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INTRAORGANIZATIONAL BENEFITS FROM PRODUCT CONFIGURATION INFORMATION – A COMPLEMENTARY MODEL

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1. Introduction

The configuration management (CM) of products has a long tradition and includes management of the way hardware, software, and information are configurated internally as well as in relation to one another (e.g. [Larmour and MacLean 1995]). Despite the long tradition, there are indications among practitioners that the benefits CM contributes with still are not clearly expressed. For example CM practitioners we are cooperating with identifies the identification of benefits of CM as particularly critical in order to strengthen CM's position in the organization and increase its impact. This communicates that within a Swedish context CM has a rather weak position. To some extent this can be related to CM being a complementary process which are needed in order to make other processes work effectively [Sörqvist 2004], hence CM becomes more or less invisible. Another potential reason could be that CM to a large extent concerns management of information which can be difficult to put a price tag on. The information that is managed could for example be engineering information (EI) that has a focus on the design process and can, according to Storga, Marianovic and Savsek, [Storga et al. 2011] be sketches, drawings, notes, and meeting minutes. Some of this information are later formally recorded in technical reports and other engineering documentation such as CAD-models, production drawings, calculations, installation instructions, user guides etc. [Storga et al. 2011]. The formalization of EI can roughly be translated to the definition of technology information (TI) provided by Öberg [Öberg 2007]. A concept that to some extent includes both EI and TI is product configuration information (PCI). PCI is defined by the Swedish Standards Institute (SIS) as "requirements for product design, realization, verification, operation and support" [SIS 2004, p. 6]. More specifically, PCI includes requirements, specifications, design drawings, parts lists, software documents and listings, models, test specifications, maintenance, and operating hand books, and should also be relevant and traceable according to SIS [SIS 2004].

A additional potential reason for the weak position of CM is that there is limited research on CM, and a lack of academic engagement according to Huang and Mak [Huang and Mak 1998] and Burgess et al. [Burgess et al. 2005]. Searching in the topic field in the databases of Science Citation Index Expanded with the search string: "configuration management" AND benefit* generates 63 hits. However, few of them are explicitly discussing the benefits of CM and none is discussing the benefits of PCI. This supports the claims of Huang and Mak, and Burgess et al.

Even though there is limited research on benefits of CM, potential benefits can be identified in for example different definitions of CM. For example in Leblang's [Leblang 1994] definition of CM a benefit like control, mainly over the configuration of the product and potential change activities related to the product, can be identified. Also in the most progressive part of CM research, in the area of software and software development (se, for example, [Conradi and Westfechtel 1998], [Sarma et al. 2003]), benefits can be identified. For example in the definition of CM found in IEEE's Standard

Glossary of Software Engineering Terminology [Standard Glossary of Software Engineering Terminology 1990], benefits like control, not only in relation to the configuration and change, but also in relation to functional and physical characteristics, can be found. Also that the designed product is in compliance with the requirements specified can be argued to be a benefit. Drawing benefits from more general definitions of CM is one thing, but there are more focused discussions concerning benefits of CM in for example Krikhaar et al. [Krikhaar et al. 2009] and in the report produced by the Aberdeen Group [Aberdeen Group 2007]. We will discuss the above identified benefits further on in this article. What however struck us was that so far we have not been able to find a model that takes a more holistic approach to benefits related to CM, and especially that recognizes the potential benefits the information related to CM like PCI can generate. Hence, the aim of this article is to develop a model that takes into account previous identified benefits as well as adding benefits identified in a study specifically targeted on this matter, with a certain focus on the information aspect.

2. Towards the development of a model – the method

The basic steps of the development of a model have been as follows:

- Investigate identified benefits in a literature review of scientifically articles and reports
- Investigate identified benefits by practitioners, in an interview study, in one company with complex products, containing hardware and software
- Compare identified benefits
- Discuss similarities and discrepancies
- Develop a model

2.1 The literature review

The collecting of articles and reports for the literature review was done by using Google Scholar [Google 2011] and Science Citation Index Expanded (SCIE)[Web of Knowledge 2012].The keywords used and combined in this search were *´Product configuration management´, ´Software configuration management´ and ´Product configuration information ´* in combination with *´benefit´.* As was discussed in the Introduction very few articles and reports were identified in this process. The ones that seemed relevant have been analyzed and the expressed benefits of CM have been extracted. The result from this analysis was a set of benefits that became the base for the coming benefit-model.

2.2 The interview study

The next step was to identify benefits identified by state of the art CM practitioners, at least according to other Swedish CM practitioners. The study was conducted as an activity in a work package (WP) within the EU funded project Technical Information Centre II (TIC II). TIC II engages practitioners within the TI industry as well as researchers with an interest in the production of TI. The particular WP where the study took part focused on CM in relation to TI. Prior to the study reported on here, the participants within the WP had been engaged in a problem identifying sessions concerning CM. The key result of this session, as was discussed in the Introduction, was that the participants identified arguments related to the benefits of CM to be crucial to identify. An interview study was launched with the participants in the WP in order to make an inventory of possible benefits as well as testing different questions to be included. The result of these activities was a set of areas to be investigated with adhering questions. The areas were: (1) general questions about the respondent´s organization role, (2) the respondents' definition of CM, (3) benefits of CM, and (4) organizational views of CM.

2.2.1 Research setting

The company, in which the interview study was conducted in, hereafter called Alfa, belongs to a global concern which employs around 12.500 people. The concern is divided into five business areas; aeronautics, dynamics, electronic defence systems, security and defence solutions, and support and services. Alfa works with production and maintenance of electronic defence systems, mostly radar systems and employs 2.000 people.

At Alfa product development almost always has its base in existing products, and the development is rather to customize each delivery in correspondence with the wants and needs of a customer. In near future different base products will be used in the production and customers offered different product options.
Alfa started to use CM fifty years ago due to the fact of a huge spectrum of different products. Today information needed for the configuration process is digitalized in different systems, several only used by one department, and one central system. The central system is updated when the design process starts and also when any product changes are made. External stakeholders interested in prepared documents are often subcontractors, auditors or users.

2.2.2 Research design

The interviewees, seven altogether, were selected in accordance to their working role´s contact with CM. Other affecting factors were that they upheld a middle manager role and were representing different departments at company Alfa. Besides being middle managers the interviewees had different roles like development project manager, team manager software development, team manager customer support, team manager customer documentation, team manager mechanics construction, process coordinator configuration.
The interviews conducted with these middle managers were recorded and transcribed. As supporting analyze software, Nvivo9 was used. The empirical material was analyzed by importing the transcribed material into the database of Nvivo9. In the analysis different categories were used like Benefits or CM process. The coded material based the foundation for the empirical presentation. The material was also analyzed by the researchers reading through it repeatedly looking for any benefits the interviewees mentioned that could be related to CM or PCI. One overarching assumption was that all benefits were seen as benefits; no matter how many of the interviewees it was identified by and during what circumstances. However the analysis process actually started much earlier, already in the interview sessions, and it was here the topic of this article first was identified.

3. CM and benefits – review of related research

Benefits that add value to the individual work also are of benefit for the organization as such [O´Shea 2009]. Ward and Daniel [Ward and Daniel 2006] mean that benefits are reached by increasing the performance of individuals or groups in the organization in their work role, or increasing the performance of the whole organization. One way of increasing benefits are by fulfiling requirements of the most important stakeholders and thereby satisfy the great mass. The most pragmatic challenge with benefits is however to measure them, because without any measures it is difficult to argue any benefits. According to Ward and Daniel [Ward and Daniel 2006] benefits can either be measured in economical values or in more subjective values. Lagsten [Lagsten 2009] gives the intangible evaluation methods more pragmatic advantage due to organizational education situations and openness towards stakeholders.
The benefits identified in the Introduction, “control”, “change management”, and “design in compliance with the requirements specified”, can also be found in the articles we have identified. Starting with “change”, this benefit is further emphasized by for example Burgess, et al. [Burgess et al. 2005] when they argue that the importance of managing change with CM is due to meet the needs of changes across a product life cycle. These changes are implemented in an increasingly higher pace, and it is also the case that the products are becoming increasingly complex and are produced in an increasing higher pace [Stock et al. 2005], [Storga 2004]. The importance of managing change is also visible in [Estublier et al. 2005] discussion concerning the importance of CM for software, as software of today is more complex, has a longer lifespan and more often is life critical. This points towards that CM at least in relation to change can generate some benefits. However, to be able to manage change is it important to know what the product will look like (design), is looking like (production), and will continue to look like (support) [Burgess et al. 2005]. Dart [Dart 1991] puts it in another way and argues that CM contributes with visualizing the structure of a product where components are identified and where it is possible to find out what makes a product unique. This discussion can be related to one of the other benefits of CM, namely control. Control is explicitly stated as a benefit by Krikhaar et al.

[Krikhaar et al. 2009] as well, however, as control is the benefit that often is highlighted CM has got a "bureaucratic" stamp according to them.
Dart [Dart 1991] also points towards one of the benefits identified in the Introduction namely that the design should be in compliance with the requirements specified. She phrases it as the configuration being a hierarchy of components and this makes it possible to control all deliveries against the configuration schema
A majority of the discussions related to benefits of CM are centred on the above identified benefits. However, there are an additional number of benefits that have been identified. Krikhaar et al. [Krikhaar et al. 2009] for example argue that through supporting of efficient building and testing of correct configuration which is done by for example reduced rework and efficient problem solving - CM is an enabler for system evolution. They also, with examples from medical device industry, illustrate an example of CM being important when it comes to being able to demonstrate how a product been produced (quality assurance). This is also a requirement of the European Machinery directive. Bershoff [Bershoff 1984] further argues that one important benefit with CM is that it supports project management. Finally the Aberdeen research group published a benchmarking report in 2007 where they argue that *"quality, time to market, and costs are top pressures driving companies to improve configuration management "*[Aberdeen Group 2007, p. 1]. The identified benefits can so far be summarized as in Table 1 below.

Table 1. Summary of benefits identified in related research

Order and control	[Krikhaar 2009], [Leblang 1994], [IEEE 1990], [Burgess et al. 2005], [Dart 1991]
Change management	[Leblang 1994], [IEEE 1990], [Burgess et al. 2005]
Design according to specified requirements	[Dart 1991], [IEEE 1990]
Enabler for system evolution	[Krikhaar 2009]
Supporting management	[Bershoff 1984]
Supporting product assurance	[Bershoff 1984]
Product quality improvement	[Aberdeen Group 2007], [Ikeda and Akamatsu 2004]
Time to market improvement	[Aberdeen Group 2007]
Development cost reduction	[Aberdeen Group 2007]
Supporting efficient building and testing of correct configuration	[Krikhaar 2009]
Quality assurance	[Krikhaar 2009]
Sharing information within a team during the product life-cycle	[Krikhaar 2009]

The benefits summarized in Table 1 overlaps to some extent even though they are labelled differently. For example order and control and CM's potential to support management are similar and could hence be discussed in relation to one another. Other examples are product assurance, design according to specified requirements, product quality improvement, and quality assurance could be related to one another; as well as change management, PCI and CM as enabler of system evolution; and development cost reduction and supporting efficient building and testing of correct configuration. These groups of benefits are difficult to clearly separate from one another and can therefore be discussed as groups instead of single benefits.
A reflection related to the literature review is that a majority of the benefits have been identified within the context of the software industry. Only Burgess et al. [Burgess et al. 2005] are not departing from the software industry. There are arguments that CM for software and hardware has evolved kind of isolated from one another [Krikhaar et al. 2009], [Persson Dahlqvist et al. 2004]. Krikhaar et al. [Krikhaar et al. 2009] argues though that there are some differences between hardware and software CM. The most important difference is that software is more manageable which means that it is easier to make changes within software than in hardware. A lot of research and practical work is though going on when it comes to solutions and methods that are applicable in both software and hardware [Kirkhaar et al. 2009], [Asklund 2001].

4. PCI, CM and benefits – the interview study

In the interviews conducted we could identify several different benefits that, to some extent overlap, with the benefits identified in the literature but also diverge from it. In this section we compare the benefits identified in the literature study with the ones identified in the empirical study to be able to identify benefits that are not overlapping. However, we start this comparison by identifying the benefits that overlap.

4.1 Benefits that overlap

4.1.1 Order, control, and supporting management

One benefit that seems to permeate any discussion concerning CM is order and control. Upon asking the interviewees about what benefits CM contributed with, everybody ascribed CM to contribute with order and control over what product that had been delivered and the configuration of that product, etc. To emphasize this follows some quotes:

"For me it is how we manage the products that we have today. Why do they look like this, and also what can respectively part in a product do. And how do we know what is going on. That's what configuration management is for me". (Team manager customer support)

"That we have control on which revision the customer has and when we are about to update them we have control what new revision it should be updated to; we have control on the status of the product, the documentation" (Team manager customer documentation)

"They feel that they have something to back them up when responding to the customer and when they send stuff. They know that they do the right thing." (Team manager customer support)

In the above quotes the importance of generating and managing information through CM is to achieve control and order, becomes evident. As it is indicated in the quotes the information serves as evidence on what has been delivered to a particular customer. It also generates a description on why the delivered product has a particular configuration and what the different parts contribute with. This is further emphasized in the following quote concerning traceability:

"I think it is obvious. Everything has a label that is traceable to what it is and how matters stand. It is a unique system, but very powerful." (Team manager software development)

4.1.2 Change management and enabler for system evolution

As it is indicated earlier in this article the design process at Alfa almost solely departs from an existing product that either are improved and/or adapted to the requirements of a customer. Rarely, it is the case that something completely new is designed. This is emphasized in the following quote:

"Rarely do we produce something completely new. What we do in nine cases out of ten is that we depart from something existing. And then we do a new version from that." (Team manager software development)

Hence, managing change and how the systems evolve are crucial. This is emphasized in the following quote:

"Some customers demand that we must report any changes after a certain point. For example if you have a customer who has ordered radar systems to ten boats, and then they are not supposed to be delivered all at once. You will deliver one or two and another one a year later or two. It is a very long deliverance plan. And then you become sensitive to changes in the configuration. They want all ten systems to look the same, something they will never do because things disappear or must be replaced. They want us to report any changes and explain why. And then we explain our system." (Project manager)

The above is further discussed related to the guarantee of a product:

"Often you have a guarantee phase that lasts a number of years. Then you have a direct connection to the customer and then you have to take it in the product. Then you have a version that is delivered to the customer and the development is a couple of versions further away. Then it's partly about solving the problem at the customer and then to implement it in the product in a controlled fashion for the future". (Project manager)

4.1.3 Product quality improvement, quality assurance, design according to specified requirements and supporting product assurance

In the empirical material there are indications that CM is used in order to assure and improve the quality of the products. One example is the following quote:

"But it gives us control on what we have done, and it also gives us that we can return to something that was good, we also know what wasn't good." (Coordinator configuration process)

The importance of CM for assuring the quality of the product is further emphasized in the following quote:

"Then CM is a big part, we must deliver the right things, we cannot build something with the wrong configuration, containing the wrong code and stuff. These things we get back and affect our results negatively. We must know what has been sent to the customer, we have CLS-agreement. We have agreements concerning spare parts and service and stuff, for a long period of time. We must know what parts to bring along when we travel across half the world." (Project manager)

The persons that have been interviewed also express some frustration when it comes to how the company succeeds in using the potential that they believe CM has. They think that a more active organization could use the information in a more proactive way to be able to improve the products even more, hence assure its quality.

4.1.4 Development cost reduction and supporting efficient building and testing of correct configuration

That CM has a favourable impact on reducing development costs is expressed by several of the interviewees. The empirical material shows a number of examples where CM reduces cost when it comes to development of products.

"Can we reuse instead of constructing new all the time, and then we make money." (Coordinator configuration process)

"We can benefit from it during manufacturing; we can see what editions there are; we can see what different parts the product is constituted of that we can replace with parts that are new developed containing new functions, etc." (Team manager mechanic´s construction)

"We don't want to do that. Because we have our version managing system we have the possibility to have a product developed just for this. If you can further develop to more functions, more opportunities, to create a broader customer base, we can put it into several different projects, but it is still the same product. This is what really the big gain is. And everything is connected to our version managing system that we have. We can further develop and add new functions without removing anything old. This makes that even though we sold it as the first version we can resell it as a spare part in the twentieth version and it still manage to do the same thing." (Coordinator configuration process)

4.1.5 Sharing information within a team

The benefit of CM for sharing information within a team was expressed in the interviewees, but not as clearly as the cost reduction. One of the interviewees, however, described this in the following manner:

"Yes, of course it does. If everyone gets, within the assignment one has, if you know where to find the information, so of course. Then you're not dependent on one person, you don't have to talk to the

neighbour. If the neighbour isn't there you still know where to find the information. This could of course be achieved by storing all the documents in one place. That's a bonus. However, I think that we create a person independency with our order. That is probably one of the big things." (Coordinator configuration process)

4.2 Benefits that do not overlap

4.2.1 Time to market improvement

Only one benefit identified in the literature could not be found in the empirical material namely, time to market improvement [Aberdeen Group 2007]. The reason for this is probably due to the products the company is manufacturing and the market they are competing on, rather than on the relevance of the benefit as such. There is very little competition on this market hence time to market becomes of more or less no importance at all.

4.2.2 Base for aftermarket design

When it comes to the benefits of base for aftermarket design discussed in this section and common language for design discussed in the next section these benefits were by the interviewees closely related to what we in this article labels PCI and not CM in general.
Alfa is offering the customers the service of delivering spare part within three days at the latest. Living up to the agreement requires that Alfa has spare parts in storage but also information of what version a customer has and if it could be replaced with some other version. But it is not just about the service of delivering spare parts to new systems. Alfa also offers long service agreements spanning over many decades as is indicated in the following quote:

"When we still today can repair or manufacture parts for a forty-year-old system, and still knows exactly what to do it is a good system." (Coordinator configuration process)

Again the information is crucial to be able to deliver according to this agreement. The information also gives Alfa a potential opportunity to do new business with the customers by knowing the customer's systems and being able to argue that the systems need to be replaced as is indicated in the following quote:

"[…] this customer has really old systems and product management can go to the market department and say:"Here, they have really old systems; we could sell something new to them. Why don't we do it?"(Team manager customer support)

This potential is however under exploited for the moment.

4.2.3 Common language for design

Within the company Alfa, CM has been used for a long period of time this has made that the chosen ontology's and how the structure been designed is well known. A positive side effect of this is that the communication is more effective, both when it comes to communication between different actors and within groups. The following quotes visualize this:

"Yes I do. Because I can go to a construction instantiation and say what I need. We're talk about […], and yeah everyone knows that it is that cable. That I would say. Otherwise I had been forced to bring a picture to show all the time, or accessing the system and show in the computer what the cable looks like or in a catalogue. It is a language I would say. To me, going into the ELFA-catalogue it is a number instead. But they have also had logic in their numbering instead. There are those who buy from ELFA and they know the numbers as well. But the language makes it easier." (Team manager customer support)

"Yes, definitely. If I say that I need a [..] on this product, do you have it and can you send it to me? Then they know exactly what type of information I want as well." (Team manager customer documentation)

PCI was identified as a benefit that earlier more or less has been overlooked in research on CM. At least there is little research to be found related to PCI in general and PCI and benefits in particular. The contribution of this work is to identify information as a crucial part and generator of benefits in relation to a product.
The differences and similarities between the empirical result and the benefits identified within literature are summarized in Table 2 below.

Table 2. Benefits of CM in theory and practice

Benefit	
Order and control + Supporting management	Confirmed
Change management + Enabler for system evolution	Confirmed
Design according to specified requirements+ Product quality improvement + Quality assurance+ supporting product assurance	Confirmed
Time to market improvement	Not confirmed
Development cost reduction+ Supporting efficient building and testing of correct configuration	Confirmed
Sharing information within a team during the product life-cycle	Confirmed
Base for after-market design	Identified within the empirical data
Common language for design	Identified within the empirical data

As Table 2 suggests many of the benefits identified in earlier studies also are confirmed by the practitioners in our study as well. However, as was mentioned earlier in this article, previous research has not discussed the role the information related to the CM process might play. In our study it became clear that PCI can contribute with benefits earlier not recognized related to aftermarket design but also as a language that can be used during design. Hence we suggest that a model of benefits related to CM really should be a model of benefits related to CM and PCI. In Table 3 below we outline a model which distinguish between the benefits of CM (process) and PCI (information).

Table 3. Benefits of CM and PCI

Benefit	
Order and control + Supporting management	Confirmed
Change management + Enabler for system evolution	Confirmed
Design according to specified requirements+ Product quality improvement + Quality assurance+ supporting product assurance	Confirmed
Time to market improvement	Not confirmed
Development cost reduction+ Supporting efficient buildingand testing of correct configuration	Confirmed
Sharing information within a team during the product life-cycle	Confirmed
Product Configuration Information	Identified within the empirical data

Base for after-market design	Identified within the empirical data
Common language for design	Identified within the empirical data

5. Discussion and conclusions

The research reported on in this article departed from a call for identifying benefits of CM by practitioners in CM. The aim of this article was to develop a model that takes into account previous identified benefits as well as adding benefits identified in a study specifically targeted on this matter, with a certain focus on the information aspect. In Table 3 above we summarized the benefits identified both in earlier research and in state of the art practice, and distinguished between benefits related to CM in general and to PCI in particular. Hence, this model does not just contribute with a set of benefits that practitioners can use in order to strengthen CM's position in the organization and increase its impact. It also provides research with an analytical lens through which CM practice can be

analyzed through. Important to remark is that the results still should be seen as explorative in its nature. The benefits identified in earlier research must be scrutinized through the provided lens of the suggested model in order to more thoroughly position them as belonging to CM or PCI. This because the earlier identified benefits was not used when the questions for the study were developed. The model could therefore serve as a base for further studies where the benefits could be used for more explicit questions about benefits.

Further on the model could be developed to become useful to managers at different levels to describe the benefits of PCI. The model then has to be further elaborated when it comes to how those benefits are related to each other. Another area of interesting research would be to compare this result with empirical data from small and medium companies since this data set is collected from a large group of companies. Finally, we think that through this explorative model of CM and PCI it can be concluded that PCI is seen as a valuable resource at the management level.

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