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CHALLENGES OF INFORMATION REUSE IN CUSTOMER-ORIENTED ETO NETWORKS

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Abstract: *Manufacturing companies, including project-based and engineer-to-order (ETO) industries, are striving for innovation acceleration, and lean supply and product processes through lifecycle. Business orientation of ETO companies is customer-centric due to the nature of ETO products, being tailored and customized according to specific requirements of each customer. However, this customer orientation may lead to inefficient performance, due to lack of mechanisms to reuse proven concepts, designs and production facilities as well as lack of feedback mechanisms from products in use and service. These challenges have been recognized in earlier empirical research projects conducted in companies providing ETO products.*
This paper is aiming at identification of factors hindering product related information reuse in ETO business environment, which comprises several networks of actors during lifecycle of ETO products. A typology of factors and challenges of information reuse is built-up and further research needs identified.
Key Words: ***Information reuse, challenges, design information, product lifecycle management, knowledge management, engineer-to-order products***

1. INTRODUCTION

The benefits and efficiency of using information technology systems in organizations are often justified with easy information reuse, which may also enable organizational learning [1]. However, only few studies have been found that deal with the different types of problems of information reuse that hinder the efficiency of information systems and organizational learning.

Challenges of information reuse are a scattered topic in the literature, as different fields of studies [2] [3] [4] [5] [6] [7] [8] [9] [10] [11] present some individual views on the challenges, but in this paper these separate views are combined and a typology of information reuse challenges is provided.

According to the typology created in the paper, the information reuse challenges can be classified into four main categories based on the information processing generic models of Choo [12] and Markus [2]. A framework of information reuse challenges is presented, that combines different theoretical perspectives on the topic, and will help practitioners, especially dealing with design information and product related information systems, like product data management (PDM), computer-aid-design (CAD) or product lifecycle management (PLM), to plan information reuse more efficiently and to understand and be prepared to the challenges.

From theory perspective, no holistic view of the challenges of design information reuse has been found. From practical perspective based on the experience of the authors, the companies find information reuse problematic, as there seems to occur a lot of such product related information requests, which can not be easily fulfilled. As a consequence it is likely to be easier to make new designs for products and implement new supply processes as existing information is not easily available. Especially this problem comes up in project-based business and with the engineer-to-order (ETO) products.

Product design, overall engineering and project management are the core competences of the ETO companies, which usually act as main contractors and operate at the international level [13]. ETO companies often also manufacture their products and may even provide turn-key deliveries, thus providing installation and commissioning services. On the other hand, ETO products include a lot of components and subsystems, which are manufactured, assembled and installed by other companies. This is why they need to work with various subcontractors or establish partnerships. Working in the ETO network as main contractor they have the managerial competency to direct and coordinate the entire project. They also possess know-how from the basic technology to architecture of the end product [14, p.19].

The PLM solutions now available are characterized by efficient data sharing processes supporting collaboration within extended enterprises. But, they still lack of essential capabilities that would facilitate the reuse of design process knowledge, such as identifying similar workflows [15].

The sales-delivery process of ETO products presents a great potential for information reuse, i.e. the reuse of previously validated concept, design, production, in-use and service/maintenance information according to customer-specific requirements. A structure based product range modeling for design reuse has been introduced for the new component definition phase [10] [16]. Information reuse together with automated processing requires an integration of techical and knowledge engineering with engineering design and manufacturing phases [17]. On the other hand reuse of in-service information depends crucially of effective information feedback processes supported by knowledge and information systems [7].

In ETO companies there is a tendency towards 'mass customization', which emphasizes more standardized workflows and repeatability, and, thus also information reuse in product processes. General characteristics of ETO companies' transition towards 'mass customization' are e.g.: they offer limited but adequate product variety, decrease manufacturing cost, optimize their processes and their configurator challenge come from complexity and creating the product knowledge base [18]. Also ETO companies can benefit from product configuration by improving business process efficiency as well as information reuse and quality [19].

The state of the art practices in information reuse concerning product related information in design phases is based on using several different IT systems [20], and often there is no knowledge transfer from one design project to another afterwards [3]. Therefore knowledge is lost and time is wasted when information reuse is not efficiently organized. In practice, data and information reuse is not a systematic approach in ETO companies and therefore not been widely studied. Their product development process may lack of a formal framework and company culture for data and information reuse. In some cases, data reuse plays a role in new product development initiatives, but there is not yet a formal approach to achieve it.

These problems will be studied in this paper with the following research question: "What are the key challenges of information reuse in engineer-to-order product processes?"

After the introduction that covers the topic and the research problem, the second section of the paper gives background understanding on the information reuse challenges first from the definition standpoint of information reuse, second from the point of view of knowledge management and organizational learning, and third from the point of view of systems engineering. In the third section, the framework for studying information reuse challenges and the research process are introduced, and based on this, a typology of challenges is presented in section four. Section five discusses the findings and offers some possible solutions to the identified challenges, and conclusions of the study are drawn in section six.

2. BACKGROUND FOR INFORMATION REUSE CHALLENGES AND ETO CONTEXT

2.1. Defining information reuse

According to the software engineering discipline, design reuse is the process of building new software applications and tools by reusing previously developed designs. New features and functionalities can be added by incorporating minor changes. Design reuse involves many activities utilizing existing technologies to cater to new design needs. The ultimate goal of design reuse is to help developers create better products, maximizing value with minimal resources, cost and effort [15].

In product development, design reuse is the process of designing new products by reusing data and information from existing products. We consider that design reuse in product development can be categorized into one of two types: 'Partial Reuse' and 'Complete Reuse'. In the first category, only a portion of the information is reused from existing products, while for the second category all the information is reused.

Based on the objects to be reused [15] have defined three types of design reuse (Figure 1).

Type I: End-of-life product reuse: the reuse and recycling of obsolete products so that they return to the product lifecycle;

Type II: Reuse of existing manufacturing resources: the reuse and sharing of production processes; and

Type III: Reuse of product information and design knowledge: a prerequisite for the two previous types of reuse because design ultimately determines the extent to which products and manufacturing resources can be reused.

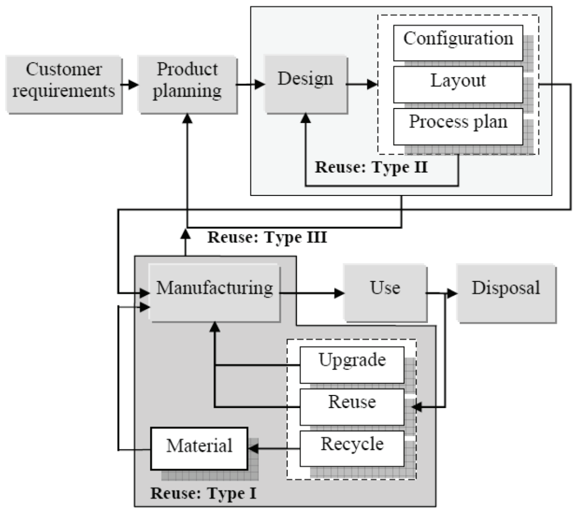

Fig. 1. *Types of design reuse in the product lifecycle [15]*

The current paper focuses on the third type, specifically product information of project based business in ETO companies.

2.2. Knowledge management and organizational learning view

The aim of managing knowledge in an organization is to maximize its value for the organization and to create a knowledge basis for long term competitive advantage [21] [22]. The hierarchy model of transforming data to information to knowledge to wisdom has been presented in information sciences field to depict the added value between these concepts. To be able to interpret data as information, we need to know the context, for information to turn into knowledge we need to be able to act upon it, and only by understanding the meaning of knowledge it turns into wisdom [23].

Knowledge management strategies in organizations usually emphasize either personalization or codification of knowledge [1] [24]. If an organization has chosen to rely mainly on the personalization strategy in its knowledge management, and has no proper procedures supporting codification of knowledge, such as shared data structures, templates and instructions, the reuse of information is ineffective. This might be the case especially in small companies, like typically the ETO companies are.

Information reuse allows feedback and learning between projects, if intra-project learning practices such as project logs, feedback discussions and lessons learnt-documentation are introduced (see for example [21] [25] [26]. However, the effective reuse of information needs right kind of knowledge packaging for different reuse purposes and users. The information needs are different in different levels and functions of the organizations (management /engineering /sales etc.) Also, the roles of the user might be different and affect the reuse situation.

Information creation and storage enables building organizational memory in the electronic repositories, consisting of codified, explicit information that can be expressed formally [8]. On a general level, the main problems regarding this kind of information storage are how to encourage the members of the organization to input data into the repository, and how to find the right information effectively in the reuse situations. This is important to notice, because knowledge retrieval, transfer, and application in new situations may result in an enhanced organizational performance [4].

The challenges in information reuse are highlighted in customer-oriented ETO companies, in which the development of new products is often guided by very specialized customer needs leading to unique products tailored to those needs. These companies usually operate in a larger network with other companies in the different lifecycle stages of the product such as design, production, delivery and in-use support. The reusable information should be available for all the partners in the network, which leads to the additional challenge of defining the ownership, user roles and access rights to the stored information.

2.3. Systems Engineering and the information reuse system in focus

The Systems Engineering approach can be used in understanding the topic of information reuse in engineering environment. Using the methodology of Systems Engineering in the early 1960 Arthur D. Hall [27] created a response to the ever increasing demands of the industrialized world. It was necessary to solve the increasingly complex and interdisciplinary problems successfully [28, pp.5-10]. Systems Engineering considers holistic systems throughout their lifecycle and is based on interdisciplinary collaboration to achieve the optimum system. This interdisciplinary approach requires a variety of views and interpretations of the tasks to be mastered.

According to Haberfellner et al. [29] systems consist of individual elements which form for themselves again subsystems or components. The individual elements are related to each other, characteristic of open systems [29, pp.4-26]. According to INCOSE [30] a definition of the term system is *„A combination of interacting elements organized to achieve one or more stated purposes.“* [30, p. 362]

Requirements management as a sub-discipline of Systems Engineering is responsible for determining, collecting, evaluating and distributing requirements. Its aim is to contribute to the maximum fulfillment of customer requirements [31, pp. 40-43]. From the perspective of Systems Engineering systems are to distinguish, to detail and, subsequently, to protect them against potential risks. Potential risks arise due to missing, incorrect and changing needs over time [32, pp. 3-8]. To reduce this, the system, as well as the relevant system environment has to be captured. Inadequate requirements capture of the relevant system environment leads to wrong assumptions on the orientation of the future system [33].

Among others, the following factors are relevant to the system environment: [33, p.22]

- People (stakeholders or stakeholder groups)
- Already existing or proposed systems
- Processes of technical, physical, economic or organizational nature
- Events
- Documents; e.g. laws, policies, standards, norms, etc.

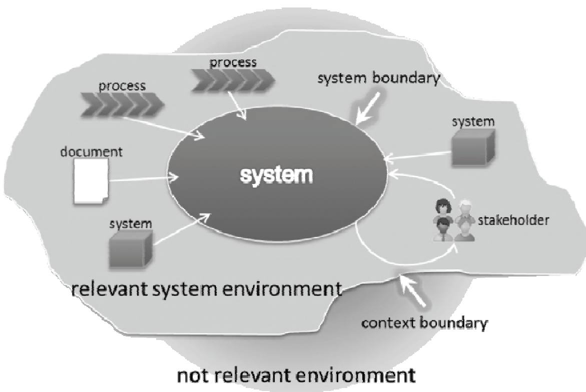

Fig. 2: Delimitation of a system to its environment (based on [29], [33])

The delimitation of the relevant system environment takes place at two sites, as shown on Fig. 2. From the outside the boundary is drawn to the non-relevant environment. According to inside the boundary line determined which aspects are to be realized within the system and which is not in the development of this system [33, p.23]. The main focus of systems engineering is situated at the document-centric approach to the security setting, that all documents are always valid, complete and consistent and that the system being developed meets the documented requirements. In practice, the document-centric approach, however, encounters with difficulties. The relevant information is usually scattered in a variety of documents. This means that individual specifications must therefore refer to other documents [34]. Model-based systems engineering (MBSE) is the formalized application of modeling to support system requirements, design, analysis, verification and validation activities beginning in the conceptual design phase and continuing throughout development and later lifecycle phases [30]. The expectation is located particularly in the promotion and enhancement of communication between various stakeholders and the reuse of specifications and components [35].

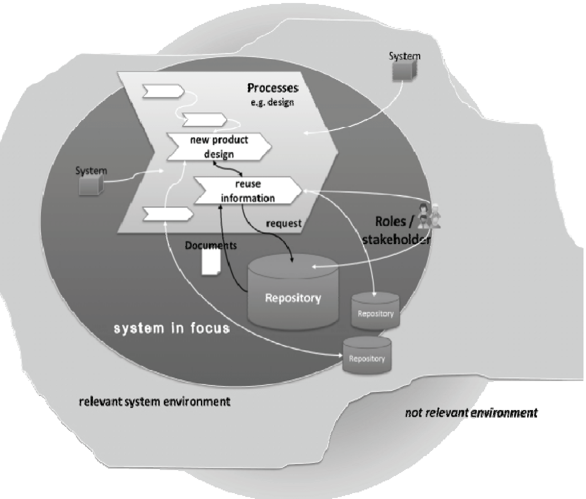

Fig. 3: Interrelation of an information reuse-situation with its environment (adapted from [29], [33])

According to Pohl's [33] statement of already existing or proposed systems Fig. 3 shows a possible representation of an information reuse-situation. The interrelation of e.g. processes, systems, stakeholder, and data repositories in a specific system communicate within the system boundary or within the context boundary. Furthermore the system model in Fig. 3 illustrates possible information and communication paths for information reuse in e.g. design phase.

3. RESEARCH FRAMEWORK AND PROCESS

Knowledge processes and information management in organizations have been discussed widely in the literature during the past two decades, as information systems have taken a crucial role in organizations. Our proposed framework for information reuse is built on the processes described by Choo [12], and Markus [2]. Choo's generic model of information processing in an organization starts with identification of information needs, and includes four consecutive phases where information is stored, shared and used, and new information needs are defined on the basis of adaptation to the new situation. In addition to the process view, Markus has included information repositories, knowledge roles and the characteristics of the reuse situations as important elements that affect information reuse. In our framework, the information needs aspect from Choo has been added to these important elements, and we see the generic models of Choo and Markus as partly overlapping. The challenges of information reuse arise from the information needs and are influenced by the needs related to knowledge processes, information repositories, knowledge roles and reuse situations. This has been illustrated in the following figure 4.

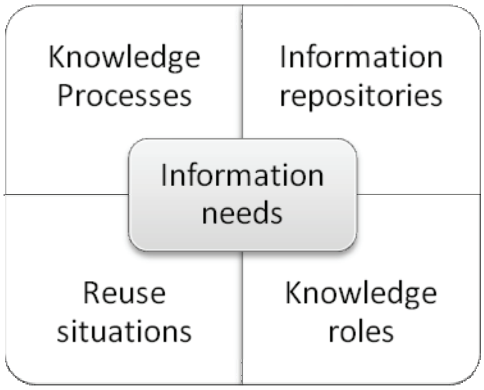

Fig.4. Framework of information reuse (adapted from [2] and [12])

According to Markus [2], knowledge reuse processes include four elements: capturing, packaging, distributing and reusing knowledge. Information repositories are characterized by the type of repository (digital/ paper, internal /external) and by the role of the repository in reuse (for ourselves, other similar users or other dissimilar users). The knowledge roles are listed by [2] as knowledge producer, intermediary or consumer. Reuse situations are further divided into shared work producers, shared work practitioners, expertise-seeking novices and secondary knowledge miners.

In the following section, we have created a typology of information reuse challenges using this framework. The terminology used for each category has been modified from the generic models [2] [12] when necessary, to better fit the ETO context.

The data acquisition for this study included a literature search and an analysis of selected articles. The literature search was commenced with using keywords (information reuse, design reuse, re-use, and knowledge reuse) in online databases Web of Knowledge and Scopus. In search results we excluded such reuse of information, which was irrelevant for our research context, like software reuse, building and waste -related reuse and industrial sectors (e.g. pharmaceutical and chemical industries, water and waste management). Also too specific issues like component reuse or modeling reuse were excluded.

Based on these general search results, we also searched directly within academic journals related with information reuse in design and engineering: Information & Management, Computers in Industry and Advances in Engineering Informatics. For detailed analysis we selected 14 articles, including the article describing the theoretical framework of knowledge reuse. These articles present multifaceted view to topics of information and knowledge reuse related generally with knowledge management systems, especially with knowledge and information reuse from repositories and particularly with design reuse situations in engineering and feedback from product lifecycle phases.

The selected articles were analyzed qualitatively in order to identify descriptions of potential challenges related to information and knowledge reuse. The identified descriptions of challenges were heuristically classified into groups according to the theoretical framework presented in Fig. 4. After identification and collection of data from the selected articles, the detailed classification of the data was designed, discussed and performed by the authors. Corrections were made to the initial classification on the basis of group discussion.

4. TOPOLOGY OF INFORMATION REUSE CHALLENGES

Information needs in the engineering context can be divided into two areas: knowledge about artifacts (product knowledge) and knowledge about problem-solving process (process knowledge) [3], i.e. what was done (declarative knowledge), how it was done (procedural knowledge), why it was done (rationale) and what could be done better (analytical knowledge) [2].

The process knowledge involves also contextual information, rationale behind decisions and background information, which together are interpreted as "know-why" information.

4.1. Knowledge processes

Knowledge processes are occurring at personal level of individuals, but simultaneously there are challenges related also with organizational practices and common set up in the organization.

Identified challenges are grouped according to the research framework into four phases of knowledge reuse process: *capturing, packaging, distributing and reusing* [2], [3].

Table 1. *Challenges related to knowledge processes*

Capturing	Source
Organizational practices and systems in use: - vocabulary and taxonomy - information format - capture of "know-why" into drawings & specifications - capture of "know-why" not explicit task or assignment	[7], [8], [17], [36]
Human factors: - IT skills and capabilities of people: o contributing to repository o knowledge repository capability o indexing o assumptions and context - motivation to share and capture (know-why) personal knowledge of individual designers for others - motivation to contribute to repository - understanding purpose and audience of reuse	[3], [4], [5], [7], [8], [17], [37], [38], [39]
Packaging	
Codification challenge: - techniques to correspond approaches in reuse - trimming down level of granularity (small pieces) - manual structuring (cross-references) & indexing of knowledge for further automation of reuse	[7], [8], [37], [38], [39]
Human factors: - motivation to contribute to repository - knowledge repository capability/skills	[4], [5], [38]
Distributing	
Knowledge repository capability	[5]
Reusing	
Finding & understanding external knowledge from repository - design tools (CAD) do not support retrieval - databases on product information in use are scattered	[3], [7], [8], [37], [39], [40]
Understanding context &"know-why" of information in repository - lack of background information - compatibility of knowledge model and design model - use of standard components	[3] [4], [7], [8], [37], [39]
Human factors to adopt external knowledge - personal assistance needed in evaluating suitability - combination of human & technology o extrinsic motivation requires knowledge repository capability o differences of intrinsic and extrinsic motivation to use repositories	[4], [5] [37]

The data demonstrate that reuse challenges are mainly related with capturing and reusing phases. Both have challenges related with organizational set-up and human factors. These both have common challenge related with "know-why" information. An organizational challenge is to identify "know-why" information capturing as an important task of individuals, and to arrange tools how this process information would be linked with the product information, both in capturing and reusing phases. Another type of challenge is related with human factors, like motivation and skills to identify, capture, share, find and understand "know-why" knowledge. That is also related with needs of novices for a personal assistance in evaluating reuse suitability.

4.2. Reuse situations

Four different general reuse situations were identified in the data. Two reuse situations at organizational level: *teams*, which are homogenous or cross-functional, sharing a common location and *networks*, cooperating on permanent or temporary basis in different locations. Two reuse situations at individual level: *experienced individuals* and *novices*. Thus, the terminology was adapted to the research context of engineer-to-order (ETO) networks, being different from that one used by Markus, but having close meaning.

Markus considers that knowledge reuse in homogeneous/cross-functional teams has minimal problems as their members share general and specific knowledge [2].

Table 2. *Challenges related to reuse situations*

Homogenous/cross-functional teams	Source
Mentoring of novices by experienced (editor, coach, expert) – to understand context and rationale for promoting knowledge reuse	[8]
Organization of long evolving design process for reusable precise artifacts - applicable only to similar situations: - understanding between well-defined & ill-defined areas - capturing sketches and blueprints - representing purpose of reuse - manufacturing process rationale	[3], [8], [9], [17]
Organization of capturing and reuse processes: - common policies, protocols and tools - combination of various NPD tasks - common definitions & vocabulary & taxonomy - quantity and details of information & applicability - relevancy - size of module	[3], [6], [8], [11], [17]
Integrating lifecycle information: - capturing information for other purposes (e.g. training) - linking different design phases	[17]
Cooperation in networks	
Common information perspective needed for effective reuse: - protocols for information exchange between disciplines - organization of information flow and reuse (tools & working culture) - retrieval tools/methods	[3],[4], [17]
Coordination need: - information exchange between main processes - build up information needs of next step - simultaneous development - complexity of semantic modeling	[17]
Experienced individuals	
Balancing between productivity and creativity: - find external knowledge on previous projects for reuse - time consuming analysis of previous designs for reuse	[3], [4], [8],
Reuse capability based on personal experience: - use of intuitive decisions - aware of relevant issues, relationships and limitations (strategic knowledge) - ask for advices and give advices - critical to data	[6],[8]
Use variety of information, different thinking models and solve complex problems - need of tools supporting reuse from external and internal repositories - have optional design decisions	[6],[8]
Novices	
Lack of experience makes reuse difficult: - to find (search), understand rationale and use information - to visualize & indexing information - to find and understand reusable items in external repositories) - to find relevant standards (incl. spreadsheets, templates and work protocols) and understand context	[6], [8], [9], [37]
Mentoring (advices and interaction with experienced) is required for: - reuse of standards missing contextual information - learning to understand standards (context and evolution history) and their use	[6],[8]

The data show that there are remarkable organizational challenges for knowledge management processes in order to enable reuse of information both in homogenous/cross-functional teams and cooperation networks. Both organizational level situations require common understanding, definitions, vocabularies, tools and information exchange approaches.

Reuse in cooperation networks is challenged by common (shared) information perspective and coordination in information exchange, flow and reuse. The data also showed that reuse is related with balancing between productivity goals and creativity for innovation, therefore an important aspect for strategic decisions.

At an individual level the personal experience is influencing to capabilities, possibilities and motivation of information (design) reuse, and needed tools. In respect to the learning process of novices, there is an organizational challenge to enable mentoring by experienced colleagues or master-novice working practice. Experienced persons are observed to possess a strategic knowledge, which was not indicated by the authors of the theoretical framework. The strategic knowledge enables the experienced persons to plan several moves in design process well ahead and use intuition and past experience in solving complex problems [6]. This valuable personal knowledge is extremely difficult to explicate and codify, even partly.

4.3. Knowledge roles

There are three major roles in reuse processes according to Markus [2]: *knowledge producers* (originator – documenting and recording)*, knowledge intermediaries* (prepares knowledge for reuse – eliciting, indexing, summarizing and sanitizing) and *knowledge consumers* (reuser - retrieving and applying). Sometimes a person assumes multiple roles.

Table 3. *Challenges related to knowledge roles*

Knowledge producers	Source
Expected output information should be identified explicitly	[17]
Personal characteristics as well as knowledge provider and consumer - relationship affect sharing and transfer:	[4]

Knowledge intermediaries	
Information processing needed: - together with knowledge producers - leads to semantic design information process	[17]
Knowledge consumer	
Limitations for reuse of information: - novices have difficulties to use information - absorptive capacity to understand knowledge and for learning	[3], [41]
Personal characteristics of consumer as well as knowledge provider and consumer - relationship affect knowledge sharing and transfer, and learning from experienced (knowledge producers) and best practice information	[4], [8]

Identified challenges show that for successful reuse the knowledge producer should be aware about the reuse situation and information needs of the knowledge consumer. When knowledge intermediaries are involved they should work together with knowledge producers. Novices are most often knowledge consumers, in the same time having limited absorptive capacity for learning and experience in information reuse.

4.4. Information repositories

The data in hands does not include clear distinctions between types or roles of repositories. Therefore the identified challenges are related to digital repositories and divided in three groups: general *design* issues, issues related with *retrieval methods* and *documenting to others*.

Table 4. *Challenges related to information repositories*

Repository – design	
Corporate memory approach: - selecting collaborative versus distributive approach - reuse system - differences for novices, experts and mentors	[8]
Dynamic reuse system: - versioning / modifications of information - enabling to evolve and improve - lacking status of information	[3], [8], [17]
Encoding and finding information (queries/exploration): - isolated design materials - relationships and integration - libraries for design artifacts for reuse & design traceability - user interface (submitting, choosing, viewing and navigating) - instance data and use of common engineering design domain ontology	[3], [8], [17]
Repository – retrieval methods	
Selection of retrieval methods (e.g. exploration or query) - keyword based search versus semantic retrieval methods - precision of design rationale capture tools - access to repositories and query efficiency - interaction method (exploration versus retrieval)	[3], [8]
Linking “know-why” background information (rationale) and understanding context for automatic recommendation of design rationale - find and understand reusable items - connecting reusable items, context of items and item's history	[3], [8]
Sensitivity of tools to familiarity of subject (supporting novice inexperienced users) - ease of finding versus familiarity with repository	[3]
Documenting to others	
Similar others: - individuals with similar perspective with author benefit from reuse of knowledge assets - reuses of complex knowledge assets requires assistance from author	[4]
Dissimilar other: - missing critical information due to intellectual property reasons - methods to provide missing semantic information	[3]
Novices need author’s personal assistance: - reuse of knowledge assets by novices requires assistance from author - novices benefit knowing (credible) author to ask	[4]

From repository system design point of view there are important factors to take into account e.g. corporate memory approach (distributive or collaborative, different user profiles), dynamics of the knowledge content and aspects related to encoding and finding information within multiple repositories.

Challenges of retrieval methods are related with reuse situations (teams, networks, novices, experts), as well as with finding and linking “know-why” information. When information repositories for reuse are designed to be used by others than knowledge producers, specific challenges are related e.g. with intellectual property rights, and with novices or with complex knowledge requiring author's personal assistance. Therefore repository design and selection of retrieval methods should take into account different reuse perspectives: processes, situations and roles as well as organizational and human factors.

5. POSSIBLE SOLUTIONS AND DISCUSSION

Based on the results of this study, the information reuse challenges are a varied topic covering aspects from many different fields and viewpoints. Some possible solutions for the challenges can be offered especially for the more technically-oriented challenges related to the information repositories and information retrieval such as the use of semantic search engines to find the required information for reuse. These search engines require an extensive set of metadata, which in turn means that the product knowledge architecture needs to be planned in advance. Also a common vocabulary, applicable for several different kinds of design information, would be necessary to agree. The vocabulary should include also 'know-why' information, enabling the knowledge producer to codify and consumers to understand e.g. decision making reasons and evolution history of the design solution captured for reuse.

To enable effective conditions for organizational learning and knowledge transfer from project to project, companies need to consider several preparations like this from both IT and human perspective.

In product lifecycle management, the efficiency of information reuse relies on the definition and management of equivalence information between various product data and structure representations in different product lifecycle (PLC) phases. Equivalence information ensures the consistency and traceability of product information throughout the PLC. This approach aims to apply lean principles in the context of information reuse within product structures and processes.

A framework of design knowledge management and reuse for Product-Service Systems provides feedback information from product usage and maintenance phases (middle of life - MOL), but business transformations are needed in order enable manufacturers to learn from past experiences, not only from design phase, but also from usage and maintenance [42].

One major solution is to create an information reuse process and mechanism, utilizing the extended product knowledge architecture and knowledge modularity through the product lifecycle. Introduction of product knowledge architecture, in close relation to product architecture, facilitates knowledge processes, and management of information repositories, as well as supports knowledge roles and reuse situations. Thus this approach enables e.g. the expanding component variety developed within previous product variants as early as the sales lead phase of the sales-delivery process, in order to reduce customer-driven design costs and shorten lead-times.

The above-mentioned solutions for improving information reuse are mainly technology oriented and based on IT applications. However, our findings indicate that there are several challenges that are related with organizational and human factors. In the context of ETO networks any solutions involve multiple integration challenges between non-homogenous environments, organizations, teams, individuals, IT systems and repositories. Our findings indicate that information reuse even in homogeneous teams is challenging from organizational perspective: to identify importance of “know-why” information capturing, and to arrange tools for linking the process information with the product information. Therefore, non-homogenous ETO context would require thorough studies of understand practical solutions, which could cope with both capturing and reusing phases as well as issues concerning with confidentiality of the product related information.

The challenges related with human factors, like motivation and skills to identify, capture, share, find and understand “know-why” knowledge, require organizational management, including strategies and human resource management (HRM) practices. These together should support codification of information, essential for further reuse, and on the another hand, establish such structures that make reuse of information easy, when reuse approach is appropriate.

Organizational practices should also take into account that, according to our findings, there exist a need for collaboration and personal assistance in evaluating reuse suitability, beside technical tools. Therefore, the reuse of information within a cross-organizational collaboration (e.g. ETO context) may be limited compared with the possibilities of homogenous teams in an intra-organizational context.

6. CONCLUSION

In this study, several types of challenges considering information reuse specifically in customer-oriented engineer-to-order networks have been identified from the current literature. The challenges were categorized using a framework developed on the basis of organizational information processing generic models of Markus [2] and Choo [12].

The typology consists of four areas: knowledge processes, reuse situations, knowledge roles and information repositories. The challenges related to knowledge processes are mainly related with capturing and reusing. In both, the identified challenges are mostly related with understanding the context and the reasoning behind decisions made earlier.

Reuse situations are challenged by common (shared) information perspective and coordination in information exchange, flow and reuse. Therefore homogenous teams are likely to be more successful in information reuse than collaboration networks. At individual level the personal experience is influencing to capabilities, possibilities and motivation of information (design) reuse, and needed tools.

Collaboration between individuals in different knowledge roles is important for successful reuse: the knowledge producer should be aware about the reuse situation and information needs of the knowledge consumer, as well as knowledge intermediaries should work together with knowledge producers. From learning process perspective there is an organizational challenge to promote mentoring by experienced colleagues or master-novice working practice.

Information repository design and selection of retrieval methods should take into account different perspectives: knowledge reuse processes, reuse situations and knowledge roles as well as organizational and human factors.

This research was based on a sample of articles in scientific literature. Some of articles related to a general information reuse and some to specific information reuse in ETO context. Literature search revealed that the information reuse is not broadly studied in a context of engineering design or ETO companies. We did not find similar kind of research based on typology of information reuse.

Majority of challenges identified in the sample articles addressed challenges in knowledge processes and reuse situations. Only few identified challenges addressed knowledge roles. The theoretical framework of information reuse supported well the first round classification into four groups of challenges. Some identified descriptions of potential challenges were addressing complex issues, and therefore classified into two categories. Further classification within each of four groups required interpretations and several discussions among the researchers.

Based on the study we conclude that the variety of the information reuse challenges requires many viewpoints and levels of consideration when planning and designing the organizational practices and IT systems to support information reuse. To guide these planning activities there should be a clear information reuse strategy, taking into account ETO network specific features. Information systems can help reuse, but human consideration is needed especially for understanding the context and the background or the history of the information.

Further research is needed to study for example the role of reuse for creativity in development processes and the balance between creating new versus reusing existing information. Another need for future studies is to further analyze the identified challenges and their implications in a concrete company context in relation to product and knowledge management strategies and product lifecycle management. This could be carried out for example as case studies, using the framework proposed in the paper, and subsequently, the framework could be further developed to help companies to understand the possibilities and challenges of product information reuse.

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