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Influence of Agility on the Innovation Capability of Organizations – A Systematic Review of Influencing Factors

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Abstract

The increasing dynamization of markets, changing customer requirements and unpredictable occurrences pose new challenges for product development and design. Agile methods and processes can serve as a solution to secure the innovation capability of organizations in this environment. Since the areas of agility and innovation capability of organizations have mostly been treated separately in research, this research effort is focusing at hollistically collecting success factors for agility and success factors for the innovation capability of organizations and analyzing them in detail - including collecting indicators and directional characteristics. The analyzed factors are specifically focused on the development of mechatronic products and are intended to serve as a type of library that enables organizations and researchers to understand their own situation as best as possible, select appropriate recommendations for action in a targeted manner, and track their implementation / operationalization on the basis of the corresponding indicators and characteristics. This research work thus makes a contribution to sustainably increasing innovation capability and agility of industrial organizations.

Keywords: Agility; Agile Product Development; Innovation; Innovation Capability; Innovation Management

1. Context & Motivation

Companies are currently facing a variety of challenges, such as the dynamization of markets, staying up to date with current megatrends, the increasing complexity of products and production processes, a growing number of variants, and rising quality and market requirements. In addition, companies must find a balance between limited resources and the shortening of product life cycles as well as accelerating technological progress - requiring a shortening of innovation times [1]. The fact that competitors can threaten the market position of companies with disruptive innovations, intensifies the need for innovations, in order to sustainably remain on the market as a company and in the long term. This raises the question of how innovation can be driven forward in a targeted manner and whether the implementation and use of agility in product development can serve as a solution for these challenges.

1.1. Innovation Capability

Innovations are characterized by uncertainty, depending on e.g. the industry sector, the product life cycle and other factors. These uncertainties arise in particular in the areas of required technical knowledge and technology, market understanding and specific product requirements, necessary internal resources and time required until market launch. [2] Also, the shortening of product life cycles as well as accelerating technological progress require product novelties and a shortening of innovation times highlighting the need for a high level of innovation capability. An innovation in general is characterized by three elements: The benefit for customers, users and suppliers (product profile) must be identified, realized in a technically satisfactory way (invention) and successfully introduced to the market [3]. Albers et al. [4] describe that only a product that satisfies all of these aspects has the potential to become an innovation. Market dynamics, customers, employees, universities and other companies or competitors are further influencing the innovation process of a company. [4]

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1.2. Agile Methods in the Product Creation Process

A variety of methods have already been developed to drive innovations forward, some of which are firmly anchored in the processes and organizational structure of companies. Among these methods, agile methods form an essential component. More and more companies are looking into the use of agile methods and are endeavoring to integrate agile approaches into various organizational units in order to increase their own effectiveness as well as efficiency (e.g. improvement of product quality and shorter development times) through greater flexibility, better use of resources and lean process structures, amongst other measures. Particularly in the early phase of product development, the targeted use of agile methods can be beneficial for a company's innovation ability and accelerate the company's internal innovation process as well as making it more efficient. The targeted use of agile methods and processes only seems reasonable if changes are likely (for example, in complex innovation-driven or large-scale projects), self-organization is possible (especially if individuals can take on different tasks and thus complement each other), requirements change quickly and value can be created incrementally. [5]

According to the current state of research, a high number of factors have already been identified that positively influence an organization's agile capabilities. The approach of ASD – Agile Systems Design allows the development process to be adapted to specific situations and requirements [6], with the goal of easing the challenges of agile change [7].

Following the international study by Komus [8], which surveyed over 600 individuals from over 20 countries, most product development projects use hybrid and selective agile development processes (about 80% of projects). Reasons of surveyed individuals for using agile approaches include shortening time to market, increasing product and process quality, and reducing risk in general. Nevertheless, companies are facing major challenges in designing their organizational and structural orientation in this context in a target-oriented manner. Companies are exposed to individual internal as well as external influences, pursue specific goals and thus bring along different organizational as well as technical prerequisites. [5]

In literature, the domains 'Innovation' and 'Agility' have mostly been treated separately. By jointly examining these domains and investigating potential cause-effect relationships between innovation capability and the agile operation system, the authors aim to gain insights into a possible increase in the innovation capability of organizations through the targeted introduction of agility into product creation processes and identification of respective synergies. A broad empirical study conducted by Puriwat and Hoonsopon [9] could show an increase of the performance in radical innovation and thus innovation capability through the use of agility in new product development teams. In addition, Hoonsopon and Puriwat [10] show that innovation capability combined with agility has a positive effect on managing the early phase of product development (including finding new ideas, idea screening, marketing analysis and technological evaluation - the so called 'fuzzy front end'). While the previous studies were focused on the differentiation between organizational agility and flexibility and their impact on the innovation capability, as well as the influence on the early phase of new product development or the fuzzy front end, this research effort aims at hollistically collecting success factors for innovation capability and success factors for agility and analyzing them in detail. The research effort is further specifically focusing on the development of mechatronic products and is intended to discuss and analyze the success factors jointly in a subsequent study.

2. Research Gap & Target

This research study contributes to the investigation of the extent to which the innovation capability of organizations can be increased through the targeted introduction of agility in product creation processes. For this purpose, characteristics and features (in the following: 'factors') are identified that an organization with a successful innovation capability demonstrates or possesses (success factors for innovation capability) based on a deep literature review. In addition characteristics of the identified factors are collected to form the basis for the investigation of which success factors are decisive for a targeted and successful implementation, use and evaluation of success of agile methods and processes in organizations in order to boost innovation capability.

For the literature-based development of the tables on innovation capability and agility, the following procedure is followed: First, boundary conditions and constraints are identified to enable classification and delimitation of the subject matter, as well as to make boundary conditions explicit with regard to the applicability of the findings. In a second step, success factors are identified and collected based on a deep literature research. These success factors are summarized in overarching clusters in order to facilitate the manageability of the complexity. Based on the current state of research, indicators for each success factor are determined to support the usability for organizations in the sense of a Key Performance Indicator (KPI). The table is concluded with a directional characteristic for each success factor in order to support researchers as well as organizations in its application.

2.1. Research questions

Based on the research needs, the research questions are listed below, which serve to operationalize the underlying objective of this work:

1. What are the characteristics of an innovative organization?

   (a) What factors are positively influencing innovation in organizations (success factors)?
   (b) What are constraints and limitations in the early phase of product development in the context of innovation capability?

2. What factors characterize implementation and use of agility in the product creation process?

(a) What are boundary conditions and constraints that exist in the early phase of product creation in the context of agile product development?
(b) What are success factors or criteria for implementing and using agile methods and processes?

3. How can the identified factors be characterized in terms of an indication (KPI) and directional weighting?

4. How can a model be set up to transparently conceptualize and describe the success factors and indicators for innovation capability and agility in order to enable a joint analysis for future studies?

2.2. Research Design

Based on a holistic literature review and analysis of results from previous research studies, factors influencing agility and factors influencing the innovation capability of organizations were collected separately and then clustered into success factors and criteria of innovation capability and agility in the context of different organizations. This results in a set of clusters with corresponding success factors. For the individual factors, indicators (KPI's) were determined, as well as the associated characteristics that can be expected to have a positive influence on innovation capability or agility.

The results are made explicit in a table form and can thus be easily used for further research projects or for use in industrial practice. As a result, all success factors for agility, which have an impact on the agility of an operation system, were conceptualized in the AM – AgilityMap and success factors for innovation capability, which have an impact on the innovation capability of organizations, were conceptualized in the IM – InnoMap.

In a further step and based on the research efforts outlined in this study, the authors plan to conduct a holistic, bipartite empirical study based on a broad range of representatives from different industries to determine the cause-effect relationships between agility and innovation capability of organizations.

3. Findings

In this section, the schematic structure and a part of the IM – InnoMap is presented first, illustrated using an example. In a next step, the schematic structure of the AM – AgilityMap will be discussed accordingly.

3.1. IM – InnoMap

IM - InnoMap – boundary conditions & constraints

The innovation capability of organizations is influenced by various boundary conditions, such as the dynamization of markets, the size of the organization, the innovation system, the central dilemma of economic activity, the existence of different types of innovation, and the constraints associated with diffusion.

These constraints are different for each organization, consequently there will be no universal best practice for the increase of innovation capability. The sum of the factors listed in the IM – InnoMap thus illustrates the need for different individual solutions in the strategic approach of organizations and serves as an aid in determining specific recommendations for action.

IM - InnoMap – success factors

Success factors for innovation capability (ISF_x) were identified on the basis of a broad literature search. Among other sources on success factors for innovation capability, Greiling, for example, already contributed to the analysis of innovation capability in companies in a comprehensive study. Hansen et al. [12] have identified in their work so-called drivers of innovation capability, which were also used as success factors for innovation capability in companies: These include the continuous competency development of employees, holistic innovation management, and the promotion of social and organizational innovation which influence productivity, innovativeness, and the implementation success of technical innovations. The IM – InnoMap developed in this research effort thus aims to analyze the characteristics of organizations' innovation capability, define their metrics and characteristics, and use these as a basis for further investigations.

IM - InnoMap – clustering

The 'twelve criteria for assessing entrepreneurial innovation capability according to the European Management Forum' [13] have been used as an aid for the categorical classification of success factors for innovation capability of companies. These twelve criteria were first adapted to the context of this work by renaming or adding to them, whereas in a second step, relevant success factors were assigned to these clusters. The clustering of the success factors for innovation capability enables a better overview of the diverse success factors.

IM - InnoMap – indicators and directional characteristics

For the success factors of innovation capability, associated KPIs are identified on the basis of a literature review. Since numerical weighting is complex, the KPIs are weighted directionally. Also, a directional weighting of individual indicators is more logical to follow. In this research effort, directional weighting is structured according to the following scheme:

'The more ($Z(KPI_x)$, ISF_x) pairs are fulfilled, the higher the innovation capability' (characteristic Z linked to KPI_x and innovation success factor ISF_x).

The schematic structure of the IM – InnoMap is shown in Table 1. In the first column, the 12 cluster are listed. Associated success factors and indicators that were identified in this research effort have been assigned accordingly. The success factors and characteristics may occur repeatedly in the IM – InnoMap, indicating thematic overlap of specific success factors for innovation capability between the cluster. An example of such an overlap is the success factor '*degree of specialization*',

Table 1. (a) Summarized overview of the IM – InnoMap; (b) Exemplary representation of a section of the IM – InnoMap linked to the examples in subsection 3.1.

a

Cluster	Success Factors [ISF_x]	Indication [KPI_x]	Characteristics [$Z(KPI_x)$]
1 Business dynamics	∑2	∑2	...
2 High growth rate compared to companies in the same industry	∑11	∑12	...
3 Efficient use of resources	∑1	∑3	...
4 Behaviour in situations of economic crisis	∑3	∑7	...
5 Quality of planning mechanisms	∑7	∑13	...
6 External relations	∑3	∑8	...
7 Remarkable social benefits	∑6	∑14	...
8 Organization of production and product engineering	∑8	∑8	...
9 Scope of research and development	∑3	∑8	...
10 Financially securing the future	∑4	∑6	...
11 Leadership style	∑6	∑9	...
12 Skills or abilities of the employees	∑5	∑5	...

b

Cluster	Success Factors [ISF_x]	Indication [KPI_x]	Characteristics [$Z(KPI_x)$]
2 High growth rate compared to companies in the same industry	2-1 Innovation power	share of product innovations in sales	greater
	2-2 Competence & Knowledge	Existence of an innovation department within the company	existing
	2-3 R&D effort with regard to innovations	R&D expenditures to date	higher
	2-4 R&D effort with regard to innovations	Number of patents (applied for / approved); Number of patent citations	higher
	2-5 Innovative power	Number of jobs in R&D or innovation department within the company	higher
	2-6 Market growth	Number of start-ups in high-tech industries	higher
	... ...	...	...
3 Efficient use of resources	3-1 Efficient value creation processes	Short lead times; No waste; Involvement of employees in the optimization process	shorter; less; more intense

which appears on the one hand in the cluster '*skills of employees*' and on the other hand in the cluster '*organization of production and product development*'. Nevertheless, associated indicators (see below) and directional weighting always differs.

In order to be able to analyze and assess the success factors for innovation capability on an application-specific basis, indicators (KPI_x) were assigned to each success factor in the third column. In the fourth column, the respective ideal directional characteristic, also called weighting or extent, are listed.

To illustrate the principle of the IM – InnoMap in an application-related manner, an example is presented hereafter. The success factors '*innovation power*' and '*R&D effort with regard to innovations*' are assigned to the cluster '*high growth rate compared to companies in the same industry*'. An indicator for innovation power in this case would be the '*share of product innovations in sales*' with the directional characteristic '*greater*'. It is true that the greater the innovation power (described by e.g. greater share of innovative products in sales), the higher the innovation capability.

Please find the full IM – Innovation Map including references for each success factor in Appendix A in Table A.3 and A.4.

3.2. AM — AgilityMap

AM - AgilityMap – boundary conditions & constraints

When identifying boundary conditions in the context of agility, consideration is given to the question of whether it seems reasonable to design a specific (sub-)process in the organization in an agile manner. The identified boundary conditions are - amongst other things - serving as a basis for the strategic decision regarding the implementation of agile methods and procedures. For the identification of the boundary conditions, the analytical examination of the decision-making process is of particular importance.

In order to use agility in a targeted approach in an organization, it is advisable to differentiate between the respective advantages and disadvantages of agile and plan-driven approaches, as well as to analyze and assess the applicable requirements, practices, and complexity of technology.

In the context of agile product creation processes, the early phase of product development is characterized by various boundary conditions and constraints that are primarily relevant for the strategic planning and implementation of agile methods as well as their efficiency and effectiveness.

These boundary conditions include various circumstances which an organization or operation system either brings with it itself or which are externally imposed by the environment and cannot be influenced or can only be influenced with difficulties.

AM - AgilityMap – success factors

Various sources were used to identify success factors (ASF_x) in the context of the introduction of agility based on a literature review, the most important of which are explained in more detail hereafter.

Schmidt and Janzon [14] describe seven success factors of an agile transformation as criteria for the successful implementation and use of agile methods and processes. These success factors include insights, approaches, attitudes, methods and tools that contribute to the success of a transformation or organizational development, taking into account various constraints and limitations. As part of the 4th international study of 'Status Quo (Scaled) Agile' (2020) [8], benefits and success factors of (scaled) agile approaches were investigated. Based on the responses of >600 participants from more than 20 countries, the study identified three success factors for the use of agile methods and processes as particularly important: only small teams with fewer than nine people could work together meaningfully using agile approaches; upcoming tasks should first be systematically evaluated in terms of their complexity; and distributed teams would make good performance more difficult. Internal processes, top management and the development team were identified as the main challenges, from which further constraints could arise. [8]

In the work of Albers et al. [7] various factors that promote an agile operation system are identified. In the context of agility, factors can be values, principles, practices or artifacts, respectively the handling or execution of these elements. In addition, factors can also be characteristics or states to strive for (for example, of the organization or of the personnel). These factors are referred to by Albers et al. as 'influencing factors on agility' and also apply to organizational interfaces (e.g. product development/production) [15]. Flat hierarchies in the organization [16], the collaboration of different actors within an organization [17, 18], clear and short decision-making paths [19], and the scalability of agile practices [20] are, for example, influenc-

Table 2. (a) Summarized overview of the AM – AgilityMap; (b) Exemplary representation of a section of the AM – AgilityMap linked to the examples in subsection 3.2.

a

Cluster	Success Factors [ASF_x]		Indication [KPI_x]	Characteristics [$Z(KPI_x)$]
1 Corporation	1-1	Corporate structure	∑4	…
	1-2	Corporate system	∑12	…
	1-3	Corporate strategy	∑13	…
	1-4	Corporate culture	∑19	…
2 Leadership	2-1	Shared values	∑5	…
	2-2	Management style	∑7	…
	2-3	Management skill	∑3	…
	2-4	Management staff	∑3	…
3 Project	3-1	PGE - Product Generation Engineering (targeted use of knowledge)	∑5	…
	3-2	Product Development Team	∑14	…
	3-3	Project Management	∑19	…
	3-4	Team output	∑4	…
	3-5	Working environment	∑11	…
	3-6	Design task	∑15	…
	3-7	Use of design tools and methods	∑15	…
	3-8	Validation	∑8	…
4 Individual	4-1	Knowledge	∑3	…
	4-2	Skills and competencies	∑12	…
	4-3	Individual styles of thinking and acting	∑3	…
	4-4	Motivation and emotion	∑4	…
	4-5	Attitude	∑14	…
	4-6	Performance	∑1	…
	4-7	Output	∑1	…
	4-8	Relationships	∑5	…

b

Cluster	Success Factors [ASF_x]		Indication [KPI_x]	Characteristics [$Z(KPI_x)$]
3 Project	3-1	PGE - Product Generation Engineering (targeted use of knowledge)	Knowledge base maintenance	maintained
			Sufficient documentation	sufficient
			Share of new development deliberately set	deliberately set
			…	…
	3-2	Product Development Team	Right size of the development team	7 ± 2 members
			Reflection in team retrospectives	continuously reflected and improved
			No hierarchy within the team	not present
			Autonomy of the team	autotomous/self-organized
			Flexible distribution of roles in the team	flexible
			…	…
	…	…	…	…

ing factors or indicators for the success of agile methods with regard to the company structural level.

AM - AgilityMap – clustering

Similar to the procedure according to Albers et al., the literature-based success factors for agility are clustered. These clusters are mainly based on the models of Hales and Gooch [21], and Gericke et al. [22] and thus correspond to VDI 2221 [23], which can generally be used for the design of individual product development processes and for the description of influences in diverse contexts of product development. The success factors for agility are now categorically assigned to the respective clusters and thus form the basis for the AM – AgilityMap that can be found in Appendix A in Table A.5, A.6 and A.7.

AM - AgilityMap – indicators and directional characteristics

Indicators (KPI_x) related to the success factors for agility and their directional characteristics ($Z(KPI_x)$) are identified and compared with existing literature, such as the study by Albers et al. [7]. Since a numerical weighting is complex and can only be determined with great effort, the weighting of the KPIs is based on the principle of ideal expression. Consequently, the weighting is structured according to the following scheme:

'The more (x, ASF) pairs are fulfilled, the more successful the use of agile methods and processes' (characteristic x and success factor agility ASF).

The schematic structure of the AM – AgilityMap is shown in Table 2. The first column summarizes the success factors for agility in four clusters. The second column lists the identified success factors for agility in categorical order. In order to be able to analyze and evaluate the success factors for agility on an application-specific basis, indicators are assigned in the third column. The fourth column lists the respective ideal characteristics, weighted according to the method described before. In this way, a total of 24 success factors in 4 clusters including 200 indicators or KPIs were empirically collected.

In order to illustrate the principle of the AM – AgilityMap in an application-related manner, an example is presented hereafter. The cluster '*Project*' is assigned the success factors '*Product Development Team*' and '*Product Generation Engineering (PGE)*'. An indicator for the product development team in this case would be the '*right size of the development team*' with the ideal characteristic (KPI weighting) '*7 ± 2 members*'. A KPI for Product Generation Engineering (PGE) in this case would be '*knowledge base maintenance*' with the ideal characteristic (KPI weighting) '*maintained*'.

4. Conclusion

Innovations are characterized by uncertainties. An increasing dynamization of markets and rising customer requirements as well as a demand for individualized products confront organizations with the challenge of shorter innovation cycles. Agile methods and processes can serve as a way to cope with these uncertainties in the context of the product development process.

In the context of this research study, success factors for the innovation capability of organizations and success factors for the use of agile methods and processes in organizations were identified and reviewed for completeness on the basis of a comprehensive literature review. For the respective success factors, indicators (KPIs) as well as characteristics of these indicators were determined based on literature in the sense of a directional expression. For a simplified application, the success factors were structured in clusters and operationalized in a table form, the so-called IM – InnoMap and the so-called AM – AgilityMap.

The AM – AgilityMap contains a total of 24 holistic success factors in 4 clusters. For these success factors, 200 indicators including associated characteristics / directional expression were determined. As part of the IM – InnoMap, 56 success factors for the increase of the innovation capability of organizations were identified along 12 clusters. For these success factors, 87 indicators and characteristics were identified. The systematic collection of these success factors is based on in total more than 120 individual sources on the subjects of agility and innovation capability of organizations.

The two tables developed as part of this research work serve in the practical application as a type of catalog that enables organizations and researchers to understand their own situation as best as possible, select appropriate recommendations for action in a targeted manner, and track their implementation/operationalization on the basis of the corresponding indicators and characteristics. This research work thus makes a contribution to sustainably increasing innovation capability and agility.

5. Outlook

In future projects and on the basis of the insights gained in this research study, the authors intend to determine the cause-effect relationships between innovation capability and agility - specifically, whether the targeted use of agile methods has a positive impact on the innovation capability of organizations. To achieve this, the success factors from this work will be utilized and validated in a broad empirical study with organizations for a paired comparison of the factors for agility and the innovation capability of organizations.

Remarks

The full list of references used in IM – InnoMap and AM – AgilityMap as well as raw data is available for sharing. Please reach out to the authors.

Appendix A.

For the full IM – InnoMap see Table A.3 (page 7) and A.4 (page 8). For the full AM – AgilityMap see Table A.5 (page 9), A.6 (page 10) and A.7 (page 11).

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Table A.3. The full IM – InnoMap (part 1) based on a literature review.

Cluster	Success Factors [ISF x]	Indication [KPI x]	Characteristics [Z(KPI x)]	References [A]: experience & interview based assumption
1 Business dynamics	1-1 Strategy: Flexibility and adaptability of the company	Flexible change of the resource base	more flexible and dynamic	OECD (2005), [A]
	1-2 Strategy: sustainable economic action	Orientation towards sustainability	more sustainable	Hansen (2010), [A]
2 High growth rate compared to companies in the same industry	2-1 Innovation power	Share of product innovations in sales	greater	OECD (2005), Halder (2016), Greiling (1998)
	2-2 Competence & Knowledge	Existence of an innovation department within the company	existing	[A]
	2-3 R&D effort with regard to innovations	R&D expenditures to date	higher	OECD (2005), Halder (2016), Schuh (2012)
	2-4 R&D effort with regard to innovations	- Number of patents (applied for / approved); - Number of patent citations	higher	Halder (2016), Greiling (1998)
	2-5 Innovation power	Number of jobs in R&D or innovation department within the company	higher	[A]
	2-6 Market growth	Number of start-ups in high-tech industries	higher	[A]
	2-7 R&D effort with regard to innovations	Number of scientific and technical publications	higher	Greiling (1998), OECD (2005)
	2-8 R&D effort with regard to innovations	Number of citations in scientific papers with the same or related topics	higher	Greiling (1998)
	2-9 R&D effort with regard to innovations	Financial expenses for innovation projects, e.g. including purchase of external technologies, purchase of machinery and equipment, license fees, expenses for qualification and training	higher	OECD (2005)
	2-10 R&D effort with regard to innovations	Economic effects of the Innovation activities on the company's success	greater	OECD (2005)
	2-11 Economic framework	Good economic performance of the company	better	OECD (2005), [A]
3 Efficient use of resources	3-1 Process; Innovation culture: efficient value creation processes	- Short lead times; - No waste; - Involvement of employees in the optimization process	- shorter; - less; - more intense	Schuh (2012), OECD (2005)
4 Behaviour in situations of economic crisis	4-1 Competence & Knowledge; Structure & Network: Knowledge Management	- Use of experiential knowledge and implicit knowledge alongside explicit knowledge; - Regular exchange of explicit & implicit knowledge via different platforms	more intense, continuous	Hansen et al. (2010), [A]
	4-2 Process: Development of successful routines and rituals	- Elimination of inefficient routines; - Keep habits that have been effective in the past; - Focusing on core competencies of the company and developing a common realistic vision and identity to create sustainable structures within the company	more efficient	Bergmann and Daub (2008), [A]
	4-3 Structure & network; Strategy; Project management; Market: guarantee of technological and sales market collateral	- Market research; - Exchange with experts from politics and research (OI)	more intense and dynamic	Schuh (2012), Zelewski et al. (2004)
5 Quality of planning mechanisms	5-1 Strategy; Project Management: Consistent strategic corporate design	Activities fit with vision and targeted strategy	greater the match	[A]
	5-2 Corporate/Innovation culture	Anchoring innovation in the corporate culture and communicating this to employees	more transparent, more intensively anchored	[A]
	5-3 Strategy; Project management; Innovation culture: Long-term corporate development planning	Engaging stakeholders and affected parties in planning and decision-making processes regarding vision and long-term strategies	more intense, regular	[A]
	5-4 Process; Project Management: Complexity reduction	- Degree of digitalization; - Industry 4.0 Maturity Index (Acatech maturity model)	higher	[A]
	5-5 Corporate/Innovation culture	- Error tolerance; - Participation of employees in decision-making processes; - Utilizing the potential of employees (e.g. process experts in their field of work)	greater	Klippert et al. (2009), [A]
	5-6 Process, Project Management; Innovation culture: Information structure	- Elimination of irrelevant bureaucratic processes; - Flat hierarchies offer the opportunity to hand over responsibility to employees and encourage them to take initiatives	more simple, faster and dynamic	Bergmann and Daub (2008), Greiling (1998), [A]
	5-7 Process: Innovative types of work organization	- Modification of work organization with regard to the use and promotion of human capital; - Implementation of innovative types of work design: freedom for learning (e.g. team learning) and opportunities to develop skills (e.g. teamwork); - Continuous learning organization	more	Trantow et al. (2013), Hansen et al. (2010), [A]
6 External relations	6-1 Structure & Network: Open Innovation in general (networking with external experts)	- Number of partners; - Type of partners (B2B, B2C, B2Academia, ...); - Frequency of interaction/knowledge sharing; - Type and manner of interaction	- larger; - more individual; - more frequent; - more intense;	Chesbrough (2003), OECD (2005), Schuh (2012), Greiling (1998), Gassmann and Enkel (2006), Ahmed (2010)
	6-2 Structure & Network: OI: Opportunities and risks related to external sources of innovation/idea generation (Outside In).	B2B, B2C, B2A (see OI in general)	more intense	Chesbrough (2003), OECD (2005), Gassmann and Enkel (2006), Ahmed (2010), [A]
	6-3 Structure & Network: OI: Opportunities and risks related to external idea exploitation (Inside Out)	- Patents; - Development of new business areas and strategic partnerships; - Spin-offs for high potential / high risk projects	more	Chesbrough (2003), OECD (2005), Gassmann and Enkel (2006), Ahmed (2010), [A]
7 Remarkable social benefits	7-1 Strategy; Process, Incentives: working time model	- Available compensated time for employees' own ideas and projects (e.g. 4:1 model); - Flexitime	more flexible	Greiling (1998)
	7-2 Strategy; Incentives: Workspace design	Type of spatial design and office concept (open/isolated, think tanks, meeting corners, rooms for unwinding, ...)	more friendly, open, beautiful, organized, tidy	Greiling (1998)

Table A.4. The full IM – InnoMap (part 2) based on a literature review.

Cluster	Success Factors [ISF x]	Indication [KPI x]	Characteristics [Z(KPI x)]	References [A]: experience & interview based assumption
7 Remarkable social benefits	7-3 Strategy; Competence & Knowledge; Incentives	- Supporting systematic and lifelong competence development among employees; - Early safeguarding of long-term expertise before older employees leave the company and transfer of knowledge to new employees; - Continuous learning in everyday work	intensiver, kontinuierlicher	Schuh (2012), Greiling (1998), Hansen et al. (2013)
	7-4 Strategy, Incentives: Health management & freetime activities for employees	- Corporate health management as a competitive factor: including health, satisfaction and motivation of employees as strategic factors in culture, vision, structures and processes; - Company offers for prevention and reduction of physical complaints - Offerings for prevention and treatment of psychological problems (e.g., yoga, meditation, orchestra?, ...)	more available (and accepted by employees)	Trantow et al. (2013) [A]
	7-5 Strategy; Incentives: Work-life balance (WLB)	- WLB activities; - Working time models: development of generation-specific, individualized concepts for WLB, aligned to different occupational phases	more available	Hansen et al. (2010)
	7-6 Strategy; Incentives: Diversity	- Integration of individual personalities and showing positive appreciation for them; - Exchange between individual experts sharing different knowledge, perspectives and skills as a driver for new ideas; - Diverse and varied design of work assignments and methods for employees	- more individual; - more intensive; - more diverse & varied	Bergmann and Daub (2008), [A]
8 Organization of production and product engineering	8-1 Competence & Knowledge: Degree of specialization	Level of specialization	optimal characteristic depending on the situation	Greiling (1998), [A]
	8-2 Process: Degree of standardization	Level of standardization	lower	Greiling (1998), OECD (2005)
	8-3 Process: Degree of formalization	Level of formalization	optimal characteristic depending on the situation	Greiling (1998), [A]
	8-4 Competence and Knowledge; Structure and Network: Degree of information/communication regarding content	Level of information/communication	higher	Greiling (1998)
	8-5 Competence and Knowledge; Structure and Network: Degree of information/communication regarding content	Use of information and communication sources.	higher	Greiling (1998)
	8-6 Innovation culture: Degree of participation	Level of participation	higher	Greiling (1998)
	8-7 Competence and Knowledge; Structure and Network: Communication structure	Short information channels and open communication structures	shorter and more open	Bergmann and Daub (2008), [A]
	8-8 Innovation culture; Strategy: Approach to decisions	Short decision-making channels & decentralization of decisions.	shorter & decentralized	Bergmann and Daub (2008), [A]
9 Scope of research and development	9-1 Competence & Knowledge; Strategy: Knowledge Management	Idea repository (wiki principle)	available	[A]
	9-2 Market; Structure & Network: Market knowledge	- Customer-centric engineering process: Involving customers in the innovation processes; - Customer proximity and continuous tracking of information about customer needs; - Way of market research; - Awareness of customer needs	- customer-centric; - continuous; - more intense; - greater	Schuh (2012), Zelewski et al. (2004), OECD (2005)
	9-3 Innovation culture: Innovation process	- Existence of an innovation department - Established innovation process - Type of innovation process (radical/incremental innovation)	- existing - more efficient	Schuh (2012)
10 Financially securing the future	10-1 Strategy: Investment in R&D	Planned investment in R&D	greater	OECD (2005), [A]
	10-2 Strategy; Structure & Network: Investments and cooperations with start-ups	Planned investment in start-ups	greater	OECD (2005), [A]
	10-3 Strategy; Structure & Network: Inorganic growth M&A, acquisitions	- Start-ups; - M&A; - Acquisitions;	greater	OECD (2005), [A]
	10-4 Strategy; Structure & Network: Partnering	Cooperations with companies	more, more intense	OECD (2005), [A]
11 Leadership style	11-1 Innovation culture; Strategy; Competence & knowledge: Promotion of innovations	Promoting social and organizational innovation	more intense	Hansen et al. (2013), OECD (2005), [A]
	11-2 Innovation culture; Competence & knowledge; Project management; Strategy: Holistic innovation management	- 'Good' management by corporate management and executive levels; - Signaling openness to ideas and creativity; - Willingness to invest in innovations and innovative ideas; - Actual significance of innovation activities within management	- better; - more open; - higher; - greater	Hansen et al. (2013), [A]
	11-3 Corporate/Innovation culture	Way of feedback culture	more established & frequent, constructive	[A]
	11-4 Culture of innovation; Competence & knowledge: Motivating relationship with employees	Subjective opinions of employees	motivating	[A]
	11-5 Culture of innovation; Competence & knowledge: Way of leading; Working relationships	Subjective opinions of employees	better	[A]
	11-6 Culture of innovation; Competence & knowledge: Ability to work in a team	Subjective opinions of employees	higher	[A]
12 Skills or abilities of the employees	12-1 Culture of innovation: Willingness to conduct and participate in training courses	Subjective opinions of employees and management	higher	Greiling (1998)
	12-2 Competence & Knowledge: Degree of specialization	Duration of the professional experience of the employees	optimal characteristic depending on the situation	Greiling (1998)
	12-3 Innovation culture	Willingness of employees to pursue certain innovation activities (employee motivation).	greater	Greiling (1998)
	12-4 Incentives: Workspace design, health management & free time offerings, WLB, diversity	Assessment of the 'importance' of various incentives as great	higher	Greiling (1998)
	12-5 Culture of innovation; Competence & knowledge: Ability to work in a team	Subjective opinions of employees	higher	Greiling (1998)

Table A.5. The full AM – AgilityMap (part 1) based on research of Albers et al. [7].

Cluster	Success Factors [ISFx]	Indication [KPIx]	Characteristics [Z(KPIx)]	References
1 Corporation	1-1 Corporate structure	Hierarchies in the company	flat	Häusling (2016)
		Collaboration within the company	collaboration (Core-Teams)	Romero (2011), Zimmermann (2019)
		Clear and short decision paths	clear and short	Meredith (2000)
		Scaling agile practices	scalable	Gregory (2015)
	1-2 Corporate system	Adherence of working hours	fulfilled	D'Souza (2015)
		Sustainable implementation of Agile	sustainable; incremental	Ranganath (2011)
		Use of agile coaches	used	Bresser (2014)
		Autonomy through borders	clear	Muduli (2018)
		Implementation of methods through training courses	implemented	Livermore (2008)
		Cross-divisional coding standards	clear	D'Souza (2015), Fruhling (2008)
		Improvement of corporate standards	reviewed and improved	Chen (2010)
		Use of agile coaches	available and continuously developed	Paasivaara (2018), Livermore (2008), Bresser (2014)
		Expansion of creative freedom	great	Lehnen (2016)
		Good provision of information	simple and quick	Lu (2011)
		Balanced salary levels	balanced	Markopoulos (2018)
		Illustration of agility in standards & guidelines	reflect understanding of agility	Albers (2020a)
	1-3 Corporate strategy	Strategy aligned to customer benefits	aligned	Fang (2008)
		Agility is not a sole purpose	existing	Albers (2020b)
		Integration of suppliers and partners	integrated	Zimmermann (2019), Chen (2010)
		Market observation	observed	Forte (2017)
		Authority of the customer	high	Fang (2008)
		Coordination between software and hardware components of technical systems	preferred	Fraanje (2018)
		Fluidity of resources	ready and quick to mobilize	Ivory (2018)
		Openness towards product variation	expandable; enabled	Romero (2011)
		Management of a virtual product portfolio	present	Vale (2001)
		Avoidance of standard contracts and pre-specifications	flexible	Gregory (2015), Heerwagen (2018)
		Common understanding of success criteria	clear understanding	Forte (2017)
		Consideration of business case and product profile	considered; done	Albers (2020a)
		Top-down agreement on procedure	existing	Albers (2020a)
	1-4 Corporate culture	Quick exchange of new ideas	quick and uncomplicated	Rinaldi (2017)
		Direct flow of information within the company	direkt	Rinaldi (2017)
		Communication between development teams	team-wide	Zimmermann (2019)
		Common visions and values	congruent	Paasivaara (2018), Forte (2017)
		Shared metamodel for process design	consistent	Zimmermann (2019)
		Distinct error culture	is practiced	Paasivaara (2018)
		Continuous synchronization between hardware and software	continuous and in high frequency	Goevert (2017)
		Company-specific understanding of agility	adapted to companie	Zimmermann (2019), Lyytinen (2006), Abrahamsson (2009)
		Lifelong learning	intensified	Paasivaara (2018)
		Interdisciplinary system development	interdisciplinary	Romero (2011), Zimmermann (2019)
		Rather pragmatics than dogmatics	adapted to companie	Komus (2014)
		Open conflict culture	systematic	Rosenberg (2016)
		Communication between agile and traditional organizational units	in constant exchange	Gregory (2015), Zimmermann (2019)
		Uniform modelling approaches	uniform	Gregory (2015)
		Avoidance of waste	avoided	Hofert (2018), Forte (2017), Komus (2014)
		Maximize knowledge through validation	at all levels	Albers (2020a)
		Rough planning instead of micromanagement	rough	Albers (2020a)
		Structures are always the starting point for cultural change	favor cultural change	Albers (2020b)
		Human interaction	appreciative and at eye level	Albers (2020b)
2 Leadership	2-1 Shared values	Uniform understanding of the problem	uniform	Pahl (2013)
		Significance of changes	undisputable/accepted	Paasivaara (2018)
		The CEO must really want agile transformation	convinced and supportive	Albers (2020b)
		Employee-centered understanding of leadership	employee-centered	Albers (2020b)
		Communication openness of all participants	is present from all sides	Hofert (2018), Forte (2017), Sutling (2014)
	2-2 Management style	Psychological empowerment	encouraged by managers	Muduli (2018)
		Adaptive leadership style	adaptive	Doz (2010)
		Helping people to help themselves	encouraged by managers	Hofert (2018), Paasivaara (2018), Forte (2017), Häusling (2016)
		Empowerment of employees	transferred from management	Hofert (2018), Forte (2017)
		Generalists in the development team	generalist (allrounder)	Forte (2017)
		Optimize working environment and reduce distractions	aligned; reduced	Forte (2017)
		Balance between demanding and encouraging employees	reasonable high	Albers (2020a)
	2-3 Management skill	Agile oriented project management	situation specific	Albers (2020a)
		Agile knowledge at management level	is present	Gregory (2015), Zimmermann (2019)
		Good moderation skills	good	Hofert (2018)
	2-4 Management staff	Intuitive processes in everyday working life	simple and intuitive	Forte (2017)
		Create and maintain Commitment	actively demanded and strengthened by leadership	Heerwagen (2018), Laufer (2018)
		Willingness to change	is present	Heerwagen (2018)

Table A.6. The full AM – AgilityMap (part 2) based on research of Albers et al. [7].

Cluster	Success Factors [ISFx]	Indication [KPIx]	Characteristics [Z(KPIx)]	References
3 Project	3-1 PGE - Product Generation Engineering	Newly developed shares of new product are deliberately determined	deliberately determined	Albers (2016b), Albers (2019b)
		Cross-industry availability of reference elements	cross-industry available	Albers (2017b)
		Maintaining the knowledge base	maintained	Forte (2017), Conforto (2014)
		Documentation in the right scope	in right scope	Ranganath (2011)
		Systematic search for references	systematic	Albers (2017b)
	3-2 Product Development Team	Regular team meetings	regular	Rebentisch (2018)
		Suitable team size	7 ± 2 members	Rebentisch (2018)
		Reflection in Team Retrospectives	continuously reflected and improved	Hofert (2018), Forte (2017)
		No hierarchy in the team	not present	Markopoulos (2018)
		Decision-making power for individual team members	according to to individual team members	Zieris (2013)
		Autonomy of the team	autonomous	Hofert (2018), Forte (2017), Rebentisch (2018)
		Flexible allocation of roles in the team	flexible	Zimmermann (2019), Hoda (2013)
		Regulated discussion culture	regulated and maintained	Gravett (2016)
		Different type profiles in the team	diverse	Steele (2015)
		Team Guide Board	accepted and maintained	Forte (2017), The Guide Board (2015)
		Team has a mission statement or team vision	present and consistent	Hofert (2018)
		Team cohesion	high	Hofert (2018)
		Adaptation of the team	adjusted depending on the activity	Albers (2016a), Albers (2020a)
		Resilience of statements	clear and resilient	Albers (2020b)
	3-3 Project management	Lead process and standards that allow agility	allow agility	Heimicke (2019)
		Common final objectives	common	Paasivaara (2018)
		Living project management	transparent, living and self-learning	Laanti (2011)
		Regular delivery of new increments	regular	Hofert (2018), Forte (2017), D'Souza (2015), Song (2011)
		Analysis of the project risk	known	Zimmermann (2019), Albers (2019b), Brandstäter (2013)
		Transparent budget controlling	transparent	Zimmermann (2019), Hammers (2012), Baumeister (2014)
		Consideration of project length	short	Chow (2008)
		Iterative process design	iterative	Chen (2010)
		Consideration of planning stability	is estimated and included in decisions	Boehm (2003)
		Adaptivity of the target system	is adaptive	Abrahamsson (2010)
		Decision basis between Traditional and Agile	systematic and criteria-oriented	Albers (2020b)
		Sufficient resources for financial hedging	sufficient and firmly allocated	Albers (2020a)
		Creation of product profiles	via product profile	Albers (2019a)
		Counteract lack of time for creative idea generation	estimated/fixed by developers	Albers (2020a)
		'Good Enough' planning	only as much as needed	Zimmermann (2019), Hanschke (2016)
		Planning meetings with customers	regular and structured	D'Souza (2015)
		Improvement of processes	continuous	Hofert (2018)
		Involvement of new stakeholders	actively identified and integrated	Forte (2017)
		Risk tracking	maintained and monitored	Forte (2017), Brandstäter (2013)
	3-4 Team output	Short release cycle times	short	Forte (2017), Rebentisch (2018)
		Internal team performance measurement	determined systematically	Böhm (2019)
		Constant team performance	constant and determined systematically	Böhm (2019)
		Working according to the flow principle	not over-/underdemanding	Hofert (2018), Reiß (2018), Csikszentmihalyi (1990)
	3-5 Working environment	High project visibility	high	Hofert (2018), Zimmermann (2019), Freedman (2016)
		Presence of the customer in the development process	high	D'Souza (2015), Fang (2008), Sandmeier (2004)
		Targeted access to tools and methods	appropriate to the situation/needs	Al-Faouri (2014)
		Intuitivity of tools	intuitive	Albers (2020a)
		Locations optimized for information flow	open-plan office	Sutling (2014)
		Low interaction between mechanics, electronics and computer science	low	Goevert (2017)
		Access to additional premises	adaptable to needs	Albers (2020a)
		Availability of work equipment	available and accessible	Albers (2020a)
		Targeted access to knowledge	available and maintained	Al-Faouri (2014)
		High availability of supervisors and stakeholders	short	Albers (2020a)
		Task board or dashboard visualization techniques	easy to handle and central	Jensen (2018)
	3-6 Design task	Evaluation of the criticality of projects	decision basis at the beginning of the project	Zimmermann (2019), Hammers (2012)
		Coevolution of objectives and objects	are coevolutionary developed	Abrahamsson (2010), Bursac (2016)
		Maintenance of the target system	expandable, maintained, transparent	Abrahamsson (2010)
		Low interface complexity	low	Goevert (2017)
		Development aligned to product profile	systematically using a product profile	Albers (2019a)
		Allow and greet later changes	allowed	Heerwagen (2018), Schulz (1999), O'Heare (2018)
		Avoidance of mutual dependencies	as low as possible	Albers (2020a)
		Result orientation through 'Definition of Done'	consistent and comprehensible	Davis (2013)
		Clear prioritization of requirements	priorised	Forte (2017), Hanschke (2016)
		Stick to a simple designs	as simple as possible	D'Souza (2015)
		Test-first development	develop prior to or simultaneously with product	D'Souza (2015)
		Knowledge about description possibilities of products	existing	Rubin (2012)
		Knowledge about description possibilities of tasks	existing	Rubin (2012)
		Contract models that allow agility	avoid as possible	Heerwagen (2018)
		Acting in the interests of the customer	shares perspective of the customer	Albers (2020a)

Table A.7. The full AM – AgilityMap (part 3) based on research of Albers et al. [7].

Cluster	Success Factors [ISFx]	Indication [KPIx]	Characteristics [Z(KPIx)]	References
3 Project	3-7 Use of design tools and methods	Low degree of formalization of the process model	low	Zehnter (2012)
		High level of detail of the process model	high	Zehnter (2012)
		Adaptivity of the process model	feasible	Zehnter (2012)
		Uniform problem solving process	uniform	Albers (2016a)
		Diversity of tools and methods	in high diversity	Albers (2020a)
		Adequate level of abstraction of methods, ways of thinking and processes	appropriate for quick augmentation	Albers (2013)
		Possibility of adapting methods, ways of thinking and processes	assimilable for own context	Albers (2013)
		Visualization of the project progress	centralized and continuously maintained	Forte (2017)
		Correct use of user stories	correct (customers' point of view)	Zimmermann (2019), Abrahamsson (2010)
		Whiteboard Modelling	by whiteboard modeling	Song (2011)
		Versatility of virtual simulation methods	present in various forms	Oliveira (2018)
		Applicability of development methods	application linked to as few boundary conditions as possible	Albers (2013)
		Use of methods with reasonable effort	low effort with high benefit	Fowler (2001)
		Intuitive preparation of methods	intuitively prepared	Albers (2013)
		Knowledge of work organization and project management elements	existing	Rubin (2012)
	3-8 Validation	Easy access to feedback from experienced users	easy accessible	Song (2011)
		Early and continuous validation of the SiD	early and continuous	Forte (2017)
		Correct and continuous integration of subsystems	correct and continuous	D'Souza (2015)
		Constant verification in the company	constant	Albers (2017a)
		Continuous validation of the development process	extensive (from product requirements to project plans)	Albers (2017a)
		Change validation mode according to the situation	deliberately chosen (physical, virtual, mixed)	Albers (2018)
		Validation via the customer	via customer	Fang (2008)
		Verification of work results	verify / avoid	Boes (2018)
4 Individual	4-1 Knowledge	Distinctive professional competence and expert knowledge	distinctive	Reiß (2018)
		Detailed technical instruction	detailed	Muduli (2017)
		Preserving and contributing experience and knowledge	is preserved and contributed	Albers (2020a)
	4-2 Skills and competencies	High social competence	high	Reiß (2018), Doeze Jager-van Vliet (2019)
		High method competence	high	Reiß (2018)
		High problem solving competence	high	Albers (2016a), Breitschuh (2016)
		High creativity potential	high	Reiß (2018)
		High potential for elaboration	high	Reiß (2018)
		Emotional stability	high	Doeze Jager-van Vliet (2019)
		Good drawing and sketching skills	good	Jensen (2018)
		Quick comprehension	quick and good	Yusuf (1999)
		Strong heuristic competencies	high	Yusuf (1999)
		High assertiveness	high	Doeze Jager-van Vliet (2019)
		Concepts of customer-developer communication	on one level (high comprehensibility, high level)	D'Souza (2015)
		Existence of agile basic competencies	existing	Baltes (2017)
	4-3 Individual styles of thinking and acting	Diversity in employee composition	diverse	Hofert (2018), Steele (2015)
		Alignment of working methods at agile and non-agile department interfaces	adapted working methods (agile and non-agile do not conflict with each other)	Albers (2020b)
		Self-image of agile team members	as a problem solver for customers	Albers (2020b)
	4-4 Motivation and emotion	Motivation and joy in experimenting with changes	high	Hofert (2018), Forte (2017)
		Feeling of self-determination and influence	existing	Muduli (2018)
		Courage, openness and self-confidence	existing	Albers (2020a)
		Recognition and appreciation of work	appreciated and recognized	Albers (2020a)
	4-5 Attitude	High commitment of the team	high	Heerwagen (2018), Laufer (2018)
		Intensive teamwork	intensive	Romero (2011)
		Direct communication channels in the team	direct (face to face)	Forte (2017), Cockburn (2000), Prenner (2017)
		Short response times and high availability of colleagues	short/high	Albers (2020a)
		High exchange of knowledge within the team	high	Forte (2017), Song (2011)
		Conviction of the use of methods	convinced and motivated	Albers (2020a)
		Open-mindedness towards new methods	high	Paasivaara (2018)
		Respectful interaction with each other	respectful	Doeze Jager-van Vliet (2019)
		Reasonable expectations of agile working practices	realistic	Gregory (2015)
		Courtesy and kindness	courteous and kind	Ortu (2015)
		Willingness to change	high	Baltes (2017)
		No feeling of additional administrative effort	not existing	Albers (2020a)
		Transparency without a feeling of paternalism	high / not existing	Boes (2018)
		Company-wide awareness of needs for agile ways of working	existing	Albers (2020b)
	4-6 Performance	Constant employee performance	at constant level	Böhm (2019)
	4-7 Output	Results are collective property of the development team	are collective property	D'Souza (2015), Song (2011), Gregory (2015)
	4-8 Relationships	Shared responsibility and mutual commitment	existing	Hoda (2013)
		Self-organisation of responsibilities	self-organized or regulated within the team	Zimmermann (2019), McCann (2009)
		Clear premises for the ability to act	known and openly communicated	Albers (2020b)
		Understanding the objectives of others	existing	Albers (2020b)
		Team success over personal interests	existing	Albers (2020b)