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Analysis of Factors Influencing Knowledge Transfer between the Product and Production System Development as well as Production

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Abstract

The product development process is characterized by accelerating development cycles and increasing customer demands for a wide range of product variants. In addition, it is very knowledge-intensive and characterized by the reuse of knowledge in product generation engineering. Developing new products based on existing references, e.g. knowledge about design parameters or manufacturing technologies, requires effective and efficient transfer of knowledge. In a knowledge transfer, people of different domains, here product and production system development as well as production, make parts of their mental model tangible for others. When doing so, problems can occur that can cause information loss. Knowledge transfer has been reviewed in literature by multiple disciplines and defined differently amongst various understandings of its design. In this work, knowledge transfer includes the identification, transmission, and application of knowledge and thus addresses the problem of distributing knowledge within a company. To optimize knowledge transfer within the product engineering process to reduce information loss and knowledge deficits, factors that impact knowledge transfer must be considered. Therefore, this contribution examines factors that either influence the knowledge transfer positively or negatively, especially between product and production system development as well as production. In addition to a literature-based identification of influencing factors, a qualitative study interviewing experts in those fields enhances the findings. Furthermore, the collection of factors was assigned to four clusters: people, organization, technology, and knowledge and transfer. By linking the factors of each cluster, a model was created to be able to investigate the impact of changing factors within and between clusters providing a basis for closing knowledge deficits to enable effective and efficient knowledge transfer.

Keywords: knowledge transfer; influencing factor; product development; production; product development process

1. Introduction

The development of mechatronic products requires a collaboration of different disciplines and thus an intensive exchange of information and knowledge throughout the entire product engineering process [1]. In knowledge transfer, people of different domains, here product and production system development as well as production, make parts of their mental model tangible for others [2, 3]. Schmidt et al. [4] developed a model of knowledge transfer (see Fig. 1), which describes how one person, an Actor 1 (e.g., product developer), does externalize his or her implicit knowledge (stage of initiation), which is then transferred to another person, Actor 2 (e.g., production employee), through a selected channel (stage of knowledge flow). The explicit knowledge, which can be extracted is then internalized to the recipient's knowledge base. Within this process, various problems can arise, such as the lack of accessibility to knowledge, the inadequate documentation of knowledge, or the unwillingness to share knowledge [5]. These and many other problems result in knowledge deficits that may hinder effective and efficient product engineering. So, the question arises as to how successful transfer of knowledge can be ensured.

To design knowledge transfer, it is necessary to understand, which factors have a positive or negative effect on the transfer

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of knowledge. According to Albers et al. [5], knowledge transfer should be understood as a success factor for product engineering. Therefore, it is important to analyze the interrelationships of factors influencing knowledge transfer between different disciplines to be able to explore solutions that reduce or even prevent knowledge deficits.

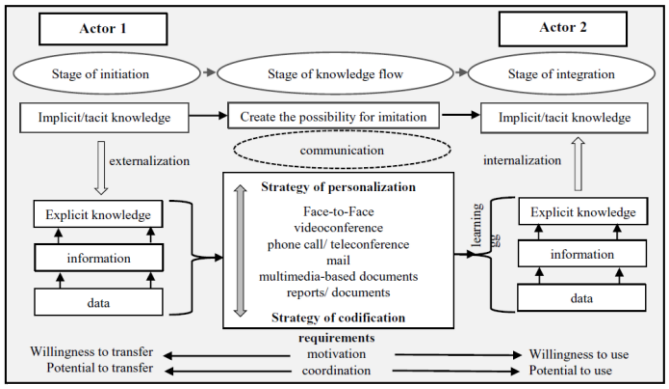


Fig. 1. Model of knowledge transfer [4]

2. State of Research

2.1. Knowledge Transfer as part of Knowledge Management

In this paper, the transfer of knowledge is referred to as a core activity of knowledge management. Knowledge management contributes to the task of providing relevant knowledge at the right time and the right place in a company. [6]

Rauter describes different process models for the transfer of knowledge [7]. According to Probst et al. [8], it includes six core processes that must be addressed. These are knowledge identification, knowledge acquisition, knowledge development, knowledge distribution and sharing, knowledge utilization, and knowledge retention. As described above, this paper focuses on knowledge transfer, in this case, knowledge distribution and sharing. Yet, if knowledge identification and knowledge utilization contribute to it, these processes are attributed to the transfer as well.

The term knowledge transfer is not defined universally and encompasses different concepts. Within those, two points emerge: knowledge transfer is a transportation problem, where knowledge must be transported to the right places within a company, and knowledge transfer is a learning problem, which must ensure the application and reapplication of knowledge. Thiel points out that both types of problems are correct and important in successful design. [9]

Here we distinguish between explicit and implicit knowledge, that is transferred. Knowledge arises from the interconnection of information with the context and is often shaped by personal experiences and expectations [10].

Implicit knowledge, which results from one's mental model, is consequently stored in people's heads and is therefore difficult to articulate. The transfer of explicit knowledge, on the other hand, is easier to implement and less context-bound. For example, this takes place through documents or documentation, training courses, or e-mails. [2, 10]

In this paper, knowledge transfer is defined according to Albers et al. [11] as the identification of knowledge, its transfer from knowledge carrier to knowledge receiver, and its application by the knowledge receiver. This understanding of knowledge transfer thus includes both the transport and the learning problem.

2.2. Knowledge Transfer in Product Engineering

Particularly against the backdrop of accelerating development cycles and increasing customer requirements for a diversity of product variants, knowledge has become increasingly relevant as an important resource in product engineering [12, 13]. In the development of a new product generation, existing knowledge from within the company or external references is used [14], which is part of the reference system of the product to be developed [15]. Storing this knowledge, distributing it, and making it usable again is a huge challenge for many companies [16]. Especially across domains, it is not always clear which knowledge is needed or needs to be provided. Often, knowledge relevant to development and production is stored in document management systems (formalized) or exchanged via face-to-face conversations (non-formalized). It is observed that the importance of problems, that occur during knowledge transfer, are not the same for various kinds of processes [17]. To be able to investigate and eliminate their causes, it is necessary to know the influencing factors of knowledge transfer. All in all, it is necessary to align cultural, managerial, and organizational elements with technological elements to profit from the benefits of knowledge management [1].

2.3. Influencing Factors on Knowledge Transfer

As stated above, successful knowledge transfer is depending on many factors. In the literature, factors influencing knowledge transfer have been discussed [5], although knowledge transfer at the interfaces to be investigated has received little attention by the time of submission. Authors who have studied this subject, identify different numbers of influencing factors and categorize them in different ways. For instance, while von Krogh & Köhne differentiate 15 influencing factors by their impact on three defined phases of knowledge transfer [18], Goh distinguishes five key factors in a framework for effective knowledge transfer [19]. Other authors identify more than 20 influencing factors and classify them by the previously mentioned clusters of people, organization, and technology or medium [20, 21, 22]. Overall, this approach to classify influencing factors identified in this work appears to be most feasible.

In total 250 factors, which influence knowledge transfer could be identified from the literature, from which 96 remained after eliminating duplicates (detailed description see Sec. 4.1). To determine which of these influencing factors affect knowledge transfer at the interfaces of product and production

system development as well as production, a methodology was defined, the procedure of which is explained in the following. Each influencing factor is formulated according to the Design Research Methodology (DRM) in this paper. Therefore, they always consist of an attribute and an element, whose influenceability is determined by the attribute and thus makes the factor measurable [23]. For instance, the *degree of trust*, the

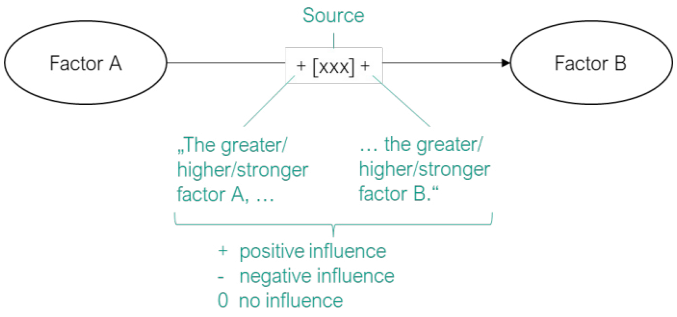


Fig. 2. Visualization of the interdependency of two influencing factors in a Reference Model following [21]

generality of knowledge, or *personal openness* are influencing factors that correspond to this scheme. Thus, the degree is the attribute that describes the respective elements of trust, the generality of knowledge, and personal openness.

This way of formulating influencing factors is required within the framework of the DRM to create a Reference Model which visualizes the interconnection of influencing factors and therefore displays the complexity of a topic. To do so, two factors are connected by an arrow, the tip of which indicates the direction of its effect. Additionally, algebraic signs labeled on each side of the source, indicate the impact of the influencing factor A on the influenced factor B [23]. Fig. 2 visualizes the schematic structure for better understanding.

The arrows and labels in green are for explanation purposes only, hence, are not part of the actual Reference Model.

3. Aim of Research and Methodology

According to the current state of research, the design of a successful knowledge transfer is challenging, as many problems can arise in this process and many factors impact it. To meet these challenges, it is essential to develop an understanding of which influencing factors contribute significantly to the knowledge transfer at the interface of product and production system development as well as production.

This contribution aims to identify initial fields of action for the transfer of knowledge at these interfaces, serving as a basis for the future development of processes, methods, and tools that support the reduction or prevention of knowledge deficits. This leads to the following research questions (RQ):

1. Which influencing factors from the literature describe knowledge transfer in product and production engineering?
2. Which influencing factors occur particularly at the interfaces between product and production system engineering as well as production?
3. What interactions and connections exist between these influencing factors?
4. Which fields of action can be derived from this regarding knowledge transfer?

To address these research questions, the procedure according to Fig. 3 is defined. The grey boxes represent methods and input for the analysis, whereas the green boxes represent the main results of this contribution.

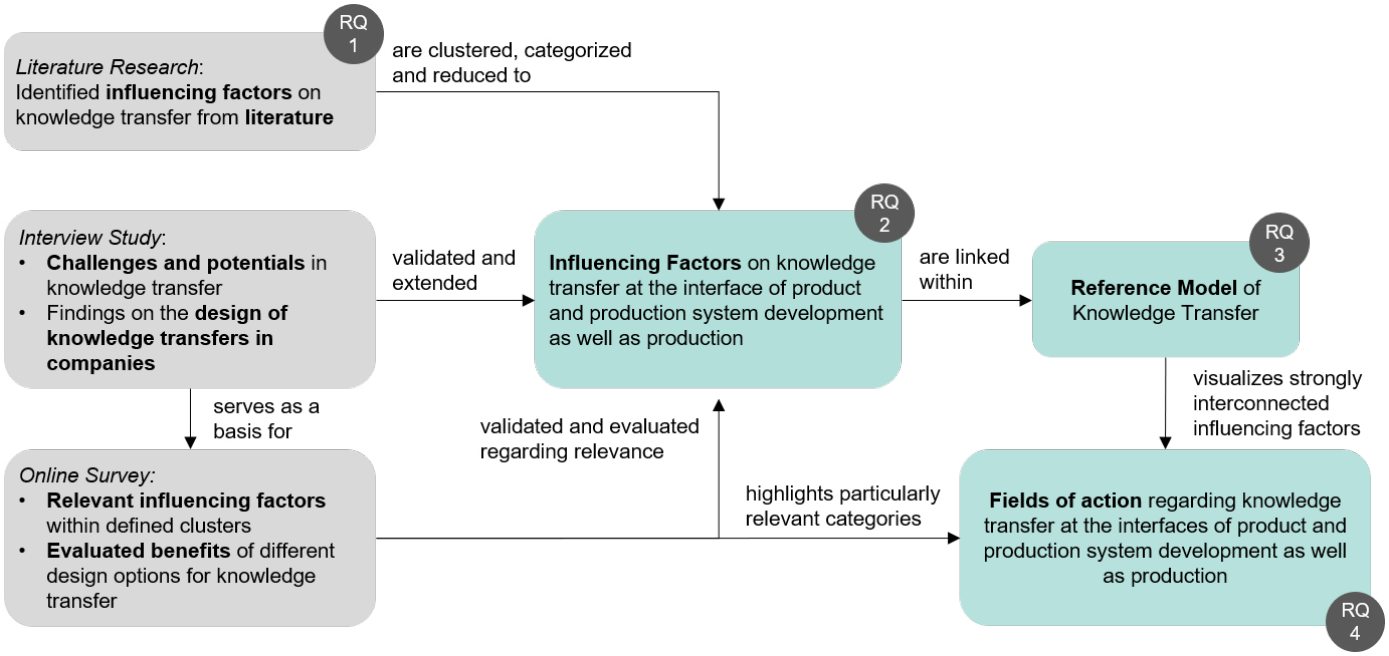


Fig. 3. Procedure to identify fields of action regarding knowledge transfer at the interfaces of product and production system development as well as production

4. Results

4.1. Influencing Factors on Knowledge Transfer at the Interface of Product and Production System Development as well as Production

To identify influencing factors on knowledge transfer a Systematic Literature Review was conducted in the field of product and production engineering. Pre-defined search terms were applied to six databases (e.g. Scopus, Springerlink, Google Scholar). From the total of all search results obtained, 48 contributions were considered particularly relevant after the examination of the title, abstract and full text and have been further analyzed. In total 20 contributions provided influencing factors on knowledge transfer.

Due to the explicit naming of influencing factors in the literature as well as the influencing factors extracted based on the summarizing content analysis, a total of 250 factors impacting knowledge transfer, in general, could be identified. Thereof, 96 factors remained after eliminating duplicates (RQ1). These include exact and logical duplicates (e.g. motivation of the participants and motivation of knowledge sender and receiver) as well as factors in different languages (German or English) where only one translation was considered relevant. To identify, which factors impact knowledge transfer, particularly between product development, production system development (RQ2) further excluding criteria have been defined (e.g. factor that relates to one or more interfaces). In total, 61 influencing factors were identified.

To enhance and further verify the influencing factors from the literature, six professionals and managers mostly from technical industries were surveyed as part of an interview study. Their professional experience ranges from two to 18 years and thus provides a differentiated picture of the transfer of knowledge in and between product and production engineering. In addition to the 61 influencing factors, further 22 factors were specifically named in the interviews, which also have been identified in the 96 influencing factors from literature. Another five influencing factors were defined based on a summary content analysis of the interviews according to Mayring [24]. Altogether, 88 influencing factors were identified and validated and therefore considered for the creation of the Reference Model.

Those 88 influencing factors were grouped into clusters, considering all relevant levels of holistic knowledge management: people, organization, and technology. In addition, the cluster *knowledge and transfer* was created, which contains all the influencing factors regarding the characteristics of knowledge and transfer per se and thus cannot be directly assigned to one of the other three clusters. Influencing factors arising from the external environment, such as the labor market situation or political factors, are out of the scope of this paper, as they cannot be influenced by the company or the employees themselves.

Within the clusters, categories delimit the factors from each other. This further differentiation helps to identify specific points or areas when targeting the reduction of knowledge deficits. To achieve this, the factors were questioned as to where does the execution of the factor happens. For instance, the factor existence of an incentive system could be allocated to the category leadership or company within the cluster organization. Questioning the execution clarifies its mapping to the category leadership. Where despite this, a clear allocation was not possible, an allocation to multiple clusters or categories respectively was carried out, considering the exact wording of that factor.

Table 1. Proportions of clusters and categories to which the validated influencing factors were grouped.

Cluster	Category	The proportion by the total number of influencing factors (rounded)
People	Competencies	9%
	Individual	17%
	Interpersonal	8%
	Personal environment	3%
		38%
Organization	Company	8%
	Globality	2%
	Leadership	9%
	Network	6%
	Processes	3%
		28%
Technology	Access and availability	3%
	Compatibility	3%
	Functionality	8%
	Tools	2%
		17%
Knowledge and transfer	Context	5%
	Knowledge characteristics	9%
	Transfer characteristics	3%
		17%

Table 1 shows the four clusters and sixteen categories that were used to structure the identified influencing factors. Further, the distribution rate of both categories and clusters is given in the right-hand column to emphasize their weighting. Summation errors result from rounding. Furthermore, in Appendix A are listed all 88 influencing factors validated for knowledge transfer between product development, production system development as well as production.

4.2. Reference Model of Knowledge Transfer

The Reference Model can be used to graphically display the results of the literature research and the interview study. In addition, the connections and interdependencies of the specific influencing factors are illustrated (detailed explanation see Sec.

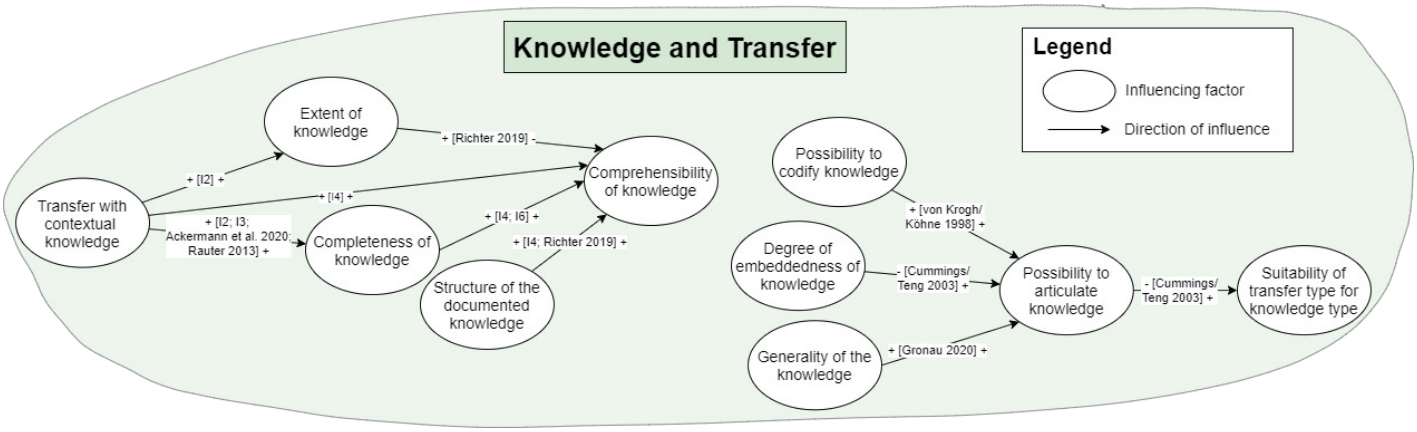


Fig. 4. Factors influencing all three dimensions of Knowledge Transfer

2.3 and [23]). These links were made based on statements and assessments of the studies described above as well as on assumptions based on the knowledge gained from these studies. Assumptions on the connection between influencing factors do not question their general relevance for knowledge transfer.

In the Reference Model, factors that are impacted by or impact other influencing factors were considered. As a result, 84 percent of the validated influencing factors are displayed. For better clarity, the clusters are depicted as colored backgrounds to the associated influencing factors. For the same reason, the previously described categories are not portrayed in the Reference Model. The full model is added in Appendix B.

People: From the cluster people, 27 out of 33 validated influencing factors are displayed in the Reference Model. Within that, factors attributed to individuals are most prominent. Especially, the *personal degree of motivation* is characterized by multiple links to other factors. It is influenced by the *personal prioritization of the project*, the *existence of an incentive system*, and the *degree of acceptance of external knowledge*, among other factors. Besides, it has a direct impact on the *personal willingness to share knowledge*.

Organization: Regarding the cluster organization, where 23 out of 25 validated influencing factors are shown in the model, a significant factor is the *existence of a knowledge culture as part of the corporate strategy*. By anchoring the knowledge culture as a culture of cooperation and collaboration in this way, the *openness of the organizational culture* is positively influenced. In addition, it is more likely that an incentive system exists that is designed to promote sharing knowledge and can increase the *personal degree of motivation* of those involved.

Technology: The technology available for knowledge transfer significantly influences its effectiveness. It supports distributed communication, offers training opportunities, and enables support for task organization, to name a few of the possibilities. Factors that should be concerned for the successful application are *usability*, *retrievability of knowledge,* and *level of data processing*, among others. Especially, when information stored in technology is overflowing and not structured or filtered, the *acceptance level to use assistive technology* is likely to decrease. Overall, the factors identified in this cluster are strongly interconnected with the cluster people since the effectiveness of technology is dependent on its users.

All three clusters described above are linked to each other through the interconnection of influencing factors. This illustrates the complexity of the interconnections of all factors influencing knowledge transfer at the defined interfaces.

Furthermore, 15 factors were identified that influence knowledge transfer independently of the rest of the factors, e.g., different types and forms of knowledge. Therefore, no direct links to specific factors of the other clusters are drawn in the Reference Model. However, they can influence the intensity in which the other factors appear.

Ten of these factors are depicted in the Reference Model as **Knowledge and Transfer** (Fig. 4). They are connected in two joining strands. The upper strand aims at the objective *comprehensibility of knowledge*, the lower strand at the *suitability of the transfer type for the type of knowledge* to be transferred.

4.3. Fields of Action regarding Knowledge Transfer at the Interface of Product and Production System Development as well as Production

To enable the successful design of knowledge transfer at the interfaces, design options and influences were evaluated in an online survey according to their benefit and relevance and put into context. Thereby the results from the 28 participants from different technical industries indicated that some companies already use community platforms for mutual exchange and contact with experts and internal wikis for documentation of knowledge.

However, there are some areas in need, which have the potential to improve knowledge transfer. To identify those fields of action regarding knowledge transfer at the interfaces, strongly interconnected influencing factors within the Reference Model were investigated. On a more general level, categories with highly linked influencing factors can be considered fields of action. Furthermore, influencing factors or categories that were evaluated to be particularly relevant for

transferring knowledge in the online survey are also considered to be fields of action.

One field of action is found to be the **leadership of direct supervisors**. When knowledge culture exists among managers, the perception of their teams towards good and consistent knowledge transfer is influenced positively. The leadership style of the direct supervisor ranks second in the online survey when assessing the relevance of influencing factors on the promotion of knowledge transfer within the organization.

The second field of action identified in this work is **competitive thinking**. In the online survey, its relevance towards promoting knowledge transfer ranks second after the openness to new knowledge on a personal and team level. Although the level of competitive thinking is influenced by personal mindset, it directly influences the personal willingness to share knowledge and therefore should be addressed by measures that mitigate the severity of its impact. One way to do so is for a manager or organization to set collective goals. This goes closely with increasing the personal level of motivation.

On a more fundamental level, the **awareness of the relevance of knowledge transfer** must be considered a field of action. Based on the findings of this work the awareness about the importance of both the own knowledge and that from others impacts willingness to manage knowledge and the time-effort-ratio of knowledge transfer.

Therefore, the organizational structure and its limitations implicated should be questioned. A strong focus on one's domain can result in lower awareness and acceptance towards external knowledge.

Functionality of Tools for Knowledge Transfer: As for the technological side of the intent to close knowledge deficits, the retrievability of knowledge in a tool that is used for knowledge transfer is a field of action to tackle. Large amounts of information require a sophisticated level of data processing to enable the users to find their requested information. This goes along with the usability of the technology being used to support successful knowledge transfer.

5. Conclusion

The development and production of products require the cooperation of different domains and the exchange of knowledge between them. From the state of research, it became apparent that knowledge is a crucial resource in this process. The exchange of knowledge often takes place via the communicative level, because the documentation of knowledge for the person receiving the knowledge is not (always) purposeful, detailed, and comprehensible enough. This is an example of how knowledge deficits can occur. The focus of this contribution is on knowledge transfer as one of the essential elements of knowledge management. In practice, it has been shown that many ways of designing knowledge transfer are used, but these are sometimes not successful. For the successful transfer of knowledge, it is, therefore, necessary to understand factors that influence this process to be able to manage them in a targeted manner. The factors influencing knowledge transfer between product and production system development as well as production are mostly unknown. The influencing factors identified here are limited to the literature included in the review and therefore not complete. Furthermore, the findings regarding the influence on knowledge transfer could be presented in a Reference Model. This Reference Model is to be conceived as a subjective image of the analyzed sources, the exact form of which allows for many variations. Hence, the fields of action derived from the Reference Model and the online survey are an initial indication, which serves as a basis to investigate how knowledge transfer is handled, e.g. in a company, and what influences it. How these influencing factors can be identified in, e.g. a company context or organization, and how measures can be developed to improve knowledge transfer, is a matter for further research.

6. Outlook

The assumptions made about the interdependencies between influencing factors in the Reference Model should be validated. Further studies could then identify possible (measurable) success factors for knowledge transfer. Additionally, the resulting fields of action regarding knowledge transfer at the interfaces of product and production system development as well as production need to be validated with a larger scale of participants. By examining knowledge transfers in various organizations, problems are to be identified and the causes of knowledge deficits recognized. The assignment to the corresponding fields of action should enable the derivation of individual improvement measures. In this context, all three clusters – people, organization, technology – as well as all factors of knowledge and transfer must always be considered for the successful implementation of these measures. Those measures should be evaluated in terms of their success and applicability.

Appendix A. List of 88 Validated Factors Influencing Knowledge Transfer

A.1. Influencing Factors of Cluster People

Category	Influencing factor
Competencies	Ability to learn
	Communication competence
	Degree of skill development
	Level of expertise
	Media competence
	Methodological competence
	Networking skills
	Teaching skills
Individual	Acceptance level to use assistive technology
	Degree of acceptance of external knowledge
	Degree of concentrativeness
	Level of awareness on the importance of knowledge
	Level of focus on own business area

	Level of personal benefit
	Level of personal openness
	Level of the importance of own power
	Level of thematic interest
	Level of willingness to manage knowledge
	Level of willingness to share knowledge
	Personal degree of motivation
	Personal prioritization of the project
	Recognition level for knowledge transfer
	Willingness to learn
Interpersonal	Common language
	Degree of similarity of involved parties
	Degree of similarity of knowledge
	Existence of common goals
	Level of competitive thinking
	Level of trust
	Type of relationship of involved parties
Personal environment	Availability of time
	Nature of effects from a specific situation
	Type of transfer atmosphere

A.2. Influencing Factors of Cluster Organization

Category	Influencing factor
Company	Existence of a knowledge culture as part of the corporate strategy
	Existence of common goals
	Integration of participating business units
	Level of detail of organizational structure
	The openness of the organizational culture
	Project priority
	Quality of personnel policy
Globality	Level of exchange rate
	Size of geographical distance
Leadership	Encouragement of forming knowledge networks
	Existence of a knowledge culture among leaders
	Existence of an incentive system
	Focus on selected topics
	Formulation of knowledge objectives
	Leadership style
	Management support
	Promoting the exchange of experience
Network	Availability of appropriate sources of knowledge
	Availability of experts
	Creation and promotion of knowledge networks
	Degree of transparency of existing knowledge sources
	Support by knowledge promoters
	Degree of coordination at interfaces
	Design of the process organization
	Existence of knowledge transfer rules

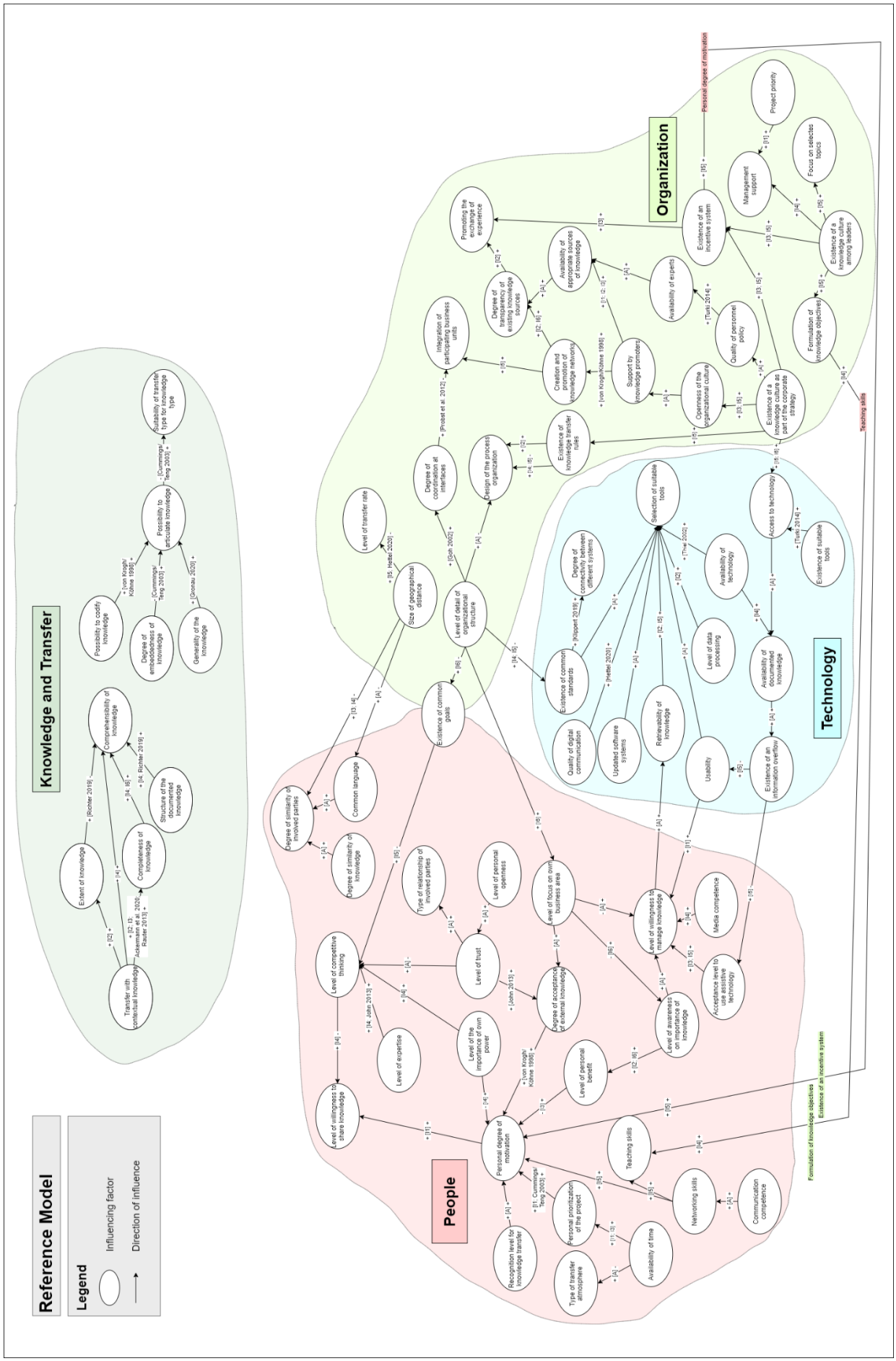
A.3. Influencing Factors of Cluster Technology

Category	Influencing factor
Access and availability	Access to technology
	Availability of documented knowledge
	Availability of technology
Compatibility	Consistency of data models
	Degree of connectivity between different systems
	Existence of common standards
Functionality	Degree of system automation
	Existence of an information overflow
	Level of data processing
	Quality of digital communication
	Retrievability of knowledge
	Updated software systems
	Usability
Tools	Existence of suitable tools
	Selection of suitable tools

A.4. Influencing Factors of Cluster Knowledge and Transfer

Category	Influencing factor
Context	Actuality of knowledge
	Completeness of knowledge
	Extent of knowledge
	Transfer with contextual knowledge
Knowledge characteristics	Comprehensibility of knowledge
	Degree of embeddedness of knowledge
	The generality of the knowledge
	Possibility to articulate knowledge
	Possibility to codify knowledge
	Relevance of knowledge for decision making
	Structure of the documented knowledge
	Usefulness of knowledge
Transfer characteristics	Duration of the transfer
	Frequency of the transfer
	Suitability of transfer type for knowledge type

Appendix B. Reference Model of Knowledge Transfer



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