Benefits and Usability of a Digital Twin System

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EXAMENSARBETE

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Inriktning: Konstruktion

Handledare: Leif Backlund och Samuli Räsänen

Titel: Fördelar och användningsmöjligheter med en Digital Twin system

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Abstrakt

Detta examensarbete gjordes åt UPM Kymmenes cellulosafabrik i Jakobstad. Jakobstads cellulosafabrik producerar råvaror för papperstillverkning, som kallas för cellulosamassa. Jakobstads cellulosafabrik kan producera cirka 800 ton cellulosa per år.

Cellulosafabriken har varit i bruk i flera decennier och ett problem som man har märkt är att information som behövs för det dagliga arbetet kan vara svår att hitta eftersom fabriken har växt och blivit mer avancerad med åren.

Syftet med detta examensarbete har varit att studera Digital Twin och att ta reda på fördelarna och användningsmöjligheter för Digital Twin.

Med hjälp av Digital Twin skulle Jakobstads cellulosafabrik kunna föra in befintlig information och data om ett föremål till Digital Twin, såsom rörsystem, maskindata och använda den data för att ta reda på till exempel när en maskin behöver underhållas. Detta skulle skapa en virtuell simuleringsmodell från produktionslinjen som skulle kunna användas för olika avdelningar som projektplanering, underhåll och drift.

I detta examensarbete intervjuades flera Digital Twin-tillverkare om deras definitioner av Digital Twin och hur deras Digital Twin-program kunde hjälpa Jakobstads cellulosafabrik. Flera intervjuer genomfördes med UPM-personal för att ta reda på vilka utmaningar de möter under arbetsdagen och hur de kan använda Digital Twin som verktyg i sitt arbete.

Resultatet baserades på intervjuer och på Digital Twin-litteraturen, resultatet visar hur Digital Twin kan användas för att hjälpa UPM-anställda en jämförelse mellan två olika Digital Twin-program.

Språk: engelska
Nyckelord: Digital Twin, Cad Matic eShare, Process genius, PLM, IoT

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Nimike: Digital Twin -ohjelman hyödyt ja käyttötarkoitukset

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Tiivistelmä

Tämä opinnäytetyö tehtiin UPM Kymmenen selluloosatehtaalle Pietarsaaressa. Pietarsaaren selluloosatehdas tuottaa raaka-aineita paperinvalmistukseen, raaka-aineen nimi on sellu. Pietarsaaren selluloosatehdas pystyy tuottamaan noin 800 tonnia selluloosaa vuodessa.

Selluloosatehdas on ollut käytössä useita vuosikymmeniä ja ongelmana he ovat todenneet, että arjen työssä tarvittavia tietoja voi olla hankala löytää tehtaan kasvaessa ja kehittyessä vuosien varrella.

Tämän opinnäytetyön tarkoituksena on ollut tutkia Digital Twiniä ja selvittää Digital Twinin hyödyt ja käyttömahdollisuudet. Digital Twinin avulla Pietarsaaren selluloosatehdas pystyisi viemään olemassa olevia teknisiä piirustuksia ja prosessi dataa Digital Twiniin, kuten putkijärjestelmiä ja konetietoa ja näiden avulla selvittämään esimerkiksi, milloin kone tarvitsee huoltoa. Ohjelman avulla voidaan tehtaasta rakentaa 3D-malli ja yhdistää siihen tehtaasta kerättyä tietoa ja näin saadaan tehtaasta luotua virtuaalinen malli. Tämän rakennetun mallin avulla voidaan jäljitellä yksittäisen koneen ja prosessin kuntoa sekä löytää teknisiä tietoja ja dokumentteja, jotka on liitetty aikaisemmin rakennettuun malliin.

Tässä opinnäytetyössä haastateltiin useita eri Digital Twin -ohjelman valmistajia. Eri valmistajat saivat kertoa miten heidän Digital Twin -ohjelmansa voisi auttaa sellutehtaan arkipäivää. Opinnäytetyössä haastateltiin myös UPM:n henkilökuntaa. Haastatteluissa pyrittiin selvittämään minkälaisia haasteita ja ongelmia heillä oli työpäivän aikana. Ongelmaksi muodostui usein se että teknisiä dokumentteja oli vaikea löytää nopeasti ja se vaati usein paljon aikaa.

Lopputulos perustuu Digital Twin -valmistajien sekä yhden käyttäjän haastatteluihin ja Digital Twin -kirjallisuuteen. Työssä selvitetään miten Digital Twiniä voidaan käyttää apuvälineenä tehtaalla. Työssä vertailtiin myös kahta eri valmistajan Digital Twin-ohjelmaa ja selvitettiin ohjelmien ominaisuuksia ja hyötyjä Pietarsaaren tehtaalle.

Kieli: englanti
Avainsanat: Digital Twin, Cad Matic eShare, Process genius, PLM, IoT

BACHELOR'S THESIS

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Abstract

This thesis was done for UPM Kymmene's pulp mill in Pietarsaari. The Pietarsaari pulp mill produces mainly raw materials for papermaking (pulp) and is capable of producing about 800T of paper pulp per year. The pulp mill has been in use for several decades and a problem they have found is that the information needed for everyday work can be difficult to find as the mill has grown and become more advanced over the years.

The purpose of this thesis was to investigate about Digital Twin to find out the benefits and usage of a Digital Twin for the Pietarsaari Pulp mill.
With the help of the Digital Twin, the Pietarsaari pulp mill would be able to retrieve existing information and data about an object to the Digital Twin, such as piping systems, machine data and, use the data to find out, for example, when the machine needs maintenance. This would create a virtual simulation model from the production line that could be used for various stakeholders such as operation, maintenance, and project supervision.

This thesis work includes an interview with different Digital Twin manufacturers, about their definitions of Digital Twin and how their Digital Twin program could help Pietarsaari pulp mill. Several interviews were also conducted with UPM staff to find out what challenges they faced during the working day and how they could use Digital Twin as a tool in their work.

The result is based on interviews and the Digital Twin literature, which shows how Digital Twin can be of use to UPM employees and a comparison between two different Digital Twin programs.

Language: English
Keywords: Digital Twin, Cad Matic eShare, Process genius, PLM, IoT

Table of Contents

Abbreviations

BIM	Build Information Module
CAD	Computer-Aided Design
DT	Digital Twin
DTE	Digital Twin Environment
DTI	Digital Twin Instance
DTP	Digital Twin Prototype
EBAM	Evidence-Based Asset Management
IoT	Internet Of Things
IIoT	Industrial Internet of Things
PLM	Product Lifecycle Management

1 Introduction

1.1 UPM-Kymmene Oyj.

UPM Kymmene is a multinational company with over 18000 employees, spread over 27 countries. UPM Kymmene's main headquarters is located in Finland's capital, Helsinki. UPM has 3 Pulp factories that are located in Finland, Pietarsaari, Kaukas, and Kymi.

Pietarsaari PULP mill has over 750 people working at the mill site and about 230 are employed by UPM. On the mill site, there are also Alhomens kraft powerplant, BillerudKorsnäs, Walki, UPM's Alholman sawmill, and UPM's wood procurement office.

The Pietarsaari Pulp mill produces paper pulp out of birch and Conifer trees. The plant has a capacity of 800 000 tonnes per year and most of it is shipped out to the world by the nearby harbour. (UPM, 2022)

Figure 1 Pietarsaari pulp mill

1.2 Problem definition

As a plant becomes bigger and more complex so does the data it generates. To keep all the data organized is not easily done, usually, the data are located in different systems meaning multiple logins and guessing where a specific data could be located. The data could be the plant's technical data, active or old project information, documentation, or process data that have been gathered throughout the years.

UPM Pietarsaari pulp-mill has the exact problem where a large amount of the data that are needed for everyday tasks is hard to find and the data is also saved in multiple programs or is located in a physical archive, making information gathering a lot harder when they don't know where to start looking for that information. Data and information are needed for literally everything, decisions making, maintenance, operation, safety, projects. For example, a person wouldn't buy a car without knowing information about it, such as fuel consumption, price, or maintenance history. The same could be said for a process plant where decisions and planning are a big part of everyday work. It could even cost millions if a wrong decision is made because of a lack of information or if the information is mistaken for something else.

How much could a company save if their workers are working effectively in searching for information or having a tool that could do it for them, instead of having them spend hours searching for the information? A tool that could reduce the time for searching information as well visualizing the information making it easier to discern information from each other. Reducing the chance of wrong decision-making or minimizing faults in a plan.

1.3 Purpose

The purpose of the thesis was to investigate if Digital Twin holds any benefits for UPM Pietarsaari and how Digital twin can help the users in their everyday tasks such as document findings.

1.4 Aim

This thesis aims to learn about digital twin from literature, software providers, user experiences, and discovered different uses of different Digital Twin systems.

1.5 Delimitation

Literature of Digital Twin and usability.

Digital Twin with cad models.

Interview with different companies and UPM staff.

Does not include process optimization.

1.6 Disposition

Chapter 1	Introduction
Chapter2	brief explanation of 4.0, IoT & PLM
Chapter3	explanation of what Digital Twin is and the different DT programs
chapter 4	Method: explanation of the execution of this thesis
Chapter 5	Results: displays the result of the investigation.
Chapter 6	Discussion: reflection on the thesis as a whole and the result.

2 Industry 4.0, IoT & PLM

2.1 Industry 4.0

The industries have been through three revolutions in the past few centuries and all of them included big changes to the industry itself and the world as a whole.

The first revolution gave the mechanization of the ordinary task. The second revolution gave mass production and the third gave computing and automation. But those mentioned are only a few changes of many happening during each revolution.

Figure1 is showing more in detail what kind of changes happen in each revolution including the fourth revolution which is happening right now.

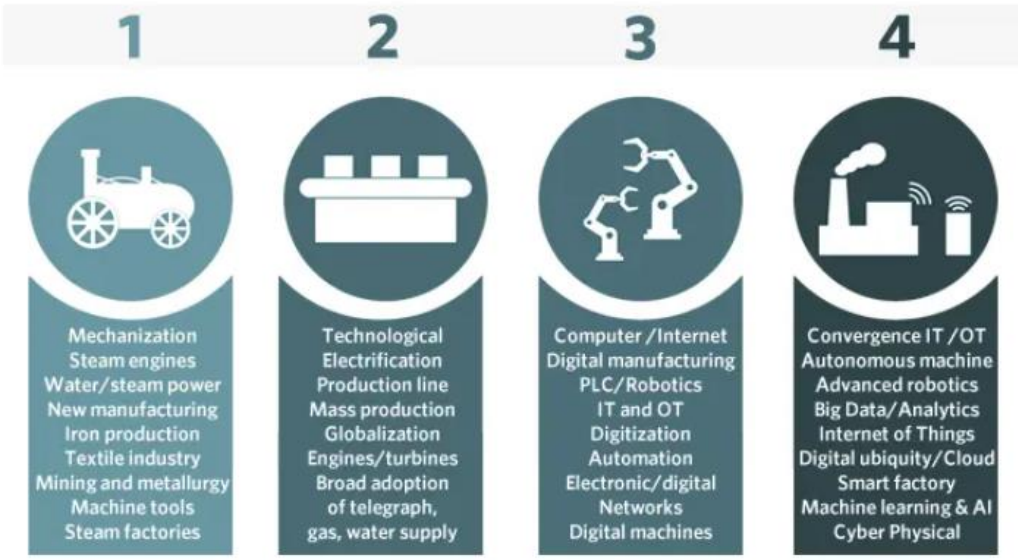


Figure 2 Different changes by each revolution (I scoop, n.d.)

The definition of Industry 4.0 could be said as follows, "name for the current trend of automation and data exchange in manufacturing technologies, including cyber-physical system, the internet of things, cloud computing and cognitive computing and creating the smart factory" (I scoop, n.d.).

The goal of Industry 4.0 is to make the industries more autonomous and connected to the world (I scoop, n.d.). Meaning the factories will not need as much human interaction.

It would be connected to the internet all time and share all its data with different sources, the factories would be smarter and more independent.

Few of those tools could be advanced autonomous robots with integrated machine learning and AI's. A Digital twin system that can connect different information to one place and cloud computing.

2.2 IoT

IoT or Internet of Things is a big "Umbrella term" meaning it contains multiple uses cases, standards, technologies, and applications into one single terminology.

I-scoop made a similar explanation of what IoT is, people can use phones or computers to get access to the internet for sharing information, and data with other people anywhere in the world. People can analyse and respond to the data they received from the internet if it is a work order or receiving a notification of a package you need to pick up from the post office. The same concept can be said for things. IoT is the concept of connecting objects to the internet and letting the object freely transmit and receive data from different IoT objects throughout the internet and act accordingly to the information it gets with minimal human interventions. (I-Scoop) (Oracle, n.d.)

There are seven criteria for something to be called IoT as seen in Figure 3.

- Things:

  It must be a device or object equipped with smart sensors

- Data

  The object needs to have analytical data that can be transmitted

- Communication:

  IoT device needs to communicate from Machine to Machine (M2M) with a stable data flow.

- Intelligence:

  IoT devices must be smart and be able to compute the analytical data

- Actions

  IoT devices can make their own decisions on what type of action they should take after analyzing the data

- Ecosystem

  IoT devices can adapt to change according to the actions of the neighboring IoT device

- Connectivity

  IoT is always connected to the internet and communicating with each other.

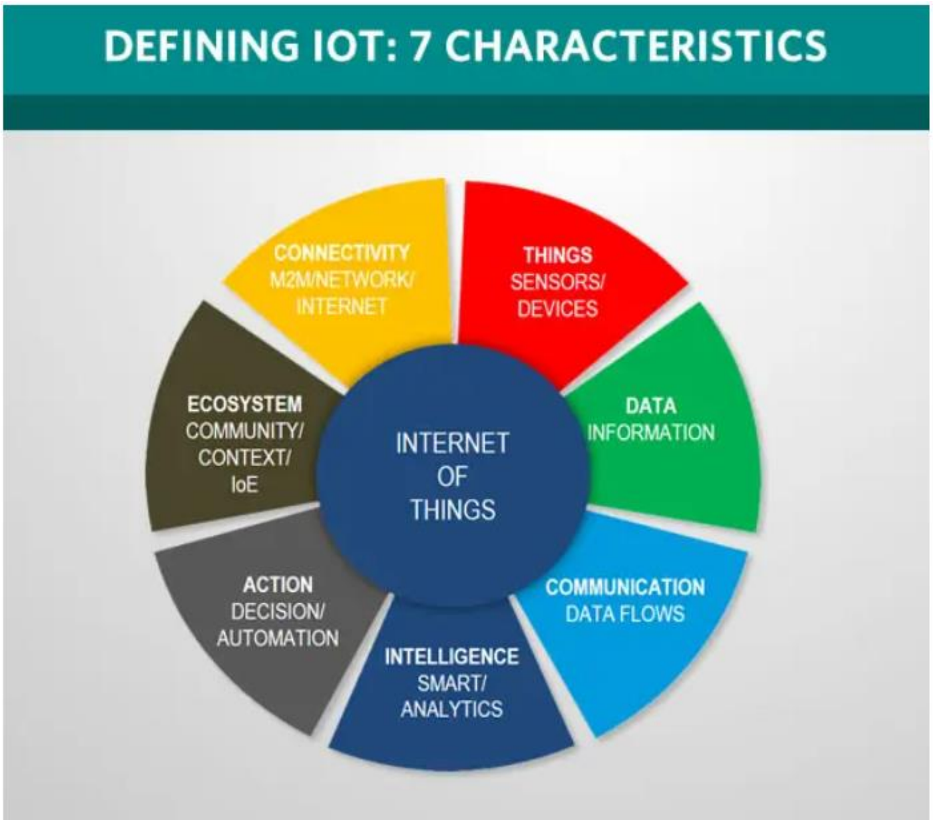


Figure 3 seven criteria for an IoT (I-Scoop)

IoT can be divided into two groups one for consumer uses and the other for Enterprises. The enterprise IoT or Industrial Internet of Things (IIoT) is to use IoT devices on an industrial level. IIoT could be used as wireless communication, control, and automation as mentioned by (Oracle, n.d.). While on the consumer level it could be communication between smartphones and smartwatches or smart households' appliances to any smart gadget.

2.3 Product Lifecycle Management

Product Lifecycle Management or PLM for short is the idea of how to handle a product throughout its lifetime and make it as effective as possible. PLM has four different stages figure 4, PLM begins from the moment there is an idea of a product that has value to the customers and how it should be designed for optimal value. When the product has left the creation stage it goes on to the build stage. In Build stage, it focuses on how it should be manufactured and how it should be installed. The Sustain stage goes through how it should be maintained and how much it can be maintained before it gets unprofitable. the fourth stage is to plan how to dispose of and recycle the product. (Salimi, 2021)

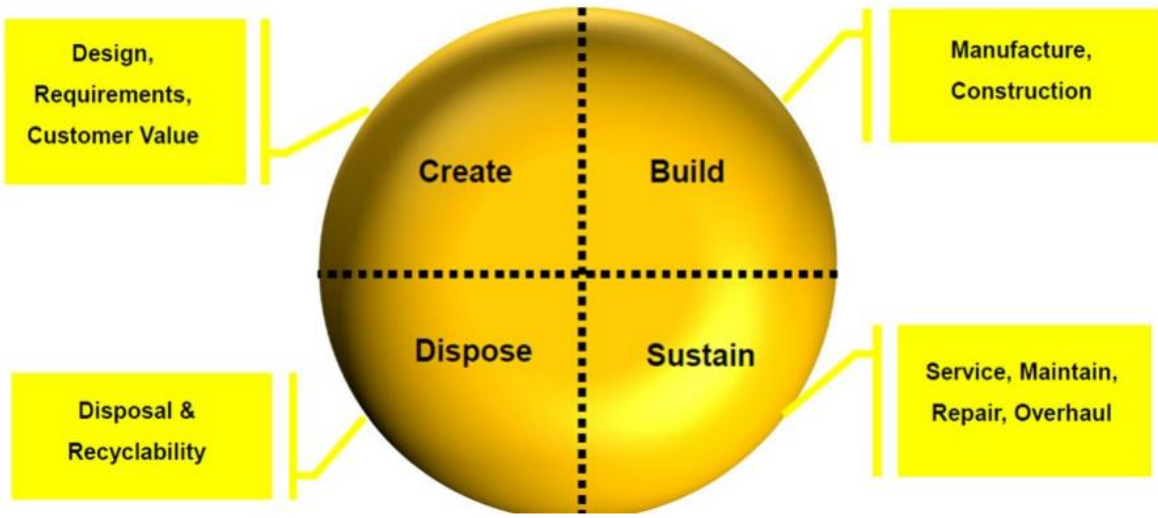


Figure 4 Product Lifecycle Management stages (Salimi, 2021)

3 Digital Twin

3.1 History of Digital Twin

The first concept of Digital Twin was brought up in a 2002 presentation for product lifecycle management (PLM) by the University of Michigan, Dr. Grieves. The presentation was called "Conceptual Ideal for PLM" but it had the elements for what could be called Digital Twin today. The presentation illustrated two boxes (Figure5). The left box represented the real world while the right box represented the virtual world and between those two boxes were two links that represented data flow from the real world to the virtual and back. Underneath the virtual space were smaller virtual spaces that represent different types of instances. (Michael, 2016)

This concept shows how the digital model evolves according to the real object and how the digital model can improve the real object by sending a new set of data that have been optimized. It also shows how one big virtual space is comprised of multiple smaller virtual spaces to create one bigger product.

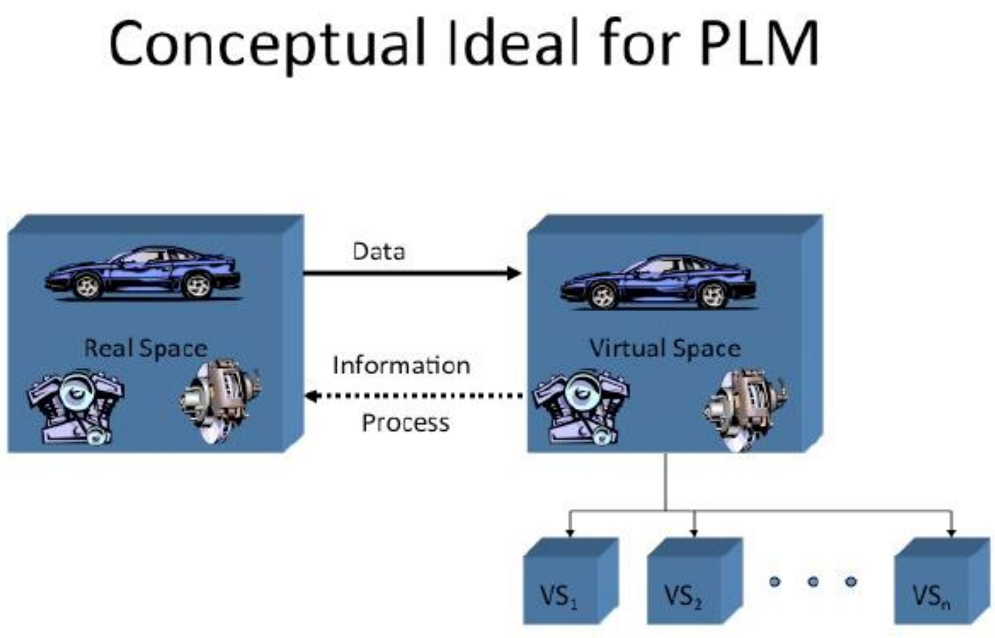


Figure 5 Conceptual Ideal for PLM (Michael, 2016)

3.2 What is a Digital Twin?

The digital twin has been defined in many ways over the years. It has been called a “digital model, doppelganger, clone, footprint, software analog, representation, information constructs or simulation of its physical counterpart.” (Maulshree, Evert, Yuansong, & Patrick, 2021) The DT does not have one correct definition because each industry has a different view on the DT, so it has then been left to each provider or scholar to determine what DT is to them. Leading to the wide variation of the DT system and definitions of DT.

The most common definition for a DT could be said like this, “Digital Twin is a digital representation of the physical product in all its aspects”. (Siemens: AI and Digital Twins for Manufacturing (CxOTalk), 2019) Meaning the DT holds all information about the object that could be observed or the actions of the physical object itself. Such as Geometry, mass, components, motion, vibration, heat, and even the software it uses. The DT could be thought of as a “library” consisting of every information that is related to the real object. DT can use other integrated systems to process the information it has. The information can come from IoT sensors or be manually added, with the information and integrated systems. It could create a simulation and optimize itself according to the result of the simulations. The Digital twin also lives through the entire life of the object as a living model where every change on the real object reflects on the virtual one and another way around. (Siemens: AI and Digital Twins for Manufacturing (CxOTalk), 2019) (IBM, 2017)

3.3 Types of Digital Twin

The Digital Twin is thought of as a cradle to the grave concept in the manufacturing, and process industry if it’s building a product or an entire plant. The DT can be divided into three types depending on which stage the object is in.

The three types are Digital Twin prototypes (DTP), Digital twin Instance (DTI), and Digital Twin Aggregate (DTA). DTP is used before there is an actual product, it is usually used to optimize and simulate the product or process before building it. For the DTP, instead of gathering data from an IoT sensor, all information is manually added to the twin model. After the product is built and put in operation a DTI is created as an independent model out of the DTP model. DTI is also connected to individual objects throughout the lifetime. Some might say there are only two DT types as DTA is the combination of multiple DTI. Figure 6 shows an easy illustration of every DT type.

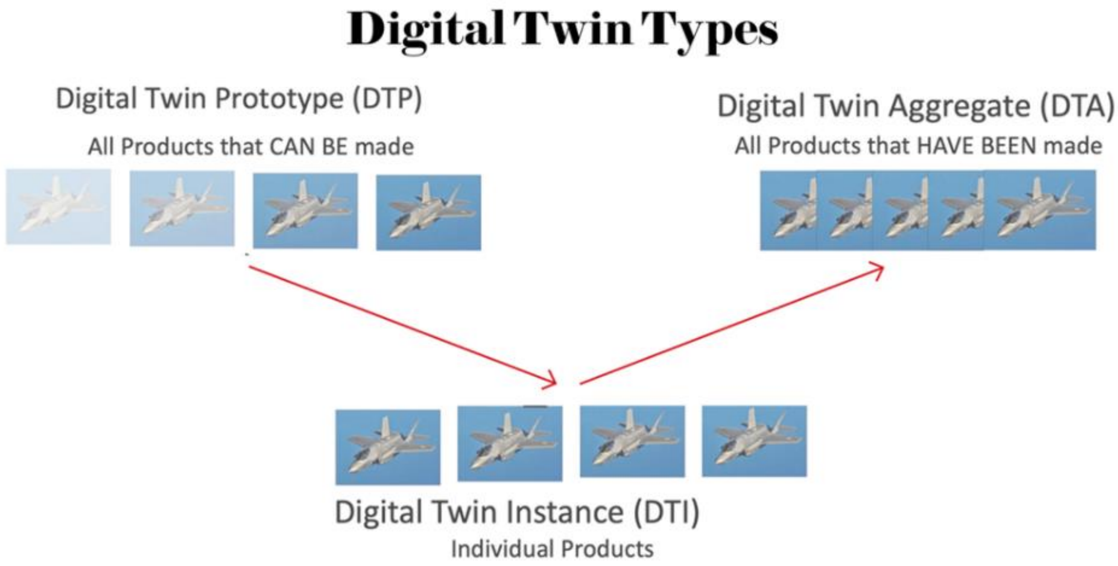


Figure 6 illustration of DT types (Grieves, 2019)

All types are also operated with a multidomain physical space called Digital twin Environment (DTE). (Vickers.J & Grieves.M, 2017) (Siemens: AI and Digital Twins for Manufacturing (CxOTalk), 2019) (Maulshree, Evert, Yuansong, & Patrick, 2021) (Grieves, 2019)

3.3.1 Digital Twin Prototype

DTP is a DT system that can describe a prototype of its physical properties and displays necessary information to create a physical object that can mimic the virtual version. (Vickers.J & Grieves.M, 2017) The information that is needed for a DTP is the entire PLM documentation and more if necessary.

The Following pointers are needed information for DTP, but it’s not limited to those only.

- A detailed 3D Cad model.
- Bill of materials.

  BoM: A list of every material, and component used in the prototype. (Littlefield, 2012)

- Bill of process.

  BoP: Bill of the process contains all information that is needed for building the product and how it's used. (Littlefield, 2012)

- Bill of services.

  BoS: contains, the cost for maintenance, maintenance plans, and any information needed for service.

- Bill of disposal.

  BoD: documentation on how the product should be dissembled and recycled.

Figure 7 shows a simplified illustration of the DTP structure. Where the user can access the DT model and the integrated systems, analytical data, and documentation. DT model receives information from the integrated system such as simulation results and optimization results

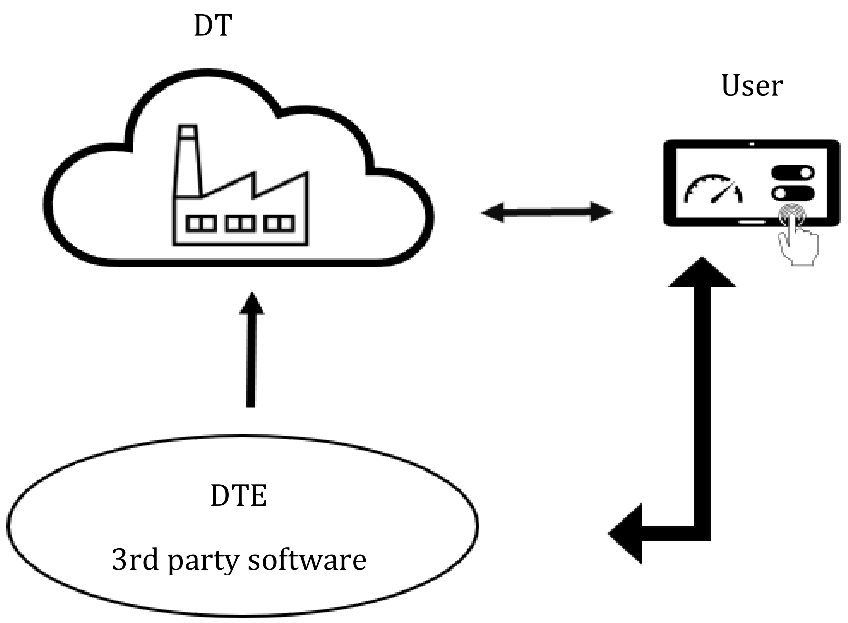


Figure 7 Simple illustration of DTP, this illustrates how the user has full control over DT, DTE, and any 3rd party software. Where any action made by the user affects what happens in the DT model.

3.3.2 Digital Twin Instance

Digital twin instance is an independent DT connected to an individual product. The DTI lives its own life and is not affected by any other product's life history. (Vickers.J & Grieves.M, 2017)

The information that can contain inside a DTI are parts of the PLM that are necessary during operation but there can be more information if wanted.

- 3D CADmodel with Geometrical Dimensioning and Tolerancing.
- Bill of materials, such as old components and newly fitted components.
- Bill of process.
- Bill of services.

Figure 8 works in the same way as Figure 7 the only difference is that DTI also receives data from the physical product and DTI can transmit a new set of data to the physical product.

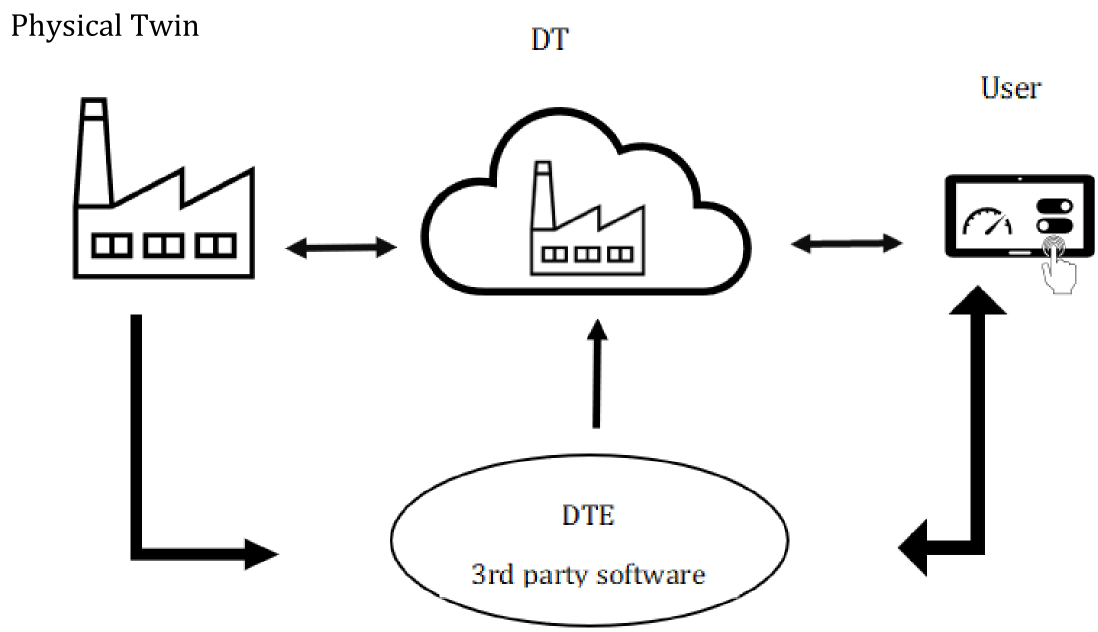


Figure 8 Simple illustration of DTI. DTI works in the same way as described in Figure 7 only difference is when something affects DT it also affects the physical twin and the physical twin is sending data to the DTE which is sending optimized data to the DT.

3.3.3 DTA

Digital Twin Aggregate (DTA) is the name when multiple DTI of the same type of object are aggregated into one single place. DTA can be used as a failure prognostic and machine learning tool for a product type. (Grieves, 2019)

3.3.4 Digital Twin Environment

DTE is an integrated, multidomain physics application space for DT's operation. The purpose of DTE is to predict the behavior of one or multiple objects inside a DTP, DTI, and DTA systems. (Vickers.J & Grieves.M, 2017)

DTP can use DTE as a simulation tool to predict if the design will hold inside the specified tolerance and optimize the design according to the result of simulations. For a DTI it can predict when the design is about to fail or how to optimize the individual product with the help of online data. DTA can use DTE to predict fault for the general type of product.

3.4 Digital threads

Digital Threads is a data-driven architecture that connects and stores data to the DT. The digital thread has been confused as a part of DT, because of how closely they are working together and because of the wide definition of DT. (Maulshree, Evert, Yuansong, & Patrick, 2021) (Miskinis, 2018)

The difference between Digital Threads and Digital Twin according to Carlos Miskinis. The "Digital twin is the current representation of a product or system, mimicking a company's machines, controls, workflows, and systems. the Digital threads meanwhile is a record of a product or system lifetime, from its creation to its removal." (Miskinis, 2018) Simply said the digital thread is not a part of DT itself, but DT utilizes the digital threads as a road to trace the information of the object, display the information at the right time and place as well as store the information for later uses.

All the data brought up in DTP and DTI is provided by the digital threads. Figure 5 and figure 6 shows a simplified structure of both DT types. the arrows in those figures are digital threads connecting everything into the Dt and providing a flow of information from different sources.

3.5 Value of Digital Twin.

The Digital twin is seen as "The backbone of industry 4.0" because of its values to gather information from different sources and using that information to reduce unexpected occurrences, wasted physical resources, time, energy, and materials. (Maulshree, Evert, Yuansong, & Patrick, 2021) (Vickers.J & Grieves.M, 2017)

Grieves and Vickers said if a human was "omniscient and omnipotent" there wouldn't be any wasted resources in any task that would be given to a human, meaning a human would know everything and could do anything with the least amount of time or material for completing a task. However, a human will always leave wasted resources as they are not a computer that knows all information and the procedures that are needed to complete the task with minimum effort.

Grieves and Vickers illustrated this with a chart (Figure9) keep in mind it's meant as an illustration of an ideal and it is not definitive. The chart illustrates the amount of physical resources that goes into completing a task. (Vickers.J & Grieves.M, 2017)

The two bottom parts show the minimum amount of physical resources needed to complete a task if a human was an omniscient and omnipotent being that would know everything and perform the task with no waste of resources. The top left pillar shows how much physical resources are being wasted on a task when the needed information is hard to come by while the top right pillar shows how much physical resources are being wasted when the information is easier to find.

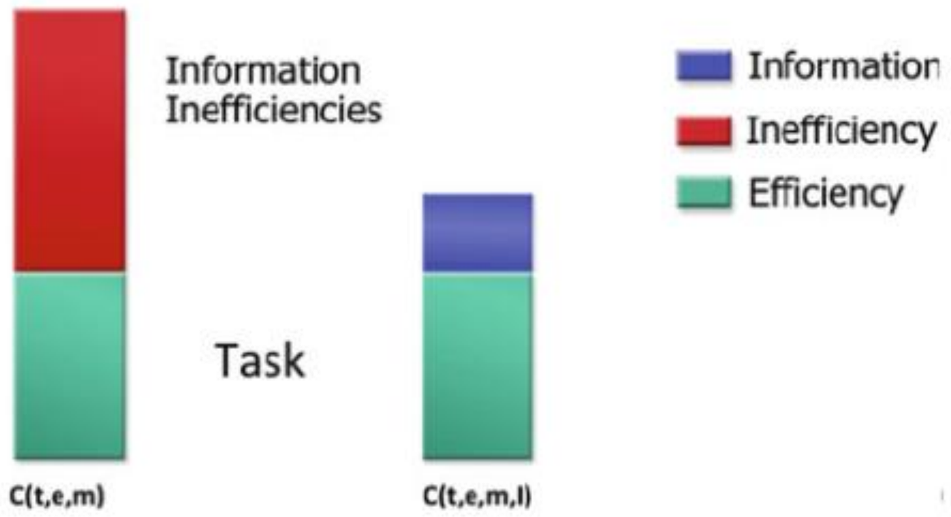


Figure 9 illustrates the amount of resources being used in a task (C(t, e, m) Cost, time, energy, material) (Vickers.J & Grieves.M, 2017).

Figure 9 showed as long as a human is a factor in any task there will be a waste of resources but with help of DT, it could reduce the amount of wasted resources that a person uses to complete a task. Here are a couple of examples of what kind of reduction in resources could be expected with DT.

- Faster product/ process planning and redesigning.

  DT's ability to gather and process information gives project planners an accurate view of the product or process will work as intended before building it leading to less material waste and redesigning will be faster with accurate data from the previous design.

- Reduce cost

  DT can reduce cost on any task that involves finding information as well as finding faults with the process plan before the actual fault is found on-site leading to more expenses for redesigning and rebuilding.

- Predicting and improving maintenance

  Maintenance planners can use DT’s online data to predict when the object needs maintenance, reducing the chance of any unexpected and costly shutdowns and improving how the maintenance is done.

- Optimizing operation

  process or product could be optimized already in the design phase but with the help of online data, it could be optimized when it is in use leading to reducing wear and tear on the machinery as well as keeping the best efficacy for the machinery at the exact time it’s in.

- Disposing of old machinery

  when disposing of old machinery. the DT can give quick access to how It should be recycled leaving less wasteful materials.

3.6 Different Digital Twin systems

As mentioned in the previous chapters, the DT has different definitions and views on how DT should work pending on the provider. This chapter will show two different Digital Twin systems with two different takes on how DT should work and two different groups of people that would be using it.

3.6.1 Cadmatic eShare

Cadmatic eShare is a DT system that focuses on the entire lifecycle (figure10) of a plant, building, or ship. eShare purpose is to gather information on the asset and display only the information the user wants to see. eShare is only a reading software where it can only show information about the asset or the object and the information on the asset can't be altered directly from the eShare.

As mentioned eShare starts from the design phase and stops with the disposal phase. It could be said that eShare has the characteristic of both DTP and DTI as the twin starts to take shape before there is a product which is the characteristic of DTP and after the product is built it stays connected to the twin until it is physically removed which would be a DTI.

eShare is using the BIM[1] model as the DT model because the BIM model already contains all visual information needed for a DT model to work and during the BIM process, all technical information of every object in the model is gathered and saved in a different location. eShare then connects all the technical information as well as any online data to each independent model in the DT.

[1]Build information modeling is the process of combining information from different disciplines to create a digital representation of a build. Such information includes a 3d model of a building with all machinery, air supply, piping, ventilation, power supply. All the technical information of each object is also documented during the BIM process and stored somewhere.

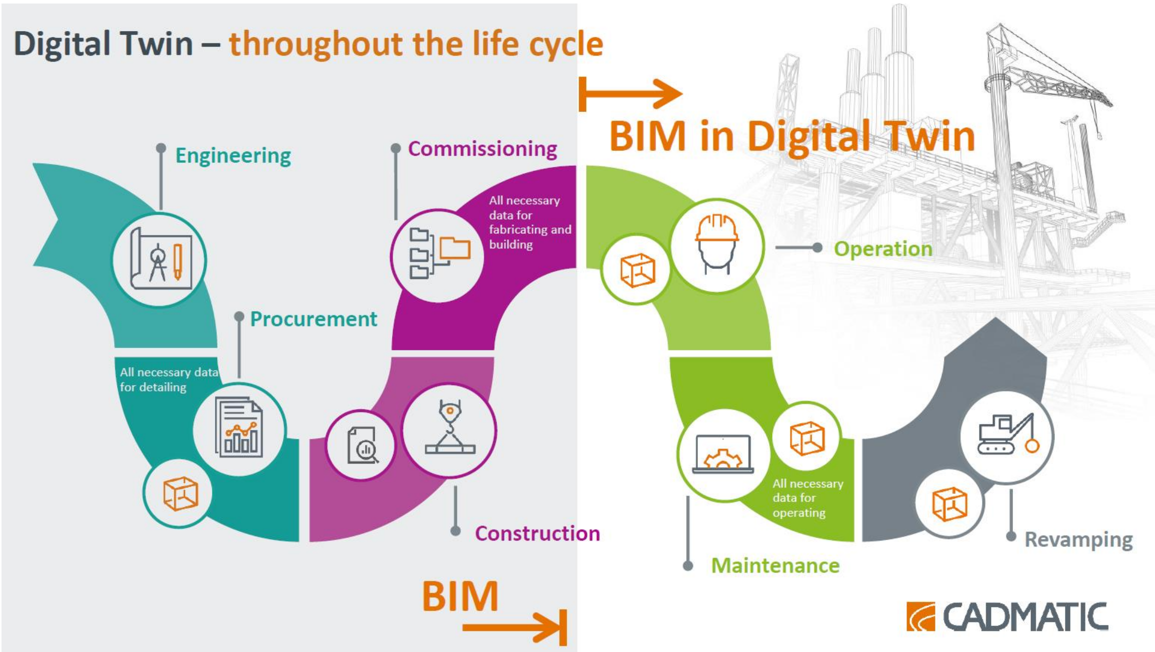


Figure 10 lifecycle of eShare

A short summary on how different discipline as shown in Figure10, could use eShare during different stages in the product lifetime.

Engineering

eShare starts to take shape already in engineering as all specifications for the project and 3D CAD models are added to the eShare. Each model is an independent DT with integrated information about the specified object.

eShare can bring asset information from 3rd party software as documentation could be saved in multiple software. Figure 11 shows as the model are clicked on the information appears on the right side and all information is customizable to suit each user.

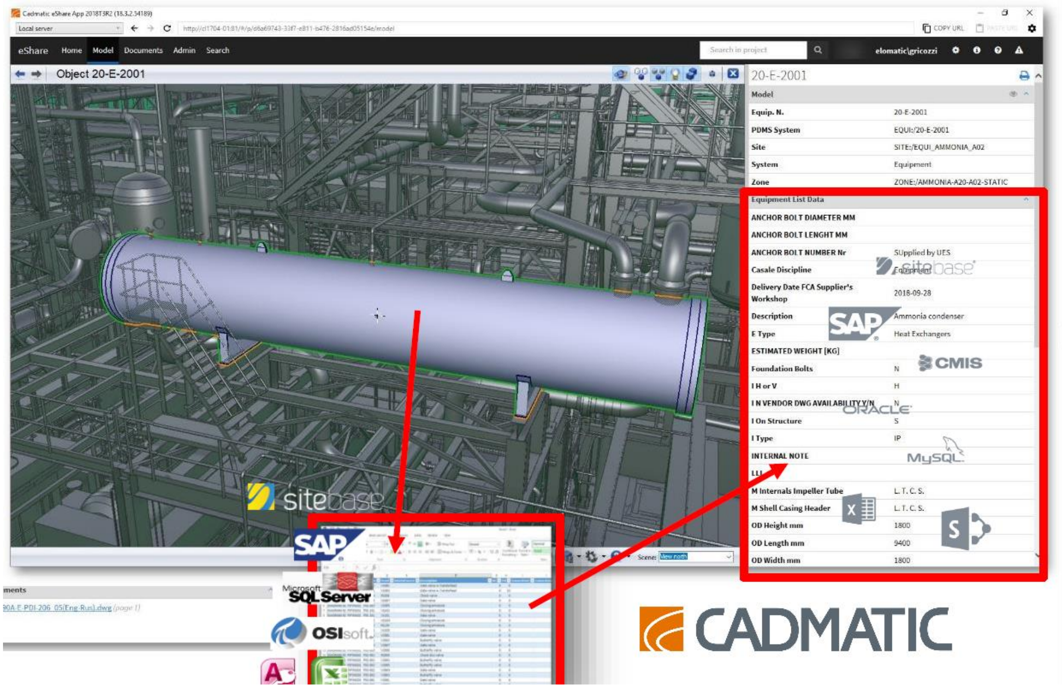


Figure 11 (Cadmatic)

Procurement

After everything is thought out the procurement office can use eShare to check if the materials already in storage are enough to build the product, if not eShare will tell how much material is missing so the right amount of material can be bought Figure12.

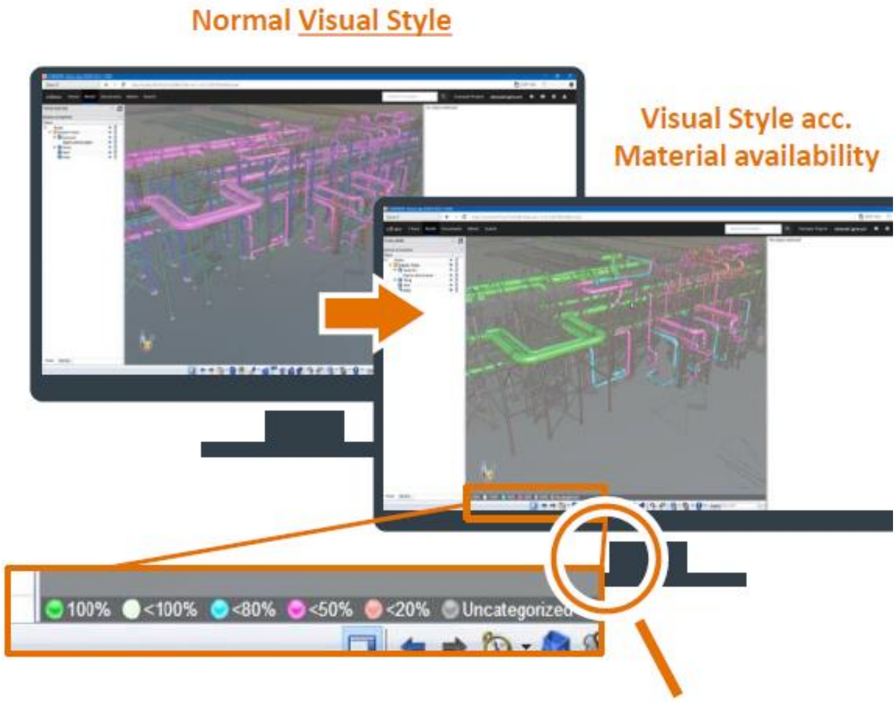


Figure 12 eShare visualizes how far the project can go with current storage material. (Cadmatic)

Construction & Commissioning

During construction, eShare acts as a monitoring device for the project where the construction workers can update the progress of the project and update what part of the project is done. The workers can also receive technical documentation on the field and correct any unexpected problems during the build phase.

Operation & maintenance

During Operation & maintenance eShare acts as an information center to easily find information about an object in the plant. During the interview with Jim Nyroos at Cadmatic. he mentioned: “eShare works as a turbo” for information searches. (Nyroos, 2021)

Revamping

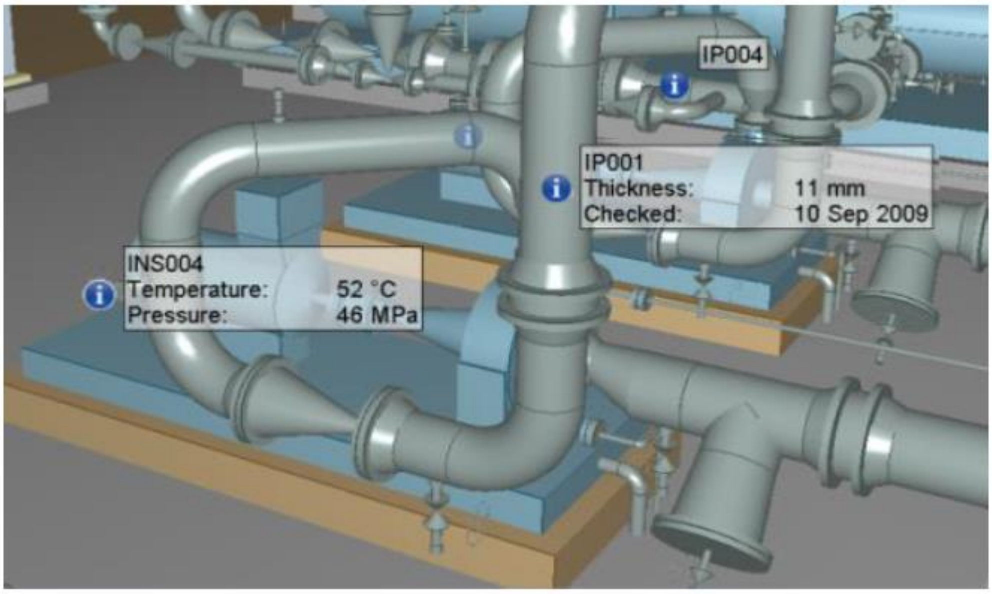
When in need of updating machinery eShare has a digital environment around the place making it easier to plan the new machinery and quick access to documentation on how to recycle the old object

Features

eShare has different features that allow it to visualize information.

Smartpoint

Smartpoint acts as customizable information points as can be seen in Figures 13 to 15. Where it can display various online, technical data as well as high-risk areas. it can also act as a weblink to different web pages. Smartpoint can also act as a DTI model if the area is 3D scanned and has no 3D model, to begin with. it gets the same functions as can be seen in Figure 10 where the model is clicked on and it gives out an information widow of the object.



In figure 13 various online and technical information is displayed by smartpoints. (Cadmatic)

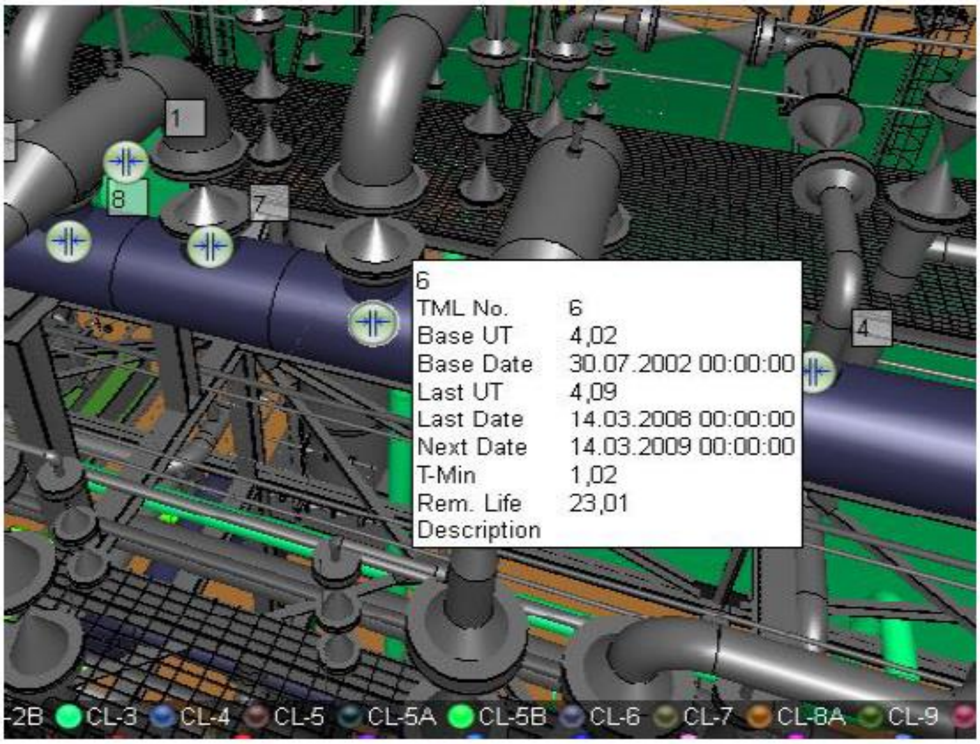


Figure 14 Predefined information displayed by smartpoints. (Cadmatic)

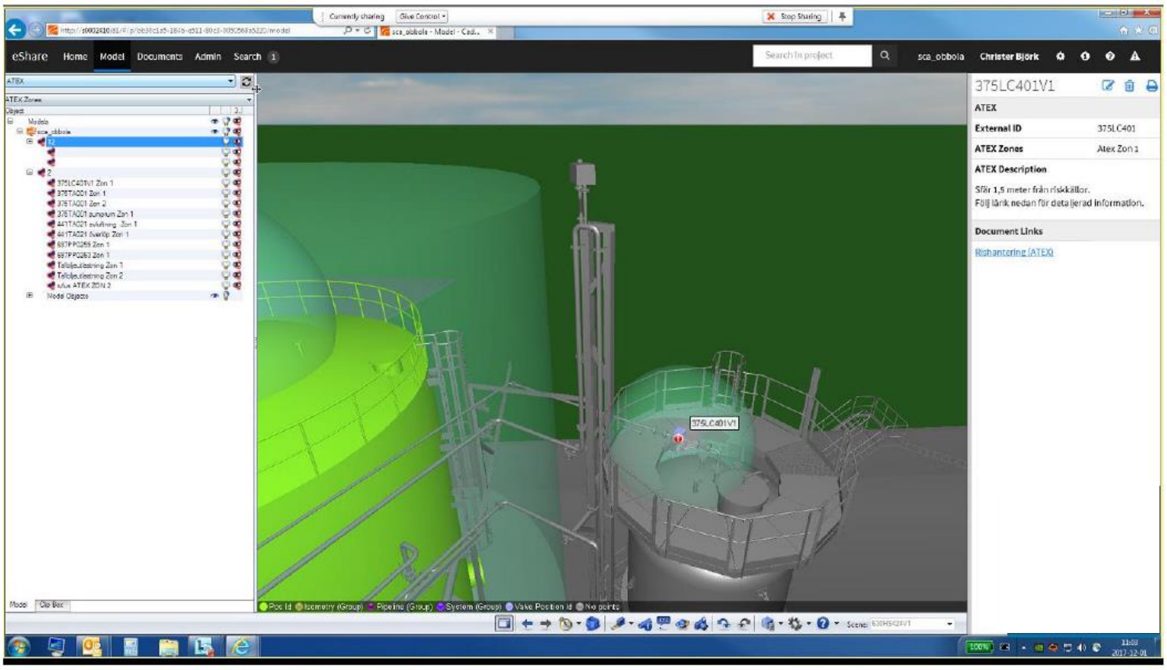


Figure 15 various areas can be highlighted with smartpoints in this case ATEX areas (Cadmatic)

Highlight & comparing

eShare can highlight different parts in the DT according to the criteria the user gives if it's to find every chemical piping in a plant or to show which machinery has an open wok order as can be seen in figures 16 and 17. eShare can also compare information between other systems and if it finds information that doesn't match, it will highlight the problem.

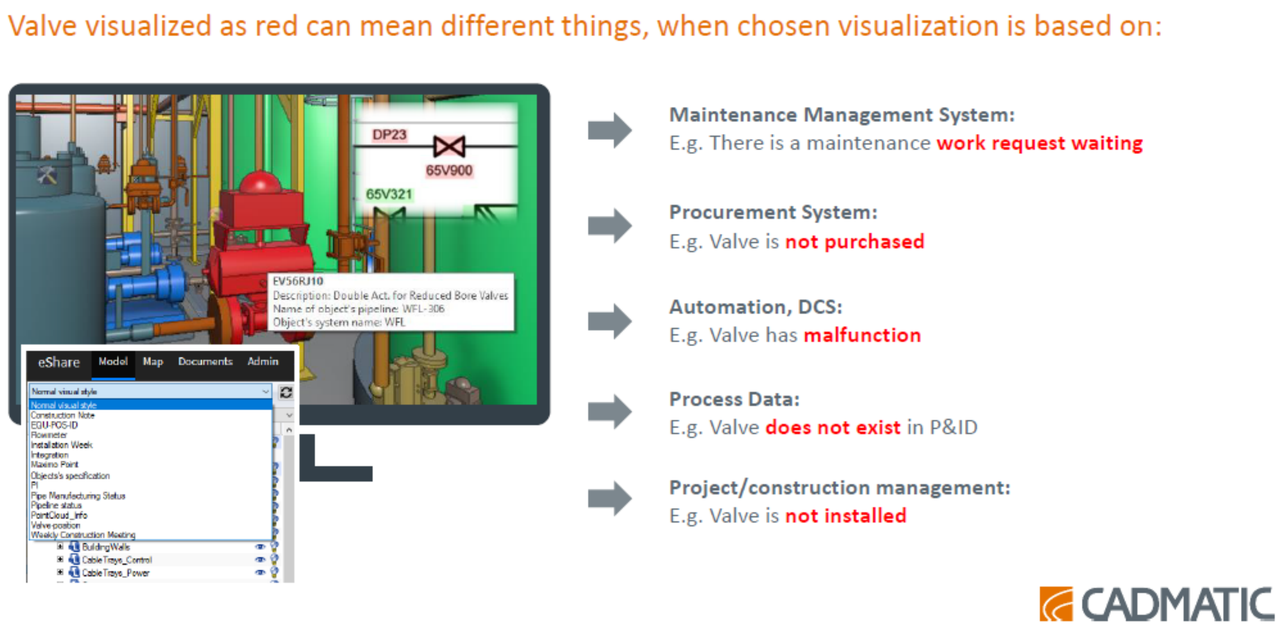


Figure 16 illustrates how red can mean different things depending on each discipline. (Cadmatic)

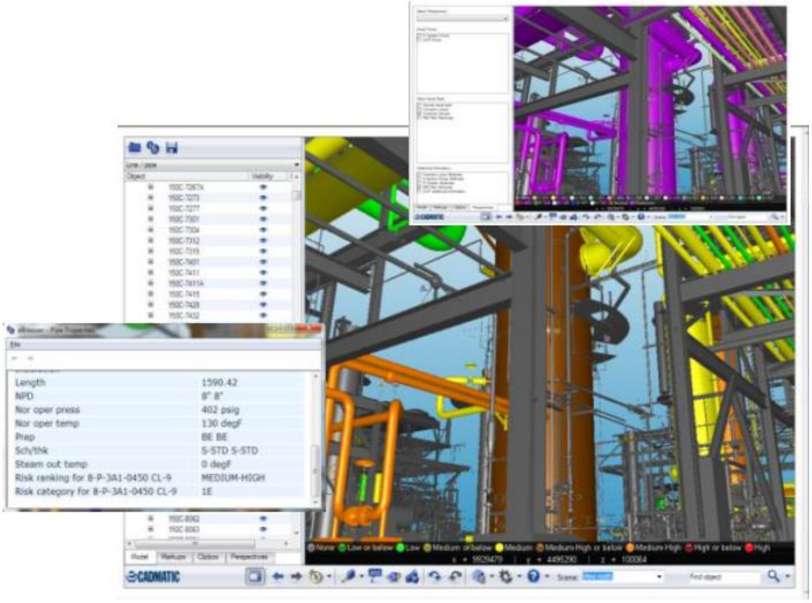


Figure 17 eShare is highlighting pipes according to each pipes Risk evaluation where green has no risk while red is high risk (Cadmatic)

Markup

with markup, it makes it easy to share any problem with other eShare users.

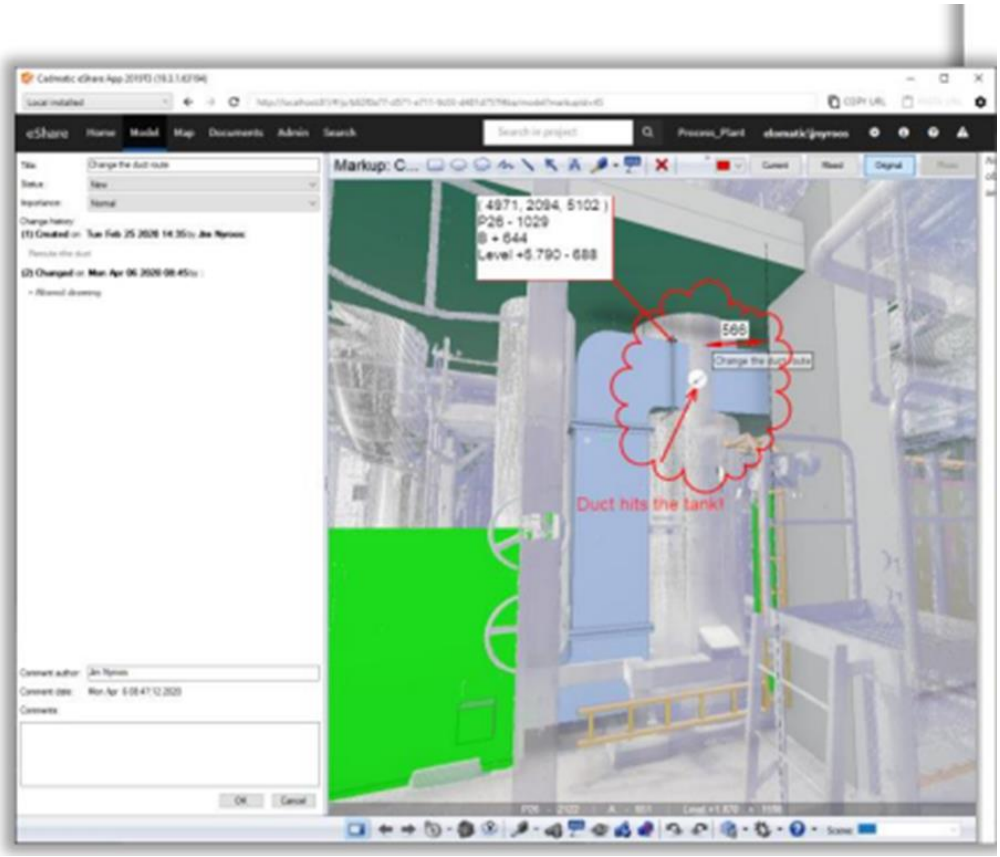


Figure 18 markup showing a newly planned duct colliding with an existing tank. (Cadmatic)

Blueprint and documents

eShare has the feature to connect P&ID, blueprints, and any other documents to eShare. eShare can also create a connection between the documentation and itself making a link where the user can switch between the two by clicking on the ID number.

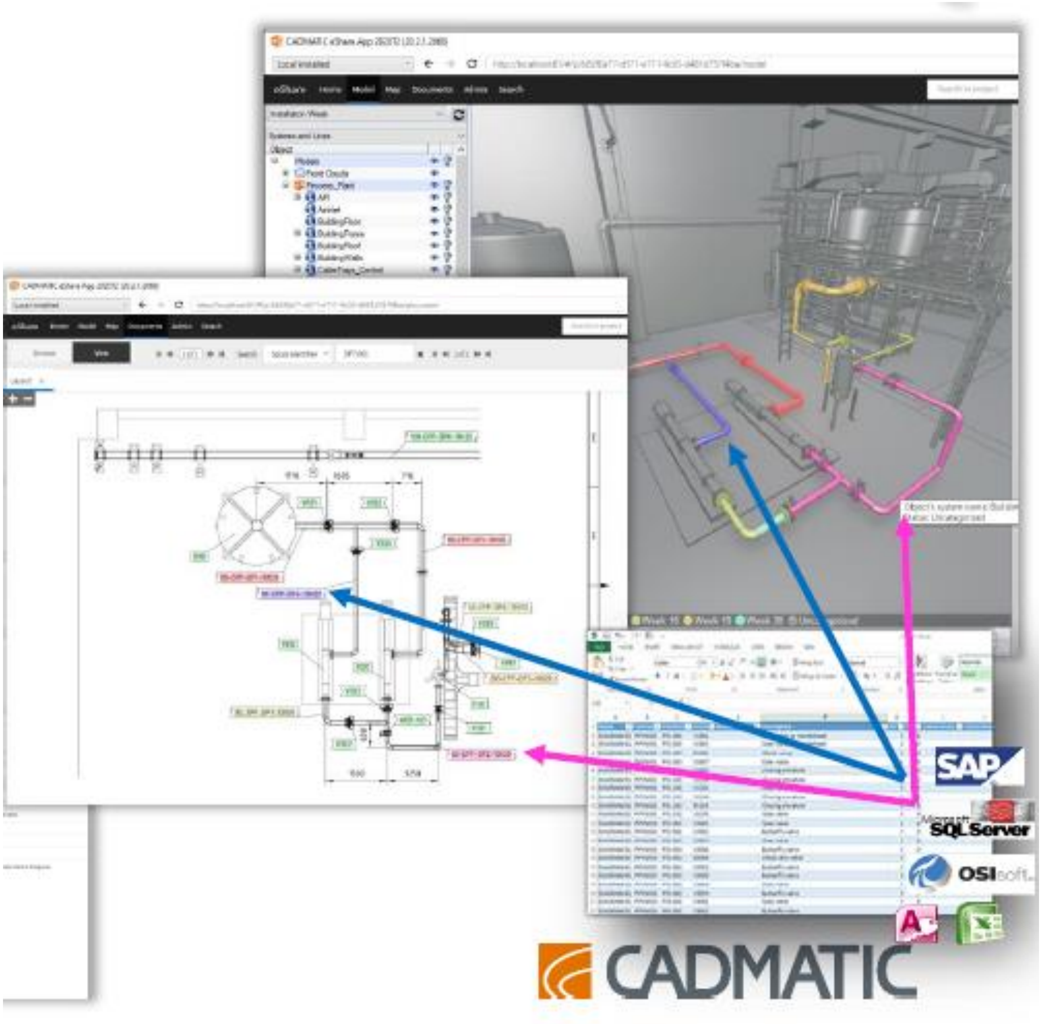


Figure 19 eShare utilizes blueprints as fast links between the two and any highlighting in eShare also shows up in the blueprints. (Cadmatic)

3.6.2 SCA Obbola

SCA Obbola is located in a town called Umeå in Sweden, they have been using Cadmatic eShare since 2016 and are still using it to this day. In an interview with the Project engineer at the SCA Obbola plant, he mentioned that eShare is one of the most used programs they have. It has made their work much easier as they can visualize information during meetings and work. He also gave a demonstration on how eShare is used by them to compare information on the piping system as well how the asset information screen could look like.

3.6.3 Process Genius PGplant

Process Genius DT is a DTI that focuses on situational awareness of one or multiple factories. It uses already existing objects and connects IoT or ordinary sensors to the DTI to give a quick overview of the entire plant. figure 20 shows how the PG plant works.

PGplant begins with a cad model being added to the genius conversion where it automatically updates the already existing models to the newer ones. After the new cad model is added all 3rd party systems, documentation, factory systems, and online data are connected to the model.

After the Cad model has been connected to everything the PGplant is then ready to be used by different disciplines. Each discipline gets its own set of data that is necessary for their work. A few examples can be seen in the top part of figure 20 where Productional, sales, business, clients, and partners have their own set of data. (Process Genius, 2021)

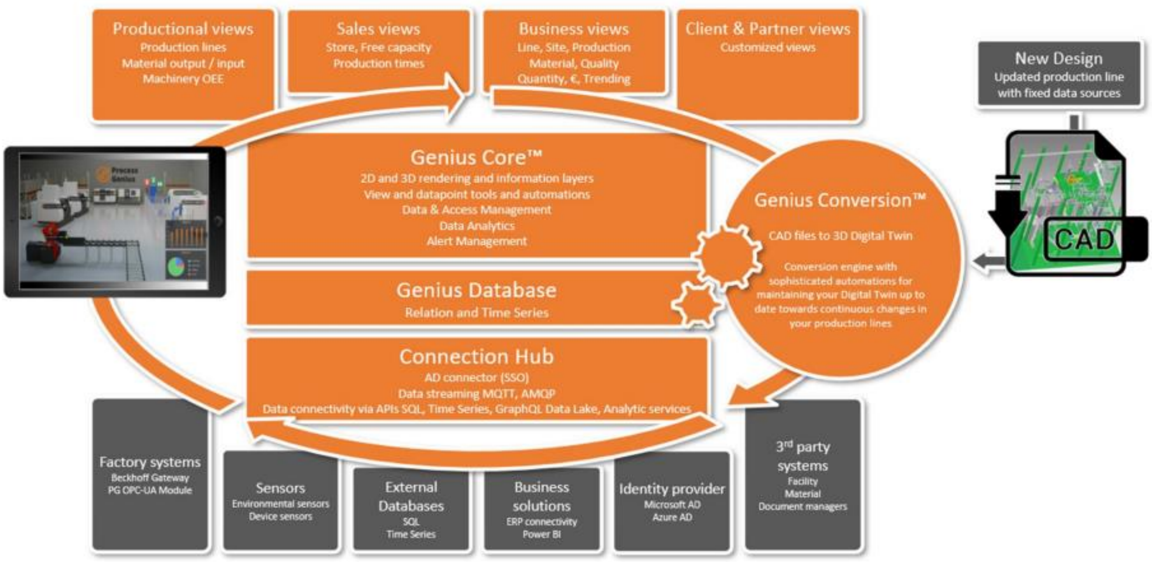


Figure 20 (Process Genius, 2021)

Situational Overview

PGplant gives a quick situational awareness of each plant owned by a company around the globe. it can display individual factories' overall efficiency as seen in Figure 21 or show more in detail on each machinery inside the factory as seen in figure 22.

in a machine-level overview, PGplant can display different things like efficiency on each machine, individual machines' operational history, notification if planned maintenance work is overdue, alarm if an object is damaged and if machinery is on or off.

Figure 21 PG can show the efficiency of multiple plants on a single screen. (Process Genius, 2021)

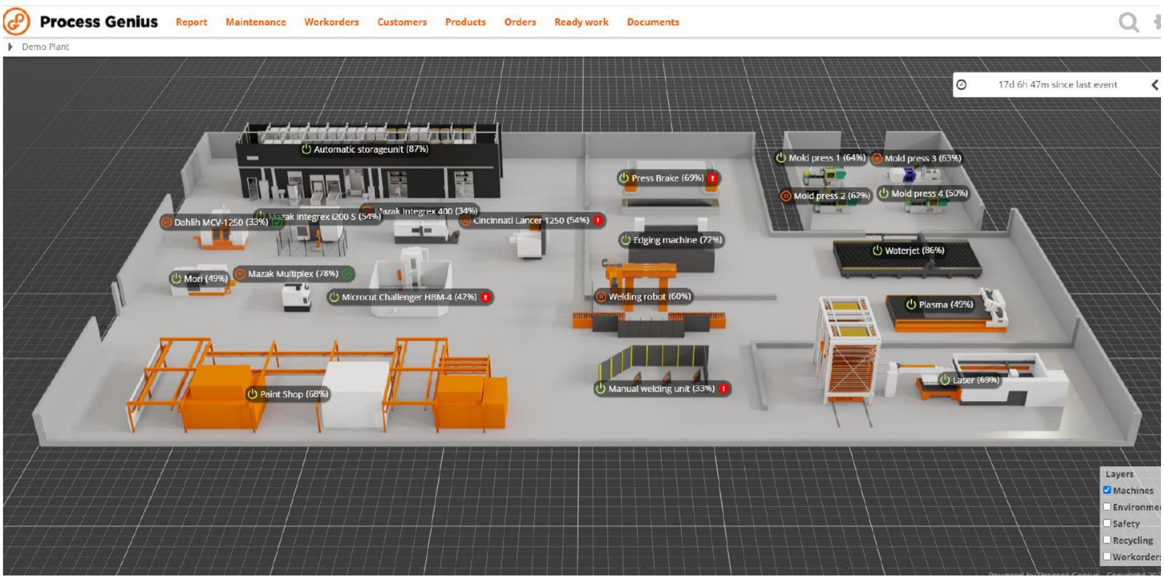


Figure 22 Overview of machinery inside a plant. (Process Genius, 2021)

Documentation & workorders

The Documentation on PGplant can either be manually placed in the model or placed by using the device location ID. the documentation view is fully customizable to choose what type of documentation should be shown up for the user. reducing the time needed to find the right documentation.

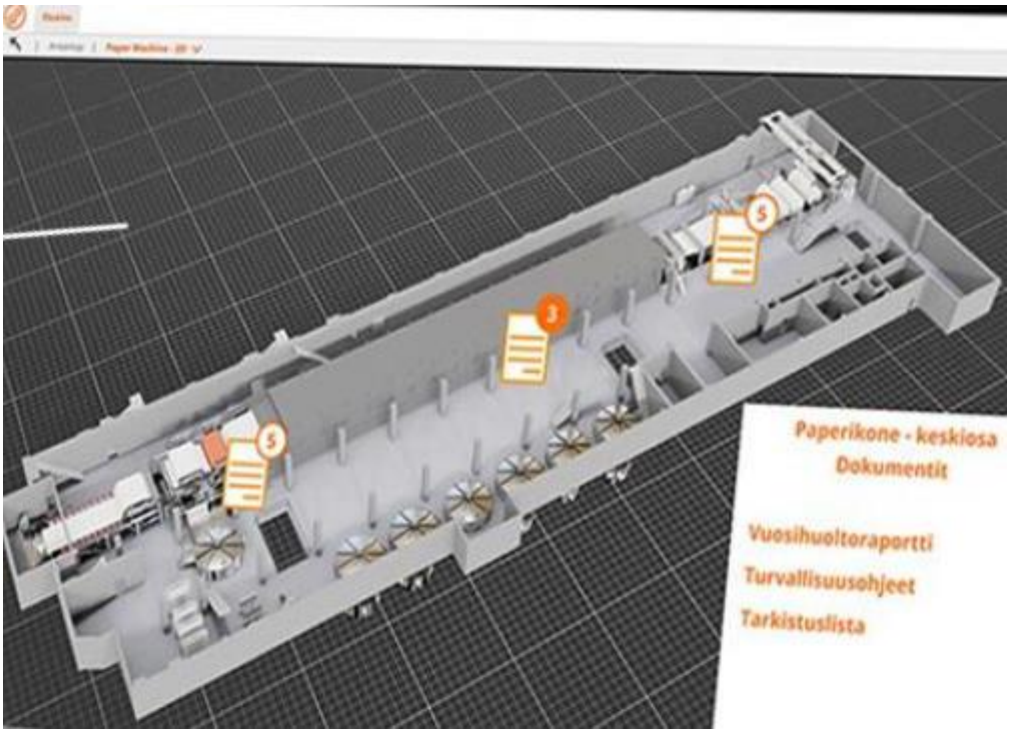


Figure 23 PGplant showing documentation in the model. (Process Genius, 2021)

Work orders and maintenance notifications can also be placed in the same way as documentation, and as they are numbered it is easier to locate them.

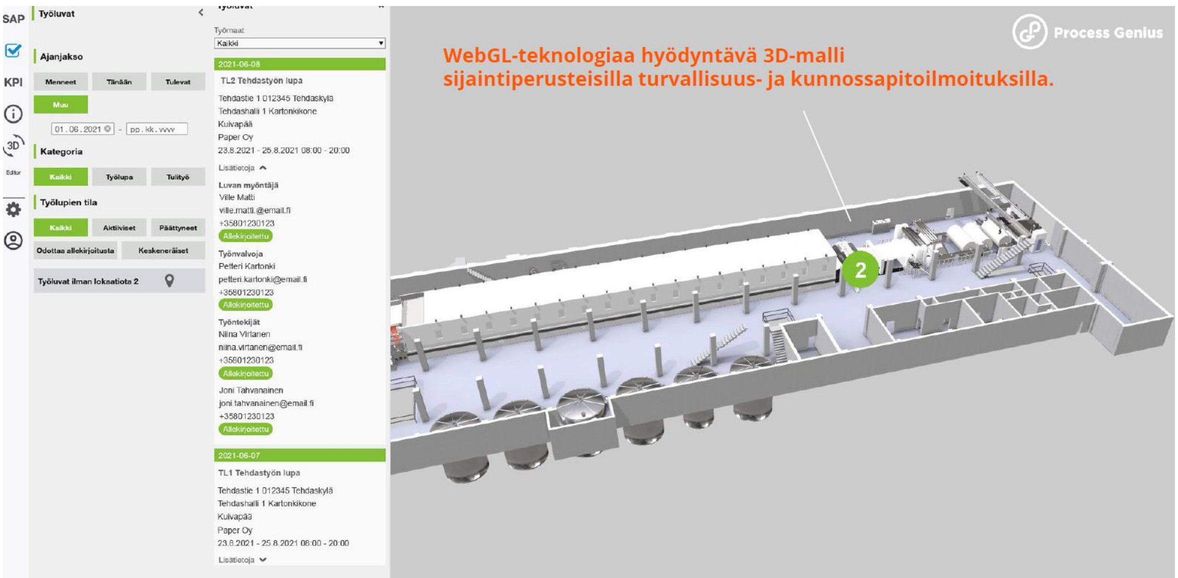


Figure 24 (Process Genius, 2021)

Safety

PGplant has also a safety layer where it illustrates every safety-related object existing on the floor level. Figure 25 shows where a person could find the closets fire extinguisher, first aid bags, and emergency stairs.

Pgplant can also show where an alarm is going off by highlighting the area.

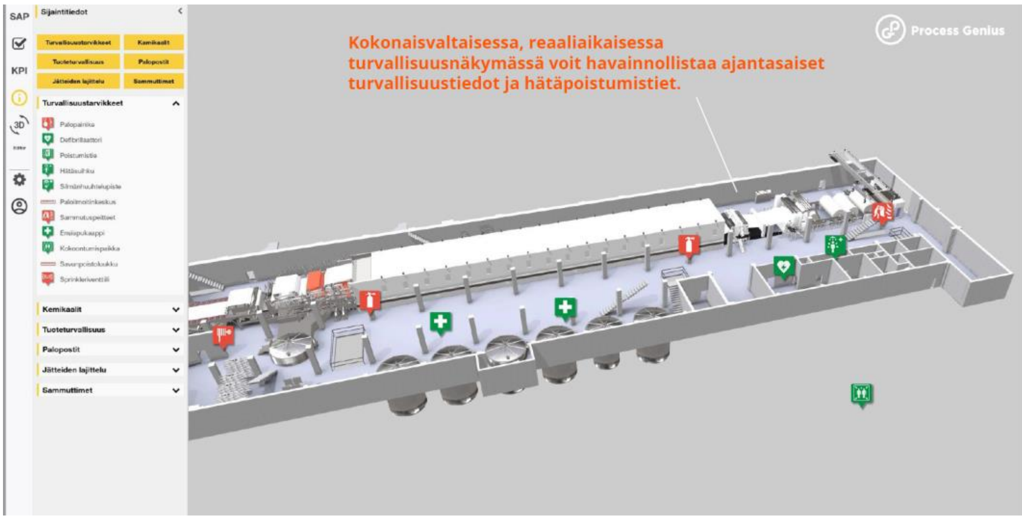


Figure 25 PG can show quickly where every safety-related object can be found. (Process Genius, 2021)

PGplant has a safety notification system where the workers can put into the 3D model a notification on safety, and environmental-related hazards.

Figure 26 Safety notifications can be placed anywhere on the 3D model (Process Genius, 2021)

Predictive maintenance

PGplant can set a Max/Min value to an online data, when the online data value exceeds a said value it will notify and highlight possible problems on the machinery.

4 Method

The thesis was first intended as aiding with Proof of Concept but turned into a research/case study on DT. A case study is to learn something in detail and explain how something works or why it works and report it in written documentation.

The thesis began with a kick-off meeting with me and my supervisors to determine what kind of aim, and delimitations should include in this thesis report to prevent it from becoming too broad for a bachelor thesis.

The literature was then decided to be about model-based DT and that it could be implemented in the process industries in some way. The literature that was chosen had to be from a reliable source.

After understanding the basics of DT, we had an interview with Senior Manager, Shutdown Development, and Digital Projects. The reason for the interview was to learn what UPM as a whole wanted from DT and how it should help the workers.

Afterward, there were interviews with two Digital twin providers, Cadmatic and Process genius. Both explained their definition of DT and how their DT system worked.

There was also an interview with SCA Obbola where they explained their views on eShare and gave a small demonstration on eShare to prove it works.

The staff interview was conducted right after the interviews with Cadmatic, and process genius. The interviews were focused on finding out what type of problems the workers are experiencing during work and how eShare could help them with improving work efficiency. The interviews were conducted in an open large group, as it could bring up great discussion between participants about the subject.

The interview began with a short introduction to DT to give the interviewee an idea of what DT is, then a detailed explanation of how eShare works and its features. After the explaining eShare, the following question was brought up to interviewees “What kind of difficulty, problems are you experience during work, and in what way could you see yourself using eShare for it to help you.” if there was difficulty’s in answering the question the author mentioned few of the functions that could help them.

4.1 UPM staff Interview

The staff interview was focused on what kind of problems workers experiences during work.

4.1.1 Mechanical Maintenance (MSA/MTO)

Maintenance planners and supervisors

During the interview with maintenance planners and supervisors, a few problems or time-consuming tasks was mentioned.

The first problem is with helping subcontractors. Helping subcontractors takes a lot of time as some need to be shown where the worksite is, where they can find everything related to the job, and help with any unexpected problems. This leads to less productive time for the planners and foremen during the day.

the second problem is identifying, finding, and tracing piping systems in a big plant. Inside the Pietarsaari plant, the majority of objects are pipes, finding the right piping system can be hard even if you are familiar with the plant. In the interview, they said tracing piping system is difficult as they can go through walls and floors which then forces the person to find another way around it, and then the same person needs to find the same pipe again among multiple other pipes. Identifying pipes is not easy either as the labels might be worn out, misplaced, or do not exist at all and there might be multiple pipes right next to each other which makes identifying the right one even harder. Even if they had an id number on it might take more time in finding the right documentation as the documentation could be either in SAP or in the physical archives.

The third problem they came up with is the documentations handling. Currently, UPM Pietarsaari is using a maintenance system called SAP. SAP system stores all kinds of information from work orders, asset information, spare parts, financials, and so on. Finding the right information can be hard as the SAP system has become more complex during the years and some asset information is not up to date or is lacking information. If the information does not exist in the SAP maintenance system, it leads to them going to the archive and finding it among hundreds of other documentation which is also a time-consuming task.

The planners and supervisors have been using a mechanical project engineer, who has been working for the UPM for a long time and knows how to find the right documentation or said asset information. Unfortunately, the mechanical project engineer is going to retire soon which is going to lead to a big void of information and increased time in finding the right information.

Maintenance workers

The maintenance workers have had the same problem with identifying, tracing piping systems as well as documentation, information handling on their part, it is more of a lack of information such as blueprints, Pressure class, DN size, required tools, and service manuals. Most of the time they are relying on memory, experiences, and guesses when choosing such as DN size and tools for the work. Most of the time they take excess tools with them or the wrong size which leads to them going back to the workshop to find the right one for the work.

4.1.2 Electrical and automation

one of the main problems brought up in this interview is that electrical and automation has a different location id for an asset compared to what the rest of the plant is using which creates confusion between the two parties.

another problem is during project planning. The electrical and mechanical has a bad communication with each other on how they are going to design the plant, which may result in collisions between the piping system and the cable shelves. the cable shelves are easier to move around than pipes, however, it brings the extra cost for redesigning and probably extra cost for material as it needs to go around the pipe.

Another problem with the cable shelves is that they may contain too many cables on one shelf without the electrician knowing about it. if there are too many cables on one shelf it can create a fire hazard if pulp mass falls from the floor above and straight onto the cable shelf.

4.1.3 Project office

The project office has the same problem with miscommunication with the different departments such as electrical, which may result in collisions between objects such as pipes and cable shelves as mentioned in 4.1.2.

The project office also has difficulty finding the right information as the information is scattered in different places. The systems they are mainly using to store the information are M-files, SAP, ALMA, and social systems such as TEAMS. This problem is especially time-consuming when they need information for example the surrounding area where the new project is being planned.

M-files is used to store all active project data exempted for the electrical. After the project is completed all its data are then uploaded to the SAP maintenance system.

ALMA is used to store only project data for electrical and automation. After the project is completed all its data are then uploaded to the SAP maintenance system.

4.1.4 Safety

During the interview with the Pietarsaari plant HSEQ manager, it came up with.

People might not know if they are working close to a dangerous area especially subcontractors who aren’t familiar with the area.

Another problem is the UPM Safety notification system OneSafety. OneSafety is an application Where every UPM worker can use to notify of any Safety related problems. The problem with this system is that when someone makes a notification, they have to add the exact location, but they can only choose from a few predefined locations in the system, the rest have to be written more in detail.

5 Results

5.1 Digital Twin

DT could help the Pietarsaari plant in many ways as it's not being limited to be used on one specific disciplinary or task, instead multiple disciplinary could use it and benefit from it. As one of the most crucial things for a DT would be information gathering. The industry has started to realize the value of data from individual sensors that have otherwise been looked at once and then been deleted. There is a vast amount of data that could be used to improve overall efficiency or to predict different scenarios involving the process. By just gathering information from every sensor and documentation to one single place, it would also need an efficient way to present that information to the end-user, otherwise, it would just overwhelm the person looking for specific information. DT would organize or visualize the information for the end-user making information gathering faster and easier.

As Pietarsaari plant has multiple systems for storing and gathering data. Finding the right information would take a while, the person would need to log in to multiple systems and go through each piece of information until the right data is found. With DT it would reduce the needed time as all documentation, information, and online data are gathered in one place. Figure 9 shoved exactly that, how resources could be saved with the help of DT.

When DT has all the data gathered in one place. DT could use an AI to help with running simulations and predicting different scenarios. It could be used to predict when machinery needs maintenance by using online data and historical data. It could be used as a training tool on how to start the plant by simulating the entire process and visually showing what kind of consequences would happen if the process were turned on in the wrong way. The simulation could also train an operator to react to different scenarios, like a sudden increase in pressure inside a tank or simulating the process with a faulty mechanical component. Maintenance could also use DT as a training tool. By doing virtual maintenance before doing it in real life, they would already know the procedures on how to do the maintenance and what type of difficulties could occur during the maintenance.

Subcontractors would also have all necessary information on the plant such as safety-related objects or information on the task.

5.2 Cadmatic eShare

5.2.1 Mechanical maintenance

Maintenances Planner & Supervisors

With the help of eShare, the maintenance planners and the supervisor for the mechanical could reduce the time needed to help the subcontractors by either showing eShare on a computer or giving them a tablet with eShare in it. The subcontractors would then have a 3D model of the worksite with all ATEX areas, acid pipes, fire extinguishers, and emergency showers showing in their correct locations as well all necessary information on the object they are working on. By using URL links, they could also add work orders directly to eShare making it easier to access on-site.

eShare could help identify and trace the piping system inside the plant. With its highlighting ability, it could easily show what type of pipes they are looking at. It also gives information faster than looking through a paper format of a P&ID chart or other kinds of blueprints.

Cadmatic eShare could be connected directly to Sap. All information on SAP could then be displayed for each machine in the 3D model. That would reduce the time needed to search for information about an asset.

The highlighting could also be used to visualize the position of all faulty assets making it easier to plan plant shutdowns and decide on who repairs what asset. it could also highlight different colours depending on the seriousness of the fault making it easier to see which machinery should first be attended to. The highlighting could also show if there are any spare parts left for the asset by showing red if there aren’t any left and green if there are. eShare could help with following over the maintenance during a shutdown, giving them situational awareness inside the plant.

Maintenance workers

eShare could give the maintenance workers all information they need about an asset with one click on the 3D model it could either display technical information, maintenance manuals, necessary tools, DN sizes, or oil type used in the machine.

eShare could display online data such as pressure and temperature to help them to determine if the machinery is cooled down or depressurized enough for them to start working on it. The online data could also help them to troubleshoot possible problems in the machinery.

5.2.2 Electrical & automation

Cadmatic has recently updated eShare so it can trace cables and cable shelves in the same way as the piping. This would help them to determine if there were too many cables on one shelf, which then would prevent fire from happening if pulp mass falls on top of the shelves.

Online data could be used to troubleshoot problems in the automation system as well as in the electrical grid.

eShare would be able to combine both location IDs used by electrical & automation, and what the rest are using. The electrical, automation would be able to search the location of the asset with the ordinary location ID and then click on the asset to gain the electrical ID and other useful information from sap like how the electric motor is wired and in which way it should rotate.

5.2.3 Operation

The operation could use eShare to locate valves that has to be closed off manually before any maintenance team can start working on the said machinery. They would know the exact number of valves and their location before even leaving the control room.

eShare could be used to troubleshoot problems in the process by observing the online data and being able to switch between P&ID and 3D models they would know the exact location of the said asset.

eShare gives quick access to P&ID charts and any highlighting from the 3D model is also highlighted to the P&ID giving quick interpretation of the information.

They could also use the P&ID charts as a way to train the operators in how to correctly start the factory up from a plant shutdown.

5.2.4 Project office

The Project office would have their own 3D model where they could design the plant without interfering with the up to date 3Dmodel used by everyone else. The mechanical and electrical project engineers could then visually determine if the plant design has any type of collisions happening between for example the piping and cable shelves, which would result in cost-saving and labour.

M-files, Sap, and alma can be directly connected to eShare giving the project office quick access to all data they need for the project.

5.2.5 Safety

Smartpoint as already said could be used as a marker for ATEX areas or other high-risk areas. They could also be used to mark up emergency exits, first aid stations, and emergency showers as an icon on the 3D model and the blueprints.

Smartpoint could also be connected to Onesafety by using a URL link to the notice, resolving the problem by defining the exact location in the safety notice.

5.2.6 Downside with eShare

The downside with eShare is that it needs a detailed 3D model to work at 100%. Currently, the Pietarsaari plant is not fully drawn out in a 3D model. There are only a few areas in the Pietarsaari plant where there exists a 3D model with all machinery and piping. Even when they could use a 3D scan to replace the 3D model, features such as the highlighting of entire piping systems wouldn't work as the 3D scan is not one solid object and the pipe would be defined with a Smartpoint instead of the actual solid model.

5.3 Process Genius PGplant

5.3.1 Mechanical maintenance

PGplant could notify maintenance planners and supervisors of possible machine failures by using the online data, which would prevent sudden failures and unexpected factory shutdowns. It will also give plenty of time to plan when to perform the maintenance. It also stores historical data of the object making troubleshooting easier as they can see if the same part on the machine is always breaking. By having predictive, historical, and online data maintenance planners and supervisors could start using Evidence-Based Asset Management (EBAM) when they are making the maintenance plan. EBAM is a technic where a person decides what type of actions should be taken solely on the raw data instead of intuition and guesses.

PGplant can display work orders from SAP or be created directly from the PGplant. Each of the work orders is numbered making it easier to find its location in the 3D model as well when discussing the task both worker and supervisor are talking about the same workorder preventing miscommunication from happening.

The machine layer gives them a quick view of the situation inside the plant and what maintenance should be done during the day.

5.3.2 Electrical & automation maintenance

PGplant gives easy-to-read and quick access to online process data that could help in troubleshooting any type of electrical fault in the plant. It could also alarm if any type of deviation is happening in the automation and if any electrical component has broken down.

Documentation and asset information are brought directly from SAP and as same with the eShare, asset location IDs could be combined into the 3D model removing the confusion when searching for the location of an asset.

5.3.3 Operation

The operation could use PGplant to supervise the process in each area inside the plant. They could see with the help of efficacy in each area where there might be a problem in the process. Depending on how detailed the 3D model is, the operation could use PGplant to locate valves that have to be closed off manually.

5.3.4 Project office

The project office could use PGplant to find information on the existing asset.

5.3.5 Safety

PGplant has its own safety notification system in the PGplant it could add the notice directly to the 3D model. This would work the same way as Onesafety and it would solve the problem with Onesafety, where it only tells about a general direction.

The safety layer would give both staff and subcontractors safety awareness on the plant

5.3.6 Downside with PGplant

The downside with PGplant could be said that the Project office can't do much with it. They would be able to find information on existing assets that are involved in the project and if the 3D model is detailed enough, they could visually check the surrounding area of the project site to determine how they should design it.

6 Discussion

6.1 Results discussion

The reason for this thesis was to investigate the benefits and usability of a DT system for the UPM Pietarsaari pulp-mill. DT could help UPM in many ways as it's not limited to one single discipline. It would help them organize the information they have and help them in any decision making involving an asset. Dt could also help in improving the efficiency of the process and predict future scenarios by using the process data

.

6.1.1 The comparison between eShare and PGplant.

eShare would give the project office as well the maintenance and operations a detailed overview of technical data of an asset as well, the possibility to easily track piping systems and electrical cables throughout the plant. eShare was also highly customizable as the user could use the Smartpoint for anything they wish for if it's a hyperlink or a notification marker. It's also compatible with all three systems used by UPM for storing data m-file, SAP, and Alma, eShare would be a great asset for UPM but as the Project office got outsourced and the amount of 3D modelling needed to be done for it to work at full capacity, it would have taken longer time to implement then what it would take for PGplant.

PGplant would not need the detailed 3D model to work. It also has all the safety-related features already implemented in the program.

PGplant is more useful to the maintenance, operation, and to the decision-makers, as it displays the live process, historical, technical data and can use that data to alarm if something is happening.

Both tools have a great way of displaying technical data from SAP which would relieve the workload on the staff as they wouldn't need to run through half the factory before finding the right information.

6.2 Continuations

The continuation of this thesis would be in helping the Proof of Concept for the DT system chosen by UPM, also to update all the information in SAP maintenance system as there is old information and some parts are lacking the necessary information needed for the maintenance.

Example of data that could be added to sap.

- More technical information about the asset
- DN sizes
- PN classes
- Electrical motors rotational way
- Maintenance manuals
- Necessary tools for the maintenance work

6.3 Improvements

The challenge I experienced during this investigation was to find information about DT and decide what information about DT should be added to this thesis. I decided to focus on a general definition of DT and about the DT systems offered to UPM. But DT is defined in many ways and is used differently in each industry. So, it was a bit hard to find information that is relating to each other and then also having to choose what part of DT should be focused on. I could have written more in detail about DT, like how asset management and predictive maintenance work in DT, or more in detail on how DT is used in industry 4.0.

I would also add more interviews with UPM personnel, but because of the current strike happening, it was not possible to keep an interview with everyone.

6.4 Self-reflection

When I began this thesis, I did not know what Digital twin was or even heard about it, but as I started to read into it, I started to see how DT could aid a company, but it has a lot of room to mature, and the limitation of current computer technology is also limiting on how a DT could be used.

This thesis has given me a lot of experience in many areas, but the most experience gained from this would be the in-depth research about a subject.

6.5 Final words

I want to thank everyone who took part in this thesis. To the people who took time to attend my interviews and to Cadmatic, Jim Nyroos as well Prosses Genius, Nadia Sabour for taking their time for this thesis.

Especially I want to thank my supervisor, Samuli Räsänen from UPM, and Leif Backlund from the Novia University of Applied Sciences, who guided me through this process of creating this thesis, and thank you, you who have been reading through this thesis.

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