

2 Theoretical background

In the following section, the theoretical basis for a comprehensible understanding of this thesis will be described. The focus will be set on the management of new technologies, the theoretical concept of functions, and the production logistics process.

2.1 Management of new technologies

Initially, the terms “technology” and “technology paradigm” will be defined and distinguished from similar notions in context of this thesis. The importance of managing new technologies in companies will be highlighted using theoretical concepts to classify technologies based on time and stages of their development.

2.1.1 Technology definition

The definition and distinction of the term “technology” in literature is and always was very controversially discussed. In German language, there is a distinction in content between the terms “Technologie” and “Technik”²⁴, whereas in English literature both terms are subsumed under the term “technology”.²⁵ The German terms are often mixed up, as there is missing a uniform definition of both terms.²⁶ As “technologies” are in focus of this thesis, it is vital to have a closer look at the origin of the term and its understanding.

The term “technology” is based on the Greek term “technikos,” which means craftsmanship and skillful procedures.²⁷ The original meaning of the word did change over the centuries, so that one of the latest definitions of “technology”, namely “science of art” is still insufficient as it leaves a lot of room for interpretation.²⁸ Perl defines the term “Technologie” as application-oriented, universally valid relations between ends and means. “Technologie” is a scientific-technical response relationship, which provides adequate possibilities for action in certain application areas.²⁹ Kroell defines three important statements on the term “Technologie”:³⁰

- Knowledge of scientific-technical relations, as long as its applied to solutions of technical problems, which are connected to economic, organizational, social, and political elements
- Proficiency and skills to solve technical problems
- Resources that are intended to implement scientific knowledge into practice

²⁴ Cf. Zahn, E. (1995), p. 4

²⁵ Cf. Schuh et al. (2011), p. 33 and cf. Gerpott, T. J. (2005), p. 18

²⁶ Cf. Kröll, M. (2007), p. 25

²⁷ Cf. Schuh et al. (2011), p. 33

²⁸ Cf. Spur, G. (1998), p. 77

²⁹ Cf. Perl, E. (2007), p. 18

³⁰ Cf. Kröll, M. (2007), p. 24

In summary, the term “Technologie” describes technical knowledge, namely proficiency, skills, and possibilities for the development and application of “Technik” in specific areas.³¹

Having discussed that, a definition of the term “Technik” has to be formulated. Brockhoff constitutes that “Technik” is a realized, applied element of a “Technologie”. It is the materialization of “Technologie” in products (objects)³² or procedures, which have the intention to solve technical problems.³³ A “Technologie” can be implemented in one or more “Technik”.³⁴ Kroell concludes two main descriptions for the term “Technik”.³⁵

- Material result of a problem-solving process as well as the related production and use of the same
- Realized products, equipment, materials, transformation processes, and transformation procedures

Consequently, “Technik” is the concrete existence and instrumentalization of technical objects.³⁶ Even though there is some conformity on the definition of the terms “Technologie” and “Technik” in literature, a distinction of both terms in this thesis is not necessary as (a) it is insufficient to proceed based on uncertainties, and (b) it is not expedient according to the topic and the research questions of this thesis. With the use of the term “technology paradigm” in the next section a precise distinction of the term “technology” is made. Moreover, the use of the terms “Technik” and “Technologie” in common parlance is subject to change due to its influence based on the English-American understanding of the term “technology”.³⁷ Therefore, it is smart to choose a more straightforward, though very appropriate definition of the term “technology” in this thesis, which is based on literature of the American National Academy of Engineering:³⁸

“Technology is the means by which human life is improved.”

2.1.2 Theory of technology paradigm

Having defined and distinguished the term “technology,” based on literature, it is vital to have a closer look at another term in conjunction with the management of new technologies – the technology paradigm. Within the scope of technology management, it seems that companies, in particular, have problems with managing technological

³¹ Cf. Spur, G. (1998), p. 77

³² Cf. Zahn, E. (1995), p. 4

³³ Cf. Gerpott, T. J. (2005), p. 18

³⁴ Cf. Peine, A. (2006), p. 18

³⁵ Cf. Kröll, M. (2007), p. 24

³⁶ Ibid.

³⁷ Cf. Spur, G. (1998), p. 77

³⁸ Ibid., p. 83f.

innovations if new products and procedures are connected to a different technological paradigm³⁹. An example of a technological paradigm shift is the transformation from centralized, isolated to decentralize, networked computer architecture.⁴⁰ As new technologies are characterized by new paradigm and new functionalities, which are developed based on scientific knowledge and have an enormous impact on existing structures in industry, an understanding of the term “technology paradigm” is essential.⁴¹

Thomas Kuhn, seen as the founder of the theory of paradigm, defines the term “scientific paradigm” in the late 1970’s by using two key features of this idea:⁴²

- On one hand, the term “paradigm” stands for the whole constellation of opinions, values, methods, and so forth, which are shared among members of a certain community.
- On the other hand, the term “paradigm” stands for elements of the given constellation, **which are concrete problem-solving components and are used as idols or examples to replace existing scientific solutions. Kuhn describes them as model solutions**⁴³.

In broad analogy with the Kuhnian definition of a “scientific paradigm”, Dosi defines, in his classic article in 1982, a “technological paradigm” as

*“[...] ‘model’ and a ‘pattern’ of solution of selected technological problems based on selected principles derived from natural sciences and on selected material technologies.”*⁴⁴

Tunzelmann et al. worked out the importance of Dosi’s paper for the theory of paradigm. They claim that the academic impact of the original paper is considerable and makes it one of the most highly cited papers in economics and technical change as it has received more than 670 ISI citations until 2008.⁴⁵ Based on the relevance of Dosi’s paper, his definition of “technological paradigm” will be used in this thesis.

2.1.3 Technology classification based on technology types

In literature, there are many alternatives to classify technologies. An appropriate classification method is to systemize technologies based on their current stage of development (maturity) and their importance for industry, customer, and business

³⁹ The terms “technological paradigm” and “technology paradigm” are used as synonyms in this thesis.

⁴⁰ Cf. Gerpott, T. J. (2005), p. 2f.

⁴¹ Cf. Heubach, D. (2008), p. 30

⁴² Cf. Kuhn, T. S. (1976), p. 186

⁴³ Cf. Peine, A. (2006), p. 48

⁴⁴ Dosi, G. (1982), p. 152

⁴⁵ Cf. Tunzelmann et al. (2008), p. 467

sectors.⁴⁶ Spur calls this innovation-orientated classification of technology types.⁴⁷ This classification is directly linked to technology life cycle models.⁴⁸ The life cycle of a technology gives information on ideal-typical courses of development of technologies. Life cycles represent a generalization of concrete, time-dependent observations of technology developments.⁴⁹ There are several theoretical models on the life cycle of technologies such as Gartner's Hype Cycle Model, Ansoff's technology live cycle model, and so on, which will not be explained in detail in this thesis.⁵⁰ A more expedient classification of technologies, as mentioned previously, is the innovation-oriented classification of technology types. There are three different technology types: pacemaker technologies, key technologies, and basic technologies.

Pacemaker technologies

Pacemaker technologies are at a very early stage of development.⁵¹ Those are potential key technologies of tomorrow if they reach the stage of a product or process innovation.⁵² Due to its stage of development, only a few companies have implemented these technologies. They have a big potential for creating high value for businesses, but also constitute a potential risk factor.⁵³ The expectations on sustainable impact pacemaker technologies on market potentials are significant because of their strategic importance for competition.⁵⁴

Key technologies

Key technologies develop from the previously mentioned pacemaker technologies.⁵⁵ They ensure and possibly facilitate market growth, as they have been introduced as innovations.⁵⁶ Key technologies create a sustainable impact on strategic differentiation against competitors in a certain sector. Several leading companies have already implemented these technologies. Thus, new competitors are attracted by the prejudices of the technologies.⁵⁷ The investments for the development of these technologies are still high (in relation to basic technologies) due to its potential extension to other application areas.⁵⁸

⁴⁶ Cf. Heubach, D. (2008), p. 35

⁴⁷ Cf. Spur, G. (1998), p. 87

⁴⁸ Cf. Heubach, D. (2008), p. 35

⁴⁹ Cf. Schuh et al. (2011), p. 37

⁵⁰ Ibid., 38ff.

⁵¹ Cf. Zimmermann, K. (2007), p. 2

⁵² Cf. Perl, E. (2007), p. 50

⁵³ Cf. Gerybadze, A. (2004), p. 130f.

⁵⁴ Cf. Heubach, D. (2008), p. 35

⁵⁵ Cf. Zimmermann, K. (2007), p. 2

⁵⁶ Cf. Spur, G. (1998), p. 87

⁵⁷ Cf. Gerybadze, A. (2004), p. 130f.

⁵⁸ Cf. Perl, E. (2007), p. 50

Basic technologies

Basic technologies are tested, approved, and already standardized in one or more industry sectors. Their potential to grow and their potential for change are bailed out.⁵⁹ These technology types, on the one hand, are responsible for business success, but, on the other hand, are not able to ensure competitive advantage anymore.⁶⁰ The use of fundamental technologies in certain sectors is a requirement for playing a considerable role in that area of activity.⁶¹

Another important technology type, which does not fit into the above-mentioned classical model from literature, but has a significant importance, is called cross-sectional technology. Cross-sectional technologies are also called enabling or platform technologies. They are characterized by their application in different areas, as they are the basis for other technologies.⁶² Information and communication technology (ICT) and microelectronics are good examples of cross-functional technologies, as they penetrate most economic and social areas.⁶³ The innovation-oriented technology types, previously mentioned, can also be perceived as cross-sectional technologies if they are used in different application areas.

2.1.4 Technology and innovation management as strategic cornerstones

Technologies have a significant influence on the competitiveness of companies. On the one hand, technologies represent new strategic company resources with considerable development opportunities. On the other hand, new technologies threaten those companies, which base their strategic position of success on outdated technologies. Hence, companies are forced to develop new, customer-oriented technologies rapidly, implement and substitute them on time.⁶⁴ Wolfrum (1995) claims that technologies might be perceived as a weapon for competition, as unique technological knowledge increasingly takes in a leading position for establishing the new potential for company success.⁶⁵ An appropriate technology management nowadays is pivotal to secure the existence of an enterprise in the long term. By definition, technology management can be described as the management of technological knowledge and proficiency. It includes the provision, storage, and utilization of knowledge particularly in the field of natural sciences and engineering.⁶⁶ Technology management represents a subsection of the

⁵⁹ Cf. Perl, E. (2007), p. 49

⁶⁰ Cf. Spur, G. (1998), p. 87

⁶¹ Cf. Gerybadze, A. (2004), p. 130f

⁶² Cf. Heubach, D. (2008), p. 36

⁶³ Cf. Zahn, E. (1995), p. 4

⁶⁴ Cf. Klapper et al. (2011), p. 6

⁶⁵ Cf. Wolfrum, B. (1995), p. 244

⁶⁶ Cf. Perl, E. (2007), p. 25

company management in terms of content.⁶⁷ Essential tasks of the technology management process are planning, organization, and controlling of technological knowledge.⁶⁸ A special focus in the literature is set on the planning aspect of technology management, where the planning activities shall ensure the strengthening of a company's market position.⁶⁹ Due to an increased responsibility and importance of the technology administration in a business's organizational structure, the development of technology strategies gains remarkable attention.⁷⁰ A technology strategy describes how a company should use its technologies to stay competitive on the market.⁷¹ The technology strategy defines technological objectives and gives hints to target the achievements. It denotes the usage of technologies according to their purpose and targeted technological level of performance. Moreover, the technology strategy determines at which dates technologies are implemented and where to procure them.⁷² Gerybatze (2004) emphasizes the consistent integration of a technology strategy into the corporate strategy of a company. He adds that successful technology-oriented companies show a particularly high "fit" between corporate strategy, business strategy, and technology strategy.⁷³ To justify the process-oriented character of technology management there have been six essential, interconnected activities identified, which can be seen as the ground pillars of a wide-ranging technology management: Technology foresight, technology planning, technology development, technology utilization, technology protection, and technology evaluation.⁷⁴ The content of this thesis will be located among two activities of the technology management process, responsively **technology foresight** and **technology evaluation**, due to the intention of identifying technology potential and deriving recommendations for action for technology supplier and technology user. Both activities will be briefly described in the next section.

In some fundamental literature on theory of technologies the authors claim, that technology management is to a certain degree an integrative part of innovation management. In fact, both areas of management have a cross-sectional character with overlaps but still are independent fields.⁷⁵ Technology management goes beyond innovation management, as its management competencies include the whole life cycle of technology. Innovation management only deals with new developments and

⁶⁷ Cf. Klapper et al. (2011), p. 6

⁶⁸ Cf. Perl, E. (2007), p. 25

⁶⁹ Cf. Klapper et al. (2011), p. 5

⁷⁰ Cf. Schulte-Gehrmann et al. (2011), p. 55

⁷¹ Cf. Wolfrum, B. (1995), p. 246f.

⁷² Cf. Schulte-Gehrmann et al. (2011), p. 55

⁷³ Cf. Gerybadze, A. (2004), p. 108

⁷⁴ Cf. Schuh et al. (2011), p. 15

⁷⁵ Cf. Zahn, E. (1995), p. 15

introductions of technologies.⁷⁶ The field of activity of innovation management is oriented on product development processes and market launch processes.⁷⁷ The Organization for Economic Co-operation and Development (OECD) defines the term innovation as “[...] first-time application of science and technology in a completely new way combined with economic success.”⁷⁸ The term innovation in turn has to be distinguished from the term invention. An invention is a “realization of solutions for scientific-technical problems from the perspective of a company”. Inventions are the result of all research and development activities.⁷⁹ Brockhoff tries to bring both terms together by concluding, if a new invention has the potential for business success, investments in preparation of production, and marketing activities have to be set up to launch the invention on the market. In the case of a successful market launch, the invention turns into a product or process innovation.⁸⁰ The innovation management process, in most cases, is initiated by either a “technology push” or “market pull”. A “technology push innovation” is a supply-induced innovation, which is often developed through new technological developments, whereas a “market pull innovation” mostly is triggered by market-induced elements such as new customer needs.⁸¹ Gerpott makes a proper definition of the relation between technology and innovation management, which will be underlying for this thesis. Gerpott uses the term strategic technology and innovation management (TIM) to describe a technology-oriented innovation management, which mostly includes the above-mentioned tasks of the technology management process such as planning, organization, and controlling of new technologies.⁸² In particular, the following three main goals are targeted:⁸³

- **Provision** of new technologies for the company
- **Realization** of technologies in new products and/or new processes
- **Utilization** of new technologies, which were elaborated by the company or other, external institutions

The main objective of TIM is to realize a technology position of the company, which lasts a) for a longer period and b) significantly ensures or improves the strategic location of the success of the enterprise.

⁷⁶ Cf. Zahn, E. (1995), p. 15

⁷⁷ Cf. Klapper et al. (2011), p. 8

⁷⁸ Cf. Spur, G. (1998), p. 161

⁷⁹ Cf. Gerpott, T. J. (2005), p. 25

⁸⁰ Cf. Brockhoff, K. (1994), p. 28

⁸¹ Cf. Gerpott, T. J. (2005), p. 51f.

⁸² Ibid., p. 57

⁸³ Ibid.

Accentuations were made by the author.

2.1.5 Technology foresight and technology evaluation

Successful companies often have a technological basis, which enables them to defend their sustainable competitive advantage. This technological basis is subject to constant change due to environmental circumstances, such as new customer needs or innovative technology developments.⁸⁴ Hence, companies are constantly well advised to monitor the market for emerging technology developments to protect or expand their strategic position on the market. This monitoring is the central idea of an extensive technology foresight. The main objective of technology foresight is to identify and evaluate systematically relevant technologies to elaborate essential information concerning future decision-making processes of the management on technology strategy (see chapter 2.1.3).⁸⁵ Through an extensive technology foresight, a company shall at an early stage get the chance (a) to build up own competencies on “highly promising” technologies, and (b) to procure technology-based assets from technology suppliers and integrate them into existing business processes.⁸⁶ In technology foresight, the foundations for decisions on future technological innovation activities of a company are laid. Thus, the quality and the type of information is vital. They include (among others):⁸⁷

- Potential for further developments of technologies
- Limitations of existing technologies
- Relations of technologies and possible substations
- Expected disruptions in the development of technologies (technological discontinuities)

Next to the identification of potential technologies, especially the evaluation of new technologies plays an essential role.⁸⁸ Technology evaluation has within the technology management process a cross-functional character. It serves in different decision-making processes as an important source of information. Decisions, which require a technology evaluation, occur in all of the six above-mentioned basic technology management activities (see chapter 2.1.3).⁸⁹

The term technology evaluation has to be distinguished from technology assessment⁹⁰. The process of technology assessment analyzes indirect effects of new technologies on all areas of social life. Technology evaluation, as previously mentioned, generally makes

⁸⁴ Cf. Wellensiek et al. (2011), p. 89

⁸⁵ Ibid., p. 90

⁸⁶ Cf. Gerpott, T. J. (2005), p. 101f.

⁸⁷ Ibid. and cf. Haag et al. (2011), p. 313

⁸⁸ Cf. Haag et al. (2011), p. 313

⁸⁹ Ibid., p. 309

⁹⁰ For the sake of avoiding misunderstandings the German translation of the term will be provided – Technology assessment = Technologiefolgenabschätzung

statements on the impacts of a technology for a certain company.⁹¹ There are several methods for the execution of technology evaluation, which are determined in VDI Guideline 3780⁹² such as cost-benefit assessment, Delphi- Method and risk analysis just to name a few.⁹³ For a successful technology evaluation the chosen evaluation criteria, which depend on the goals of the assessment, play a significant role. In literature several criteria, such as costs, quality, flexibility, and so forth can be found.⁹⁴ Heubach in his dissertation, which was a big inspiration for the methodical approach of the present thesis, uses technological functions as evaluation criteria to examine the technological relevance of nanotechnologies in product planning processes.⁹⁵ The usefulness of functions as evaluation criteria for technologies in the context of Industry 4.0 will be explained in chapter 2.2.2.

The illustration in figure 2 puts important theoretical concepts of the previous chapters into the contextual relationship of this thesis.

⁹¹ Cf. Haag et al. (2011), p. 311

⁹² VDI Guidelines are rules for the procedure of scientific-technical processes made by the Association of German Engineers (Verein Deutscher Ingenieure, VDI)

⁹³ Cf. Kröll, M. (2007), p. 39

⁹⁴ Ibid. 56ff.

⁹⁵ Cf. Heubach, D. (2008), p. 42

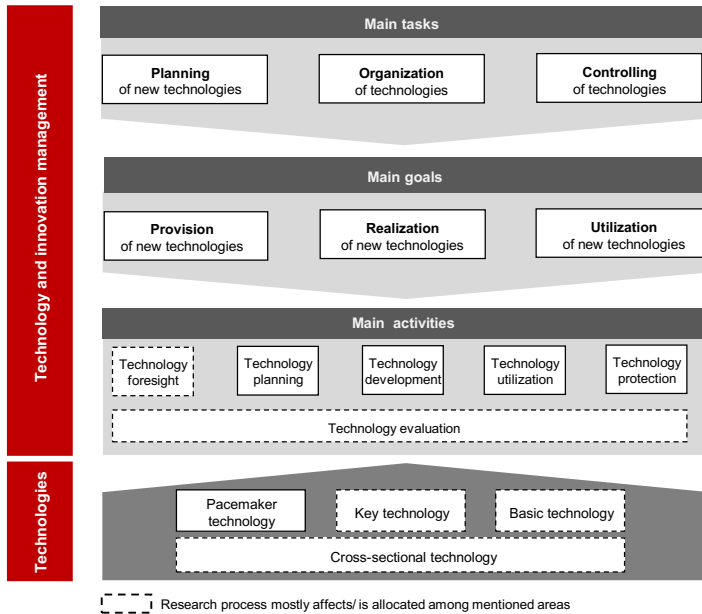


Figure 2: Technology and innovation management
(Source: Own representation)

2.2 Function aspect of technologies

In this section, initially the term function will be explained and afterwards its importance concerning the identification of technology potential will be emphasized.

2.2.1 Function definition

In literature, there are many definitions of the term “function”.

Concerning technology, a very accurate definition, and distinction is made by Spur (1998). He describes the function of a technology and a technological system as “[...] *explicit, reproducible relationship between input and output parameters.*”⁹⁶ The standard DIN EN 1325 defines technological function more output-oriented as the “[...] *effect of a product or its components.*” The term “effect” in this context has to be understood as “procedure” or as “result” of an effect of a component.⁹⁷ The guideline VDI 2803 refers to DIN standard 66910, where the term function is defined in a relation to value

⁹⁶ Cf. Spur, G. (1998), p. 29

⁹⁷ Cf. DIN EN 1325, p. 10

analysis.⁹⁸ VDI 2803 defines an important module of value analysis, namely the function analysis. Function analysis tries to identify functions of products, processes, and services in the theory of design, to achieve optimal performance. It analyzes the effects, purposes, and concepts of objects. Moreover, VDI 2803 standardizes the methodical procedure of a function analysis and defines central terms such as function classes, and function types. Just to name a few, there are primary functions, overall functions, and undesirable functions.⁹⁹ In VDI 2803, the formulation of functions is also standardized. According to this, functions have to be described with a noun and a verb, e.g. “transmit torque.”¹⁰⁰ In this thesis, such a formulation will be refused, as the technologies of Industry 4.0 are quite unexplored, and a too detailed disassembly of functions would not be expedient, especially for the empirical study.

According to DIN EN standard 1325, a difference is made between user-oriented functions and product-oriented functions of a product, process, or service. User-oriented functions are defined as an effect, which is expected of the product to fulfill a part of the user’s needs. Whereas product-oriented functions affect a component of a product or rather the effect between the elements of a product to fulfill the previously mentioned user-oriented functions.¹⁰¹ By referring to DIN EN 1325, Heubach emphasizes the constitution of technologies as **target-means combinations**. He names user-oriented functions “purpose function” and product-oriented functions “system functions”. Hence, system functions of technology (means) cause effects on a product to fulfill a “purpose function” of a product (target).¹⁰²

2.2.2 Function as evaluation criteria for technology potential

Numerous measures to evaluate technology potential can be found in literature. Spur (1998) states that technology potential can be assessed by its capacity for innovations, especially based on apparent, future-oriented factors.¹⁰³ He references Kornwachs, which claims that the potential of technology might be evaluated based on its actual and possible application areas, expected further development, chances for novel solutions to existing problems, and range of improvements for work and life quality. Tshirky understands technology potential as a socio-technical subsystem of a company, which includes the company related potential users of all available technologies and their

⁹⁸ Cf. VDI 2803, p. 2

⁹⁹ Ibid.

For more detailed information on function classes and function types see: VDI 2803.

¹⁰⁰ Ibid.

¹⁰¹ Cf. DIN EN 1325, p. 10

¹⁰² Cf. Heubach, D. (2008), p. 91.

¹⁰³ Cf. Spur, G. (1998), p. 90f.

synergies.¹⁰⁴ These approaches are not sufficient for the present research initiative. A more sophisticated and detailed approach for the evaluation of technology potential is the investigation of the capabilities of a technology in terms of material, energy, and information capability.¹⁰⁵ This approach reflects the use of technological functions as evaluation criteria, as a function by its output-oriented definition is a measure of the “effect” of a component (see previous chapter). This approach does initially imply a trade-off between the expressions of individual needs and the technological possibilities of solving a problem (user-oriented vs. product-oriented functions). Both sides seem to speak different technological “languages”, though using the same terms.¹⁰⁶ A clarification of how the application of the principle of functions as evaluation criteria for technology potential, in particular, is useful will be explained briefly.

Technological systems only make sense if they work. Consequently, the guiding principle for the development of technologies has to be targeted on functionality.¹⁰⁷ From the perspective of a customer, technological functionality means “usability” of the system and its effects. Whereas, on the other hand, functionality from the viewpoint of an engineer or a developer means “feasibility” or “technical efficiency as the output of a possible increase in performance”. Hence, the technological function has two main tasks:¹⁰⁸

- (1) The concept of function serves as value assignment. The value of technology results from its technological efficiency and innovation potential. Thus, a technology, which improves a process and so forth using a certain function, has a particular value.
- (2) The concept of function tries to solve the aforementioned problem of “different languages.” It serves as a translator between user-oriented and product-oriented perceptions of technology.

Pfeiffer claims that “thinking in functions” is especially important for the technology foresight process (see chapter 2.1.5) of the technology management, as it shows the lowest level of complexity by reducing a problem solely to its potential function.¹⁰⁹

Within the scope of this thesis, both tasks of technological functions have a special meaning. On the one hand, this thesis tries to examine the value of technologies for end-to-end digital integration based on functions (value assignment). On the contrary, the effects of technologies have to be “translated” to make the technologies accessible to

¹⁰⁴ Cf. Spur, G. (1998), p. 90f.

¹⁰⁵ Ibid., p. 94

¹⁰⁶ Cf. Heubach, D. (2008), p. 91

¹⁰⁷ Cf. Spur, G. (1998), p. 29

¹⁰⁸ Cf. Heubach, D. (2008), p. 42

¹⁰⁹ Ibid., p. 91

the experts of the empirical study. Furthermore, only product-oriented functions (system functions) will be explored within the analysis. User-oriented functions will play a minor role, as they will be identified to show the practical relevance of the identified technologies in production logistics in Chapter 6. There are three basic elements of the identified function, which constitute technology potential in this thesis:

- (1) Influence on end-to-end digital integration
- (2) Practical relevance
- (3) Market readiness

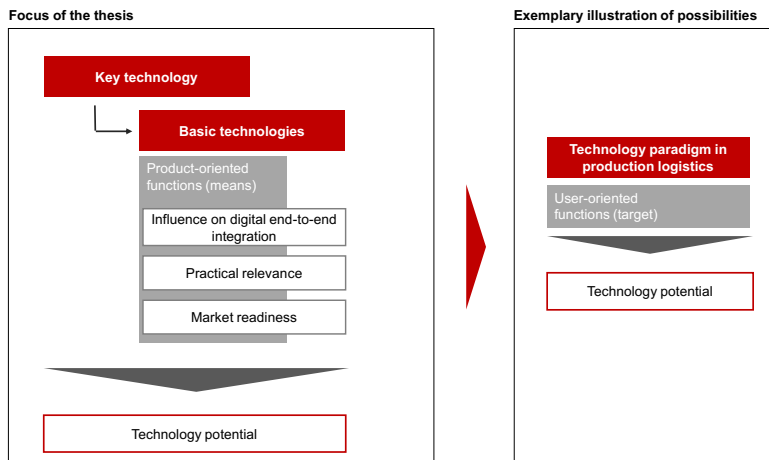


Figure 3: Underlying approach of technology potential identification

(Source: Own representation)

2.3 Production logistics

This section completes the theoretical background information. The terms “logistics” and “production logistics” will be defined, described based on their main tasks, and brought into the context of this thesis’ research initiative.

2.3.1 Logistics definition

The origin of the term “logistics” can be traced back to the 19th century, where it was defined as planning of supply and troop movements in military terms. The French term “logis” means troop accommodation and is said to be the root of the term “logistics.” A relation to the Greek term “logos” (logic), which often is mentioned as the origin of the

term “logistics,” is questionable.¹¹⁰ The importance of logistics, as a management discipline, was never as big as it is currently. Baumgarten, which is an essential pioneer and forerunner of the massive development of logistics, states that 30 years ago no one would believe that the logistics of the 21st century is a significant factor for competition and simultaneously a meaningful source of hope for German economy.¹¹¹ Logistics for a long time was simply reduced to the classical triad of the functions storage, handling, and transport. This picture has changed over the years. Today’s logistics is faced with enormous social responsibility, e.g. in dealing with questions of demographic change, climate change, sustainability, and resource efficiency.¹¹² Even though nowadays no one can deny the practical relevance of logistics, the basic understanding of the scientific discipline logistics differs considerably. This variance probably arises due to its multifaceted nature and diversity of topics.¹¹³ A very basic, though appropriate understanding, defines logistics as “[...] the holistic planning, controlling, coordination, execution and monitoring of all company internal and company external flows of information and goods.”¹¹⁴ The same flow-oriented approach is used by the American Council of Supply Chain Management Professionals (CSCMP), which defines logistics as follows: “[...] the part of a supply chain process that plans, implements, and controls the efficient, effective forward and reverse flow and storage of goods, services, and related information between the point of origin and the point of consumption in order to meet customers’ requirements.”¹¹⁵ Hence, the major characterization of logistics in comparison to other scientific disciplines is its flow orientation, which is the first underlying principle. From this particular point of view, economic phenomenon and relationships are perceived as flows of objects, goods, people, and values through chains and networks of activities and processes.¹¹⁶

A second underlying principle of logistics is its holistic view of activities, systems, and networks. The management and the execution of individual storage or transport processes, for example within a factory, has always been a primary task of logistics (see above). The particular way of the “logistical thinking” is the consideration of several processes simultaneously as “one flow” in a network and its coordination concerning the overall objectives of the system.¹¹⁷ Pfohl (2010) calls this phenomenon “system theoretical approach” of logistics, in short “systems thinking.” He claims that the

¹¹⁰ Cf. Arnold et al. (2008), p. 3

¹¹¹ Cf. Baumgarten, H. (2008), p. 13

¹¹² Cf. Hompel, M. ten et al. (2014), p. 3

¹¹³ Cf. Delfmann et al. (2011), p. 1

¹¹⁴ Cf. Hompel, M. ten et al. (2014), p. 6

¹¹⁵ Cf. Pfohl, H.-C. (2004), p. 3

¹¹⁶ Cf. Clausen, U.; Geiger, C. (2013), p. 4

¹¹⁷ Cf. Arnold et al. (2008), p. 3f.

questions to be considered are not “which” logistics tasks are addressed but rather “how” logistics tasks are tackled. “Systems thinking” has its origin in biology, where it defines a certain number of interconnected elements. The main characteristic of “systems thinking” is the finding that it is not possible to explain the entire system by explaining its parts. To define the complete possibilities of a system, the relationships of the systems’ elements also have to be considered.¹¹⁸

2.3.2 Production logistics as phase-specific subsystem of logistics

A distinction of logistics systems is necessary concerning different challenges and problems, which arise in the planning and design process of logistics systems. Pfohl (2010) points out two different approaches, which are based on the scope and the point of view (aggregation level) on logistics systems. From the perspective of the aggregation standards of a logistics system, it is differentiated between macro, micro, and meta level.¹¹⁹ Logistics systems on the macro level have macroeconomic dimensions, such as the entire freight transport (road, rail, and sea), whereas micro logistic systems consequently have micro economic dimensions. They deal with logistic systems of, for example, hospitals, military, and individual companies.¹²⁰ Meta logistics is in between both previous mentioned logistic systems.¹²¹ A more functional distinction, which meets the requirements of the above-mentioned flow orientation of logistics, is the phase-specific view on in logistics subsystems and its flow of goods (see figure 4).¹²²

¹¹⁸ Cf. Pfohl, H.-C. (2010), p. 25f.

¹¹⁹ Ibid., p. 14ff.

¹²⁰ Cf. Wannenwetsch, H. (2014), p. 14

¹²¹ Cf. Pfohl, H.-C. (2010), p. 14ff.

¹²² Ibid., p. 16f.

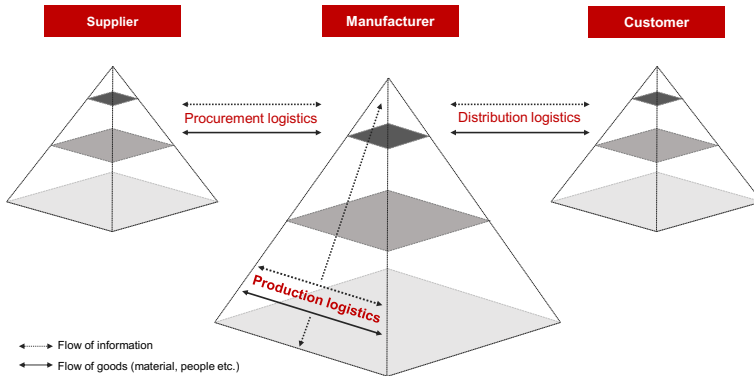


Figure 4: Phase-specific view on logistic subsystems
(Source: Own representation based on Schuh et al. (2011))

The flow of goods starts with the procurement and the following flow of raw materials, auxiliary materials, and consumables from the supplier network. This phase is called *procurement logistics* and handles the availability of manufacturing goods, which are not produced by the company itself. It includes all necessary activities to supply the production side with all needed production inputs.¹²³ The second phase, where all the delivered and partially stored raw materials, components, semi-finished goods, and finished products are transported to either manufacturing stations or internal warehouses is called *production logistics*.¹²⁴ In literature, the term *intra logistics* is often used as a synonym for production logistics.¹²⁵ The third phase is characterized by flows of semi-finished goods and finished products either to distribution warehouses or directly to the customer. This phase is called *distribution logistics*.¹²⁶ Within the scope of this thesis, the focal point is set on the production logistics of a company and its main tasks, which will be explained as follows.

2.3.3 Main tasks

The manufacturing industry follows logistics, not the other way round, as it was the practice in recent centuries (see chapter 2.3.1).¹²⁷ This ongoing change of logistics, as management discipline, has especially consequences for the tasks in production

¹²³ Cf. Schuh et al. (2011), p. 13

¹²⁴ Cf. Pfohl, H.-C. (2010), p. 17

¹²⁵ Cf. Arnold et al. (2008), p. 5

¹²⁶ Cf. Pfohl, H.-C. (2010), p. 17

Pfohl mentions a fourth phase, *disposal logistics*, which is not explained explicitly here, as it's not a part of the value creation process and therefore has no considerable meaning in the context of this thesis.

¹²⁷ Cf. Auffermann et al. (2014), p. 6

logistics. The core task of logistics can be formulated very appropriately using the so-called Six-R-Rule of logistics, which simultaneously describes the main goals of logistics. According to this, Logistics handles the supply of the right *product*, in the right *quantity*, with the right *quality* at the right *time*, at the right *place* and to the right *costs*. To fulfill the “six-Rs”, the execution of main logistics processes such as transport, handling, storage, commissioning, and packaging has to be guaranteed.¹²⁸ An adequate execution of logistics process cannot be assured without prior planning and control processes. This leads to the planning functions of production logistics, which by many authors are seen as vital competencies of production logistics. Production logistics deals next to execution with “[...] the planning, control and monitoring of production and internal transport, handling, and warehousing processes.”¹²⁹ Pawellek emphasizes the flow-oriented perspective on the tasks, where the production inputs are moved “[...] from a raw material warehouse through phases of production processes into a finished goods warehouse.”¹³⁰ According to Arnold, these tasks can be assigned to the phase-specific view on logistics subsystems (see previous Chapter) to create a planning matrix. Within this matrix, the activities can be systemized by three different levels of planning, namely the long-term strategic, the middle-term operative, and the short-term operative planning of internal processes (see below figure 5). In terms of production logistics, especially the middle-term operative and short-term operative planning have a certain relevance. Initiated by customer orders, the middle-term planning involves the following processes:¹³¹

Production planning process:

- Production program planning
- Quantity planning (material requirements planning)
- Planning of deadlines and capacities

The short-term operative planning sometimes is used as synonym for production control and consists of the following functions:¹³²

Production control:

- Release of customer orders

¹²⁸ Cf. Schuh et al. (2011), p. 8f. and cf. Delfmann et al. (2011), p. 3

¹²⁹ Cf. Arnold et al. (2008), p. 181

¹³⁰ Cf. Pawellek, G. (2004), p. 417

¹³¹ More detailed components such as *lead time scheduling* are not mentioned explicitly for the sake of clarity.

¹³² Cf. Arnold et al. (2008), p. 324

More detailed components such as the *forming of order sequences* are not mentioned explicitly for the sake of clarity.

- Monitoring of customer orders

The operational execution of production logistics mainly includes five different core activities, which will be briefly described in the following, as they have a particular relevance for this thesis.

The **transport**, as the term already suggests, mainly handles covering of distances of goods. It moves the goods to either warehouses or manufacturing workplaces. Each transportation system consist of transportation means, a good, which has to be transported and a transport system.¹³³ **Handling** processes deal with the loading and unloading of transportation means and storages as well as with the collection and sorting of goods. Handling processes connect external and internal flows of material and different transport sections.¹³⁴ The **storage** has the function of covering time. Goods are stored and taken out of the warehouse by various storage strategies. The storage itself is no activity, only the processes to fulfill the storage. **Commissioning** means compiling stored articles for a customer order, consisting of one or more different goods. The customer of commissioning order can be either a final customer or a working place in production, which needs stored material.¹³⁵ The **packaging** has an auxiliary function.¹³⁶ It serves as protection for the aforementioned activities, namely transport, handling, storage, and commissioning of goods. The packaging is defined by the designing process of packaging materials and actual packaging process.¹³⁷

	Long-term strategic planning	Middle-term operative planning	Short-term operative planning	Operational execution
Planning horizon	Several years	6-18 months	1-3 months	Hours, days
Activities	<ul style="list-style-type: none"> • Production depth and outsourcing strategies • Investments in production assets and storage facilities • Layout of production and warehouse • ... 	<ul style="list-style-type: none"> • Production planning <ul style="list-style-type: none"> ▪ Production program planning ▪ Quantity planning (material requirements planning) ▪ Planning of deadlines and capacities 	<ul style="list-style-type: none"> • Production control <ul style="list-style-type: none"> ▪ Release of customer order ▪ Monitoring of customer order 	<ul style="list-style-type: none"> • Transport • Handling • Storage • Commissioning • Packaging

Figure 5: Production logistics planning activities

(Source: Own representation based on Arnold (2008))

¹³³ Cf. Pfohl, H.-C. (2010), p. 149f.

¹³⁴ Cf. Arnold et al. (2008), p. 7

¹³⁵ Ibid.

¹³⁶ Cf. Pfohl, H.-C. (2010), p. 134

¹³⁷ Ibid., p. 137ff.

The above-mentioned activities are mostly combined with technical logistics systems, which support the activities by guaranteeing:

- (1) The flow of information between different planning and control activities as various data is needed to fulfill process on different levels
- (2) The flow of materials between the various manufacturing locations

The systems, connection between these systems, and resulting challenges of these systems in contextual relationship to the topic of this thesis will be explained in the next Chapter, as they are the core of the underlying research initiative.

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