Towards the Analysis of Information Systems Flexibility: Proposition of a Method

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ABSTRACT
The flexibility of information systems (IS) is a topic of growing importance within IS analysis and design. IS have to cope with the increasing structural and behavioral complexity of environmental and business systems. Both increase the need for flexibility of a company's IS. On the one hand, researchers and practitioners agree that IS flexibility is a crucial success factor for the viability of business systems, on the other hand, however, earlier research has come to the conclusion that the concept of flexibility is hard to capture. One of the reasons for this is the difficulty to perform flexibility analyses on IS. This paper investigates different definitions of flexibility and methods for the analysis of IS flexibility regarding their precision, completeness and applicability by using a systems and organizations theoretical foundation. The paper's research goal is to propose a certain way of understanding flexibility as well as a method for analyzing it. Furthermore, "rules of thumb" are introduced to support the development of IS strategies with regard to flexibility aspects. Finally, the applicability of the IS artifact is exemplified by a scenario within the Plant Engineering and Construction industry.

Keywords
Flexibility, Method, Systems Theory, Organizational Theory, Plant Engineering and Construction, Strategic IS Planning

1. PROBLEM SETTING
The flexibility of information systems (IS) is a topic of growing importance within IS *analysis* and *design*. An IS can be considered the *information processing part* of an *environmental system* or a *business system*. Hence, an IS consists of (a) information processing tasks (management processes and servicing processes) and (b) IS task actors (business application systems, managers and other staff) [1]. From a *systems theoretical* perspective, an IS exhibits the characteristics of *structure* (system components and the relations between them) and *behavior* (change of system states in time) [2], [3]. The primary goal of a system is its *viability*, i. e. the successful existence over time [4], [5]. Due to the increasing *structural* and *behavioral complexity* of the *environmental system* and the *business system* [6], [7] the *flexibility potential* of an IS gains importance for IS analysis and design – besides the consideration of *functional* (e. g. production, distribution) and other *non-functional requirements* (e. g. data security, Business-IT-Alignment, IT availability). The IS has to *fit*, in particular with regard to flexibility, into both the environmental system and the business system in order to ensure the *viability* of a business system.

In view of these challenges it is essential for IS managers to get a precise and comprehensive understanding of the concept of *flexibility*. Generally, flexibility is understood as the *ability to adapt to changes* [8] or "capability to respond to environmental changes" [9]. These definitions capture the concept of flexibility on an abstract level. CONBOY and FITZGERALD postulate that "the body of research on the definition of flexibility indicates such an interpretation is too simple" [10]. Hence, these definitions lead to many semantic (mis)interpretations of the term by IS managers (problems of *ambiguity* and *imprecision*). It is therefore important to analyze the available definitions of flexibility with regard to their *linguistic* characteristics. In addition, due to the increasing structural and behavioral complexity of IS, IS managers have to cope with increasing demands regarding their functional and cognitive capabilities. As a conclusion, IS managers need an appropriate method to support the analysis and design of IS.

From a systems theoretical perspective the problem setting can be interpreted as an *input output system* $S_{IO} \subseteq IN \times OUT$ (cf. Figure 1), with IN representing the input set and OUT the output set (external view). Furthermore, let be $IN \cap OUT = \varnothing$. The relationship between IN and OUT of S_{IO} is unknown (internal view, "black box") [1], [11]. IN represents the characteristics of the given IS and the environmental system, OUT the need for adjustments of the existing IS to close the gap between current and

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required IS flexibility. In order to support the analysis of flexibility, we investigate the following research questions:

a) *How is the term flexibility currently understood in literature (esp. IS literature)?* In order to answer this research question, we have to identify the dimensions which constitute the term flexibility. A precise understanding of the term flexibility is a prerequisite for a successful "opening of the black box" of S_{IO} (*conceptual perspective*).
b) *How can the analysis of the current degree of flexibility and the required degree of flexibility of an IS be supported?* This research question shall "fill the black box" of S_{IO} with a method which copes with IS flexibility (*methodological perspective*).

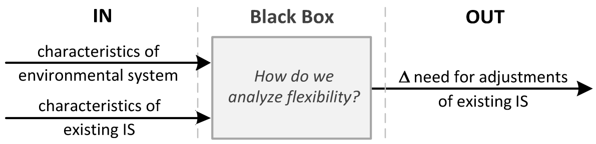

Figure 1: Problem setting interpreted as input output system

The research goal of this paper is to examine the two research questions (a) and (b) and to propose a method to support the analysis of IS flexibility as a conceptual IS artifact. To do so, we use a *systems theoretical* [2], [3] and *organization theoretical* foundation [12]. The paper is organized as follows: section 2 offers an overview of the current understandings of the term flexibility in literature and identifies the research gap. In section 3, we develop a systems theoretical understanding of flexibility. In section 4, a method is introduced representing the IS artifact. The applicability of the IS artifact is shown in section 5, exemplified by a scenario within the Plant Engineering and Construction Industry (PEC industry). Finally, section 6 summarizes the paper, discusses limitations, and gives an outlook on our future research.

The *deductive* research method used in this paper is based on VON GLASERSFELD's *Radical Constructivism* [13] and results in a *method* [14] as a *conceptual IS artifact*. This paper reflects a *design-oriented IS research* and is developed according to the guidelines of HEVNER ET AL. [15], and also [14].

2. RELATED WORK

In order to investigate the research question (a), we perform a literature review according to FETTKE, LIGHT et al. and COOPER et al. [16], [17], [18]. The literature review is aimed at (1^{st}) identifying the *current understanding* of the term flexibility, particularly within IS research, and (2^{nd}) gaining an overview of the *available methods* which support the analysis of flexibility. We investigate literature especially within the period of 1990-2010 rated with "A+" to "B" within the VHB-JOURQUAL 2 ranking (part *IS and information management*). Furthermore, the IS conferences AMCIS, ECIS, ICIS and HICSS of the same period are consulted. Papers are selected if they contain the concept of "flexibility" (with or without post- or pre-fixes) or methods for analyzing flexibility. In addition, typical papers of other domains (e. g. industrial industry, service industry) are consulted in order to provide a broad overview. The *quantitative* results of the literature review are as follows (cf. Table 4, Appendix): 113 papers mention the term "flexibility"; 34 definitions of the term flexibility are further investigated. Certain concepts to define flexibility, like "change" (59 %), "adaption" (35 %) or "environment" (38 %) are used frequently. Others are used rarely, like "structure" (9 %) or "behavior" (6 %).

From a *qualitative* perspective, the analyzed definitions of flexibility can be divided into a main class (a) of *generic* definitions and two subclasses. Subclass (b) provides definitions referring to *objects of flexibility,* whereas subclass (c) provides definitions referring to special *kinds of flexibility* (cf. Figure 2).

The generic definitions in class (a) capture the concept of flexibility on a very abstract level (e. g. "Flexibility is a quality of a system, which allows it to change effectively and recently" [19], "Flexibility of a system is its adaptability to a wide range of possible environments that it may encounter" [8] or "flexibility as an adaptive response to unpredictable situations" [20]).

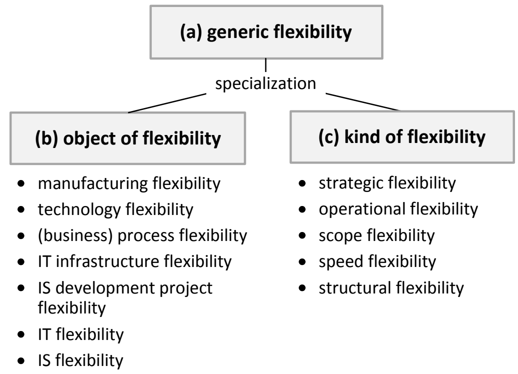

Figure 2: Classification of flexibility definitions

Generic definitions use concepts such as *adaption*, *change*, *reaction* and *variability* to define flexibility (cf. Table 4, Appendix). Due to the multiplicity of different definitions including different meanings (one-to-many relation between concept (syntax) and meaning (semantic), in the narrower sense ambiguity), there is the risk that IS managers misinterpret the flexibility concept, which might lead to lower decision quality. Furthermore, the concept flexibility as well as the concepts used to explain flexibility (e. g. *adaption*, *change* or *response*) exhibit *intrinsic fuzziness* (ordinal scaled values) and *informational fuzziness* (complex concept with the need for decomposition and usage of other metric scaled concepts) [21], [22], [23]. Summing up, the generic definitions may lead to decisions with less decision quality because of *ambiguity* and a *lack of precision*.

The second class of definitions (class (b)) concretizes the generic considerations of flexibility to a (special) object of flexibility like *manufacturing flexibility* [24], *IT infrastructure flexibility* [25], [26], [27] *IT flexibility* [28] or *business process flexibility* [29]. These definitions either use the generic definitions within a specific domain without adding any further details, or enumerate certain aspects of flexibility which are applicable for a special domain. However, these definitions may be incomplete. An IS manager who uses these definitions might miss important aspects while analyzing and designing an IS.

Several authors limit the general understanding to specific kinds of flexibility (class (c)). Examples are: *strategic flexibility* [30], *operational flexibility* [31], *scope flexibility* [32], *speed flexibility* [32] or *structural flexibility* [33].

Apart from the above analysis of different understandings of flexibility, we investigate available methods supporting the analysis of IS flexibility. None of the investigated papers offers such a method. Nevertheless, some authors offer flexibility understandings regarding single aspects:

- De Leeuw and Volberda [34] implicitly develop a solution to the informational fuzziness mentioned above. They propose an understanding of organizational flexibility and differentiate between flexibility of management and organization tasks. However, a method is not presented.
- Schober and Gebauer [35] present a formal model to determine the value of IS flexibility. Their approach is based on decision tree analysis (DTA) as well as on real options analysis (ROA) and supports IS managers evaluating IS flexibility.
- Based on a comparison of available IS planning methods, Palanisamy [36] develops hypotheses representing relationships between user *involvements*, *flexibility* and *IS success*. The author concludes that IS success and organizational flexibility can be achieved by IS flexibility. IS flexibility itself can be influenced by user involvement. This causal chain might support IS managers in preparing IS design decisions.

Other authors (e. g. [37], [38] and [39]) offer abstract methods without explicitly considering flexibility. Summing up, we identify two flexibility problem fields:

- **Flexibility problem field (a) – 'Possible problems due to imprecision, ambiguity and incompleteness of the term flexibility':** The term "flexibility" is often defined in a generic way, resulting in intrinsic and informational fuzziness (imprecision) as well as ambiguity. Furthermore, the completeness of the definitions (at least to a given model or concept) remains uncertain. This raises the imminent danger of focusing on the wrong aspects or leaving out important ones.
- **Flexibility problem field (b) – 'Lack of methodological support':** None of the papers investigated offers a method to support the analysis of flexibility. In contrast to that, we postulate that a support by a method is mandatory in order to reduce the complexity of the task complex 'analysis and design of flexible IS'. Likewise, a stepwise approach simplifies the task execution by the IS manager (decomposition of the task complex). Note that a solution of the problem field (a) is a necessary condition to maximize the decision support of a method.

In the following sections, we investigate possibilities for resolving the flexibility problem fields (a) and (b).

3. DERIVATION OF CONSTRUCTION IDEAS

As a starting point, the flexibility problem fields (a) and (b) are analyzed using an *analysis level hierarchy* to gain *construction ideas* that support the construction of an IS artifact. The analysis level hierarchy consists of four *analysis levels* representing the *level of abstraction* of the concept of flexibility (cf. Figure 3). All hierarchically lower analysis levels *inherit* the characteristics of the hierarchically higher analysis levels (specialization relationship).

In relation to our research questions, the analysis levels represent the following (cf. Figure 3):

- **'Analysis level 3':** This level represents the theoretical foundation, i. e. the theoretical (and also philosophical) assumptions of a flexibility definition. The findings of 'analysis level 3' are the foundation of all further hierarchically lower levels. The theoretical foundation of the generic flexibility definitions remains almost uncertain. This level is missing in the existing flexibility definitions. Only one of the investigated papers explicitly mentions a theoretical foundation. De Leeuw and Volberda develop their findings from an organizational and control theoretical perspective [34]. Nevertheless, the authors focus on *variety* and *structure*. Hence, *behavior* is missing (cf. section 1 and subsection 3.1).
- **'Analysis level 2':** The theoretical assumptions of 'analysis level 3' are the foundations for 'analysis level 2'. Within this level the term flexibility is elaborated. From the perspective of linguistics, a meaning (semantic aspect) (here: explanation with e. g. adaptability) is assigned to a symbol (syntax aspect) (here: flexibility). The precision and unambiguousness of this relation is an important aspect for further maximizing decision quality (cf. flexibility problem field (a)). The considered object to which the flexibility refers to is still left open.
- **'Analysis level 1':** Within 'analysis level 1' the considered object is limited to a class of objects. The available flexibility definitions focus on special objects of flexibility (e. g. manufacturing flexibility, IT flexibility) and special kinds of flexibility (e. g. speed of change). The completeness of these definitions remains uncertain (cf. flexibility problem field (a)). Furthermore, the missing theoretical foundation of the 'analysis level 3' and existing imprecision and ambiguities located within the 'analysis level 2' lead to additional problems (e. g. incomplete analysis, misinterpretations).
- **'Analysis level 0':** Within this level a concrete object (e. g. an existing enterprise) is located. Existing definitions do not consider this level. We treat this level in section 5 of this paper.

Based on the previous analysis, we postulate that an IS artifact is needed that focuses on 'analysis level 3' and 'analysis level 2'. On the one hand, the IS artifact can be applied to multiple problem classes (high degree of abstraction), on the other hand, the completeness of the investigations are increased simultaneously. The challenge is to tackle these at least partly conflicting goals. In the following, we develop the right hand side of Figure 3.

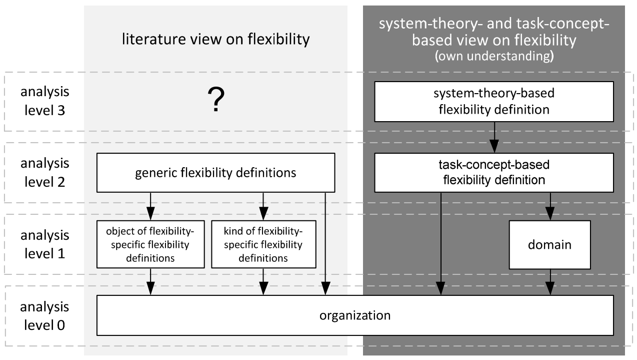

Figure 3: Analysis level hierarchy

3.1 Elaborating 'Analysis Level 3'

The first *construction idea (a)* is the use of the *General System Theory* (GST) by Bertalanffy as a theoretical foundation [2].

The core concept of GST is the *system*, which has already been introduced in section 1. Furthermore, the methods *decomposition* and *abstraction* simplify the dealing with structure and behavior complexity as origins of the need for IS flexibility. Due to its generality, GST can be applied to multiple problem classes.

In the following, an IS is interpreted formally as a system according to GST. In order to render our argumentation more precise, let $I \neq \varnothing$ be an arbitrary index set and $v = \{V_i\text{: } i \in I\}$ a family of non-empty sets. Therefore, the general system S_G is defined as a relation on the sets V_i, $S_G \subseteq \times V_i$, where $i \in I$. The sets V_i within S_G are the system components. The set $R_G \subseteq \{(V_i,V_j)\text{:}i,j \in I \wedge i \neq j\}$ is the structure of S_G describing the pairwise relationships between system components. The projection $S_G \rightarrow V_i \times V_j$ describes the behavior of the structure element (V_i, V_j) [11], [1].

If we interpret an IS as a general system S_{IS}, the set V_i can be divided into the subsets V_t representing *tasks* and V_{ta} representing *task actors*, where $V_t \cap V_{ta} = \varnothing$. The subsets V_t and V_{ta} are the subsystems S_t and S_{ta} of S_{IS} [2], [3], [11]. By analyzing the structure and behavior of S_{IS}, an IS can be investigated completely.

Both, behavior and structure can be flexible to a certain extent. This extent is either passively generated by IS design or it is explicitly considered at IS' build time. Our approach enables the inclusion of flexibility aspects into IS at build time. Summing up, we introduce an own concept of flexibility on level 3:

Flexibility is the capability of a system to react to or anticipate system or environmental changes by adapting its structure and / or its behavior considering given objectives.

From a systems theoretical perspective, we postulate that this definition is *complete*. The enhancement of the *precision* of the flexibility concept is developed in the following subsection.

3.2 Elaborating 'Analysis Level 2'

The second *construction idea (b)* concerns the usage of KOSIOL's task concept[1] [12] extended by [1]. The task concept's utility has been proven within IS research in numerous cases e. g. [40], [41], [42]. Although already developed in the 70s, the task concept is *robust* with regard to new requirements such as increasing flexibility. An IS consists of information processing tasks (*task level*) and task actors performing these tasks (*task actor level*) (cf. section 1). Every task within the task level is interpreted according to the construction idea. A business process that is part of an IS can be considered as a *network of tasks*. This network of tasks reflects the *structure* of the business process. The sequence of the task executions characterizes the *behavior* of the business process. Modeling languages (e. g. Unified Modeling Language (UML) or Semantic Object Model (SOM)) offer independent models for modeling the structure and behavior of business processes [43]. Ideally, task actors are designed or chosen ("make-or-buy-decision") with respect to the flexibility requirements of the task level (top-down approach). For this reason, we concentrate on the task level.

Every task (e. g. the task 'plant construction') can be characterized from an *external view* and an *internal view* (cf. Figure 4). The *external view* reveals (1) the *object of the task*, (2) the *goal* and one or more *objectives* of a task as well as (3) one or more *pre-events* and (4) *post-events*. The object of the task includes all *attributes* of the system that are affected by the procedure of the task (e. g. material, building ground). The goal specifies the expected results after the task has been executed (e. g. 'produce plant!'). An objective specifies the degree of goal achievement after the execution of tasks such as *time*, *quality* or *cost constraints* (e. g. 'minimize costs!' and 'maximize security!'). For the current investigations we distinguish between types of goals or objectives (e. g. "produce plant!" or "costs") and instances of the goal or objective (e. g. "*one* plant" or "*minimize* costs!"). Furthermore, one or more pre-events trigger the execution of a task (e. g. 'production order exists'), while one or more post-events are generated after the execution of a task (e. g. 'plant construction is finished'). The *internal view* defines the *procedure* which realizes the goal of the task. The procedure can be further decomposed in *workflow management* and *activities*. The workflow management controls the process of activities, whereas the activities interact with the object of the task by using *sensor* and *actor relationships*. The relationship between workflow management and activities forms a control loop. Furthermore, a task is executed by one or more *task actors* which may be a human for *non-automated* tasks, an application system or machine for *fully automated* tasks or a man-machine system for *partially automated* tasks. The components of the task concept can be analyzed by using both structure and behavior to gain support in analyzing and designing IS.

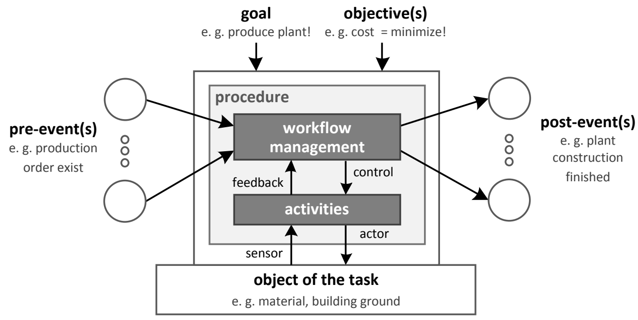

Figure 4: Task concept

The task is analyzed from a structural and behavioral point of view by combining the *construction ideas (a)* and *(b)*, (cf. Table 1).

Table 1: Flexibility of task components from a systems theoretical perspective

task component		flexibility type: structure flexibility adding or removing of…	flexibility type: behavior flexibility
	pre-event	pre-event(s)	time characteristics of pre-event(s)
	goal/ objective	goal and/or objective(s)	variety of goal and/or objective(s)
	procedure	parts of the procedure (workflow management or activities)	variety of possible results of the procedure
	object of the task	attribute(s)	variety of attribute(s)
	post-event	post-event(s)	time characteristics of post-event(s)

[1] Note that the method in section 4 includes KOSIOL's *task analysis*. The *task synthesis* is part of the *design* of an IS strategy, which is not treated in the paper.

The above flexibility types can occur (a) separately, which means that only a *single task component* is flexible (“single task component flexibility”). In addition, also (b) *multiple* task components can be flexible. In this case, *more than one task component* is flexible (“multiple task component flexibility”). In order to simplify the analysis of multiple task component flexibility, some task components can be summarized:

- **‘Loose task coupling flexibility’**: Tasks can be *loosely* coupled using *pre-* or *post-events* [44]. Considering $task_A$ and $task_B$, if $task_A$ (e. g. ‘production’) is loosely coupled with $task_B$ (e. g. ‘distribution’), one or more post-events of $task_A$ are identical with one or more pre-events of $task_B$ (post-event $task_A$ (e. g ‘product is manufactured’) is identical to pre-event of $task_B$). In the case of *structure flexibility*, the type or existence of those events change, whereas in the case of *behavior flexibility* the time of occurrence of the events changes. Two variants of loose task coupling flexibility can be identified: flexibility of one or more pre-events *or* post-events *as well as* one or more pre-events *and* post-events.
- **‘Task coordination flexibility’**: Tasks are coordinated *hierarchically* or *non-hierarchically* using goals and objectives. Goals as well as objectives can be *typecasted* (e. g. the goal type is “produce!” or the objective type is “costs”) and *instantiated* (e. g. the goal instance is “1,000 pieces” or the objective instance is “minimize!”). Task coordination comprises goals and one or more objectives.

4. INTRODUCTION OF THE METHOD

Based on section 3, a method aimed at supporting IS analysis and design with regard to flexibility is constructed (cf. Figure 5). The method supports the identification of current as well as required IS flexibility. Note that the method *does not* imply a *functional* relationship between IN and OUT of S_{IO} (cf. section 1).

Firstly, business processes are “captured”, using a business process modeling language (e. g. BPMN, ARIS, SOM). The business process model abstracts from the complexity of the real system and consists of a network of tasks. *Secondly*, every task within the business process can be examined in detail by determining the components of the task in inside and outside view (cf. Figure 4). Note, that every task (in analogy to a system) can be further *decomposed* into several tasks (in analogy to subsystems). The granularity of the model is sufficient if the IS manager is able to differentiate between *inflexible* and *flexible* tasks.

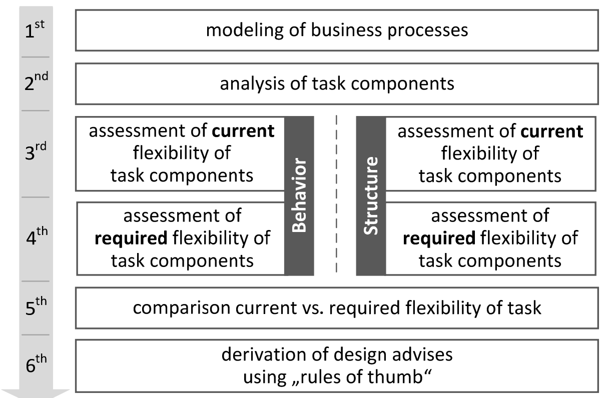

Figure 5: Method as an IS artifact

In the *third* step, the current flexibility of an individual task is assessed. For every component of the task the IS manager has to decide *which* component is *currently* flexible with regard to its *structural* and *behavioral* aspects. Furthermore, the IS manager has to investigate *in what way* the components *are* flexible with regard to *these* aspects. The results can be classified on an ordinal scale using Figure 6 and Table 1. The portfolio consists of the two dimensions *flexibility of inside view* and *flexibility of outside view of the task*. Inside view as well as outside view of the task can be more or less flexible independent of each other (orthogonality of the dimensions). The classification of the task components has to be done twice: once for *structure* and once for *behavior flexibility*. Depending on the classifications of the dimensions, the structure or behavior flexibility is either “low”, “medium” or “high”.

The results of the structure and behavior flexibility can be aggregated (cf. Figure 7). The fields 1, 2, 4 of the matrix (cf. Figure 6) correspond to “low”, 3, 5, 7 to “medium” and 6 as well as 8 to 12 to “high” values of flexibility. The results represent the *current* structure and behavior flexibility of the investigated task.

flexibility of outside view of the task	**flexibility of inside view** of the task: none	workflow management or activities	both
none	1 **low** (fixed)	2 **low** current **behavior** flex.	3 **medium**
(**a**) loose task coupling or (**b**) task coordination or (**c**) objekt of the task	4 **low** current **structure** flex.	5 **medium**	6 **high**
two of (**a**), (**b**) and (**c**)	7 **medium**	8 **high**	9 **high**
all of (**a**), (**b**) and (**c**)	10 **high**	11 **high** required **structure** flex.	12 **high** required **behavior** flex.

Figure 6: Determination of the structure and behavior flexibility level

In the *fourth* step, the *required* flexibility is determined in analogy to the *third* step described above. Characteristics of the environmental system and the business system (e. g. frequently changing suppliers or business model and plans) constitute the input IN for this assessment. Depending on IN, the IS manager has to answer questions about the *way* in which the IS *should* be flexible. The results are the *current* and the *required* flexibility of a task (output OUT of S_{IO}).

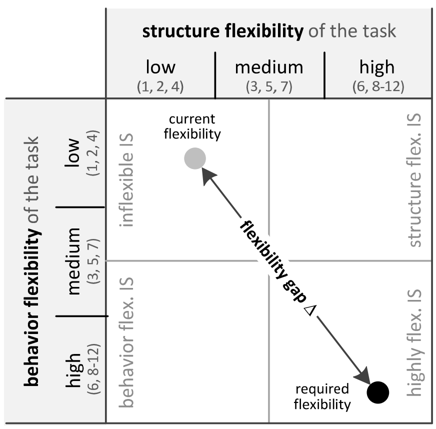

Figure 7: Flexibility level portfolio

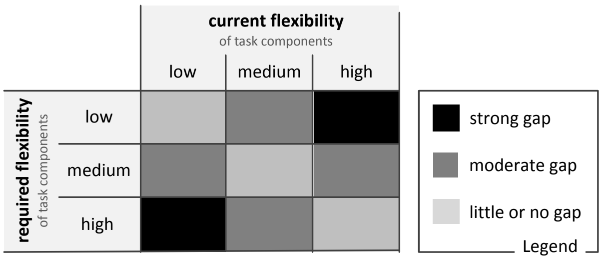

Figure 8: Flexibility gap portfolio

In the *fifth step*, the required structure and behavior flexibility of each task component is evaluated. The results of the "flexibility level portfolio" are interpreted using the 3 × 3 "flexibility gap portfolio" (cf. Figure 8). The location of the examined task components in the portfolio depends on the findings of the *third* and the *fourth* step. Black quadrants suggest *strong gaps*, grey quadrants indicate *moderate gaps*. In particular for task components residing in black quadrants, a flexibility-oriented modification of the IS is recommended. If the levels of current and required flexibility are equal, the organization is in a good position and does not have to make any major changes concerning the analyzed task. If the required flexibility is lower than the current flexibility, the organization may think about lowering the current flexibility rather than providing too much flexibility. On the basis of the steps *one* to *five*, it is possible in step *six* to deduce recommendations for action. These "rules of thumb" might support IS managers in designing the IS strategy and are *complete* with regard to the structure of the task concept.

- **Rule of thumb (a) – 'Flexibility of the goal and objectives of the task':** The inside view and the object of the task is defined depending on its goal *type* (e. g. "construct power plant!") or objective type (e. g. costs). Nevertheless, goals may vary regarding the type (e. g. power plant variants) and instances (e. g. number of power plants) ("variety of goals"). IS managers should be aware of the variety of the goal (types and instances). *Recommendation: Investigate the procedure of the task regarding its current flexibility. Furthermore, a decomposition of the procedure into workflow management and activities (cf. Figure 4) might be necessary. The current flexibility of every decomposition product has to be investigated. If necessary, the procedure has to be changed. It is recommended to evaluate the utility of a Service oriented Architecture (SOA), for example, as a paradigm for IS strategy.*
- **Rule of thumb (b) – 'Flexibility of pre- and post-event(s) of th*e task':*** Flexibility requirements often originate from the need to execute tasks in a sequence that differs from the initially planned sequence. Another driving force of flexibility requirements is the uncertainty concerning the time characteristics of pre- and post-events. A flexible IS must be able to handle uncertain points of time of pre- and post-events. *Recommendation: It is recommended to evaluate the utility, for example, of an Event-Driven Architecture (EDA) [45] as a paradigm for IS strategy.*
- **Rule of thumb (c) – 'Flexibility of the procedure of the task':** For both behavior and structure flexibility of the procedure, *building subsystems* of the procedure is recommended. Subsystems can either be determined using an *object-oriented* decomposition [1] of the procedure or a decomposition of the procedure according to the *action principle* [1]. *It is recommended to evaluate, for example, the utility of a SOA as a paradigm for IS strategy in order to support modularized procedures.*
- **Rule of thumb (d) – 'Flexibility of object of the task':** Flexibility within the object of the task means that the attributes of the task can be changed. The IS needs to ensure that all attributes can be accessed by the procedure at the time needed. *Recommendation: It is recommended to evaluate Enterprise Application Integration (EAI), e. g. object integration [1].*

5. APPLICATION OF THE METHOD

The Plant Engineering and Construction industry (PEC industry) is used in this paper to (a) highlight the special requirements of the domain concerning IS and (b) to show the applicability of the IS artifact. For giving evidence, we chose a stepwise research design:

1. We carried out *semi-structured interviews*[2] with experts (n = 5) of the PEC industry from two different companies. As the PEC industry represents an *oligopoly*, it is difficult to increase the sample size. The interviews include questions concerning the understanding and concept of flexibility, the postulated origin of flexibility (process- or IT-driven), the determination of flexibility levels as well as PEC-specific processes.
2. The results (anonymous summaries and models) are discussed and the interview partners committed to them (*consensus theory* as *theory of truth*) in a second round.

The interviews confirmed the study of GALLIERS [46] which revealed that the practitioners' understanding of strategic IS planning differs from the definitions in academic literature. All persons confirmed that the process of evaluating flexibility requirements in practice differs from IS literature (e. g. [37], [47]). Furthermore, none of the interviewees could confirm that the evaluation of flexibility requirements of the business system or the environmental system is part of their strategic IS planning. From this we conclude that the existing concepts for evaluating flexibility requirements of business processes and transforming the results into recommendations for IS strategies are unknown to practitioners or provide insufficient support. Furthermore, the interviewees state that the PEC industry has *high flexibility* requirements compared to other industries. From the point of view of the IS artifact, those requirements can be divided into *structure* and *behavior flexibility requirements*. Behavior flexibility can be considered as the kind of flexibility which can be handled by using *variants,* for example. The structure flexibility of a business system poses bigger challenges to IS managers. The high flexibility requirements basically result from the fact that companies acting in the PEC industry often have to cooperate flexibly with varying partners in order to fulfill the project task. As most of those companies operate globally, it is nearly impossible to cooperate with the same companies in every project, starting with alternating members of the project consortium right up to the countless contractors worldwide that deliver minor products or

[2] We have not included the interview guidelines for reasons of lack of space but will provide them on request.

provide services. The challenges arising from this fact are further increased by the international setting of projects. The mentioned characteristics of the PEC industry lead to difficulties in the IS design. In practice, this often leads to *fragmented* instead of *integrated* IS architectures.

Based on these findings, a scenario is introduced using the *interaction schema* (IAS) as part of SOM [43], [1]. All the following findings are evaluated by practitioners. An IAS represents the *structure* of a business process (cf. Figure 9) and consists of business objects (BO) which encapsulate tasks according to the task concept (cf. Figure 4). The business objects are connected by transactions (TA).

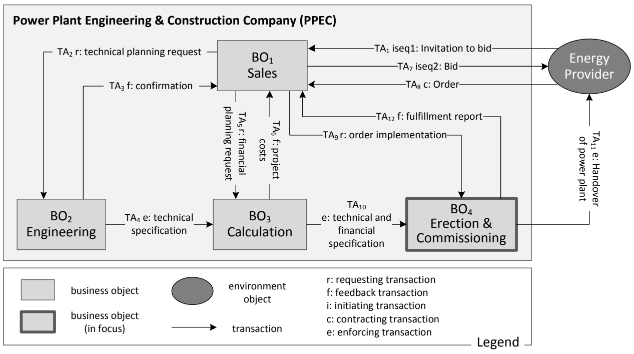

Figure 9. Business process of PPEC industry (structural view)

The IAS shows the interaction of a *power plant engineering and construction company* (PPEC) with an *energy provider* (EP) who purchases a power plant. After invitation to bid (TA_1), the BO_1 *Sales* determines the scope and price of the power plant with the help of BO_2 *Engineering* (TA_2, TA_3) as well as BO_3 *Calculation* (TA_5, TA_6) and submits an offer to the customer (TA_7). *EP* negotiates with *PPEC* through a contracting transaction (TA_8). Afterwards, the BO_1 *Sales* requests the BO_4 *Erection & Commissioning* to implement the order using TA_9 *order implementation*. The BO_4 is hierarchically coordinated by the TA_9 'order implementation' and TA_{12} 'fulfillment report'. Firstly, we use *conventional / available* flexibility definitions (cf. section 2) to derive flexibility requirements on this business process. The following results can be achieved:

1. BO_1 *Sales* must be able *to adapt* to different customer needs.
2. BO_3 *Calculation* must be able to perform *different kinds* of calculations.
3. BO_4 *Erection & Commissioning* must be able to *adapt* to different situations and surrounding conditions on the construction site.

From the interviewees' perspective, only few or no conclusions regarding the design of an IS can be drawn from these generic requirements. In fact, the information gained concerning flexibility requirements is considered too generic. Secondly, in contrast to the previous flexibility assessment, we use the IS artifact developed in section 4. Step (1) of the method is already completed by modeling the business process (cf. Figure 9).

Using the task concept in step *two*, the task 'Erection & Commissioning' can be decomposed into its components (cf. Figure 10).

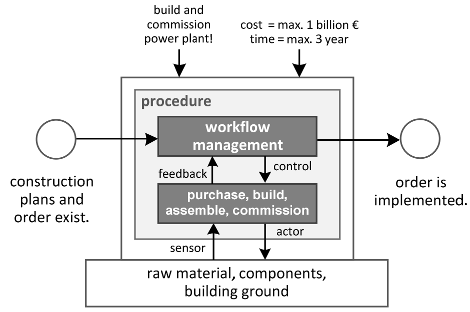

Figure 10. Decomposed task 'Erection & Commissioning'

Based on the components of the task, the current flexibility of the IS is determined (step *three*). According to the flexibility concept, every task component is examined from a behavioral and structural perspective (cf. Table 2).

Table 2. Current IS flexibility

	behavior flexibility	structure flexibility
goal	IS offers flexibility regarding the *size* of the power plant	different *types* of fossil power plants
objective	completion date and/or production cost level	change of objective(s), e. g. higher prioritization of production costs
pre-event	date of request is unknown	not yet supported
procedure	production of variants of a power plant	not yet supported
object of task	different variants of components	not yet supported
post-event	date of completion of task is unknown	not yet supported

Table 3. Required IS flexibility

	behavior flexibility	structure flexibility
goal	***CO_2 emission level of the power plant,*** size of the power plant to be implemented.	***all types of power plants (fossil, solar, wind, nuclear)***
objective	completion date and/or production cost level	change of objective(s), e. g. higher prioritization of the level of production costs
pre-event	date of request is unknown	***engineering and construction services will be offered to other companies, too → task must be available as a service for other companies***
procedure	production of variants of a power plant	***use of new methods and procedures to build power plants***
object of the task	different variants of components	***availability of new construction tools must be considered***
post-event	date of completion of the task is unknown	***post-event must also be provided to external company if the request to provide engineering and commissioning originates from outside PPEC.***

In step *four* of the method, the *required* flexibility is evaluated. Like in the previous step, flexibility requirements are determined from a behavioral and structural perspective. Comparing the current and required flexibility (step *five*), we conclude that there are several flexibility gaps in the current IS. The required flexibility aspects which are not yet provided by the current IS are written in bold, italic letters (cf. Table 3).

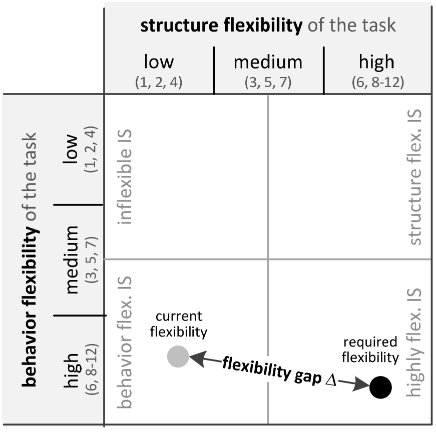

Figure 11: Flexibility level portfolio

We conclude that the flexibility requirements concerning the goals of the task are higher than the flexibility currently provided by the IS. Besides, structure flexibility is not provided by the current IS within pre-events, procedure, object of the task and post-events. The findings of Tables 2 and 3 can be aggregated to the "flexibility level portfolio" (cf. Figure 11) and summarized in a flexibility gap portfolio (cf. Figure 12) in order to provide recommendations.

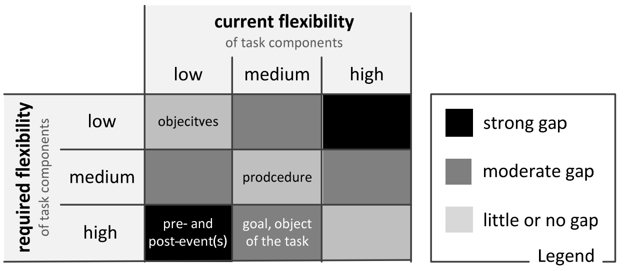

Figure 12: Flexibility gap portfolio 'Engineering & Construction'

Based on the comparison of the current and the required flexibility of the IS, the following (brief) recommendations are made for the design of the IS (step *six*):

- PPEC should implement a SOA. New requirements, like the consideration of CO_2 levels, could be realized by including new services.
- The engineering and construction department would like to offer its services to other power plant engineering and construction companies as well. Therefore, a platform is necessary to interact with external contractors. This could be realized using web technologies.
- The flexibility requirements within the pre- and post-events could be handled by applying event-oriented techniques. By posting events, an EDA abstracts from the origin and destination of messages and thus notably enhances IS' flexibility.

6. CONCLUSION, LIMITATIONS AND FURTHER RESEARCH

This paper provides an analysis of the term flexibility within IS research and develops an own understanding of flexibility based on systems and organizational theory. In addition, we propose a method for determining flexibility gaps ("filling the black box") in order to encourage scientific discourse about IS flexibility. The OUT of S^{IO} (cf. section 1) is determined by offering "rules of thumb". The "rules of thumb" offer input to support the construction of an IS strategy with regard to flexibility. Finally, the *viability* of the method is *deductively* shown using a scenario within the PEC industry. Arguing with POPPER's *Fallibilism* [48], the inherent *hypotheses* of the method – represented by the *construction ideas (a)* and *(b)* – can be *accepted*. Nevertheless, the method still has certain *research limitations*:

- A "semantic gap" exists between the *"rules of thumb"* regarding flexibility and the *construction of IS strategies.* The research goal is to close the gap to increase the utility of the method.
- In order to maximize the support of IS managers, a *software tool* is needed. Ideally, such a tool implements the entire procedure model to reduce time effort and support managing complexity.
- Because of the single scenario, there is the need for one or more extensive case studies which investigate the applicability of the method. Ideally, those scenarios cover different industries. One goal of future research is to increase the evidence of the method.

Although this paper offers only a small contribution towards a deeper understanding of the term *flexibility,* the presented method has the potential to support IS managers in IS analysis and design. However, the research limitations mentioned above are significant. Our research strategy includes further *laboratory experiments* with students and practitioners to identify additional improvements of the method. Furthermore, we carry out an extensive case study within a *medical care center* in order to reduce research limitations.

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8. APPENDIX

Table 4: Mentioned aspects in flexibility definitions

	Origin	**kind of flexibility**	**terms mentioned in literature regarding flexibility** (not (!) the way we understand it)									
			reaction	adaptation	variability	(business) processes	un-plannedness	behavior	structure	objectives	change	environment
generic flexibility	[49]	flexibility	x	x			x				x	
	[50]	flexibility									x	x
	[34]	flexibility			x					x		x
	[51]	flexibility		x			x			x		
	[52]	flexibility	x	x							x	
	[20]	flexibility					x					x
	[53]	flexibility									x	x
	[31]	flexibility	x									x
	[31]	flexibility	x				x					x
	[9]	flexibility	x								x	x
	[54]	flexibility					x			x		
	[19]	flexibility	x							x	x	
	[55]	flexibility		x								x
	[56]	flexibility			x	x				x	x	
	[8]	flexibility		x			x				x	x
	[57]	flexibility	x	x			x					x
kind of flexibility	[31]	operational flexibility			x				x		x	
	[32]	scope flexibility			x							
	[32]	speed flexibility								x	x	
	[30]	strategic flexibility	x				x			x	x	x
	[31]	strategic flexibility			x			x	x			
	[58]	strategic flexibility	x							x	x	x
	[31]	structural flexibility		x					x			
	[33]	structural flexibility		x		x					x	
	[59]	structural flexibility					x					
object of flexibility	[29]	business process flexibility	x	x	x					x	x	x
	[33]	process flexibility				x					x	
	[60]	IS flexibility		x		x					x	
	[39]	IS flexibility		x		x					x	
	[9]	ISD project flexibility								x	x	
	[28]	IT flexibility	x			x				x	x	
	[25]	IT infrastructure flexibility			x					x		
	[24]	manufacturing flexibility						x				
	[61]	technology flexibility		x		x				x	x	