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State of the Art on Relevant Research Areas Connected to Complexity Management

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Abstract – The article is focus on describing the connected or associated concepts and disciplines for managing complexity. The approach will follow: (1) the holistic perspective; (2) the specific approach of complexity management (service-related); (3) the special (nonservice-oriented) research areas of complexity management; (4) characteristics of complexity in outsourcing projects. In the final chapter, relevant conclusions related to the state of the art will be made. The aim of the article is to emphasize the necessity of viewing complexity management as a new organizational challenge and initiatives. The main finding of the research consists of the identification of different knowledge sources related to complexity management connected disciplines that have to be considered by managers in order to define successful strategy, methodologies and processes.

Keywords: complexity, management, outsourcing, project management, Industry 4.0

I. INTRODUCTION - THE COMPLEXITY ROLE IN PROJECTS RELATED TO INDUSTRY 4.0

In the last years, companies are currently facing the challenges of increasing products and services customization, increasing resource efficiency and shortening the time-to-market. These challenges need an IT diffusion to all company functions and areas, to support networking develop products, manufacturing resources and processes. These concepts are often grouped under the Industry 4.0 strategy [32]. In 2015, a study with 56 experts from industry has recognized the key success factors that are innovation, flexibility and complexity management, and data security [58].

Fraunhofer Institute, with various universities and industrial companies, develops Industry 4.0 initiative, strategy. In 2013, the Institute published a study done with 661 manufacturing companies, supplemented by 21 renowned experts in the industry, leading scientists and association and trade union representatives. Because of the survey, three future-relevant topics were identified as particularly important and urgent: dealing with complexity, innovation capacity and flexibility [52].

In the same context, Bauernhansl sustained that the assessment of the Industry 4.0 potentials in large company can be done via so-called “use cases”. He considered these as application scenarios that use Industry 4.0 technologies. He suggested that preliminary, there have to be analyzed the internal environment of the large company in order to identify which use cases are useful for the application and for which the Industry 4.0 technologies are possible to be used. A graphic detail in Figure 1 illustrates these relationships [3].

Industry 4.0 strategy wants to bring the German industry to be ready for the future challenges. Industrial production has to be able to deliver strong customization products under the conditions of high flexible large-scale production, high degree of customers and business partners’ integration in business and value-added processes and the coupling of production and quality services. New business models and significant potentials for optimization in the context of the production and logistics have to be developed. This adds new services to important areas of application, such as mobility, health, climate and energy [5].

The organization process levels are consistently linked to each other and can be tuned with one another repeatedly based on the most recent process data. Horizontal integration is the starting point of the flexible design of joint value creation processes. Many companies are increasingly confronted with a complex value chain, the steps of which can no longer be described as a chain, but form a web of relationships in which individual companies focus on specific skills. Market volatility continues to grow while the development predictability is declining [6].

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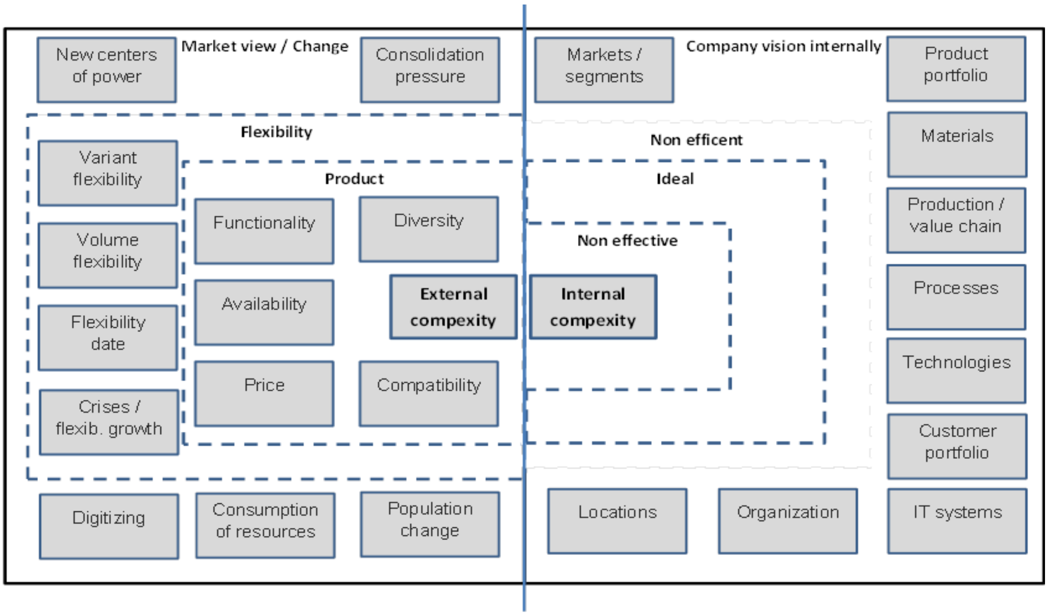

Fig. 1. The complexity explosion [3]

Some institutions and companies currently concretize the development of the value chain in order to control the growing instability. The Deutsche Ingenieure e.V. association published a status report in April 2014 and there have been recognized that product life cycle is increasingly oriented towards individual customer requirements. The life cycle starts with the product idea to order processing and ends with the completion of the order. Through the combination of people, objects and systems dynamic, real-time optimized and self-organizing, enterprise-wide value networks arise in order to support a specific product life cycle [56].

More recent, for the implementation of the Industrial 4.0 Vision there has been recommend to develop an Industry 4.0 roadmap. The following dimensions should be considered [16]: (1) market perspective: customer segments and the structure of the customer needs; (2) product perspective: benefits and added value for the customer; (3) process perspective: resources and technology; (4) network perspective: partners to fulfil customer benefits.

After this brief introduction to the research context defined by the Industry 4.0 strategy, the article will be focus on describing the connected or associated concepts and disciplines for managing complexity. The approach will follow: (1) the holistic perspective; (2) the specific approach of complexity management (service-related); (3) the special (nonservice-oriented) research areas of complexity management; (4) characteristics of complexity in outsourcing projects. In the final chapter, relevant conclusions of the actual references research will be made. The aim of the article is to emphasize the necessity of viewing complexity management as a new organizational challenge and initiatives. Presented researches suggests different knowledge sources related to complexity management (inter-)connected disciplines that have to be considered by managers in order to define successful strategy, methodologies and processes.

II. CONCEPTS FOR MANAGING COMPLEXITY IN BUSINESS SITUATIONS

1. Holistic complexity management

In the following section, scientific concepts will be analyzed and presented, focused on the holistic approach of complexity in business situations.

Gerberich research (cited by [36]) shows that the principal aim in complexity management is creating a balance between internal and external complexity. Gerberich emphasized that not only the reduction should be in the foreground; otherwise, there is a risk that the company is concentrated on its core competencies. In addition, he mentions the following recommendations for action [36]:

- Complexity management is a critical success factor. Not the minimum is desirable, but the optimum;
- The complexity causes have to be recognized. These are often in management, product, organization, and value chains;
- Product and process structuring is the central element of complexity management;
- Complexity management requires real commitment by management;
- Complexity management is an ongoing task and has to be performed from both an inwardly and an outwardly perspective.

The industrial ecology is still a young research filed of interest, with an emphasis on science, engineering and planning sciences. It searches for viable solutions to manage business processes in ecosystems and deal overall, with the increasing complexity and uncertainty. A guiding principle of this research discipline is that there are no laws of nature dealing with complexity. The human mind is led by motives, which has a significant influence on the approach in dealing with complexity in the planning, information gathering and derived actions.

In order to cope with problems in a complex environment, the five processes presented in Figure 2 are recommended; they should always be performed sequentially [14]. The phase *Objectives Labora Transportation* includes the formulation of upper and lower targets, but also the conducting of a situation analysis. In the phase *Information gathering, model creation* a surroundings analysis (technological, legal, economic, social and environmental dimensions) needs to be performed. In the *formation of the model*, the expected effects of the environment must be considered and defined. The analyst must be aware that the results are dominated by a limited perception and rationality (*prognosis* should be developed).

In the next phase, *Planning and decision-making*, the future steps have to be planned. A de-conditionality is to be performed which is an appropriate method in this step. Specifically, this does not mean to carry out detailed planning to reach the overall target, but rather systematically, to proceed in the direction of the target. In the last phase *Controlled action and self-criticism*, the previous steps must be reflected; results should be discussed in a group. At the end, a decision for the next steps must be taken. If a correction of partial results is required, the steps listed shall be repeated. In summary, the following recommendations are given [14]:

- Most of the events are not only dependent on one factor;
- The conditions are changing. The conditions are constantly changing; this must always be considered in carrying out the tasks;
- General rules should be distrusted;
- Detailed planning is not always useful if the complexity of factors can affect the project;
- When carrying out any measure, the actions should be followed by the question: "*Why do you do that?"*

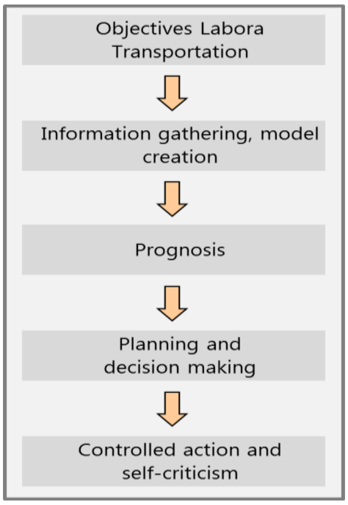

Fig. 2. Process Map Stations of action [14]

According to [15], there is recommend a four-column procedure model for dealing with complexity, which are:

- *Strategy Anchoring*: Anchoring of complexity management in the company's strategy and culture;
- *Transparency*: Complexity transparency costs on product and customer level;
- *Value chain*: Targeted regulation of complexity along the entire value chain;
- *Sustainability*: Tools and systems to ensure continuous monitoring and control.

In the article [37] there is recommended a holistic enterprise wide approach to the complexity of management. It described "*three guiding principles*" for implementation [37]: (1) Comprehensive analysis of the initial situation; (2) Holistic demonstration of various interactions; (3) Constructive management of complexity. The aim is that various influencing factors are taken into account when making decisions; holistic decisions are made by considering interactions, as well as successfully align the company to the complexity of the environment [37].

In addition, [54] have developed a *logic to measure complexity* based on analyzing the different relationships between system's elements. At first, it is differentiated between the node (feature) and second, between the following relationships: mandatory feature relationship (and-relationship), optional feature relationship, alternative feature relationship (case-relationship), groupings of relationships (cardinality) and relationships among nodes and constraint relationships.

More recent in [7], researchers recommend the following eight strategies for mastering complexity:

1. Make complexity transparent:

Analyze and expose areas where complexity arises in an organization and what the related costs and benefits are. Companies can implement this simple system for measuring the degree of complexity in order to streamline the complexity and minimize costs within the organization. This may be realized through a company-wide *complexity index*. For this example, the respective departments, number of portfolio products, brands, legal entities, manufacturing plants and suppliers must be taken into consideration as complexity factors. The company is then able to improve this *basic complexity index* by concrete and targeted measures and thereby control the complexity existing in the company.

2. Apply the 80/20 rule:

In many companies, the 80/20 rule is established and it means that 20% of customers or products account for 80% of sales. This rule can also be applied to the complexity. In the second step, the same calculation for the remaining 20% of revenue shall be carried out. The aim is to identify the customers and products, where a mismatch to the generated turnover exists in order to initiate targeted improvement measures.

3. Optimize the whole, not separate silos:

Silo mentality hinders all efforts to reduce operational complexity systematically. Without a cross-functional, end-to-end view of the entire enterprise, decision-makers tend to concentrate on their own functions or departments. The silo thinking is a source of process complexity. In order to optimize processes and minimize costs, companies should analyze all critical, cross-functional processes, as well as those that serve internal purposes only. Measuring factors such as time, cost, error, volume and the number of people and points of contact should be considered. This analysis includes the identification of costs and potential costs in processes, systematically.

4. Segregate complexity into separate systems:

Due to the separation of complex products and processes, it is possible for the company to realize the company's standard processes efficiently and in a cost-optimized manner. For example, if a complex product must be built according to customer requirements, it is possible to separate this line of products and the production processes from each other. A part of the production process is made by mass production; other sub-processes, such as finishing work and customization are produced individually.

5. Bundling features together to "standardize" complexity:

By bundling groups of arbitrary functions in standard packages, industrial companies are able to produce standard elements efficiently while providing added value for customers individualized.

6. Defining plant and asset roles:

To minimize the complexity of the production and to achieve more output from the production, network characteristics with the needs of specific products and customers shall be classified. Products with similar characteristics are to be consolidated to achieve greater cost savings, flexibility and efficiency. In the next step, the classification of the preparation of the product lines must be performed in two categories:

- High-volume elements - These requirements are classified into as *high-volume production* with a limited number of products with only a few changes.
- Multi product or flexible assets - For a broader portfolio of small series products or products with volatile or unpredictable demand, production facilities are involved with quick-change ways of reaching versatility and flexibility.

By defining specific asset roll-like *high-volume asset* or *low-volume assets* and creating strict guidelines for the allocation of products to assets, the company has the possibility to reduce the costs per unit.

7. Identifying organizational blockages—and delayer:

Complex organizational structures include layers and interfaces, which have no clear responsibility. There is a risk that difficult decision and obscure responsibility takes place leading to 'orphan' costs and complexities. This complexity, often outside the company, extends to joint ventures, investments, suppliers, subcontractors and other partners. This increases the number of people in the business processes. A high number of interfaces can paralyze the organization in practice in their actions. Moreover, the addressing of organizational complexity management requires a large-screen view. Networks must be analyzed, information flows between organizational silos and blockages have to be identified and relevant processes with no clear owner shall be subjected to a particular observation. The dependencies between functions and interfaces are often not visible and important elements can fall through the cracks. Therefore, it is important to clarify responsibilities, especially for tasks and processes in the organizational units.

8. Challenging assumptions and model new scenarios:

The impact on the cost of complexity is rarely clearly identifiable. By modelling different optimization scenarios, a company can strategically gauge where relevant improvement can be achieved. Often, the findings are not unique. A modelling of the impact of various scenarios for reducing the complexity can show how capacity utilization for the overall performance of the organization behaves [7].

An important achievement for the complexity approach is described in [1], which developed a recommendation methodology called *Seven Steps in the intuitive handling of complexity*. In step 1, *Get the situation*, the core of the problem is described and graphically represented. Step 2 involves the *Intuitive by characterizing the problem into archetypes*. This is an analytical method of psychology to analyze the structure of the collective unconscious. In systems theory, the structure of behavior patterns is described. Step 3 involves the use of archetypes, step 4 *formulating the problem as a dilemma cloud*, as well as the formation of hypotheses, which are then discussed afterwards. Step 5 *questions the hypotheses* put forward. Step 6 is the so-called *Intuition Check* with different approaches, such as encapsulation and thematic vagrancy. Step 7 is the *examination of the methodological approach* of step one to six and a fresh start, if required, to assess the complex situation [1].

In the same context, [13] presented a list of various natural phenomena, which pass over a system behavior of a complex state in a chaotic state. As an example, there have been used a sand pile, where an additional grain of sand is sufficient for an avalanche. This sensitive dependence of a system behavior, for example, of the initial and conditions is referred to as "*deterministic chaos*". The word "*chaos*" is derived from the Greek language and includes several aspects: complete irregularity, incalculability, unpredictability of the system and the instability of the system state. Deterministic systems are unstable and easily interruptible: Minute alterations lead to large changes in the results. In addition, [13] imposes the following reasons for the steady growth of complexity:

- The functions of systems are constantly being improved;
- Systems are differentiated and flexible so that they can better correspond to a more differentiated reality;
- Systems can be expanded with more and more features to appeal to a wider range of customers;

- Various systems are inter-twined with each other to provide the overall benefit of a combined system.

In [13] there are recommended (like in previous cite researchers, too) capturing complexities through networks and making them tangible. The networks have two types of components: (1) *Node*: these are the place where the connections are linked with each other; (2) *Edge*: these are the connections between the nodes themselves and edges can possess certain properties.

In [23] there are described the main components of complexity management as follow:

- "The system is a collection of many interacting objects or agents;
- This objects behavior is influenced by storage or feedback loops;
- The objects can adapt their strategies according to their tale;
- The system behavior is usually open;
- The system is to be kept functional;
- The system displays emergent phenomena that are generally unpredictable, and can take extreme forms;
- The emergent phenomena typically occur in the absence of any kind of "*invisible hand*" or "*central management*";
- The system displays a complicated mix of ordered and disordered system behavior".

Furthermore, [27] recommends a five-point programme to control complexity by taking into account the following organizational issues: 1) Product; 2) Process; 3) Production; 4) Innovation; 5) Personnel.

In [22] there is described a generic and holistic complexity model (*Complexity: Toward an empirical measure)* by defining the *Generalized Complexity Index* (GCI), with three dimensions: *Multiplicity*, *Diversity* and *Interconnectedness*. The base of the complexity evaluation model was originally the product management; however, it can also be applied in a generic context, such as organizational review. For each of the dimensions, a mathematical formula was defined as described in the following [22]:

$$\textit{Multiplicity} = \#\ \textit{of variants} = V; \qquad (1)$$

$$\textit{Diversity} = 1 - (\textit{unique elements}/\textit{total elements}) = 1 - U/T; \qquad (2)$$

$$\textit{Interconnectedness} = \textit{connections}/\textit{max connections} = A / M. \qquad (3)$$

This approach suffer from of the lack of uncertainties consideration and because of it is most suitable to product management.

In 2013, there have been developed a model to analyze and present complexity in a graphical way, called "*The House of project complexity*". The core of the model are the following two dimensions: (1) institutional features and (2) technical features. [33], presented in Figure 3.

More recent in [53] there have been presented a model dealing with complexities focus on the researches and modelling is the "*definiteness degree of information"*. Starting point is the idea that business decisions are nowadays usually meet in an environment that is characterized by indirect effects, relationship networks and delays. Nevertheless, the identification and mapping system contexts in decision-making is often limited as cause-effect relationships and generally leads to erroneous handling of complex systems because the actual networking processes of system elements are ignored. The long-time sufficient uncross linked approach reaches its limits at a time of highly complex systems and networks with their respective structures and processes.

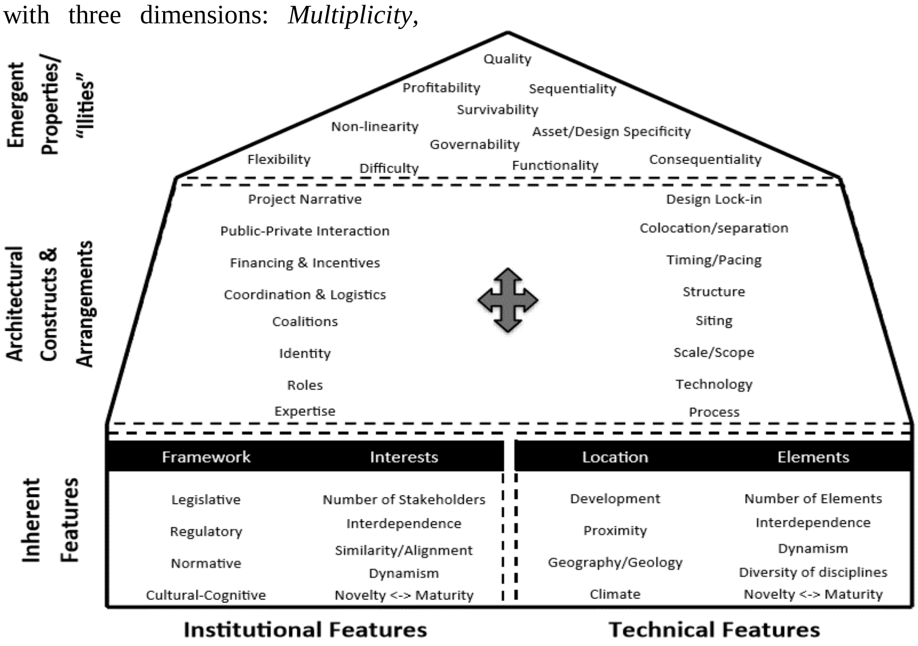

Fig. 3. The full house of Project complexity [33]

The decisive factors in the detection of a complex system are the level of aggregation; the selection of the essential elements of the system and identification of characteristic relationships between the system elements. Therefore, not only the collection of *quantitative information* but also, *qualitative information* is necessary to evaluate the system performance adequately.

The decision problems are characterized by the importance, complexity and the structured nature of the problem, the duration of action and the reversibility problem solving as well as the degree of uncertainty of environmental factors and the dynamics of the environment. The decision field of the decision-maker comprises selectable alternatives or strategies in a given time that state the business environment and the consequences of each alternative course of action in a given state.

Many of the planning and decision-making situations are performed in an environment in which the objectives, constraints and consequences of possible actions are not known in detail. In these cases, the planning and decision-making processes underlying information are imperfect. For the classification of imperfect information, used information can be distinguished by their definiteness as follows: security grade of determination, insecurity and un-sharpness.

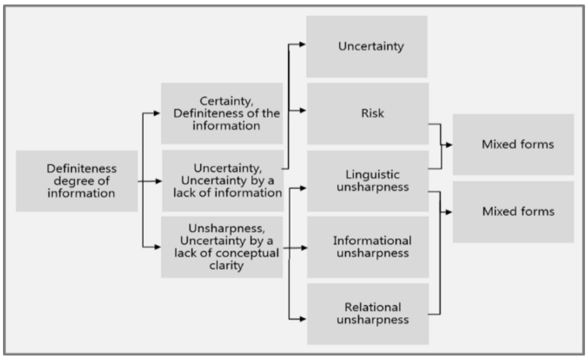

Fig. 4. Certainty degree of information [53]

Strategies	Design	Time effect in ...
Reduce complexity	Reduce the existing complexity	Today
Manage complexity	Efficient handling of unavoidable complexity	Tomorrow
Avoid complexity	Preventing the development of new complexity	Future

Fig. 5. A universal complexity management [60]

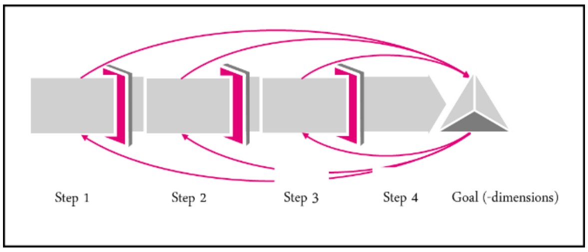

Fig. 6. Transitions Management (derived from [25])

Three types of un-sharpness can be distinguished (see Figure 4) [53]:

- *Linguistic impreciseness*: These are substantive indefiniteness of words and sentences of the human language;
- *Informational un-sharpness*: This type of un-sharpness results from the difficulty to compress a large amount of information about a clear overall judgment. Although they are precisely defined terms, however, a large number of properties is necessary in addition to this comprehensive description;
- *Relational un-sharpness*: This type of un-sharpness includes statements that the mutual dependencies of the included objects do not have dichotomous character. This means that the relationships between the objects are not sharp, by way of example statements like: “A” is greater than “B”.

In 2013, [60] has presented 23 functional modules that are considered relevant for complexity management in a company. These are specified in more detail in Figure 5, with respect to a service company and will be used in the present research, too. The complexity drivers in the business environment are manifold; these can be classified into a narrow sense (*detailed view*) and a broader sense (*holistic view*). Based on the detailed view, [60] has also developed three relevant basic strategies:

- *Avoiding complexity* - Through preventive measure the generation of complexity itself is to be avoided. Examples are modularization and standardization of products, organizational structures and processes. A complexity avoidance may not be very pronounced to permanently survive in the market;
- *Mastering complexity* - The aim of this strategy is to handle unavoidable complexities. Caused by external system requirements, internal complexity applies it to dominate as efficiently as possible. The control can for example be done by organizational conditions, flexible interface designs or flexible and scalable IT systems;
- *Reducing complexity* - A reduction can be done through targeted measures in an existing system, for example by reducing the variety of products or the diversity of the system elements and their connections or processes” (prese4nted in [42] based on the research results in [47] and [60])

In 2014, [25] shows how to manage complexity with a systemic focus on a process model in transition management. The transition management focuses on changing the system and is geared towards sustainable development (Figure 6) [25].

In [38] researchers explained that situations in management are often unclear objectives that can be ambiguous, diverse and contradictory. The ideal of the perfect control is an illusion. This ambiguity, lack of transparency and inconsistency is the justification for the necessity of the role of the manager in the company [38].

The research presented in [47] recommends practical possible tools and methods of managing complexity. Holistic and interdisciplinary approaches are in the foreground. In addition, [47] characterized the complexity drivers using internal and external perspectives, related cluster issues and specific criteria (Table 1).

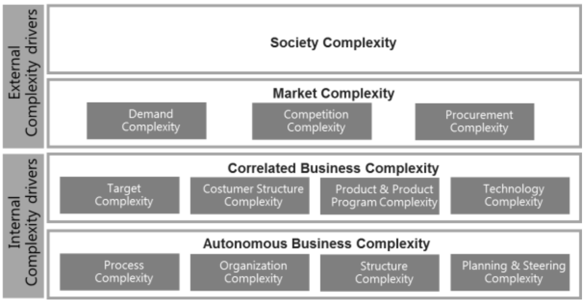

Fig. 7. Complexity drivers [47]

Table 1. Complexity drivers [47]

Complexity drivers		
View	***Cluster***	***Criteria***
External complexity drivers	Society complexity	– changing values; – environmental awareness; – economic and environmental factors; – political framework;
	Demand complexity	– diversity of customer requirements; – individuality of the demand; – market dynamics; – global requirements;
	Competition complexity	– number of strength of competitors; – changing markets; – competitive dynamics; – globalization;
	Procurement complexity	– number of suppliers; – procurement strategy and concept; – fluctuations in demand; – uncertainty of the delivery or quality;
Internal complexity drivers	Target complexity	– number of tracked targets in parallel – dynamics of the target adjustment – maturity of goal achievement
	Costumer structure complexity	– number of customers and customer groups – heterogeneity of customers and customer groups – level of participation
	Product and product program complexity	– structure of products – product and version number – dynamics of the product changes
	Technology complexity	– technological change – availability (innovative) technologies – technology lifecycle
	Process complexity	– number of interfaces and design – degree of crosslinking of the processes – degree of standardization
	Organization complexity	– number of hierarchy levels – degree of centralization – number of organizational units
	Structure complexity	– number of distribution levels – number of stock, staff, equipment, ... – communication systems – vertical integration
	Planning and steering complexity	– communication systems – frequency and level of detail of the management and control area

In [57] is presented an analysis based on past research objects, and on the following six main strategies:

- High sensitivity: pay attention to weak signals, establish a broad radar, high attention and mindfulness;
- Interpretation of information, think and play through possible consequences, create and study the connections, promote variety of thought (simulation);
- Management is a permanent process of progressing and the road map is drawn just during the walking;
- Flexibility, perspectives change, think in the view of the involved parties and contacts;
- High responsiveness by high problem solution ability and increased inside complexity (resources, potentials and options);

- Higher security to be able to master uncertainties better (stability and mistake tolerance).

In [57] is proposed a method, originally based on the VUCA (Volatility – Uncertainty – Complexity – Ambiguity) concept, which was developed in 1995 in the military field and which has been developed further. The core of the strategy is thinking in options and chances. The management observes emphatically the development of the defined scope (e.g. in projects), preparation is made for pre well-thought-out options in parallel, around then at the right moment, possible measures will be initiated to perceive an expected chance.

In [39] is introduced a special concept: "*Komplexithoden"* (in German) that link complexity and method words. According to this approach, for coping with complexity, numerous concrete tools are recommended:

- Methods for performance;
- Methods for agility related to dissolution of workplace, agile project work and the sense making.
- Methods for learning related to the informal structure work, communities of interests/practice and cultural observation.

Within these basic adjustments, concrete proposals for methods were developed [39]. Due to the limited extent in this research, only three methods for each strategy category are listed and analyzed.

In [59] research is presented a package of complexity management methods with focus on *supply chain management*. After an extensive analysis of the external and internal complexity drivers, a method for visualization is presented. On this base, some methods for *change and/or reduce complexity* are discussed in detail. These methods are designed for the strategy "*Complexity design*" [59]. According to the same reference, the following methods were created for the strategy of c*omplexity control*: project planning; changing demand; IT as an enabler and logic of communication.

A holistic and relevant approach for the present by [24]. The focus of their research was the complexity caused by the environment and the development of a concept of utilizing the illustrative capacity of modelling, in order to understand processes and decision-supporting scenarios. Here small and large-scale situations are considered. In large scale, focusing on the processes within a system and existing trends are explained. In small case systems, the focus is directed to the characterization and the importance of the parameters that describe a system itself. The systems' environment is characterized by the following criteria [24]: large-scale and long-term; multicomponent; real world conditions; multiscale and multidisciplinary; multivariate and nonlinear. The structure of a complex system can be modelled in a sequential procedure as suggested in the following [24]:

1. "Describing the relevant system;
2. Identifying actual variables;
3. Checking for systematic relevance;
4. Studying interactions;
5. Determining a role within the defined system;
6. Examining overall interconnectedness and system dynamics;
7. Weighting preferences and impact of variables;
8. Combing variables to forecast individual scenarios;
9. Evaluating the model;
10. Formulating strategy".

In [31] is discussed the intensive dealing with complexity in business situations; however, a concrete application is left open. Focus is the handling of conflicting objectives, bureaucracy-orientation in the organization and manager's behavior when dealing with complexity [31].

According to [31], situations in business have showed the most common mistakes in dealing with complexity and identified various recommendations for action; the most common mistakes in dealing with complexity are [31]:

- "Unfavorable division of work;
- The illusion of uniqueness;
- The illusion of objectivity;
- Switch off one's head;
- Formalism and bureaucracy;
- Compulsion to control and culture of mistrust;
- Either-or thinking and unresolved dilemmas;
- Neglect of the "*big picture*";
- Uncross linked thinking;
- Application of the "*if-then logic*";
- Unsuitable know-how".

Based on many years of practical experience and the study results published as "*Common mistakes in Management*", a complexity method "*Change®Evolution*" was developed. The method's six steps in detail are the following [31]:

1. "Capturing the current state to target-state discrepancy holistically from multiple perspectives;
2. Analyzing and re-modelling background and objectives;
3. Understanding relationships and areas of tension;
4. Developing design and steering options;
5. Assessing possible troubleshooting issue;
6. Implementation and anchoring of troubleshooting solutions".

2. Specific approach of complexity management (service-related)

The following section describes specific concepts, which have "*service provisioning*" in scope.

According to [20], the researcher combines aspects of complexity theory and application to the public service management. He analyses the complexities within the "*New Public Management*" approach and the challenges and applications of management techniques in the key areas of the public sector, such as performance management, staff development leadership, strategic management and use of IT. He also examines the relevance of the new theories such as knowledge management, emotional intelligence and risk management in association with complexity management [20].

Furthermore, [4] developed a comprehensive framework for assessing complexity in terms of their cost and benefit effects, in the case of service companies. At the lowest level, the different forms of complexity are described as:

1. Characteristics of service complexity;
2. Manifestations of the complexity of the performance, support and customer processes;
3. Manifestations of employee's complexity. This level affects the middle level "*a result complexity*". This level comprises of the following:
   - Complexity of the performance, support and customer processes;
   - Task complexity;
   - Complexity of the external factor;
   - Technological complexity;
   - Material complexity;
   - Location and branch complexity;
   - Employees complexity;
   - Customers structural complexity;
   - Service complexity;
   - Performance program complexity.

According to [4], the complexity cost and complexity benefit can be derived. The cost elements are subdivided into the following categories: complexity cost planning; cost of documentation; costs of coordination; costs by deviation; opportunity cost of complexity; complexity cost of willingness to perform. The benefits of complexity are divided into three categories: synergies; productivity effects and revenues [4].

The publication [28] discussed how the management and engineering of innovative services with global-distinctive customer in the service sector, can be controlled with the continuously increasing complexity. One possible strategy is to support this strategy through modern technological-oriented service architectures and solutions. The goal is to support the creation and delivery of services in complex processes and relationships through information systems, e.g. web portal. One example is value networks that consist of distributed value chains. These networks can, through the use of complex web portals, connect a large number of participants and roles [28].

3. Special (nonservice-oriented) research areas of complexity management

In the following sections, approaches of the complexity of management, which support specific (but nonservice-oriented) research areas, are analyzed and presented. In [45] is described the research results on the *Generic Model of Complexity (GeMoC)*. The scope of the research is to identify arising problems in collaborative networks. Furthermore, these problems will be linked with different system characteristics (e.g. network structure, trust, degree of commitment, coordination, change, and more). The GeMoC model approach is based on the following complexity drivers (explanations from [45]):

- Uncertainty (e.g. limited information);
- Dynamics (e.g. sudden or constant change);
- Multiplicity (e.g. a large number of participating elements and influence factors);
- Variety (e.g. many types of elements);
- Interactions (e.g. communication load);
- Interdependencies (e.g. feedback loops).

The GeMoC model links the 11 identified following complexity-related problems and the twenty-four system characteristics [45]:

1. Interdependencies of the participating organizations;
2. Strategic incompatibilities;
3. Lack of confidence;
4. Culture incompatibility;
5. Heterogeneous customer requirements;
6. The establishment of partnerships;
7. Misunderstanding in communication;
8. Insufficient and inefficient flow of information;
9. Inefficient network management;
10. Inefficient knowledge management;
11. Inefficient process architecture.

The GeMoC model can be used to identify root causes for specific problems arising in complex networks. This can be reached by analyzing the relationship between the problem and the system characteristics, as in Figure 8 [45].

In [35] are analyze the complexities in product design, which are characterized by a steady increase in complexity. The focus of the research is a structural concept; the structures result from the complex interdependencies of system elements. They have developed a method that allows the analysis, control and optimization of complex structures and applicability of cross-domain problems. The proposal of the procedure is shown in Figure 9 [35] published in German and in 2010 in English

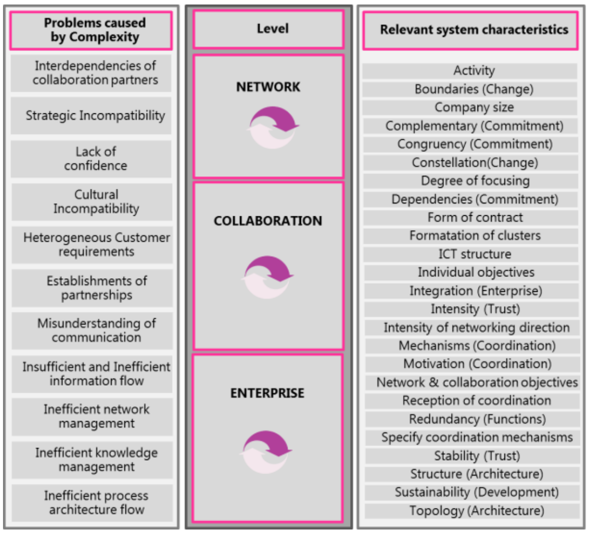

Fig. 8. GeMoC - Generic model for complexity [45]

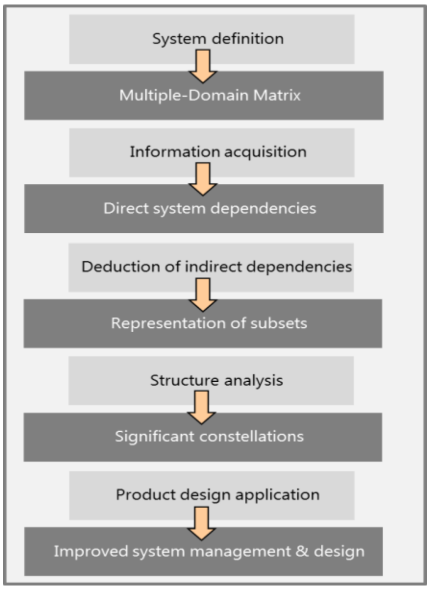

Fig. 9. Procedure of complexity management [35]

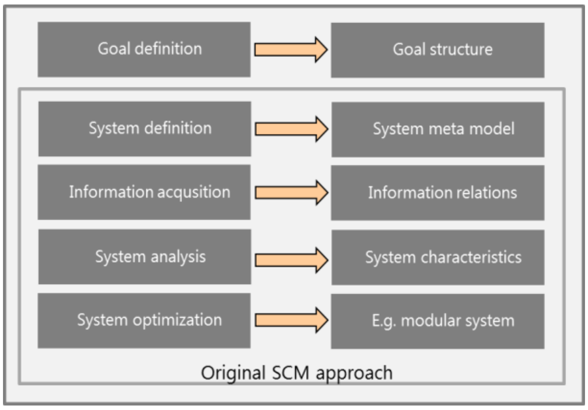

Fig. 10. Structural Complexity Management [11]

Table 2. Process management phases of an integrative approach (derived from [27])

Phases	Description
0	Develop overarching target system for the process landscape
1	Identify processes
2	Define processes
3	Operate and control processes
4	Monitoring Processes

Table 3. Eight patterns procedure (derived from [43])

Pattern number	Description
1	Layout Guidance, to reduce clutter, especially in large process models
2	Layout Split, to transform the existing processes and apply the layout guidelines BPM
3	Group Highlights, to characterize the elements to different groups
4	Graphical Highlights, to highlight certain features and relationships
5	Pictorial Annotation, to strengthen model-specific concepts
6	Textual Annotation, to supplement and add domain-specific information
7	Explicit Presentation, to visualize and distinguish the various ingredients of a process model
8	Naming Guidance, to bring clarity and convey domain-specific information

The approach is based on the *Design Structure Matrix* (DSM) method, which consists of detecting, modelling, analysis and synthesis of interconnection of elements in highly networked systems. Typical examples of such systems are complex and highly integrated product architectures, organizational structures and processes. DSM allows putting in such systems, elements of a kind with respect to the fact that they are connected by a comparable relationship among themselves. As modelling base, a square matrix is used that maps the vertical and transverse axis of the individual elements of the system and each individual cell can be used to map the relationship between two elements. In this case, such a DSM is modelled as "*line has influence on the column*" or "*column affects the line*".

Based on the recent research state, in [11] is presented the concept of *Using Structural Complexity Management for Design Process Driven Modularization*. Starting from a high internal complexity and diversity in most companies, they developed a systematic approach and methodology to modularize a product architecture of the design process view by using the general procedure of structural complexity management. The overall objective is to reduce complexity, cost and product development time in the company and to streamline product architectures through modular design. The approach is based on the *Structural Complexity Management (SCM)* method (Figure 10).

The design process result is presented by the Whitney index (WI), which sets the dependencies of system elements in relationship with their number [11].

In [27] is presented a *model of the integrative process management*, in which were considered the complexities strategies in relation with following concepts: *managing complexity*, *complexity prevention* and *reduction of complexity*, in connection with the specific process management phases (Table 2). Furthermore, the *process management* instruments mapping is created.

A process-based approach to identify complexities was developed and described in [43], based on the *Business Process Management* (BPM). The proposal incorporates the detection of a broad range of functions required by a collection of patterns. The eight patterns are shown in Table 3.

The work described in [43] provide a systematic analysis of the properties, which are suitable for the management of complex process models in which these properties affect the concrete syntax, but there does not exist a corresponding abstract model. The analysis result provides a form of a collection of patterns and an evaluation of the state-of-art languages. In this pattern-based analysis in process modelling, identified relative strengths and weaknesses in the languages and tools are considered [43].

In 2012, considering the research results of [11], which is a stepwise systematic approach to manage complexity tasks with scope in the product development process. The stepwise approach includes the following phases: define goal, plan goal, structure goal and define measures. The core of the approach lies in the "*Goal definition*" phase where it is possible to define a number of concrete objectives (derived from each strategy). An example of objectives list could include [11]:

- Optimization of the internal complexity and variety;
- Optimization of the product architecture regarding the actual organizational structure;
- Optimization of the product architecture regarding the actual manufacturing process;
- Highlight the interrelations between development process and product architecture;
- Highlight the communication network within the development process;
- Analyze and highlight of changes' impact on product architecture;
- Thereby, a distinction is made between "*complexity control*" and "*complexity reduction".*

The paper [12] shows the relationship between products varieties and the complexity increasing phenomena. He focuses on inventory management, using the case of the automobile manufacturers, but companies from other industries, too. The result is summarized as follows [12]:

1. Large range of variants are the strongest complexity drivers;

2. Complexity costs are critical and difficult to assess;

3. Complexity Management is seen as an "*Optimum diversity*" and in this context, the following strategies could be developed: avoid complexity; reduce complexity; master complexity.

The article [44] examined the increasing complexity of companies' business processes. According to their studies, one possible strategy for dealing with the complexity is processes standardization. They analyzed the interactions between standardization effort, business process complexity and business process standardization. They analyzed the hypotheses that the increasing of business process complexity is associated with increasing standardization effort as well as declining business process standardization and that increasing standardization effort is related to increasing business process standardization [44].

For this purpose, a conceptual model was developed and evaluated. The model supports the understanding of the business processes complexity effects on their standardization and the standardization effort to understand and analyze business processes. To test the model hypotheses, a survey of 255 experts was developed in the field of business process management. The results show that business process complexity has a strong positive impact on standardization efforts. In addition, it was clear that increasing standardization effort could not be considered a tool to achieve the standardization of complex business process [44].

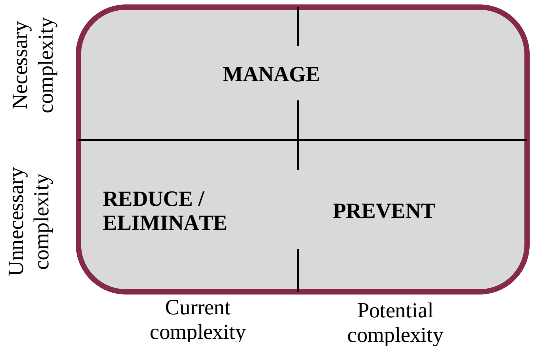

Fig. 11. Matrix of approaches to dealing with complexity [51]

In 2013, the article [19] focus their research on "*Complexity and Robustness Influence on Production Performance - A Theoretical Framework*" in the field of product design and manufacturing by taking into consideration factors as operating, resources, labor and materials. The following variables are defined and integrated into the proposed valuation model [19]: *complexity, stability, flexibility, robustness and performance.*

Furthermore, in [21] is examined the impact of corporate expansion in terms of complexity. Here, the following variables are used: TMT (Top Management Team) growth rate; Common TMT-specific experience; Added product scope; Added cultural distance; Expansion steps; Cultural diversity; Product diversity; Minority; Acquisition; Total ownership; Firm size; Profitability; Capital structure; Slack; Industry mix. These variables are evaluated according to different use cases and then, they are consolidated at different complexity values [21].

In the article [30], researches are focused on organizational development in conjunction with strategic management. Author turns out that the management between *stable* and *unstable* states of a system must be different and he recommended for the unstable systems management the following two strategies for action: (1) trial and error and (2) self-organization [30].

In [51] are presented the results of the study on the complexity drivers in supply chain management where were analyzed the complexity drivers from a temporal perspective (current and potentially) and from the point of whether the complexity is avoidable or unavoidable (Figure 11). The research described in [51] refers to leading researchers in the complexity area, as the studies in [60] and the concept of leading consulting companies was used. According to [51] complexity drives in the supply chain are grouped, by taking into consideration their origin, into the following groups: internal; supply / demand interface; external. Complexity inherent in the supply chain is observed in different forms and origins (Table 3):

- *static complexity*, that is related to the connectivity and structure of the subsystems

involved in the supply chain (e.g. companies, business functions and processes);
- *dynamic complexity*, that results from the operational behavior of the system and its environment;
- *decision-making complexity* that involves both static and dynamic aspects of complexity.

Table 3. Some drivers of supply chain complexity [51]

ACCORDING TO ORIGIN			
Type	***Internal***	***Supply/demand interface***	***External***
Static	– Number/variety of products – Number /variety of processes	– Type of product – Number/variety of suppliers – Number/variety of customers – Process interactions – Conflicting policies	– Changing needs of customers – Changing resource requirements – New technologies
Dynamic	– Lack of control over processes – Process uncertainties – Employee related uncertainties – Unhealthy forecasts / plans	– Lack of process synchronization – Demand amplification – Parallel interactions	– Changes in the geopolitical environment – Shorter product lifecycles – Trends in the market – Market uncertainties – Developments in the future
Decision making	– Organizational structure – Decision making process – IT systems	– Differing and conflicting – Decisions and actions – Non synchronized decision making – Information gaps – Incompatible IT systems	– Changes in the environment – Factors that are out of span of control – Uncertainty of the unknown and uncontrollable factors

More recent, [8] used the three dimensions for analyzing complexities: internal mechanism, environment and co-evolution.

In [18] was described a specific approach (used in military defense) for an innovative procurement process. This uses the PBL (Performance-Based Logistics) model, also known as performance-based life-cycle product support or performance-based contracting, which is a strategy for cost effective weapon system support. Their study is based on five theses for the usability of PBL for the German defense procurement:

1. The procurement of complex service bundles will increase;
2. Efficiency over the life cycle requires the integration of procurement and utilization phase;
3. The increasing importance of incentives as a coordination mechanism for industry;
4. PBL will be procurement alternative to be checked in the future;
5. PBL in numerous projects requires overarching Governance structures.

The core of the research described in [18] approach is given by the contracting for the acquisition, the product support management processes that have to determine the performance increasing of the delivery outcomes, in the case of a system or a product. Thesis one to three and five are incorporated in the further course of this research; reason for this is that the insert is different, but essential features for the use cases fit (e.g., high-voluminous projects, buying complex services, long-term projects, operation management etc.).

Bundesvereinigung Logistik (BVL) Board Annual Report 2014 includes the results of a survey developed with the members' involvement (10,000 members from the top echelons of industry, commerce, services, and science). The report entitled "*Complexity, cost, cooperation*". The analysis of the results shows that "*Industry has learned to deal with complexity*". Complexity management and process optimization are among its main tasks. About 70% of the respondents have recognized that in companies in industry, trade and logistics services have been introduced specific projects for management of complexity. "*Complexity management becomes the drive and pulse generator for process optimization and innovation. Complexity characterizes the logistics sector - efficient management of complexity is therefore a competitive advantage*". In addition, almost 77% of respondents describe structures and processes as complex to very complex. "*It is the diversity of customer requirements and product diversity, leading to more complexity above all in the economic sphere*" [26].

In the article [34] there has been developed a model to analyze consulting firms, complexity-related problem areas and questions based on different *sense-dimensions* (as seen in Figure 12). Each of the dimensions can be characterized from the perspective of the current issues and challenges (with which an organization is facing); the map-based on questions result that is provided by consultants could provide an insight into the events of the company and guide the consulting work, too [34].

The work [55] continue the systems approach for managing complexity in the case of the industrial supply chain. The leading questions of their research are:

- How is a complex supply chain to be evaluated?
- How can we assess the complexities induced by changes of a system?
- How to develop the implementation methods and tools for complexity measurement?

- How to verify the first three questions with industrials cases and thus reduce the non-value added complexity?

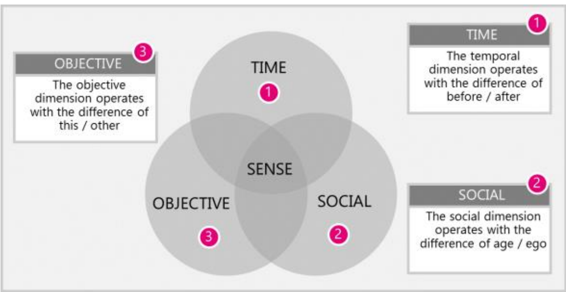

Fig. 12. Model of complexity-related problem areas [34]

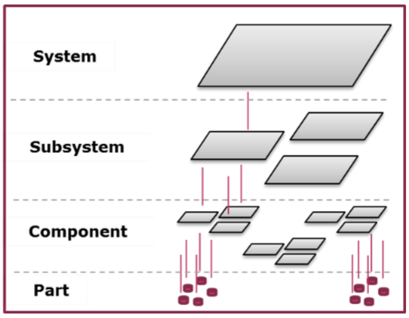

Fig. 13. System decomposition into three layers (figure adapted from [55])

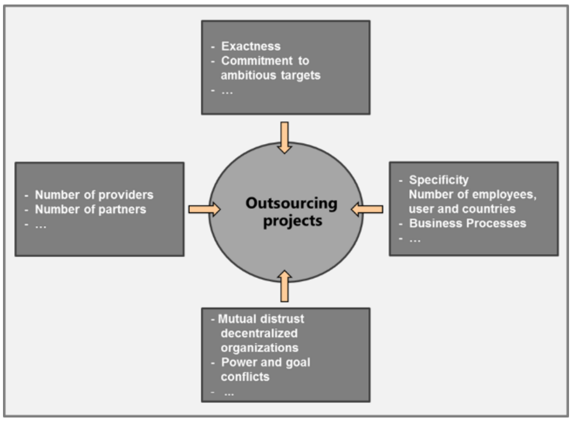

Fig. 14. Complexity factors in Outsourcing [49]

To create a model for complex supply chain, a three-layer architecture was proposed (Figure 13).

For each level, the attributes of basic elements and their interfaces have to be defined. The basic element for the subsystem layer is the subsystem, similarly for the layer of component and part. In the created model, the interfaces are described as the relationships among all the elements. The article [55] employs a conceptual model including the following four elements: process, role, object and its states (PROS), in order to describe a complex system.

4. Complexity in outsourcing projects

In [48] is discussed the topics of complexity, using the example of outsourcing projects. These projects are characterized by unmanageability, opacity, networked, intrinsically dynamic, severe predictability of the consequences, politely; there has been emphasized three possibilities to deal with complexity by: (1) avoiding complexity; (2) reduce complexity; (3) the ability to manage complexity. Furthermore, [49] work notes that the level of complexity mainly depends on the nature and extent of the outsourced functions (Figure 14). In addition, internal resistances, especially for projects with staff transition, impede the course of the project [49]. Because of many debates, in [49, 50] there is noted that complexity in outsourcing can be limited as follows:

- Reduce the scope of the project;
- Building confidence and do not move rules or processes in the foreground;
- Set clear steps within the organization that are precisely defined and fixed by contract;
- Involving external know-how;
- Only set realistic goals;
- As a prerequisite for the outsourcing process, clear, identifiable structures and processes are set up.

In the article [50] there has been analyzed the dimensions of the negotiation process from the perspective of the service provider. Both researchers have worked out on the various incentives and motivations behind their actions of the parties and provide concrete negotiation strategies to avoid projects complexity. A relevant key message was that the contract cannot cover all the options and therefore a way must be found to cover a corresponding flexibility of future-oriented uncertainties. Another statement was that the contractual arrangements will often be given too much importance and this is a bad start for the future of supply and services relationship [50]. In addition, there have been presented ten propositions, in which he reaffirmed: outsourcing is complex. The impacts of complexity are not reflected enough [50].

In 2014, the Project Management Institute (PMI) has published a book about how to navigate with complexity. PMI pointed out that complexity in programmes and projects will always be existent. However, globalization, new technologies, and fragmented supply chains have significantly increased and compounded the complexity situations that practitioners are confronted with. Faced with objectives that are more challenging and a higher percentage of their budgets at risk due to complexity, business leaders realize the critical need for successful delivery of these unique programmes and projects. As a result, there have been a variety of studies and publications on complexity, but few of them are focus on providing practical approaches [40]. For navigating complexity, the „*Practice Guide*" provides methods in order to effectively manage complexity in programmes and projects, in the following six sections:

- Organizational Considerations;
- Encountering Complexity;

- PMI Foundational Standards and Useful Practices;
- Navigating Complexity: The Assessment Questionnaire;
- Complexity Scenarios and Possible Actions;
- Developing the Action Plan.

PMI has formed three main categories of complexity for the control of programmes and projects: Human behavior; System behavior; Ambiguity [41].

In the last years, in the field of Project management the need has arisen for an intelligent and fundamental strategy to address the challenge of dealing with complexity [9].

According to [17] there have been identified key issues for a successful outsourcing project: dealing with uncertainty and importance of mutual trust relationship. Besides the importance of trust, dealing with the uncertainties in outsourcing projects has been recognized as a very important aspect. In [17] there are described these aspects (only) on a very high level. In addition, it has been worked out that all the parties involved in an outsourcing projects are trying to maximize their benefits during the project development. The first package of measures recommended has been the consideration of uncertainties in the pricing models. Second, it has been recommended that the parties' behavior have to be evaluated permanently through a third company [17].

Although *outsourcing process* was intensively studied in recent years, together with its impact on organizational aspects that is still not very well understood [2].

III. CONCLUSION

Many of the concepts are aimed at the assessment and the mastery of individual complex situations rather than on long-term complex situations in an overall context, e.g. *Seven Steps in the intuitive handling of complexity*. The concept *Managing Process Model Complexity via Concrete Syntax Modifications* focuses on the representation of the processes and the contained complexities. In [48, 49] were analyzed complexity in outsourcing situations for the first time in 2007 and recommends three strategies and derived theses to deal with the complexity. These researches analyze the causes of complexity trap in the case of outsourcing project and derives complexity factors. Furthermore, practical guidelines on how complexity can be limited are given. These recommendations are partially inconsistent with other researchers in this research field. For example, it is known that the complexity of the company itself is a trigger for an outsourcing project. However, the above mention works recommend the creation of clear structures in the run-up to the project. The research results are of the few that bring the complexity of management with outsourcing projects systematically together. A scientific universal model for use in large-scale projects is not provided.

In the research [7] was developed eight strategies, which are gradually performed one after the other. The view and the examples shown relate to the industrial production of products. With the aid of production-related classification, complexity should be manageable. Simulation modelling support that the company will be able to prepare for future challenges. The *Generic model for complexity* described in [45] can be regarded as the standard model in the management of complexity from a perspective of collaboration. A derivation of management strategies, scenario building and recommendations for practice are not included in the model. The empirical study named: "*The influence of complexity to the standardization of business processes"* described in [44] analyses the standardization strategy in dealing with complexity in business processes. The focusing of the study and the development of a model assesses the relationship of this complexity strategy. An extension of the perspective on external corporate networks would be an interesting perspective to include the internal and external view of a company. The work included in [14] focuses on the management under uncertain environments and proposes a procedure model for dealing with complexity. In addition, it provides general recommendations for action at the highest strategic level. Furthermore, it is using a global view and focuses on human action behavior in management. The relevant research included in [53] in based on a derivation of a model for dealing with complexities, which is based on safety, uncertainty and indefiniteness. They specify requirements for a model and apply these to manage technology in a holistic view (also to apply for outsourcing situations). Specific models for the management of complexity in business are not pronounced. The work described in [13], analyses the reasons of complexity and recommends (like other researchers also) complexities through networks to capture and to make transparent. The focus is on the border of complexities to chaos. In [40], PMI published "Practical guide", therewith creating a new standard approach for the first time in science (besides the research from [48, 49] for Outsourcing projects), where complexity management and projects / programmes are linked with each other. The practical analyses and concepts included in [60] are very extensive and all-encompassing: they relate to functional blocks in the company. Despite the fact that a specific reference to provision of services is lacking, the approach described in [60] will be of relevance in the context of the future managing complexity model development.

The science of complexity management significantly existed only in the last 10 years. Moreover, it should be noted that (due to the interdisciplinary) a wide variety of research approaches exist. It can be observed that a variety of concepts in the past three years include similar structures, for example, the necessary internal and external view of complexities. It must also be noted that a variety of models have got a "*decision making-character*". In the context of long-term (outsourcing) projects, the time perspective must be considered. Exclusively a literature of 2014 uses the terminology: „navigating complexity". In the systematic approach with environmental focus presented in the article [24], external factors are adequately sufficiently taken into account. In outsourcing relationships, also external factors are of great relevance and therefore the content to be taken into account in this research.

The approach provided by [31] is very extensive and refers to the management of complexities in the business environment. The steps in the recommended procedure are extensively enriched with a variety of different management tools. This is what the strong interdisciplinary nature of complexity management needs. A modification of projects for major customers, such as large-scale outsourcing is not given.

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