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MANAGING CYCLES IN DEVELOPMENT PROCESSES – ANALYSIS AND CLASSIFICATION OF EXTERNAL CONTEXT FACTORS

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ABSTRACT
Industry is facing diverse challenges initiating from the dynamic temporal behavior and interdependencies of the elements within the innovation process as well as in its context. One central element underlying these intense variations and uncertainties is the development process, experiencing various cyclic variations and influences from the process interior as well as from process- and company-external factors.
Consequently, research is aiming at a sophisticated management of these cycles and dependencies. Paving the way for a holistic management of cycles and correlations, this paper addresses the specific aspect of influencing factors from the external development process context. Based on an evaluation of established approaches characterizing the product development context, an integrated concept is synthesized, providing a classification of the various specific influencing factors. Thereby, an enhanced, structured understanding of the dynamics, dependencies and implications of the external influencing factors can be supported, thus laying the ground for an empirical validation in industry.

Keywords: Managing cycles, innovation processes, development processes, design context

1 INTRODUCTION
The development of innovative products from the field of consumer as well as capital goods is influenced by numerous external and internal parameters with a dynamic temporal behavior. Innovating companies have to deal with high pressure concerning time, costs, competition, development etc. This is even intensified by challenges like increasing globalization, emerging new technologies, increased interdisciplinary work or dynamics in the context of entrepreneurial activity ([1], [2]). Moreover, the structure of commercial solutions is changing to integral combinations of products and services, the so-called product-service systems (PSS) ([3], [4]).
To ensure the competitive capability as well as the capacity for innovation, manufacturing companies constantly have to optimize the performance, efficiency and effectiveness of their innovation processes [5]. One vital challenge industry in this regard is the dynamics of the innovation process context factors, leading to uncertainty, implicating the need for adaptations and significantly influencing the innovation process results.
To support industry in this challenge, research is addressing this field of highly dynamic surrounding factors as well as necessary adaptations, aiming at acquiring a more profound understanding of these dynamics. Consequently, one vital issue is the anticipation of the temporal variations of influencing factors that are crucial for the innovation process result. Moreover, a sound understanding is needed of the effects induced within the innovation process by the context factors. Subsuming, an enhanced understanding of possible changes, variations and implications within the overall innovation process is necessary. Therefore, current research is focusing the analysis, classification and structuring of these fields.
This paper concentrates on the development process as a part of the overall innovation process. Central aim is a compilation of factors and elements describing the external context of development processes. Based on this, a structuring and classification has to be established. Moreover, a step towards a more detailed description of the temporal variations mentioned is necessary. In the context of the ongoing research, these elements signify the basis for the design of an empirical study, the subsequent analysis as well as the necessary classification and interpretation of the findings.

2 DYNAMIC TEMPORAL BEHAVIOUR OF THE PRODUCT DEVELOPMENT CONTEXT

2.1 Dynamic cyclic behavior – a fundamental challenge for industry

One of the crucial challenges industry is facing is the complex, dynamic behavior of elements and parameters from both within and outside the companies. According to Lindemann et al. [6] this behavior is referred to as cyclic. Following this definition, cycles characterize:

- the repeated succession of similar occurrences and of results initiated by them like sub-processes, artifacts, developments etc.
- the succession of different occurrences within one sequence, like e.g. the innovation process

Regarding the industrial innovation process, various cycles exist within the different business processes – like research & development, production, logistics, finance or service – that are highly interdependent.

Moreover, considering elements outside of the innovation process, the term cycle also encompasses dynamic temporal variations of available (production) technologies, customer requirements, personnel, competitive environment, society or product life cycles.

These diverse cycles from in- and outside the innovation process are closely interconnected and decisively affect companies and their innovation processes. Deficits resulting from that are numerous changes due to insufficient coordination, inadequate definition of objectives, missing transparency or deficient cross-disciplinary collaboration, thus complicating the achievement of temporal, quality-related and economical targets.

To face these disturbances from within and outside the company, different approaches like e.g. strategic product and process planning [7] exist. Some models of the innovation process already even consider the cyclic aspects of the entire innovation process. A major step in this direction provides the 3-cycle model of the innovation process according to Gausemeier et al. [8], that addresses cyclic behavior from the beginning of the innovation process initiated by requirements from the market until the successful introduction on the market.

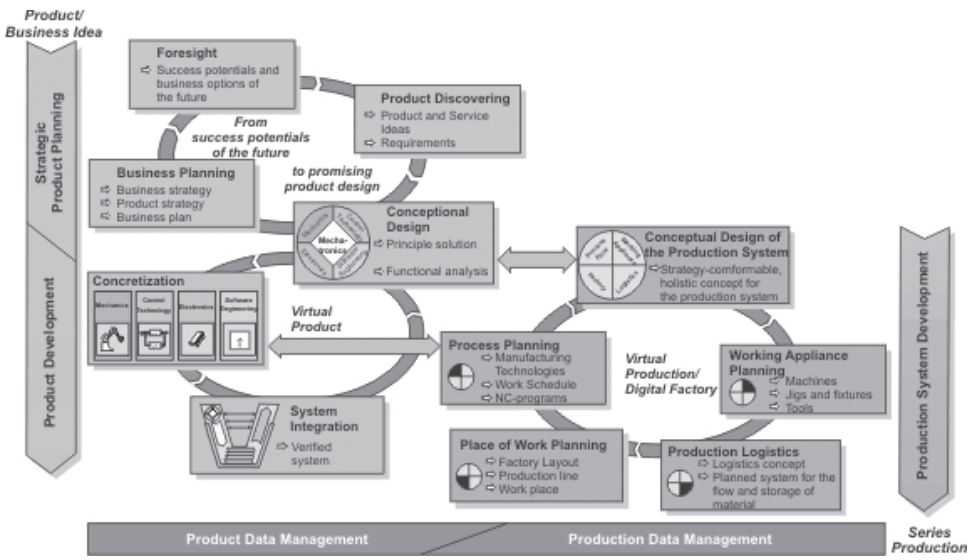

Figure 1:Three-cycle model of Product Design according to [8]

Nonetheless, approaches like this or from Bullinger [4], Spath [1]or Weber [9] mostly just address iterations and repetitions of events and process steps within the innovation process. Interdependencies between sub-processes, cycles within and between sub-processes as well as occurring iterations are often not considered adequately. Thus, the central aspect of mutual interferences between the internal and external cycles is neglected. Moreover, these approaches are not applied for the planning of

company internal process flows. They solely offer a starting point for the planning of measures for the innovation process aiming at the coordination of external and internal cycles. Due to this, these approaches derived from static strategies can only marginally contribute to a long-term economical success.
Considering this, it becomes obvious that theoretical and empirical approaches available currently are not sufficiently addressing the challenges posed by cycles within industry. So far, a sophisticated management of variations in the innovation process as regards content or temporal behavior is missing in academia as well as in industry. Moreover, analysis and modeling approaches as well as methods for deriving measures are lacking that provide a comprehensive consideration of cycles in the context of the innovation process. Subsuming, a holistic approach is needed that provides enhanced analytical methods and measures to cope with the challenges industry is facing and thus to ensure successful innovation processes [7].

2.2 Managing cycles in innovation processes – a transdisciplinary approach

This leads to the vital, yet unsolved challenge of controlling and managing the collectivity of cycles and their dependencies occurring within the innovation process. Therefore, current research is aiming at developing sophisticated approaches and methods to systematically support industry.
Funded by the German Research Foundation (Deutsche Forschungsgemeinschaft – DFG), the collaborative research centre 'Sonderforschungsbereich 768 – Managing cycles in innovation processes – Integrated development of product-service-systems based on technical products' is addressing this subject.
The term 'Managing cycles' as the central element of this research project comprises the planning, management and control of the cycles and their interdependencies described. To ensure the long-term success in the management of cyclic processes it is vital to anticipate future developments of interacting domains, to act preliminary, to react instantaneously and to efficiently organize the adaptation to changed conditions [6]. With this approach, research is aiming at building up a sound understanding of specific characteristics and requirements of cycles as well as of their interdependencies inherent in innovation processes. Based on this, possibilities have to be developed for influencing and managing cycles in order to improve innovation processes in terms of time, costs and quality.
Bundled in the collaborative research centre SFB 768, a transdisciplinary research team from the fields of engineering, social and business sciences is focusing the diverse aspects relevant within the overall life-cycle of product-service systems. Among others, discrete areas of research are:

- Life-cycle-oriented strategic product planning
- Requirements engineering
- Development process design
- Development of competencies
- Complexity management
- Flexible production structures
- Customer integration
- Customer relationship management
- etc.

To provide a mutual understanding of the innovation process within this research team, a generic innovation process model was generated as synthesis of several established models ([10], [11], [12], [13], [14], [15], [16]). This underlying mutual understanding subdivides the overall innovation process into 7 discrete phases (see Figure 2).

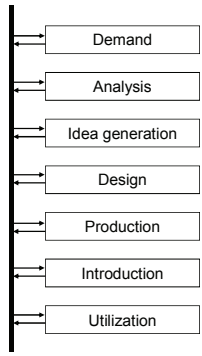

Figure 2: Model of the generic innovation process and the understanding of cycles according to [6]

Thus, this generic model offers a mutual understanding applicable in the different fields involved in the research project. The focus of this model is on the depiction of different sub-processes of the innovation process. Though iterations and recursions are solely indicated slightly, the cyclic structure of the innovation process becomes apparent, representing its non-sequential course [12].
Picking up the definition of managing cycles, the overall aim is to plan, manage and control cycles and their mutual interdependencies within all fields of the innovation process. As an example, managing cycles would encompass such diverse aspects as cycles ranging from product development, production, production planning and technology development to staff competencies, integration of external stakeholders (like customers), management of the process integration as well as to tool design of activities from all relevant process cycles.

2.3 Cycles in the context of development processes

One specific aspect when focusing the management of cycles is the development process of new solutions, in particular of product-service systems. The central issues to be considered in the field of development processes initiate from the complex and dynamic context companies are facing.
Complexity and dynamic change have been objects of research in the fields of organization as well as systems engineering for a long time ([17], [18]). However, the relevance and urgency for an enhanced solution has significantly increased within the last years, due to reduced product and technology life-cycles, increasing complexity and interdependencies of products, processes and markets as well as raised turbulences in the design context ([8], [19], [20]).
Regarding the specific context of development process, cyclic behavior occurs both within the development process as well as outside of it. Variations caused by cycles in the companies' surrounding as well as objects from the development process itself (like artifacts, resources etc.) can cause changes and unintentional iterations and recursions within the development process. These variations have to be minimized to avoid negative effects like increases in development times [21], (non-conformity) costs or quality issues [22].
Consequently, handling these variations is seen as a core element for the overall concept of managing cycles. This leads to the specific interest of identifying the relevant factors influencing the design of organization, processes and products as well as their interdependencies and dynamics. Research on the influencing factors already described means addressing a variety of questions in a complex and dynamic company surrounding with multiple implications for the development process. Figure 3 shows an overview of the initial understanding within the research project of possible influencing factors on the development process.

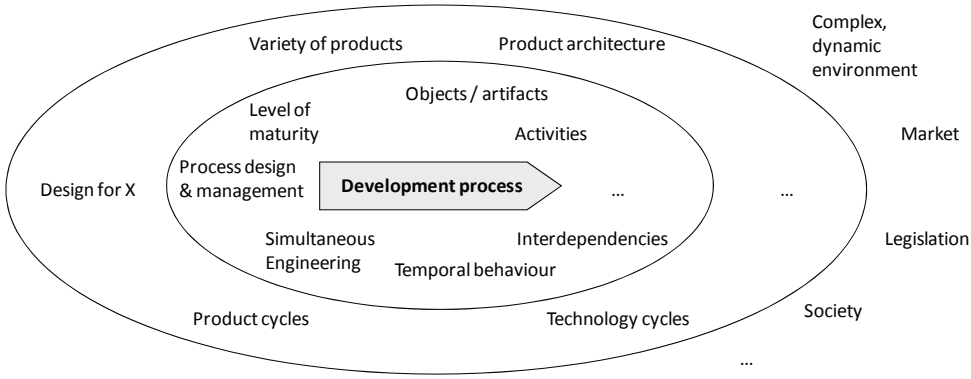

Figure 3: Influencing factors on design and management of development processes (according to [6])

According to this overall understanding and approach, all of the elements can be object of cyclic effects and behavior, moreover being interconnected to a specific, individual, even changing degree. Elements within the inner circle illustrate artifacts of the development process that can predominantly be related to the internal organization, design, implementation and management of the development process itself. The factors outside of the outer circle represent influencing factors from the companies' external context. Finally, the elements in between the inner and outer circle represent the characterization, adaptation and behavior of the structure and output of the development process elements. Thus, the behavior of the development process as a part of the innovation process can be characterized, showing the adaptation of the development process performance to solution-, strategy- or context-related factors.

3 SUPPORTING AN ENHANCED UNDERSTANDING OF CYCLIC CONTEXT BEHAVIOUR THROUGH ANALYSIS AND CLASSIFICATION

3.1 Research objective and approach selected

As sketched in paragraph 2.3, a holistic understanding and modeling of the cyclic behavior of the development process elements and their interdependencies has to be developed. One part of the research necessary is the investigation of the influencing factors described as external in Figure 3. These cycles, occurring as boundary conditions and external influences on the development process, can be identified within the entire company as well as its surrounding ([23], [24], [25], [26]). Paving the way for a holistic understanding of the complex correlations and dynamics, this paper specifically addresses the analysis and structuring of these external factors and cycles. Therefore, two discrete elements have to be set up:

1. The state-of-the-art from the different fields of research addressing variations of products and processes is summarized. Based on this review, a synthesis of the factors triggering variations within the development process is generated and a model for classification proposed.
2. In a second step, criteria have to be established that allow the characterization of variations of the external surrounding conditions as well as of the changes induced by those context variations.

These two elements provide a basis for a subsequent empirical validation and a capturing of the cyclic behavior of the identified external context factors. Thus, an analysis of the development process context and of the occurring reactions of the development subject and the process can be executed.

3.2 Synthesis and classification of external design context factors

For the identification of relevant influencing factors from the development process context, eight established approaches are selected for a critical analysis and further investigation [12, 24, 27-32]. All of these approaches cover variations of context, product and processes, but differ in the viewpoints selected and the classification scheme chosen.

For example, Hales & Gooch [27] emphasize the major importance of a sound knowledge of the context of a development project for its overall concept. They suggest an extensive model for the analysis of the innovation process context. The model consists of five discrete levels of resolution:

- macroeconomic
- microeconomic
- corporate
- project
- and personal

Based on this model, they develop a design context checklist, supporting the identification of the most relevant context factors for specifying development projects. Moreover, the checklist assists in monitoring the development progress and enhancing the process outcome quality.

McQuater et al. [29] examine the management and organizational context of New Product Development by collecting empirical data in eight companies of diverse size, sector and development activity. They propose a set of influencing factors classified in the 5 groups of

- Stakeholders
- Business Practices
- Environmental contingencies
- the Firm
- and New Product Development

Reyman et al. [32] develop a domain-independent model for the structured reflection on design processes. As one aspect, they address the design situation and the need for analyzing design task and context. Thus, they derive a checklist adaptable to specific design situations.

These examples show the diverse approaches selected by the different authors for describing the innovation process context and structuring the result. Regarding the purpose of the research project, it is necessary to generate a framework that encompasses the diverse dynamic, interconnected influences and factors with relevance for the development process.
Moreover, the following conclusions derived from the review of the different approaches have to be considered:

- Most approaches lack the consideration of temporal aspects
- Cyclic behavior is addressed insufficiently
- Most approaches show an intense consideration of sources of influencing factors, yet influenced elements are addressed to a comparatively low degree

Consequently, these findings and requirements were considered for compiling an initial synthesis and classification of external context factors as shown in Table 1. This compilation summarizes the context factors addressed by the several approaches and models analyzed in the first step. As pointed out before, these different approaches incorporate varying scopes, aims and levels of detail. Therefore, the premise for an enhanced consideration of development context factors has to be the consideration of these heterogeneous aspects and the consolidation within one comprehensive approach.
To attain this initial framework describing context factors as comprehensive as possible, the elements and factors from the different models are summarized and categorized into three main sections:

- Environment
- Market
- Company interfaces

These three main levels of classification are subdivided into 5 sub-domains, namely

- Society
- Technological development
- Sales
- Purchases
- Interaction market - company

Thus, the diverse elements covered by the approaches for context modeling can be allocated as shown in column "contributing factors" in Table 1. While the detail level shown in Table 1 stops at the contributing factors, each factor itself comprises a set of elements to specify the criterion and to evaluate its specific characteristics. Subsuming, the framework provides a first step for unifying the diverse criteria addressed in different models of development context factors.

Table 1. Synthesis and classification of external context factors of the development process

Level	Influences	Contributing factors
Environment	Society	Culture
		Demography
		Economy
		Policy
		Legislation
		Norms
		Ecology
		Random
	Technological development	Research / academia
		Industry (external)
		Industry (internal)
Market	Purchases	Funding
		Product components
		Manufacturing technology
		Services
		Human resources
		Energy
		Raw materials
		Knowledge / information
	Sales	Stakeholder demographics
		Stakeholder requirements
		Competitors
		Market position
Company interfaces	Interaction market - company	Purchasing
		Market analysis & requirements engineering
		Stakeholder integration
		Sales & marketing
		Customer services

3.3 Proposal of a model for classification of external design context factors

The initial synthesis and classification of external context factors presented in section 3.2 provides a comprehensive, hierarchical overview of elements and factors defining the context of product development by subsuming diverse established context-modeling approaches.

Nonetheless, scrutinizing this synthesis for its applicability for monitoring cycles in the development context (the major aim of the overall research project) shows unsatisfying results. While factors and elements influencing development can be allocated to the contributing factors within the framework due to the broad synthesis of different approaches, issues of demarcation occur. Factors like e.g. legislation or economical development can not be allocated unambiguously whether they initiate from society or the market and whether they influence the company in focus or the context of application of the future product. Moreover, changes and variations (i.e. cycles) of context factors leading to changes

in the elements affected necessitate adaptations in classification – a fact the initial framework is not capable of (same as the various established approaches).
To resolve this, the model for classification of external context factors shown in Figure 4 is proposed. The first main element, the context classification, consists of five elements:

- Environment,
- Market
- Company interfaces
- Company
- Development process

In this model, market is considered as being an element of the overall environment. Consequently, company interfaces are part of the market, functioning as the interface to the company. Within the company, the overall development process takes place, thus laying an emphasis on this in the model. To further facilitate the allocation of factors, a differentiation between purchases and sales is introduced in the model, thus offering the possibility to distinguish factors from environment or the market influencing the company from one perspective or the other. The last essential addition introduced is the application context, bundling fields of context possibly affecting the application and usage of the future product (like e.g. legislation, energy etc.). These different fields can also be considered as different "degrees of proximity", thus also indicating a level of significance for the development process.

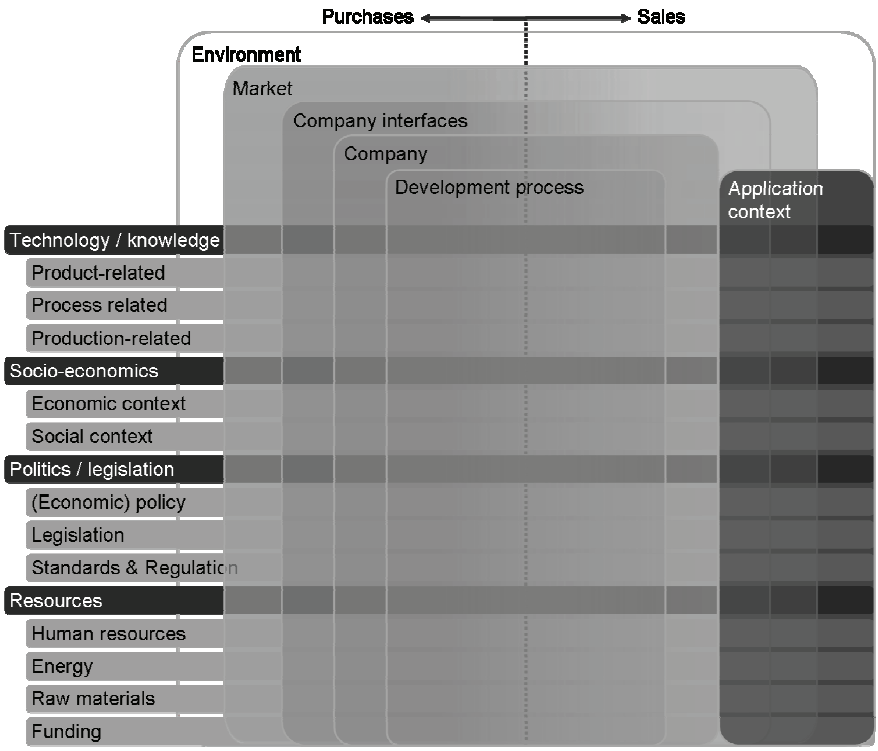

Figure 4: Proposed model for classification of external context factors

The second main element are the four main classes of influence:

- Technology / knowledge
- Socio-economics
- Politics / legislation
- Resources

Applying the synthesis of context factors from section 3.2, twelve main elements are allocated to these four classes, leading to the framework shown in Figure 4. Each of these elements is considered as possibly influencing or contributing to the different fields like market, application context or development process. Thus, the effect of single factors and their variations like e.g. tax reductions can be allocated to the different elements affected (like application context, purchase market etc.). The specific elements of the twelve elements again can be derived from the initial synthesis of context factors presented in section 3.2.

3.4 Development of a set of criteria for the classification of cyclic context factors

The classification model suggested in section 3.3 offers an enhanced framework for classifying and monitoring external influencing factors of development processes. Nonetheless, the demand for an improved consideration of the dynamic, cyclic aspects of these factors has not been addressed yet.
In a first step, a general definition of the applied understanding of external cycles in the context of development processes has to be provided. Figure 5 illustrates the elements determining a general process. Despite input, output and functions/activities, processes possess a certain structure and necessitate a specific duration and use of resources. The external context of processes has a certain influence on all of these elements and can be subject to changes and variations (cycles). Moreover, the internal elements of the process as well as the factors from the context are interconnected and influence each other.

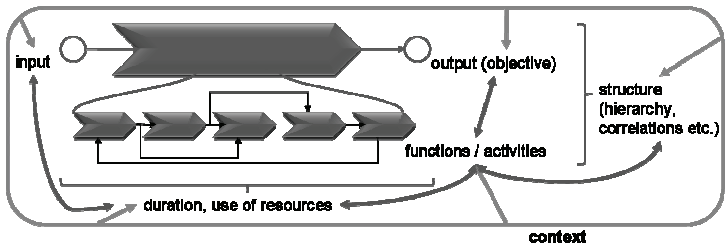

Figure 5: Process elements and the understanding of external cycles

Consequently, to understand and model the changes implied within the process, the overall chains of effects have to be analyzed. Therefore, a set of questions has to be addressed:

- Characteristics and cyclic behaviour of the influencing external context factors
- Correlations between these context factors
- Interdependencies between context factors and process elements
- Response characteristics of process elements

By answering these questions, influencing factors, chains of effects and consequences can be identified, classified and evaluated regarding their cyclic relevance. Therefore, the initial set of classification criteria shown in Table 2 is proposed.

Table 2. Classification criteria for cyclic external context factors of the development process

Influencing external factor	
Cyclic behavior	Time of occurrence
	Frequency of change
	Rate of change
	Gradient of change
	Probability of change
Relevance	Degree of change
	Relevance of change
	Interdependencies

Induced effect	
Cyclic behavior	Delay of reaction
	Sensitivity
	Response characteristic
	Path of transmission (direct / indirect)
Relevance	Degree of effect
	Criticality of effect
	Interdependencies

Core element of this suggestion is the consideration of both the cyclic behavior of the external influencing factors as well as of the effect induced. By considering both of these aspects, an analysis of interdependencies can be executed based on empirical data. Thus, applying the criteria suggested in Table 2, the cyclic behavior as well as the relevance of the factors considered can be determined. This offers the opportunity for an improved consideration and anticipation of the cyclic external factors, supporting the overall goal of understanding and managing cycles in development processes.

4 CONCLUSIONS AND OUTLOOK

Cycles in the overall context of the development process pose a fundamental challenge for the success of the innovation process. To enhance the industry's capability to cope with this challenge, current research is addressing the management of these cycles.

As a contribution, this paper focuses the external context factors influencing the development process. In a synthesis based on a literature review, a compilation of external influencing factors is generated. In a second step, a model for classification of these context factors is proposed capable of covering various viewpoints as well as the description of changing context conditions. Moreover, a set of criteria for the classification of the cyclic behavior of external design process context factors is suggested.

In the next step, the temporal behavior of the specific factors has to be determined. Moreover, investigation is necessary on the degree and characteristic (strength, delay, temporal behavior) of influence of these factors on sensitive elements of the innovation process. Furthermore, the interdependencies of the single factors have to be investigated. These next steps will be addressed by an explorative field study. Establishing this understanding as well as necessary approaches for modeling signifies the first major part of a holistic understanding of cycles influencing development processes.

Simultaneously, research has to be done equivalently on the internal factors of the development process as they were sketched in chapter 2.3. This means, that the design context within the company – that is the various characteristics, their temporal behavior as well as their interdependencies – has to be investigated and validated empirically.

Based on these results, the cyclic correlations between the elements of the development process, the external influencing factors and the interfaces of the overall innovation process can be addressed. Thus, an integrated, holistic understanding of cycles within innovation processes can be established within the overall research project.

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