is essential that at the beginning of this phase, all planning documents are again subjected to an examination for the topicality, feasibility, and compliance with standards, laws, and ordinances.[164]

The contents of this phase are[165]:

- Structure and define work packages
- Create flow charts and time schedules
- Define responsibilities
- Submit permit applications and lay down regulations
- Create requirement lists and relocation planning

Furthermore, the invitation to tender, the bid comparison, and the ordering of the trades or complete systems are carried out in this phase.[166] Other decision criteria, such as projects completed with a supplier, a company's economic situation or schedule, and payment and delivery periods, can significantly influence the selection of suppliers in addition to prices and scope of services.[167]

The implementation planning phase has several advantages. In this phase, several project management tools are available and can be used to plan the implementation phase. A particular focus is supported by proper planning of earlier phases. Client involvement in the implementation planning phase can lead to an increase in customer loyalty.[168]

Straub claims that a straightforward approach and a definite beginning and end point for this phase of factory planning should be set. Customers should be involved because it will increase the loyalty of the client.[169]

However, When the implementation planning phase is carried out superficially, there is a risk that it could have a reduced impact on the implementation phase. Implementation

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[162] Cf. Grundig (2018), p. 196
[163] Cf. Martin (2016), p. 471
[164] Cf. Kettner et al. (1984), p. 29
[165] Cf. Grundig (2018), p. 195 ff
[166] Cf. Martin (2016), p. 471 ff
[167] Cf. Kettner et al. (1984), p. 29
[168] Cf. Straub (2014), p. 97
[169] Cf. Straub (2014), p. 98

planning should differ from other planning phases; otherwise, a risk could arise the neglecting of implementation planning.[170]

There are two main risks, and the first one is that project initiators, users, or clients push the project without exactly planning the implementation. Secondly, the providers could transfer know-how to competitors.[171]

2.6.5 Implementation

This implementation phase is the realisation of the project and can be divided into three steps. These three steps consist of the application itself, handover to the user and commissioning.[172]

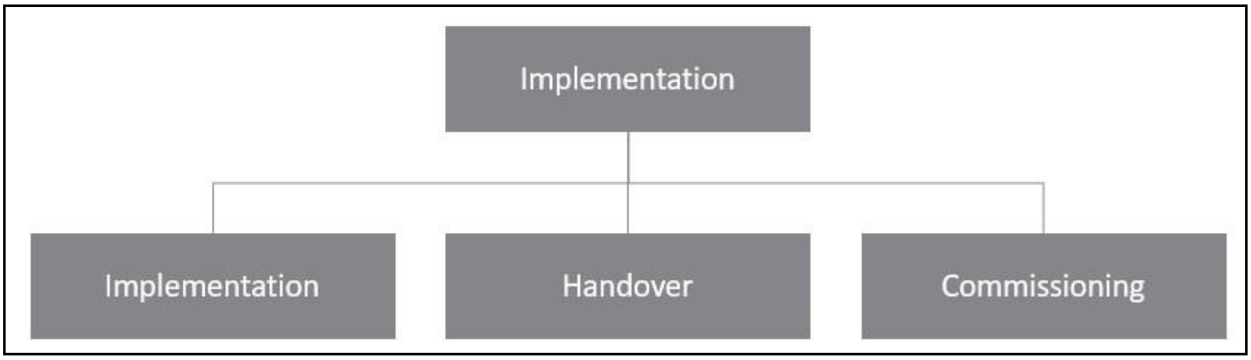

Figure 24: Overview of Implementation Phase[173]

In the first phase of the implementation, all construction, assembly, and installation works are carried out. The focal points of this phase are divided into coordination, monitoring, and testing tasks.[174] So the planning phase is not involved anymore.[175] The commissioned companies are responsible for all planned work and measures. The project manager must be responsible for management, coordination, and monitoring as well as the ongoing schedule and cost control, which are great importance.[176] During this final phase, time limits often coincide with construction work, assembly operations, test runs, and furnishing operations.[177] Standard, functional, and load tests must be conducted in parallel to the implementation work.

Consequently, it is essential to monitor work progress and adhere to deadlines consistently.[178]

[170] Cf. Straub (2014), p. 97
[171] Cf. Straub (2014), p. 98
[172] Cf. Grundig (2018), p. 198
[173] Based on Grundig (2018), p. 198 own representation
[174] Cf. Grundig (2018), p. 198
[175] Cf. Martin (2016), p. 472
[176] Cf. Kettner et al. (1984), p. 30
[177] Cf. REFA (1985), p. 229
[178] ibidem

The contractor shall hand the factory over to the customer after a rigorous acceptance test, draw up acceptance records and acceptance certificates. Finally, full project documentation and a final account statement must be prepared by the planning team.[179]

The term of commissioning refers to the beginning of manufacturing. The commissioning of the production system is regarded as the period from the beginning of the production to the achievement of the set objectives. The pilot, ramp-up, and series phase constitute the commissioning. This is the formal conclusion of the project and constitutes the basis for the customer to accept the project.[180]

The implementation phase has several advantages. For example, the immediate responses can be obtained when the implementation phase is included in the planning approach and applied as planned. The knowledge required for the next factory planning project is produced with the help of the experience gained in this stage. The experience gained during the implementation phase can be used when the factory becomes operational as well.[181]

Straub argues that planners can convince the customers by emphasising the quality, effectiveness, and efficiency of the integrated system. If the customers and planners are involved in this phase and working together, then customers can give responses to the planning team directly.[182]

This is the last phase of factory planning, and wide knowledge is gained during the project. Therefore, this knowledge can be used for the next projects. Furthermore, the knowledge and experience gained in this phase can be used in other phases since errors and deficiencies can be detected. Because planners and customers receive results after the implementation. In other words, they will have feedback from the commissioned system. If everything works fine, this will be the basis of reference about the planners for the customers and users. However, this can only be done by transmitting the system knowledge that arose during planning to the operative level. Planners should also handle the improvement request in this stage. [183]

One of the deficiencies encountered in the implementation phase is that each planner is not included in every phase of the factory planning projects until to the implementation phase, which may result in the loss of the knowledge and know-how gained in the structural and detail planning phases. In this phase, since the planners and the

[179] Cf. Grundig (2018), p. 198
[180] Cf. Grundig (2018), p. 198 ff
[181] Cf. Straub (2014), p. 100
[182] ibidem
[183] Cf. Straub (2014), p. 100 ff

implementers do not work together, the system cannot be installed as planned, and this will cause the system not to operate effectively and efficiently. Straub claims that the method of the shop floor is not applied.[184]

The other deficiency is that planners and company employees involved the implementation phase can give the gained know-how to the competitors, and the suppliers can sell the system established by them to the competitors. In some cases, suppliers cannot deliver on schedule.[185]

2.7 Challenges in Factory Planning

Today´s dynamic and turbulent environment cause some challenges in factory planning as in every field. In this section, the challenges encountered in planning the factory in the literature are described. Figure 25 shows these main challenges.

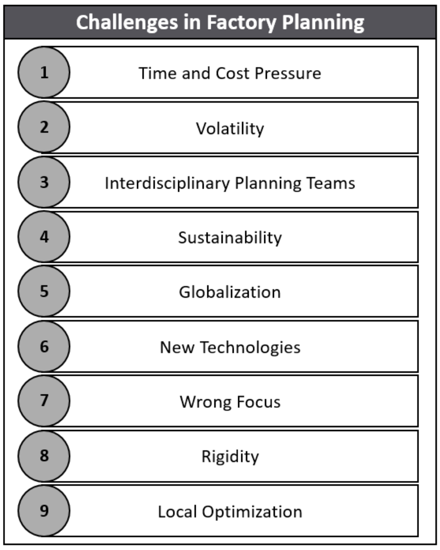

Figure 25: Challenges in Factory Planning

1. Time and Cost Pressure

Companies are under increased time and money pressure as a result of global rivalry.[186] One of the general assumptions is that existing factory planning models are no longer agile enough, and the basis of this assumption is shortened the time in the new product development and shortened the time to market. The procedures currently used are lacking agile techniques for planning.[187]

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[184] Cf. Straub (2014), p. 100
[185] ibidem
[186] Cf. Schuh (2005), p. 174
[187] Cf. Bertling et al. (2018), p. 25

In the future, the factory planning process should also use the resources efficiently until the factories.[188]

This reflects a key issue in planning the factory. Eventually, the main reason for the time and cost pressure is the increasing requirements and the increased planning effort resulting from this. In the end, this contributes to price, and time objectives were not met.[189]

2. Volatility

Innovative technology and more personal client demands have resulted in shortened product and process life cycles.[190] That means, in the planning of factories, the production must be more rapidly adapted to present requirements.[191] The reason for the increasing demand for flexible plant structures is to respond to changes proactively. This plays a key role in competing with other companies, while at the same time increasing the planning effort.[192]

When planning the factory, the framework conditions are sometimes changed and caused micro-volatility.[193] For example, since some planning tasks are interdependent, for example, the change in the quantity of production does not affect the planning process to a great extent but requires some changes that take some time.[194]

While the production quantity can be scaled quickly and changes in the production system must be met without undue effort at the same time. Also, the design of the production system should be implemented as soon as possible and adapted to meet the objectives of the factory.[195]

3. Interdisciplinary Planning Teams

The participation of a large number of experts from different disciplines is needed for social trends, such as urbanisation and resource efficiency.[196] This interdisciplinarity, while having many positive aspects in planning the factory, increases the effort required for coordination.[197]

[188] Cf. Kampker / Burggräf / Krunke / Kreisköther / Voet / Backs (2014), p. 1
[189] ibidem
[190] Cf. Wiendahl et al. (2009), p. 55
[191] Cf. Westkämper (2002), p. 251
[192] Cf. Kampker et al. (2014), p. 1
[193] Cf. Schuh et al. (2011), p. 90
[194] Cf. Kampker et al. (2014), p. 1
[195] Cf. Bertling et al. (2018), p. 25
[196] Cf. Pawellek (2014), p. 2
[197] Cf. Kampker et al. (2014), p. 1

4. Sustainability

While sustainability is mentioned as another challenge, this aspect should be taken into consideration when planning the factories of the future. The notion of sustainability covers the ecological, economic, and social three aspects. This means that factories designed considering these three aspects can be used by both now and in the future generations. Combining these three aspects within the term of sustainability is realised by the energy efficiency of the factory. Factories that use energy in an optimum way are economical, ecologically beneficial because they protect natural resources and protect people from unnecessary loads.[198]

5. Globalisation

Increased interest in global markets is another challenge in factory planning. First of all, it is necessary to establish a global production network and be a part of it to compete worldwide. In the future, this will mean first of all the local factors in the country where the factory is located, and more critical consideration of the building legislation and laws in the country concerned when planning a factory.[199]

6. New Technologies

New technologies are an essential point that cannot be ignored when planning a factory. The production and handling of high-voltage equipment, for instance, will be a significant obstacle for car producers about electric mobility because compliance with unique structural legislation is required here. The emergence of new processes, in the future, such as the processing of carbon fibre reinforced polymers, or the hot forming of steels is one of the challenges of factory planning. Changing surface requirements can also be included in this situation.[200]

7. Wrong Focus

Lack of reactivity is usually caused by ignoring the interactions between planning tasks. In general, many tasks must be done correctly to complete factory planning projects. In the meantime, factory planners do not give importance to the interactions between these tasks. Plant planning projects are mainly based on collaborative work, so interactions should be managed well in order to avoid conflicts between tasks. Most of the time, effort estimation is not done correctly, so it causes to be put unnecessary much effort for some task and less effort for other tasks. Therefore, it causes a bottleneck in the following stages of the planning projects. While dealing with unforeseen events such as changing market conditions, changing process requirements, delays in deliveries, or unexpected weather conditions, that are not easy to foresee, these challenges arise.[201]

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[198] Cf. Loos / Ovtcharova / Heinz (2012), p. 259
[199] Cf. Loos et al. (2012), p. 259
[200] Cf. Loos et al. (2012), p. 259 ff
[201] Cf. Kampker et al. (2013), p. 1

8. Rigidity

Rigid planning approaches cause a lack of flexibility. The common goal of the project setting is not to allow active cooperation but to share information. In general, the planning process is basically linear and deterministic. In factory planning projects, it is believed that the target will generally be reached by successive planning steps. However, different and new requirements that arise during the factory planning process cannot be eliminated by rigid planning processes. Although design problems must be foreseen in advance, they are noticed when planning. This situation should be better tackled[202]

9. Local Optimization

Local optimisation is caused by separate planning procedures. While it is recognised that silo mentality is not effective for a company, many planning activities are affected by this phenomenon. In-house experts, for example, often carry out manufacturing systems planning while external partners do industrial building planning and implementation. While both areas are vitally linked, interaction often only moves between the managers of two fields. There can be similar inefficiencies wherever data is kept away, not transmitted, or never recognised for different causes. As a result of the absence of data, local optimisation will happen depending upon planner data and objectives, which are not merely the ideal solution for the full plant and can operate parallel to this.[203]

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[202] Cf. Kampker et al. (2013), p. 1 ff

[203] Cf. Kampker et al. (2013), p. 2

3 Agility

The changing customer expectations, global competition, and technology accelerate the challenges that manufacturers increasingly face in an uncertain turbulent environment.[204] To cope with the challenges, companies try to be responsive, flexible, and agile. However, these terms are overlapping concepts in the literature.[205]

Bernardes and Hanna put the different definitions of agility from the literature together, and some of them are:[206]

- "The ability to accelerate the activities on a critical path that commences with the identification of a market need and terminates with the delivery of a customised product"[207]
- "A comprehensive response to the business challenges of profiting from rapidly changing, continually fragmenting, global markets for high-quality, high-performance, customer-configured goods, and services"[208]
- "The ability to produce and market successfully a broad range of low cost, high-quality products with short lead times in varying lot sizes, which provide enhanced value to individual customers through customization"[209]
- "The ability of enterprises to cope with unexpected changes, to survive unprecedented threats from the business environment, and to take advantage of changes as opportunities"[210]
- "Ability to efficiently change operating states in response to uncertain and changing demands placed upon it"[211]

Therefore, there are two principal factors in the concept of agility:[212]

- Reacting correctly and in due time to changes (foreseen or unexpected).
- Take advantage of changes and use them as opportunities.

In the literature, there are also several definitions of flexibility and responsiveness. However, the term of flexibility can be defined as the company can meet increasingly

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[204] Cf. Zhang / Vonderembse / Lim (2003), p. 173
[205] Cf. Bernardes / Hanna (2008), p. 32
[206] Cf. Bernardes / Hanna (2008), p. 38
[207] Cf. Kumar / Motwani (1995), p. 36
[208] Cf. Goldman / Nagel / Preiss (1995), p. 3
[209] Cf. Vokurka / Fliedner (1998), p. 170
[210] Cf. Sharifi / Zhang (2000), p. 9
[211] Cf. Narasimhan / Swink / Kim (2006), p. 443
[212] Cf. Sharifi / Zhang (2001), p. 774

different expectations of customers without overhead cost, time, corporate disruption or loss of performance.[213]

The term of responsiveness is defined as how fast can the system adjust its output within the four external flexibility types available: product, mix, volume and delivery in response to an external stimulus.[214]

Figure 26 shows the scope and the definition of flexibility, agility, and responsiveness together in order to understand the difference better.

Organizational perspective	Flexibility	Agility	Responsiveness
Scope	Operating characteristic	Business level organizing paradigm	Business level performance capability
	Inherent system property	Approach to organizing the system	System behavior or outcome
Definition	Ability of a system to change status within an existing configuration (of pre-established parameters)	Ability of the system to rapidly reconFigure (with a new parameter set)	Propensity for purposeful and timely behavior change in the presence of modulating stimuli

Figure 26: Scope and Definition of Flexibility, Agility, and Responsiveness[215]

Flexibility and responsiveness are essential capabilities to be agile, and the companies need to respond to and benefit from the changes positively.[216]

3.1 Reasons Motivating Adoption of Agile

There are several reasons to adopt agile methods. The first and foremost reason for the adoption of agile methods is to adapt to changes thanks to agile methods easly. Agile methods are able to adapt rapidly to the evolving customer demands. Customer demands are recognised by agile methodologies. This implies that the modifications can be adjusted rapidly already.[217]

Secondly, market pressure require brief periods and launches. Agile methodologies are designed for frequent changes. Therefore, they release the products frequently. Agile methods are focused on tiny 1-week iterations between working software launches.[218] In

[213] Cf. Zhang et al. (2003), p. 173
[214] Cf. Reichardt / Holweg (2007), p. 10
[215] Cf. Bernardes / Hanna (2008), p. 41
[216] Cf. Sharifi / Zhang (2001), p. 775
[217] Cf. Rao / Naidu / Chakka (2011), p. 40
[218] ibidem

order to achieve importance in smaller periods, avoid anticipating information that would need to be changed, creating waste in future.[219]

The third reason is to have the ability to get instant feedback from the customer. Developers think that periodic feedback on currently developing software will be successful. Small time frames between working software releases allow developers to quickly collect customers and users ' feedback. [220]

The fourth reason is that Organizational processes demand high-quality bug-free software. Designin and testing iteration is key issue in agile methods because it helps to remain high quality. With the release of software in periods, faults can be almost publicly seen and easily rectified.The continuous inspection and inclusion system of agile methods which enforce the provision of error safe software with high performance.[221]

3.2 Situations where agile methods are most effective

Agile methods are not suitable for sizeable complex team structures. Separate teams in the massive project could make use of the elements of agile methods.[222] Certain domains are clearly more suitable for agile development processes. These include internet applications, which are subject to considerable time-to-market pressure and minimize cost upgrades to the next launch. It is also clear, however, that firms that develop long-term, complex systems can not use agile processes as they stand.[223]

Agile methodology promotes a management style of leadership and collaboration, where the function of the project manager is that of facilitator or assistant. The teams are able to organize themselves and respond to emerging situations with alacrity. There is currently little proof that flexible concepts are effective in the lack of qualified and over-average individuals. Agile methodology is suitable for initiatives with high task variation. Clients are willing to play a vital part in the growth process. Flexible, participatory, and social action promotes organizational structures. In conclusion, technology should be oriented towards the object.[224]

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[219] Cf. Melo et al.(2013), p. 544
[220] Cf. Rao / Naidu / Chakka (2011), p. 40
[221] ibidem
[222] Cf. Rising / Janoff (2000), p. 28 ff
[223] Cf. Turk / France / Rumpe (2002), p. 46
[224] Cf. Nerur / Mahapatra / Mangalaraj (2005), p. 75 ff

3.3 Agile Manifesto

The 17 representatives of agile methods met in February 2001. The objective was to agree on standardized software development guidelines.[225] The primary reason for the general strategy was to respond to the constant need for software development to be adapted. In many instances, classical techniques were hardly feasible for this. Therefore, however, it is not necessary to develop a policy against changes, but rather a manner to better deal with modifications.[226]

The signatories' objective was to create the development method much more flexible and leaner than conventional methods. During software development, however, the technical and cultural difficulties had to be considered.[227] The outcome is the "Agile Manifesto," passed and ratified on 13 February 2001 by all participants. It discusses the fundamental belief of agile software development through four fundamental values and twelve principles. This shows that agile software development is more than just a set of process models. In software development, the Agile Manifesto still creates the foundation for all agile process models.[228]

3.3.1 Agile Values

Agile values are a fundamental part of the Agile Manifesto. These are described as a pair of values. The part of the statement to the right of the word "over" describes a value that is considered important and must be followed. The left part, on the other hand, is considered even more elementary and mus, therefore, be prioritized. [229]The following agile values are:[230]

- "Individuals and interactions over processes and tools
- Working software over comprehensive documentation
- Customer collaboration over contract negotiation
- Responding to change over following a plan."

The first value is **"Individuals and interactions over processes and tools."**[231] One of the decisive factors for project success is the interaction and communication between the project participants. This means that the most critical component of software development is the human being. Methods, processes, and tools are also important, but

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[225] Cf. Beck et al. (2001)
[226] Cf. Dogs / Klimmer (2005), p. 21ff
[227] Cf. Borowski (2011), p. 65
[228] Cf. Eckstein (2009), p. 14
[229] Cf. Baron / Hüttermann (2010), p. 10
[230] Cf. Beck et al. (2001)
[231] ibidem

they must not be stubbornly acted upon.[232] If the focus of the project work is too much on the existing processes and tools, the potential of the employees cannot be sufficiently exploited.[233]

The second value is **"Working software over comprehensive documentation."**[234] The customer primarily orders the executable software. Only this offers him added value and indicates whether his requirements have been met. If the documentation is too elaborate, there is a risk that it will quickly become obsolete due to changes.[235] Nevertheless, the leanest possible documentation is an essential component of the product, as it is necessary for understanding the software and troubleshooting. However, documentation should only be created for those areas in which it provides a benefit.[236]

The third value is **"Customer collaboration over contract negotiation."**[237] Cooperation and interaction with the customer should be at the center of the cooperation. In this way, any need for change can be identified at an early stage and managed accordingly. Practice shows that the performance requirements cannot be adequately described in early phases. Too rigid contracts often limit the possibility of controlling changes excessively. Contracts should be drawn up in such a way that friction between software development and the customer is minimized as far as possible. This regulates cooperation if problems arise.[238]

The fourth and last value is **"Responding to change over following a plan."**[239] The underlying assumption of agile software development is the presence of permanent change controls. This creates a learning process for all participants. In order to achieve the project goals at the same time, it is necessary to react to these changes and, if necessary, to deviate from the original plan. Adherence to the plan must not jeopardize business objectives. Only if the set goals are achieved will the customer receive the desired added value. In the sense of keen understanding, the short-term plan offers a high degree of detail, the long-term plan a rough orientation framework.[240]

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[232] Cf. Bleek / Wolf (2011), p. 13 ff
[233] Cf. Dogs / Klimmer (2005), p. 34
[234] Cf. Beck et al. (2001)
[235] Cf. Dogs / Klimmer (2005), p. 35 ff
[236] Cf. Baron / Hüttermann (2010), p. 12
[237] Cf. Beck et al. (2001)
[238] Cf. Baron / Hüttermann (2010), p. 12
[239] Cf. Beck et al. (2001)
[240] Cf. Bleek / Wolf (2011), p. 15

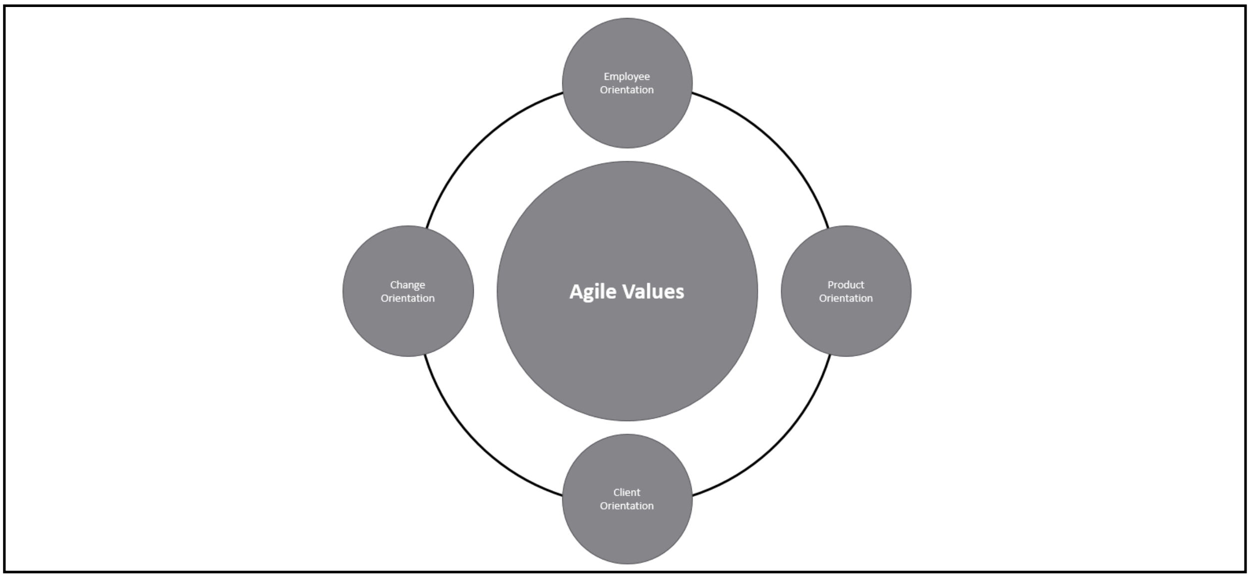

Figure 27: Agile Values[241]

3.3.2 Agile Principles

Moreover, the Agile Alliance follow the 12 principles which are defined in the Agile Manifesto. The Agile Principles describe principles of conduct derived from the Agile Values and represent a concretization of the basic convictions defined in the Agile Values.

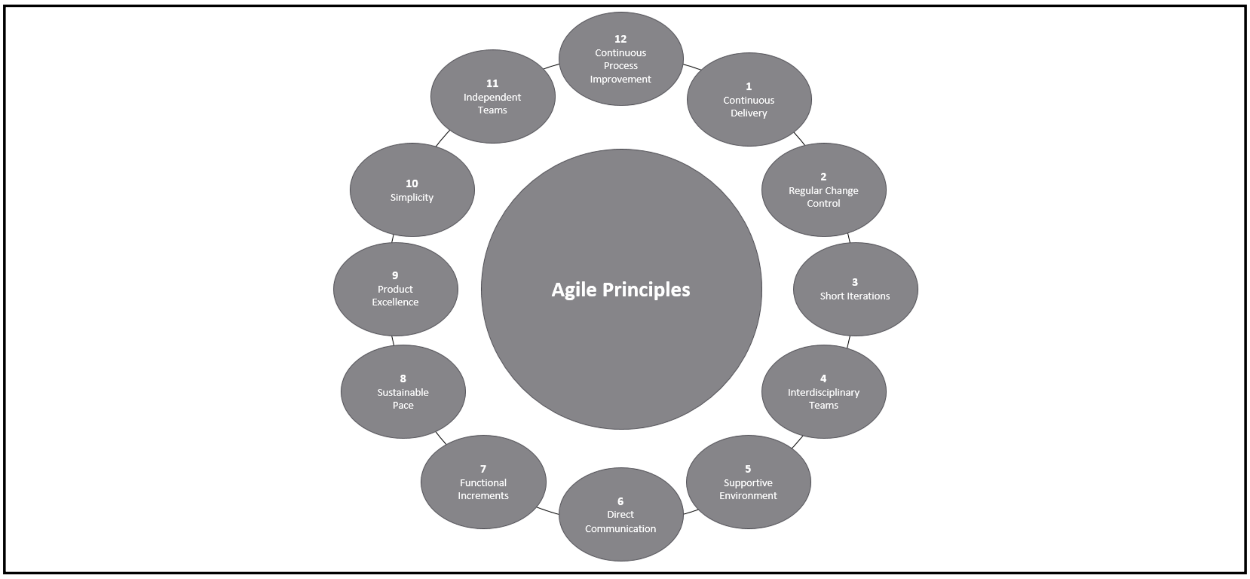

Figure 28: Agile Principles[242]

The first principle is, "***Our highest priority is to satisfy the customer through early and continuous delivery of valuable software.***" [243] The task of development is to deliver useful software to the customer as early and as often as possible. Any over-

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[241] Based on Schneider (2015), p. 56 ff own representation
[242] Based on Schneider (2015), p. 57 ff own representation
[243] Cf. Beck et al. (2001)

dimensioning and overproduction should be avoided. No functions may be created that are not required at the time of delivery. The only software that represents an improvement over the latest version offers added value for the customer.[244]

The second principle of Agile Manifesto is ***"Welcome changing requirements, even late in development. Agile processes harness change for the customer's competitive advantage."***[245] Practice shows that requirements can change quickly with increasing project duration due to market changes and the growing understanding of the requirements of all parties involved. At the same time, however, it is important to be able to adapt them to changing framework conditions. The customer benefit can only be optimized if the product is adapted to the changed requirements. For this purpose, the product must be designed in such a way that these changes are also possible late in the development process.[246]

The third principle of Agile Manifesto is ***"Deliver working software frequently, from a couple of weeks to a couple of months, with a preference to the shorter timescale."***[247] The software versions should be delivered as often as possible. The duration between two deliveries should be as short as possible but kept constant. Consistent quality and continuous use of resources are also taken into account. Only the scope between the individual iterations changes. This leads to a fast added value for the customer since parts of the software are used as early as possible. At the same time, the customer is enabled to give early feedback on the product. This means that the software is created over several iterations by individual increments.[248]

The fourth principle of Agile Manifesto is ***"Business people and developers must work together daily throughout the project."***[249] The customer must be involved right from the start. Ideally, this should also take place spatially. Through constant, close communication and cooperation, the goals can be better achieved. Nevertheless, a balanced level of discussion and exchange of information between all project participants must be ensured. Too high frequencies can lead to failures.[250]

The fifth principle of Agile Manifesto is ***"Build projects around motivated individuals. Give them the environment and support they need, and trust them to get the job done."***[251] Employees can be a decisive competitive advantage. It is the task of the

[244] Cf. Baron / Hüttermann (2010), p. 16 ff
[245] Cf. Beck et al. (2001)
[246] Cf. Padberg / Tichy (2007), p. 162 ff
[247] Cf. Beck et al. (2001)
[248] Cf. Baron / Hüttermann (2010), p. 42 ff
[249] Cf. Beck et al. (2001)
[250] Cf. Baron / Hüttermann (2010), p. 52 ff
[251] Cf. Beck et al. (2001)

managers to show sufficient trust in the employees, to equip them with the necessary decision-making powers, and to create a pleasant working atmosphere.[252]

The sixth principle is ***"The most efficient and effective method of conveying information to and within a development team is face-to-face conversation."***[253] Personal communication ensures that information is exchanged as quickly as possible. This enables misunderstandings and questions to be clarified as quickly as possible. In addition, the documentation should be as brief as possible.[254]

The seventh principle of Agile Manifesto is ***"Working software is the primary measure of progress."***[255] This principle describes a central understanding of agile software development. Only functional and delivered software represents a customer benefit. This makes it a particularly suitable metric for measuring development progress.[256] Only increments that have already been completed and tested are included in the measurement.[257]

The eighth principle of Agile Manifesto is ***"Agile processes promote sustainable development. The sponsors, developers, and users should be able to maintain a constant pace indefinitely."***[258] Agile projects should be carried out at an even and sustainable pace, since the output of employees cannot be increased at will. This leads to simplified planning and ensures a healthy workload for the employees. At the same time, however, time must be reserved for activities outside the project and for cushioning risks.[259]

The ninth principle of Agile Manifesto is ***"Continuous attention to technical excellence and good design enhances agility."***[260] The focus shall be on state-of-the-art development and programming. At the same time, the employees must always be informed about all innovations and technological progress so that these can be incorporated into their processes and thus into the product.[261]

The tenth principle of Agile Manifesto is ***"Simplicity - the art of maximizing the amount of work not done - is essential."***[262] Within the framework of an agile project, the simplest solution is favored. This means that only the required minimum is developed.

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[252] Cf. Dogs / Klimmer (2005), p. 43
[253] Cf. Beck et al. (2001)
[254] Cf. Borowski (2011), p. 69
[255] Cf. Beck et al. (2001)
[256] Cf. Baron / Hüttermann (2010), p. 86
[257] Cf. Martin (2012), p. 7
[258] Cf. Beck et al. (2001)
[259] Cf. Baron / Hüttermann (2010), p. 98 ff
[260] Cf. Beck et al. (2001)
[261] Cf. Baron / Hüttermann (2010), p. 114 ff
[262] Cf. Beck et al. (2001)

Thus all additional and currently not necessary functionalities are deleted. The result is a lean development process and therefore the simplest possible product with full functionality.[263]

The eleventh principle of Agile Manifesto is ***"The best architectures, requirements, and designs emerge from self-organizing teams."***[264] The development teams organize themselves. Tasks and responsibilities are assigned to the entire team and not to the individual members. This gives rise to both the right and the obligation to work on the overall solution. There are no responsibilities for individual tasks beyond team boundaries.[265] This requires a pronounced teamwork. At the same time, this self-organization leads to a stronger connection with the task at hand.[266]

The twelfth and last principle is ***"At regular intervals, the team reflects on how to become more effective, then tunes and adjusts its behavior accordingly."***[267] Due to the continuously changing environment, a continuous adjustment of the procedure is necessary. The team must regularly reflect on its own performance and results. The real potentials are collected and prioritized. Concrete improvement measures are derived from this and implemented in the team. The prerequisite for this is a corporate culture that allows mistakes to be made and criticism to be expressed.[268]

3.4 Agile Methods

There are several well-known agile methods in the literature. All of those methods acknowledged that only "lightness" could be achieved with high-quality software and, more importantly, customer satisfaction. Figure 29 shows the evolution of Agile methods over the years. Also, painted agile methods are mentioned in this chapter.

[263] Cf. Baron / Hüttermann (2010), p. 128 ff
[264] Cf. Beck et al. (2001)
[265] Cf. Cohn (2010), p. 219
[266] Cf. Dubinsky / Hazzan (2004), p. 165
[267] Cf. Beck et al. (2001)
[268] Cf. Baron / Hüttermann (2010), p. 150 ff

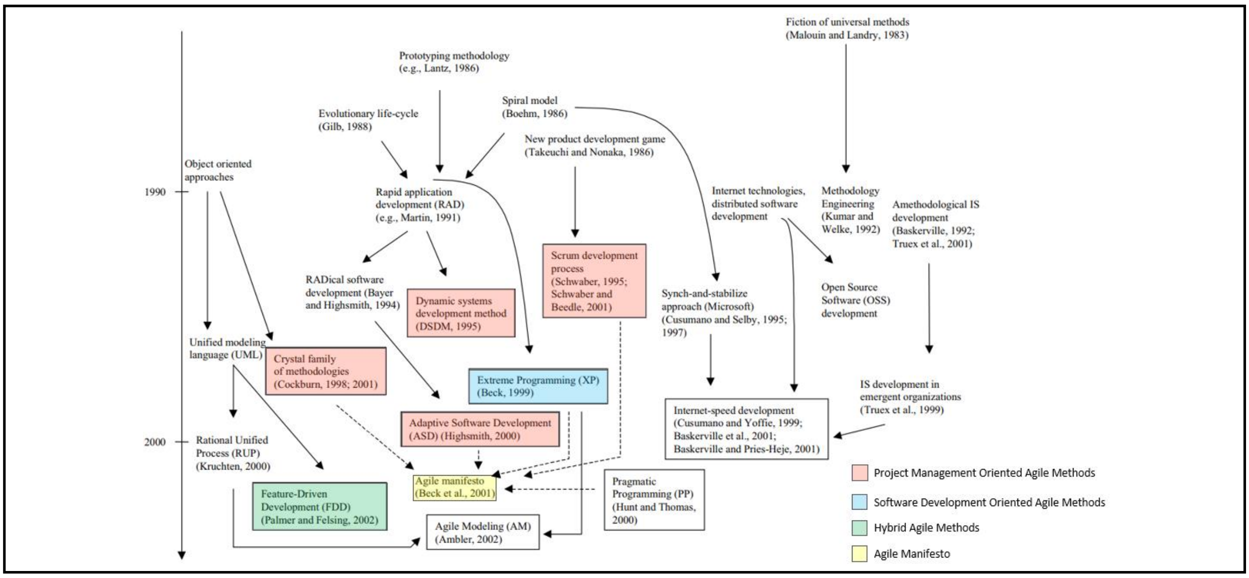

Figure 29: Evolution of Agile Methods[269]

Iacovelli and Souveyet divide the agile methods into three grouped: software development practices oriented, project management oriented and hybrid.[270] In this chapter, mostly project management oriented methods are mentioned. However, extreme programming, which belongs to software development practices oriented, is mentioned as well because it is one of the most common agile methods in the literature based on the number of citation of primary source.

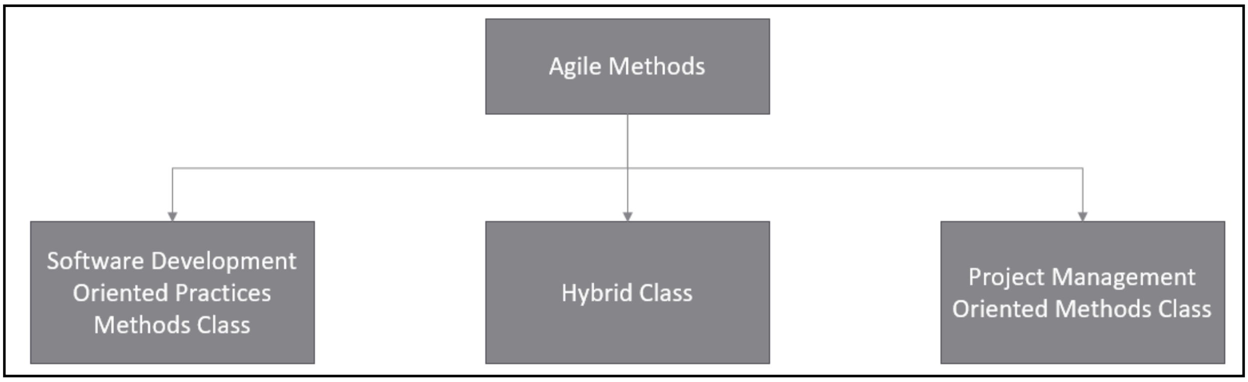

Figure 30: Agile Methods Classes[271]

3.4.1 Extreme Programming (XP)

The problem of the great development cycling of traditional models has resulted in extreme programming.[272] Short development periods, incremental planning, frequent feedback, communications dependent, and progressive design can characterize the XP method.[273] The programmers of XP with all these qualities respond with much more

[269] Based on Abrahamsson / Warsta / Siponen / Ronkainen (2003), p. 3
[270] Cf. Iacovelli / Souveyet (2008), p. 98
[271] Based on Iacovelli / Souveyet (2008), p. 98 own representation
[272] Cf. Beck (1999), p. 70
[273] Cf. Beck (2004), p. 3

courage to changing circumstances. Members of the XP group waste some minutes on programming, some minutes on the project management, a couple of minutes on design, some minutes on feedback.[274] "Extreme" emerges from the extreme level of these common values and procedures.[275]

Below is an overview of XP terms and practices:[276]

- **Planning Game:** The client and programmers interact closely. Programmers estimate the effort required for customer stories and then decide the scope and timing of releases.
- **Small Releases:** A secure system is quickly "productionized" – every 2-3 months at least once. Even daily, but at least monthly, new versions are released.
- **Metaphor:** A metaphor or set of metaphors between clients and programmers defines the system in explaining how the system functions, this "shared story" guides every process.
- **Simple Design:** It is crucial to design the most straightforward solution that is currently applicable. Inconvenient complexity and additional code are immediately removed.
- **Testing:** The design of the software is tested. Before the code, unit testing is introduced and continually performed. Functional tests are written by clients.
- **Refactoring:** System Restructuring is carried out with removed duplication, improved communication, simplified, and added flexibility.
- **Pair Programming:** On one laptop, two individuals compose the software.
- **Collective Ownership:** Everybody can always alter some portion of the software.
- **Continuous Integration:** As quickly as it is prepared, a fresh piece of software is incorporated into the code base. The system is therefore incorporated and constructed several times a day. Every test is executed and must be performed in order to accept modifications to the software.
- **40-Hour Week:** The working hours per week is up to 40 hours. There are no two extra work weeks in a row. This will be regarded as an issue that needs to be addressed.
- **On-Site Customer:** The customer must be accessible to the squad at full time.
- **Coding Standards:** There are coding guidelines, and programmers follow them. It should be emphasized to communicate through the code.

[274] Cf. Williams (2003), p. 17 ff
[275] Cf. Beck (1999), p. 71
[276] ibidem

- **Open Workspace:** It is preferable, a big room with small cubicles. The pair programmers should be placed in the center of the space.
- **Just Rules:** Teams have their rules, which can be pursued, but also modified at any moment. It is necessary to agree on modifications and assess their effectiveness.

XP projects consists of six phases, as shown in Figure 31:[277]

- **Exploration Phase:**
  Clients write out the story cards they want in the first release. A function to be included in the program is described in each story card. The project crew also gets acquainted with the instruments, techniques, and methods they will use in the project. It will test the technique to be used and explore the architectural options for the system through the construction of a system prototype. It takes a couple of weeks to several months for the exploration, depending on how familiar the technology is to programmers.
- **Planning Phase:**
  In the planning stage, the priority order is given to the stories, and the content of the first tiny publication is agreed. First of all, the programmers assess the effort required by each story, and the accepted timetable is established. Usually, there are not more than two months in the period of the first release. It requires many days to plan itself.
- **Iterations to Release Phase:**
  Several iterations of the systems before the first release are carried out in this phase. A total of iterations each take one to four weeks to execute the timetable in the planning phase. In the first iteration, a system is created with the entire system architecture. The selection of the stories to build the entire scheme will achieve this. For each iteration, the client chooses the stories to select. At the end of each cycle, the functional tests produced by the client are performed. The system is prepared for manufacturing at the end of the final iteration.
- **Productionizing Phase:**
  In the productionizing phase, additional system performance testing and verification are required before the system is released to the customer. New modifications can still be discovered at this stage, and a choice must be taken if they are part of the immediate release. The iterations may need to be speeded up from three weeks to one week during this stage. For further execution during, for

[277] Cf. Abrahamsson / Salo / Ronkainen / Warsta (2002), p. 21ff

example, the maintenance stage, the delayed thoughts and recommendations are recorded.

- **Maintenance Phase:**
  The following manufacturing for client use of the first version, the XP initiative must maintain the system operational and produce new iterations. For this purpose, the maintenance stage also client support functions will require effort. Therefore, after the system is in production, the speed of development can be decelerated. In the maintenance stage, new personnel can be included in the squad, and the team composition changed.
- **Death Phase:**
  When customers have no stories to implement, the death stage is close. The system also, in other ways, needs to fulfill client requirements. It is a time in the XP process when the necessary system documentation is finally written as no architecture, design or code changes are made anymore. Death phase can also happen if the system fails to produce the required results or if it is too costly to develop further.

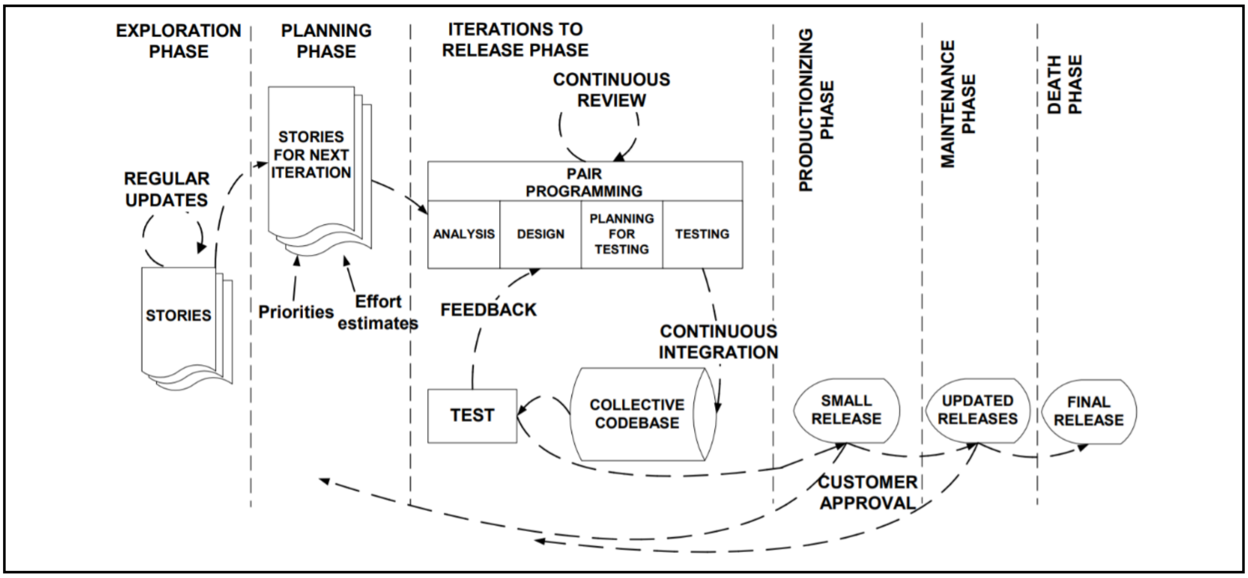

Figure 31: Phases of Extreme Programming[278]

3.4.2 Scrum

Scrum is incremental and iterative processes for the development or management of every product and project. In order to achieve system flexibility in a changing environment, Scrum focuses on how team members should operate. It generates a possible number of functions at the end of each iteration. This word “scrum” was born

[278] Cf. Abrahamsson et al. (2002), p. 21

from a strategy in the rugby game that refers to “getting an out-of-play ball back into the game” with teamwork.[279]

There are no particular methods or practices for developing software required or provided by Scrum. Instead, specific leadership procedures and instruments in various stages of Scrum are required to prevent chaos from becoming impredictable and complex.[280]

Below are essential scrum procedures, and Figure 32 shows the scrum method:[281]

- **Product Backlog:**
  Based on present information, the product backlog describes everything necessary for the final item. This describes the job to be achieved in the project. This includes a list of company and technical demands for or improved systems that are prioritized and continually updated. For instance, characteristics, functions, problem fixes, faults, enhancements, and software upgrades are included in the product backlog. Problems that need to be resolved before other backlog products can be made are also listed. Many actors such as customers, the project team, advertising and sales, management, and client help can engage in the generation of the product backlog.
- **Effort estimation:**
  An iterative method in which the Backlog item evaluations focus on a more precise stage if more data on a product backlog item is accessible. Together with the Scrum team, the product owner is accountable for estimating the effort.
- **Sprint:**
  Sprint is the method by which the evolving environmental factors are adapted. In a Sprint lasting about thirty calendar days, the Scrum team organizes itself to create a new executable item increase. Sprint Planning Meetings, Sprint Backlog, and Daily Scrum meetings are working tools of the team.
- **Sprint Planning Meeting:**
  A two-part planning meeting organized by the Scrum Master is a Sprint planning meeting. In the first phase of the meeting, customers, users, management, product managers and Scrum team will decide on the objectives and features of the next Sprint. Scrum Master and Scrum Team will focus on how the product increment is achieved during the Sprint, during the second phase of the meeting.

[279] Cf. Abrahamsson et al. (2002), p. 29
[280] Cf. Rising / Janoff (2000), p. 26ff
[281] Cf. Abrahamsson et al. (2002), p. 33ff

- **Sprint Backlog:**
  For each sprint, the Sprint Backlog is the start. This is a list of the Product Backlog chosen for the next Sprint implementation. The Scrum Master and product owners select the items at the Sprint Planning Meeting based on the priority items and objectives of the Sprint. The Sprint Backlog is stable until the sprint is complete, as opposed to the product backlog. Once all items are completed in the Sprint backlog, a new iteration will be provided in the system.
- **Daily Scrum meeting:**
  The daily Scrum meetings will be held to monitor the progress of the Scrum Team continuously and also to be used to plan. The focus of these meetings is what has been done since the previous meeting and what should be done to the next meeting. In this brief session, which takes place every day, issues and other varying matters are also addressed and monitored. In order to improve the process, any deficiencies or impediments in the system development or engineering procedures are identified. The Scrum meetings are held by the Scrum Master. For instance, the management can also take part in the Scrum meeting in addition to the Scrum team.
- **Sprint Review Meeting:**
  The Scrum Team and Scrum Master presented Sprint`s outcomes at an informal meeting on the final day of Sprint to Management, clients, users, and the Product Owner. Participants evaluate the progress in the product and decide the following activities. At the review meeting, new backlog items may be identified, and even the way of system designing might be changed.

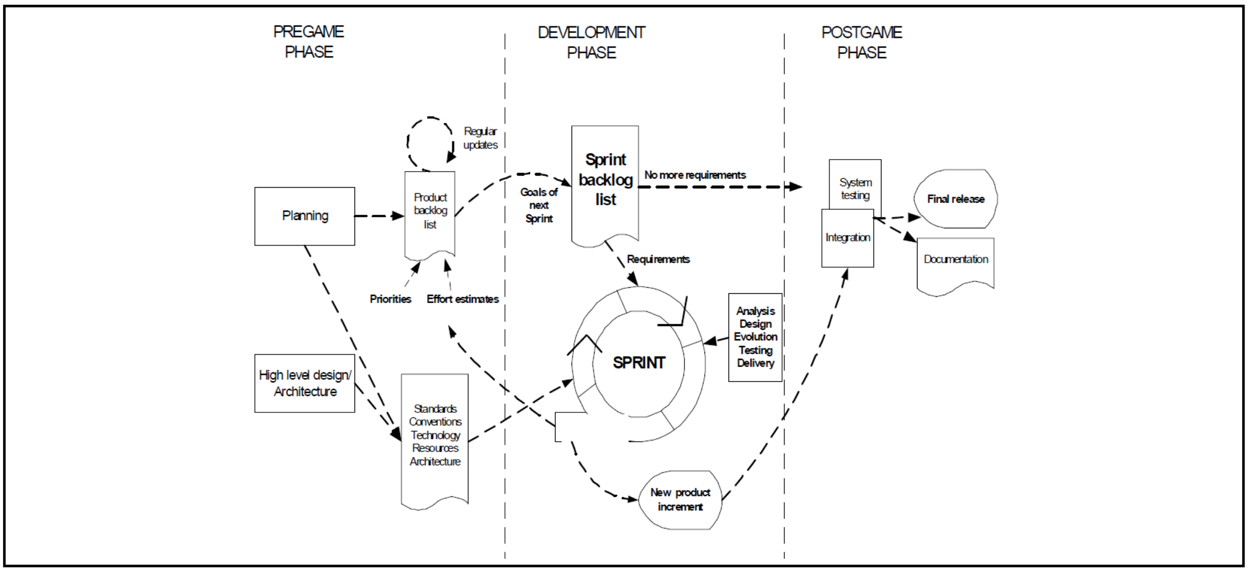

Figure 32: Scrum Process[282]

The Scrum may significantly alter the Scrum Project team's work description and traditions. For instance, the Scrum Master as project manager no longer has to organize the team, but the team organizes itself and decides what to do. Typically, the majority of the management uses the project to tell the team what to do and ensure it is done. Scrum is a self-organized team that determines what to do during management removes roadblocks.[283] Over thousands of initiatives in 50 organizations, Scrum has been effectively used and, significant improvements in efficiency have been achieved.[284] Scrum is not a big and complicated team strategy, but even small and remote teams can use specific Scrum components in a big project. A real diversity of processes can achieve it.[285] Efforts have recently been created to merge XP methods and the Scrum Project Management Framework in a package. More research is required to sustain this package.[286]

3.4.3 Feature Driven Development (FDD)

For the first time in the late 1990s, Feature Driven Development (FDD) was used in a project to develop significant and complicated finance software.[287] The Feature Driven Development method, contrary to other methodologies, does not encompass the full software development method but concentrates on design and building phases.[288]

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282 Cf. Abrahamsson et al. (2002), p. 30
283 Cf. Abrahamsson et al. (2002), p. 29 ff
284 Cf. Awad (2005), p. 11
285 Cf. Rising / Janoff (2000), p. 29
286 Cf. Mar / Schwaber (2002), p. 1 ff
287 Cf. Abrahamsson et al. (2002), p. 49
288 Cf. Palmer / Felsing (2002), p. 55

At the beginning of the project, the first three stages are completed. These last two phases form the iterative part of the process that helps the agile development to adapt to late changes in business needs and requirements rapidly. Actual results, as well as precise tracking of advancement, are included in the Feature Driven Development method.[289]

Feature Driven Development is composed of five steps:[290]

- **Develop an Overall Model:**
  As the overall model is being developed, the domain experts are already aware of the scope, context and requirements of the system to be developed. There are probable to be documented demands at this point, such as use cases and functional specifications. Feature Driven Development does not, however, deal explicitly with the problem of requests collection and management. Domain experts report high-level system descriptions to team members and chief architect as so-called "walkthrough".
- **Build a Features List:**
  A complete list of characteristics for the system being created is provided with advances, object designs, and current request paperwork. Each client valued function included in the system is presented by the design squad. For every domain area, the functions are shown, and these function classes consist of so-called main function sets. The primary function sets are additionally split into functional sets. They represent various activities in particular areas of domain. For validity and completeness, the feature list is checked by the system users and sponsors.
- **Plan by Feature:**
  Plan by feature includes a high-level plan to sequence the feature sets by their priority and dependence and to assign them to the Chief Programmer. Also, individual designers, i.e., class owners, will be allocated classes recognized in the phase of "developing of an overall model". Timetable and critical milestones for the feature sets may also be laid.
- **Design by Feature and Build by Feature:**
  From the feature sets a small group of features is chosen. The class owners make up the necessary feature teams to develop the selected features. Design by feature and build by feature processes are iterative procedures for producing the selected features. It should take a total from a few days to two weeks for an

[289] Cf. Abrahamsson et al. (2002), p. 49
[290] Cf. Abrahamsson et al. (2002), p. 50

iteration. Multiple teams can design and construct their characteristics simultaneously. It involves duties such as design inspection, coding, testing, integration, and verification of codes. The finished characteristics are supported in the main build after a good iteration while the design and construction phase starts with a new group of characteristics taken from the feature set.

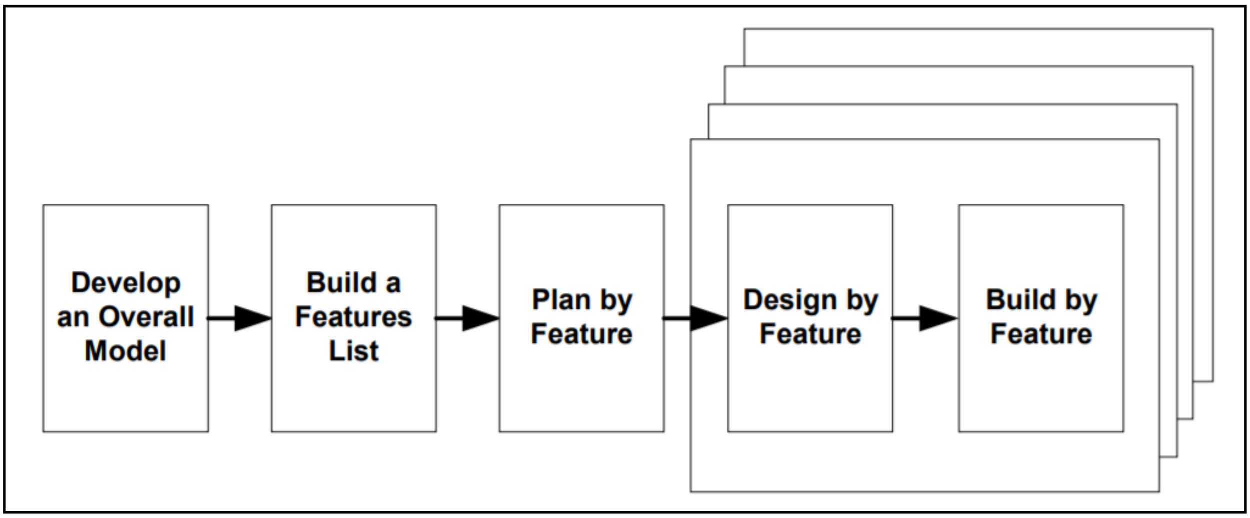

Figure 33: Processes of Feature Driven Development[291]

3.4.4 Adaptive Software Development (ASD)

Developed by James A. Highsmith, Adaptive Software Development provides a flexible, responsive strategy to high-speed and high-change software initiatives.[292] In a quick changing and unexpected company setting, it is not feasible to plan effectively. ASD replaces the static life cycle of the plan-design by a vibrant speculate-collaborate-learn life cycle.[293]

The focus of ASD is on three phases, which are nonlinear and overlapping:[294]

- **Speculate:** Make clear what is ambiguous in order to identify the project task.
- **Collaborate:** Stresses the significance of teamwork in the development of high-change systems.
- **Learn:** The need to recognize and respond to errors is highlighted during this stage, and during the development, the requirements may change.

[291] Cf. Abrahamsson et al. (2002), p. 50
[292] Cf. Abrahamsson et al. (2002), p. 72
[293] Cf. Awad (2005), p. 14
[294] Cf. Abrahamsson et al. (2002), p. 73

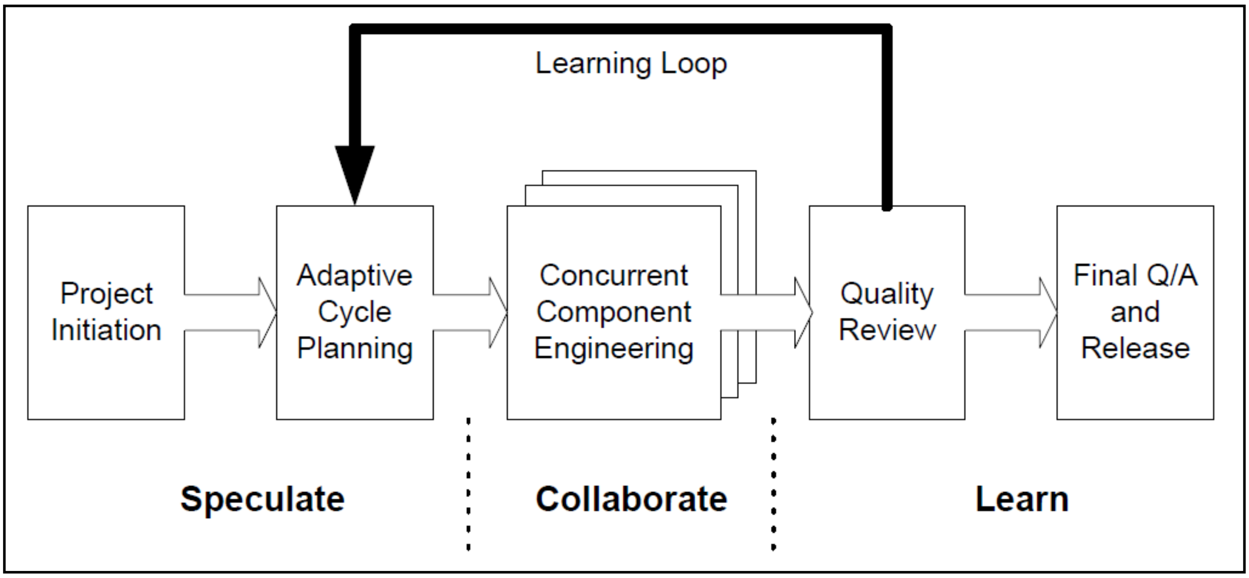

Figure 34: The Adaptive Software Development Cycle[295]

Highsmith sees planning in an agile setting as a paradox because the results are unpredictable. If events do not go as planned, this is seen as a mistake that must be corrected in traditional planning methods. However, deviations should not be avoided because, in flexible environments, these deviations indicate the path to resolution.[296]

More than the duties or processes for generating the outcomes, Adaptive Software Development focuses on outcomes and their performance. Individuals are needed to work in a collaborative way to cope with the uncertainty in an unexpected environment. Instead of telling individuals what to do, management is more about promoting interaction to receive more creative responses.[297]

Designs are pursued in the same manner in traditional predictive settings; thus learning does not exist. Learning forces all stakeholders, such as promoters and their clients in an adaptive setting to review their expectations in order to adjust to each growth cycle. Since this learning is a significant and ongoing characteristic, plans and designs must evolve as growth continues.[298]

Instead of Extreme Programming, Adaptive Software Development offers a structure that promotes cooperation and learning within a venture and does not have general principles as Extreme Programming. In addition to the strategy or attitude that an organization must adopt in the application of agile procedures, Adaptive Software Development is not provided as a framework for software projects.[299]

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[295] Cf. Abrahamsson et al. (2002), p. 74
[296] Cf. Abrahamsson et al. (2002), p. 72 ff
[297] Cf. Awad (2005), p. 15
[298] Cf. Abrahamsson et al. (2002), p. 74
[299] Cf. Awad (2005), p. 15

3.4.5 Dynamic Systems Development Method (DSDM)

In the United Kingdom, in the middle of 1990, the Dynamic System Development Method was created. This combines and expands on rapid application development and iterative development. The Dynamic Systems Development Method has many practices that follow the values of the agile methodology strategy and have more advanced traditional methodologies. Dynamic Systems Development Method is based on the basic idea of adjusting time and resources, and then the number of functions is adjusted accordingly, rather than the number of functions in the product, then the time and resources are adjusted to reach that feature. Five phases constitute the Dynamic System Development Method[300]:

- **Feasibility Study:**
  In the feasibility study phase, the appropriateness of the Dynamic Systems Development Method is evaluated for the given project. The choice is taken whether to use Dynamic Systems Development Method is based on the nature of the initiative, and especially on organizational and individual problems.
  Furthermore, this stage of the feasibility research addresses the professional opportunities and the hazards involved in the venture. A feasibility study and an overview design plan are prepared in this phase. A quick prototype can optionally also be created if the company or technology is not sufficiently recognized to determine whether or not to continue in the next stage. It should not be more than a few weeks for the feasibility study stage.
- **Business Study:**
  A business study is a stage in which critical business and technology characteristics are analyzed. It is suggested that meetings be held in which an adequate amount of customer specialists are assembled to take all relevant aspects of the scheme into account and agree on growth objectives. A company area definition describes the company procedures concerned and customer categories. Identifying the impacted user courses enables the client to participate, because essential persons in the organization, at a first point, can be acknowledged and engaged. In the business area definition, high-level process descriptions are provided in an appropriate format.
  During the business study stage, there are two other results. First is the definition of system architecture, and the second is an outline prototyping plan. During the DSDM initiative, the architecture definition is the first sketch of the system

[300] Cf. Abrahamsson et al. (2002), p. 63 ff

architecture. In the prototyping plan, the prototyping strategy for the following phases, and an arrangement management plan should be established.

- **Functional Model Iteration:**
  The first iterative and incremental stage is the functional model iteration stage. The content and approach for the iteration are scheduled in every iteration, the iteration is carried out, and the results are analyzed for further iteration. The analysis and code are both performed, prototypes are constructed, and the results of the experiments are used to improve the analytical model. Prototypes should not be rejected entirely but should be progressively directed to such an end system quality that the prototypes are included. An output functional model with the prototype code and the analysis models is produced. In this stage, testing is also an ongoing, important component.
- **Design and Build Iteration:**
  Design and Build Iteration is the central part of the scheme. Tested systems meet the minimum number of demands at least accepted. The result is a test system. The design and construction are iterative, and the users review the design and functional prototypes, and further development is based on the comments of the users.
- **Final Implementation Phase:**
  Finally, during the final implementation phase, the system is transferred from the development environment to the actual manufacturing environment. Users will receive training, and the scheme will be passed on. Where the roll-out worries a large number of customers, it can also be iterated throughout the moment. The supplied scheme involves a users ' manual and a project review report as well as the output of the execution stage. The second resume, the outcome of the project, and the course of further development are determined based on the results. Four available growth classes are defined by the Dynamic Systems Development Method. No additional research is required if the scheme meets all criteria. If on the other side, considerable demand is to be kept aside, the method can be completed once again, from beginning to end. If a less critical feature is omitted, the process may resume from the iteration phase of the functional model. Finally, if specific technical issues due to time constraints cannot be resolved, they can be achieved by iterating again, beginning with the iteration stage layout and construction.

Nine procedures describe the philosophy and the foundation for all Dynamic Systems Dynamic Method activities. Effective customer communication, standard delivery, enhanced teams, and tests throughout the process are some of the fundamental values. High performance and adaptability to evolving demands are emphasized. Dynamic

Systems Development Method approaches iterations, such as other agile techniques, as short periods of two to six weeks.[301]

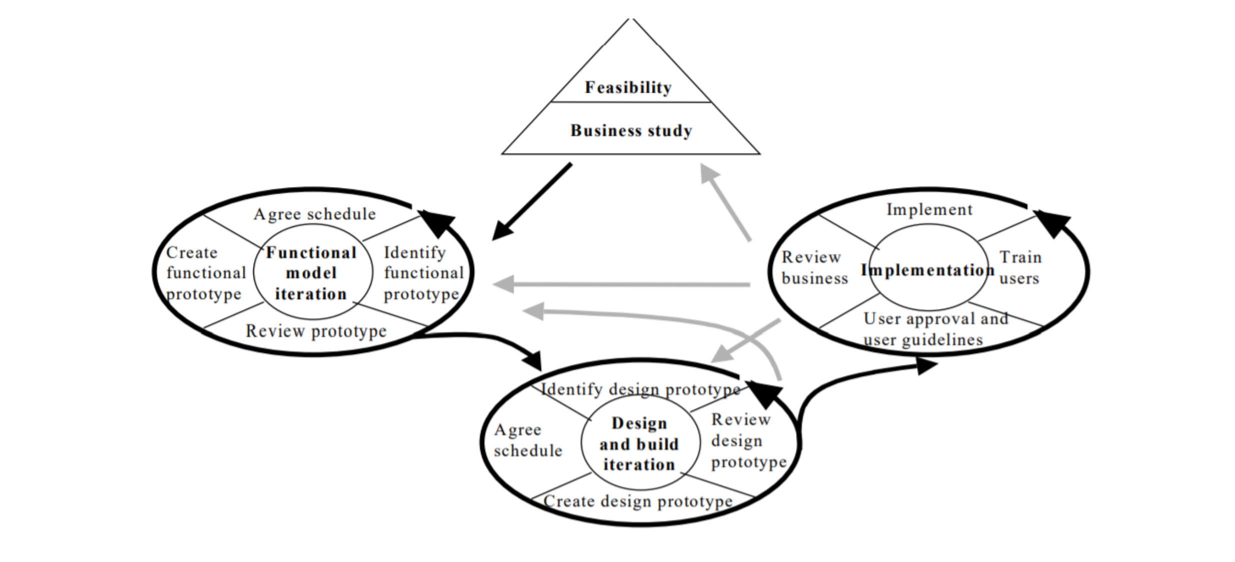

Figure 35: Dynamic Systems Development Method Process Diagram[302]

3.4.6 Crystal Family of Methodologies

The feature that distinguishes Crystal from other models is that it is a conceptual framework rather than a precise process model. Incremental product development, determination of milestones by joint decisions and deadlines, direct integration of users, application of standardization templates, functional tests, product tests before delivery by at least two team members and periodic workshops to assess product and process specifications form the core principles of this collection of methods. The role of the sponsor, senior designer, designer, and consumer in a Crystal is usually given.[303]

In contrast to other approaches, Crystal emphasizes the principle of "parallelization and flow," which includes a continuous review of the work plans, the stability of the project, and the degree of synchronization.[304] Crystal is based on the idea that each project needs its approach. The bigger and more critical the project becomes, the more communication and cooperation move into the center of attention. Critical observations criticize the lack of design of the method in teams with more than 50 members, life-critical projects, and the need for the entire team to be present in one place. [305]

There are several procedures in all Crystal methodologies, like incremental development. The increment involves operations like staging, revision, and review, monitoring,

[301] Cf. Abrahamsson et al. (2002), p. 68 ff
[302] Cf. Stapleton (1997), p. 3
[303] Cf. Ludewig / Lichter (2010), p. 226ff
[304] Cf. Abrahamsson et al. (2002), p. 41ff
[305] Cf. Ramsin / Paige (2008), p. 70

parallelism and flux, holistic diversity strategy, methodology tuning technique, user viewings, and reflection workshops in the definition of Crystal Orange. These activities are described below:[306]

- **Staging:**
  The next increase in the system is planned. An operating release should be planned for up to three to four months. A timetable is chosen for 1 to 3 months. The requirements that can be applied and delivered in the increment are selected by the team.
- **Revision and Review:**
  There are several iterations for each increment. Construction, representation, and review of the objectives are the activities of each iteration
- **Monitoring:**
  Progress in terms of advancement and stabilization is tracked for the group results during the development phase. Progress is measured through milestones and stages of stability. Crystal Clear and Crystal Orange are both subject to monitoring.
- **Parallelism and flux:**
  The next assignment can begin once the stabilization surveillance provides the outcome "stable enough to review" for the supplies. This implies that in Crystal Orange, the many players can continue effectively with the highest parallelism. The surveillance and architecture managers are reviewing their job schedules, stabilization, and synchronization to guarantee this.
- **Holistic diversity strategy:**
  A method for dividing major functional teams into inter-functional groups is involved in Crystal Orange. Multiple specialties in a given squad are the central idea here. In addition, the holistic diversity strategy enables small teams to develop the specialized expertise needed and also addresses issues such as team positioning, communication, documentation, and coordination between several teams.
- **Methodology-tuning technique:**
  One basic method of Crystal Clear and Orange is the methodology tuning technique. They use project surveys and group sessions to develop a particular Crystal methodology for each venture. A key idea of continuous growth is to allow the development method to be fixed or improved. Each time the design increment, its experience can be learned and utilized for the further development of the method.

[306] Cf. Abrahamsson et al. (2002), p. 45

- **User viewings:**
  For Crystal Clear, two customer views are proposed in a single release. For each increment, the user assessments in Crystal Orange should be arranged three times.
- **Reflection Workshops:**
  Crystal Clear and Orange both have the requirement that a squad should conduct workshops for reflection before and after development.

No particular practice or technique for project participants to use is defined by Crystal Clear and Crystal Orange in their software design duties. Crystal may substitute some of its own methods, for example, reflection workshop, by applying methods based on other methodologies such as XP and Scrum.[307]

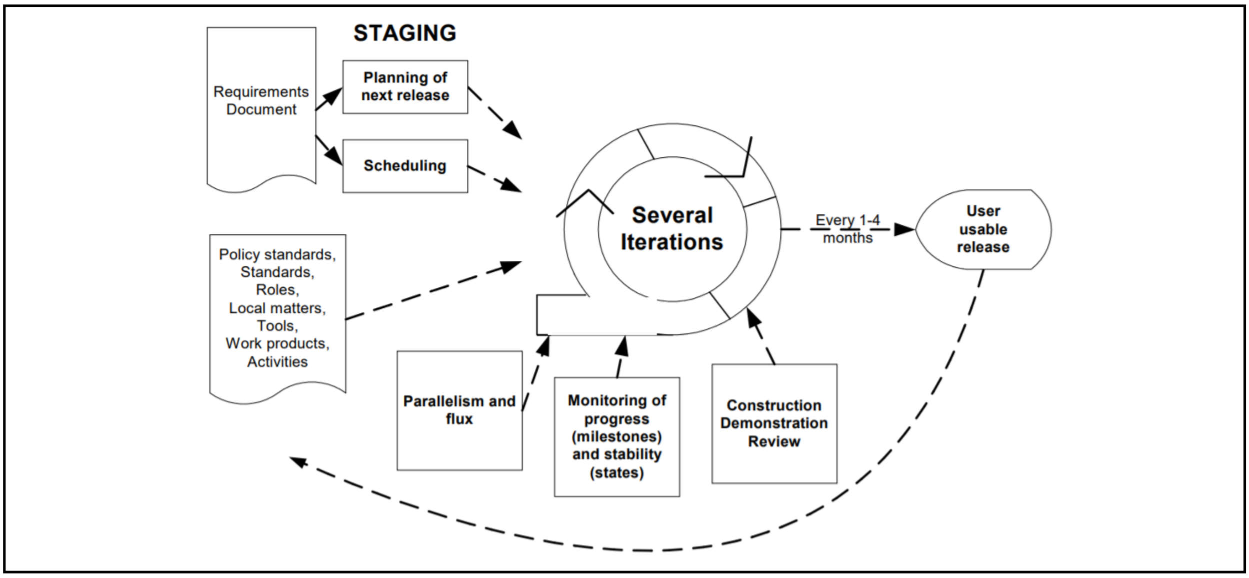

Figure 36: One Crystal Increment[308]

3.5 Comparison of Agile Methodologies

In the last few sections, six agile methods are described separately. In this section, these methodologies are compared regarding their similarities and differences.

There are some common points of agile methods. The authors in the United States and the UK released all the techniques between 1995 and 2002. Methods are primarily objectivist because they address how to solve a particular business problem technologically. They all use continuous growth with iterations of one week to four months and with iterations of one month suggested by all techniques. All significant variables in the techniques include the active participation of the customer, feedback and learning,

[307] Cf. Abrahamsson et al. (2002), p. 47
[308] Cf. Abrahamsson et al. (2002), p. 43

teamwork, and partnerships empowering decision making. Communication among all the project participants, executives, project leaders, designers, and clients, is also essential. The regular gatherings facilitate this. In small teams of between 2 and 40 individuals, with an ideal team capacity of 3 to 10 individuals, each technique discusses the need for efficient monitoring of continuous growth. Practitioners developed all methods based on experiences, and all of them have the perspective of project managers and developers. Methods for fixing company issues are intended to impact the project throughout its life cycle, as modifications in both demands and techniques. Working software is the primary result of development. None of the methods indicate a specific modeling method and minimization of paperwork is an objective in all techniques. More emphasis is given to paper minimization by XP and Crystal.[309]

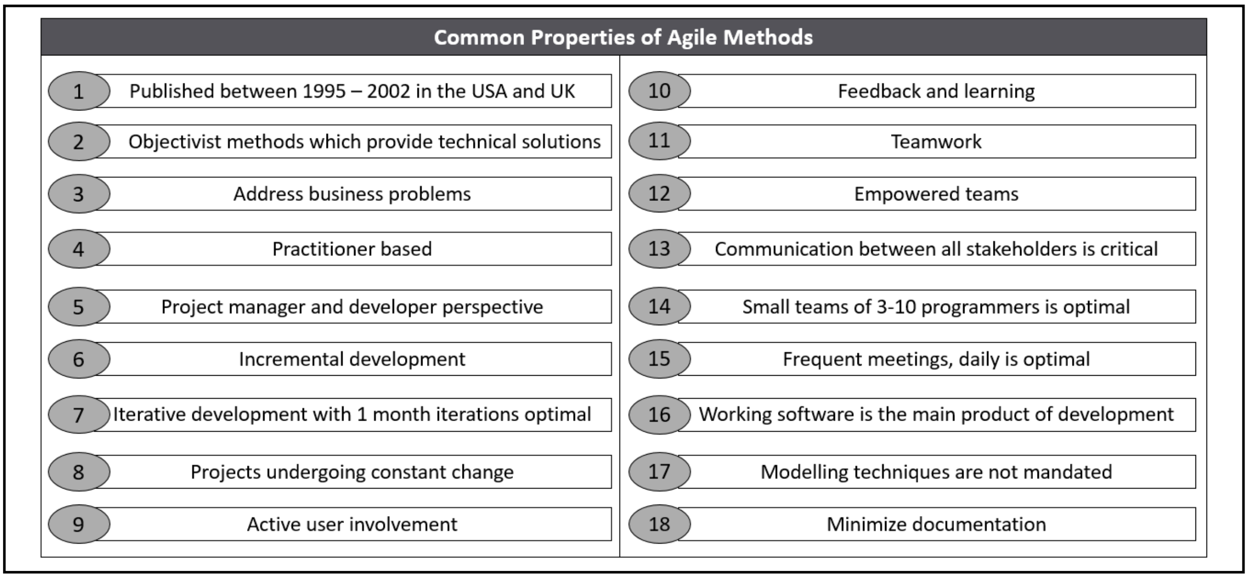

Figure 37: Common Properties of Agile Methodologies[310]

The Figure 38 shows that XP and Scrum can be used in small and medium-size applications, Crystal, FDD, and DSDM can be used in small, medium-sized and big company applications, and ASD can be used in big and complicated applications. The size of the team is not defined in FDD and ASD while the size of the teams is specified by the XP, DSDM, Scrum and Crystal. Every method produces software rapidly, but ASD also explores distributed software development. All techniques generate software quickly, but ASD also discusses the creation of distributed software development. The coding style (clean and simple) is discussed only in XP, and not explicitly specified by others. XP, ASD, and Crystal mention the physical environment for software

[309] Cf. Strode (2006), p. 261
[310] Based on Strode (2006), p. 261, own representation

development; however, others do not mention this. XP and DSDM only explicitly specify collaborative and cooperative business culture.[311]

Criteria	XP	Scrum	FDD	ASD	DSDM	Crystal
1 Project Size	Small & Medium	Small & Medium	Small, medium, and large (business projects/ applications)	Large and Complex projects	Small and large projects (Business Applications)	Small and medium
2 Team size	<10	<10 and multiple teams	No limit – scalable from small to large teams	Not mentioned	Minimum 2 and Maximum 6 (Multiple teams)	6 - Crystal Clear (single team) 40 – Crystal Orange (multiple teams) 80 – Crystal Red (multiple teams)
3 Development style	Iterative, rapid	Iterative, rapid	Iterative design and construction	Iterative and rapid development – distributed development	Iterative, rapid development and cooperative	Iterative and rapid development
4 Code style	Clean and simple	Not specified	Not specified	Not mentioned	Not mentioned	Not mentioned
5 Technology environment	Quick feedback required	Not specified	Not specified	Not mentioned	Not mentioned	Not mentioned
6 Physical environment	Co-located teams and distributed teams (limited interaction)	Not specified	Not specified	Co-located and distributed teams	Not mentioned	Co-located team – no support for distributed development
7 Business culture	Collaborative and cooperative	Not specified	Not specified	Not specified	Collaborative and cooperative	Not mentioned
8 Abstraction mechanism	Object-oriented	Object-oriented	Object-oriented	Object-oriented/ Component-oriented	Object-oriented/ Componen-toriented	Object-oriented

Figure 38: Comparison of Agile Methods[312]

According to Qumer and Seller, Crystal is the most agile method at the phase level, and Scrum method is the most agile in practice. Also, in comparison with other agile methods, DSDM is considered less agile at the phase level and ASD as less agile at the practice level. [313]

Methods	Key Points	Special Features	Shortcomings
1 XP	Customer-driven development, small teams, daily builds	Refactoring – the ongoing redesign of the system to improve its performance and responsiveness to change.	While individual practices are suitable for many situations, overall view & management practices are given less attention.
2 Scrum	Independent, small, self-organizing development teams, 30-day release cycles.	Enforce a paradigm shift from the "defined and repeatable" to the "new product development view of Scrum."	While Scrum details in specific how to manage the 30-day release cycle, the integration and acceptance tests are not detailed.
3 FDD	Five-step process, object-oriented component (i.e., feature) based development. Very short iterations: from hours to 2 weeks.	Method simplicity, design, and implement the system by features, object modelling.	FDD focuses only on design and implementation. Needs other supporting approaches.
4 ASD	Adaptive culture, collaboration, mission-driven component based iterative development	Organizations are seen as adaptive systems. Creating a new order out of a web of interconnected individuals.	ASD is more about concepts and culture than the software practice.
5 DSDM	Application of controls to RAD, use of time boxing, empowered DSDM teams, an active consortium to steer the method development.	First genuinely agile software development method, use of prototyping, several user roles: "ambassador," "visionary," and "advisor."	While the method is available, only consortium members have access to white papers dealing with the actual use of the method.
6 Crystal	Family of methods. Each has the same underlying core values and principles. Techniques, roles, tools, and standards vary.	Method design principles. Ability to select the most suitable method based on project size and criticality	Too early to estimate: Only two of four suggested methods exist.

Figure 39: General Features of Agile Methods[314]

[311] Cf. Qumer / Sellers (2008), p. 288 ff
[312] Cf. Qumer / Sellers (2008), p. 284
[313] Cf. Qumer / Sellers (2008), p. 289
[314] Based on Abrahamsson et al. (2002), p. 94 ff, own representation

ASD is the most conceptual approach in software development. It may be attractive, but professionals will find it challenging to translate the latest techniques into their use to create an emerging order from the Internet. XP is a practical point of view. It includes an amount of validated empirical methods that designers have found helpful. DSDM is distinguished by its prototyping application from the other techniques. DSDM also uses user roles like ambassadors, visionaries, and advisors who are not used by other techniques. The disadvantage with DSDM is that they must belong to the DSDM community so that white papers dealing with the various elements of the technique can be accessed. FDD is focused on identifying, designing, and implementing characteristics in a straightforward five-stage strategy. FDD implies that specific project research has been accomplished.[315]

In conclusion, Scrum is a project leadership strategy based on autonomous self-organized teams that implement a software project called sprints over 30 days.[316]

The size of the development team is one of the critical problems for the various agile techniques. The focus of the XP and Scrum teams is smaller than ten developed groups preferably. FDD, ASD, and DSDM argue that up to 100 designers within a team are capable of developing. However, when the size of the development team increase, it makes the project “less flexible” because of the number of paperwork increases. When the development team reaches 20 employees, agilists encounter communication issues a lot. Competent individuals within large teams are essential to achievement.[317]

3.6 Agile vs. Traditional Project Management

There are the advantages and disadvantages of both traditional and agile methods, so one strategy is not even stronger than another.[318] However, both methods often need to be used. In the organization, distinct project leadership approaches may also be necessary at the project portfolio stage based on the project features or even the use of particular methods and techniques, based on project stage demands and also concerning the features of the project. Appropriate approaches to the particular project should be borne in mind because an improper strategy may not contribute to project achievement, but could contribute to other issues and project failure.[319]

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[315] Cf. Abrahamsson et al. (2002), p. 96 ff
[316] Cf. Abrahamsson et al. (2002), p. 97
[317] Cf. Abrahamsson et al. (2002), p. 102
[318] Cf. Aguanno (2004), p. 354
[319] Cf. Shenhar (1999), p. 382

For projects with precise original customer demands and clear project objectives, the traditional strategy is, therefore, more suitable with minimal volatility. These projects should have a tiny shift in demands and no heavy involvement of end-users in the project.[320] The emphasis will be on planning and the predictable and linear follow-up of this project plan, to optimize project activities and achieve efficiency in these situations. Traditional project management methods require formal documentation at all stages of the project.[321] Another habit of traditional project management methods is to manage projects with predefined and predictable project steps.[322]

While traditional project methods are suitable for large projects, the number of those involved in the project, how long the project will last, and even the nature of the requirements, are not considered.[323] The organizational environment is one of the main achievement variables in the choice of approaches. Sometimes the most important source of the use of traditional methods is that the company culture is not prepared and willing to adopt these agile methods.[324] Larger organizations are also more prepared to take up the traditional strategy, with the numbers of organizational units participating in single initiatives, as this strategy emphasizes job monitoring.[325] It is suggested to use traditional strategy because of monitoring, and because the significance of the human factor is not accentuated in traditional approaches. Another situation in which traditional methods are recommended is that the team members and the project manager are not in constant communication, the team members are inadequate as experience, and the team members have difficulty in meeting different issues.[326] Lastly, if system criticality is an essential characteristic of the project when the consequences of system failures can be dire, it is recommended to use a traditional approach.[327]

Agile project management approaches are above all appropriate for projects that require creativity.[328] Given the characteristics of the most appropriate projects for agile methods, the concept of uncertainty is in the foreground.[329] Given the continual demands for changes, projects are once again structured iteratively, not linear, with regular changes and project schedule changes.[330] Also, this iterative method enables quickly to implement the demands owing to tight time restrictions, and functional specifications are structured

[320] Cf. Coram / Bohner (2005), p. 367 ff
[321] Cf. Boehm (2002), p. 64 ff
[322] Cf. Chin (2004), p. 22
[323] Cf. Spundak (2014), p. 944
[324] Cf. Conforto / Amaral (2010), p. 73 ff
[325] Cf. Spundak (2014), p. 944
[326] Cf. Coram / Bohner (2005), p. 367 ff
[327] Cf. Spundak (2014), p. 944
[328] Cf. Chin (2004), p. 25
[329] Cf. Spundak (2014), p. 944
[330] Cf. Boehm (2002), p. 65 ff

by improved project surveillance and control.[331] As a result, the most appropriate project for agile methods is a typical small software development projects.[332]

As a result, when the characteristics of traditional and agile methods are compared, it is seen that the value given to human and quality of communication between the team members come to the fore.[333] Therefore, small teams working in the common area are recommended.[334] As a result, agile projects do not focus on comprehensive documentation, so project knowledge is primarily tacit.[335]

There are differences between project organizations of agile and traditional project management approaches. Consequently, the organizational environment has considerable effects, and organization should be ready to adopt the modifications enforced by an agile strategy.[336]

Characteristics	Traditional Approach	Agile Approach
1 Requirements	Clear Initial Requirements, Low Change Rate	Creative, Innovative, Requirements Unclear
2 User	Not Involved	Close and Frequent Collaboration
3 Documentation	Formal Documentation Required	Tacit Knowledge
4 Project Size	Bigger Projects	Smaller Projects
5 Organizational Support	Use Existing Processes, Bigger Organizations	Prepared to Embrace Agile Approach
6 Team Members	Not Accentuated, Fluctuation Expected, Distributed Team	Collocated Team, Smaller Team
7 System Criticality	System Failure Consequences Serious	Less Critical Systems
8 Project Plan	Linear	Complex, Iterative

Figure 40: Difference Between Traditional and Agile Approach[337]

3.7 Characteristics of Agile Methods

The most important factors that make Agile methods successful and distinguish it from other project management approaches are adaptive and effective as well as putting stakeholders at the center. The result is an agile worldview based on a fresh mixture of values and principles. [338] Agility is a great reaction to the company problems of profiting from quickly evolving, ever-fragmenting, worldwide products, services, and industries.[339]

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331 Cf. Boehm / Turner (2005), p. 31
332 Cf. Boehm (2002), p. 67
333 Cf. Boehm (2002), p. 65
334 Cf. Chin (2004), p. 154
335 Cf. Boehm (2002), p. 66
336 Cf. Lawrence / Yslas (2006), p. 5
337 Based on Spundak (2014), p. 945, own representation
338 Cf. Highsmith / Cockburn (2001), p. 122
339 Cf. Goldman / Nagel / Preiss (1995), p. 3

As the principal distinctions between agile and traditional approaches, the following elements of agile methods are seen.[340]

Figure 41: Characteristics of Agile Methods[341]

1. People Oriented:

One of the most important characteristics of the agile methods is that it gives great importance to all the stakeholders involved in the project. This leads the project managers, who have adopted and implemented agile methods, to pay more attention to communication among employees and their skills. When the people involved in the project are good enough, almost every process can be used, and their job carried out. No method can fix their inadequacy if they are not good enough.[342]

2. Adaptive:

Participants are not scared of transition during an agile method. At all phases of the project, the agilists welcome modifications. The main reason why the team is not afraid of change is that it considers change as a learning tool.[343] The task today is not to stop adjustments, but rather to determine how to manage modifications during a project better. Changes in the external environment are critical. Since these changes cannot be eliminated, the only viable strategy is to reduce the cost of reacting to them.[344]

[340] Cf. Kaur / Singh (2016), p. 2
[341] Based on Kaur / Singh (2016), p. 2 ff, own representation
[342] Cf. Cockburn / Highsmith (2001), p. 131
[343] Cf. Fowler (2004)
[344] Cf. Highsmith / Cockburn (2001), p. 120

3. Conformance to Actual:

In contrast to compliance with the comprehensive scheme, agile methodologies value conformance to real outcomes. Agile activities are not governed by plan conformity, but by company quality conformance.[345] The business value is added to ongoing products after each iteration. In the case of agility, it is not developers but end users and customers who decide whether the business value is added or not.[346]

4. Balancing Flexibility and Planning:

The unpredictability of future problems leads to a reduction in the importance and impact of plans. Therefore, agile methods recommend making detailed plans for short-term rather than detailed plans for the long-term.[347] Because it is more difficult to realize this in long term plans when it is desired to return for some reason from the decisions taken. This implies that if the decisions can be changed easily, this makes life much simpler. For agile development, developers must consider how irreversibility can be avoided in their choices. Instead of attempting to get the correct choice now, seek a manner to either postpone the judgment or decide so that you can reverse the choice subsequently without too much trouble.[348]

5. Empirical Process:

The processes involved in agile methods are not linear. However, in engineering, processes are both predefined and experimental. The most important feature that distinguishes predefined processes from experimental processes is to receive the same result consistently. The main reason why agile methods are experimental is that there are many changes that will affect the result. This means that many changes in requirements are the main reasons why predefined steps cannot deliver the desired outcome.[349]

6. Decentralized Approach:

The integration of a decentralized leadership approach can have serious implications for a software project as it can save much time than an autocratic leadership method. Developers can make decisions in agile software development methods. However, the developers do not take over the function of management Because it is still necessary to manage to remove obstacles to progress, and managers are responsible for this. The

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[345] Cf. Highsmith (2002), p. 17
[346] Cf. Kaur / Singh (2016), p. 2
[347] ibidem
[348] Cf. Fowler (2004)
[349] Cf. Williams / Cockburn (2003), p. 40

management nevertheless acknowledges the technical team's skills in making technical choices without their consent.[350]

7. Simplicity:

Agile teams are always following the easiest route in line with their objectives. Agile teams will not anticipate the issues of tomorrow and attempt today to protect themselves from them. The reason is that this makes it simple to alter the design if required subsequently. The reason for the simplicity is. No more than is needed, and no documentation will ever be produced that predicts the future when documents are outdated.[351] The biggest handicap of further documentation is to keep the information up-to-date and make much effort to achieve this updated information.[352]

8. Collaboration:

Agile methods, as mentioned before, are people-oriented and give importance of communication, which make frequent customer feedbacks the basis of agile methods. Software customers work tightly with the development team and provide their attempts with regular reviews. It is also vital that agile team members continue to cooperate. Because agile techniques are decentralized, co-operation promotes debate.[353] There can be no agile teams with occasional communication. They need ongoing access to company knowledge.[354]

9. Small Self-Organizing Teams:

A team of agility is a team that organizes itself. The entire team is told about the responsibilities, and the team decides how they can best be carried out. In all elements of the project, agile teams discuss and interact. This is why, in small teams, agility operates well.[355] With bigger teams, agile development is harder. Only nine individuals can achieve the average amount of individuals in the project, which is the most fundamental and flexible. Nonetheless, effective agile initiatives with 120 or even 250 individuals are sometimes fascinating.[356]

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[350] Cf. Kaur / Singh (2016), p. 3
[351] ibidem
[352] Cf. Wendorff (2002), p. 3
[353] Cf. Kaur / Singh (2016), p. 3
[354] Cf. Fowler (2005)
[355] Cf. Kaur / Singh (2016), p. 3
[356] Cf. Cockburn / Highsmith (2001), p. 130

3.8 Advantages of Agile Methods

In the literature, there are several advantages of agile methods. In this section, these main advantages are described.

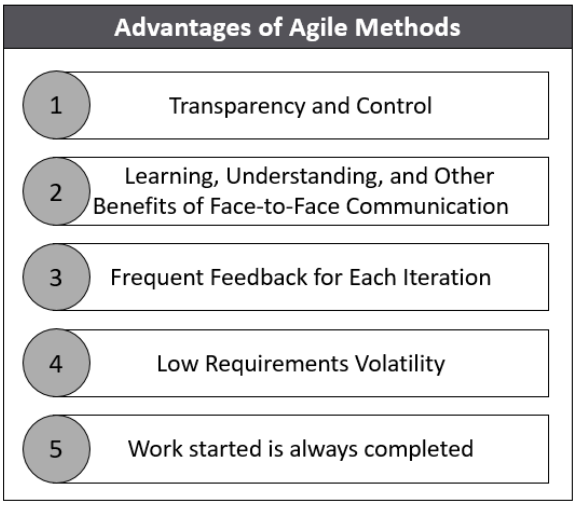

Figure 42: Advantages of Agile Methods[357]

1. Transparency and Control

Small and manageable assignments achieve more control and accountability. The lists of demands are prioritized, and requirements sets have a small range and must be enforced. Compared with traditional approaches, for instance, the entire range of requirements is described at first. Because the packages of requirements supplied as an increment are separated, growing transparency can be described as responsibility for increment. Problems and achievements in specific are more open. This means that it can be traced which problems and achievements have occurred and who is in charge. This, therefore, gives teams an incentive to achieve high performance because their results are connected to them.[358]

2. Face-to-Face Communication

Members interact intensively face to face with agile team participants as they meet frequently and are physically positioned. Therefore, learning and comprehension are strengthened by each other. For examples, in traditional approaches, developers, and testers the project are usually segregated. As a result, developers could not place themselves on software testers shoes or comprehended what data or paperwork would assist testing. Designers and testers are now sitting together to learn from each other. Designers understand how testers are affected by the quality of the application. Also,

[357] Based on Petersen / Wohlin (2009), p. 1485 ff, own representation
[358] Cf. Petersen / Wohlin (2009), p. 1485 ff

testers can point developers to system components that are critical from their point of view and therefore, involve more detailed testing. Due to short lines of interaction, the immediate contact also allows immediate testing. Another advantage is improved casual interaction with continuous sharing of significant data, which eventually results in lower processing and greater performance.[359]

3. Frequent Feedback

Software is created over several iterations in an agile software design technique. The analysis, design, execution, and testing characterize each iteration.[360] When team members complete and deliver an iteration, the knowledge is transmitted with regular reviews.[361] The mini-project is provided to the client for use and reviews after each iteration. Customers are invited to make any modifications to the system at each point of growth and to implement the modifications.[362] This provides the visibility of who provided what and what level of quality is clear. Each couple of weeks, predefined meetings enhance the integration frequency. Naturally, this also makes feedback often easier.[363]

4. Low Requirements Volatility

Due to their restricted range, small packages for requirements are given priority and may be developed fast. This is a significant benefit as the industry in this situation is extremely vibrant. This means that warm demands can be applied rapidly and can, therefore, be published before the demands of clients alter.[364]

5. Work started is always completed

The packages that have been implemented have always been finished. Consequently, little waste is being developed as a job does not go away but finishes up being a working component of the software. It should be emphasized, however, that the right actions need to be carried out and the priority of demands an important matter in order to pay off this benefit.[365]

In conclusion, in the last two sections of this chapter, the characteristics, and advantages of agile methods were mentioned. Particularly, the fourth advantage of the agile method is low requirement volatility, and it is a sign that volatility challenge in factory planning projects can be solved regarding this advantage. Moreover, its characteristics of adaptiveness and flexibility help to overcome the time and cost pressure and rigidity

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[359] Cf. Petersen / Wohlin (2009), p. 1486
[360] Cf. Sharma / Sarkar / Gupta (2012), p. 896
[361] Cf. Petersen / Wohlin (2009), p. 1486
[362] Cf. Sharma / Sarkar / Gupta (2012), p. 896
[363] Cf. Petersen / Wohlin (2009), p. 1486
[364] ibidem
[365] ibidem

challenges. Last but not least, as mentioned above, one of the main advantages of agile methods is frequent feedback. Therefore, the wrong focus and local optimization challenges will be eliminated by using agile methods.

4 Brownfield Factory Planning Project

In this section, a factory planning project, including current state analysis and rough planning, is explained and taken as a case to define challenges in the real-life situation.

The company provides maintenance and modernization services for rail vehicles and their components, some of which are also newly manufactured. This project is a brownfield factory planning project, and the main aim of the project is to re-plan the actual layout regarding the products currently maintained in the plant and products from another location as well.

Firstly, current state analysis was conducted as a feasibility study to determine the availability of existing working areas that are adequate for both internal products and product form the other location.

Secondly, several real layouts were prepared and selected. These layouts were prepared based on capacity calculation and material flow analysis.

4.1 Current State Analysis

The main objective of this phase is to analyze the current situation of the factory. For this study, data was collected directly and indirectly. This analysis was made for two main sub-components of rail vehicles. In total, 39 products were considered in this project.

Production program analysis and process flow analysis are the first step of current state analysis. Afterward, the capacity calculation was carried out for ten years. Finally, the required areas were calculated based on the capacity calculation and compared with existing areas.

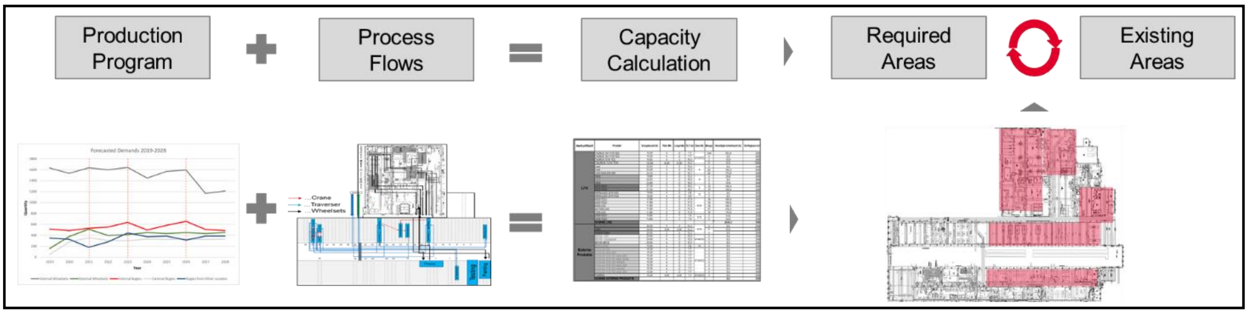


Figure 43: Current State Analysis Steps

4.1.1 Production Program Analysis

The primary purpose of the analysis of the production program is to see the distribution of the changing demand over the years. In this project, production program analysis was carried out until the year 2028. The distribution of the amounts of demands can be seen in the graph below. This analysis consists of internal products, external products, and products from other location.

The forecasted demands were provided by the company. Red, blue, and light grey lines show the changing demands of bogies. The blue line shows the number of bogies from other location. Dark grey and green lines show the demands for wheelsets over the years.

The highest demand for wheelsets is expected in 2021, and it will be 2147. The highest demand for bogies is expected in 2026, and it will be 1302. The highest demand for the sum of both sub-products is expected in 2023, and it will be 3439.

These critical years will take place in capacity planning and rough layout planning. Because these years were taken as a basis to develop a new layout in order to avoid bottlenecks in the future.

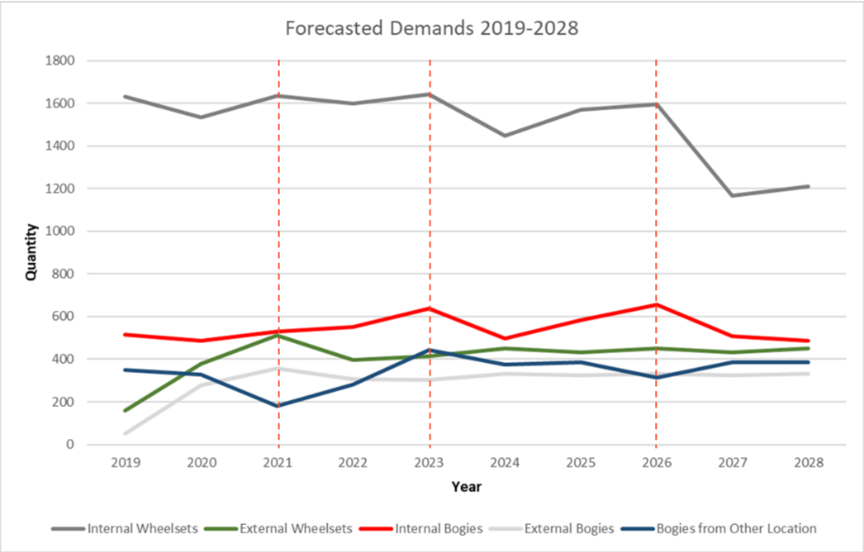


Figure 44: Forecasted Demands Over the Years

After analyzing the production program, the next step was understanding the process flow. Not only required demands but also process flows form the capacity calculation. The figure below shows just an example of one product, and it was created for different product groups. The figure also shows the transportation type roughly. For instance, traverser is often used in this process. Also, this figure shows where different product groups are located and processed. Mainly, wheelsets are processed upper side of the layout, and bogies are processed in the lower side of the layout.

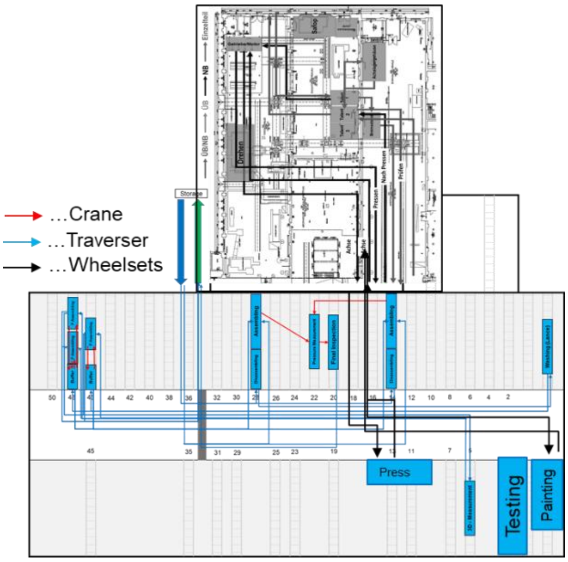


Figure 45: Process Flow Example

4.1.2 Capacity Calculation

The capacity calculation was made from 2018 to 2028. The most critical data required for this calculation is the production schedule and production quantity of each product. Another critical factor is the number of shifts. Usually the number of shifts in this capacity account was taken from two while the company was working with one shift. The reason for this is that the amount of hours the factory currently works is not enough to process external products and products other location. The number of working days per year is 210. Totally, 3066 hours per employee are available for a year.

While calculating the capacity, availability of the machines was taken into account as well. Machine availability is the percentage that production equipment can be used. Downtime and unexpected maintenance time are extracted to have machine availability. Figure 46 shows the availabilities of the machines considered during the calculation.

Machines	Availability
Press Machines	94 %
Testing Chambers	96 %
3D – Measurement	95 %
Pressure Measurement Stand	99 %
Pressure Stand	99 %
Lathe	90 %
Washing (Machine)	94 %
Sandblasting	95 %

Figure 46: Machine Availability Rates

The capacity calculation was carried out for two different sub-products. According to the production program analysis and capacity calculation, 2026 is the critical year for bogies. That is the reason the figure below shows the comparison of actual state and 2026. In actual state, products from the other location have not involved the calculation. In 2026, the required time is more than double the required time in 2018. In this calculation, the required time of washing and painting stations consist of required time for wheelsets. It does not have any importance because only one machine for each station is needed as the current state.

Process	Required Working Time 2018	Required Working Time 2026
Disassembling	1836 h	2753 h
	2516 h	6453 h
Washing (Machine)*	1151 h	1882 h
Washing (Lance)*	864 h	2464 h
Sandblasting	1346 h	1304 h
3D - Measurement	1363 h	2532 h
Magnetic Particle Inspection	426 h	81 h
Visual Inspection	1436 h	4030 h
Painting*	1992 h	2574 h
Pre-Assembling	746 h	6446 h
	7315 h	16833 h
	1371 h	409 h
Assembling	1341 h	3760 h
	1496 h	4209 h
	711 h	0 h
Pressure Measurement Stand	876 h	2090 h
Final Inspection	276 h	658 h
Total	**27.062 h**	**58.476 h**

Figure 47: Comparison of Required Time for Processing Bogies in between 2018 and 2026

The capacity calculation for wheelsets was also carried out. 2021 was selected as a critical year for wheelsets after the calculation of capacity and production program analysis. In 2021, 18.790 more hours are needed to maintaining the wheelsets, and it means required working time in 2021 is almost 1.5 times current state. Figure 48 shows how many hours are needed for the current state and critical year.

Workstation	Required Working Time 2018	Required Working Time 2021
Disassembling	1996 h	2572 h
	1114 h	4104 h
	2333 h	4213 h
	3779 h	3978 h
Gearbox Reconditioning	374 h	249 h
	1025 h	1250 h
Gearbox / Motor	3804 h	7515 h
Press Machine Old Press Machine New Press Machine Small	726 h	619 h
	556 h	1081 h
	880 h	1166 h
Lathe	981 h	1486 h
	72 h	36 h
	960 h	960 h
	366 h	771 h
Assembling	1593 h	2261 h
	2001 h	3741 h
Testing Chamber	1201 h	1262 h
	723 h	1639 h
Oil Filling Stand	435 h	456 h
Axle Bearing	995 h	1796 h
Axle Bearing Housing	1900 h	3757 h
Brake Stand	1435 h	3238 h
Axle Alignment	1148 h	1511 h
Incoming Check	1136 h	866 h
Revision	1084 h	827 h
Wheel Separation	419 h	363 h
	795 h	654 h
Oven	126 h	110 h
Bearings	3152 h	3318 h
Pressing On (Assembling)	1113 h	1171 h
Brakes (Assembling)	892 h	933 h
Total	**39.113 h**	**57.903 h**

Figure 48: Comparison of Required Time for Processing Wheelsets in between 2018 and 2021

Last but not least, during the capacity calculation, manipulation time was not included the calculation.

4.1.3 Determination of Space Requirements

The area required to make a layout in further steps of the project should be calculated. This calculation is divided into three categories: boogie, wheelsets, and the calculation of potential fields that can be used while planning a new layout. The data and dimensions for determining the size of the machines and manual workstations are obtained from CAD files.

4.1.3.1 Space Requirements for Bogies

Figure 49 shows which areas are currently used for processing bogies. These areas are including the logistics area that is used by buffers and material handling.

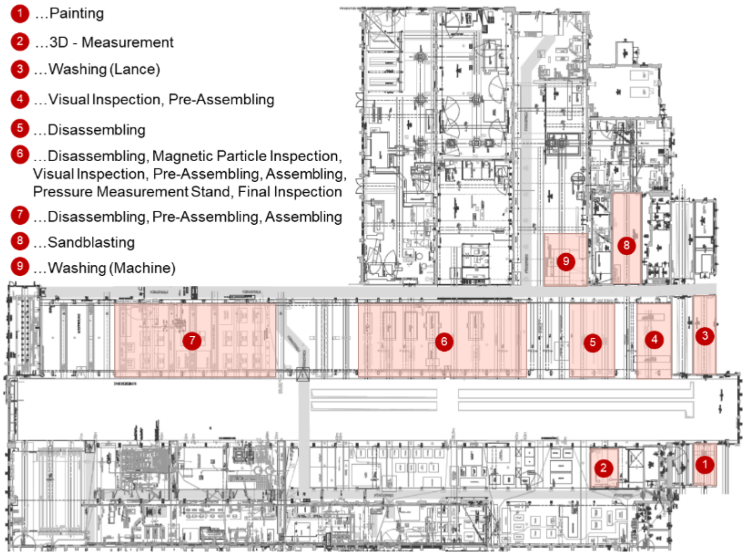


Figure 49: Considered Area for Bogies

The year 2026 was selected as a critical year for the bogies according to production program analysis. Figure 50 shows the required area for each workstation. When determining the area for the processes, the size of the products was taken into consideration. Therefore, workstations were clustered according to how much area is needed by one bogie. These clusters can be seen in disassembling, pre-assembling, and assembling processes. Moreover, when required areas for washing process and painting were being calculated, not only bogies but also wheelsets were taken into consideration. Because these areas are being shared by both main sub-products. In total, 2.527 m² is necessary for processing bogies. The pre-assembling process in 2026 will occupy the largest area.

Process	# of Workstations	Required Area
Disassembling	1	108 m²
	3	216 m²
Washing (Machine)*	1	277 m²
Washing (Lance)*	1	128 m²
Sandblasting	1	297 m²
3D - Measurement	1	83 m²
Magnetic Particle Inspection	1	56 m²
Visual Inspection	2	174 m²
Painting*	1	69 m²
Pre-Assembling	3	312 m²
	6	324 m²
	1	56 m²
Assembling	2	161 m²
	2	144 m²
Pressure Measurement Stand	1	84 m²
Final Inspection	1	36 m²
Total		**2.527 m²**

Figure 50: Required Space for Bogies

4.1.3.2 Space Requirements for Drive Wheel Sets

Figure 51 shows which areas are currently used for processing bogies. These areas are including the logistics area that is used by buffers and material handling.

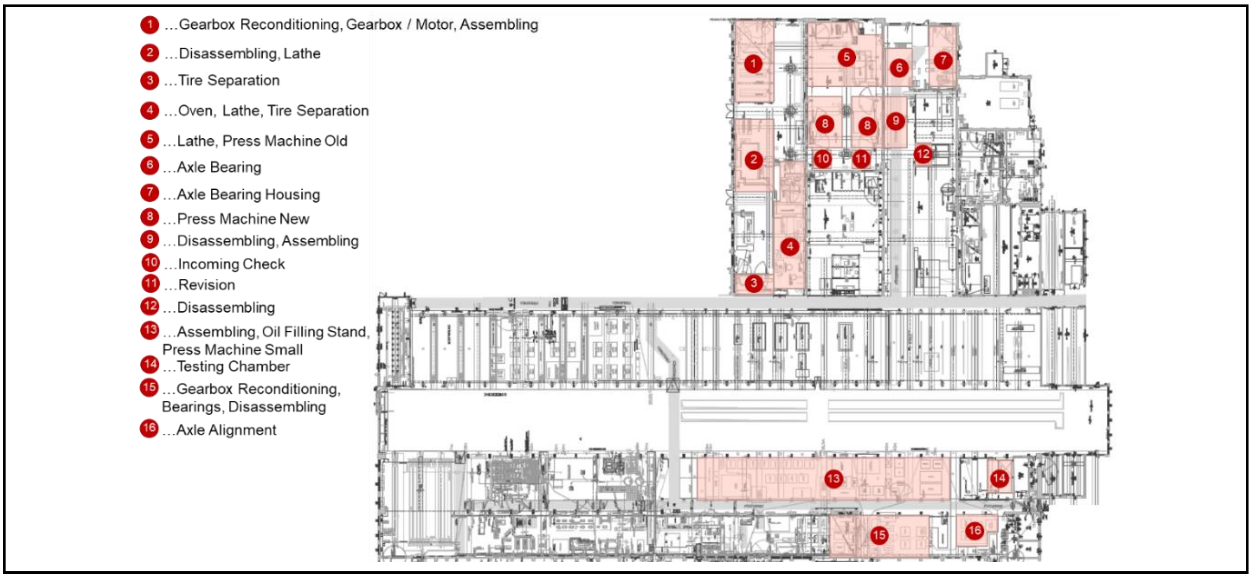


Figure 51: Considered Area for Wheel Sets

According to production program analysis, 2021 was selected as a critical year for wheelsets in order to calculate the proper amount of work stations for the future. Otherwise, the process would be faced with bottleneck situations. Figure 52 shows the required space for wheelsets in 2021. Total required space in 2021 for the processing wheelsets is 3.179 m². The largest area will be occupied by “Pressing On (Assembling)” process is as 427 m².

Workstation	# of Workstations	Required Area
Disassembling	1	43 m²
	2	86 m²
	2	88 m²
	1	45 m²
Gearbox Reconditioning	1	127 m²
	1	30 m²
Gearbox / Motor	3	97 m²
Press Machine Old	1	234 m²
Press Machine New	1	133 m²
Press Machine Small	1	6 m²
Lathe	1	162 m²
	1	102 m²
	1	45 m²
	1	102 m²
Assembling	1	17 m²
	2	88 m²
Testing Chamber	1	34 m²
	1	34 m²
Oil Filling Stand	1	25 m²
Axle Bearing	1	137 m²
Axle Bearing Housing	2	176 m²
Brake Stand	2	92 m²
Axle Alignment	1	79 m²
Incoming Check	1	39 m²
Revision	1	39 m²
Wheel Separation	1	87 m²
	1	91 m²
Oven	1	87 m²
Bearings	2	46 m²
Pressing On (Assembling)	1	427 m²
Brakes (Assembling)	1	381 m²
Total		**3.179 m²**

Figure 52: Required Space for Wheel Sets

4.1.3.3 Potential Areas

These potential areas are being used. Therefore, the main reason to calculate the additional area to identify the areas that can be used in deciding the optimal layout. When calculating the potential areas, transport routes, storage spaces, and current production areas were not taken into consideration. According to the decision made by the company, old machines and suboptimally used areas can be considered as a potential area. Area of traverser is also partially applicable for further using area. These areas are 4.557 m² in total.

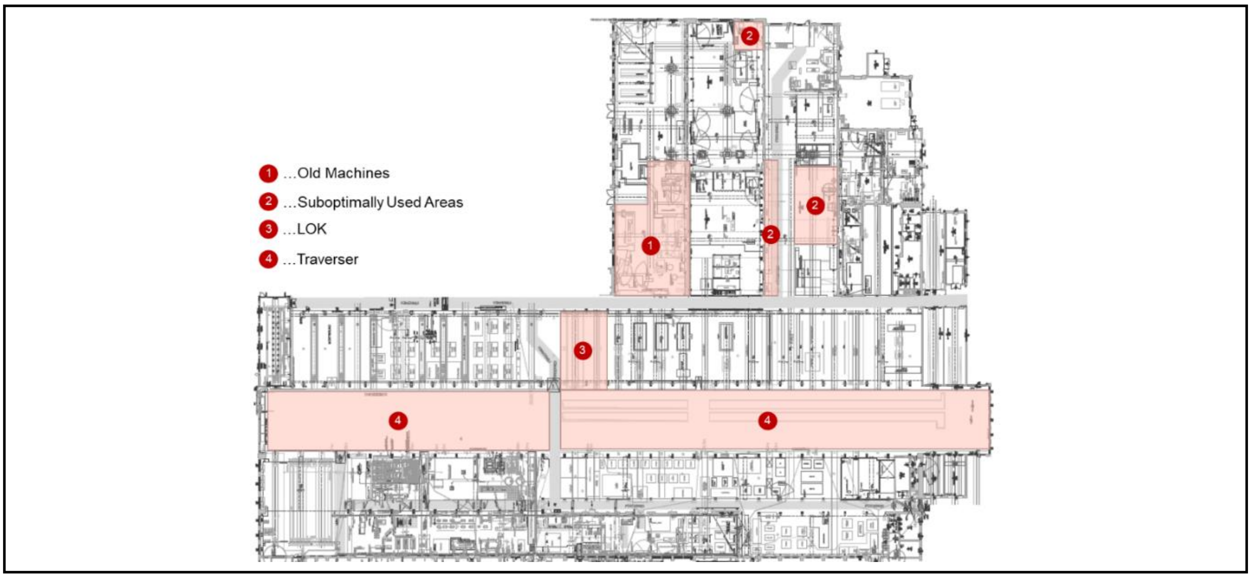


Figure 53: Potential Areas

4.2 Rough Planning

The main objective of the second part of this project is to choose the real layout. In order to achieve this primary goal, the material flow analysis and the ideal layout were prepared. Most of the data required for this stage of the project were obtained from the current state analysis.

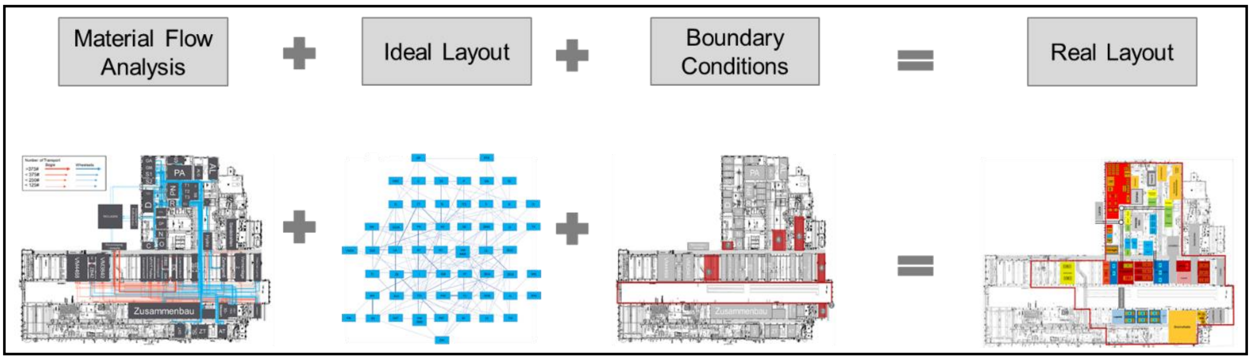


Figure 54: Rough Planning Roadmaps

4.2.1 Material Flow Analysis

Material flow analysis was the first step of the second phase of this project. In order to conduct this analysis, transport intensity matrix, transport route related material flow diagram and finally, process clustering has been done.

4.2.1.1 Transport Intensity Matrix

As mention in section 1.5.2, transport intensity matrix is one of the efficient ways to analyze material flow. Distance matrix and transport matrix are necessary to create transport intensity matrix. Green cells shows that there ise a relationship between the workspaces. In order to calculate total amount of transportion between the workspaces, transport matrix was carried out for each product and then they were combined. The figure below was created for 2023 because there is the highest amount of demand that will be processed in 2023 as mentioned in production program analysis.

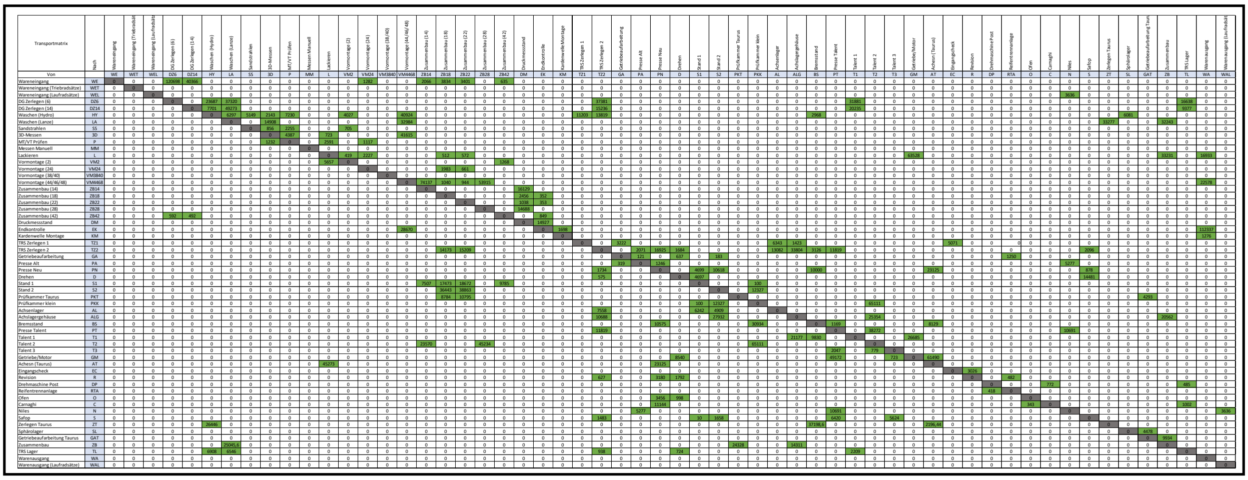


Figure 55: Transport Intensity Matrix for 2023

4.2.1.2 Transport Route Related Material Flow Diagram

Transport route related material flow diagram is a effective way to analze the current situation and to see where is the conflicts and problematic point on the layout. In this diagram, material flow follows the current path of the flow. The reason using two different color is to aware of which type of product uses which areas of the factory. It shows that traverser is used intensely. In current situation, the total amount of transportation in the plant is 20.039. However, traverser is used 10.937 times. It means that almost half of the transportation was carried out by traverser.

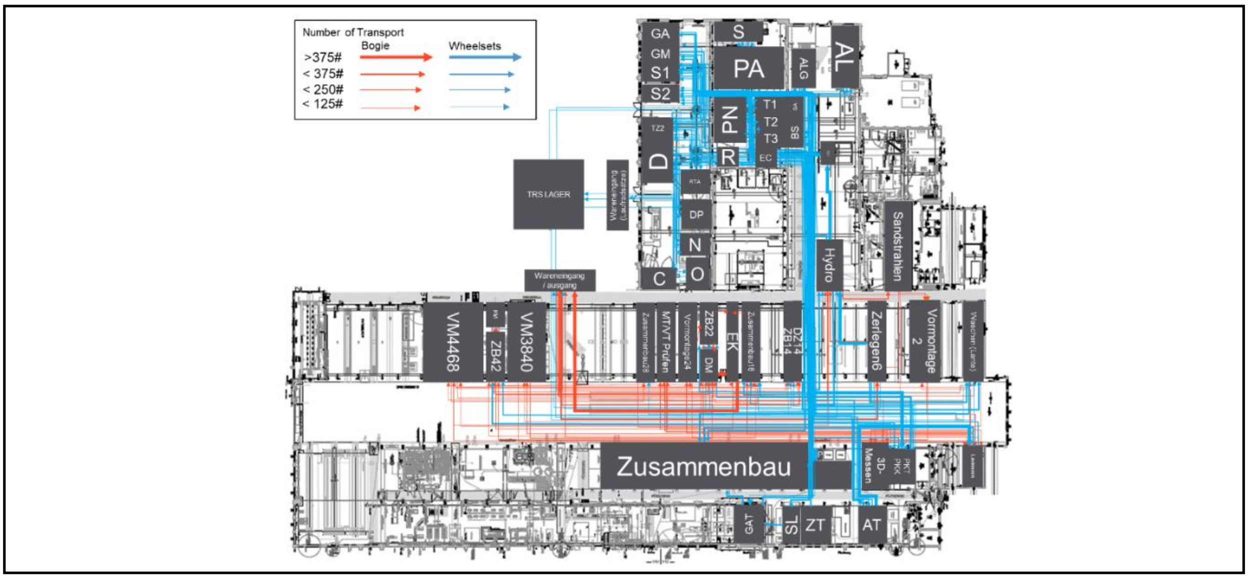


Figure 56: Transport Route Related Material Flow Diagram for Current Situation

4.2.1.3 Process Clustering

As already mentioned, 39 products were taken into account in this project. Although the processes of them are not the same, some of them have similar processes. Therefore, it is necessary to cluster them in order to avoid conflicts on material flow and long transportation distances. In the clustering of processes, not only the process of products followed but also the characteristics of the product were considered. In the end, 4 clusters for bogies and 5 clusters for wheelsets were determined. These clusters were considered while creating a real layout. The figure below shows one of the clusters of bogies.

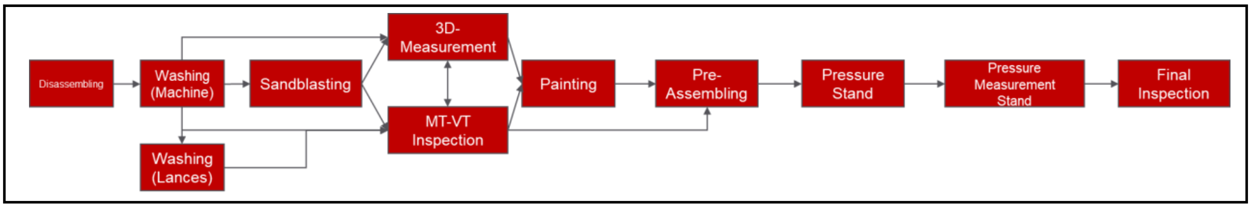


Figure 57: Example Process Cluster

4.2.2 Ideal Layout

The ideal layout was prepared with the help of the triangular method of Schmigalla. Figure 58 shows the ideal layout. This ideal layout shows the ideal places of work stations. The entrance and exit points of the factory are also shown in this figure. Moreover, the line thickness in this figure indicates the amount of transportation. In other words, as the line thickness increases, the number of transport increases. As shown in the figure, the most intensive transportation is occurring between the testing chamber and assembling stations for wheelsets. This ideal layout was used to prepare rough layout variants.

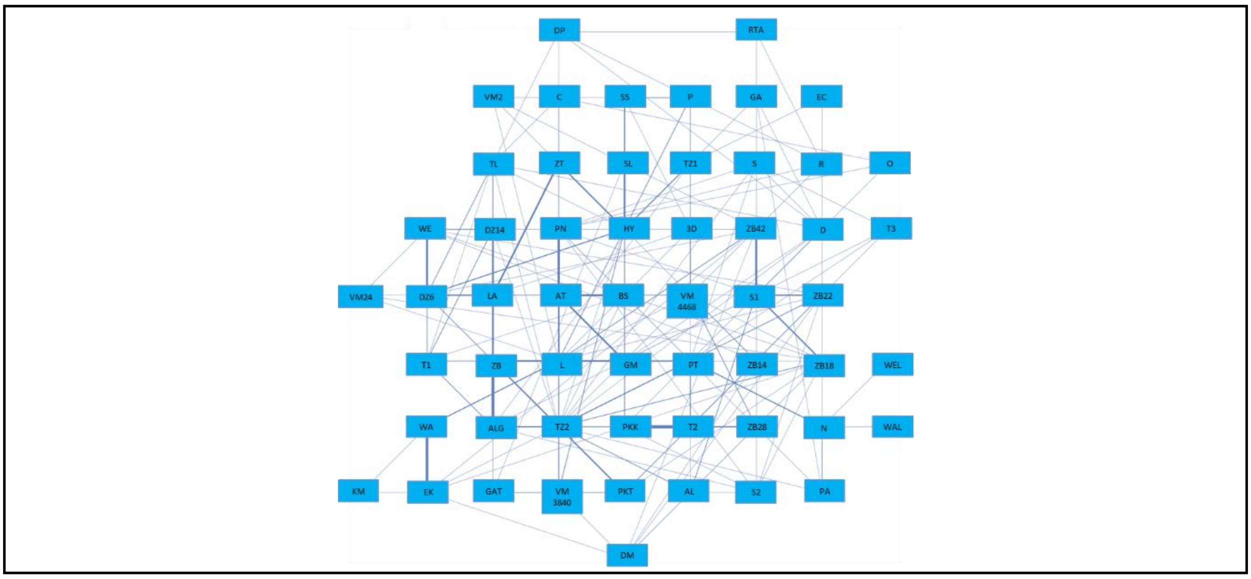


Figure 58: Ideal Layout

4.2.3 Real Layout

In order to reach the exact real layout, boundary conditions and evaluation criteria are considered as much as ideal layout. In this project, the main boundary conditions were about the fixed machines. Moreover, four main evaluation criteria were used to select a layout among variants.

Boundary Conditions

There are boundary conditions that need to be considered to plan the real layout. Besides the structural restrictions, there are some limitation especially about workplace. In other words, in this project, the main boundary condition was about fix workplaces. Some machines and workspaces cannot be replaced while performing real layout planning.

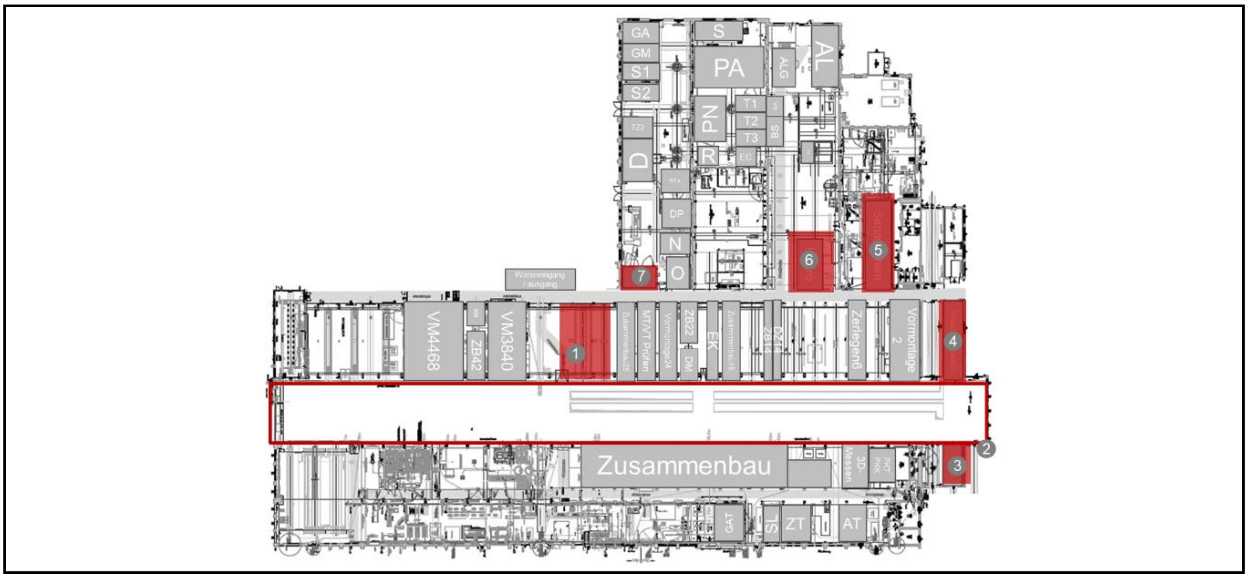


Figure 59: Fixed Placed Workstations and Machines

As shown in figure 59, there are seven workstations and functional units that they cannot be replaced, and these are:

1. Reconditioning for Locomotives
2. Traverser
3. Painting
4. Washing Hall (Lance)
5. Sandblasting
6. Washing Hall (Machine)
7. Lathe

These workstations and functional units were considered while generating different real layout variants.

Selection of Real Layout

With considering the fixed placed machines and workstations, 11 layout variants were prepared, but for value benefit analysis, four layout variants were selected after the discussion with the project team of the company. The selection criteria are:

- Production Logistics
    - Number of Transports by Traverser
    - Transport Intensity
    - Transports of External Products
- Compact Arrangement
    - Bogie to Wheelsets
    - Bogie to Bogie
    - Bogie to Free Areas for Additional Components
    - Wheel Sets to Wheelsets
- Extensibility Bogie
    - Extensibility of Manual Work Station
    - Extensibility of Logistics
- Extensibility Wheel Sets
    - Extensibility of Manual Work Stations
    - Extensibility of Logistics

Figure 60: Selected Real Layout

Moreover, the result of material flow analysis between selected and planned layouts shows the magnitude of the change and the comparison of both layouts can be seen in figure 61. This analysis was made for wheelsets in the year 2021 because the year 2021 is the critical year for the wheelsets. However, when this analysis was conducted, the lot sizes were not taken into account. In the end, the total travel distance for a wheelset was reduced by 257% after planning a new layout for the facility. Moreover, the usage of cranes and traverser will significantly reduce in the selected real layout. The main reason that the workstations are much closer comparing the current locations of them.

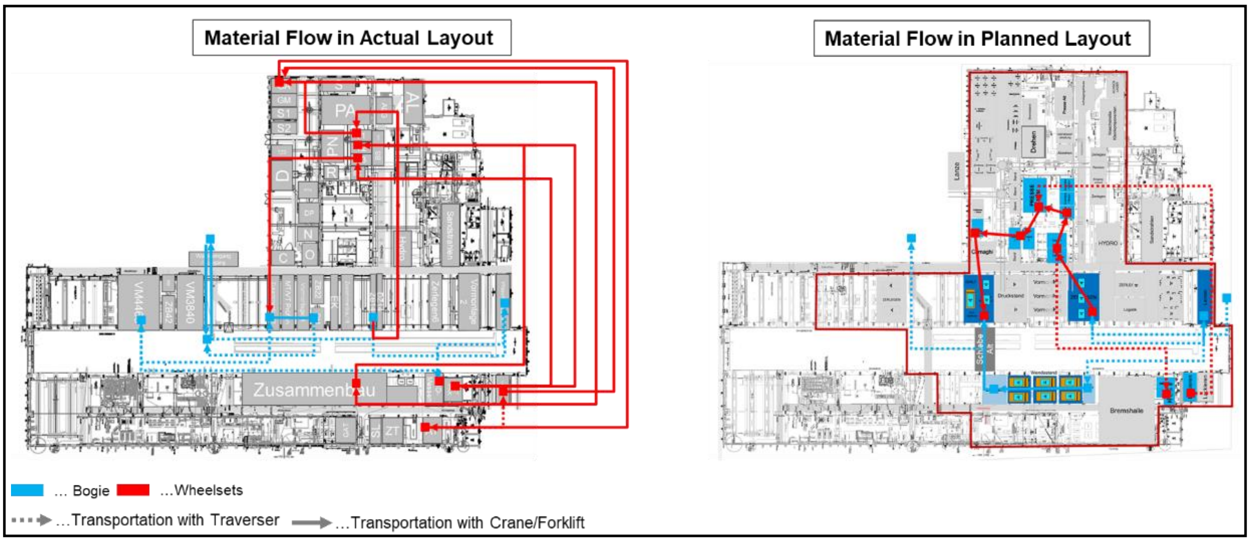


Figure 61: Material Flow Comparison Between Actual and Planned Layout

4.3 Challenges from Case Study

As already mentioned in section 2.7, several challenges arise while planning a factory. Mainly in this project, three challenges observed which are volatility, rigidity, and wrong focus, and these can be seen in the figure below as painted. In addition, this section discusses the reasons why some challenges were not encountered during this brownfield factory planning project.

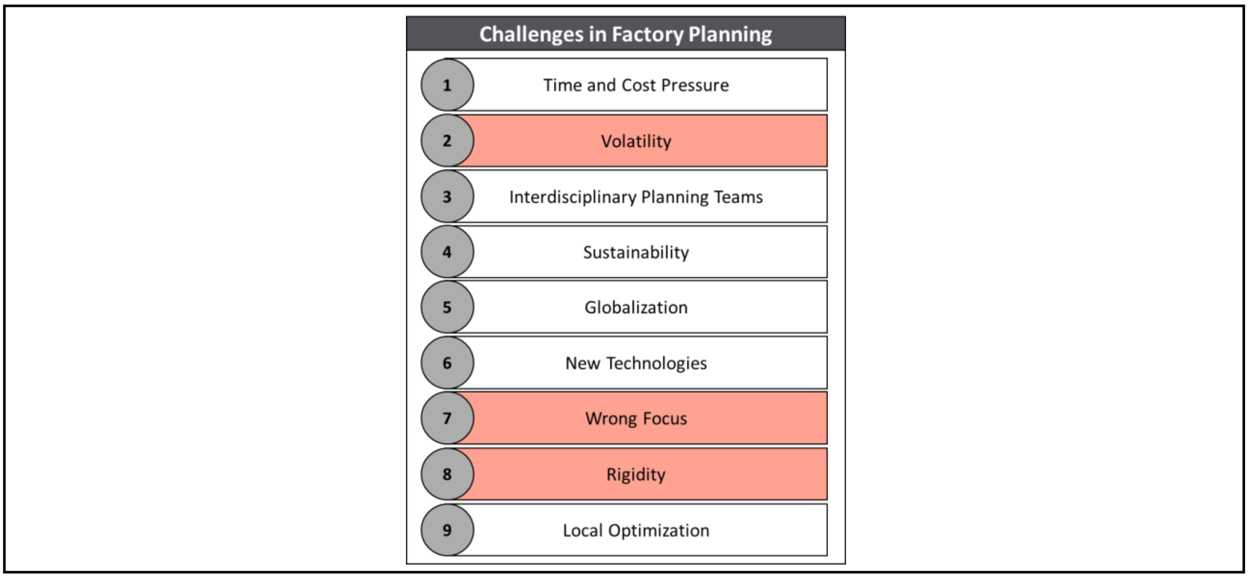


Figure 62: Challenges Encountered in Case Study

One of the essential and common challenges in factory planning is about volatility. As described, volatility refers to changing demands, requirements, and boundary conditions during the factory planning projects. In this project, production program analysis was taken the first place. This analysis was the basis of capacity calculation. The capacity calculation was firstly carried out for only bogies. Primarily, the demands of bogies for the next six years were provided for the capacity calculation, and these demands were just about internal products. Then, the number of years covered by the demand list increased ten years.

Moreover, the required data of products from other location was provided later than the internal products. The shortcoming is that the data format was not the same as the data provided earlier. In other words, processes required by products were not clear to understand. Afterward, during the capacity calculation, forecasted demands for external products were provided by the company. Also, the percentages for some products were used instead of the exact amount of demands. Last but not least, additional processes were added for a small number of products.

Briefly, demands and requirements were changed several times during the capacity calculation task. Frequent changes in requirements and demands have changed the required working hours and the number of workstations several times. This caused to make late decisions in the early phases, and so much effort was spent on changing the input data.

Among the challenges encountered in this project, rigidity can also be mentioned. As it is described in section 2.7, rigidity refers to the stiffness of the factory planning processes. For instance, ideal layout variants are necessary for making real layouts. Therefore, in this project, the ideal layout was created using the Schmigalla method; however, it was never used during the planning of real layout variants. It was just time-consuming practice during this brownfield factory planning project. Because it could be useful in greenfield factory planning projects, but it cannot be fully applicable under several constraints and boundary conditions. As a suggestion, simulations can be used in the early stage of factory planning activity. This can make the factory planning process more flexible.

Another challenge arose during this project is the wrong focus. The main shortcoming of this challenge is about effort estimation. Effort estimation is one of the key activities in project management. Therefore, neglecting the interdependencies between different tasks leads to the wrong estimation of the required effort.

For instance, in the determination of space requirement step, traverser was defined as cannot be used in layout planning. Therefore, it was neglected to be a potential area in the upcoming steps. Therefore, real layout variants among the planning team were prepared based on this informations, and they did not contain the area of the traverser.

However, in the real layout planning workshop with the company, they decided to make some layouts with taken into account the area of the traverser. It means that the effort to prepare the layout variants among the planning team members was not used effectively because the possibilities were already eliminated.

Furthermore, after the determination of space requirement, additional halls of the plant were started to consider by the customer. The company decided the use the hall occupied by brakes and storage for the components of the brake. The space of additional hall was included in the potential area. However, the same size of the area should be placed somewhere in the plant. It means, until that time, this hall was not considered as part of the space dimensioning task.

Another example of this challenge is regarding fix placed machine. Before conducting real layout planning, the company provided information about which workstations cannot be moved, and they mainly considered the workstation occupied by wheelsets. However, in the real layout planning process, the company realized that pressure measurement stand could not be moved as well. This means that the already prepared real layout already among the planning team lost its importance. In other words, the effort of the planning team was wasted.

Last but not least, the task of clustering the processes of the products took a severe time. First of all, each product has nearly a different process or uses different workstations. However, the customer has knowledge that some products can be processed in the other stations. This shows that the active customer involvement has an impact on the decision-making points. Otherwise, planners have to make an assumption with less knowledge.

Contrary to the challenges encountered, many of them were not encountered during this project. In section 2.7, nine main challenges in the factory planning projects are mentioned. However, only three of them were faced in this project. First of all, as for every project, this project also had time targets for some milestones. However, this pressure is not encountered in real terms because no product should be released to the market; therefore, this situation did not cause pressure on the factory planning team. In other words, it is not possible to mention this challenge in this project since time is one of the primary sources of cost pressure.

Furthermore, the scope of the project will affect the number of challenges that the factory planning team will face. That means if the project has more comprehensive scope, then the planner will face more challenges. For this project, ecology, economy, society, or building legislations were not considered. That is the main reason that the planning team did not face the challenges of sustainability, globalization, and new technologies. Besides the scope of the project, also the size of the project and the planning team will be a factor that can have an impact on the probable challenges. For instance, in this project, the planning team was tiny therefore, interdisciplinary planning team and local optimization challenges were not encountered.

5 Agile Factory Planning Approach

As mentioned in the previous chapters, a few challenges arise when planning a factory. When projects are carried out with current factory planning approaches, these challenges cannot be overcome and dealt with them. Moreover, the characteristics and advantages of agile methods seem to cope with these challenges. Therefore, it is necessary to develop a new approach based on an agile perspective.

Classical factory planning approaches are linear and stepwise, as described in section 2.5. This is one of the main characteristics of factory planning projects. However, it can be harmonized with an agile perspective. Therefore, agile factory planning approach should protect its solid structure but also give some opportunities to the customer to make their requirements clear during projects. Thus, the new approach should give them a rough structure of factory planning in order to determine necessary or unnecessary steps and make some modifications on the steps.

5.1 The Basics of the New Approach

First of all, the development of this new approach had to be based on a factory planning approach, and Grundig's approach was chosen among the most classical methods, as this approach had to reflect the characteristics of the factory planning procedures. In other words, the agile factory planning approach has been developed based on Grundig's factory planning approach. The main reason for Grundig's approach is that Grundig himself, as he states in his book, covers the characteristics of most fundamental factory planning approaches such as Kettner and Aggteleky. This makes it a comprehensive approach that reflects the characteristics of factory planning.

Second, the overall framework of the Feature Driven Development method was taken into account because there are no solid repetition models in place of Scrum and Extreme Programming. The essential feature of Feature Driven Development method is to create the overall model and feature of the system step by step and then to develop this model in detail with iterations. The first step is to play a significant role in this new factory planning approach. As already explained in the Feature Driven Development method, while already developing the overall model, domain experts are already aware of the scope and requirements of the project. In factory planning, the situation is the same, so planners are aware of the scope and requirements. In short, this new factory planning approach was influenced by the Feature Driven Development method’s processes, especially develop an overall model, which is the first step of Feature Driven Development method.

Thirdly, the first two steps of the factory planning were affected by the planning game of Extreme Programming. The planning game includes both customer and programmers. Customers in this game mention the requirements, and programmers advise the customer how much effort is required for the implementation of these requirements. This plays a significant role in determining the scope and duration of the project. This is the reason that the preparation phase was distributed all over the other phases to play a planning game.

Fourthly, active customer participation is significant in agile project management. Active customer engagement ensures that problems can be seen and resolved beforehand, the necessary data is reached quickly, and the decisions or assumptions required are taken quickly. Therefore, this new approach recommends on-site customers of Extreme Programming for active customer engagement. Where this is not possible, the Product Owners from Scrum model should be present. The difference from the on-site customer is that they should attend daily meetings even though they do not work closely with planners.

Last but not least, the quality of communication within the stakeholders involved in planning projects is as important as active customer participation. The best practice for this is the daily meetings of the Scrum. In these meetings, the main context of these small meeting is about what is done until this time, if there is a problem, what is this and what to do until the next meeting. Thanks to these meetings, all the stakeholders of the project are aware of the problems encountered in the project, and these problems can be solved more quickly.

5.2 Application of New Approach

The new agile factory planning approach is based on the foundations described in the previous section, and figure 63 shows the general framework of this approach. In general, factory planning projects start with the preparation phase, as described in section 2.6.1. The main task of this phase is, in order to prepare for the further planning phases, obtaining a sustainable database. However, since the required inputs are not analyzed and evaluated adequately, it is not possible to mention the accuracy of the data collected. Therefore, the data and requirements are changed in further steps, and this causes time losses during the project. In order to avoid this situation as much as possible, it is necessary to perform the preparatory phase at the beginning of each critical phase as shown in figure 63 instead of thinking as a single task that should be done at the beginning of the projects. In other words, the preparation phase should be distributed over the different phases of the factory planning projects. The main advantage of this is the gathering information for the focused phase rather than collecting all of the necessary information for the whole factory planning projects in the beginning. Therefore, planning experts can analyze the collected data more efficiently. This also allows for noticing missing and unnecessary data and requirements. In addition, it helps to determine more precisely how much effort, that the team should put into completing the task, from just necessary data.

Moreover, the second main factory planning phase is Structural Planning. This phase typically consists of four main parts, which are the determination of functions, dimensioning, structuring, and design.[366] This phase is critical because it has a significant impact on the structure of further calculations. Therefore, this phase should be conducted very carefully. For this reason, this phase was divided into two main phases, which are current state analysis and target conception. The current state analysis is comprised of determinations of functions and dimensioning tasks. To put it another way, the capacity calculation will be the last step of this phase. On the other hand, structuring and design tasks will be the essential parts of the target conception. This main phase of the factory planning begins with material flow analysis and ends with real layout selection.

Last but not least, constant monitoring is very significant activity in order to detect the problems and estimate the necessary effort to carry out the tasks. This monitoring activity should be done for each phase. While conducting this activity, burndown charts should be used rather than Gantt's chart. Following section of this chapter is mentioned this activity in more detail.

[366] Cf. Grundig (2018), p. 46

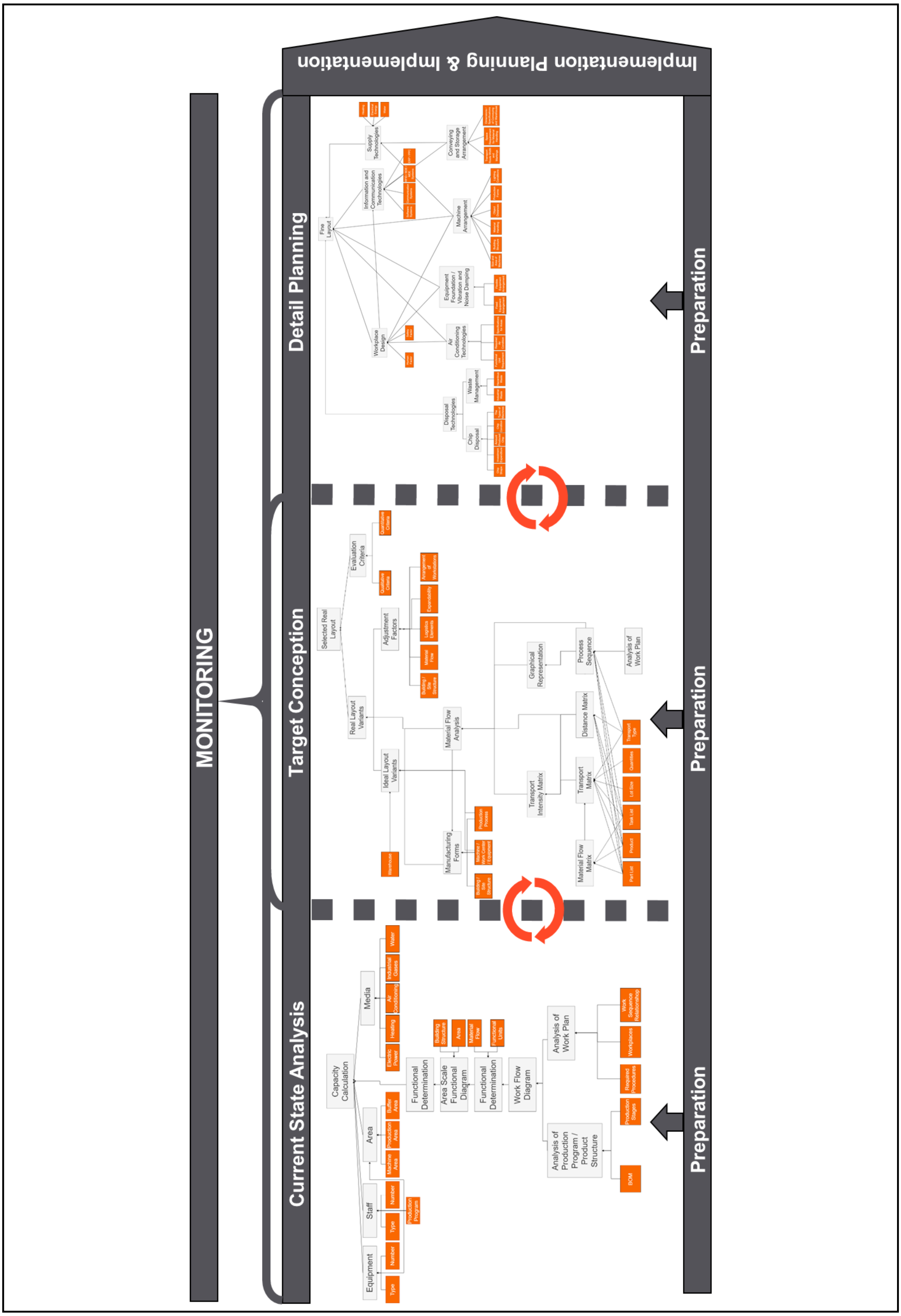


Figure 63: Agile Factory Planning Approach

Another essential feature of this approach is that it provides a kind of map to customers and planners. In this case, if external consultants carry out the planning projects, customers would be the company the factory is planned for. Otherwise, customers would be the factory management if the factory planning projects are conducted by internal consultants.

The example map for current state analysis is shown in figure 64, and thanks to this map; customers may be more involved in the project. Because, in general, customers are not experts in factory planning and cannot predict to what extent data will be needed and to what extent they will be able to meet their demands. The map prepared in advance by these planners will make the project more prominent and will be easier to follow the flow of the project.

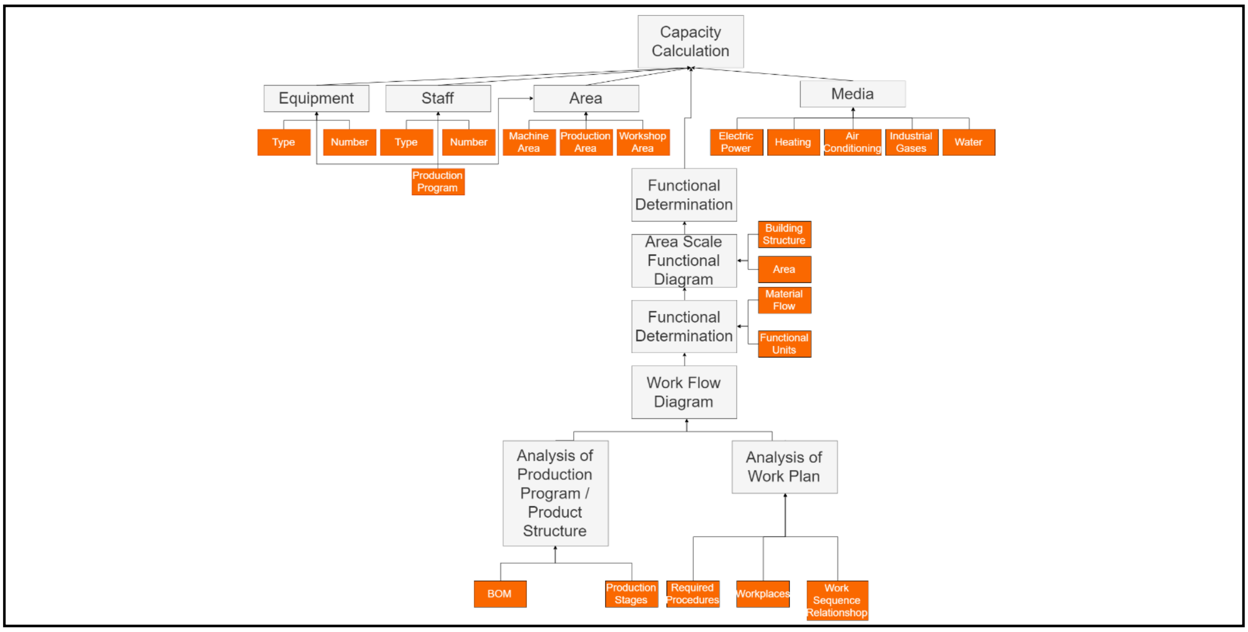


Figure 64: Work Flow for Current State Analysis

In addition, thanks to this map, which data is required in which step is clearly specified, the customer needs to provide the data with the required depth and when it is required. This will allow planners to discuss in advance the data and requirements and minimize late requirements changes.

At the same time, this map can help to determine the effort required, as it can be foreseen how long the desired unnecessary changes can cost. This will help avoid changes that are not really necessary.

As one of the characteristics of the agile methodologies, agile methods are people oriented rather than processes. This element is also mentioned in the values of the agile manifesto. Therefore, individuals should play a significant role in the factory planning approach.

In classical approaches, factory planners gather the data, conduct all the phases, and present the results to the customer. However, customers do not involve the project actively. In the agile methods, which are investigated during the thesis, customers or users have an impact on the projects. For instance, on-site customer, product owner, and active user involvement are used in extreme programming, scrum, and dynamic system development method.

Active customer involvement is necessary for different reasons. Firstly, quickness is one of the vital factors to be agile. While conducting a project, sometimes assumptions are made for making small decisions. However, the assumptions are sometimes different from what the customers think and want, and this affects the result. Changing this decision again means doing the same job a second time. Therefore, extreme programming suggests on-site customers who should always be accessible by the planning team in order to assist them quickly, answer questions, and resolve issues.

Moreover, customers sometimes are not willing to share information with the planning team. Therefore, it affects the quickness and quality of the results. If customers are available on site and participate actively, they can understand how important the information that is asked by the planning team, and they can access and provide necessary data with the proper form.

Koskella and Abrahamsson claim that even without a customer's presence, the project can survive, but if the client is present, the projects will get faster and smoother.[367] As figure 65 shows that face to face communication is the most effective way to exchange the information.

[367] Cf. Koskella / Abrahamsson (2004), p. 2

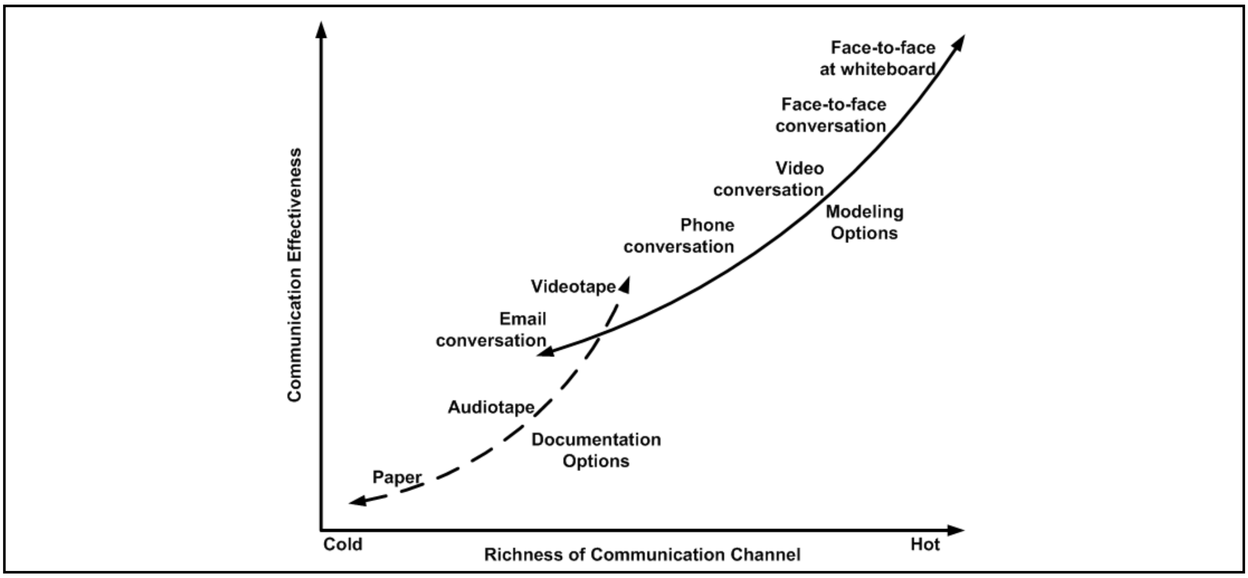


Figure 65: Effectiveness of Communication Means[368]

Frequent meetings play a significant role in the agile methodologies. Main aim to arrange meetings frequently is identifying problems and obstacles quickly. These meetings should be held daily to discuss the current situation of the project and task assigned individuals. Then it becomes easier to identify the problems that the planners face. Furthermore, customers should involve these frequent meetings as well. Because it helps to determine further requirements in advance. So the planning team can react quickly and make necessary modifications.

Another characteristic of the agile methods is simplicity. The main source of this simplicity comes from minimal documentation. For less documentation, planners only need to keep the necessary data. As mentioned before, this new agile factory planning method only deals with the data needed for the phase currently focused on because the extra data can not only increase the documentation but also may disappear.

At the same time, this new model only deals with the phases that need to be done, which is another source of simplicity. For example, in some projects, only phases until the implementation planning are done by the factory planners, and the rest is outsourced. This means that the factory planning projects cannot be reached simplicity by division into phases, but also unnecessary phases and step can be removed.

Last but not least, an amount of participants for the factory planning projects should not exceed a single digit. As mentioned in section 3.7 and shown in figure 41, one of the essential characteristics of agile methods is the number of people in the team. According to agile methods, the team size should not exceed ten persons. However, according to Kampker et al., the number of participants for the factory planning projects cannot

[368] Cf. Cockburn (2001), p. 84

achieve single digit participants, which is required for working efficiently.[369] Therefore, the team size should fit the team size as a recommendation of Kampker et al. based on agile methodologies.

5.3 Monitoring in the New Approach

People cannot foresee the future. For instance, the competitors release a new product or service unexpectedly, or unforeseen technical issues may arise, which lead to a shift of direction.[370]

In addition, the scheduling of unclear events in the future is especially difficult for human beings. For example, planning, how eight months will be spent from today, could lead to an unrealistic schedule. That is the reason why many of Gantt's thoughtfully designed charts have collapsed.[371]

Static instruments such as the Gantt charts become an ongoing burden when complexity rises. Furthermore, if these tools are not updated as process changes, incorrect and outdated information will stay in the system. Thus this leads to undermining confidence to the tool. [372]

The agile team manages itself and has to understand how to do this effectively. Every day, team members update their estimates of the time remaining to complete their current tasks. Once this update has been made, somebody adds the remaining hours for the entire team on the burndown chart. Every day this diagram shows that the amount of work left until the work of the team is complete. This is ideally a downward sloping chart to "zero effort remaining" by the last day of the project. Therefore, it is called as a burndown chart. It is essential because the burndown chart shows the progress of the team. It is not important how much time was spent in the past because it is an irrelevant fact in terms of progress, but the significant thing is how much work remains in the future. Moreover, it shows how far the team is from its objective. The burndown chart should move downward. If the downward movement does not continue, team members should make an adjustment on the scope of tasks, or have to find the problem which leads them to work ineffectively.

[369] Cf. Kampker et al. (2013), p. 3
[370] Cf. Deemer / Benefield / Larman / Vodde (2010), p. 3
[371] ibidem
[372] Cf. Sommer / Hedegaard / Dukovska-Popovska / Steger-Jensen (2015), p. 41

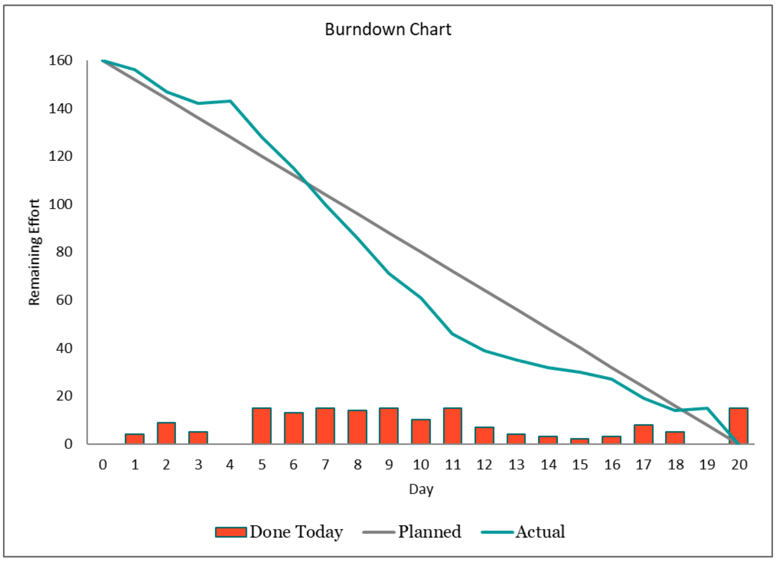


Figure 66: Burndown Chart

5.4 Agile Factory Planning Approach As A Solution

As mentioned in section 2.7, there are several challenges in the literature, and this approach has been developed to cope with them. They are shown in figure 67, and green painted challenges can be removed by the agile factory planning approach.

Figure 67: Overcome Challenges by the Agile Factory Planning Approach

As a first challenge, the challenge as time and cost pressure is one of the main issues not only in factory planning projects but also the projects in different fields and the agile factory planning approach can overcome this challenge. As mentioned before, the main reason for time and cost pressure is increasing requirement and planning effort. Through the maps created in this new approach and the preparation phase at the beginning of each stage of factory planning, the requirements and required data will be determined in advance. This means that only the necessary effort will be estimated. At the same time, this process will be monitored more effectively with the burndown charts instead of the Gantt chart. This will also reduce the time pressure, and this reduction will contribute to decreasing the cost pressure as well.

Secondly, volatility is another challenge in factory planning. Active customer participation, daily meetings, and map structure of each phase will help to remove the challenge of volatility. From beginning as the preparation of each step until the end of each phase, customers take place in every process of factory planning. This leads that customers will be aware of which process is being carried out and what will be the next step. The map structure also helps to decrease in volatility because in the beginning, which requirements and data will be needed in further steps. Therefore, they will have time to prepare the required data and to think about further requirements. The daily meetings will also be helpful because customers have a feeling about the requirements and problems faced by the planners.

Furthermore, another challenge is about interdisciplinary teams. The main reason for this challenge is coordination effort. The daily meetings and frequent feedbacks will reduce the effort for coordination of different teams because everybody will be updated every day thanks to these daily meetings.

Moreover, the wrong focus is also mentioned as a challenge arisen while planning a factory. Wrong effort estimation and ignoring the interaction between the tasks are essential causes for this challenge. The map structure created at the beginning of each phase can show the interdependencies between tasks clearly, and the effort estimation can be done much more precisely according to this pre-determined structure. In addition, the burndown chart will be beneficial to monitor how much effort spent, and if there is something wrong, it can be detected more easily. This means that the challenge of wrong focus will be eliminated.

The next essential challenge is about the rigidity of the factory planning processes. Typically, traditional project management approaches do not consider active collaboration. These approaches just focus on sharing the information, and this leads the factory planning approaches stepwise and rigid. However, in the new agile factory planning approach, active customer involvement, daily meetings, and frequent feedbacks are significantly important. This means that new requirements can be detected and during the factory planning processes earlier, then they can be implemented. Moreover, in the preparation phase of each step and map structure help to determine the requirements so the factory planning process can be formed based on the requirements determined at the beginning or expected changes will be kept in mind of planners and customers. Therefore, this helps to adjust factory planning procedure based on the scope and requirements of the cases.

Last but not least, the main reason for the challenge of local optimization is a lack of information exchange. Because typically, only the leaders of different teams have direct communication, so this means that the information is only shared between them. However, in this agile factory planning approach, there are daily meetings and active customer involvement so the information will be shared among all stakeholders thanks to these activities. Therefore, well-distributed information is expected to prevent local optimization.

Unfortunately, this approach may not be a solution to the challenges of sustainability, globalization, and new technologies. The reasons are that the legislation and regulations are changing all the time, global competition is getting tighter, and uncertainties for the necessary manufacturing processes in the future. Therefore, these continuous changes cause these challenges to remain.

In a nutshell, this developed agile factory planning approach comprises of the characteristics of agile methodologies. It has been constructed based on Grundig's factory planning approach and Feature Driven Development agile method. Also, it was enriched with different tools of several agile methods such as on-site customer, product owner, daily meetings, and planning game. Therefore, it is capable of dealing with six out of nine factory planning challenges.

6 Summary and Outlook

Today, one of the most critical problems in the factory planning projects is the uncertain changes within the project life cycle. These changes cause challenges which are not overcome by essential factory planning approaches. Therefore, agile methods were developed in order to find a solution to overcome uncertainties and changes emerging while planning a factory. This thesis deals with the challenges faced by classical factory planning approaches and the characteristics and advantages of agile methods. Finally, a new agile factory planning approach has been developed as a solution by bringing these two together.

Firstly, commonly used factory planning approaches were identified, and selected and described five of them which structurally differ from each other. Besides the phases of factory planning approaches, advantages and disadvantages of each phase were mentioned. As the last step, challenges encountered when planning a factory were determined as a result of the literature review.

In the second part of the thesis, agility, flexibility, and responsiveness were described. Before explaining Agile manifesto and its principles and values, reasons led to adopting agile methods are mentioned. The six most common agile methods are described, and they are mainly project management oriented agile methods. Characteristics of agile methodologies were identified based on the comparison of agile methods between themselves, comparison of agile and traditional project management approaches, values and principles of Agile Manifesto and situations where agile methods are most effective. Lastly, the advantages of agile methods in large and complex projects were described.

Thirdly, brownfield factory planning project was carried out and taken as a case in order to identify challenges occurring in the current state analysis and rough planning phases. Challenges determined in these stages were matched with challenges from the literature.

Last but not least, the new factory planning approach was developed as a suggestion in order to cope with the challenges emerging during the planning of a factory. This approach was developed based on the identified characteristics and advantages of agile methods. The new approach also relies on the classical phases of factory planning to reflect the characteristics of existing approaches.

In conclusion, agile methods seem to overcome uncertain changes faced in the field of factory planning. Because the identified and experienced challenges have been highly matched with the characteristics of the agile methods. This, in turn, points to the need to use agile methods to deal with the challenges in factory planning, even though it is difficult to be adopted. At least the harmonization of these two fields should be reviewed by scientific studies. As can be seen in the literature research, the number of sources seeking solutions to factory planning problems with agile methods is not sufficient. As a result, scientific studies should be carried out on this subject, and at the same time, these studies should be supported with practical results and more in-depth knowledge should be produced about whether these agility and factory planning can work together.

References

Abrahamsson, P., Salo, O., Ronkainen, J., & Warsta, J. (2002). *Agile Software Development Methods: Review and Analysis.*

Abrahamsson, P., Warsta, J., Siponen, M. T., & Ronkainen, J. (2003). New Directions on Agile Methods: A Comparative Analysis. In *25th International Conference on Software Engineering.*

Aggteleky, B. (1987). *Fabrikplanung (Band 1).*

Aggteleky, B. (1990). Fabrikplanung (Band 3).

Aguanno, K. (2004). *Managing Agile Projects.*

Arnold, D., & Furmans, K. (2009). *Materialfluss in Logistiksystemen.*

Arnold, D., Isermann, H., Kuhn, A., Tempelmeier, H., & Furmans, K. (2008). *Handbuch Logistik.*

Awad, M. A. (2005). A Comparison between Agile and Traditional Software Development Methodologies .

Baron, P., & Hüttermann, M. (2010). *Fragile Agile - Agile Softwareentwicklung richtig verstehen und leben.*

Beck, K. (1999). Embracing Change with Extreme Programming. In *Computer 10* (pp. 70-77).

Beck, K. (2004). *Extreme Programming explained: Embrace change.*

Beck, K., Beedle, M., Bennekum, A., Cockburn, A., Cunnigham, W., Fowler, M., . . . Thomas, D. (2001). *Principles behind the Agile Manifesto*. Retrieved from Agile Manifesto: http://agilemanifesto.org/principles.html

Bernardes, E., & Hanna, M. (2009). A theoretical review of flexibility, agility and responsiveness in the operations management literature. In *International Journal of Operations & Production Management* (pp. 30-53).

Bertling, M., Caroli, H., Dannapfel, M., & Peter, B. (2018). The Minimal Viable Production System (MVPS) - An Approach for Agile (Automotive) Factory Planning in a Disruptive Environment. In R. Schmitt, & G. Schuh, *Advances in Production Research* (pp. 24-33).

Bleek, W.-G., & Wolf, H. (2011). Agile Softwareentwicklung: Werte. In *Konzepte und Methoden.*

Boehm, B. (2002). Get Ready for Agile Methods, with Care. In *Computer 1* (pp. 64-69).

Boehm, B., & Turner, R. (2005). Management Challenges to Implementing Agile Processes in Traditional Development Organizations. In *IEEE software 22.5* (pp. 30-39).

Borowski, E. (2011). *Agiles Vorgehensmodell zum Management komplexer Produktionsanläufe mechattronischer Produkte in Unternehmen mit mittelständischen Strukturen.*

Chin, G. (2004). *Agile Project Management: How to Succeed in the Face of Changing Project Requirements.*

Cockburn, A. (2001). *Agile Software Development.*

Cockburn, A., & Highsmith, J. (2001). Agile Software Development: The People Factor. In *Computer 11* (pp. 131-133).

Cohn, M. (2010). *Agile Softwareentwicklung - Mit Scrum zum Erfolg.*

Conforto, E. C., & Amaral, D. C. (2010). Evaluating an agile method for planning and controlling innovative projects. In *Project Management Journal 41.2* (pp. 73-80).

Coram, M., & Bohner, S. (2005). The Impact of Agile Methods on Software Project Management . In *12th IEEE International Conference and Workshops on the Engineering of Computer-Based Systems (ECBS'05)* (pp. 363-370).

Deemer, P., Benefield, G., Larman, C., & Vodde, B. (2010). *The Scrum Primer.*

Dickmann, P. (2015). *Schlanker Materialfluss .*

Dogs, C., & Klimmer, T. (2005). *Agile Software-Entwicklung kompakt.*

Dubinsky, Y., & Hazzan, O. (2004). Roles in Agile Software Development Teams. In J. Eckstein, & H. Baumeister, *Extreme Programming and Agile Processes in Software Engineering* (pp. 157-165).

Eckstein, J. (2009). *Agile Softwareentwicklung mit verteilen Teams.*

Felix, H. (1998). Unternehmens- und Fabrikplanung Planungsprozesse, Leistungen und Beziehungen .

Fowler, M. (2004, May). *Is Design Dead?* Retrieved from https://www.martinfowler.com/articles/designDead.html

Fowler, M. (2005). *The New Methodology*. Retrieved from https://www.martinfowler.com/articles/newMethodology.html

Goldman, K., Nagel, R., & Preiss, R. (1995). *Agile competitors and virtual organizations: strategies for enriching the customer.*

Gonschorrek, U., & Hoffmeister, W. (2006). *Ganzheitliches Management Rechnungslegungs- und Finanzprozesse.*

Grundig, C.-G. (2012). Fabrikplanung Planungssystematik - Methoden - Anwendungen.

Grundig, C.-G. (2018). *Fabrikplanung Planungssystematik – Methoden – Anwendungen.*

Herrmann, A., & Huber, F. (2009). *Produktmanagement: Grundlagen - Methoden - Beispiele.*

Highsmith, J. (2002). *Agile Software Development Ecosystems.*

Highsmith, J., & Cockburn, A. (2001). Agile Software Development: The Business of Innovation. In *Computer 34.9* (pp. 120-122).

Hopf, H. (2015). *Methodik zur Fabriksystemmodellierung im Kontext von Energie- und Ressourceneffizienz.*

Iacovelli, A., & Souveyet, C. (2008). *Framework for Agile Methods Classification.*

Kampker, A., Burggräf, P., Krunke, M., Kreisköther, K., Voet, H., & Backs, M. (2014). *Das Aachener Fabrikplanungsvorgehen.*

Kampker, A., Meckelnborg, A., Burggräf, P., & Netz, T. (2013). Factory Planning Scrum: Integrative Factory Planning with Agile Project Management.

Kaur, N., & Singh , G. (2016). *A Quantitative Study on Critical Success Factors in Agile Software Development Projects .*

Kettner, H., Schmidt, J., & Greim, H.-R. (1984). *Leitfaden der systematischen Fabrikplanung.*

Kumar, A., & Motwani, J. (1995). A methodology for assessing time-based competitive advantage of manufacturing firms. In *International Journal of Operations & Production Management 15.2* (pp. 36-53).

Lawrence, R., & Yslas, B. (2006). *Three-way Cultural Change: Introducing Agile within Two Non-Agile Companies and a Non-Agile Methodology.*

Liebetruth, T. (2016). *Prozessmanagement in Einkauf und Logistik.*

Loos, M. N., Ovtcharova, J., & Heinz, S. (2012). Fabrikplanung im Fokus: Im Spannungsfeld zwischen Anlagen und baulichen Strukturen. In *Bautechnik 89.4* (pp. 257-263).

Ludewig, J., & Lichter, H. (2010). *Software Engineering.*

Mar, K., & Schwaber, K. (2002). *Scrum with XP.*

Martin, H. (2016). *Transport- und Lagerlogistik Systematik, Planung, Einsatz und Wirtschaftlichkeit.*

Martin, R. (2012). *Agile Software Development.*

Matt, D. (2005). *Design of self-contained, adaptable factory modules.*

Melo, C. O., Santos, V., Katayama, E., Corbucci, H., Prikladnicki, R., Goldman, A., & Kon, F. (2013). The evolution of agile software development in Brazil. In *Journal of the Brazilian Computer Society* (pp. 523-552).

Narasimhan, R., Swink, M., & Kim, S. W. (2006). Disentangling leanness and agility: an empirical investigation. In *Journal of operations management 24.5* (pp. 440-457).

Nerur, S., Mahapatra, R., & Mangalaraj, G. (2005). Challenges of Migrating to Agile Methodologies. In *Communications of the ACM* (pp. 73-78).

Padberg, F., & Tichy, W. (2007). Schlanke Produktionsweisen in der modernen Softwareentwicklung. In *Wirtschaftsinformatik 49. Jahrgang* (pp. 162-170).

Pawellek, G. (2014). *Ganzheitliche Fabrikplanung: Grundlagen, Vorgehensweise, EDV-Unterstützung.*

Petersen, K., & Wohlin, C. (2009). A comparison of issues and advantages in agile and incremental development. In *Journal of systems and software 82.9* (pp. 1479-1490).

Qumer, A., & Sellers, B. (2008). An evaluation of the degree of agility in six agile methods and its applicability for method engineering. In *Information and software technology 50.4* (pp. 280-295).

Ramsin, R., & Paige, R. (2008). *Object oriented software development methodologies.*

Rao, K. N., Naidu, G. K., & Chakka, P. (2011). A Study of the Agile Software Development Methods, Applicability and Implications in Industry. In *International Journal of Software Engineering and Its Applications* (pp. 35-46).

REFA. (1985). Methodenlehre der Planung und Steuerung.

Reichardt, A., & Holweg, M. (2007). *Creating the Customer-responsive Supply Chain: A Reconciliation of Concepts .*

Rising, L., & Janoff, N. S. (2000). The Scrum Software Development Process for Small Teams. In *IEEE software* (pp. 26-32).

Schenk, M., Wirth, S., & Müller, E. (2010). *Factory Planning Manual Situation-Driven Production Facility Planning.*

Schenk, M., Wirth, S., & Müller, E. (2014). *Fabrikplanung und Fabrikbetrieb Methoden für die wandlungsfähige, vernetzte und ressourceneffiziente Fabrik.*

Schneider, S. (2015). *Agile Prozessplanung im Produktentstehungsprozess am Beispiel der Motorenproduktion.*

Scholz, D. (2010). *Innerbetriebliche Standortplanung Das Konzept der Slicing Trees bei der Optimierung von Layoutstrukturen.*

Schuh, G. (2005). Fabrikplanung in Zeiten der Globalisierung. In *wt Werkstattstechnik online 95* (p. 174).

Schuh, G., Gottschalk, S., Lösch, F., & Wesch, C. (2007). Fabrikplanung im Gegenstromverfahren.

Schuh, G., Kampker, A., & Wesch-Potente, C. (2011). Condition Based Factory Planning. In M. Merklein, & H. Hagenah, *Production Engineering Research and Development* (pp. 89-94).

Sharifi, H., & Zhang, Z. (2001). Agile manufacturing in practice Application of a methodology. In *International Journal of Operations & Production Management* (pp. 772-794).

Sharma, S., Sarkar, D., & Gupta, D. (2012). Agile Processes and Methodologies: A Conceptual Study . In *International journal on computer science and Engineering 4.5* (pp. 892-898).

Shenhar, A. J. (1999). Strategic Project Management: The New Framework. In *PICMET'99: Portland International Conference on Management of Engineering and Technology* (pp. 382-386).

Spundak, M. (2014). Mixed agile/traditional project management methodology – reality or illusion? In *Procedia - Social and Behavioral Sciences 119* (pp. 939-948).

Stapleton, J. (1997). *DSDM, dynamic systems development method: the method in practice.*

Straub, M. (2014). *A New Framework for Designing and Developing Cost-Effective Logistic Chains for Long Items.*

Strode, D. (2006). *Agile methods: a comparative analysis .*

Turk, D., France, R., & Rumpe, B. (2014). Limitations of Agile Software Processes. In *Third International Conference on Extreme Programming and Flexible Processes in Software Engineering* (pp. 43-46).

VDI-Richtlinien-2498. (2011). *Procedure in material flow planning - Fundamentals.*

VDI-Richtlinien-3644. (2010). *Analysis and Planning of Factory Areas.*

VDI-Richtlinien-5200. (2011). Factory Planning Planning Procedures. Blatt 1.

Vokurka, R. J., & Fliedner, G. (1998). The journey toward agility. In *Industrial Management & Data Systems 98.4* (pp. 165-171).

Wendorff, P. (2002). *An Essential Distinction of Agile Software Development Processes Based on Systems Thinking in Software Engineering Management.*

Westkämper, E. (2002). Die Digitale Fabrik - Kontinuierliche und Partizipative Planung. In J. Milberg, & G. Schuh, *Erfolg in Netzwerken* (pp. 245-260).

Wiendahl, H. P., Reichardt, J., & Nyhuis, P. (2015). *Handbook Factory Planning and Design.*

Wiendahl, H.-P., Reichardt, J., & Nyhuis, P. (2009). *Handbuch Fabrikplanung Konzept, Gestaltung und Umsetzung wandlungsfähiger Produktionsstätten.*

Williams, L. (2003). *The XP Programmer: The Few-Minutes Programmer.*

Williams, L., & Cockburn, A. (2003). Agile Software Development: It's about Feedback and Change. In *IEEE Computer 36.6* (pp. 39-43).

Wirth, S., & Müller, E. (2004). Objektmanagement und Fabrikplanung. In U. Lutz, & K. Galenza, *Industrielles Facility Management* (pp. 113-128).

Zhang, Q., Vonderembse, M., & Lim, J.-S. (2003). Manufacturing flexibility: defining and analyzing relationships. In *Journal of Operations Management* (pp. 173-191).

Online References

Agile Manifesto (25.03.2019)
http://agilemanifesto.org/iso/en/manifesto.html

Fowler (2004) (9.04.2019)
https://www.martinfowler.com/articles/designDead.html

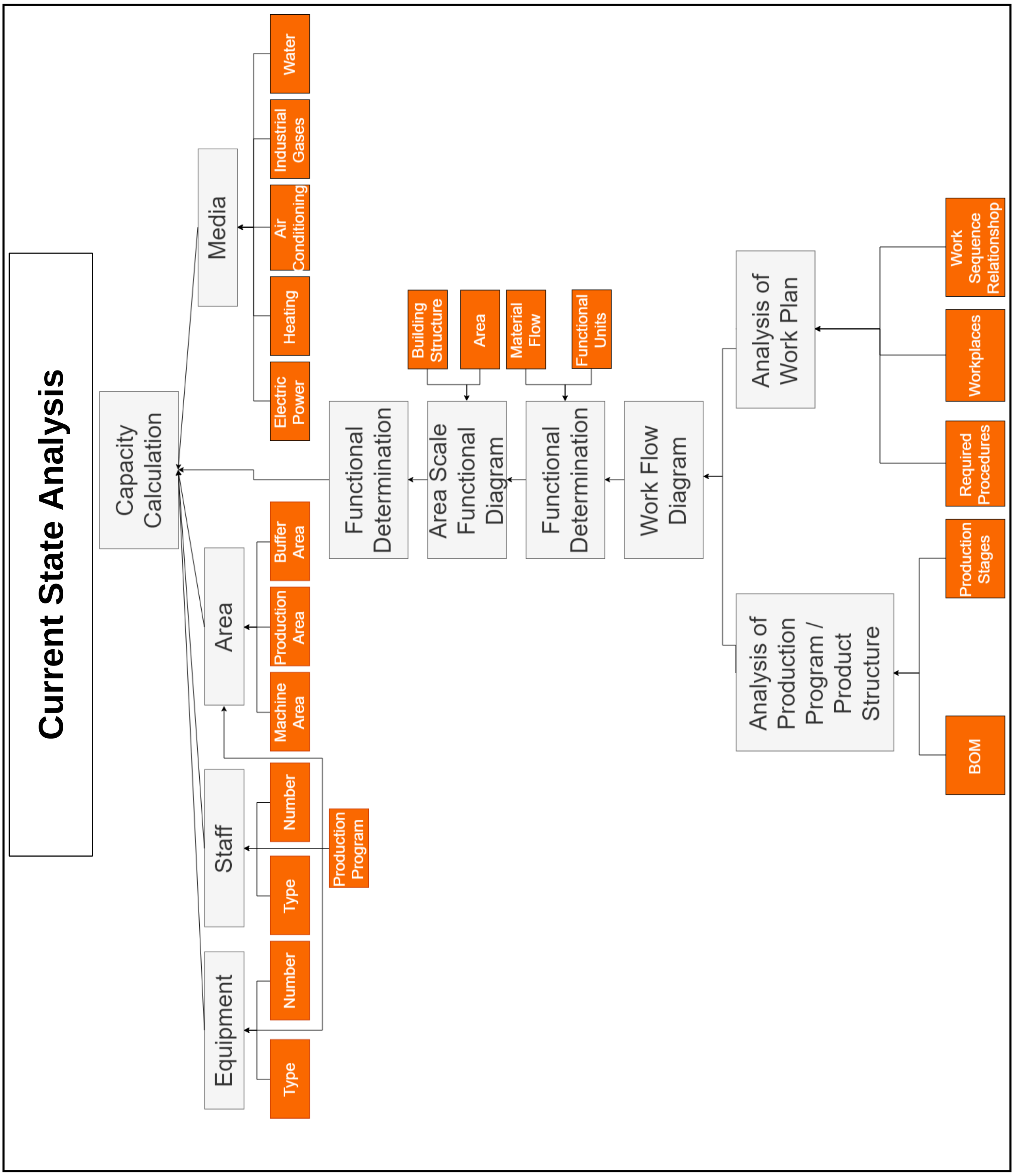
Fowler (2005) (17.04.2019)
https://www.martinfowler.com/articles/newMethodology.html

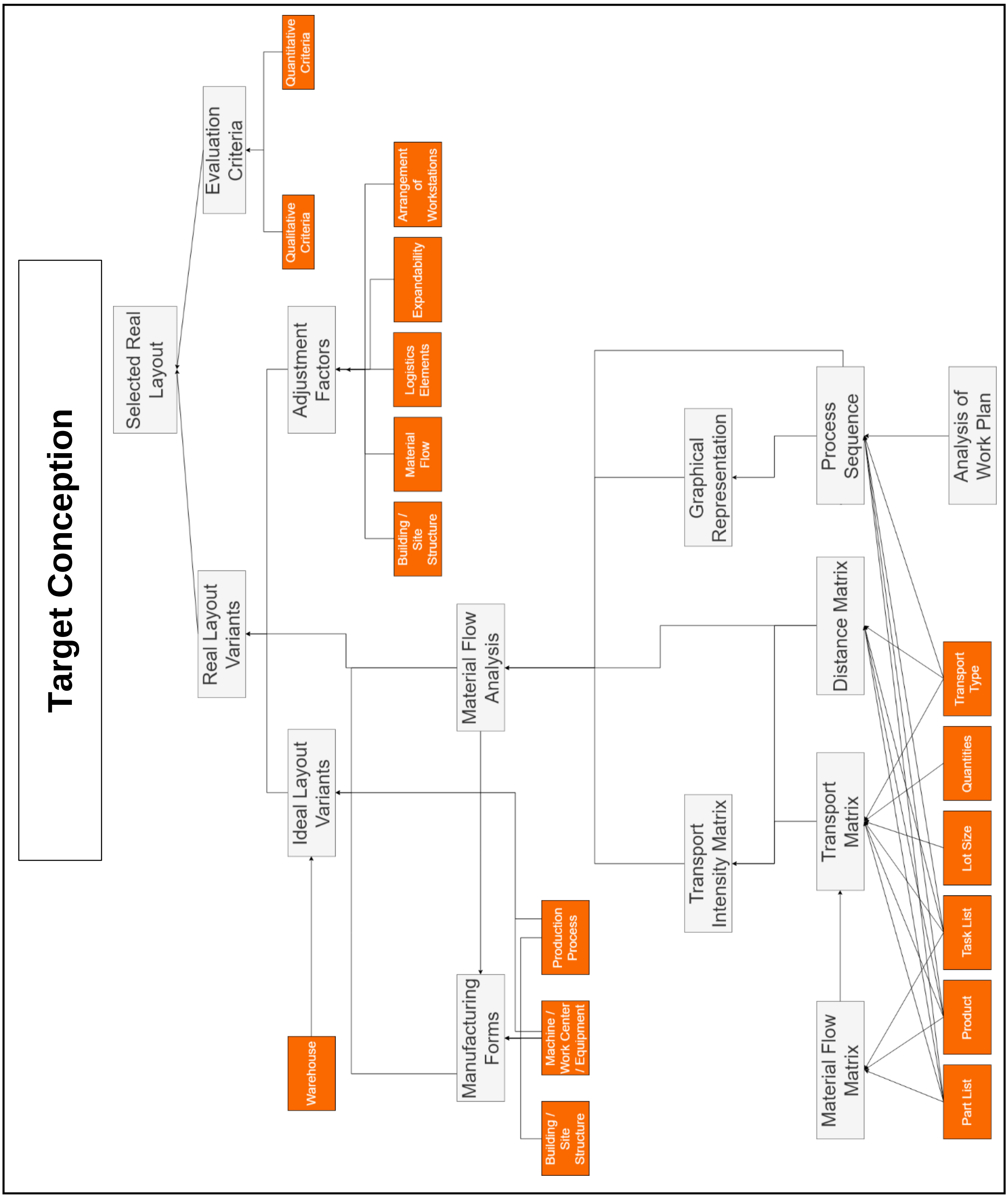
List of Figures

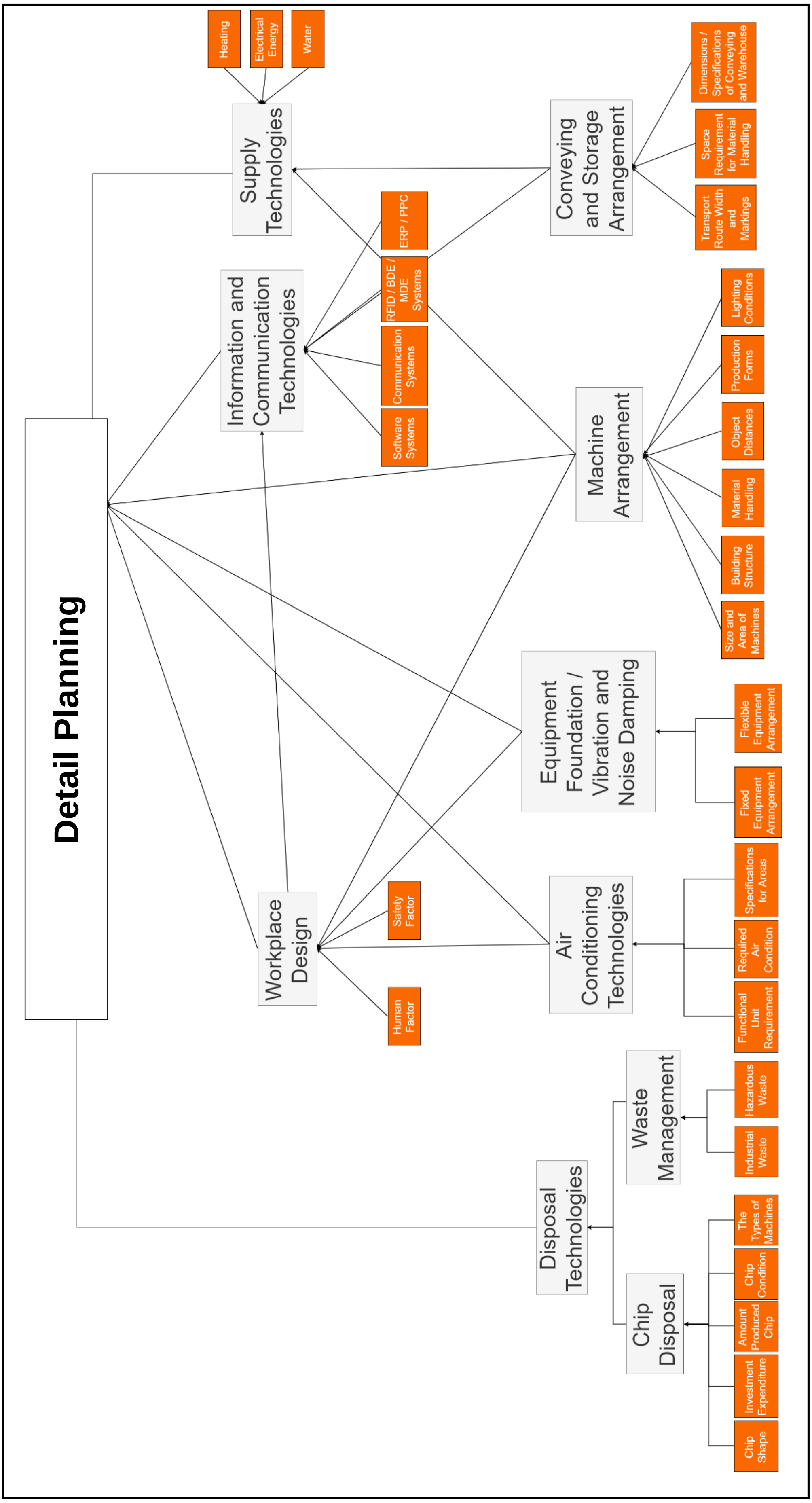
List of Abbreviations

ASD	*Adaptive Software Development*
BOM	*Bill of Materials*
CAD	*Computer Aided Design*
DSDM	*Dynamic Systems Development Method*
e. g.	*example given*
FDD	*Feature Driven Development*
IIM	*Institute of Innovation and Industrial Management*
VDI	*Verein Deutscher Ingenieure*
XP	*Extreme Programming*

Appendix A: Agile Factory Planning Approach




Target Conception
Selected Real Layout
Evaluation Criteria
Qualitative Criteria
Quantitative Criteria
Real Layout Variants
Adjustment Factors
Building / Site Structure
Material Flow
Logistics Elements
Expandability
Arrangement of Workstations
Ideal Layout Variants
Warehouse
Material Flow Analysis
Manufacturing Forms
Production Process
Machine / Work Center / Equipment
Building / Site Structure
Graphical Representation
Transport Intensity Matrix
Process Sequence
Distance Matrix
Transport Matrix
Material Flow Matrix
Analysis of Work Plan
Transport Type
Quantities
Lot Size
Task List
Product
Part List


Detail Planning
Supply Technologies
Heating
Electrical Energy
Water
Information and Communication Technologies
ERP / PPC
RFID / BDE / MDE Systems
Communication Systems
Software Systems
Conveying and Storage Arrangement
Dimensions / Specifications of Conveying and Warehouse
Space Requirement for Material Handling
Transport Route Width and Markings
Machine Arrangement
Lighting Conditions
Production Forms
Object Distances
Material Handling
Building Structure
Size and Area of Machines
Equipment Foundation / Vibration and Noise Damping
Flexible Equipment Arrangement
Fixed Equipment Arrangement
Workplace Design
Safety Factor
Human Factor
Air Conditioning Technologies
Specifications for Areas
Required Air Condition
Functional Unit Requirement
Disposal Technologies
Waste Management
Hazardous Waste
Industrial Waste
Chip Disposal
The Types of Machines
Chip Condition
Amount Produced Chip
Investment Expenditure
Chip Shape