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# Knowledge Reuse during New Product Development: A Study of a Swedish Manufacturer

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**Abstract**

As organisations grow, consequences of poor knowledge management are evident for new employees in product developing companies. The problem of leveraging existing knowledge between development projects and departments is still relevant. This paper presents an industrial case study of a traditional manufacturing company and extends prior research addressing the reuse of organisational knowledge in new product development. The paper outlines barriers that hinder effective reuse of codified engineering knowledge and suggest means to overcome those barriers by using A3-reports in the PLM-system.

*Keywords: knowledge management, knowledge sharing, product lifecycle management (PLM), product development, case study*

## 1. Introduction

Organizational knowledge related to companies' capability to learn from experience as well as effective knowledge reuse can provide competitive edge (Stenholm and Bergsjö, 2020). In the context of new product development, knowledge reuse is perceived as important but also challenging especially when companies grow and become more digitalized (Ulrich et al., 2020, Assouroko et al., 2014). Development of products even of a moderate complexity requires integration of outcomes of several specialized engineering knowledge fields such as product development (including mechanics, software, electronics, etc..) and production engineering (Ouertani et al., 2011). When different engineering knowledge fields work together new knowledge is built and accumulated. Knowledge that is based on experience and problem-solving is highly valued by companies (El Souri et al., 2019, Jokinen and Leino, 2019, Tell et al., 2017). However, for companies it is important not only to build new knowledge base but also ensure that knowledge developed in a product development project is captured and reused in other development projects. Transfer of knowledge and best practice between development projects has proved to be challenging (Matta et al., 2011). Often, for example during development projects design rationales and experience are not transferred and product developers struggle with similar problems in different development projects (Bergsjö et al., 2021, Tell et al., 2017). Reuse of organizational knowledge includes knowledge that is gained through experience and knowledge that is used and shared to achieve company's objectives and assist in taking decisions and actions (Stenholm, 2018, Meyer and Marion, 2013). There are many benefits related to effective knowledge reuse such as shorter development time, less feedback loops, fewer late engineering changes to product or production system, reduction of development cost and quality problems (Tell et al., 2017).

Companies use Product Lifecycle Management (PLM) systems to span across all engineering efforts that work on a product. It is important to not only present knowledge in a way that it is easy to acquire, but to present the right knowledge, at the right time, and to the right person (Stenholm et al., 2016, Matta et al.,



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2013). Although companies may possess a great amount of knowledge, prior studies have identified barriers that might hinder reuse and thus exploitation of codified engineering knowledge (Vezzetti, 2012). That is why, companies need to adopt proper organizational structures and means for managing knowledge which allow for identification of relevant knowledge, integration of knowledge and reuse of internally developed and codified engineering knowledge (Essop et al., 2016, Jokinen and Leino, 2019).

This paper builds on and extends prior research that addresses reuse of organizational knowledge in new product development. The paper has two objectives:

- Outline barriers that hinder effective reuse of codified engineering knowledge
- Suggest means to overcome those barriers

## 2. Barriers preventing reuse of codified engineering knowledge

Common problem mentioned in the literature on new product development is (re)using existing engineering knowledge. Transfer of knowledge between different development projects has been mentioned by several researchers (Ulrich et al., 2020, Tell et al., 2017). That is why, researchers in the field of knowledge management have been emphasizing the importance of knowledge (re)use and cross-project knowledge transfer (Assouroko et al., 2014) as well as discussing different factors that are important to increase opportunities for knowledge acquisition (Stenholm et al., 2016).

Knowledge in this paper focuses on the technical 'know-how' of an organisation, that is dependent on the context and created within an individual (Tell et al., 2017). Knowledge is related to an individual's awareness to understand future implications of taken decisions and actions necessary to solve engineering problems (Stenholm, 2018). In the knowledge management literature, Nonaka discusses the spiral of knowledge, where transition between tacit and explicit knowledge takes place (Nonaka, 1994). Explicit knowledge is knowledge that is formalized and written down as opposite to tacit knowledge that is difficult to articulate and express. Codified knowledge is knowledge that is explicit, and it is expressed in writings which allows for easier dissemination. According to (Nonaka, 1994) companies need to have capability to convert personal, tacit knowledge into explicit knowledge which can be disseminated and used by others in an organisation. Using existing knowledge can increase the possibility for an individual to take effective actions. Knowledge that can lead to effective actions need to be prioritised for disseminations (Stenholm, 2018). Many researchers have struggled with the question of how to make codified knowledge reusable (Stenholm and Bergsjö, 2020). To make codified knowledge reusable it is important to capture its design rationale including justification for making a certain design decision, different alternatives discussed and trade-offs made, as well as including information about the conditions and the context associated with the decision (Stenholm, 2018). Furthermore, for codified engineering knowledge to be reused it is important that the knowledge is simple and relevant. Relevancy refers to the fact that the knowledge should be supplied to the recipient at the right time and place (Jokinen and Leino, 2019, Essop et al., 2016). Easy to understand and simple refers to the fact that it should be structured and organised in a way that can support the recipient's understanding of the context and when this knowledge could be applied. (Stenholm, 2018) summarizes quality characteristics of codified knowledge for reuse including (1) relevance of content; (2) ease of application; (3) completeness (richer contextual detail); (4) traceability (design rationale so that the knowledge can be applied in a new context); (5) shareability (follow a standardized structure to ensure knowledge sharing between different engineering disciplines), (6) interpretability (use of common language that is understood by the recipient); (7) accuracy (reuse in dynamic environment); (8) relevance in time (when in time the knowledge can be reused) (9) minimality (integrated with existing knowledge assets); (10) degree of coherence (avoid contradictions between different sources of knowledge).

Although valuable codified engineering knowledge might be still difficult to acquire and reuse because of different barriers that can hinder that (Meyer and Marion, 2013). During new product development barriers can be related to several categories, namely people, organisational structure and management processes, as well as technology (Stenholm and Bergsjö, 2020). (Stenholm and Bergsjö, 2020) identify eighteen barriers related to knowledge reuse during new product development. Barriers related to the category people might emerge because, among others, (1) individuals might have low awareness of knowledge repositories and existing documents; (2) individuals might be overloaded with information; (3)



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time pressure that limits the opportunities for an individual to search information; (4) recipient encounters difficulties to understand codified engineering knowledge, for example, due to lack of unified used terminology between sites or departments; (5) lack of incentives as well as lack of awareness regarding usefulness of knowledge reuse; (6) lack of trust in the codified engineering knowledge; (7) difficulties for individuals to give up knowledge and acquire new knowledge; (8) difficulties to reuse certain knowledge in a new context (Stenholm, 2018). Barriers related to the category organisation and management might emerge because, among others, (1) lack of integration of knowledge reuse in the companies' goals and strategies; (2) lack of leadership encouraging and enabling knowledge reuse; (3) organisational structure and process (used in the past) that hinders knowledge reuse; (4) organisational culture might hinder knowledge reuse (Stenholm and Bergsjö, 2020, Essop et al., 2016). Barriers related to the category technology (information and communication technologies) might emerge because, among others, (1) inappropriate technology integration that does not reflect individuals' needs might hinder knowledge reuse; (2) lack of compatibility and integration between systems; (3) use of complex technologies; (4) great abundance of different IT systems that might lead to engineers that are reluctant to learn and use new systems (Stenholm and Bergsjö, 2020, Ahlers et al., 2016, Assouroko et al., 2014).

## 3. Means to overcome knowledge reuse barriers

The resulting documentation from product development often come in the form of CAD drawings, software code and test protocols. These describe the results of the design in the final state and are stored in repositories such as product lifecycle management (PLM) systems, describing "what" the product is but not "why" it became like this. The reasons behind the design decisions, its trade-offs, and the design alternatives are not presented and hence not available for reuse in subsequent projects. This is challenging, considering that up to 80% of design is adaptive or variant design (Pahl, 2007) indicating that an efficient utilization of past information and knowledge resources is critical for most design projects. The "why" information, which is often called design rationale, aims to explain the reasons behind a specific design (Lee and Lai, 1991). However, for this information to be practically useful, there are several barriers that must be passed, as described in section 2.

One way to represent "why" information is to use A3 reports. It has been proposed by scholars (Raudberget and Bjursell, 2014, Sobek and Smalley, 2008, Morgan and Liker, 2006) as means for capturing, organizing, and reusing engineering knowledge. The term A3 report refers to Toyota's form for communicating complex information and the reasoning behind a problem-solving activity (Morgan and Liker, 2006). The name "A3" refers to the size, a single, A3-sized page (297 × 420 mm), and all information must fit on a single sheet using a normal font size. The limited size fosters well-defined, concentrated descriptions of a single subject (Sobek and Smalley, 2008). Visual information is often included, enabling rich information despite the compact format.

It is important to stress that the design of an A3 is a structured methodology. It follows a review process that increases the quality of the content which is discussed among peers and often iteratively revised before approval. Another characteristic of A3s is that they have a standardised form that makes them easier to read and reuse (Sobek and Smalley, 2008, Kennedy et al., 2008, Shook, 2008, Morgan and Liker, 2006). (Sobek and Smalley, 2008) also view the A3 as a way to foster intellectual development, while (Shook, 2008) emphasises the mutual learning that occurs between the author of an A3 and a reviewer/mentor.

One disadvantage of A3´s compared to longer reports, is the necessity to create multiple A3s to describe different aspects of a subject, thus increasing the number documents. This can be seen as an impediment to the use of A3s (Kennedy et al., 2008), since the ability to reuse any document depends on the ability to retrieve it. However, it is suggested to map specific A3s to specific engineering artefacts, such as modules (Raudberget et al., 2019), which enables a natural way to retrieve an A3 in its context, which otherwise presents a barrier for its reuse (Stenholm and Bergsjö, 2020). Furthermore, many product realization organisations have a broad spectrum of technologies with the potential to support storage and retrieval of codified knowledge and the PLM systems has a central role in information management. PLM systems are built for securing digital assets and have different ways to retrieve information, such a semantic, structural, and geometric search of information and drawings. PLM systems may also help to overcome the Knowledge Management (KM) barriers of incorrect and outdated information (Matta et al., 2013) providing versioning, approval and authorisation of documents.



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## 4. Research design and empirical material

### 4.1. Research design

Based on an in-depth case study approach, the results in this study elaborate and add insights into existing literature on knowledge reuse in new product development. A case study method was appropriate to enhance understanding in this area and help extend the existing knowledge (Yin, 2014, Eisenhardt, 1989). The unit of analysis was knowledge reuse in the context of new product development. An appropriate case was found at R&D site at a Swedish manufacturing company, referred to as Company Comfort. The R&D site located in Sweden had over 80 employees within mechanic, electric, and electronic design. The main criteria for selecting the case were that the R&D site was (1) fast expanding with product development department that has recently increased its number of employees and product portfolio; (2) developed products of moderate complexity including electronics, software, and mechanical design; (3) the time for development of products has become shorter due to pressure from external environment; (4) the R&D site has expressed interest in developing improved ways for managing knowledge reuse during new product development.

As acting on the international arena, Company Comfort relied on frequent introduction of new products to achieve competitive advantage and meet customers' requirements in terms of price, quality, time, and volume. The company had design and production sites in several countries.

The first data was collected by eight semi-structured, open-ended interviews and through internal company documentation. The initial interviews aimed at mapping the current state of practice and identifying challenges with which the Company Comfort was faced with. The respondents were experienced personnel from different departments and represented mechanical and electrical designer manager, mechanical designer, industrialization engineer, electronics development, manager, project manager, PLM architect, software engineer manager, product development manager. Based on the industrial challenges and research opportunities found in the interviews, knowledge reuse in research and development was selected as the unit of analysis and further investigation. A core team was formed, consisting of a mechanical design manager, one mechanical engineer, one electrical engineer, the new product development process manager, and the PLM architect. To further investigate ways to improve KM, eight 1,5-2 hours workshops were held online with the core team. The first 3 workshops aimed at clarifying the state of practice for knowledge reuse in new product development, to plan the work and to get a common understanding of the challenges related to knowledge reuse from different viewpoints. This was followed by 5 workshops arranged by the researchers around different themes, focusing on different aspects and different KM approaches from literature. Each theme introduced different KM approaches and served as a basis for discussion around the applicability of each method in the company. Some of the approaches covered were KM strategies (codification vs personalization), KM tools (A3 reports, Ishikawa diagram, Engineering Check Sheets), knowledge formats (A3, Thin slicing), knowledge structure (PLM, SharePoint, Knowledge teams) and support for communication and knowledge transfer (Wiki, blog, Asana, Microsoft Teams).

The data analysis followed the steps prescribed by (Miles et al., 2014) namely data condensation, data display and conclusion drawing/verification. Contrasting the literature to empirical results was crucial to secure the external validity of the study (Voss et al., 2002).

### 4.2. Empirical findings

The empirical analysis showed several barriers that hindered reuse of knowledge during new product development. The study indicated that a lot of knowledge resided within an individual and it was not documented. It was pinpointed by one respondent that because the organisation has been expanding, many of the more experienced individuals had to spend a great deal of time in educating new employees and consultants about Company's Comfort processes, methods, and procedures. The lack of documented knowledge led to repetition of old mistakes and 'reinventing the wheel'. Company Comfort further lacked procedure of how to reuse knowledge and design experience from the product improvement department that took care of maintaining existing products into new product development projects. Changes in



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completed development projects did not include history of the rational for making certain design decisions and improvements which resulted in repetition of old mistakes when new products were designed.
Company Comfort used a PLM system where during new product development projects engineering change orders on components were tracked and recorded. The information that was captured was related to problem description, changes that were needed to solve the problem, connected components that were impacted from the changes. This information was then delivered to all the concerned engineers. Thus, information regarding changes on components was easy to find in the PLM system. However, there was no standardized way as to writing the text which led to recipients that in many cases could not understand what was meant in the text and misinterpretation occurred.
Yet another barrier preventing knowledge reuse was the fact that often documents were not updated and hence the individuals could not rely on them. Some respondents expressed that in many cases there was a lack of clear responsibility for revising and reviewing documents. It was not clear who administrated and updated documents, often the responsibility was on the individual that has created a certain document. Hence, the documents were managed by individuals rather than by a group or a team. The empirical analysis further indicated that a barrier preventing knowledge reuse was related to time pressure. Due to time limits updating and revising documents was not a priority and the focus was on daily work tasks.
Furthermore, barrier preventing knowledge reuse was documents expansion. Many documents that contained related information were created as well as documents could be found on different places or systems in the organisation. This made it difficult to find the right piece of information and the expert (s) of a specific design knowledge area. This also created confusion as to which source of information an individual could trust.
The empirical analysis indicated that Lessons Learned (LL) at Company Comfort took place at a project level. Every new product development project carried out LL however there was no clear procedure for sharing LL between development projects. Hence many of the experiences in a project were documented however not used and shared with future development projects.

#### *4.2.1. A proposed means to overcome the barriers for knowledge reuse in new product development*

Considering the opportunities and advantages using the A3 as a knowledge reuse tool, Company Comfort decided to start with exploring the use of A3s in their organisation and to use the PLM system as a facilitator. The main reason for this was the ease of application and the short learning curve for the A3 and the functionality and widespread use of PLM. By having the PLM system as an integrating factor, several of the barriers identified in literature and in the case could be overcome. A summary is presented in Table 1:

**Table 1. Identified barriers and the proposed corresponding enablers**

| ***Barrier*** | ***Enabler in PLM*** | ***Enabler in A3*** |
|---|---|---|
| Lack of procedure for knowledge reuse | PLM enables systematic procedures and workflow. | A3 creation is a process. |
| Lack of clear ownership for document administration | PLM enables scheduled requests for updates and creates a time stamp of approved documents.<br>PLM can assign a team with clear roles of ownership and reviewers. | A3 reports are short and quick to review/update. |
| Information scattered in different systems | PLM can link different information sources. | - |
| Information hard to find | PLM provide a variety of search tools, semantic, geometric, tags. | Standard form and structure that is easy to read. |
| Time pressure to create knowledge | - | A3-format is concentrated to one page, thus less work than traditional reports. One subject per page. |



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| | | |
|---|---|---|
| Time pressure to reuse knowledge | PLM should shorten the time to retrieve relevant information. | Updating and revising documents is relatively quick. |
| Documents expansion | PLM should shorten the time to retrieve relevant information. | A3-format can contain links to related documents. |
| Lessons Learned not fully used and shared | PLM could facilitate better sharing of Lessons Learned. | LL could be generalised and subject for new A3-documents. |
| Content and structure of codified engineering knowledge | - | A3-format contains 'Why'-information and standardized way of writing. |

The table summarises the barriers that could be overcome by the proposed combination of PLM and A3s.

### *4.2.2. Evaluation of the proposed means*

The proposed means were presented to the core team. For using the A3-format and its creation process, the team found several advantages compared to the current way of storing codified engineering knowledge. The A3 process having a built-in review and standardized format was considered by respondents from Company Comfort as a benefit in terms of content quality and readability. The focus of a specific knowledge subject area was further considered as an important feature. Moreover, the compact A3-format was perceived as an enabler for conveying critical engineering knowledge in a concise and simple way and thus avoiding writing and reading lengthy reports. The Company Comfort was positive towards the use of A3-formts and even mentioned that the PLM system could be familiar environment where the A3-formats could be efficiently stored, retrieved, and maintained.

Even though Company Comfort perceived several advantages with using A3-formats, several concerns were also discussed. One of the concerns was related to administration of a potentially vast number of documents that must be created, organized, maintained, and shared. Yet another concern was related to the organization of the engineering knowledge in a logical way so that the recipients could find relevant information. Since the application of codified knowledge is context sensitive, it was also mentioned as a concern that the recipient of the A3 must be clearly defined since there is a difference between the needs of junior designers or new employees and those with longer domain experience. Another concern was the time that would be needed for the development and maintenance of the documents. This was possibly related to the organizational culture where management and employees had to prioritize the work with A3-formats over the daily work tasks.

## 5. Discussion and conclusions

This paper has contributed to the field of knowledge reuse in new product development. Many papers have discussed the knowledge reuse and the related barriers, however, there were less papers that addressed how these barriers can be overcome. This paper extends prior research. Using case study method, it fulfilled two objectives: 1) outlined barriers that hinder effective reuse of codified engineering knowledge; and (2) suggested means to overcome those barriers.

This paper has several implications for the industry. The suggested approach builds on codified knowledge supported by the A3-format and the PLM system. However, the introduction of A3s and a PLM system is far from sufficient to improve all aspects of knowledge reuse. The interviews highlighted that knowledge resides in individuals and it is unlikely that all knowledge can be identified, codified, stored, retrieved, and reused. Therefore, apart from the focus on storing codified knowledge we also would recommend improving the personalization strategy in accordance with (Stenholm, 2018). Company Comfort has a work-culture based on interpersonal communication and teamwork, and one way to reinforce this is the establishment of teams that are responsible for developing and maintaining knowledge and competence within specific domains. Previous knowledge reuse initiatives were assigned to individuals and failed when this individual was unable to sustain this responsibility or



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changed position. This may be avoided if the responsibility is held by a team for each specific competence area.

In addition to that, to overcome the barrier related to time pressure it is necessary that companies acknowledge the importance of structured knowledge development and assign time for this in parallel to daily work routines. The implementation of the suggested approach must be seen as an investment and be given resources to develop a process in PLM and to develop the content in the A3s.

A PLM system has capabilities to store, retrieve, and search data (Matta et al., 2011). It can be context sensitive as to provide relevant information depending on the situation by linking different documents and make them available from different systems. In this way, A3s can be retrieved from process documentation, from other A3s or CAD system. The relevant guidelines and standards are available through links in the CAD models of a specific component or module type. To summarize, a tentative suggestion for implementing A3-format within PLM can be seen in Figure 1.

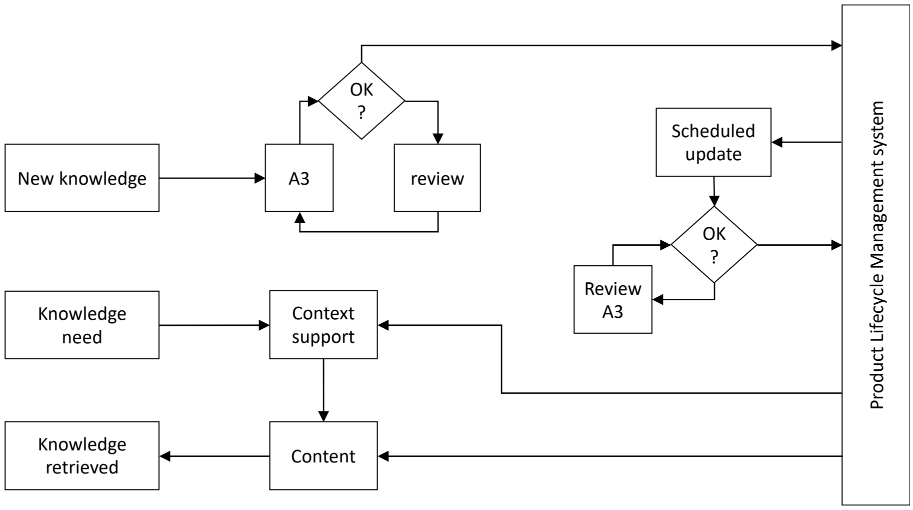


**Figure 1. The suggested structure for integrating A3s as a KM tool in a PLM system.**

New knowledge is codified and reviewed in the A3- process and stored in the PLM system. Though the PLM system's workflow capability, a scheduled request for update is sent to the team responsible for the knowledge domain. After the review, the information is tagged with a new date stamp, and it will be valid until the next update is done. When a need for knowledge emerges the PLM system will supply links to different systems and retrieve related documents without an extensive search.

Company Comfort has initiated the work of implementing the A3-format and is currently working to expand the approach broadly into more knowledge areas/ disciplines, such as the classification of surface treatment for sheet metal, CAD design rules for specific components, rules for energy declarations and other areas. The evaluation of the complete solution will be a part of future work. The focus of this paper was to outline barriers that hinder effective reuse of knowledge and to suggest possible ways forward. In the next step, a pilot implementation in the PLM system with the created A3s will be conducted with the goal to evaluate it with the daily users.

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