Facing Complex Challenges—Project Observations

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Abstract Today, the terms "complex" and "complicated" suffer from overuse—without providing a clear definition of these terms. This contribution shows the implementation of a practice-oriented definition for an industry project as a basis for a clear scope of action. Subsequently, it is clarified that increasing complexity in project management mostly originates from increasing system interdependencies. And knowing about these interdependencies allows solving complexity challenges with adequate strategies and methods. This contribution deals with the problem of steadily growing complexity and lack of its understanding in connection with missing solutions. Therefore, a research project was initiated for explicating the stepwise identification of types of complexity, promising strategies, and useful methods for managing complexity. Applied in the context of an industry project this allowed preventing the failure of premature selection of a specific method in case of insufficient transparency of the challenge. The contribution presents a straightforward process for identifying types of complexity, promising strategies, and useful methods in a project context. It is clarified why established methods of complexity management can result in insufficient solutions when applied in the wrong context.

1 Introduction

Today, the term "complexity" suffers from overuse. "Complexity increases" in almost all areas and "complexity is the most important challenge" of the future. Sometimes, descriptions of "complexities" appear. Apparently, the plural shall express a further increase of complexity. When asking the authors of such statements for a definition of the fundamental challenges, this often remains unclear. Declaring a question as being complex is often based on insufficient knowledge

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about the situation. Or in other words: If one describes a situation or question as being complex, he often means that the cause is not transparent.

Methods provide procedures and support systematic problem solving. Numerous methods exist for managing complexity—with different objectives. And declaring a question as being complex can be misleading when selecting a method. The reason for this is that the intentional selection of a method requires knowledge about the objective. However, if a "complex" problem is not understood (not transparent) it is hardly possible to determine a specific objective. Thus, if the declaration of complexity is directly followed by selecting a method for complexity management, the success of this method application is doubtful.

Successful complexity management requires the initial identification of complexity causes. Then the type of complexity has to be determined. After this, suitable strategies and methods can be selected.

In the following sections types of complexity and their causes will be detailed. These causes, complexity strategies and methods will then be integrated into a comprehensive process designed for purposeful management of complexity. The general layout of this process provides the possibility for understanding the different aspects of complexity management and their interaction. Thus, also the field of application for established methods like variant reduction or modular design will become clear. With this general process layout it gets easier for practitioners to identify a suitable method for solving a specific complex challenge.

2 The Challenge

A large and globally operating service company planned to renew its software systems. Services provided require processes to run permanently and therefore unbroken software system availability is mandatory. The pool of software systems used possesses many legacy subsystems, which are interconnected in historically grown networks. The software systems have been build up and are applied by several departments, whose mutual delimitation is also historical. Renewing the software systems can only be executed step by step, while maintaining the operability of the entire system. However, extracting a single system element means to break up (partly unknown) interconnections and to create new interfaces. And several departments may require a software element or interface, whereas the renewal is processed by one department only. The creation of news interfaces and the partial mismatch with the organization seems to even increase the system complexity that has to be managed. Initial attempts increased resources for better managing the complexity. However, this resulted in a further increase of complexity due to more general interfaces. This situation illustrated the need for an applicable process of complexity management.

3 Complex and Complicated Challenges

Research for a complexity management process started with the situation analysis: In the industry project considered here, project managers assumed that a high amount of complexity needed to be managed. The software-supported internal company processes should be renewed completely after being applied for more than 20 years. Several hundreds of software modules are interacting in daily processes. These modules are associated to different responsible organizational units and possess different needs for adaptation or replacement. Many interdependencies between modules are unclear to the project team—and so is the impact in case of displacement, implementation, and updating of single modules planned for execution during ongoing operation. With these facts in mind it is understandable that project managers of the enterprise described the situation as a complex challenge.

In everyday language the terms “complex” and “complicated” do often appear in the same context and are even used as synonyms. However, complex and complicated challenges differ in possibilities of solution. A short consideration of both terms helps to understand this:

Searching the needle in the haystack is an example for a complicated challenge. As well is the search for a number in a telephone book, in which the sequence of numbers and names is arbitrary. Both problems may be difficult to solve but can be mastered with effort (meaning time and resources), and investing more resources results in less time required for finding the solution. In contrary to this, predicting the further development of the world climate represents a complex challenge.

What makes the difference between complicated and complex questions as described in the examples before? First, a complicated question is a static one and can be subdivided, i.e., be reduced to several but less comprehensive questions. For the example of the telephone book this means that parts of the book can be searched in parallel by several persons, as long as the names and numbers stay in place (static system versus dynamic system). Subdividing a complex question is not possible, consequently time required for problem solving cannot be decreased by increasing resources.

In the industry project described before the project participants had to clarify if they have to manage a complex or a complicated problem, as this influences all further process steps. According to the explications above, project participants had to determine if the challenge could be subdivided into smaller questions; and if the challenge is based on a static or a dynamic system. In practice, the organizational layout of departments means a subdivision of the challenge, as each department is occupied with some aspects of the comprehensive system. However, analyses resulted in the fact that dependencies between software modules are often caused by distributed organizational responsibilities. The system also implies significant dynamics, as the project is executed in parallel to the continuous update and bug fixing of the product and process environment.

As mentioned before, the importance of distinguishing complex from complicated questions lies in different possibilities of problem solving. Whereas a complicated problem can be solved with effort (and even faster with more effort), this is not sufficient for solving a complex problem. As complicated problems can be subdivided, increasing resources can accelerate finding a solution. The same is not efficient for solving complex questions—but often applied in practice.

Project workshops on problem clarification resulted in the finding that the challenge on hand was a complex one. The clear differentiation from a complicated challenge did foster the understanding for the need of a new approach on problem solving. Next, the type of complexity and its origin has been investigated in detail. This is explained in the following chapters.

4 Types of Complexity

After the clarification of a complex (or complicated) situation the research focus was set to the possible types of complexity. The frequency of using the term complexity indicates that a multitude of complexity types must occur in practice. Clarification was searched for complexity in the context of product design and management. Of course, other disciplines know even more complexity types. In the project described here, complexity was considered as abstract phenomenon. However, a clear description was necessary for creating common understanding of the problem. Therefore, a classification of complexity by four mutually connected areas (see Fig. 1) was the basis.

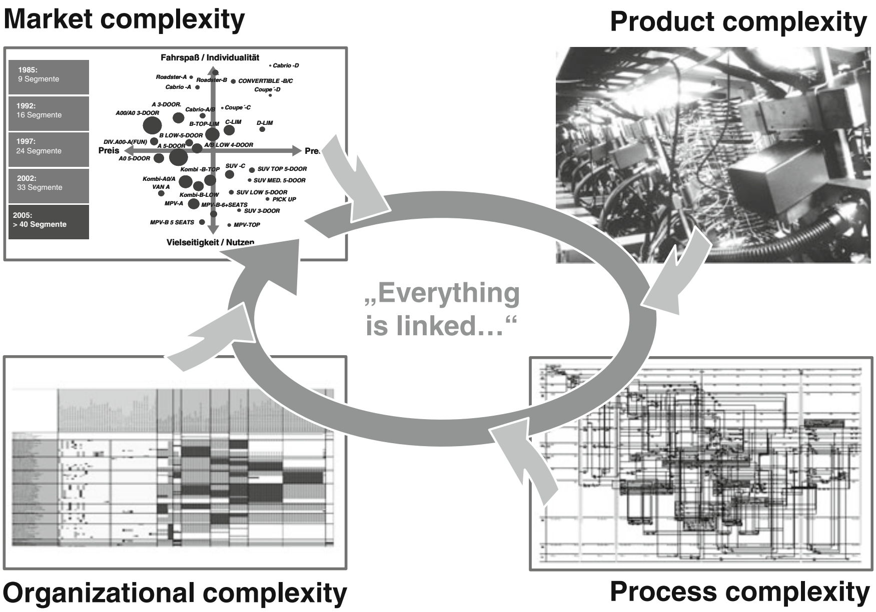

Fig. 1 Types of complexity (Photo: Tsgt L. Hernandez)

Market complexity represents a fundamental source of complexity issues, as market conditions and changes can hardly be influenced by enterprises. Market complexity emerges, e.g., by a variety of customer requirements. Further, boundary conditions based on, e.g., laws, regional, or linguistic characteristics can increase market complexity (also called external complexity for an enterprise).

From the point of view of an enterprise the external complexity is supplemented with internal complexity emerging from the offered product portfolio. This includes the variety and possible combinations of components, which are intended to serve the external complexity when assembled to product variants. Creating suitable modules, building blocks, platforms, and interfaces are examples for challenges in the field of product complexity.

Product complexity can cause process complexity. For example, the increase in products' functionalities can result in more partial processes (e.g., in development, production, and service) and the need for more intense synchronizing of these processes. Thus, process complexity can increase as a consequence of product complexity. Boundary conditions like shortened development times, globalized product portfolios, or distributed development activities contribute to this process complexity.

Organizational complexity is also interconnected with the already described types of complexity. Management of complex products and executing complex processes causes the need for adequate organizational design. In this context, "Conway's law" describes the interdependency between products and organizations within an enterprise (Conway 1968). Hierarchical or matrix-based forms of organization do often not meet existing product and process complexity.

Within the industry project it was required to highlight the interrelation between the different fields of complexity in order to identify and clearly describe the complex challenge. It was an important finding that the origin of complexity and its appearance do not have to be located in the same field. The enterprise did show a significant organizational complexity. However, intensive analyses brought up the fact that on the one hand this is a consequence of the process complexity the enterprise has to deal with. This was relevant for assessing the complexity's value for the enterprise. Of course, a complex organization itself does not possess any added value compared to a simple organizational design. The need for such a complex organization and its benefit only becomes clear when considering the process complexity, which becomes manageable with this organization.

On the other hand organizational and process structures both have been gone through evolutionary formation—partly independent from each other. For example, organizational departments have been defined initially, as processes of departments did not connect to other departments. Over time, processes have become more and more interconnected integrating more and more features of different departments. Thus, the organizational and the process network did show increasing mismatch, which increased complexity for any transformation approaches.

5 Complexity as Result of Interconnectedness

Whereas the field of origin of a complexity issue is often poorly considered in practice, the amount of interdependencies often becomes mentioned. In fact, in many cases complexity results from a multitude of highly interconnected elements. So, besides the pure amount of product components, process steps, or organizational roles the mutual links between these elements cause system behavior, which people perceive as being complex. Practitioners lack transparency of cause-and-effect chains, and systems often possess (undesired) momentum.

In the project described in this contribution such lack of transparency and momentum have not been regarded as main challenges of complexity. But these facts did cause the missing of a systematic approach for the reliable sequential design of an improved software environment.

When managing complex systems, people often make the same mistakes. These have been described by (Dörner 1989). For example, system analysis gets executed incompletely and subsequently only parts of the system are considered. Often the own personal focus guides a practitioner into concentrating on familiar system topics only. If, however, changes occur in non-considered parts of the system, impacts seem to happen accidentally—and practitioners lack explanations for that. Another typical mistake is the non-sufficient consideration of side effects. This can happen when practitioners rely on single key figures for managing progress in solving complex challenges. Then undesired effects are neglected but can have severe consequences to the complex system. As well, if unfavorable effects become visible in a complex system, practitioners tend to react with oversteering in order to compensate for the initial effect. Thus, people try to correct the effects quickly, for this reason resolute measures seem to be adequate. But lack of transparency and the associated lack of knowledge about interdependencies can lead to unexpected impact. In addition, short resources can reduce the available scope of action and the management often tends toward authoritarian decisions. People get the impression that the severity of the project requires a clear decision, even if the basis for a well-considered decision is not available. In such a situation people try to avoid discussions about alternative procedures.

All in all, it often seems to be impossible to solve a complex challenge systematically. This was also the finding of the project team in the considered industry project. For the successful management of complex challenges it is important to be aware of the mistakes described above. This is a prerequisite for a systematic approach for determining suitable methods of complexity management. Therefore, a process has been developed and applied to the industry project. This is further detailed in the following sections.

6 Strategies for Complexity Management

Strategies for complexity management are not in the focus of users. In most cases one wants to get rid of complexity. However, other strategies can be useful or even necessary. Here, this has been considered in detail. Complexity was perceived as being obstructive in the context of the industry project. For this reason, project participants asked for a strategy of complexity reduction or avoidance in the beginning. Then several workshops resulted in the awareness, that the type of complexity has to be known first, before strategies of complexity management can be selected.

Reduction and avoidance of complexity are not helpful per se, as the following example shows. As long as the company offers a multitude of customized services, the company has to deal with significant process complexity due to a multitude of customer requirements. This complexity could be avoided by implementing one simple measure: no offering of customized solutions anymore, instead offering standardized services only. Even if this measure would avoid complexity, also market chances of the company would be restricted significantly.

Of course, this example is rather trivial, but the conclusion is fundamental for managing complexity: If complexity is useful, e.g., in the example for realizing the company’s success, then the pure reduction or avoidance of complexity is not

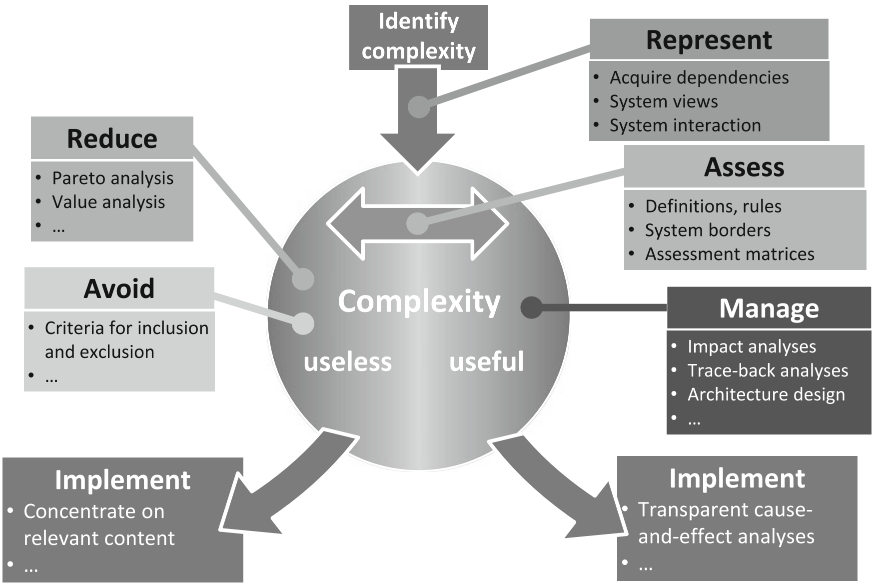

Fig. 2 Types of complexity, complexity management strategies and methods

productive. It is important to differentiate between useful and useless complexity—and apply the result for selecting an appropriate strategy of complexity management.

Figure 2 shows four general strategies of complexity management and assigns them to the two categories, useful and useless complexity. Basis for selecting the right strategy is the determination of the type of complexity. As described above, this type of complexity of often unclear to practitioners—as it was in the exemplary industry project. Several questions were used as guidance through project workshops for identifying the type of complexity with project participants: Where does complexity appear? What is the impact of the observed complexity? What can be identified as being harmful concerning the observed complexity?

Guided by these questions, the project team identified complexity as being useful regarding the company's success. Transparent representations of system interdependencies were applied extensively in workshops for obtaining this awareness. This will be detailed in the following section.

7 Generate Transparency by System Views

Many approaches exist for representing complex systems. Often graph depictions are applied, which are most suitable for highlighting the embedding of specific elements to a network. These depictions have been increasingly applied with the upcoming trend toward social networks and their analysis. Graph-based software tools apply several kinds of element alignment (e.g., force-directed graphs) and auxiliary information representation (e.g., size, form, and color of elements) for generating system transparency. Complex systems can comprise several thousands of elements and models cannot allow a complete depiction of such systems. With increasing amount of depicted information (e.g., the email communication of an enterprise) the visibility of details of the structure diminishes. Thus, showing large amounts of information only allows making vague and general statements (e.g., the interlinking of groups of people due to their email communication).

The application of specific system views is an option for generating transparent representations of complex systems. This is possible, as only a subset of system aspects gets depicted. This can be realized in two ways: On the one hand specific content, i.e., parts of a complex system can be isolated for being represented. Thus, this content gets extracted from the system while blinding out all other system parts. If, for example, the interactions within a large development department shall be depicted, one could concentrate on the exchange of documents between people. Centrally located people as well as closely interacting groups of people then can be identified in a graph representation of the structure. When applying this approach it must be assured that the extracted system part allows meaningful conclusions—and that the possibilities of interpreting the results are limited. This is important as the number of interconnections in complex systems makes it difficult to extract partial aspects without neglecting significant aspects.

On the other hand, interdependencies can be concentrated into a specific system view in order to generate transparency for a complex system. Hereby, system content becomes aggregated. For representing, e.g., the interdependencies between people in a development department, different interdependencies like documents' exchange between people or component responsibility shared between people become superimposed (represented by one interdependency). The single cause of interdependency gets lost in such a representation, in return the amount of information to be depicted decreases—without disregarding any content. A systematic approach toward the creation of system views is described by Lindemann et al. (2009). The transparency, which can be obtained by this approach, provides a better system understanding for practitioners as well as improved possibilities of interaction with the complex system.

In practical application both possibilities for creating transparent system views got applied. Isolated partial views are often created on a technical working level. This is because each expert possesses a clearly defined view on his tasks and responsibilities. In the industrial project example, resulting views on system content were still very extensive, despite the constraint to partial system aspects. Several hundreds of system elements and up to several thousands of interdependencies had to be managed. Therefore, intensive use of expert software tools was required and also necessitated training for technical experts.

Aggregated views on a complex system are mainly created for being used by the project management. By extensive aggregation of system content the amount of elements and interdependencies could be decreased significantly in this system view. Consequently, those views did not allow deriving specific decisions on details but allowed appointing significant development trends. Aggregation was done in terms of time as well as topics. For example, one system viewed showed dependencies between main modules of major software releases. This allowed identification of modules with highest impact to up- and downstream releases. An aggregation by topic was based on the existing organizational structures. This way system views were available, which corresponded with a valid and familiar form of classification.

8 Useless or Useful Complexity?

As already mentioned, complexity should be classified regarding the characteristics "useful" and "useless," In the project mentioned here, complexity was initially perceived as being negative, and therefore project participants aimed at avoiding it. This one-sided perception and direct conclusion can be observed very often. However, a simple example can show that complexity is not always a hindering system attribute.

Anderson (2006) describes in his book “The long tail” the phenomenon of increasing importance of individual and small product sales. He provides an explanation for the fact that the famous “80:20 rule” is no longer a general principle. It has been a rule in conventional industries saying that 80 % of sales are made with only 20 % of the product portfolio or product variants. But Anderson explains with numerous examples that since several years the amount of products with low sales numbers can add up to a significant ratio of all sales. If one would declare this “long tail” as being useless without any detailed analysis, a company offering these products would probably lose a large part of achievable revenue.

Regarding the example, assessing complexity represents an important step in the process of successful complexity management. Assessment rules have to be case-specific and general requirements can delimit the possibilities of decision significantly. In the context of the industry project, standardized decision tables have been created. These tables made it possible to classify complexity by several criteria and to make this decision process repeatable. As assessment criteria, e.g., technical competence concerning the module content and relevance for customers were applied. As well, relevance to the fundamental platform strategy and resource requests were taken into account.

9 Reduce or Avoid Useless Complexity

The type of complexity within the industry project has been identified as product complexity. A multitude of system modules possess a very high quantity of mutual interdependencies. Therefore, the management of the continuously changing product environment is extremely difficult. The cause of the product complexity could be found in the market, which has to be addressed. This market shows many individual requirements and can hardly be influenced by the company. Negative consequences of the product complexity mainly occur in the company processes. These processes have to be robust and range over several product interfaces. The initial complexity has been declared as being useful. So the basis for defining a suitable complexity management strategy was the systematically elaborated analysis that provided.

Figure 2 shows three strategies. Hereby, reduction and avoidance of complexity are both well established and can be applied successfully to useless complexity. Especially, variant management has to be mentioned in this context. Because of its popularity, it is often stated synonymously with the comprehensive expression of complexity management. However, variant management represents only one strategy of complexity management. Its benefit is the reduction or even avoidance of useless complexity. But when applied to useful complexity it results in undesired effects. Then the limitation of variants can mean the limitation of beneficial customer offers.

It is often helpful to define entrance barriers for the implementation of product or component variants in order to avoid the creation of useless complexity. Companies that are not aiming for customization can avoid that every variant becomes integrated into the product portfolio without even considering its profitability.

One possible strategy for reducing complexity is based on the Pareto analysis focusing on profit-related contributions of products. Products with a contribution below a specific (individually defined) value can be filtered. For example, products with less than previously defined sales figures or above specific production effort can be excluded from a portfolio. Value Analysis and Target Costing provide similar possibilities. Here, it is of major importance to set the right assessment criteria.

10 Manage Useful Complexity

In the industry project considered here, complexity has been identified as being useful considering the company's objectives. Therefore, a strategy for reducing or avoiding complexity could not be applied but the management of existing complexity was required. The better useful complexity could be managed, the more complexity the company could handle—and this allows increasing the company's success.

Amongst others, cause-and-effect analyses have been identified as effective methods for managing useful complexity. Therefore, the method has been implemented into the company processes. This allows identifying required measures in case of adaptations to the complex environment of software modules even though manifold interdependencies exist.

Modularization of products is often mentioned as method of complexity management. This becomes clear in the context of useful complexity and consideration of system structures. With the focus on structure development, modularization means the assembly of highly interconnected system parts and standardization of interfaces between these parts. Platforms, building blocks as well as differential and integral design can be seen as methods for managing useful complexity by system design. In context of the industry project modularization meant new design of the software environment. Analyses led to the insight that enormous benefit could be achieved by this. However, the effort required for the fundamentally new modularization would exceed the project scope in terms of time and budget.

The lack of transparency, which results from interconnected system elements, is often the reason for negative consequences from complexity. In such a situation, decision-making based on simple cause-and-effect chains is hardly possible, because these chains cannot be clearly identified. Acquisition as well as modeling of all elements and interdependencies cannot be executed for the entire scope of typical complex systems. In this context, we could clarify that decisions in the industry project have often been based on incomplete system descriptions so far.

Usually, people create their own models (consciously or unconsciously), which contain relevant information. Thus, the challenge of managing complex systems is to integrate the required information into a model for decision-making—and not to provide as much system information as possible. For this reason, the initial clarification of existing types of complexity is of major importance. Insufficient or wrong determination of the complexity type can result in building unsuitable models. One distinct measure in the industry project was the definition of basic system views, training project members in using these system views and to create a process for updating and distributing these views.

Visualizing the required models allows discussing implicitly known aspects within the system context. And interpretations are created more easily. Often matrix and graph representations are applied for visualizing system views, e.g., by means of standard office software. In our industry project also, a tool solution provided by a specialized software developer was implemented to the management process. Representations in condensed form of diagrams have been customized for the regular management reports. Especially, influence portfolios have been applied for visualizing the embedding of cost intensive and risk carrying software modules into the software environment.

11 Impact of Research Findings to Practice

The elaboration of a complexity management process could be implemented successfully into practical application. Users could better classify approaches toward complexity and understand the sequence of process steps required as well as necessary inputs and obtainable outputs for those steps. This way, the phenomenon of complexity became better manageable.

Based upon the general process layout the project team of the company recognized that the previously applied approach on complexity management was inadequate. So far, methods for overcoming complexity were selected and implemented first—before even the problem was clearly identified. With the new general process the reliable identification of the prevailing type of complexity could be systematized. This identification is followed by categorizing complexity with the categories “useful” and “useless.” Therefore, standardized representations for the complex system in question were defined and attached to the general process. These representations were used at relevant milestones and provided the basis for discussions and assessment of complexity issues. Results of complexity assessment were decisive for selecting the suitable strategy of complexity management. Only with the clearly approved strategy on hand one or several methods of complexity management were finally selected and implemented.

All in all, the research findings of a general process layout for complexity management were implemented reasonably for gaining access to the phenomenon of complexity. The sequential process enabled a step-by-step understanding of problem causes. Proposals for solutions based on strategies, methods, and required tools became assessable in the context of these clarified problem causes.

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