LAPPEENRANTA UNIVERSITY OF TECHNOLOGY
DEPARTMENT OF ELECTRICAL ENGINEERING

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A Model for Product Transfer Project

Thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Electrical Engineering

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LAPPEENRANTA UNIVERSITY OF TECHNOLOGY Abstract of the Master's Thesis

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In this thesis a model for managing the product data in a product transfer project was created for ABB Machines. This model was then applied for the ongoing product transfer project during its planning phase.

Detailed information about the demands and challenges in product transfer projects was acquired by analyzing previous product transfer projects in participating organizations. This analysis and the ABB Gate Model were then used as a base for the creation of the model for managing the product data in a product transfer project. The created model shows the main tasks during each phase in the project, their sub-tasks and relatedness on general level. Furthermore the model emphasizes need for detailed analysis of the situation during the project planning phase.

The created model for managing the product data in a product transfer project was applied into ongoing project two main areas; manufacturing instructions and production item data.

The results showed that the greatest challenge considering the product transfer project in previously mentioned areas is the current state of the product data.

Based on the findings, process and resource proposals for both the ongoing product transfer project and the BU Machines were given. For manufacturing instructions it is necessary to create detailed process instructions in receiving organizations own language for each department so that the manufacturing instructions can be used as a training material during the training in sending organization. For production item data the English version of the bill of materials needs to be fully in English. In addition it needs to be ensured that bill of materials is updated and these changes implemented before the training in sending organization begins.

Keywords: product transfer, knowledge transfer, technology transfer, product data, product data management, off-shoring

LAPPEENRANNAN TEKNILLINEN YLIOPISTO   Diplomityön tiivistelmä

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Tässä diplomityössä kehitettiin malli tuotetiedon hallitsemiselle tuotesiirtoprojektissa ABB Sähkökoneille. Kehitettyä mallia sovellettiin sitten meneillään olevaan tuotesiirtoprojektiin sen suunnitteluvaiheessa.

Yksityiskohtaisempaa tietoa tuotesiirtoprojektien vaatimuksista ja haasteista saatiin analysoimalla jo tehtyjä tuotesiirtoprojekteja projekteihin osallistuneissa organisaatioissa. Tätä analyysiä ja ABB Gate-malleja käytettiin perustana mallin luomiseksi tuotetiedon hallinnalle tuotesiirtoprojektissa. Luotu malli esittää suoritettavat päätehtävät tuotesiirtoprojektin joka vaiheessa, päätehtävien alitehtävät sekä niiden mahdolliset yhteydet toisiinsa. Lisäksi malli painottaa tarkan analyysin tarvetta tuotetiedon tilasta jo projektin suunnitteluvaiheessa.

Projektin suunnitteluvaiheen aikana, luotua mallia tuotetiedon hallitsemiseksi tuotesiirtoprojektissa sovellettiin meneillään olevan projektin kahteen päätehtävään; valmistusohjeisiin ja tuotannon tuotetietoon.

Löydökset osoittivat, että suurin haaste tuotesiirtoprojektin suhteen edellä mainituissa päätehtävissä on tuotetiedon tämänhetkinen tila. Löydöksiin perustuen, prosessi- ja resursointiehdotukset annettiin sekä tuotesiirtoprojektille, että Sähkökoneet-liiketoimintayksikön toimintatavoille.

Ohjeiden suhteen on tärkeää luoda yksityiskohtaiset työohjeet joka osastolle vastaanottavan organisaation kielellä niin, että ohjeita voidaan käyttää koulutusmateriaalina koulutuksen aikana lähettävässä organisaatiossa. Tuotannon tuotetiedon suhteen on varmistettava että englanninkielinen osaluettelo on kokonaan englanniksi. Lisäksi on varmistuttava siitä, että osaluettelo päivitetään ja tehdyt muutokset implementoidaan ennen kuin koulutus lähettävässä organisaatiossa aloitetaan.

Avainsanat: tuotesiirto, tietämyksensiirto, teknologiansiirto, tuotetieto, tuotetiedon hallinta

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I am obligated to say thank you to all those numerous people at ABB who contributed into this thesis by giving me insight to the product transfer projects and product data management.

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Tapio Sirén

Abbreviations

BOM	**B**ill **o**f **M**aterials
BU	**B**usiness **U**nit
CPCP	**C**ollaborative **P**roduct Commerce
cPDM	**c**ollaborative **P**roduct **D**ata **M**anagement
EDM	**E**lectronic **D**ata **M**anagement **E**ngineering **D**ata **M**anagement **E**lectronic **D**ocument **M**anagement **E**ngineering **D**ocument **M**anagement
ERP	**E**nterprise **R**esource **P**lanning
PDF	**P**ortable **D**ocument **F**ormat
PDM	**P**roduct **D**ata **M**anagement
PIM	**P**roduct **I**nformation **M**anagement
PLM	**P**roduct **L**ifecycle **M**anagement
PRU	**P**roduct **R**esponsible **U**nit
PU	**P**roduction **U**nit

1 Introduction

1.1 Background

Current world market situation and growing globalization has not only created opportunities but challenges as well. Currently companies struggle with a need to increase the global presence, capacity and lower the costs, all at the same time.

One possible answer for these problems is a product transfer project where manufacturing is either expanded or transferred to another country. A goal for this kind of project is to increase capacity, lower manufacturing cost, and get closer to the customer. Initiative can also come from the customer as they may demand a local presence from the supplier.

ABB is one of the world's leading companies in automation and power technologies that operates in around 100 countries and employs more than 110,000 people. In Finland ABB has over 6500 employees and over 40 local branches, main factories located in Vaasa and Helsinki. Synchronous Machines profit center in Helsinki is a part of the Business Unit (BU) Machines and its main products are synchronous generators and motors for industrial and marine applications.

Currently BU Machines has factories all over the world, for example in Estonia, India and China. There have been product transfer projects into these countries mentioned above in BU Machines but newest project is first of its kind for the Synchronous Machines profit center.

Current project, named Phoenix after mythical firebird in Phoenician mythology, is a response to the market situation mentioned above. It has been seen necessary to produce these generators closer to the customers, increase capacity and lower production costs, in a way that the quality of the product is maintained.

1.2 Research problem

There is an understanding that the previous projects have had problems related to the product data. In order to avoid the same mistakes it has been seen necessary to analyze previous projects to create understanding what has been done, what has happened, why and how to avoid these problems.

Research problem has then been formed into a question:
Is there a general solution that could be applied for the current and upcoming product transfer projects?

1.3 Objectives of the study

The main objective of this thesis is to use theory and reference cases to create a model for product data transfer in product transfer projects. Model should give answers to questions like what to do and when to the product data during the product transfer projects.

Secondary objective is then to apply this model to the current project and the Synchronous Machines profit center. Main goal of this application is to give process and resource proposals for the Project Phoenix. In addition the current situation and the working methods in the Synchronous Machines profit center are analyzed and possible pitfalls identified. The PDM policies of the BU machines are lightly touched as well.

1.4 Scope of the study

The problems considering product transfer projects have been notified in other PRU and there has been already some research considering product transfer projects in ABB. However the focus of this study has been on a general level. In the figure 1 a fictive example of a product transfer project is shown to give a brief idea about the scope of these projects and possible tasks related to it.

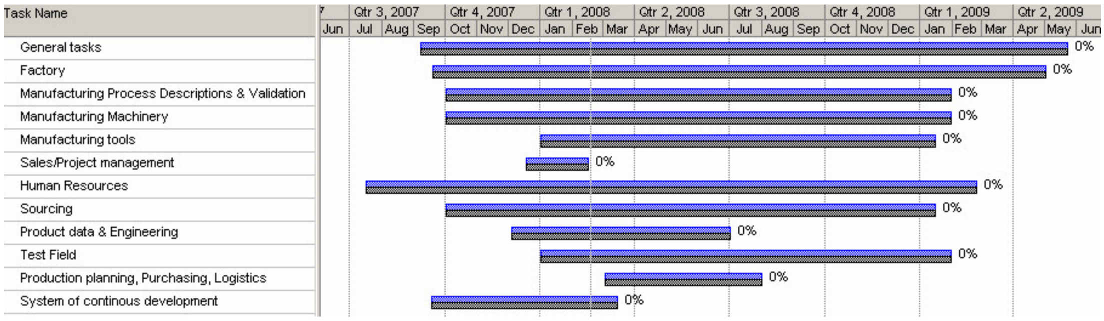

Figure 1 Fictive example of product transfer project

As product transfer projects are huge and can last for years, it was seen necessary to put emphasis on one particular area. Thus, the scope of this study has been narrowed down to the tasks related to the product data and manufacturing knowledge in a situation where only the manufacturing of the product is transferred:

1. Manufacturing Machinery, which refers to the knowledge about the machines that are used to manufacture actual product or some parts for it.
2. Manufacturing Tools, which is the knowledge about the tools that are used while manufacturing the product.
3. Training, process where the workers from the receiving organization are taught the actual ways of working.
4. Manufacturing Instructions, instructions that are used in manufacturing.
5. Item data, the data that suppliers and organizations own production use to produce the product or its parts. Embodiments of this data are, for example, bill of materials and drawings.

Application of the created model has been narrowed down even further based on the situation in the Project Phoenix and findings from the cases to the manufacturing instructions and the production item data (especially the bill of materials).

2 Theory

This chapter first introduces different forms of knowledge in organizations and explains how knowledge is transferred. Then definitions for product data and product data management and difficulties in product data management are explained.

2.1 Knowledge in organization

Knowledge in organizations can be examined and controlled with various conceptual typologies. Currently the dominating view is that there are three different types of knowledge which complete each other rather than exclude. These types are: Explicit knowledge, tacit knowledge and cultural knowledge. (JYU 2005)

2.1.1 Explicit knowledge

Explicit knowledge is formal, systematic and carefully defined. It can be processed and saved easily just as it can be communicated, shared and combined with other existing explicit knowledge. It exists in different forms, for example, equations, graphs and documents. (JYU 2005)

But explicit knowledge is just a tip of an iceberg of the knowledge that organization truly has. Main theorists in the field of knowledge creation Nonaka and Takeuchi criticizes the explicit nature of the knowledge. According to them knowledge is social and continuous change is peculiar for knowledge, thus making it dynamic by its nature. Nonaka and Takeuchi emphasize the interaction processes between individuals, groups and organizations which make it possible to create new knowledge collectively. (JYU 2005)

2.1.2 Tacit knowledge

Tacit knowledge within organization is the knowledge that its members have. It is bind to the actions, way of actions, routines, values, feelings and ideals. Tacit knowledge is something very personal, non-articulated knowledge, which is hard to put into the words and share. Tacit knowledge has both cognitive and technical elements. Cognitive elements refer to the mental models that people use to perceive, conceptualize and understand the surrounding world. Technical elements for their part are connected to professional skill and know-how. It can be said that tacit knowledge is the sum of those experiences and skills that make humans capable to act and learn new things. (JYU 2005)

Tacit knowledge has born through the experience and doing and even the person himself might have difficulties to become conscious of it. However tacit knowledge can be knowingly transformed into the explicit knowledge. Tacit knowledge is a rich vault of knowledge which makes it possible to use and analyze explicit knowledge and to learn new things. (JYU 2005)

There are also opinions that between tacit and explicit knowledge there is implicit knowledge which can be expressed whereas tacit knowledge cannot be. However most of the theorists use these two as synonyms. (JYU 2005)

2.1.3 Cultural knowledge

In organization cultural knowledge is a combination of structures, feelings and attitudes that its members use to explain, understand and measure the organization. It also includes the organizational values, beliefs and assumptions. Cultural knowledge creates common base for interpretation and thus improves the knowledge sharing and delivering. Cultural knowledge is hard to codify but it is widely spread through the interactions between members of the organization. Thus it can be said that cultural knowledge includes plenty of tacit knowledge. (JYU 2005)

2.2 Knowledge transfer

Nonaka and Takeuchi (1995) suggest that there are four basic modes for creating knowledge in terms of the distinction between explicit and tacit knowledge. The figure 2 shows these four modes.

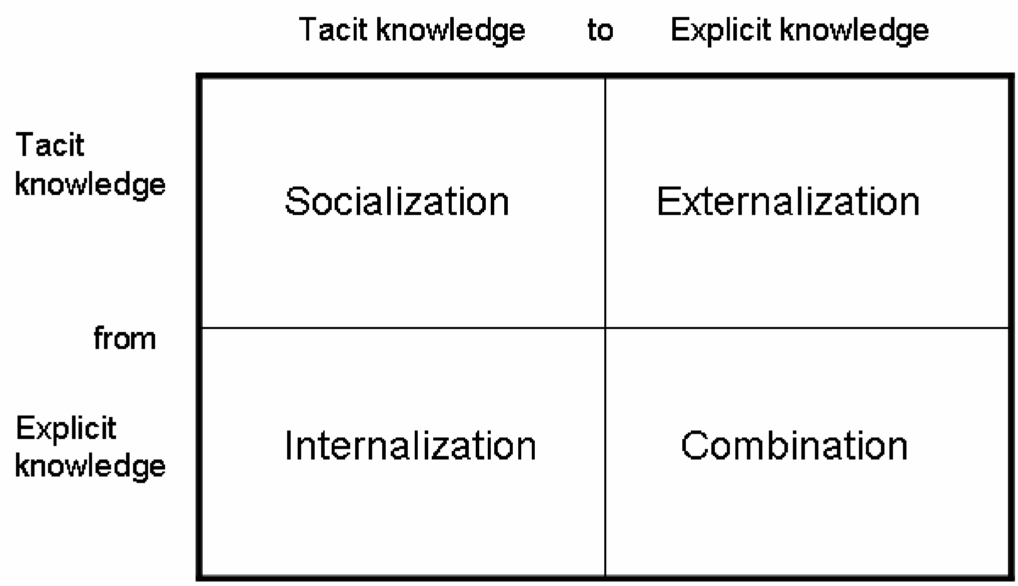

Figure 2 Four modes of knowledge conversion (Nonaka&Takeuchi 1995)

Socialization is a process where the experiences are shared. A person can acquire tacit knowledge directly from other without using language. For example apprentices learn craftsmanship not through the language but observing and imitating their master in practice. (Nonaka&Takeuchi 1995)

Externalization happens when tacit knowledge is articulated into explicit concepts, taking the shapes of analogies, hypotheses, metaphors, concepts or models. (Nonaka&Takeuchi 1995)

Combination is a process of codifying concepts into a knowledge system. Combination also involves combining different bodies of explicit knowledge. People combine and exchange knowledge through such media as meetings, documents, or computerized communication networks. (Nonaka&Takeuchi 1995)

During internalization explicit knowledge converts into tacit knowledge. This process is closely related to ”learning by doing”. Experiences are internalized into individual’s tacit knowledge in the form of technical know-how or shared mental models through socialization, externalization and combination. (Nonaka&Takeuchi 1995)

Xiaobo, Xuefeng and Wang (2006a) have further developed this model to describe how the knowledge transfer can happen between organizations. The model is shown in the figure 3.

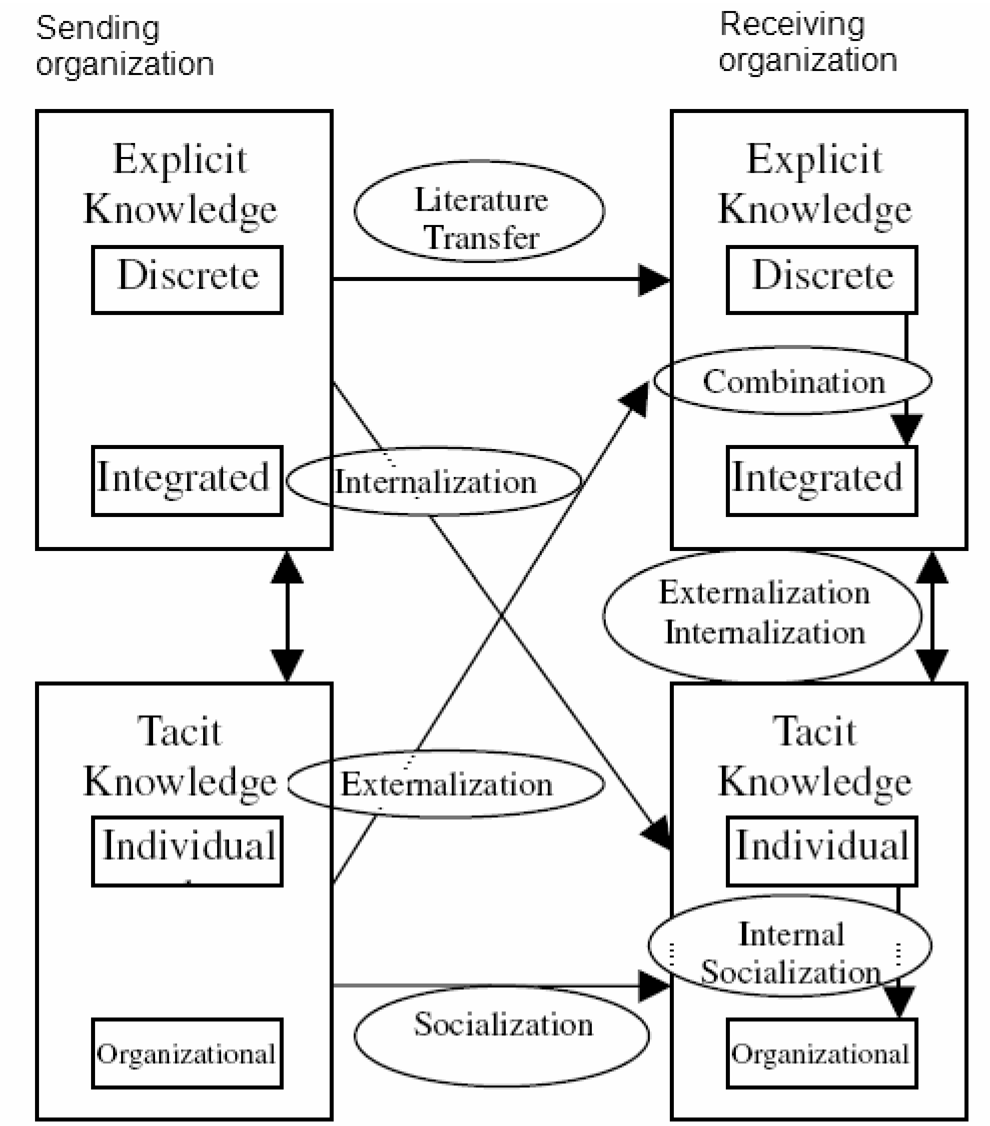

Figure 3 The processes of knowledge transfer between organizations (Xiaobo, Xuefeng&Jiong 2006a)

For example, in order to help the receiving organization to manufacture products that meet standards of the sending organization, sending organization will provide its explicit knowledge in forms of blueprints, machine, quality plan, standards for service and production (literature transfer). Receiving organization then assimilates and absorbs this knowledge, and turns it into explicit knowledge with local characteristics (combination). This knowledge is first assimilated by workers in receiving organization and then turned into experience through everyday work (internal internalization). (Xiaobo, Xuefeng&Jiong 2006a)

Externalization can be done in two ways: Workers either get trained in sending organization or sending organization sends trainers to the receiving organization. During the process the tacit knowledge is transformed into explicit knowledge.
However in the most situations, receiving only the explicit knowledge isn't enough to master the production system comprehensively. (Xiaobo, Xuefeng&Jiong 2006a)

To ensure that receiving organization learns also the production know-how the workers from the receiving organization come to practice and observe production in sending organization's factory or comprehensive field training is provided, thus the tacit knowledge of the sending organization is transferred to receiving organization (socialization). But this tacit knowledge is discreet by nature and it is stored into the brains of individual workers thus making it individual tacit knowledge. Later on during the daily production the workers in receiving organization will learn from each other, which gradually make the individual tacit knowledge transform into organizational tacit knowledge (internal socialization). In the mean time the internal knowledge of the receiving organization transforms from explicit to tacit and vice versa, which can possibly create new knowledge (internal externalization and internalization). (Xiaobo, Xuefeng&Jiong 2006a)

When knowledge is being transferred between organizations there are two main factors that affect into the performance of the knowledge transfer.

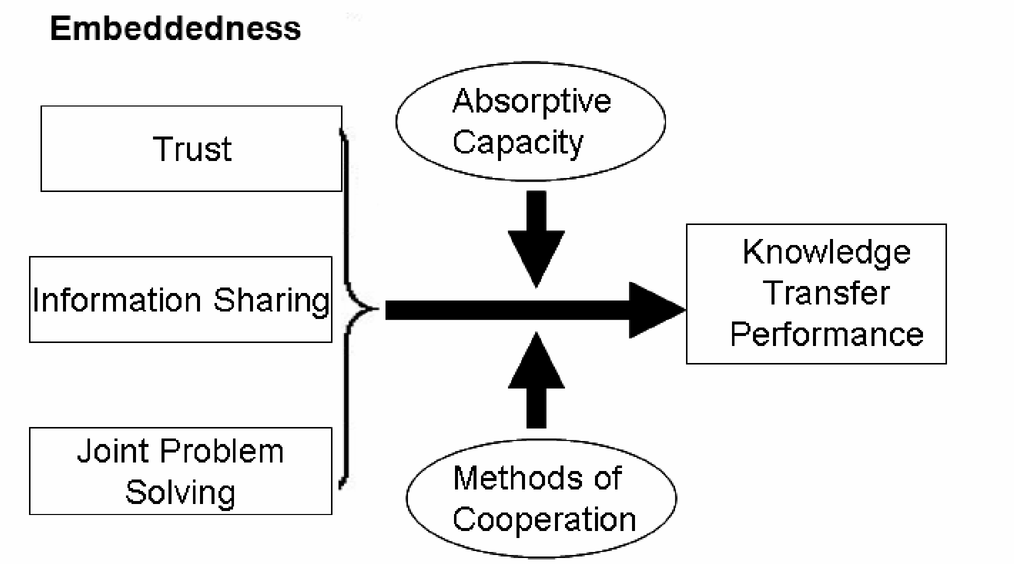

Figure 4 The affecting factors of knowledge transfer (Xiaobo, Xuefeng&Jiong 2006b)

The first one is organization embeddedness. Embeddedness describes the inter-organizational ties between organizations. It is possible to measure embeddedness by looking at such things as trust, information sharing and joint problem solving between organizations. (Xiaobo, Xuefeng&Jiong 2006b)

The second factor has two elements that are absorptive capacity and methods of co-operation. Absorptive capacity means organizations capability to recognize the value of the received information, assimilate and apply it. Different methods in co-operation between the organizations affect to the knowledge transfer as they have different features as shown in the figure 5. (Xiaobo, Xuefeng&Jiong 2006b)

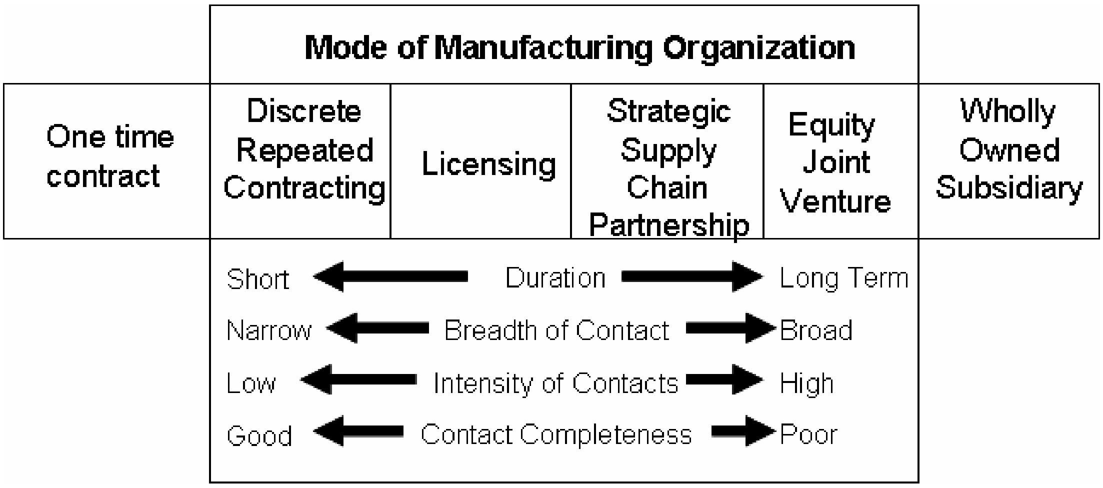

Figure 5 Mode of manufacturing organization (Xiaobo, Xuefeng&Jiong 2006b)

2.3 Product data definition

According to John Stark (2005) product data includes "*all data related both to a product and to the processes that are used to specify, develop, produce and support it*". Processes that are related to the product can be, for example product design, development, production, maintenance and disposal processes. Product data usually contains plenty of various data such as Bill of Material, analysis, tests, CAD drawings, specifications, computer programs and manufacturing instructions etc. (Jalonen 1999)

Sääksvuori and Immonen in their book (2002) say that product data can be divided roughly into three separate sections: product definition data, product lifecycle data and metadata:

Product definition data defines unambiguously product functional and physical attributes. It also describes product attributes from one point of view and connects the information into this. This section includes both technical and precise information and very abstract information related to the nature of the product. This variation in the information and possible different point of views can possibly create problems due to these different interpretations. (Sääksvuori&Immonen 2002)

John Stark (2005) describes the product life cycle as term that describes the stages that product moves through as it evolves from a simple concept through development to production and from there to operational use, obsolescence and recycling.

Product lifecycle data is always related to the product and product- or customer process phase such as research, manufacturing, maintenance and disposal. (Sääksvuori&Immonen 2002).

Metadata is generally defined as data about data and it contains information about in which form the data is, where it can be found, who has done it and when. But Tony Gill (et al. 1998) argues that this definition is too broad. Metadata should be divided into different categories based on the metadata functionality as shown in table 1.

Table 1 Different type of Metadata and Their Functions (Gill et al. 1998)

Type of metadata	**Definition**
Administrative	Metadata used in managing and administering information resources
Descriptive	Metadata used to describe or identify information resources
Preservation	Metadata related to the preservation management of information resources
Technical	Metadata related to how a system functions or metadata behave
Use	Metadata related to the level and type of use of information resources

Product data is the product knowledge in explicit form. A part of the product data is the item data. Embodiments of the item data are, for example, drawings and bill of materials (BOM) for suppliers and organization's own production. In addition sourcing needs information what are the critical selection attributes and features of the part that has to be taken into account when selecting suppliers.

2.4 Product data management (PDM) definition

PDM isn't the only term referring to the same topic. Some other commonly used terms are (Peltonen, Martio&Sulonen 2002):

PIM =	**P**roduct **I**nformation **M**anagement
EDM=	**E**lectronic **D**ata **M**anagement
	Engineering **D**ata **M**anagement
	Electronic **D**ocument **M**anagement
	Engineering **D**ocument **M**anagement
PLM=	**P**roduct **L**ifecycle **M**anagement
cPDM=	**c**ollaborative **P**roduct **D**ata **M**anagement
CPCP=	**C**ollaborative **P**roduct Commerce

As Peltonen, Martio&Sulonen (2002) say consultants and vendors have commercial pressure to make new abbreviations to increase the differentiation. These terms have the same basic idea and functionality even though they put emphasis on slightly different things. In this master thesis the only term used is PDM.

One definition of PDM is made by Uninova (2002): "*Electronic handling and control of product information throughout the whole product life cycle across system and organization boundaries by means of vaulting, workflow, and product structures*".

Previous definition identifies PDM as IT software. This happens to be a quite common view, but PDM shouldn't be seen as just a single IT software or electronic method as Sääksvuori&Immonen (2000) point out in their book. PDM is as McIntosh puts it (cited in Sääksvuori&Immonen 2000) "*a systematic way to plan, command, control and supervise all that information what is needed for product documentation during its development, design, manufacturing, testing and use, within its whole lifecycle.*"

Although product data management is mainly done by different IT systems this doesn’t have to be the case. There are many things that can be done to further develop PDM in organizations. A base for this development can be for example an agreement or operations model about standards and methods in data handling. These agreed operation methods are usually the key factor for success in data handling and creation development. (Sääksvuori&Immonen 2000)

Most of all product data management is management of the entity. How this is done depends about the organization, its goals and strategy in this area. In addition the selected view point to the problems affects to the decisions. Because of the factors mentioned above it is crucial for the organization to define its own processes from different levels and point of views before making any big decisions considering PDM. (Sääksvuori&Immonen 2000)

Development in product data management has been fast and the new IT systems have been able to solve most of the problems that have been bothering organizations. However some of these problems still exist and these are being discussed in the next chapter.

2.5 Difficulties in product data management

2.5.1 Product data diversity

Havola (2005) explains that usually when talking about product data, the term product data tends to mean only technical data. However it is usually very hard to separate technical and commercial data from each other. From an enterprise point of view product descriptions, sales- and purchase specifications and pricing principles are all product data. Product data management should not be seen as an isolated problem that can be given as a responsibility to a one single department. The crucial part of the product data management is sharing the information, integration of the business processes and the IT-systems within the organization and also between separate organizations.

The figure 6 shows different kind of data groups related to a product data. It can be seen from the figure 6 that there are numerous different data groups related to the product during its lifecycle. In product transfer project it is necessary to identify those data groups that are crucial for manufacturing, for example, production information.

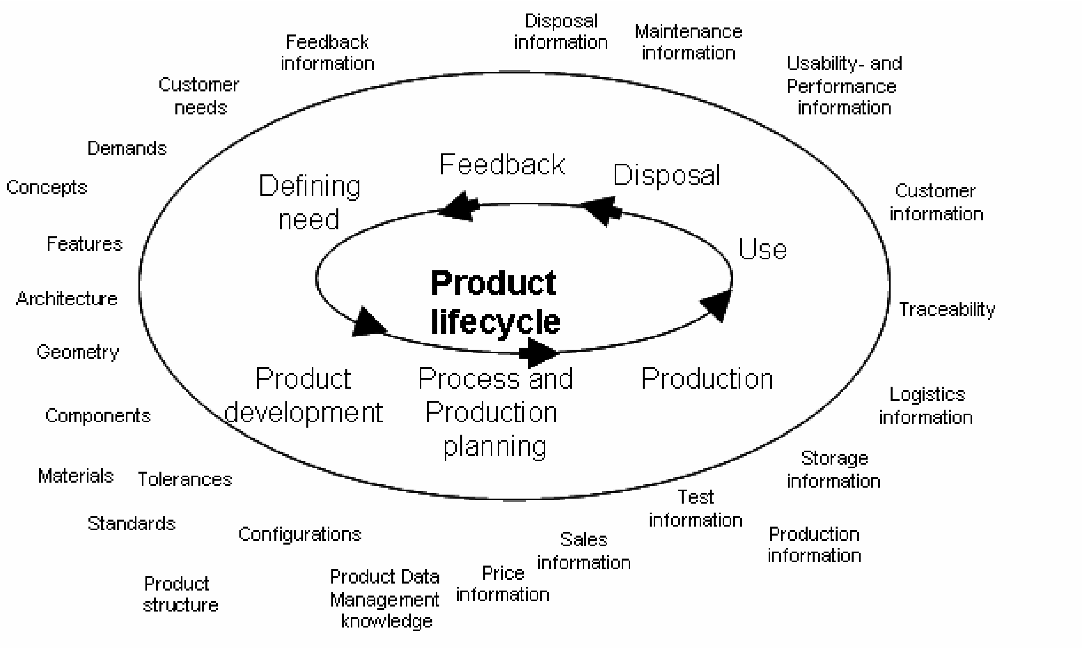

Figure 6 Product lifecycle data related to a product during the lifecycle (Havola 2005)

Product data can occur in many different forms, for example in calculations, drawings, photos, noise, movies, text or even as combination of some these. Situation is usually even more complicated as there are different embedded softwares included in the product or closely linked softwares that support organizational processes related to the product. Different forms of electrical media aren’t the only ones used in different organizations. More traditional recording tools like papers, folders, post-it notes are widely used as well. Actually when considering the product data, media can be almost anything even human memory. There are many situations where some critical information is only stored in a person’s memory. As a result the preservation of this information can be very hard or even impossible. A good example of this kind of information is handicraft. (Jalonen 1999)

The figure 7 gives a small example about the diversity of the product data.

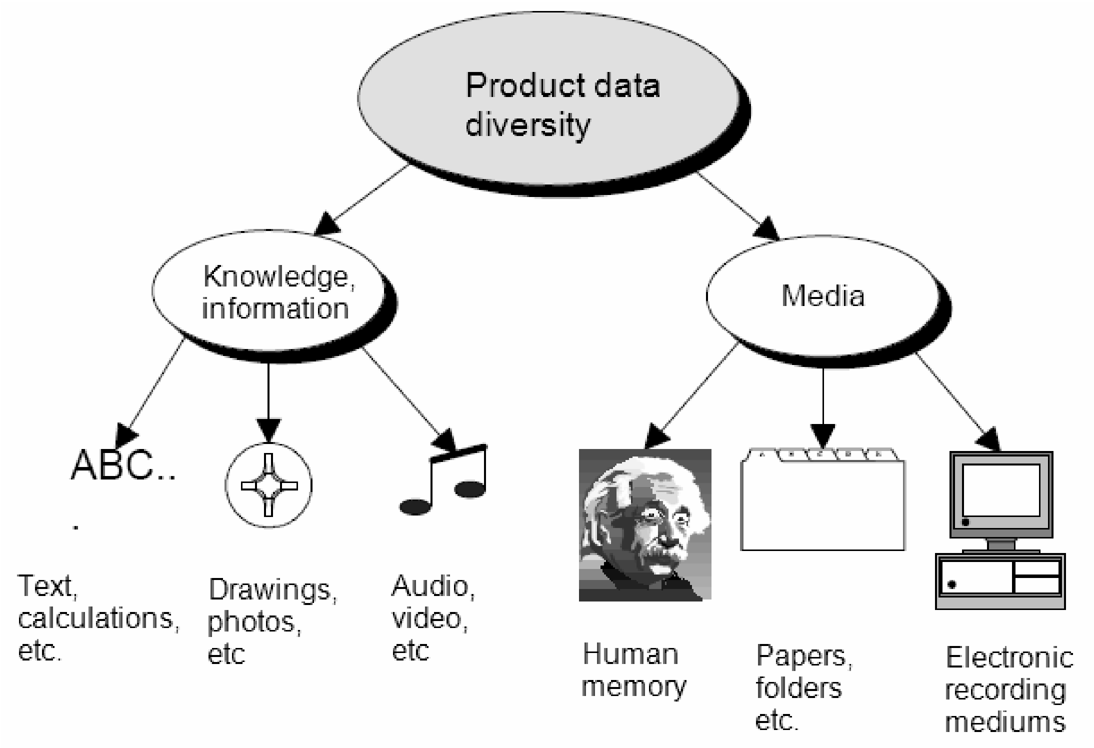

Figure 7 Product data diversity (Jalonen 1999)

The increase of electrical recording mediums is important to product data management as it makes possible to handle data in electrical form which is nearly non-existent form of existence, compared for example, to a paper. Product data can be duplicated and spread quickly with these IT-systems. Other existing remarkable qualities are free editing and storability. Product data in electrical form doesn't require much physical space so it is easy to store. However there are also negative sides as well. It can be easy to enter wrong data either on purpose or by mistake and this can spread easily all over the system. (Jalonen 1999)

2.5.2 The amount of product data

In today's world companies try answer to the growing demands in the market and increasing competition by introducing new models of the products faster and faster. This development has caused that the product density (the number of product variants that are introduced over the life-cycle of the product family) has increased as shown in the figure 8. This kind of trend causes problems in product data management as the amount of product data grows as product development creates new models. (Erens 1996)

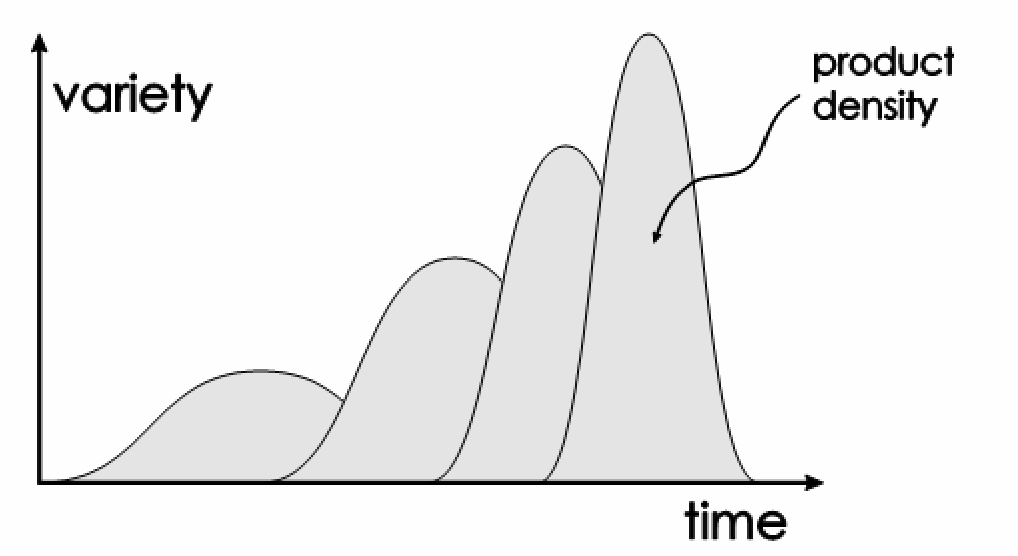

Figure 8 Increasing product density (Erens 1996)

To meet the needs of increasing product density product data needs to be organized so that no time is wasted for finding the correct information.

There are some other factors that affects to the fast growth of product data. Improvements to product functionality and performance by better product technology has made the products more complicated as more design, testing and manufacturing information has been attached to the products. Different regulations, directives, standards and laws are directed to products which usually increase the need to improve the product quality control methods. These methods can drastically increase the amount of the critical product data which management is crucial to an organization. (Jalonen 1999)

During the product and individual product lifecycle vast amounts of product data produced with various tools is accumulated to the product. With efficient tools large organization product development network can easily create thousands of megabytes of product data in a short time. These organizations usually manufacture very complex products and the amount of documents consisting product data can be humongous. For example a “simple” car can have more than 100 000 parts and each of these parts can have a few documents related to it. Or the documents that tells about the structure and functions of Boeing 747 weights more than the plane itself. In the figure 9 there is an example about how the amount of the product data grows during the product lifecycle. (Jalonen 1999)

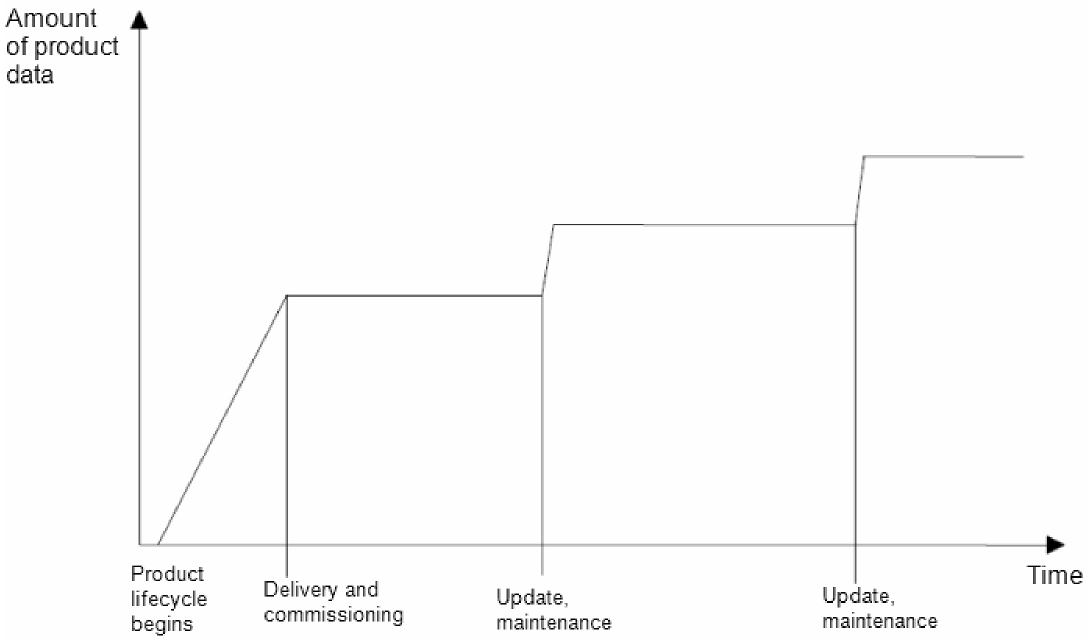

Figure 9 Example of product data growth during a product lifecycle (Jalonen 1999)

2.5.3 Product data scattering

During the last decades the manufacturing industry has invested great sums of money to develop IT-systems when they have been developing processes in the product lifecycle. Markets around CAD (computer aided design) programs, CAM (computer aided manufacturing) and other product data handling programs has grown significantly since the late 70's. Despite all the positive effects this development has caused a phenomenon called islands of automation which has turned out to be a problem for many different organizations. (Jalonen 1999)

According to Porter (1985) organization consists from a group of functions which are done to design, manufacture, market, deliver, and support the product. All these functions can be described in value chain which can be seen in the figure 10.

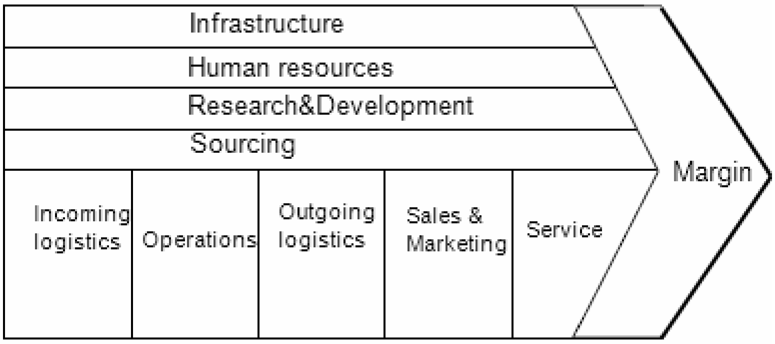

Figure 10 Value chain (Porter 1985)

The figure 11 gives a fictive example of this phenomenon from the product data point of view. In most of the cases these functions use various systems for financial, sales, personnel control and product data creation. These systems form more or less separated islands of information.

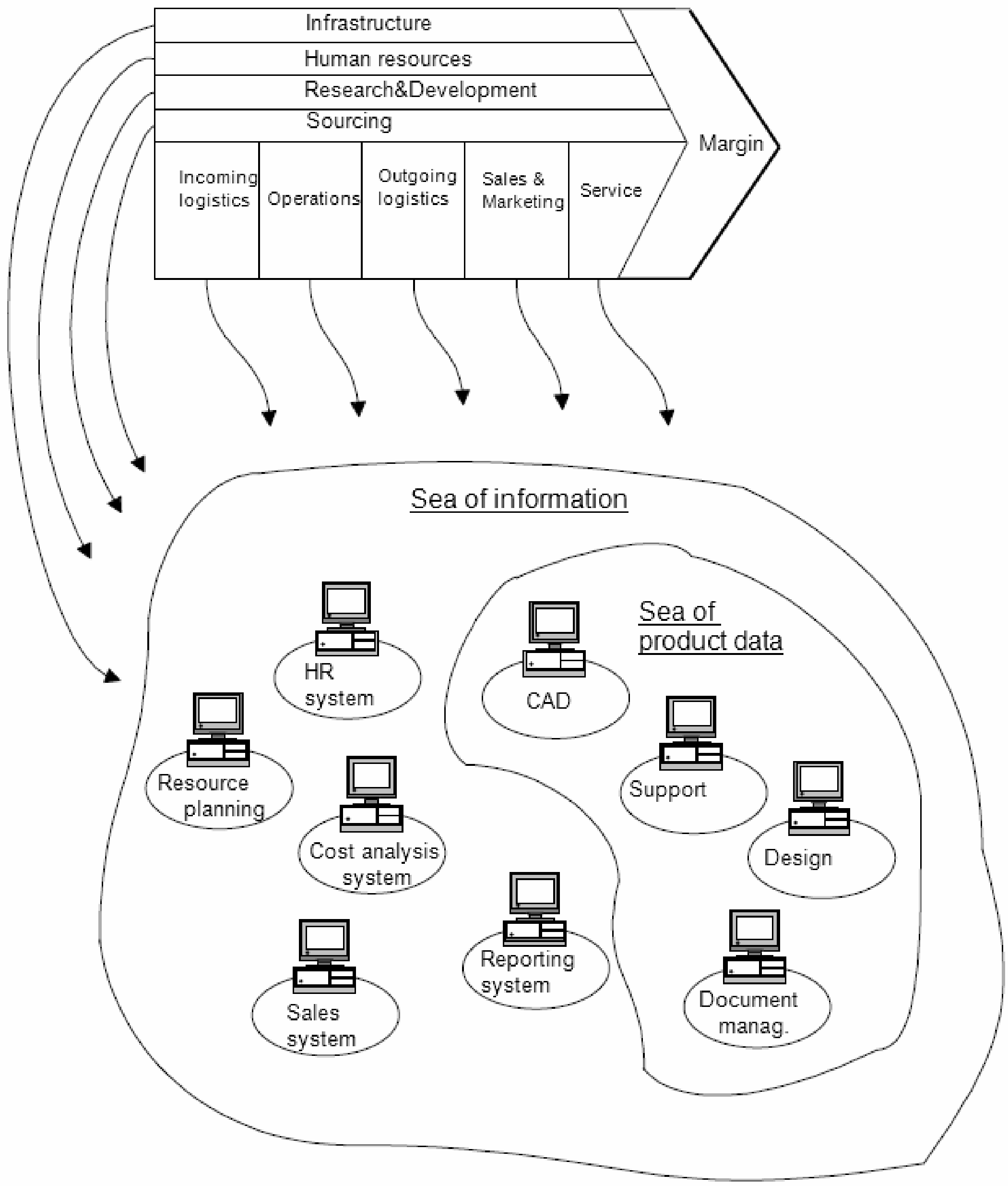

Figure 11 Islands of automation from product data management point of view (Jalonen 1999)

Mainly two problems arise in this kind of situation. First these separate systems create a great deal of information in a short time. Secondly accurate conversion of information between these systems can be sometimes hard, even impossible. As a consequence the integrity of the information decreases creating controversial and inaccurate date. In addition the redundancy of the product data increases as the same data is produced and stored in different systems. On the other hand if the systems aren't integrated the value and usability of the data could decrease. (Jalonen 1999)

Organization value chain is part a larger group of functions which is called the system of values. Organization partners and suppliers have their own value chains that will create and deliver the inputs used in organization own value chain. Inputs will sometimes go through the organization value chain to the customer. In this case extra options in the input will create extra value for the organization itself and to the customer. At the end organizations product will become a part of customer's value chain. (Porter 1985)

Based on the value chain theory product data is created and used in many organization functions. Possible other sources for product data can be partners, suppliers, delivery channels and customers. The users of the product data can be located physically in the same office or factory. On the other hand globalization and internationalization has caused that users can be located even in different continents. In the figure 12 there is a fictive model about organization decentralized operational environment with its value chains and the flow of information between different value chains. Arrows in the figure 12 describes the important directions of product data flow for organization operational capability. (Jalonen 1999)

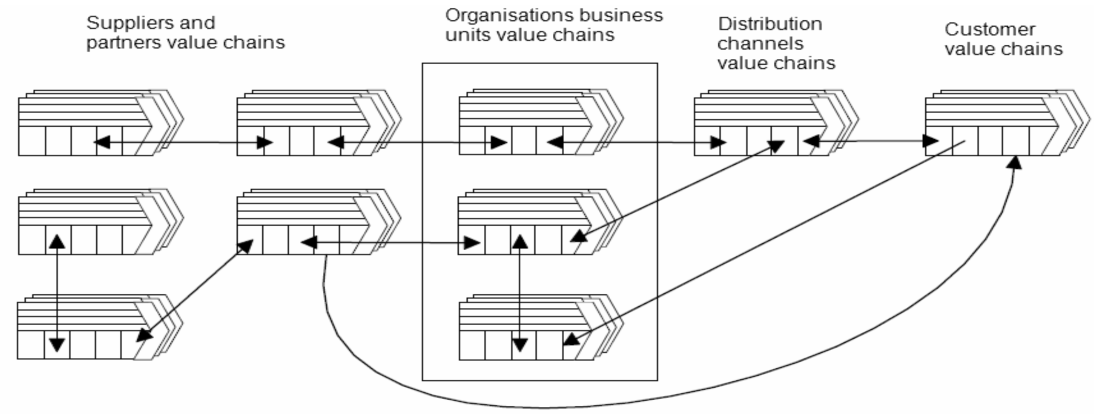

Figure 12 Organizations distributed operation environment with the value chains and the flow of the product data within the value chains (Jalonen 1999)

Product data is usually produced for different purposes but it should be usable in other situations as well. One good example of this is bill of materials (BOM) in manufacturing. Usually it has been created once in the product development but due to the separate systems that don't understand each other BOM needs to be inserted to the manufacturing system manually. (Sääksvuori&Immonen 2002)

3 A background for the model for product data transfer in product transfer projects

This chapter introduces the foundation of the created model. The ABB Gate Model gives the frame work for the model whereas the case studies will provide the content.

When analyzing the creation process of the model all the parts of the knowledge transfer could be identified. Analyzing project documentation can be seen as combination as pieces of information were gathered from project documentation in various projects. This information has been then internalized by analyzing the combined material. During the interviews the tacit knowledge considering projects has been acquired through the socialization process. Finally this knowledge has been combined and externalized into the actual model.

3.1 ABB Gate Model

In order to achieve better performance and results in conducting projects ABB has created a more standardized and focused approach for project management, which is called the ABB Gate Model. This model is based on a gate approach which purpose is to ensure that projects are driven by business objectives and are executed with full management accountability. (ABBa 2007)

Gate approach divides project into phases in order to minimize the risk. Between these phases there are defined management checkpoints, called gates, where go/no decisions are made. Using this procedure it is possible to ensure that project management is actively involved, the project work is synchronized and all necessary tasks are completed before the next step. (ABBa 2007)

Currently ABB uses three model types of the ABB Gate Model: product development, process improvement and technology development. In the figure 13 ABB Gate Model for Product Development is shown as an example. Model shows the main tasks between the gates, the most important result of each stage, and names the next stage.

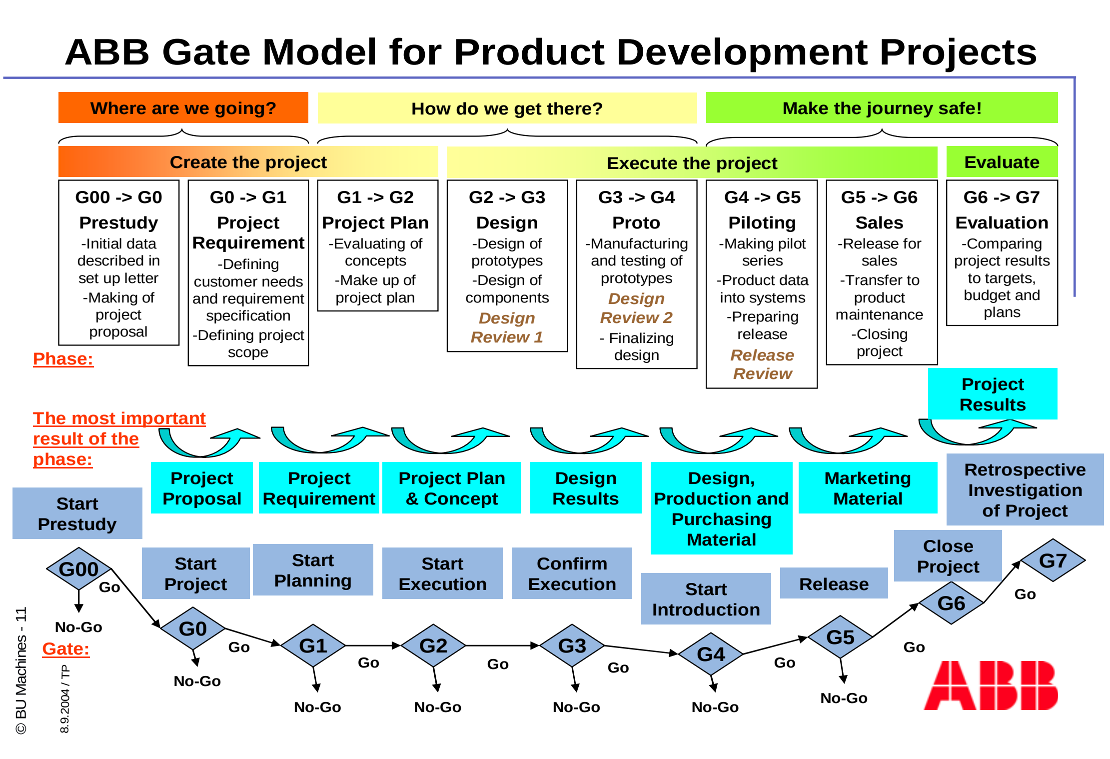

Figure 13 ABB Gate Model for Product Development Projects (Safroskin 2008)

3.2 Cases

In order to create model it was seen necessary to analyze and understand the previous product transfer projects. Knowledge about the product transfer projects exists in both explicit and tacit form. To capture both of these the research was done by going through project documentation and interviewing participants from both sending and receiving organizations.

Explicit knowledge about the projects could be found in project material in the form of documents, charts, minutes of meetings etc. However most of the projects didn't have much existing documentation, which clearly indicated that the information mainly exists in tacit form.

Tacit knowledge about the product transfer projects lies hidden in the minds of the people who participated in the projects. This knowledge has been then transferred from project to another in tacit form using the same people, for example, the same project manager. By doing this the knowledge transfer between the projects has been ensured. However, this knowledge has then stayed within these persons.

There are three different units that participate at product transfer projects: Business unit (BU), product responsible unit (PRU) and production unit (PU). BU's responsibility is global strategy and marketing in selected business are and to manage PRUs and PUs on strategical level. PRU is responsible of product design, product development, strategy and marketing of selected products. In addition PRU responsibility is to decide which product will be transferred. PU is responsible of handling the orders, managing the projects, production, sourcing and managing the order-delivery chain. (Murremäki 2008)

In total six projects from three different departments in ABB were examined. Examined projects are grouped into three categories: case A, case B and case C depending on their differences and similarities. Main difference was that each case was conducted in separate departments.

In case A projects were large as a new factory had to be built, new machines had to be bought and existing organization in the receiving end was new and small. In addition some of the designing was also transferred which increased the amount of transferred product data and knowledge.

In case B product transfers have been done into various destinations but these projects have been smaller in size as there has been existing factory, organization and machinery in the receiving end. In addition the products have been standardized, only manufacturing of the products have been transferred, and in some projects the production of the same product was transferred into two destinations.

Case C contains only one case. However it brought different perspective into the analysis as it was done in different BU and the actual product was totally different compared to the products in cases A and B. Furthermore PU in this case had even less responsibilities as it was basically just a production line located geographically in an another country. For example, all the sourcing transactions are done in PRU's ERP system.

The case analysis and Miika Murremäki's (2008) study showed that from the product data point of view the greatest challenges in product transfer projects have been preparation, resource allocation, production item data, instructions, training, and quality assurance. The root reason for difficulties lies in inefficient preparation and resource allocation. It has been assumed, for example, that the existing instructions contain enough knowledge for manufacturing and thus other critical tasks such as training have been ignored. Or it has been assumed that current BOM is accurate enough and situation hasn't been further analyzed which then caused that sourcing bought wrong parts.

4 A model for product data transfer in product transfer projects

This part of the thesis introduces the actual model. A model for product data transfer in product transfer projects is a model that gives to the project manager a more precise view what are the tasks related to the product data, what needs to be done within those tasks and in what order. Gates in the model have been situated so that they ensure that tasks are ready on acceptable level before the next main phase can begin.

The figure 14 and the appendix I shows the created model on a general level, whereas a more detailed version of the model can be found in appendix II. The detailed model shows sub-tasks for each main task in the order where they should be done. Furthermore, the model points out the possible relations of sub-tasks to other main tasks and their sub-tasks and shows which organization should have the responsibility of conducting the task.

During the phases between the Gates 00-1 prestudy and project requirements are defined. The project planning phase (G1->G2) is the phase where the actual project plan is created. Project plan should give accurate information what tasks and resources are needed in the project. There are three supportive tasks to be for making the project plan: select persons, process walk and estimation of resources. These are further discussed in Chapter *4.1 General tasks during the project planning phase (G1->G2)*. At the Gate 2 project plan is then evaluated. When the Gate 2 is successfully passed the actual execution of the product transfer project can begin.

During the execution phase all the necessary tasks are conducted so that training in PU can begin on an agreed date. There are five main tasks during this stage that are: Manufacturing machinery, Manufacturing tools, Training, Instructions, and Product data. These main tasks and their sub-tasks are studied in more detail in *Chapter 5 Main tasks during the project execution phase (G2->G4)*. At the Gate 4 the main tasks and their readiness are examined. Based on this study a decision is made whether to start the training in PU or not.

After the training the Gate 5 meeting is held to analyze the training. Trainers and other from each department give their recommendations whether the intense training should continue in that department or not. After successful passing of the Gate 5 the actual ramp-up of production is started. Trainers from those departments where the trainees have learned necessary skills can be sent back home. However, it needs to be ensured that local support is no longer needed.

The purpose of the Gate 6 is to evaluate the ramp-up and to decide the closing of the project. After successful passing of the Gate 6, PU is ready to fully operate on its own without any local support. However, the evaluation of the PU and the project still continues after the Gate 6.

Evaluation before the Gate 7 happens in forms of audits by PRU in PU and by comparing project results to targets, budgets and plans. Before the Gate 7 the core project team is brought together for the last time. During this session the results and project material is combined into a project analysis and at the Gate 7 a retrospective investigation is held.

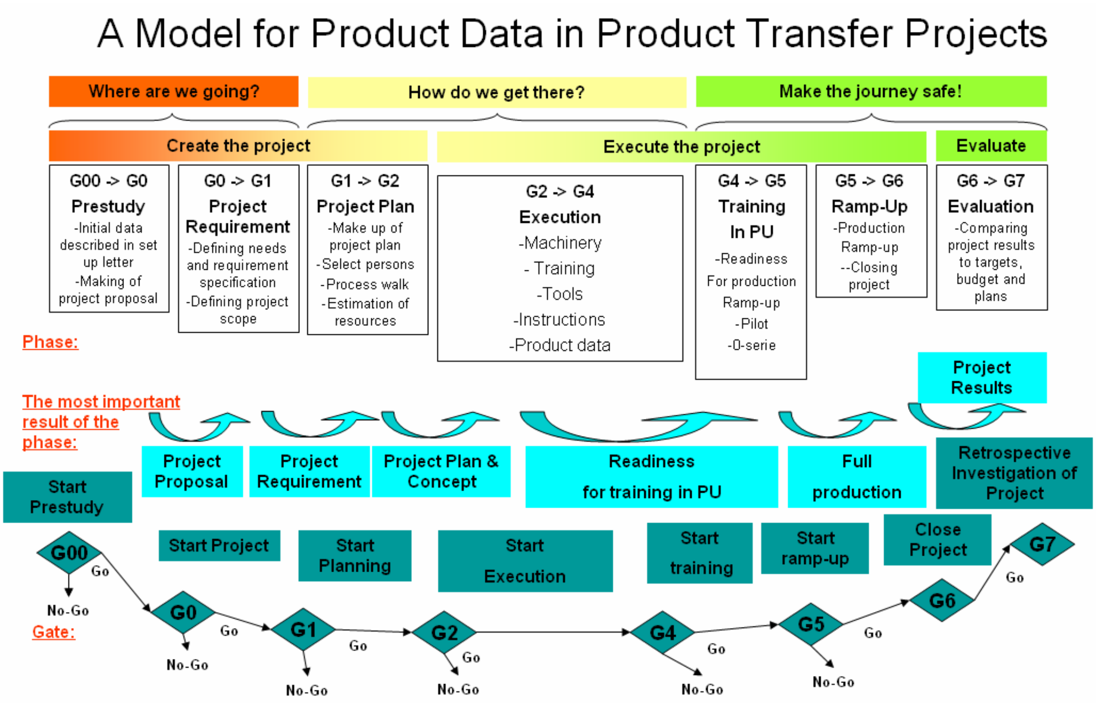

Figure 14 A model for Product Data in a Product Transfer Project

4.1 *General tasks during the project planning phase (G1->G2)*

The main output of this phase is the project plan. There are three supportive tasks to do for making it: Select person, process walk and estimation of resources. The goal of these tasks is to find and ensure that necessary persons can be used, get detailed information about the current situation, and estimate resources (persons, time, and money). Although these tasks consume more resources than having just project manager preparing the project plan it is critical to do them with great care as inaccurate information easily leads to the wrong decisions.

4.1.1 Select person

Project planning phase starts with the selection of the core project team. Miika Murremäki (2008) explains that from the project management point of view clear and defined organization model for product transfer project in both sending and receiving organization is seen crucial. This kind of organization is called the Mirror Organization. In Mirror Organization all the tasks have a responsible person in both sending and receiving organizations. In Mirror Organization there is a risk that members of the organization will start to communicate with each other without notifying project managers. This creates communication blackouts and decreases efficiency. Thus all the communication between organizations should go also through project managers. The figure 15 shows an example of the Mirror Organization. (Murremäki 2008)

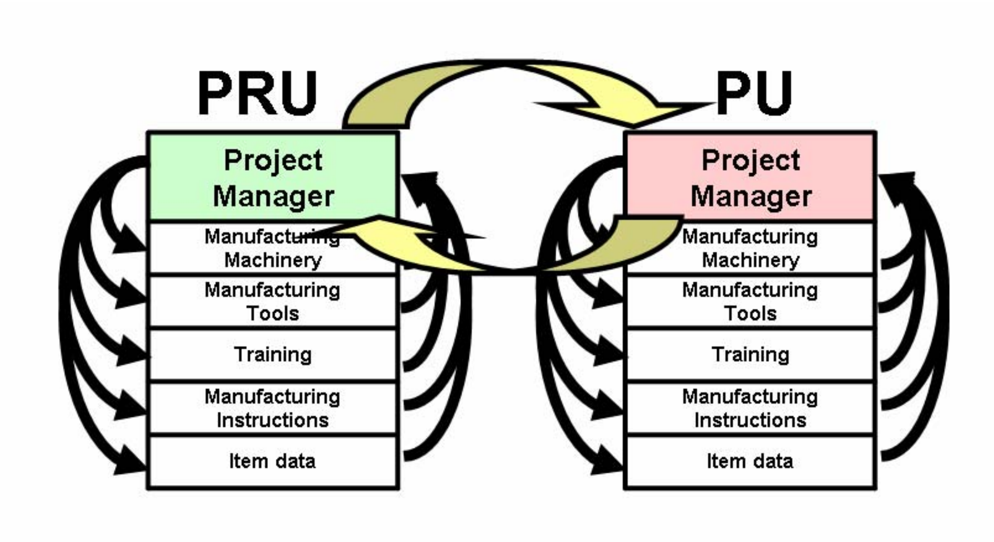

Figure 15 Example of the Mirror Organization (Murremäki 2008)

All the five main tasks in the model are usually so large that they should be seen as sub-projects and thus each task should have a person responsible of it. Thus the Mirror Organization showed in the figure 15 should be created already at the beginning of the project planning phase.

Selected persons should preferably have existing knowledge about the tasks or be in some other way capable of managing them. Furthermore these persons should have the responsibility of the same tasks through the whole project as they will gather more knowledge about the situation during the project planning phase. If it is already known that selectable persons will have enough time and that existing information is adequate they can be responsible of managing more tasks.

4.1.2 Process walk

The process walk is a crucial task that will provide the information about the current situation and possible challenges in the project execution phase. During the process walk main persons of each task goes through the manufacturing process so that they can familiarize themselves with the product and analyze the state of the product data in their task. Before the process walk begins it is beneficial to collect all the material related to the five main tasks and analyze it. Process walk can be done separately for each task, although a natural combination would be manufacturing machinery and manufacturing tools together and training, manufacturing instructions and production item data together.

In case B projects, the process walk had been conducted during the project execution stage. Process walk has been done by members from PU and project manager. During the process walk the needed machines and the special tools have been mapped (Murremäki 2008). This has given some benefits as more accurate information of the tools has been received and members have been able to familiarize themselves with the product. However, there are some disadvantages as well. As the project has been already in execution stage it has been harder to make changes to the project plan and get more resources. In addition only some people from the core project team have been involved and all the mentioned areas of product data haven’t been mapped.

Doing the process walk during the project planning phase to all main tasks with the core project team has many advantages. First, the current situation of all the tasks can be mapped and even some minor tasks (such as off the shelf tools mapping or identifying machines with long delivery time) can be done.

Second, process walk affects positively to the knowledge transfer (see the figure 3). Embeddedness is affected as the whole core team can actually work together. As members get to know each other their ability to solve problems, share information, and trust increases. In addition receiving organization's absorptive capacity grows as the members from PU will get better understanding (through socialization and internalization) about the whole manufacturing process and learn the importance of the product data and its quality.

Third, even if the project would be cancelled the process walk still provides valuable information about the current situation considering the product data and increases organizational ties.

If there is an existing factory in the receiving side, the necessity of doing the process walk over there needs to be taken into consideration. Process walk in the receiving organization will provide information about their working methods, product data management, and organizational culture, thus making it possible to identify possible differences and challenges in these areas.

However all this will require time and resources as all the members need to participate. If there is a different person selected for each task, the group is so big that preparation and managing the process walk needs more time. All this can cause difficulties in the normal business processes as key personnel are not available but once again the benefits of the process walk needs to be taken into the consideration.

4.1.3 Estimate resources

Third supporting task in project planning stage is estimation of the resources. There are many points that should be taken into consideration during the project planning stage and especially during the process walk. Answers to these points will then help to decide what needs to be done during the project execution phase, how much time it will take, what kind of personnel are needed, and what tasks can be dropped.

There are some general questions to consider: who is capable to do tasks, state of the existing information, what is the needed time for sub-tasks, and need for local support in receiving organization.

In addition to the general questions there are many task specific points to consider. These have been collected into the table 2, where they have been categorized by the tasks and sub-tasks. However, it needs to be remembered that these given points are only indicative. Most of the product transfer projects have unique qualities that need to be taken account case by case.

Table 2 Points to consider while estimating the resources

Manufacturing machinery - Delivery time - Possible sub-projects - Making specifications - Instructions for use & maintenance - Testing - Using old suppliers - Using new suppliers - Same machines used	**Manufacturing tools** **Off the shelf tools** - Needed time for gathering information - Possible quality requirements - Need for same suppliers	**Manufacturing tools** **Special tools** - Tools with long delivery time - Need for redesign - Existing manuals - Existing information - Drawings
Training - Amount of trainees - Amount of trainers - Training time in PU/PRU - Need for interpreters - Impact to the production - Training of trainers - Training plan - Training coordination - Current training methods - What takes time to learn - How many work phases	**Instructions** **Make/Update** - Existing instructions in PU - How many new instructions - How many updates - Inspectors - Quality plan - Need for photos - 1 day for 1 new page	**Instructions** **Translation** - Current language - Receiving language - Need for other language, such as English - How many pages - Who checks - Outsource or in source - Time vs. persons
Item Data **Sourcing & Suppliers** - Use of old suppliers - New suppliers - Accuracy of data - Need to check data - Possible translations - Instructions - Training of suppliers	**Item Data** **Production** - Current accuracy - Wanted accuracy - Need for further analysis - Needed changes - Changes to structure	**Product Data Management** - Existing data formats - Existing integration - Design the interface - Test - Possible changes to PDM or ERP system

5 Main tasks during the project execution phase

Some general sub-tasks related to all the tasks were discussed in the previous chapter. In this chapter the five main tasks and their sub-tasks during the project execution phase are introduced and discussed in further detail.

5.1 Manufacturing Machinery

Manufacturing machinery refers to the machines that are used to manufacture actual product or some parts for it. A machine can be, for example, a taping machine in coil manufacturing.

Machines can have a very long delivery time which needs to be taken account in the early stage of the project planning phase. Thus the process walk should be held as early as possible to identify these machines.

The timeframe in execution phase has to be long enough so that machines can be bought and delivered. This affects to the start of the training in the receiving organization as the manufacturing is dependent of the machines. Other option that has been used in case A is to create sub-projects for machines with long delivery time. These machines are then documented and bought during the project planning phase. Risk in this method is that the project might be still cancelled and then cancellation fees have to be paid. On the other hand training at receiving organization can start much earlier. (Suontausta 2007)

5.1.1 Documentation of the machines

Documentation of machines goal is to provide accurate information and support so that machines that have all the necessary attributes and functions to produce the products can be bought.

Basically this can be seen as the specification of the machines. However, even though the technical specification is the most important part in the machine documentation there are other issues to check that can be easily forgotten. Identifying these issues will help in the selection of the correct machine and minimize possible need for changes later on. Issues are listed below (ABBb 2007):

1. The demands of environment
2. Tools used with the machine
3. Process description
4. Photos about the machine
5. Issues considering maintenance
6. Items to be checked for suitable machinery
7. References within the company
8. Other known references
9. Accessories required / good to have
10. Options / extensions that could be needed in the future
11. Safety issues
12. Unusual issues

Although the machine documentation creates a good base for buying the machines there usually many questions considering designing and other aspects that will rise later on. The usual communication difficulties such as time difference increase the response time to these problems.

According to Teemu Antola (2007) in one project in case A this was solved so that the main person selected for the manufacturing machinery task spent five months in receiving organization as an expatriate to provide local support. Using expatriate greatly lowers the problem solving time as the questions can be answered instantly. In addition expatriate knows the sending organization and knows from whom to ask if such a need rises. The disadvantage of this method is that expatriate is no longer available in sending organization and it is fairly expensive to send one.

5.1.2 Buying the machines

When the machine documentation has been prepared it is time to select the suppliers and buy the machines. One option is to buy similar machines as in the sending organization but this has to be considered case by case. This isn’t always possible as some of the machines might not be manufactured anymore or it can be otherwise more practical to buy different machines. For example if just one type of product is going to be manufactured there can be more optimal machines to perform necessary functions. (Antola 2007)

On the other hand there can be a good reason buy totally identical machines. For example the ones that are used for testing the products. Thus it can be guaranteed that all the test results are similar and comparable in every factory. (Antola 2007)

Important decision is whether to buy machines from the old suppliers or locally from the new ones. There are four factors that should be taken into consideration in this situation.

First is the needed time for selecting the machines. It requires a lot of time to map and compare various machines. When there is no time the way to go is to use old and trustworthy suppliers even though they might be expensive or located geographically far away from the receiving factory. (Antola 2007)

Second one is the quality. There are usually machines which quality has to be high or guaranteed. In this case it might be better to use the old suppliers. (Antola 2007)

Third is the availability of the spare parts. The most crucial spare parts should be bought right away and stored. In addition it is important to know the closest location from where the spare parts can be obtained and how much time it will take. (Leinonen 2007)

Finally, using new suppliers creates more risks. They should be monitored closely in order to avoid any surprises such as delays in delivery. Even one machine being late can create huge delays to the project. When the machines arrive they should be tested before they are taken into the actual use. (Antola 2007)

5.1.3 Testing and creating instructions

Testing of the machines is done to confirm that they work and will work as wanted. According to Markku Leinonen (2007) it should be done before the training starts in the receiving organization to eliminate possible surprises. Testing requires the presence of the experts from the sending organization since they have the necessary knowledge to see whether the machines work correctly or not. If the machinery differs a lot from the sending organization's machinery it needs to be taken account when designing the training plan as work is then done with different machines during training sessions in PRU and PU. Good idea would be to involve the trainers in testing so that they can familiarize themselves with the new machines.

Jarkko Saramo (2007) adds that in a case where the machinery differs, the sending organization can only provide instructions for those machines that they have in use and that are also used in the receiving organization. Instructions for different machines can be done during the testing or the training in the receiving organization. Making of the instructions is discussed in detail in *Chapter 5.4.2 Creating of new instructions and updating the existing ones*.

5.2 Manufacturing Tools

Tools task can be divided into two separate tasks: off-the-shelf-tools and special tools. This is done because different tools have different requirements that need to be taken into account.

5.2.1 Off the shelf tools

Off the shelf tools means all the normal tools used in the manufacturing that can be usually bought from any hardware store. This task might seem to be a minor task and so it can be easily ignored or forgotten, especially in situations where there is an existing organization in the receiving end. However, as Markku Leinonen (2007) explains, missing tools can cause (and has caused) delays during the training and the ramp-up.

Robert Kahar (2007) points out that even without product transfer projects the situation of the tools should be well documented at all times. Usually a lot of time is spent on finding this information when a tool needs to be replaced. The documentation of tools should have at least the following information (Kahar 2007):

1. Possible drawings and photos
2. Application
3. Contacts
4. Description
5. From where it was bought
6. When it was bought
7. How much did it cost

To emphasize the need for this kind of documentation it is necessary to point out that in all the analyzed project transfer projects there wasn’t existing information about the off the shelf tools in sending organization.

If there is an existing organization in the receiving end it should have similar information about its own tools. Then it would be possible to compare those lists and identify possible missing tools.

If there is not existing information about the off the shelf tools, the situation needs to be mapped. This can be done, for example, during the process walk. In addition, possible improvements to the tools can be made if more time can be spent on evaluating possible new options. (Hautamäki 2007)

During the mapping it is important to find out if there are any limits considering the tools. For example, is it required to get a tool from one particular supplier? For these kinds of tools it is necessary to find that supplier, although it can be time consuming especially if there is not information available. (Hautamäki 2007)

Next step is to estimate the actual amount of each tool that is needed in the receiving organization. This might vary a lot depending on the size of production line. Furthermore, it is necessary to consider whether one tool is enough for the whole department or does every worker need their own tool. (Hautamäki 2007)

5.2.2 Special tools

Special tools refer to the tools that have been specially designed and made for some specific purpose in manufacturing. These tools cannot be bought from hardware stores. As for the off the shelf tools it would be also better to have a complete documentation about special tools. If the receiving organization has similar tools already in use, they need to be checked for their usability.

In a case where there isn't existing information available or it is clearly insufficient, special tools can be listed during the process walk. This list needs be further analyzed to identify the tools with long delivery time and tools that need to be redesigned to make them easier to use and make. (Heino 2007)

According to Harri Heino (2007) next steps are to do the actual redesign and create necessary instructions for use and maintenance. At the beginning of the re-design it is really important to think about the supply side as well. Delivery time, quality, spare parts and suppliers, factors that have been mentioned earlier in *Chapter 5.1 Manufacturing Machinery* apply here as well. Especially in situations when the tools aren’t made close to the receiving organization it is necessary consider whether the spare tools should be bought at the same time. Heino (2007) continues that in case A where all the special tools had to be bought, most of them were bought from the old suppliers as they were the only ones with necessary skill to make them.

Testing of these tools should be conducted either in sending or receiving organization depending on the location of the suppliers, possibility to test the tool independently and availability of the experts who are capable to do the actual testing. All this should be done in good time so that tools can be delivered to the receiving organization before the training begins. As in manufacturing machinery, instructions needs to be checked tool by tool, whether the existing instructions can be used and how the possible differences affect to the training.

5.3 Training

Training is the process where the workers from the receiving organization are taught the actual ways of working. It plays a critical role in product transfer projects as it is the only task that is capable to transfer the still existing tacit knowledge. Training activates two modes of the knowledge conversion: socialization and internalization. During socialization trainees will watch and imitate the trainer and so learn the correct ways of working. Due imitation the effect of language barrier to the learning is lower. Internalization happens in two ways: First, workers will learn the working phases by reading the instructions. Second, this acquired knowledge is further increased as the trainees learn by doing under the supervision of the trainers.

Training should happen in both sending and receiving organization. The biggest advantage of the training in sending organization is that it is not dependent of the manufacturing machinery and manufacturing tools tasks. In addition makes it possible for trainees to learn the organizational culture and get a first hand feel about the full production. Due to the full production in sending organization all the trainees can be trained simultaneously and there is more adaptability to possible problems situations.

Training in receiving organization is equally important as then workers will not only learn more but also learn to work in their own environment with guidance of the trainers. Furthermore, the presence of trainers ensures the quality and thus lowers quality and other costs later on.

This training should start straight after the training finishes in sending organization. The longer this gap between trainings gets the more important it is to have local support from sending organization. During the ramp-up many questions and problems will arise and without local support precious time can be lost while waiting for the answers from the sending organization, especially situations when there is a big time difference. (Miika Murremäki 2008)

According to Miika Murremäki (2008) there are three main factors that affect on the success of training: instructions, trainers and trainees. Arla-Netta Paasikoski (2007) adds that in addition to these factors, a training plan and coordination of the training have impact to a successful training. These factors are being discussed in this chapter whereas instructions are further discussed in *Chapter 5.4 Manufacturing Instructions*.

5.3.1 Trainers

Trainers are the persons who will do the actual training and are responsible that trainees will learn all the needed tasks. They should be carefully selected based on three factors: experience and motivation, ability to train and willingness to travel. (Paasikoski 2007)

Experience means that trainers should have enough knowledge about their field of specialization so that they know what they are doing and they do it right. Preferably they should also have training experience and be highly motivated. Some extra salary or benefits can possibly increase the motivation. Motivation also includes some risks as some trainees might be unwilling to train as they might think that they are training others to do their work. (Paasikoski 2007)

Trainers need to have ability to train others. Trainer’s character affects how well the trainer will get along with trainees. Language skills affect the communication between trainer and trainees, especially if there is no common mother tongue. In addition trainer needs to have authority to keep things in control so that all the instructions are followed and things are done correctly. (Paasikoski 2007)

They must be willing to travel. Quite often the case is that some of the good trainers are agreeable to train only in their own workplace or country. It is important to use same trainers in both ends because during the training in sending organization trainers and trainees will familiarize themselves with each other and thus training will be easier in receiving organization. (Paasikoski 2007)

5.3.2 Trainees

Trainees are the workers from the receiving organization who will be responsible of the production during the ramp-up and later on. In some cases they might be also responsible of training other workers in the receiving organization.

Selection of the trainees needs to be done with great care, especially when trainees are going to train other workers later on. Selected persons have to be fast learners, responsive and capable to give feedback. They should be the actual workers in the manufacturing (Murremäki 2008). Although it would good idea to include some people from the management as well, especially if they can work as interpreters during the training. In this case they can also learn the organizational culture, and see what the workers should and shouldn’t do.

Arla-Netta Paasikoski (2007) and Kari Koskelainen (2007) agree that the optimal situation would be that the trainees have previous experience about the similar products, although sometimes this is not possible. No matter what the situation is, it is very important for receiving organization to provide the background information about the trainees to the sending organization so that this can be taken into account while designing the training plan.

Motivation has a huge impact on trainees. There might be many factors that affect on trainees attitudes that managers aren’t aware off. For example, in one of the cases receiving factory workers have a low base salary. Normally they work under contract salary and get paid more. However when they are in training they only get paid by the base salary. This greatly affects to their motivation and creates problems in training as they try to other work whenever they can. (Koskelainen 2007)

5.3.3 Training plan

The main purpose of the training plan is to ensure that all the necessary tasks are taught and enough time is reserved for the training. Design of the training program should be done so that the whole manufacturing process is analyzed together with trainers and management. First thing in this is to decide the goals of the training as there might be differences in this even between departments.

Usually trainer's job isn't only to teach how to make the product but also to teach the organization culture. This might require actual training of the trainers as it has to be ensured that the trainers will teach correct behavior, especially in safety and quality issues. (Leinonen 2007)

It is also important to include a theory section to the training program. It provides understanding about the functions, applications and physical phenomena related to the product. Miika Murremäki (2008) adds that this can help to understand the importance of quality, learning new work phases and solving possible problems. However timing of theory part shouldn't be at the beginning of the training as it is easier to comprehend the theory when trainees have some practical experience about the actual product.

Next step is to estimate the needed time for the training. This estimation depends on the experience of the trainees, language skills, and cultural differences. One good way to estimate this time is to simply ask from the workers how long did it take to learn the work and then take into account the factors mentioned above. Furthermore, there should be a time buffer or a back-up plan in case that something doesn't turn out as planned during the training. (Koskelainen 2007) (Leinonen 2007) (Paasikoski 2007)

One method to ensure the correct training is to make a list about the work phases taught in the training. After one work phase is taught and learned correctly both trainee and trainer sign this phase and move to a next one. This is a good way to keep track about taught things and also it can be proved that training has happened in case of an error. (Koskelainen 2007)

5.3.4 Coordination of the training

Whereas training plan concentrates on the content of the actual training the coordination of the training secures that all the supportive actions for the training are done.

The coordination of the training should be started in a good time before the training begins. It is crucial for the success of the training in the sending organization that the manufacturing managers support and collaborate during the training. With managers, it needs to be agreed what products are used for training, how this will affect to the production and to the production plan and what can be done if something changes or goes wrong. As important part is to secure that all the needed materials, parts and tools used in manufacturing are available. Lots of the training time is wasted if missing parts or tools needs to be searched. (Paasikoski 2007)

Although, things such as booking the hotels, arranging transportation etc. can be easily regarded as insignificant they have a great impact on the attitudes of trainers and trainees. (Koskelainen 2007)

The timing of trainers' arrival to the sending organization needs to be thought as well. Usually all of the production phases cannot be started simultaneously during the training. It is better to send trainers for first production phase first and little by little rest of the group. (Leinonen 2007)

5.4 Manufacturing Instructions

Instructions are the manufacturing knowledge in explicit form. Main purpose of the instructions is to support the training and provide help for the workers later on if some work phase needs to be re-checked. In addition working instructions serve as a base for quality audits as they can be used as checklists. Together with training, instructions will create a good foundation for workers to learn and do their work. However, either of these should not be used alone as a starting point for production ramp-up. Suontausta (2007) points out that in one project in Case A the production was started using the manuals only. This affected greatly to the quality and the whole ramp-up process had to be re-started from the training in sending organization.

Instructions-task is divided into four sub-tasks: Pre-work, which is actually done in project preparation stage (List instructions & Check Content tasks), creating new instructions and updating the old ones, and translation & check. Paasikoski (2007) points out that the important factor to be noticed is that unlike most of the other tasks instructions should be fully ready before the training begins in the sending organization. This is mainly because the instructions support the training and the trainees need to learn to use their own instructions. Training is also the final check for the quality of the content and translation of the instructions. If mistakes are found there is still some time to repair these before or during the training in receiving organization.

5.4.1 Pre-work

Tasks during the pre-work give more accurate information about the situation considering the instructions. Main goal is to find the "*black holes*" in the existing instruction set (for example, that there is not detailed instruction for final assembly).

First, the existing instructions should be mapped. A good starting point for this is the existing quality plan as it can give a brief overview about the situation fairly quickly. List can be then completed through discussions with various experts. (Suontausta 2007)

When the list of the instruction is ready, the content of the instructions has to be checked that they have acceptable amount of information (photos, latest information etc). Final check for the instructions is the process walk during which the gathered information is compared to the reality of the situation. All this should be done with care to avoid situations where missing instructions are notified during the training or even later. (Saramo 2007)

It is also important to identify the crucial instructions (such as inspections instructions) and supportive instructions. If time and resources are low, crucial instructions should then have a priority. In addition it is wise to separate all inspection related material (tolerances etc.) from the actual working instructions preferably into one single inspection sheet. This makes it easier to monitor the quality and update the changes in inspection attributes. (Saramo 2007)

There are also some PDM related issues that should be taken into consideration during this stage. One challenge is to decide what kind of information receiving organization needs in overall. General instructions should be avoided when possible as they may contain extra information that can create confusion in the receiving end. Other matter to consider is that especially in low cost countries there is always a risk of data seepage. (Suontausta 2007)

On the other hand if the delivered instructions differ a lot from the instructions that are used in sending organization the maintenance of the instructions is more complicated as there are two different sets of instructions. The whole maintenance, delivery and use of the instructions should be agreed at least on a general level so that both organizations have clear understanding about the process and have an understanding how to manage it.

5.4.2 Creating new instructions and updating the existing ones

This task's purpose is to complete the instruction set so that it has all the needed and agreed information. This can be done either creating totally new instructions or updating the old ones.

There are several important factors that should be taken into consideration when making or updating the instructions: scope, target group, language and vocabulary, clarity and photos, and examples.

The scope of the instruction has to be thought carefully. In the optimal situation all the information can be in one single instruction but quite often this is not the case. There might be some areas that can be applied for other products. If the same text is in many instructions the management of updates will be difficult. Thus it is better to create smaller general instruction and then refer to it in larger instructions.

When writing or updating instructions it is good to know who is going to use the instruction and what it is for. For example, designer and worker needs different kind of information, so if the instruction is made for workers the instruction should be examined from their point of view and have the information that will support their work. Quite often engineers are the ones who make the instructions and then the output tends to be from engineer to engineer when it should be from worker to worker. Language and vocabulary are also related to this. The language used in instructions should be clear and easy to understand and the vocabulary should match the vocabulary used by the target group.

Clarity simply means that the instruction is easy to understand. Markku Alanen (2007) explains that the optimal situation is that there is one work phase described in one page with supporting photos. Alanen (2007) and Koskelainen (2007) agree that photos are important as they lower the language barrier even further. The old saying "*a picture tells more than a thousand words*" truly makes a point in this situation. Due to this, it is crucial that photos will have the correct information. Leinonen (2007) adds that if it reads in the instruction that during this work phase safety gloves must be worn, they should be worn in the photo as well. Also the photo shouldn't include any text. All the text should be outside the photo so that during the translation there is no need to edit the photos as well. Alanen (2007) emphasizes that the design of the layout affects to the clarity. The layout it needs to be designed so that same information can be attached into the same place in translations as well. This makes it easier to track possible errors in them.

Alanen (2007) continues that instructions should as detailed as possible so that even the tiniest point can be checked from the instructions. Stanislav Sillaste (2007) gives a great example of detailed instructions that comes from case C. There one manager (without any technical background) from the receiving organization managed to do the final assembly of the product by using only the manual.

Examples about the correct and wrong methods should be given through explanations and photos. Emphasis should be on the correct methods but if there is existing information about used wrong methods and faults that they have caused they should be used. By showing the both reason and the cause will help the workers to understand why things are done in a certain way.

5.4.2.1 Methods for creation and update

According to Alanen (2007) the optimal way to make the instructions is to follow the manufacturing process and take notes and photos at the same time so that workers can clarify unclear points right away. This slows down the production somewhat but on the other hand instructions can be done quickly with the correct information. After creating the first draft instructions should be checked together with all the groups of interest (workers, management, trainers and design) so that final corrections can be made and everyone is aware about the changes made and correct methods. By activating all the groups of interest at the same time a lot of time can be saved as possible disagreements can be solved simultaneously.

Pasi Oikkonen (2007) explains that in the product transfers projects in case B students have been used to make the new instructions as they are cheaper and they can concentrate on task full-time. However, expert’s contribution is still needed as they need to check the created instructions. For those instructions that need to be updated it is good to use persons that have been responsible of the instruction in question before. They are already familiar with the instruction and might actually have a knowledge how the instruction should be updated.

Eero Tihilä (2007) introduces a totally different approach to the creation of instructions. In case C, there were two motivated full-time experts creating the instructions using advanced layout software. This method has increased the cost but on the other hand the quality and similarity of the instructions has been ensured.

Software that is used for creating the instruction play important role as well. Usually the normal text editors can be used, but if there are many instructions and the goal is to create high quality manuals it is necessary to consider more advanced software. (Alanen 2007)

Advantages and disadvantages of these softwares are shown in table 3.

Table 3 Advantages and disadvantages of different software

	Advantages	Disadvantages
Normal text editor (MS Word, Word Pad, Lotus Word Pro, Word Perfect etc.)	- People know how to use - Easy to edit later on - Usually available	-High resolution photos create problems -Hard to create good layout -Large manuals hard to edit
Advanced layout software (InDesign, PageMaker etc.)	- Easy to create layout -Possible to use high resolution photos - Easy to create links and structures - Possibility to compile all the manuals into one manual/file - Can handle large files	- Takes time to learn -Large file size lowers transferability -It takes time to download manual from database -Needs a license -Same software needed for editing

5.4.3 Translation and check

When all the instructions have been created and updated it is time to translate them if needed. Need for the translation depends on the used language in sending and receiving organization. In addition there might be rules or standards that require instructions to be, for example, also in English. Or due translation incapability in either end there is a need to translate the instructions to a more common language first.

Translation can be done in-house by the experts. Using experts isn’t often an option as they have many more important tasks to do or they don’t have the necessary skills. Due to this it is better to use either students or outsource the whole task to a company that is specialized for the translations. Paasikoski (2007) explains that in both cases translation has to be checked for mistakes as the instructions usually contain special terminology that is often mistranslated. This check needs to be done by the experts. Kahar (2007) adds that if there are a lot of instructions that needs to be translated, this task can prove to be very time consuming.

All this should be done in good time especially if there is a need to do another translation before the training starts. Another option is to check the instructions during the training but doing this a lot of valuable training time can be lost.

It is important to have a clear plan how to manage the whole translation process and who is responsible of what. In previous projects PRU has been responsible of the translation to English and PU about the translation from English to the destination language. Information about the amount of instructions should be sent to the receiving organization as soon as possible so that they can prepare enough resources for the translation and check.

5.4.4 Quality Plan

Quality Plan is the combination of methods to measure the quality in the manufacturing. It should define the quality goals, select appropriate detection and prevention methods and be realistic about the sources of defects (Contrux 2003).

Quality Plan is used to measure the success of the training, the production ramp-up and the receiving organization capability to work on its own. Existing Quality Plan can be used but it needs to be analyzed and modified to meet the needs of the product transfer project and new PU.

5.5 Item data

Item data in this task mainly means production drawings and Bill of Materials (BOM) for suppliers and organization's own production. Production drawings are used to show how to manufacture the product. They have detailed information about the task to be performed, needed equipment, related instructions and procedures which are to be followed. Machine operators, assemblers and managers all use the production drawings as a reference how to do their work. (Kendal 2007)

A Bill of Material is well defined by Visitaks (2008) as "*the complete set of physical elements required to manufacture a product*". It is the accurate list of all parts and raw materials needed to make the product. It should have clear parent-child relationships, which differentiate between components and materials that are part of a subassembly versus the overall assembly. BOM works as a central source of information for engineering management, sourcing, and product costing, and production. Instructions and production drawings are supportive data that will help to build up the product. Due to many different users, inaccuracies in BOM may result in severe problems.

Errors in BOM can be divided into three categories: completeness, consistency and correctness. Usually the BOM is simply incomplete, critical information, such as part description or quantity is missing. On the other hand the critical information might exist but it can be in conflict with other information. For example, quantities won't match in drawings and BOM. Incorrect data causes problems in forms of obsolete data, or incorrect supplier information etc. (NEMI 2002)

The figure 16 shows the information flow between different groups in product transfer projects. In the case of own production situation is a bit better as there aren't any intermediaries between PRU and PU. Response time for possible problems can be long especially in the situations where the question comes from the new supplier and then this information has to be checked from the original supplier. In order to minimize the possible problems it is necessary to check the data before hand and make it accurate.

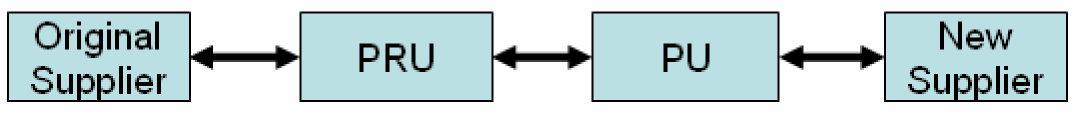

Figure 16 The flow of information between different groups in product transfer projects.

Item data has been divided into three separate sub-tasks: production item data, sourcing & supplier data, and product data management. These sub-tasks are examined in next three chapters.

5.5.1 Production item data

Production item data means the drawings and BOM that the organization is using in its own manufacturing. Production item data is first analyzed during the process walk and if it reveals that the accuracy of the production item data doesn't seem to be on an acceptable level a more detailed analysis is needed. According to Saramo (2007) accurate and simple method is to collect all the parts mentioned in the BOM together and then build the product while checking the BOM and the production drawings. This should be done by workers and experts together so that possible problems can be identified and solved right away. These problems can be, for example, different opinions what parts should be used.

When the BOM analysis is ready, necessary changes need to be done and sourcing in the receiving organization informed about upcoming changes. Saramo (2007) and

Kahar (2007) points out that the situation is easier in projects were the product is a standard product. Once the BOM and drawings are finished they can be “frozen” and be used for manufacturing multiple products. With configurable products situation is more challenging as possible variations in parts has to be listed and necessary changes to configurators made.

During this the update it is important to consider how to implement the changes. Workers, managers and designers have to be informed of all the changes, how these will affect to their work and what is their responsibility in the implementation.

The update and its implementation should be ready in good time before the actual training begins so that trainees can be taught to use correct production item data and thus training is not wasted for teaching unnecessary things. Leinonen (2007) also emphasizes this as unlearning already learned things is a very difficult task.

5.5.2 Sourcing & Supplier Item Data

Sourcing & Supplier data doesn’t only mean BOM and drawings as the production item data. In addition sourcing needs information what are the critical selection attributes and features of the part that has to be taken into account when selecting suppliers. This information can be, for example, quality requirements for steel and methods to measure this. If this information doesn’t exist it needs to be created for the sourcing. (ABBb 2007)

Furthermore, the sourcing needs information about how the items are stored and what are the methods for ordering the material. For example, does the designer always make a purchase proposal for the item or is the item ordered by using two box-method.

Supplier BOMs and drawings can be checked similarly to the production item data, although it needs to be done in cooperation separately with each supplier. Priority should be put on those parts that will be supplied from the new suppliers and have a complex structure.

Furthermore, preparing instructions and training for selected suppliers is equally important to the instructions and training tasks for PU. Instructions have been discussed in detail in *Chapter 5.4 Instructions* whereas training has been examined in *Chapter 5.3 Training*

5.5.3 Product Data Management

Data management in this case means managing changes in the product data and the product data flow between the sending and the receiving organization. During the design task it is necessary to agree who are the responsible persons of managing the data, what are the systems that exchange data between the organizations, and what are the methods for transferring the data.

At this stage it is also necessary to consider the situation after the product transfer project. As there will be changes to even standard products it is important plan how possible changes to the data are done, informed, and how changes will be implemented and how these implementations are supervised.

The data flow problems mainly arise because of the islands of automation. For example, CAD programs might create drawings in formats that can be opened only with the same program. This problem is fairly easy to over come as there is existing standardized file formats for drawings such as PDF (Portable Document Format). However it needs to be ensured that programs used in both organizations are able to create and read such formats.

The problem usually exists on a larger scale as organizations have different PDM or ERP systems which now should be able to communicate with each other. Main issue here is how to transfer the BOM. This could be done manually, especially if a standard product is in question. However it is important to remember that later all the changes to the BOM has to be done manually as well. Managing of hundreds of items like this is time consuming and exhausting. In addition same work is done many times as first somebody has to do the change for the first time. Then this change has to be informed to all the other factories and inserted into their systems as well. This drastically increases risk of errors as there are multiple entries and all the factories have to have rights to modify the BOM. (Kahar 2007)

Other option is to create interface between these different systems. For a standard BOM this can be done quite fast but more challenges will rise especially in situations where order-specific structures needs to be transferred. Making of the interface requires know-how from both sending and receiving organization due to different systems. If there isn't enough in-house expertise to make the interface consultants are needed. (ABBb 2007)

6 Applying the model to the Project Phoenix

In this chapter the created model is applied for the Project Phoenix. Selected areas of application are the manufacturing instructions and the production item data. Analyzing these two areas was seen necessary as both of them had been problem areas in most of the analyzed cases. Furthermore, there was a general feeling that the state of the data in these areas might not be on acceptable level.

The manufacturing instructions and the production item data are discussed in separate chapters, although the general structure for both chapters is the same. First, a description about the data, how it appears, and how the application of the model was done, is given. Then results are given, followed by resource and process proposal considering the project. Finally proposals for the BU Machines and the preparation for the future product transfer projects are given. Application of the model shows that situation can be unique in for each organization and highlights the importance of the detailed analysis of the situation before the project execution phase.

6.1 Manufacturing instructions

In ABB Synchronous Machines manufacturing instructions are named as P-instructions. P-instructions are part of Synchronous machines permanent document management system and they define processes, working methods, common rules and operation models. (Murremäki 2008)

All P-instructions are stored in Lotus Notes data base where they have been categorized by department or function. In addition each manufacturing department has the most important P-instructions for that particular department printed in a folder that is stored close to the workers. BU Machines has announced that P-instructions should be bilingual, so that the first language is the language used in the factory in question and the second one is English.

Application of the model was done so that first the Quality Plan was checked and used to create list of the needed instructions. List was then further completed with workers and managers from each department. Second round of discussions was held to check the content of the instructions to define their status. The process walk was supposed to be done with people from PU but due to the changes in timetables this was cancelled and this area was touched only lightly during the analysis of the production item data. However, as part of this thesis a detailed process description was made for the final assembly of the product. During this time, the use of the instructions was studied in more detail.

6.1.1 Results

Results showed that the needed set consists of around 116 instructions that contain about 1000 pages. Table 4 gives a small explanation about what each status means whereas the results of the actual analysis are shown in the table 5. The more detailed results are sorted by departments and by the status of the instruction. The results have been fixed due to the sensitivity of the data.

Largest deficiencies were found from departments E, F and G, where the work process instructions don't exist. Same situation seemed to apply for departments A, C and D. However it was found out that these instructions have been mostly created, but are still under inspection or waiting for approval. For example, the creation of detailed working instruction in department A was started around 11 months ago and so far the instruction has not been put into the official distribution. Another interesting point is that only 14 instructions are bilingual and ready for the delivery to the PU. However it was found out that that most of the recently updated instruction were bilingual which indicates that translation is progressing although slowly.

The analysis also showed that the information is mainly passed through socialization from mouth to mouth as workers rely on more experienced workers and instructions are not used. Several factors affecting on this situation were identified. Probably the most important factor is simply that the needed instructions don't exist. Findings mentioned earlier support this as none of the departments have detailed working process instructions in official distribution. Other found factors were: Lotus Notes database was seen difficult and slow to use, there weren't enough access points to the data base, workers were unaware of the instructions and that instructions were seen fussy. Fussy means that instructions tend to refer other instructions many times and thus the clear picture of the task is hard to create. This is supported by the fact that some of the departments have many separate instructions. For example, department E has 27 separate instructions in use whereas in department A there are only 8.

Table 4 Explanation of each status

Status	Explanation
Remove	Unnecessary or out of date
Create	Totally new instruction or the update requires a lot of work
Update	Needs only minor update or further check
Translation	Ready for translation to English
Check	Translation needs to be checked
OK	Instruction is in acceptable condition for delivery to PU for further translation

Table 5 The results of the instructions analysis (the results have been fixed)

	Status						
Department	**Remove**	**Create**	**Update**	**Translation**	**Check**	**OK**	**Total**
General	0	1	5	1	0	0	7
Department A	0	1	5	2	0	0	8
Department B	4	1	3	0	0	2	10
Department C	0	1	4	9	0	0	14
Department D	1	2	6	2	0	0	11
Department E	7	1	14	12	0	0	34
Department F	0	4	10	4	0	5	23
Department G	3	2	8	6	0	7	26
Total	**15**	**13**	**55**	**36**	**0**	**14**	**133**

6.1.2 Resource and process proposals for the Project Phoenix

From the Phoenix point of view the greatest challenge considering the instructions is the current readiness. Although the main goal is to complete all the instructions, it is necessary to ensure that at least the most important ones will be ready before the training begins at PRU. Due to this instructions should be divided into high and low priority instructions. High priority should be given to the detailed process instructions, inspection sheets and their instructions and low priority to the instructions the support these.

As mentioned earlier none of the detailed working process instructions are in official distribution. Creation and update process is often slowed down because it is noticed that some photos or other data is missing from the instructions. As the production cannot be stopped due to the tight deadlines, the work phase in question is often conducted during the evening or the night shift. Therefore, it is necessary that the person responsible of the instruction is able and willing to work longer hours in order to get the missing data. This method will increase costs as this extra work has to be compensated. However the benefit is that the time used to get the instructions to the official distribution decreases drastically.

In order to speed up the approval process it is crucial to, ensure that the inspectors and the approver of the instructions are committed to the task. In optimal situation inspectors takes a part to the creation process in an early stage so that possible mistakes and disagreements are noted and fixed right away. Approver should then inspect and approve the instruction immediately when it is ready.

Especially with large or new instructions, it is crucial to agree when the instruction is on acceptable level so that the translation task can begin. This is most likely going to require compromises, but after the translation is done it is still possible to add new text or photos and do translation for these parts. However theses later changes should be done before sending the instruction to the PU, otherwise the risk of errors will rise.

One possible solution for successful completion of this task is to create small teams who are responsible (creating, updating, and checking, inspecting) of one smaller instruction set, for example one department. This team should then have a time frame during which they can commit themselves fully on this task.

As the instructions contains around 1000 pages in total it is necessary that PU is informed about this as early as possible so that they can prepare a plan for managing this task on their side. One possibility to consider is that each instruction is sent to the PU straight after it has reached OK status. Then the translation and check work can be happen during a longer time frame also in PU.

Table 6 shows estimations about the resources needed for instructions task. However, the results have been fixed due to the sensitivity of the data. Most of the instructions in new category are currently being made and nearly ready. However there are several instructions that need to be created. Thus it can be estimated that completing all the instructions in new-category will take approximately 1000 hours. Estimation of the hours spent on update is a rough estimation that updating and checking one instruction will take around 4 hours. Needed time will vary in each instruction but total time that needs to be spent on this task is around 220 hours. Estimation of the resources needed for translation is based on enquiries to ABB own translation service suppliers. Hours needed for check is based on the information that it will take roughly 1 hour from native English speaker to check three pages of translated text. Check of the translation doesn't mean checking of the grammar but that the vocabulary used by translators matches the one that the BU Machines is using. Thus it can be estimated that it will take about the same time from experts to check the translation.

Table 6 Estimation of resources for instructions task (the results have been fixed)

Task	Hours / Money	Persons
New	1000	Trainees, Experts
Update	220	Trainees, Experts
Translate	34 000 €	Outsource
Check	350	Experts

For the management of the instructions task an excel sheet was created. In this sheet all the instructions are sorted by their departments and colored based on their status. Instructions can be sorted, for example, by their current status, responsible person, and task. In addition a graphic status bar was created in order to give a better visual view of the situation. Example part of this sheet is shown in the figure 17.

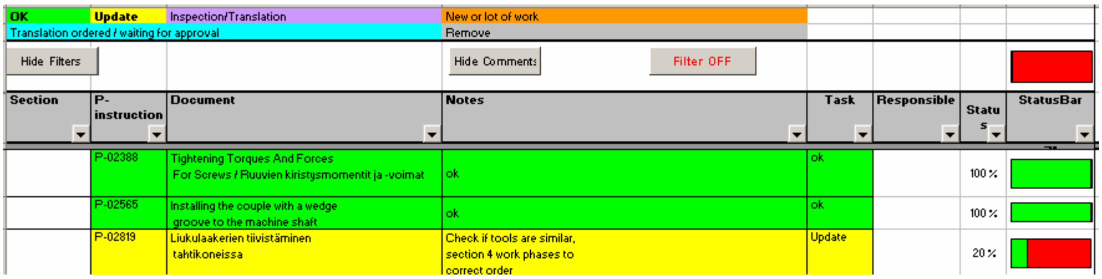

Figure 17 Managing the instruction task excel sheet

6.1.3 Proposals for the future product transfer projects in BU Machines

In BU Machines major updates in the manufacturing instructions have been done during the product transfer projects. This approach has limited the scope of the update only to the manufacturing instructions related to the transferred product. However, a more complete update of the manufacturing instructions on BU Machines level could be beneficial as it would increase the quality of the work and efficiency at the current manufacturing locations, harmonize the instructions, and help to speed up the future product transfer projects.

The importance of the development of the manufacturing instructions in own production and the externalization of the tacit knowledge into the instructions is supported by following example. Although tacit knowledge is impossible to measure accurately it is possible to roughly estimate the amount of tacit knowledge by looking at the work experience. Department F currently has 59 workers and their total work experience is 793,4 years. Twenty of the most experienced (and mainly oldest) workers hold 69 % of these years (526 years). However 20 of the most inexperienced workers have only 3 % of the total work experience (22,4 years) (Jokela 2008).

These statistics indicate the possibility that the BU Machines in whole face the same situation. In the existing factories there are many new and inexperienced workers who could use instructions during their training and work. Of course the situation is better in the existing factory as there are experienced workers as well, but there can be situations where their help is not available. Furthermore, the current trend is that workers tend to change the workplace more often which creates the situation where the work experience doesn't accumulate and more time needs to be spent on training.

However, from the BU Machines point of view, the whole situation won't be solved just by creating the new manufacturing instructions. Only in the Pitäjänmäki factory there are three different profit centers working together under the same roof and each of them have different ways of working. These differences can be seen in the manufacturing instructions as each profit center has a slightly different approach in making them. Situation can be especially challenging for new PU as during a product transfer project they might need to learn working methods of several different profit centers simultaneously.

Therefore, from the manufacturing instructions point of view, one of the key issues is the standardization of the manufacturing instructions on a BU Machine level. The creation and management of the manufacturing instructions should have common rules established.

The manufacturing instructions should have common vocabulary and layout. Even more important factor is the common content. It needs to be decided what kind of information should be in instructions and where rest of the information is shown (for example in BOM or in drawings). Furthermore, what should be included in product specific instructions and what should be in more general level instructions needs to be decided.

One possible option for the management and the creation of the manufacturing instructions is to separate them into different levels. There should be person(s) responsible of each level and each instructions set on each level. For example, there should be a responsible person of profit center level instructions in each profit center. These persons would also be responsible of managing the revision process. In addition, a proper feedback channels should be created. Table 7 shows an example of possible division of the manufacturing instructions.

Table 7 An example of possible division of the manufacturing instructions

Level	**Description**
BU	Instructions that can be applied for all the profit centers and products
Profit center	Instructions that can be applied on profit center level
Product specific	Instructions that can applied only on specific products

6.2 Production item data

The main parts of the products are very similar to each other and the variation mainly happens in accessories. However, the products sold by the Synchronous Machines are project specific and thus the BOM and drawings are viewed as product specific. Within the project, it is possible that the products are identical.

Creation of the order specific item data begins from the order. After the order is received it is driven through the sales configurator, which gives a preliminary specification for the product. Next step is to do the performance design, which defines the optimal performance of the product.

After the performance design, design configurator is driven and BOM and the drawings are finalized by electrical and mechanical designers. Created data is then used by the sourcing and the production. The created BOM doesn't only contain items but also additional information such as dimensions, needed instructions, manufacturing steps etc. Item data creation process of product specific data is shown in the figure 18.

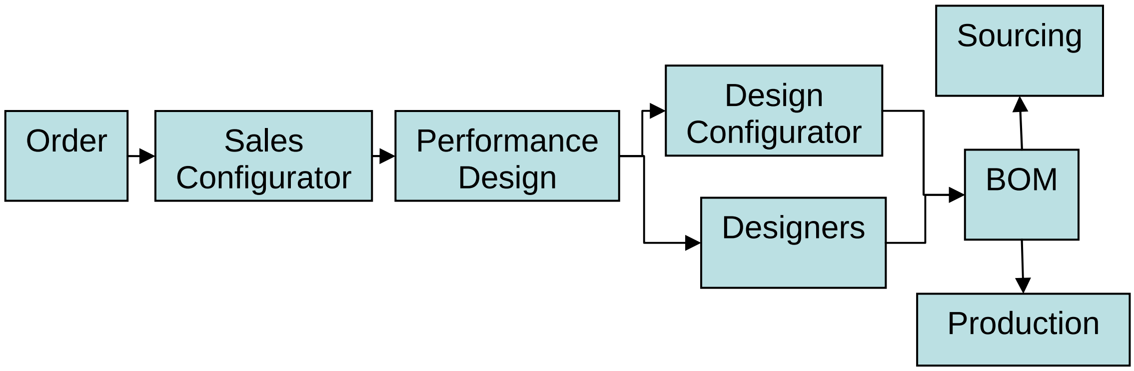

Figure 18 Item data creation process of product specific data

Production item data analysis concentrated on the BOM and it was done by following one machine through the production. A double-check was done in final assembly with identical sister machine, because in final assembly most of the items and materials are used. However, the analysis cannot be called process walk as there were participants only from the PRU as the existing PU doesn't have nominated person for this task. Chosen perspective to the BOM was that it should be 100% accurate, thus all the possible materials and parts that workers used were listed.

6.2.1 Results

The BOM analysis was found to be a very demanding task. However, there were two supporting factors from PDM point of view that make the current BOM and its use, effective and helped in this task. First, the current BOM has standardized structure that helps to define where each item belongs or should belong. Second, most of the items in the production are clearly marked with tags that include the item code, functional code and commonly used description. During the analysis as it was found out that sourcing, design and manufacturing all tend to have their own names for the items. Thus the item code was sometimes the only method to identify the item in question, which highlights its importance.

One of the main issues found was that the English version of the BOM isn't totally in English. Items are mainly translated correctly but especially dimensions and additional information contains Finnish. Other issue that was found out is that the instructions mentioned in the BOM have old instruction numbers and most of the instructions are not mentioned.

The figure 19 shows overall results of the analysis. Listed items and materials have been sorted into four categories based on the NEMI (2002) BOM error categories. Table 8 shows the explanation of these categories. The results have been fixed due to the sensitivity of the data.

Table 8 Explanation the categories

Category	Explanation
OK	Item accurately in BOM
Amount	Item had wrong amount
New	Item not in BOM but was used
Not used	Item was in BOM but wasn't used

From the figure 19 it can be seen that the current accuracy of the BOM is 69 %. Lowest accuracy was found from the final assembly. However, it is natural that lowest accuracy can be found here since the final assembly has the most of sub-assemblies and items.

OK	213
Amount	17
New	46
Not used	35
Total	311

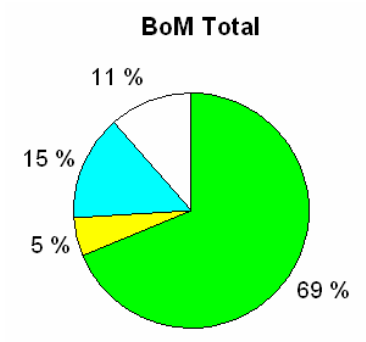

Figure 19 Overall results of the BOM analysis (the results have been fixed)

During the analyze some items were found which amount is difficult to estimate before the actual use. For example, the amount and thickness of adjustment plates for bearings depends on the air gap and how it needs to be adjusted.

Process walk's purpose was to provide a more specific data about situation. However the results are only indicative as there are many possible errors. First of all as the analysis was conducted to one machine only there is a high chance that all the accessories and items related to them haven't been listed. Furthermore, human factors such as rush, fatigue and inexperience likely affected to the workers and the person who conducted the analysis.

The actual design of machine is done about 6-8 months before the production of the machine starts. As the design configurator is under update all the time, it is possible that BOM contains old information. Designers use also "compare structures"-application which is used to compare created BOM to older BOMs. Purpose of this application is to make the design faster as the designer can see what components and accessories have been used in similar machines. By using this application designer can also copy wrong items as corrections are done to the configurator not to the old BOMs.

Due to the misinformation in the BOM workers tend to rely on each other especially in situations when they look for confirmation should some certain item be used or not. It seems that new workers learn not to use BOM as they first use it and then older worker comes and corrects the mistakes. As a result BOM is mainly used to check the needed accessories and dimensional data such as values for an air gap.

6.2.2 Resource and process proposals for the Project Phoenix

From Phoenix point of view there are two major tasks considering the BOM. First one is to update BOM so that its accuracy is on wanted level, meaning that BOM has all the items physically inserted to the product under correct structure with correct amount. In other words the BOM needs to have a “*facelift*”

In order to do this a more detailed analysis and designing of the facelift is needed. This should be done department by department in cooperation with experienced worker, BOM expert, configurator programmer and designer. BOM analysis created a good base for the more detailed analysis as it shows which items should be analyzed with care. During the analysis drawings should be checked as well in order to see how possible changes to the BOM affect to them.

As the manufacturing process in some departments is slow and new items are not inserted all the time it is not effective to follow the process all the time. For example, for winding and rotor the detailed analysis can be done so that ready stator package or rotor is examined.

Detailed analysis slows production and consumes resources but there are advantages in this method. As experts from all the sides are involved it is possible to agree on necessary changes right away so that all the groups of interest know about the change and reasons for it. Furthermore, if detailed analysis is conducted with care and necessary changes noted down, the design of the facelift will be done at the same time.

Second major task is to update the current English version of the BOM so that it only contains English. This task can be divided into three sub-tasks: Analysis, translation and application. Due to the limits of the current PDM system it necessary to analyze the order-delivery process and identify when the language of the BOM needs to be decided and how this will affect to the system. Translation sub-task is simple manual labor, however due to the amount of data it will take time to do and check it. Final sub-task is to make the actual application that creates the language version correctly.

Table 9 shows the major tasks, their sub-tasks and estimations of needed resources. The results have been fixed due to the sensitivity of the data.

Table 9 The BOM "facelift" (the results have been fixed)

Main Tasks	**Hrs**	**Needed persons**
Design the face lift		Experts, workers, designers, programmers
Find item codes & create new ones	80	
Check items to be removed	40	
Mark materials that might vary	16	
Transfer items under correct sub-structure	80	
Instructions	16	
Programming	40	Programmers
Check & fix drawings	120	Workers, trainees, designers
Language version		Trainees, programmers,
Analyze	16	
Translate	320	
Application	160	
Total hours	888	

When the facelift has been finished it is time to implement the changes. This will require managements support as someone needs to inform about the upcoming changes and also provide training if that is needed.

One of the main issues in implementation is that the design of the generator is done about 6-8 months before the production. Thus changes in the design configurator are normally seen in the production after 6-8 months in earliest. The machines that will be built during the training in PRU are going to be designed in next couple months, which mean that the changes done in the facelift won't show in their BOMs. This creates a challenge for the implementation as configurator cannot be driven again which means that design of the machine needs to be postponed or that the changes needs to be inserted manually. Furthermore, as the data produced by design configurator is going to change significantly it is necessary to inform designers that the compare structures application will show a lot of variation and it is crucial that items are not copied from the old BOMs.

6.2.3 Proposals for the future product transfer projects in BU Machines

Also in item data the profit centers of the BU Machines have slightly different views. Therefore, just like for the manufacturing instructions, the key issue is to create BU Machine level standards for the item data and then continuously develop this data. This process will then further increase the efficiency and quality of current factories and speed up the future product transfer projects.

In order to achieve all this, it needs to be agreed what is the wanted accuracy of the BOMs, what they should include (miscellaneous materials, shelf materials etc.), where rest of the data is shown (manufacturing instructions, drawings etc.), and what would be the most efficient and clearest structure of the BOMs. Furthermore, BOMs needs to be created in such a format that it can be also understood by other ERP and PDM systems.

A couple supporting solutions were found for continuous development of the production item data in the BU Machines. First of all, it was noted during the process walk that smaller shelves and cables were not tagged. These items had old codes, old names or no information at all. In order to increase the usability of BOM all the items storage in the factory be tagged correctly. Other thing to consider is how to increase the motivation of workers to report a found mistake. One method that has been used in Case C is that when a worker reports a mistake, the mistake is checked and if it is found to be correct, the worker is rewarded with a lunch ticket. This simple system had been in use before the product transfer project and due to this ongoing development the BOM was already accurate and wasn't seen as a problem unlike in all the other cases. As the product item data is constantly tested in the actual production more mistakes are to be found comparison to the situation where a major update is done for the product transfer project.

The ideal situation would be that all the created BOMs would be 100% accurate. However, in BU Machines this is basically insuperable task. Especially for unique products updating the BOM consumes too many resources compared to the achieved benefits. When a product transfer project is under planning it is crucial to identify what kind of product is in question. Transferring a non-standardized product will be a lot more challenging than transferring a standardized one.

7 Conclusion

In product transfer projects it is critical to transfer both tacit and explicit knowledge considering the product and its manufacturing. In order to do this efficiently it is necessary to activate all modes of the knowledge conversion: combination, externalization, internalization, and socialization. All this should happen first internally in the sending organization so that all the needed knowledge can be captured. Second phase is then to transfer this knowledge to the receiving organization.

Product data management faces three challenges: First, there are numerous different data groups related to the product during its lifecycle. In product transfer project it is necessary to identify those data groups that are crucial for manufacturing, for example, production information. Second reason is the amount of the product data. During the product and individual product lifecycle vast amounts of product data produced with various tools is accumulated to the product. Third, product data is often scattered into separate systems which creates problems in data conversion and transfer.

In order to get detailed information about the challenges in product transfer projects, six previous projects from three different profit centers were analyzed. The analysis provided valuable information and gave insight into these projects. The challenges in product transfer projects have been preparation, resource allocation, production item data, manufacturing instructions, training, and quality assurance. Based on the acquired knowledge a model for managing the product data in a product transfer project was created.

The model (appendix II) shows all the five main tasks (manufacturing machinery, manufacturing tools, training, manufacturing instructions, and item data), the order of the sub-tasks in each main task and their relatedness. This helps the project manager to form a better picture about the project in overall and identify the possible challenges in it. Furthermore, the model highlights the importance of the detailed analysis during the project planning phase. Although sub-tasks such as the process walk will consume resources more than normal project planning it provides crucial information about the current situation and thus affects to all the other problem areas. Proper planning and information reduces costs later on in the project as enough resources can be allocated into the correct tasks. Due to the general nature of the model it can be applied to the similar projects. However, it needs to be remembered that the model describes a project where only the manufacturing is transferred. If, for example, also design is transferred it is necessary to plan needed tasks for that as well.

Application of the model was done to the manufacturing instructions and the production item data so that the current state of the product data in these areas was analyzed by following the created model. It was found out that in both areas the state of the product data is not on the acceptable level considering the Project Phoenix and the Synchronous Machines profit center.

In manufacturing instructions the main deficiency was that the detailed working process instructions don't exist which is also the main reason why the instructions are not used. For production item data the largest deficiencies were that the English version of the BOM is not entirely in English and the current accuracy of the BOM insufficient.

Based on these findings recommendations and resource proposals for the Project Phoenix were given. The main challenge for both tasks is the current state of the data. For manufacturing instructions it is necessary to create detailed process instructions in receiving organizations own language for each department so that the manufacturing instructions can be used as a training material during the training in sending organization. For production item data, the English version of the bill of materials needs to be fully in English. In addition it needs to be ensured that bill of materials is updated and these changes implemented before the training in the sending organization begins.

For production item data situation is even more complicated as the designing of the machines is done 6-8 months before the production starts which affects to the implementation of the update. It was estimated that it would take roughly 10 man months to the fix the manufacturing instructions and about 6 man months to fix the production item data.

In order to increase to quality and efficiency of the existing factories and to speed up the future product transfer projects in BU Machines the manufacturing instructions needs to be standardized on BU Machines level. The manufacturing instructions should have common vocabulary, layout, and content. Furthermore, they should divided into three levels: BU (general ones), profit center (instructions that can be applied on profit center’s products), and product specific instructions.

To further increase the performance in the areas mentioned above it is necessary to standardize also the production item data. It needs to be agreed what is the wanted accuracy of the BOM, what the BOM should include, where there rest of the data should be and what would be the most suitable structure for it. Furthermore, the BOM should be in such a format that it can be easily understood by other ERP and PDM systems.

The model and the analysis provided valuable information about the current situation and challenges in the Project Phoenix within these tasks were able to be identified. Furthermore, the analysis also showed deficiencies in the current processes of the BU Machines in product data management area. These results support the necessity of the detailed analysis about the current situation during the project planning phase and use of the model to identify the possible challenges.

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