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Adoption of Model-Based Definition

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Abstract

The purpose of this study is to clarify what MBD is and what it means to the Finnish industry. This study shows the reader how to reach MBE Level step by step. The purpose of this study is also testing the creation and the visualization of PMI.

The theory chapter describes what the terms PMI, MBD, and MBE are and how they are related to one another. The theory describes the usefulness and the risks of using MBD. The theory also includes the file format, the CAD program and the visualization program. The method of this study is an exploratory case study.

The result includes a process scheme of how MBE can be adopted. It explains step by step where to start and how to proceed. The process scheme proceeds from 2D drawing to MBE level. The result also shows how the PMI data can be created in NX11. It shows an easy version of the 3D model, including PMI data, which may be displayed on a laptop or a mobile device.

In the discussion the result is analyzed. Issues and notifications are presented on how the PMI was issued and how it is displayed. The negative and the positive aspects about adapting the model is analyzed. Future outlooks of the digitalization are also discussed.

Language: English Key words: MBD, PMI, MBE

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Abstrakt

Syftet med detta examensarbete var att klargöra vad MBD innebär och vad det betyder för finska industrin. Ett sätt på hur man ska gå tillväga för att uppnå MBE nivå kommer att klargöras. Syftet är även att visa en 3D modell där PMI skapats.

Teoridelen beskriver vad termerna PMI, MBD och MBE är och hur de är relaterade till varandra. I teorin tas det upp nyttan och riskerna med att ta i bruk MBD. Teorin består även av en data del var olika filformat, CAD program och visualiseringsprogram tas upp. Metoden som använts i denna studie är en fallstudie.

I resultatet visas ett schema på hur man skall tai bruk MBE. Den visar stegvis var man ska börja och hur man skall gå till väga. Schemat går från att ha 2D ritningar till MBE nivå. Resultat delen visar också hur PMI har gjorts i en 3D modell i NX 11. Det visas också hur en lätt version av 3D modellen med PMI data kan visas på en laptop och en mobiltelefon.

I diskussionen analyseras resultaten. Problem och anmärkningar lyfts fram beroende på hur PMI data gjorts och hur det syns. De negativa och de positiva aspekterna med att ta i bruk modellen presenteras. Framtida visioner om digitaliseringen diskuteras även.

Språk: engelska Nyckelord: MBD, PMI, MBE

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Tiivistelmä

Tämän lopputyön tarkoitus oli selvittää mitä MBD on ja mitä se tarkoittaa Suomeen teollisuuteen. Esitetään malli vaihe vaiheelta, miten MBE-taso voidaan saavuttaa. Tämän lopputyön tarkoitus oli myös näyttää 3D malli, missä PMI on tehty.

Teoriaosiossa kerrotaan mitä PMI, MBD ja MBE ovat ja miten ne liittyvät toisiinsa. Teoriaosuudessa kerrotaan myös MBD:n hyödyistä ja riskeistä, esitellään erilaisia tiedostoformaatteja ja esitellään CAD- ja visualisointiohjelmistoja.

Tulososiossa esitellään prosessikuvaus, kuinka MBE voidaan ottaa käyttöön. Tämä malli kertoo miten pitää edetä vaiheittain. Tämä prosessi alkaa 2D-piirustuksista jatkuen MBE-tasoon asti. Tuloksissa nähdään myös esimerkki, kuinka PMI-dataa luodaan NX 11 ohjelmistolla. Nähdään myös, miten matkapuhelinta ja kannettavaa tietokonetta voidaan hyödyntää PMI-datan visualisoinnissa.

Tulokset analysoidaan keskusteluosassa. Ongelmat ja huomiot tuodaan esille ja näytetään kuinka PMI tehtiin ja millainen se on todellisuudessa. MBD:n käyttöönoton malli analysoidaan hyötyjen ja riskien näkökulmasta. Tulevaisuuden visioista keskustellaan myös.

Kieli: englanti Avainsanat: MBD, PMI, MBE

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Acronyms

Acronym	Definition
2D	Two Dimensional
3D	Three Dimensional
AR	Augmented Reality
BIM	Building Information Modeling
CAD	Computer-Aided Design
FGSU	Fuel Gas Supply Unit
GD&T	Geometric Dimensions and Tolerances
PMI	Product Manufacturing Information
MBD	Model-Based Definition
MBE	Model-Based Enterprise
STEP	Standard for the Exchange of product model data
TTF	True Type Font

1 Introduction

1.1 Background

The digitalization in every industry is growing faster than ever before, and the competition between different companies is also nowadays harder. The need of new technologies is growing, and new ways of working have become an important aspect of the industries. The companies aim towards higher efficiency in the manufacturing process by faster delivery time and lower costs.

We are living in the fourth industrial revolution called Industry 4.0. This means with other words, smart manufacturing, smart factory, the cloud, and the industrial internet of things. This term, Industry 4.0, was firstly used in Germany in 2013. (Industry 4.0 voi palauttaa valmistuksen perinteisiin teollisuusmaihin, 2017)

Digitalization have become a hot topic, and it can also be measured. Digitalization means turning business functions, communication and business models into digital ones. Digitalization often refers to digital business and how it can be digitalized. (Bloomberg, 2018)

The digitalization in each county can be seen in Digibarometer (Ali-Yrkkö, Mattila, Pajarinen, & Seppälä, 2019). Digibarometer is a study which evaluates the utilization of digital capabilities. The measurement is done on three levels, capabilities, utilization, and implications. It measures across company, civic, and public. The survey compares 22 countries and 36 variables. (Ali-Yrkkö, Mattila, Pajarinen, & Seppälä, 2019)

In 2019 Finland was third in ranking after The USA and Denmark. Our country has been in top 3 in the last 6 years. In 2019 Finland was on second place in utilizing digitalization, fifth in actual utilizing, and sixth in implications. The industry in Finland was in third place by using Big data analyses. Big data means the use of the technology and the program tools for Big data analyses. (Ali-Yrkkö, Mattila, Pajarinen, & Seppälä, 2019)

1.2 Purpose

The purpose of this study is to clarify what MBD is and what it means to our industry. This study will show the reader how to reach MBE level step by step. The purpose of this study is also testing the creation and the visualization of PMI.

1.3 Scope

This research will focus on MBD, PMI, and MBE, as well as the viewpoint on the mechanical industry on auxiliary modules for powerplants. It will concentrate on how the designers and the manufacturers can take MBD into use instead of using 2D drawings. The research will also comment on what kind of action is needed for it to work, the benefits of adoption, and what challenges to be prepared of.

Another focus is the technical function when creating PMI in NX 11. It will also look at the visualization part in JT2Go on both computer and mobile device.

1.4 Etteplan Finland Oy

Etteplan is an engineering company with over 3400 employees. It was founded in 1983. The company provides software and embedded solutions, such as product and software engineering and consulting, testing services, and production testing systems. They also provide technical documentation solutions like illustrations, writings, animations, and simulations. They also do manuals and service instructions. Etteplan provides engineering solutions that refers to engineering innovation and calculations of the technical attributes in manufacturing. Examples of engineering services is plant engineering, product cost analyses, product safety, project management, and product development projects. It is one of the largest companies in Europe to provide technical documentation solutions. (Etteplan, n.d.)

The vision of Etteplan is to provide the best service solutions to its customers regardless of their location. Etteplans purpose is that they help their customers create a better world through engineering, innovation, and digitalization. The key element in Etteplans strategy is customer value, service solution, and success with people (Etteplan, n.d.)

Etteplan had a revenue of 236 million EUR in the year of 2018. The company is situated in Finland, Sweden, the Netherlands, Germany, Poland, and the United States. The headquarters is to be found in Vantaa, Finland. The CEO of Etteplan is Juha Näkki. The company is on Nasdaq Helsinki. (Etteplan, n.d.)

1.5 Disposition

Chapter two contains the basics of PMI, MBD, and MBE and how they are related to each other. The chapter also includes future technologies like AR technology.

The third chapter explains the methods of this study. It will for example tell what an exploratory case study is and which way it is suitable for this thesis.

Chapter four is the results part which includes a process scheme of the working process towards MBE. The chapter will also show how PMI data can be created in the NX 11. The visualization of the PMI in JT2Go will also be shown and explained.

In chapter five the results will be discussed and analyzed. The benefits and the risks of implementing MBD will be discussed. The challenges and the usefulness of the creation and the visualization PMI will be discussed and analyzed.

2 Theory

2.1 Definition of MBD

MBD is a shortened term of *Model Based Definition.* MBD means, in other words, a 3D model with product information. An MBD product model can consist of measurement, tolerances, materials, projections, sections, and other documents. The 3D MBD model replaces traditional 2D design documents. (Rapinoja, 2016)

An MBD dataset is a 3D geometry of the product including 3D annotation. All of this information will specify a complete product definition. An MBD dataset does not include 2D drawings. The 3D annotations of the product are placed on planar views which are called *annotation planes*. The 3D annotations can be visualized in the 3D environment. (Quintana, Rivest, Pellerin, Venne, & Kheddouci, 2010)

PMI (Product Manufacturing Information) is a part of MBD. The definition of PMI is the product data of the 3D model that consist of 3D annotations. This 3D annotations includes attributes like geometric dimensions and tolerances (GD&T), welding symbols and surface finishes symbols or texts. The relation between PMI and MBD can be seen in Figure 1 below. (Rapinoja, 2016)

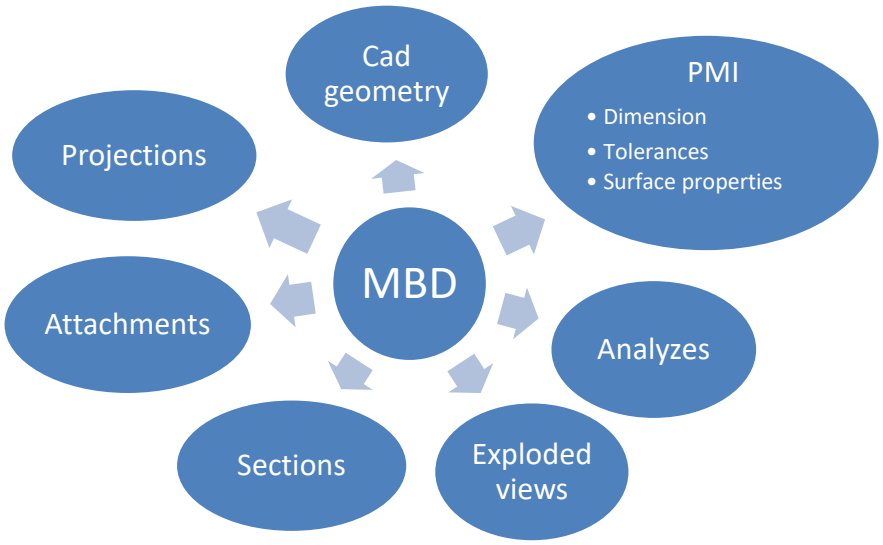

Figure 1 Relation between MDB and PMI (Rapinoja, 2016)

MBE (Model Based Enterprise) is when the same 3D model can be used in the whole organization. MBE is an engineering strategy that aims to clarify design intent during the manufacturing process. The process will use the MBD which includes PMI data. MBE is not based on a single solution; it is a result of many applications integrated for a common goal. The goal of MBE is to improve product quality, efficiency, and reduce costs. (Rouse, 2016)

2.2 Time saving with MBD

A research by Lubell, et al. (2016) has tracked the designing time of three different products. In the test they compared the drawing process and the model-based process. The drawing process consisted the creation of a 2D drawing with 2D annotation tools. The model-based process consisted the creation of MBD including 3D annotation tool. The same product information is included in both versions. Each test case has been done on different CAD systems. The time to create the 3D model have not been tracked and it is expected to be equal regardless of process. Table 1 presents the observed times to annotate the MBDs and the drawings. (Lubell, Fischer, Maggiano, Feeney, & Hedberg, 2016)

Table 1 shows that time saved in the test case 2 and in the test case 3 is less than one hour when using MBD instead of 2D drawings. In test case 1 the designers struggled to use the 3D annotations tools. It is also important to note that the designer was well trained to use 2D annotation tools.

(Lubell, Fischer, Maggiano, Feeney, & Hedberg, 2016)

Table 1 Observed time to annotate the design definition (Lubell, Fischer, Maggiano, Feeney, & Hedberg, 2016)

Test case	Number of characteristics	Drawing time	MBD time (hrs)	Delta (hrs)
1	84	3,1	8,7	5,6
2	57	2,7	2,1	-0,6
3	53	2,2	2,0	-0,2
Total	194	7,9	12,8	4,9

In Figure 2 below, the time of designing a product may be read. 21 percent of the time is spent on creating 2D drawings and 12 percent is spent on making changes to 2D drawings. In total a third of the total time goes to creating or making 2D drawings. (Boucher, 2017)

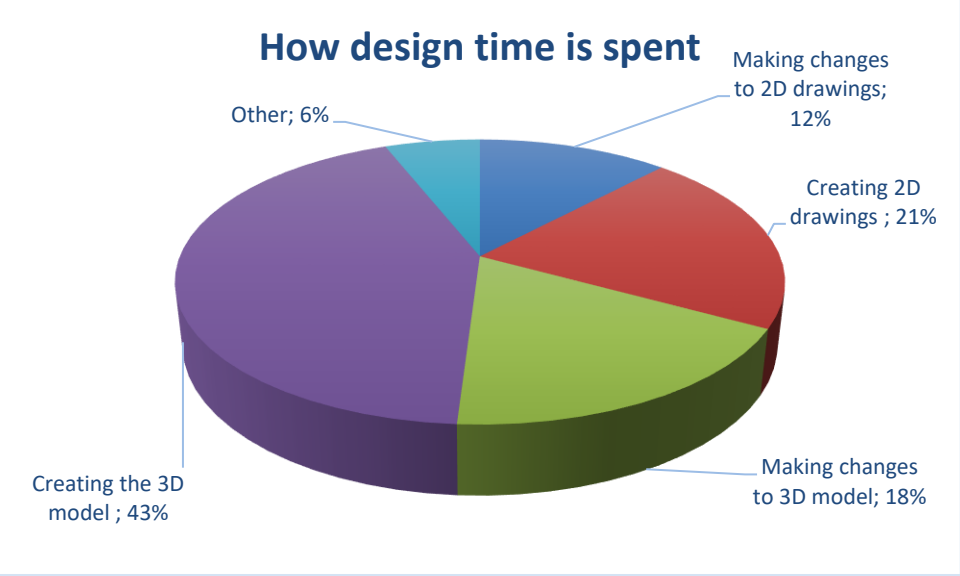

Figure 2 How design time is spent (Boucher, 2017)

2.3 PMI standardization

The visual PMI representations are supported by industry standards like ASMEY14.52009 symbology. This standard contains TTF (True Type Font). This will ensure that all created symbols in PMI are the same universal symbols regardless of what system they are using. Without this standardization there would be misinterpretation of data, which could cause extra costs and errors. (pdf3d, 2019)

2.4 Benefits of adopting MBD

When making 3D modeling, updates and changes are constantly occurring. With MBD all the changes are made with the model and nothing else needs to be updated. This will contribute to an increase in efficiency. (Welker, n.d.)

According to a study from (Boucher, 2017) those who have already adopted MBD have noticed the following things: fewer manufacturing mistakes and less rework, and improved communication with the supplier. They also mentioned that the employees are happier and now more focused on the added valued work. Time saving have been noticed in the design and the access to the product information have been more effective. None of these companies said that there were no benefits at all.

According to (Boucher, 2017) 89 percent of those who have implemented MBD are satisfied or extremely satisfied and none are dissatisfied. They are satisfied because they spend as much time on the less enjoyable tedious tasks that involve drawings. Instead the time is now spent on designing the products.

Many young engineers today see the product more in 3D than what the old engineers do. For young engineers the creation of 2D drawings is like taking a big step backwards. The 2D drawing require many points of views in order to understand the complete product compared to the 3D model. (Madhavi, 2017)

A full CAD workstation is rather expensive, but many MBD solutions do not require high end workstations. Many visualization programs can work on lower-cost tablets, which minimizes the hardware investment. (Boucher, 2017)

It will save data storage to use MBD instead of 2D drawings. The amount of data which have been stored, created, and tracked is now much smaller than compared to 2D drawings. This data can now be re-used throughout all departments. Printed documentation will be reduced which also have limited effectivity. (Adamski, 2010)

When turning paper into digital format less paper will be used. There are two reasons for minimizing the use of paper. These two reasons are the costs and the environmental aspects. The use of paper in the office is expensive. It is often believed that paper and printing is cheap, but the final cost also includes recycling, storage, transportation, and the cost of use. (Peck, 2017) Paper production is harmful for the environment as well. In the paper production toxic chemicals like chlorine, iodine, and sulfur dioxide are harmful for the aquatic eco-system. (environmentalprofessionalsnetwork.com, 2014)

2.5 Challenges of adopting MBE

When looking at the challenges at MBD we are required to look at MBE level to be able to spot the challenges and issues. When implementing new technologies there are extra investments involved. This includes investments in software, hardware, and extra training. When adopting MBD at enterprise level organizational change are needed. This cost both money and time. There will be a new established way of communication between the engineers and the manufacturers. (Goher, Shehab, & Al-Ashaab, 2019)

This will need a work of cultural change because the processes, procedures, and manuals need to be updated. This will also require acceptance of the change into a new manner of working. This require that every stakeholder own a software which can visualize the product, and more importantly, that the software is able to read all the specific details. All CAD software does not support PMI. (Goher, Shehab, & Al-Ashaab, 2019)

2.6 CAD software

SOLIDWORKS MBD is one way to produce and publish product information to the production. This works directly in 3D. Solidworks can publish formats like eDrawings, Step Ap 242, and 3D PDF. Solidworks MBD is integrated in Solidworks 3D programs. The PMI information can be put directly in the model. There is no need for 2D drawings with Solidworks MBD. (Solidworks, n.d.)

Inventor, which is provided from Autodesk, also have MBD. Step AP 242 and 3D pdf is supported in Inventor. In the program there are many 3D annotations commands like GD&T annotations, Feature Control Frames, Datum Identifiers to part faces or features. This program comes with a Tolerance advisor to check the health of the tolerances scheme. It also comes with a display which shows a list of potentially problematic datums as well as datum reference frames. Information of which features that are not fully controlled and errors in tolerance feature. (Autodesk, 2019)

NX MACH 2 Product Design packages provides 3D annotations for PMI and basic routing. PMI in NX MACH 2 supports dimensions, weld and surface symbols, notes for materials and other manufacturing, and process-related annotations. NX 11 support JT format and STEP format, but it does not support eDrawings or 3D pdf. (NX MAXH esign solutions, 2015)

2.7 File format

Native CAD format refers to formats that are proprietary to specific CAD systems. Native CAD formats include more information and are more accurate than the Neutral CAD format. Neutral or Standard file formats make the exchange easier between different CAD softwares. (transmagic, n.d.)

Step, *Standard for the Exchange of Product model data,* is defined in standard ISO 10303. Step is developed and kept by the ISO technical committee. Step consists of many standards that are used in mechanical design. STEP AP 242 (ISO 10303-242) connects old standards of STEP AP 203 and AP214. This was published in 2014. Step AP242 format can include the 3D model assembly and the geometry of the 3D parts. Step is supported by a

large amount of CAD programs like Autodesk inventor, SolidWorks, and Siemens NX. (CAD exchanger, n.d.)

JT, *Jupiter Tesselation,* is an ISO-standardize 3D data format. It's developed by Siemens PLM. They received a status of international standards ISO14306 in 2012. It's used for product visualization, collaboration, and for data transfer. This format can be opened on a free visualization program. A JT format can include assembly of the 3D model, geometry of the 3D parts, PMI tolerances, and marks, and attribute information. JT format is a compact version of the 3D model. All PMI data which has been created in the 3D model will remain in the JT format. JT format is supported by the Siemens NX, the Inventor from Autodesk, and SolidWorks. (CAD exchanger, n.d.)

Table 2 Different data transfer format (Rapinoja, 2016)

Transferring data	**Data transfer format**					
	Native	**Step AP 242**	**Step AP 203/214**	**JT**	**eDrawing**	**3D-pdf**
3D-model (native and accurate geometry)	x	x	x	x		
3D-model (only watch)				x	x	x
Drawing history	x					
Measuring	x	x		x	x	x
Tolerances	x	x		x	x	x
Annotations	x	x		x	x	x
Assembly	x	x	x	x	x	x
Saved pictures/projections	x			x	x	x
Section view	x			x	x	x
Exploded view	x			x	x	x
Attribute/metadata	x	x		x	x	x
Parts list	x				x	x
Attachments						x
Video	x				x	

2.8 Visualization programs

eDrawings is a communication tool for sharing 2D and 3D drawings between the designers and the manufacturers. eDrawings and Solidworks are both owned by Dassalt systems. eDrawings can read files straight from Solidwork in DWG formats. NX is not compatible with eDrawings. eDrawings support AR and VR technology. It also has a desktop version for computers, tablets and mobile devices. An eDrawings file is created with eDrawings Publisher add-in, which works with most cad programs. An eDrawings file is rather compressed and it can easily to send via email etc. (eDrawings, n.d.)

JT2Go is a visualization program for JT files. This program is created by Siemens NX. This program is compatible with Android, iOS, and on windows computers. (JT2Go, n.d.)

3D PDF is created by Adobe. 2D PDF that includes texts and pictures is a extremely common format. A couple of years ago 3D information could be imported into a PDF file. It is possible to show PMI and 3D model picture information in the 3D pictures pdf file. To a PDF file format, it is also possible to create an attachment file, like a 3D model (native or STEP), measurement protocols (xls or PDF), and manufacturing instructions. This format is highly popular because it can be viewed on smart phone and tablets. (Rapinoja, 2016)

2.9 Augmented reality for future visualization

Augmented reality is a combination of reality and a visual storage of data. Augmented Reality is shortened AR. The visual and the real world should always match each other and is always happening in real time. When the AR application starts it searches for marks or areas or other references so that the application can place the AR objects on it. When the objects are founded the application knows what type of information should be shown, such as text, pictures, videos, or 3D objects. AR requires software applications and hardware devices. The AR application can work as a program in computers, tablets, mobile devices, or as a web-based software. This can also work with so called optical see trough technology, such as smart glasses. There are four different types of AR technology; recognition based, marker less, projection AR, and Superimposition. (Gupta, 2019)

Superimposition based AR is one of the four types of Augmented Reality. This can be done when replacing a partial, or the entire view, with an augmented view. In this type of reality, the object recognition plays a vital role. The application must know what it is searching for, otherwise it cannot replace the original view with the augmented one. (Digit.in, n.d.)

According to (AR provides a competitive edge for manufacturers, 2018) AR helps to improve assembly timelines by 50 percent and decreases training time by 60 percent.

2.10 BIM

BIM is a shortened term of *Building Information Modeling*. BIM is a working process which begins with the creation of an intelligent 3d model. The 3d model includes document management, coordination, and simulation. BIM means automatization of using data. A BIM cad tool contain the whole process of planning, designing, building, and operating. BIM brings all of the information of, for example a building, or an engine or anything similar, all the components into one place. (Lorek, 2018)

BIM can be divided into four different levels. Level zero BIM (Low collaboration) means the Cad program is used for creating drawings, paper, and prints which are shared with the team. Level 1 BIM (partial collaboration) includes a 2d draft which is combined with a 3d model. Level 2 BIM (Full collaboration) adds additional dimensions, such as time and cost calculations. Level 2 BIM is also called 4D and 5D. The highest level is level 3 BIM (Full integration) also called 6D. It contains full collaboration and full integration in a cloud-based environment. (Koutsogiannis, 2017)

3 Method

The method of this thesis is a case study. A case study is a research method which aims to dive into what you are researching about. The general goal in using the case study is to generalize the theory. This method takes the information from other researches and put them all together into one easily researchable topic. A case study can be rather free, but it needs a strict scope. This type of study is great for small scale studies which focuses on one, two, or a few things. With a case study it is possible to describe things in detail and compare different alternatives. This study researches something which already exists, and it will continue to exist once the study is finished. The goal with this case study is to analyze the situation and to reach some kinds of different concepts, hypotheses, and suggestions. (Denscombe, 2016)

There are some different types of case studies, illustrative, explanatory, descriptive, critical, exploratory ones. I am using an exploratory case study. An exploratory case study comes from the word explore which refers to investigate, study, and/or analyze. This answers the question on how and why a definite event has happened. This type is relatively new and its highly common for students in the higher education. An exploratory case study is a research where the writer tries to make up a model of the collected data. When the data is analyzed, the writer tries to make sense of it. The goal of an exploratory case study is to prove that further investigation is necessary. (writemyessay, 2018)

I have chosen exploratory case study because this research needs to go deep into the subject. This subject is getting more common in everywhere around the world. The two main questions to get an answer to in an exploratory case study are, *how* and *why*. I am investigating on how manufacturers can adopt MBD, and why they need to do it. The goal of this thesis is to prove that further investigation is needed to make this happen, which is also the goal of an exploratory case study.

4 Results

4.1 Scales of PMI data

Every big change needs to be started with one small step. The change of adopting MBD can't happen immediately. Below in Figure 3, models have been categorized based on their size of PMI.

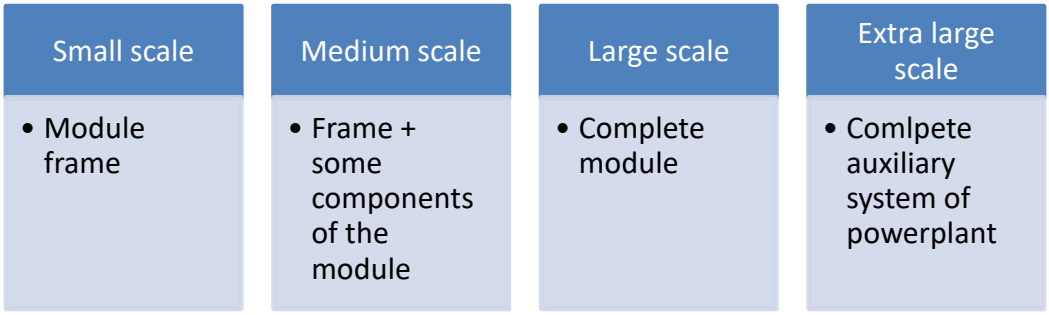

Figure 3. Categorized models

Small scales, like module frame**,** are models with quite small amount of PMI data. There is usually only one material on the frame. PMI data at this scale may include GD&T**,** welding symbols**,** and surface symbols.

Medium scale drawings contain a greater amount of PMI symbols than a small scale. In this model there is different kind of materials. There are many different types of components in this stage. Different components should be marked with a different color for better understanding.

Large scale contains the complete module. The amount of PMI symbols and data is now much larger than the small and medium scales. PMI creation will at this scale take much longer time.

Extra large scale consists a whole Auxiliary system of a powerplant. This scale is held by many different manufacturers.

4.2 Levels towards MBE

The road towards MBE has been divided into different levels which can be seen in Figure 4 below. The model starts from level zero where 2D drawings are master and goes all the way towards MBE level where no 2D drawings are allowed.

Level 4

- Model-Based Enterprise
- Drawings are not alowded
- Way of working: MBD file

Level 3

- Model-Based Enterprise
- Will be used in every process in the organization
- Way of working: MBD file

Level 2

- 3D model is master
- Drawings only for exeptional cases
- Way of working: Annotated 3D model + light version of 3D model for visualization

Level 1

- Drawing or 3D model is master
- Way of working: Annotated 3D model + light version of 3D model for visualization

Level 0

- Drawing is master
- Way of working: 2D drawing + 3D model

Figure 4 Levels from 2D drawings towards MBE, inspiration from (Rapinoja, 2016)

Level zero

This is the level where most companies are today. All drawings are 2D drawings that are made from a 3D model. The 3D model is original in CAD format. 2D drawings are in PDF format or printed out on paper.

Level 1

At this level they aim to have 3D models as master. 2D drawing will always be made at this level as backup. A light version of the 3D model will be made for visualization.

Level 2

At this level we try to work without 2D drawings. Now 2D drawings will only be made for exceptional cases. The 3D model is always master from this level and on.

Level 3

Model-Based Enterprise level. The 3D model will now be used in every process in the company. 2D drawings can be made for exceptional cases.

At this level other relevant documents, such as part lists, material lists, and test lists will be made as before. Instead of having them separated, they will be attached to the MBD file. The lists will remain the same format as before, such as pdf or xls etc.

Level 4

All product information and manufacturing information is in the MBD file. There are no 2D drawings available. 2D drawings can't be created anymore.

4.3 Working process

The process of working can be seen in Figure 5. The working method should start from the left upper corner at small scale at Level 1. When the small scale is done on Level 1 we move to Level 2. At small scale we'll move up to Level 3. This means that frame is done, and 3D model is the master with 2D drawings only for exceptional cases. After that we move to medium scale and we begin at Level 1. Then medium scale goes towards Level 3. The same process repeats with large scale. When we are at the point that the large scale (complete module) is at Level 3, we move to Large scale Level 4. This means we don't allow 2D drawings any more at any scale.

When large scale has been reached the same process start again from the beginning, from a small scale with Level 1 for a new module.

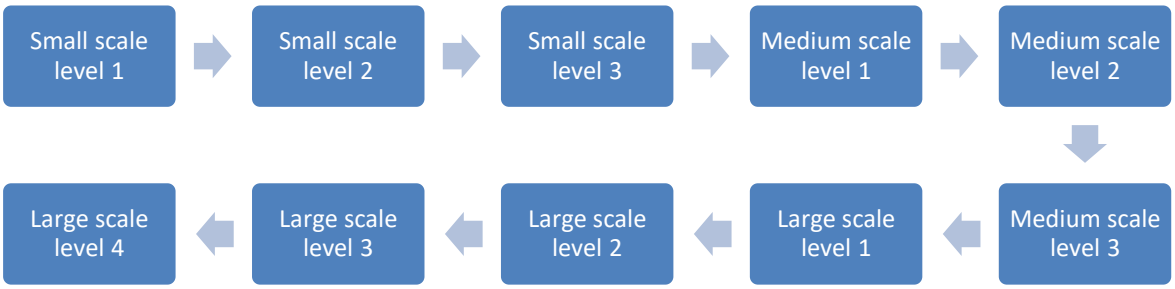

Figure 5 Process scheme of way of working

4.4 Creation and visualization of PMI

Siemens NX 11 comes with a PMI package that incudes GD&T, 3D annotation like Surface symbols, welding symbols, and notes. The package also includes section view.

Below in Figure 6, a 3D model including PMI data can be seen. The part belongs to a frame of an FGSU (Fuel Gas Supply Unit) module. The visualization has been checked in the JT2Go app on a computer and on a mobile device. The picture below in Figure 6 is a screenshot from JT2Go desktop app on a computer. It has been exported as a JT format from Siemens NX 11. All PMI data except the measurement of the non-bendable plate was possible to create in one single view in PMI. The measurement of the non-bendable plate in a 2D drawings can be seen in Figure 8. To get all the information needed in PMI, more amounts of views needs to be created.

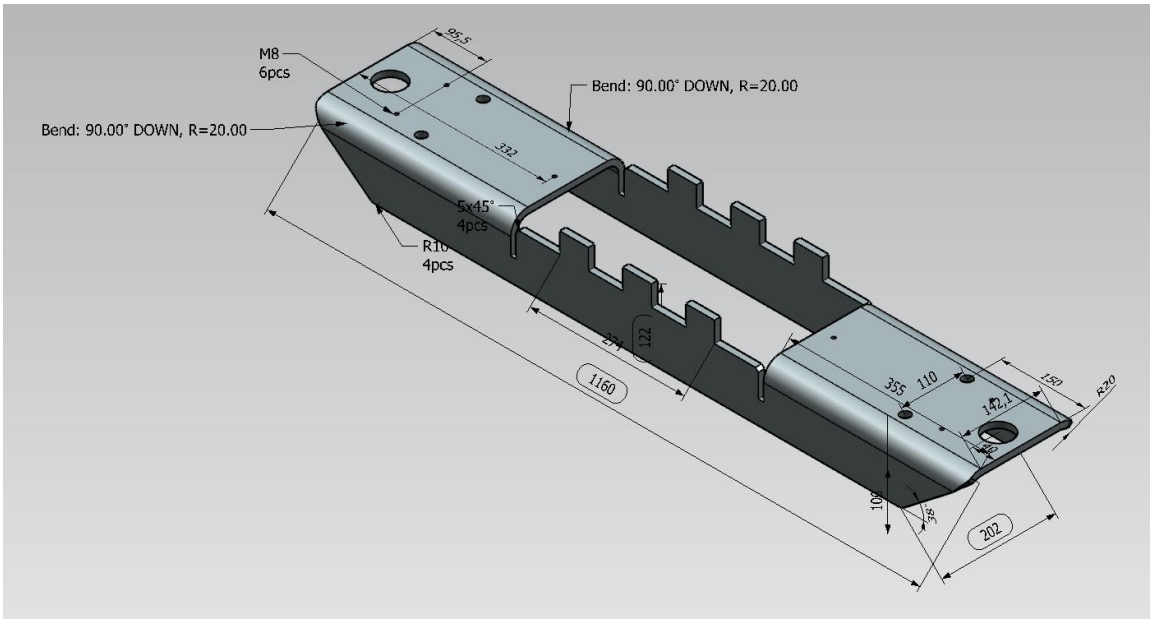

Figure 6 3D model including PMI on desktops app on windows computer

The same JT file have also been tested on a mobile device. The size of the screen is 5.8 inches. This can be seen in Figure 7 below.

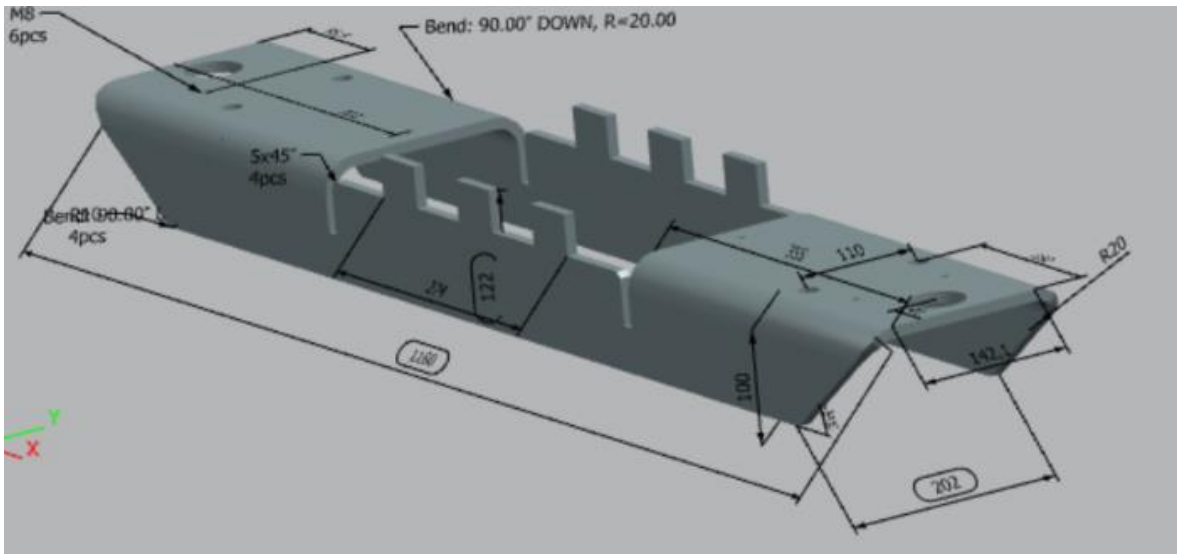

Figure 7 3D model including PMI on JT2Go on a mobile phone.

2D drawings require 4 different views of measurement for this product, as well as the isometric view. A screenshot from a PDF file of the 2D drawing can be seen in Figure 8 below.

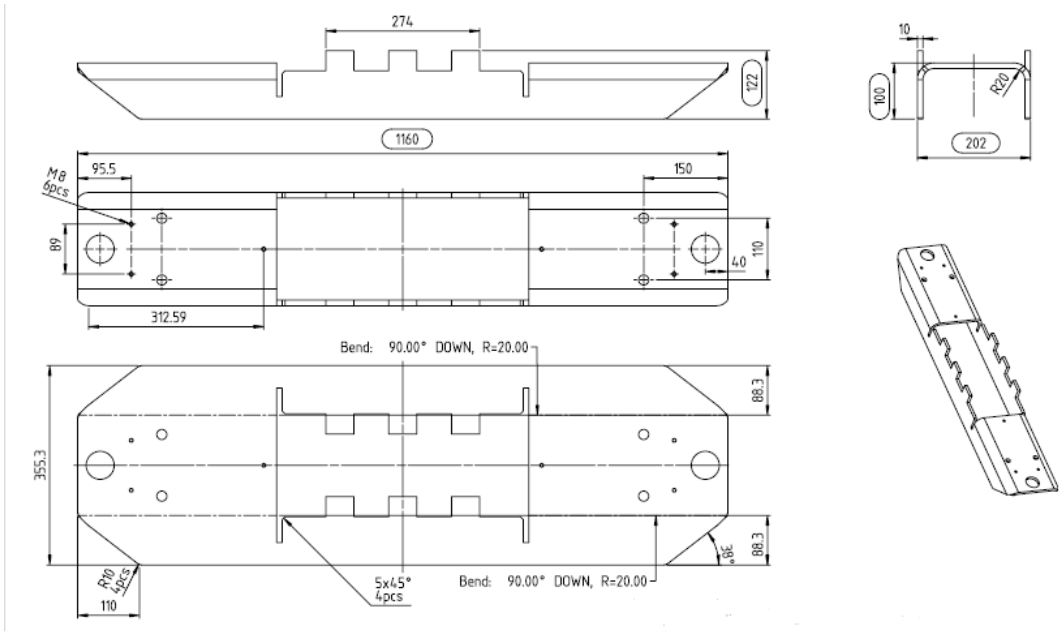

Figure 8 Screenshot of a corresponding 2D drawing of the same product

The views that are in 2D drawing are also possible to make in PMI. All views that are made in PMI are rotatable. The PMI information can be divided in different views that can be seen in Figure 9 and 10.

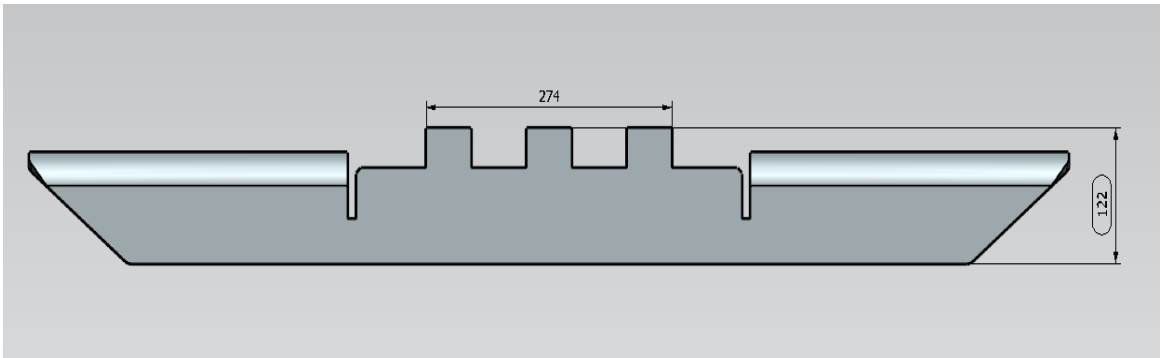

Figure 9 Side view from JT2Go

When the PMI is divided in different views the information is more clear and easier to understand.

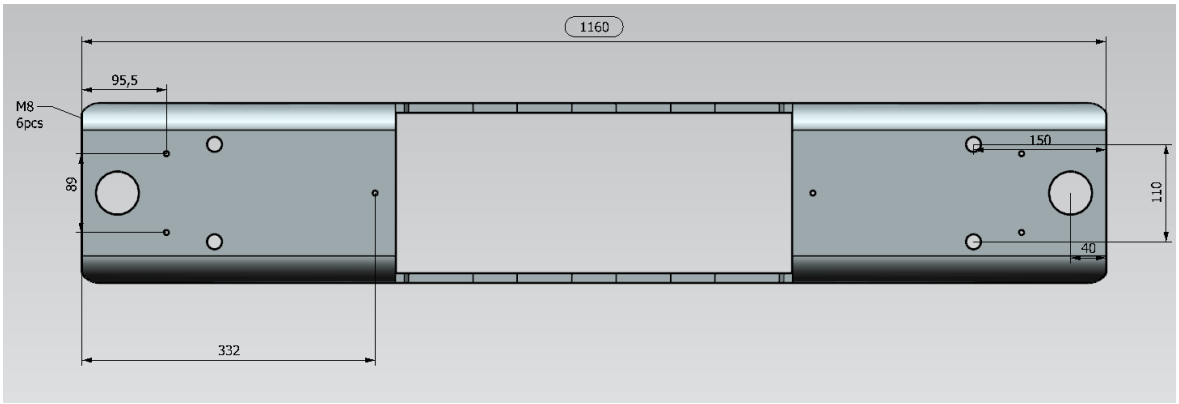

Figure 10 Top view from JT2Go

5 Discussion

5.1 Creation of PMI

The creation of 3D annotation is extremely similar to the creation of 2D annotation in 2D drawings. The symbols look notably alike one another in the PMI and the 2D drawings.

The visualization plays an important role here. The way of showing the 3D model can be done with only one view as seen in Figure 6. This works with rather small pieces and a limited amount of PMI data.

When the amount of PMI data increases, the data needs be divided into different views like side view (Figure 9) and top view (Figure 10). Every view contains different measurements and in every view the 3D model can be rotated. If a large amount of PMI data is placed in the same view there will be hard to find the measurements.

When measurements are created it can go wrong by mistake. Wrong line or corner can be selected by mistake instead of another one. It seems that you have selected one line, but another line is selected and the CAD program the give the user a wrong measurement. In the 3D model there are more lines, surfaces and corners that in a 2D view. Therefor the risk of choosing wrong is bigger. The designer needs to be careful when putting all the measurements.

5.2 Visualization of PMI

The visualization has been tested on JT2Go, which is a software provided from Siemens. This software can read JT files. A JT file is a light version of a 3D model.

In Figure 6 we can see how the 3D model is visualized on a computer compared to Figure 7 where the same figure is shown on a mobile device. The 3D model on the mobile device is extremely hard to see. The symbols are not as clear as on the computer. The size of the screen plays an important role for visualization.

The data transfer is exceedingly smooth. Exporting the prt file (CAD file) to an JT file goes by easy and fast. The JT file includes all PMI information that has been created, and they are visualized in the same views as they have been created in the CAD program.

When changes in the 3D model are necessary, they can edit the same PMI version. However, a new JT file needs to be exported from the CAD program.

5.3 Time saving

How much time can then really be saved when using PMI instead of creating 2D drawings? According to Table 1, the designers almost saved no time at all when creating 3D annotations instead of 2D annotations. The same amount of 3D annotation needs to be created in the PMI as in the 2D drawings. However, it needs to be noticed that one of the designers was not trained for 3D annotation but had much experience of creating 2D annotations.

According to Figure 2, 21 percent of the designing time was spent on creating the 2D drawings and 12 percent was spent on making changes to the 2D drawings. This means that 33 percent of the total designing time are spent on 2D drawings. This does not show us how much time it will take to create the 3D annotations.

The delivery of the drawing could run much faster with digital drawings compared to a paper version. The need for actual printing the papers is not included when we are talking about digital drawings.

The time savings are not in the PMI. The time saving is in the whole process when fever mistakes are made.

5.4 Risks of when using the process scheme

There are several risks that may occur while taking MBE into use. Taking MBE into use should happen in a slow pace. When moving too fast more errors and mistakes will happen.

Risks of misunderstandings between designers and the manufacturer are at a rather high risk. There needs to be scheduled time for check-ups between the designers and manufacturers every week. When using the model in Figure 5 the risks can be seen in rather early stages and can then be minimized quicker. Risks can be seen before they happen. But still, risks and misunderstandings will probably always happen when implementing something new. That is why we need to start at small scale.

There is a big step between the small and the medium scale, as well as between the Medium and the Large Scale. There are plenty of new components with much manufacturing information. A lot of time needs to be put at the work when moving into these stages.

5.5 The acceptance for the manufacturers

How can we then get the manufacturers get agree and adopt MBD? To make this happen we need the acceptance from the manufacturer. The manufacturers are used to look and take all information from the 2D drawing, and they are well trained of that. When a manufacturer agrees on starting adoption towards MBE, they still need to take a lot of action in order to make it happen. An MBD file is completely different to read from a 2D drawing. New hardware like tablets, computers, or mobile devices is obligated to be obtained. Instead of 2D drawings that have been on paper or in PDF format they will now have a light 3D model for visualization. This requires new software, such as eDrawings or in JT2Go. This demands training for understanding the software and the PMI model.

What benefits will the manufacturers get? The process will be faster when using MBE. There is no need to print new revision all the time. Instead the newest PMI model will already be ready on the tablet.

There is a big use of the 3D model containing the PMI data during assembly. When doing the assembly, the 3D model can be rotated, and the manufacturer will get a better understanding of where the parts should be placed. According to (AR provides a competitive edge for manufacturers, 2018) the assembly time by 50 percent by using AR technology. AR technology requires PMI data. AR technology does not work with 2D drawing in paper or pdf format.

5.6 Future outlooks of digitalization

How will a factory use digitalization in 2030 or 2040? Computers and tablets are the most common digital tools for visualization of drawings in factories today. VR and AR technology have been expanding a lot over the past years in many different environments. eDrawings format is supported in VR and AR technology. This means that an eDrawings file can be seen in VR or AR glasses.

Superimposition based AR technology could be one good alternative for assembly process in the future. The AR glasses that includes a camera can for example recognize the frame in the reality and show a virtual 3D picture where the components should be placed. The manufacturer can see the drawings (3D model) and the workpiece at the same time. The AR technology recognize the different components and informs the manufacturer if the components are assembled right or wrong. This technology also works on tablets and mobile devices.

The environment and the climate change have become a hot topic in the recent years. MBD doesn't mean paperless manufacturing, but when using PMI instead of 2D drawings, the use of paper will be less. Less use of paper means less harm for the climate and is also a way of saving money.

BIM (Building Information Modeling) has been studied. BIM and MBD is quite close to each other. Both BIM and MBD contains a 3D model with technical information. The difference is that BIM is focusing on constructions and not on a single product like MBD. BIM at highest Level is 6D, which means full collaboration and full integration in a cloud-based environment. This corresponds to MBE (Model-Based Enterprise) which means an organization that uses model-based engineering.

Is there anything that we can learn from BIM? The BIM is much categorized, and the Levels are extremely clear. In BIM they want to have all needed information in the model including time management and costs. MBD instead is only about technical data information about the product.

This thesis can be used as a base for further investigation regarding the adoption of MBD. There is a need for further studies which could investigate the complete process from an MBD model to a manufactured product. A prototype should be manufactured based on an MBD file including PMI data. This would require action from the designers and the manufacturers. This could for example be done on a small or a medium scale and have 3D models as master and 2D drawings as backup.

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