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ANALYSIS OF THE ODOO SOFTWARE CAPABILITIES REGARDING PRODUCT LIFECYCLE MANAGEMENT, MANUFACTURING EXECUTION SYSTEMS AND THEIR INTEGRATION

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Academic Year 2020 – 2021

ACKNOWLEDGMENTS

I would like to thank Dr. Giulia Bruno for her expert advice and invitation to develop this project, as well as Emiliano Traini, for his extraordinary support in this thesis process.

My most sincere gratitude to my parents, Julio and Michelle, who gave me everything, from my life to their extensive and unconditional support and encouragement; also, to my brothers and my fiancée Ana, who inspired me through all these years.

My deepest thanks and appreciation to Icaro, Matt, and Maz, for their endless help and support throughout not just this project, but for all the other moments in which they pushed me to be better. Also, for those who have touched my life, being my greatest gifts, you all know who you are, and I am truly grateful for sharing special moments of my life with you.

ABSTRACT

ANALYSIS OF THE ODOO SOFTWARE CAPABILITIES REGARDING PRODUCT LIFECYCLE MANAGEMENT, MANUFACTURING EXECUTION SYSTEMS AND THEIR INTEGRATION

The second half of the 20th century had been marked for the advancements of computer technology in all aspects of production.

The key feature of that statement is the undeniable truth that alongside the increased complexity allowed by computing power comes an ever increasing production of overwhelming amounts of information.

From separate perspectives of the industrial landscape, several systems were brewed by that sheer necessity for organization, automation and waste reduction focusing on that pool of useful data.

ERP (from a managerial perspective), MES (from a production perspective) and more recently PLM (from a strategic development/redevelopment perspective) emerged as information solutions tackling this problem from different angles. These solutions, however effective, are always plagued by the fundamental incompatibility between the tools that implement those systems.

This paper objectives revolve around analyzing the integration PLM and MES systems from a theoretical perspective and comment on the use of the Odoo software tool to implement said integration.

The Odoo software was described in detail (regarding its use for manufacturing envirorment) icluding how it implements PLM and MES. Then, the software was subjected to the simulation of a fictional firm devised in the molds of Industry 4.0. This company was a fictional recently founded small case manufacturing company that uses plastic injection molding as their primary mean of production and uses additive manufacturing and fast prototyping as part of their business strategy.

Keywords: Product Life-Cycle Management, Product Life-Cycle Management, Odoo

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LIST OF ACRONYMS

ERP	Enterprise Resource Planning
MES	Manufacturing Execution System
PLM	Product Lifecycle Management
MRP	Material resource planning
WO	Work Order
BOM	Bill of Materials
MO	Manufacturing Order
ECO	Engineering Change Order
CPS	Cyber Physical System
IoT	Internet of things
DT	Digital Twin
GUI	Graphical User Interface
CNC	Computer Numerical Control

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1. CHAPTER

INTRODUCTION

1.1. Objective

The thesis has the objective of finding out how far PLM+MES system can be implemented by using the readily available Odoo software by analyzing the different concepts and dynamics that would consist said integration and they apply a fictional scenario to determine if and which of those concepts are included within this packaged solution.

To contextualize, the Odoo software differs from other solutions in the market substantially both in implementation and business model. To summarize, the Odoo software was originated as an open-source ERP software as oppose to a PLM or MES software and as such its availability and modularity are reasonably expanded. It goes without saying that the counter point for this that its usability in the field of PLM or MES is uncertain hence the value of this work.

Specifically, from the perspective of small manufacturing business and startups, the idea of an all-around ERP that implements a PLM-MES system is extremely valuable. Although ERP systems are somewhat available, they rarely venture deep enough into manufacturing to expand into PLM or MES solutions. In addition, the other direction is also relevant since PLM solutions tend to not have the expandability of an ERP which usually means that any integration requires specialized ad-hoc work.

Although modifying the software do not fall within the scope of this work, the fact that the software has an open-source community version means that adapting the software even to the most specific cases may prove to be easier and economical barriers for adopting lower, further emphasizing the possible utility of this software in the context of small business.

Ultimately, the thesis will give theoretical and practical advices on how to further exploit this system. It will also lay the ground for future works on the Odoo software and checks on how the solution is performing by identifying specific key aspects of PLM-MES integration and implementation.

1.2. Structure

This work could be a reference for an actual implementation of the described solution in small manufacturing enterprises and it can be treated as introductory material to PLM-MES and their implementation, as well as first principles and review of the current state of the Odoo software regarding it. To such end, this thesis presents the following structure:

- Chapter 1 - Introduction to this work and its objectives. Furthermore, it provide a succinct explanation of why this software solution requires this sort of analysis in the first place and how it was be structured.

- Chapter 2 – This chapter introduce the basic theoretical background to PLM, MES, ERP and Industry 4.0. These are presented in order to create the grounds to a meaningful contribution in this kind of analysis as well as providing meaningful context for its implementation in case the reader is a small business representative.

- Chapter 3 – This chapter is all about the integration between PLM and MES systems as discussed by previous works and as was be analyzed in this work. This is useful to stablish the concepts and dynamics that are the subject when analyzing the Odoo software.

- Chapter 4 – Introduction to the fictional company and products chosen in the molds of Industry 4.0 to be used in the further analysis and evaluation of the Odoo software.

- Chapter 5 – The introduction to the Odoo software as well as a more in-depth explanation of its use and functionalities. The description of the experimentation of the Odoo software taking in consideration all the previous chapters

- Chapter 7 - Conclusions The last chapter describes the takeaways of the work: how a medium enterprise can improve its processes through an informed use of a PLM+MES system implemented using the Odoo software.

2. CHAPTER

THEORETICAL BACKGROUND

This chapter is a brief introduction to the different systems that deal with data production collection and processing around the concept of enhancing all aspects of production that are favored by the academic community as well as the current and future state of industry for which these systems should prove to be indispensable.

It is important to notice from this part that these are not completely separate information systems. They start from different perspectives and they try to solve different problems but because of broad definitions they unavoidably expand into each other. That represents a problem on its own since from the available literature it becomes difficult to pinpoint where the boundary of a system ends and another one starts.

The Odoo management software (that is a topic of this work) considers PLM mainly as a tool for tracking change and improvements, while other key characteristics of PLM, like the use of digital items (later detailed at section 2.1), is a base characteristic of the material requirements planning which is a tool utility that also dabbles into MES.

2.1. Product lifecycle management

Any information produced by an individual or team is done by an empirical creative process. A task requires either previous knowledge/experience or it will be inevitably plagued by mistakes and corrections, which in turn generates said experience in exchange of time and resources. That experience is, traditionally, embedded in the human resource (employee) that produced the information in the first place.

Product Life-Cycle Management (PLM) is an organizational process that aims to control the flow of information regarding all aspects of a product throughout its life-cycle. As one can imagine, this definition, and its broad scope, does not make understanding PLM any easier. The thing to focus on, for all purposes, is that PLM true value is in what concerns change.

Figure 1 Product lifecycle stages (Tripaldi, 2019)

PLM is above all a connecting technology, not an individual technology islet or information processing system (Saaksvuori and Immonen, 2008). The idea is that every information produced by company personnel holds value equivalent to the time and money invested. Using that information saves money, not using that information wastes money. This is easier to understand when looking to a design process.

E.g. if an engineer designs an electronic circuit, the file holding the CAD drawing has an equivalent value to the time and money invested in it. The problem comes from the fact that in a traditional system only the engineer knows the design process behind the file, the extent of what is inside and its possible uses. While, from the perspective of the rest of the company, that is just a file in the database alongside thousands of others. The result is that, on its own, the information is of limited use.

If by any chance there is another engineer working in a similar design it will become extremely difficult for him/her to find that file and use it in his own design. Ultimately this results in waste because Engineer#2 will have to spend more time and money doing something that was already made just because that information was not easily available or well organized.

This scenario is not limited to product design, but also to all aspects of the product lifecycle that produces change over time. Someone had to orchestrate how that piece will be produced , how that piece will be moved,packed , distributed and disposed of. When a problem is found or improvements are possible those changes also produce information and consume resources. If the company cannot take advantage of that existing information about all those phases of the product conception it will waste resources at every single redesign.

Product Lifecycle Management consists of an information system that allows information and knowledge sharing within and between organizations (Sudarsan et al., 2005) minimizing the waste by controlling and organizing those files with information that would otherwise be carried only by the human resource that produced said files. The way it accomplishes that is by virtualizing all components of the product life-cycle in the form of digital "items" in an object oriented architecture. As explained by (Saaksvuori and Immonen, 2008),an item is a systematic and standard way to identify, encode and name a product, a product element or module, a component, a material or a service.

These item objects are, by all means, virtual representations that hold metadata regarding what it tries to represent and allows to connect and link the information. As described by (D'Antonio et al., 2015) product information should be connected to its production process. PLM allows to link defined processes to the product and to provide constraints on the order of process execution. E.g. a CAD drawing for a circuit schematic is attached to a virtual circuit object that holds basic information about what is contained in the file and all the previous iterations of that file over time as well as links to items representing which bill of materials (BOM) it belongs to, the machines necessary to manufacture it, the processes necessary to assemble it and more importantly how all those items changed over each improving iteration.

This all-around virtualization gives precious context to information otherwise lost on its own complexity. It allows for faster access, easier understanding of the whole and the consequences of what happens when there is change for each part. This is the best way of organizing the existing data for future reference because it allows for structure as well as transparency.

To sum up, PLM as a system aims to track functional change in all aspects regarding the product life, in a way that the company can benefit strategically from it by avoiding informational waste. It does so by virtualizing the real thing in the form of digital items that store the files regarding what the item is supposed to represent. These can in turn be correlated and tracked over time using metadata.

2.2. Enterprise Resource Planing

In the early days of information systems, one of the first systems to find wide implementation was the called MRP (Material Requirements Planning). Although not necessarily software based, this system wide implementation was a natural consequence of computing technology and it aimed to solve bottlenecks regarding the material supplying and product output by calculating the material needs for production. As it became more ubiquitous in the enterprise in the late 70's and early 80's the system evolved. This gave origin to MRP II (Manufacturing Resource Planning) and, more important to the scope of this paper, ERP (Enterprise Resource Planning).

For the most part modern Enterprise Resource Planning expands the original MRP function to encompass many other aspects of enterprise operations all while adding modularity to the system.

Modern ERP systems are often module based; different modules have different user interfaces and different user groups. For example, Manufacturing module, Procurement module, Logistics module, Financial module, Maintenance module, Sales module. (Saaksvuori and Immonen, 2008). These modules expand across many domains of knowledge but for the most part they do so always from the perspective of Production, Sales and Service. Figure 2 depicts the scope of the ERP system in comparison to other Information systems.

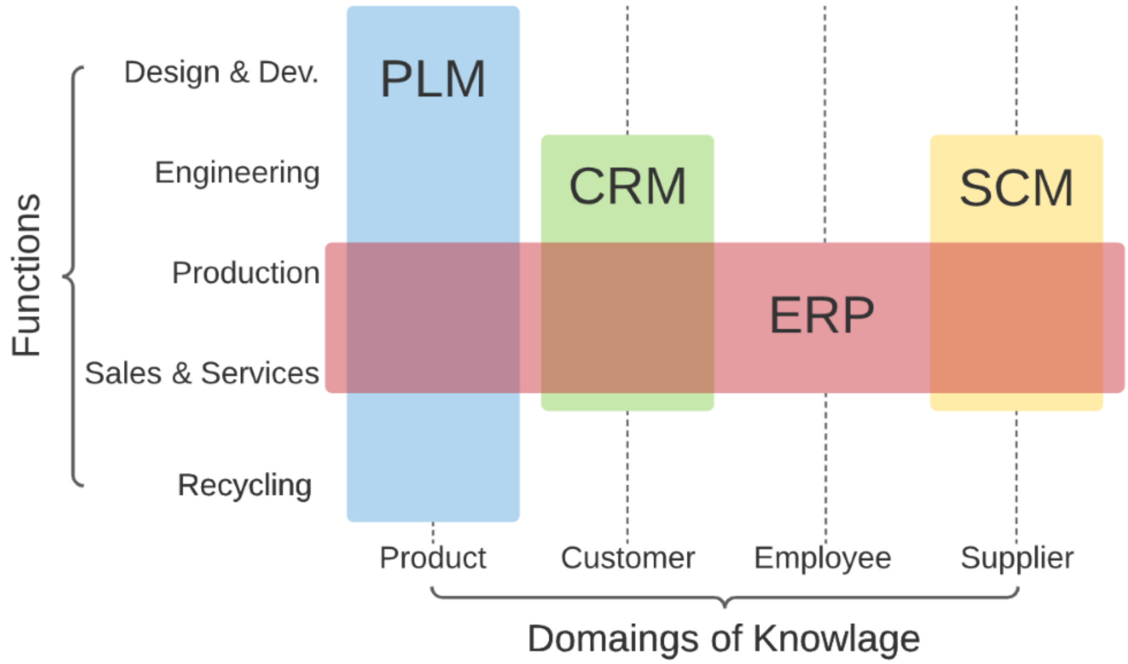


Figure 2 Visual representation of the scope of different information systems (Adapted from Stark 2015)

This sort broad reach across the domains makes sense because the ERP operations, as were in the case of MRP, focus on handling transactions and orders. The focus of the ERP is controlling the change in input, retention and output of resources to the company, be of products, raw materials or packing.

From the same image, it is possible to see the theoretical contrast between PLM and ERP even though they are both extremely broad. While ERP expands across the domains of knowledge but limits itself to a few functions, PLM expands across all functions that involve the product. As portrayed by Figure 3, another point of view that represents a good difference between the two is the lack of overlap in what concerns the scale or level of detail in which ERP and PLM affects the industry (i.e. the granularity of the two systems).

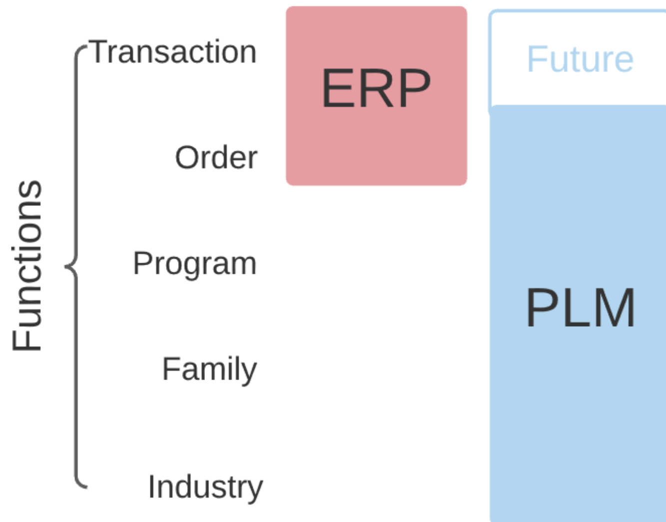


Figure 3 Visual comparison of ERP and PLM concerning granularity (Adapted from Stark, 2015)

As we can see, ERP is primarily concerned with the transaction and the order. Once an order is closed out, the ERP system processes the transactions with respect to that order but is not very much concerned with the order beyond that. On the other hand, PLM's granularity is concerned with the order for the product and extends not only into the program, but into the family and the entire industry (Stark, 2015).

This is particularly interesting because it demonstrates how the two systems can and do complement each other in the field. One of the aspects of ERP that should point out is that it is comparatively easier to integrate with other systems. ERP-MES integration for instance has been widely studied and implemented to the point where standards have been developed for it (ISA 95 - IEC 62264). One argument for this is the modular nature of the ERP system which is discussed further in the paper in (Chapter 5) with the analysis of the Odoo software. That is because the Odoo software evolved originally from an open-source ERP system.

The nature of the ERP system is best summed up by (Umble et al. 2003): ERP provides a unified enterprise view of the business which encompasses all functions and departments, and an enterprise database in which all actions concerning finance, sales, marketing, purchasing and human resources are traced. The aim of this achieving is to expand the customers target and increase customers share in a market that slowly pivots to innovation (Vásquez and Escribano, 2017).

2.3. Manufacturing Execution System

The final key of a fully integrated system would be the Manufacturing Execution System (MES). A MES is a layer of communication between the management and the production levels; it is a software that allows data exchange between the organizational level, usually supported by an ERP, and the shop-floor control systems, in which several, different, very customized software applications are employed (Meyer et al., 2009).

Figure 4 is a nice depiction of how different systems fit within the scope of manufacturing and development.

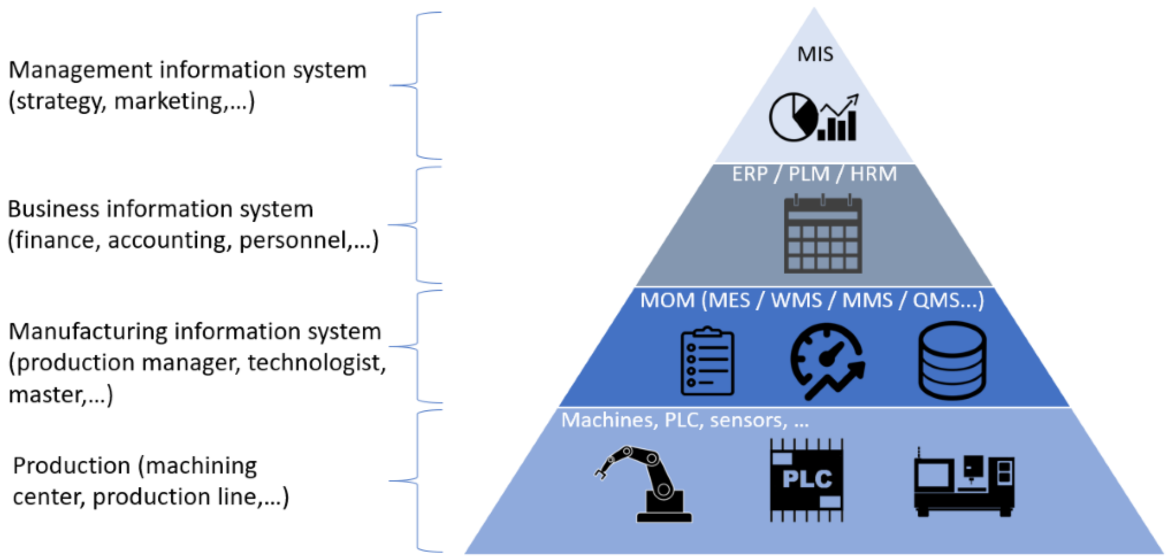


Figure 4 Visual representation of the roll of different systems including MES (Adapted from mescenter.org)

For all purposes MES main goal is to provide the numbers and data that ultimately is used to ascertain the condition and quality of not only the products but also all the processes that affect production. Machines, sensors, and anything that comes in contact with the product and provides output of any kind, basically, handing said data to the MES for sorting and processing in real time. E.g. if a manager wants to know the instant production numbers or to see a graphical representation of the rejection rate, that data will be available from a MES software.

Traditionally it is from this sort of information that management will evaluate efforts and make decisions. As mentioned before this sort of data collection fits perfectly to the use of ERP not only because the management of resources can be much more detailed if complemented by real time production data but also because the modularity of ERP usually means a seamless integration. MES (like ERP) has also been proven and implemented for decades and their implementation have already been standardized to a reasonable degree.

The functionalities of a MES have been grouped in 11 categories by MESA International (1997); furthermore, the tasks for each enterprise layer and, in turn, for each kind of information system are listed in the ISA95 – IEC62264 (2013) standard. This standard also provides definitions for the data structures to be exchanged among information systems aiming to enhance their integration; however, it mainly focuses on ERP-MES-Shop floor integration (D'Antonio et al., 2015).

PLM studies by comparison are much more recent and PLM-MES integration, a main focus of this work, even more so. The challenge of this sort of integration and the state of the art regarding it was be covered in (Chapter 3) as well as the theoretical structure behind it. For now, suffice to point out that since MES provides the feedback by which changes are orchestrated and results are validated by generating information in the form of files and PLM focus on the tracking change by file organization there sure is value in the PLM-MES integration.

2.4. Industry 4.0

The term Industry 4.0 is one mentioned time and time again in modern literature as the next or current step in the evolution of production. It represents what is the 4th industrial revolution where the first was marked the adoption of steam power, the second was marked mainly using electrical power and the 3rd was characterized by the implementation of digital technology. Figure 5 nicely represents the progression of industrial revolutions.

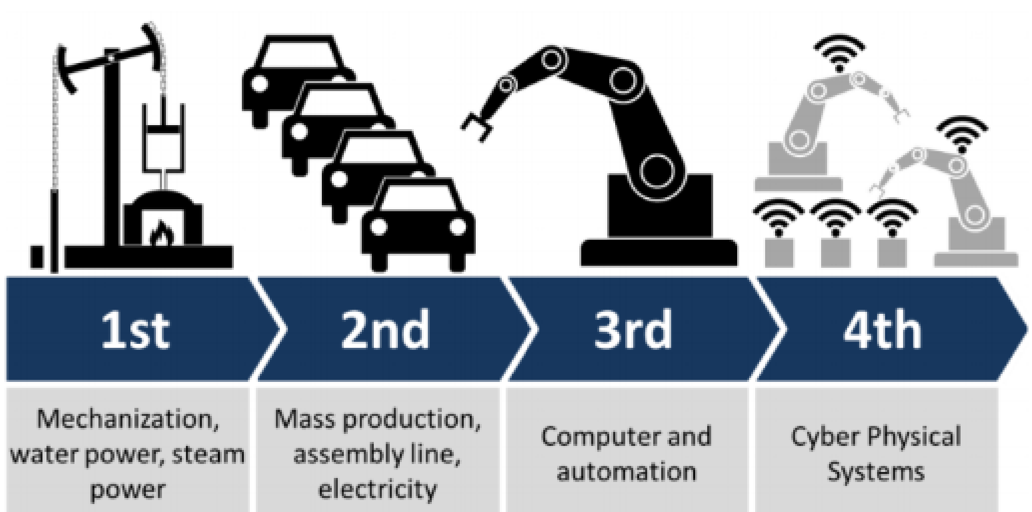


Figure 5 The industry evolution
(Adapted from STANCIOIU Alin, 2017)

In broad strokes the 4th industrial revolution is (or will be) ultimately marked by the full integration between digital connectivity and production. As it is well known that the development of digital networks is the pivotal technology that sustain the modern world. It has changed the way humans interact and do business. However, whether the current level in which it is applied to the industry constitutes an industrial revolution is still uncertain because in all other revolutions have been marked by a violent increase in production that is yet to happen this time around. In fact, we are still to reach a shared definition of Industry 4.0.

What has been widely accepted however is that there are at least 3 technologies that characterize Industry 4.0. Those are the Internet of things (IoT), Cloud computing and the development of Cyber-Physical Systems (CPS), the last of which is particularly important for the context of this thesis.

CPS are systems consisting in a real entity (for example, a machine) and its corresponding virtual model – embedding all the models for mimicking the behavior of the real counterpart – capable to communicate with each other (D'Antonio et al., 2017). The idea is that, if one were to develop a digital twin (DT) of all physical instruments regarding a process in a system that allows for the digital counterparts to interact with each other as well as interacting with the physical world, innovation or change of said process would occur much faster and effectively. E.g., an engineer could simulate a change using the DT's interaction, then, if successful, apply the change automatically to the production line in real time, execute tests, gather data and feed it back to the system without the need of manual input with all being done through the network.

The main point to be derived from all this is that PLM-MES systems possibly are the first step to achieve a proper CPS since it provides for the virtualization and necessary control to reach something near a virtual twin. The debatable matter is how deep is its current effect in industrial application.

Nonetheless, the term Industry 4.0 is, if anything, a useful denotation to the increasing application of digital connectivity, network development and the internet to industry.

Another term often included within the scope of Industry 4.0 is the called Lot Size One or Lot 1. This is the idea of each item customized to the individual specifications of the buyer in a system in which a customer order does not start supply chain equipment moving; it turns on manufacturing machines.

The theory behind it is that as production and development becomes more and more flexible as this sort of manufacturing becomes not only viable but also attractive. Having a tailored requested product means that there are no storage requirements, no inventory overhead, and of course a 100% guaranteed sell. This concept is not new by any means, in fact it predates Industry 4.0 quite a lot. In the book “The machine that changed the world” the authors (Womack et al., 1990) discuss that toward this end, lean producers employ teams of multiskilled workers at all levels of the organization and use highly flexible, increasingly automated machines to produce volumes of products in enormous variety.

In a way ‘Lot Size One’ is nothing more than the extrapolation of this sort of thinking. Of course, the industry is yet to reach such level of production flexibility, but glimpses of this sort of mentality can already be seem on more modular productions. One of the best examples is amazon packing systems. E.g. a customer receives a package from Amazon containing a mix of products that has been packaged just for him/her according to their specific order. Although superficial in nature, this represents a high level of customization for the customer.

Another great example is electronics prototyping. Currently there are companies that take your printed circuit board designs and BOM, delivering small batches of assembled prototypes at a low cost. Prototyping of electronical devices used to be a highly expensive process, but some companies have flexibilized their production to the degree where they are able to deliver it fast and reliably. Again, that is possible because electronics components are inherently modular systems even if of high complexity. The following image (Figure 6 Example project of power supply adaptor circuit) is an example of an electronic circuit that was designed by this student and manufactured by JLCPCB within a single week.

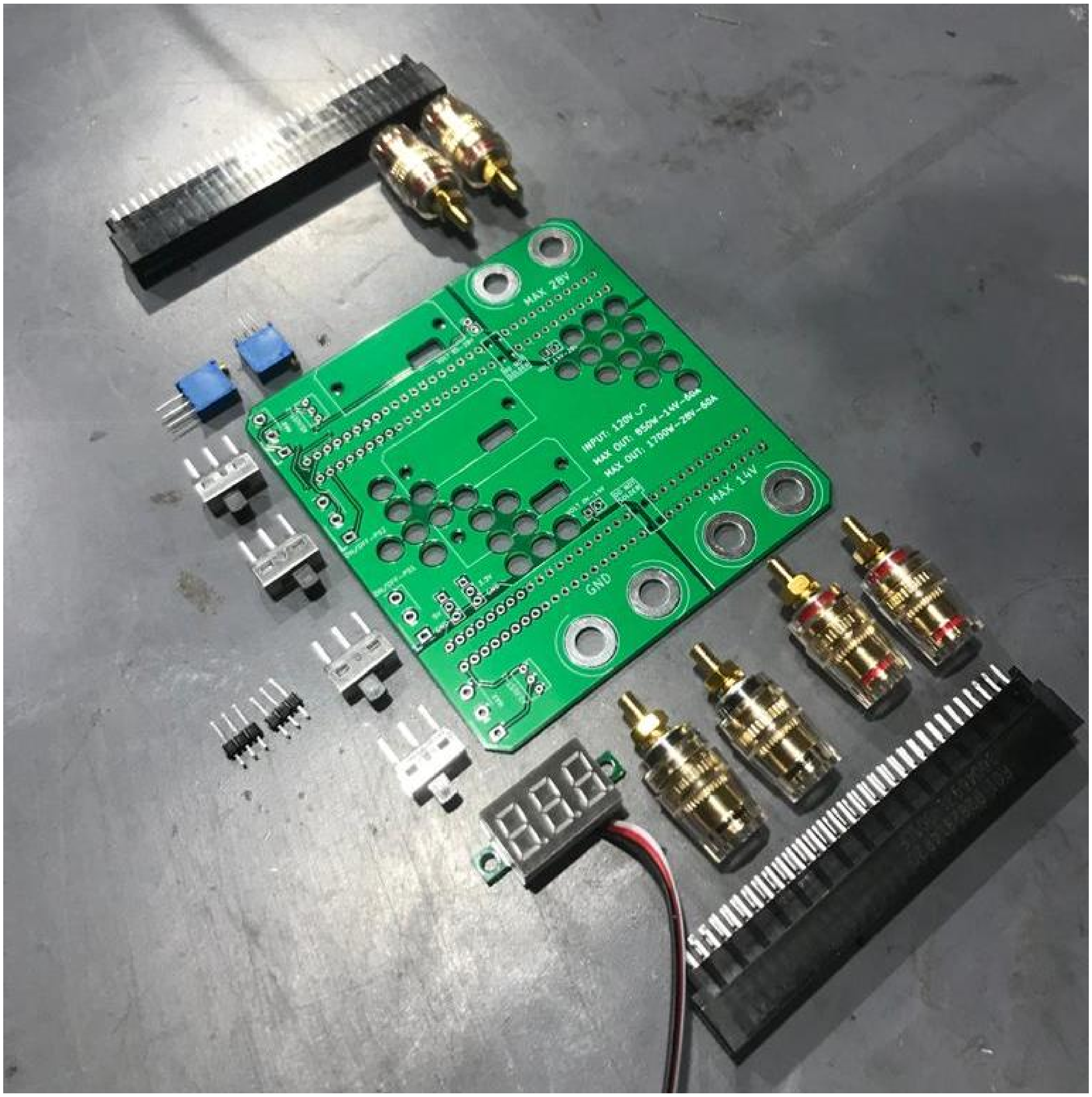


Figure 6 Example project of power supply adaptor circuit

All and all, the result is again a greater need for control and management of change. Which means the implementation of a PLM-MES system would be of great help. PLM would be required to manage change and innovation throughout the lifecycle of small batch products and MES would provide the real time reaction and feedback necessary to reduce errors that could cause losing a whole batch.

3. CHAPTER

THE STATE OF THE ART AND THE INTEGRATION OF PLM AND MES

Unfortunately, there are not many published studies in the matter of integration between PLM and MES systems. But there seems to be a consensus in the most probable effects of said integration. Those being synchronization and tighter tolerances.

As explained by D'Antonio et al. (2015), which focus on a case study involving the manufacturing of precision components for aeronautical applications, the first advantage expected by the deployment of the monitoring and control system is product quality improvement: sensors allow to detect, measure and monitor variables, events and situations that affect process performance or product quality.

One of the central problems regarding integrating PLM with any other system revolves around the ownership of information. A possible solution relies on database integration as well as the use of middleware between systems. As is written in Saaksvuori and Immonen, (2008). A reasonable objective is that information should always be updated in one place. Other systems can read information directly from the PLM databases, and if necessary, the required information can be replicated on the databases of other system, as depicted in Figure 7. Although it points this out mainly from the perspective of PLM-ERP integration, it is still very valuable from the perspective of PLM-MES integration because it is an example of how the better operation can be expected by working around systems in which files of different nature are loaded into a centralized PLM-ERP system.

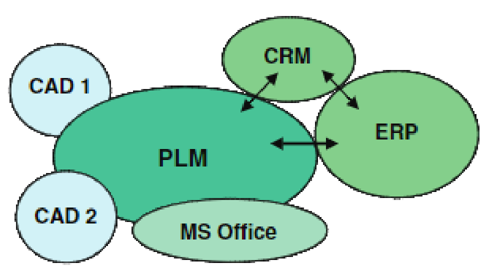


Figure 7 Diagram of PLM integration (Saaksvuori and Immonen, 2008)

The middleware would therefore be a software framework to organize and connect all the information given to the system database in a user-friendly way. This sort of application is also referred to as integration application and, as specified by Stark (2015), these applications enable exchange of product information between PLM applications (for example, between a CAD application and a CAE application). They also enable exchange of product information between PLM applications and other enterprise applications such as ERP and CRM.

In a very relevant fashion, this middleware line of thinking is expanded upon by (Ben Khedher et al., 2011). In their work regarding different systems architectures for the implementation of an integrated MES+PLM they describe the use of a mediation system in web service architecture. As depicted in Figure 8, the proposed architecture uses data exchange based on internet technologies to help companies, especially expanded companies, to take advantage of opportunities generated by the Web Services. The concept of "web service" means an application (program or software system) which is designed to support interoperable machine-to-machine interactions over a network, according to the definition of W3C (Ben Khedher et al., 2011).

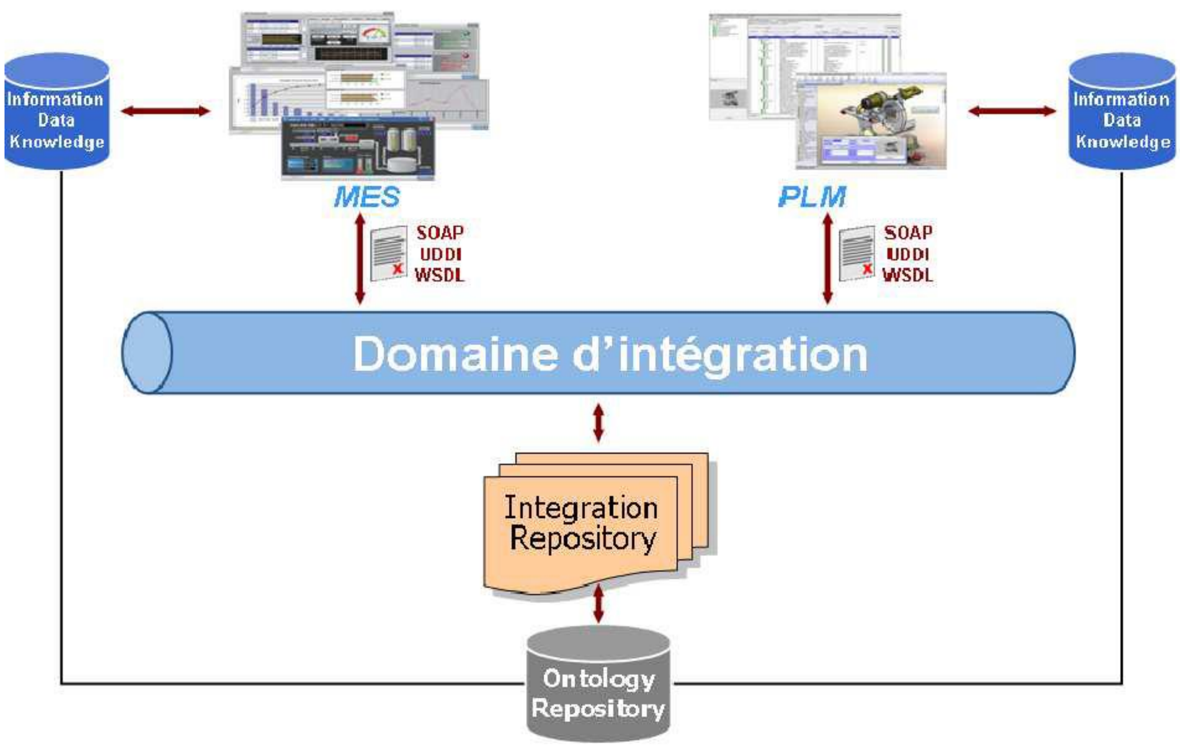


Figure 8 Diagram of Web service architecture
(Adapted from Ben Khedher et al., 2011)

The reason this expansion is so relevant from the perspective of this work is that the Odoo software works in a similar fashion through a similar web service architecture. In theory the Odoo software could act as the middleware working through the local network or hosted in the cloud and enacting the layer of integration that was previously mentioned.

3.1. How would this integration look like in practical terms

As mentioned in CHAPTER 2 the main idea of PLM is to manage change in all processes related to the product, and it does so mainly through the use of virtualization. The word virtualization here denotes representation of item of the real world to the digital space and, as one can imagine, there are several levels of abstraction through which a real object or process can be represented. As consequence there is no exact consensus regarding PLM of how deep and/or detailed the virtual representation must be to serve its purpose.

In an ideal world that would be the lowest form of abstraction which, essentially, would come down to a digital twin as explained in the CHAPTER 2. This is a '1 to 1' digital representation of every aspect of the production cycle where every part involved would have a digital representation that not only carry the physical characteristics of the item but also all its information produced over time. To this end, as explained in CHAPTER 2, MES takes a fundamental role in obtaining the real time information required for the DT even be possible.

For instance, a CNC machine would have a digital 3D model for simulation as well as a fully integrated list of all the pieces it produces, data regarding its current level of production, the current wear of its mechanical pieces, all other machines it relates to, history of all the alterations and improvements by which it was affected and many other aspects, all well packaged in an intuitive graphical user interface (GUI) that allows for maximum interaction.

Outside of fiction, we are yet to achieve such level of virtualization. It takes too much time and money to obtain and organize information to such a level of minutia, specially, the aspects that need to be inserted by hand, not to mention the subjectiveness of how this information can be integrated and interacted with. Regardless of that it is useful to identify, within the ideal, the aspects of most importance for this implementation.

Those are:

- The means of virtualization – What sort of information is used to build the virtual items. This includes the metadata and files that are directly attached to the item. In an ideal fashion this would contain all possible information available about the item.

- The means of data input - How this information is being loaded and organized. Ideally this information would be loaded into the system as automatically as possible, be it by means of MES during quality control or through the use of automated input tools like bar code scanners.

- The means of access – How this information is presented to the users. Although more subjective than the previous aspects this is incredibly important to the way the system is interacted with. How intuitive it is the information availability plays right into the core strengths of PLM. Afterall, everything would be for nothing (even if all else would be perfect) if the only way to interact with the system were a command line interface that would make difficult for the end users to access the information.

- The means of integration - How items and their contained information can interact and benefit from one another, i.e., the integration with other systems and key softwares. E.g., if an item has access to a cad file, there should be no need to fill in the metadata fields by hand. Hoe items can automatically affect other items also plays into this aspect.

4. CHAPTER

INTRODUCTION TO THE COMPANY AND PRODUCT

As one can imagine, one of the unique aspects of this work is its focus in one specific software solution that tend to be quite flexible in terms of ease of implementation to different sorts of business. This is contrary to most use cases regarding PLM implementation where the business case is the constant and the system is built around it. Nonetheless, in order to evaluate Odoo as a PLM+MES tool, it is important to consider an example. The advantage here is that a fictional company can be picked for this end maximizing the perceived effect of the software during a simulation.

It is considering all those previously mentioned systems that, for the sake of exemplification, the theoretical company was organized in the molds of Industry 4.0. This company is a recently founded small case manufacturing company that uses plastic injection molding as their primary mean of production and uses additive manufacturing and fast prototyping as part of their business strategy. As explained in chapter 2 those are great examples of the path that industry is taking regarding innovation where mass production is becoming slowly less important than product variety and time to market.

In order to maximize the tracking of change, most of its business are based on lower production batches on mainly automated machinery. This company focus in the production of injected plastic products and rely heavily in flexible machinery for setting production and prototyping. Having that in mind, it should be simple enough to simulate continuous improvement of both product and process to the extent of the evaluated software. Since this sort of everchanging production is extremely dependent on information management of all kinds, it must prove to be a perfect base for applied PLM+MES.

In this example the company has already implemented, since its recent foundation, the Odoo software and has taken all the necessary training and steps to its proper use. This allow the removal of the boundaries and limitations that are so common regarding implementation of the PLM+MES system to an already existing business, i.e., dependences on legacy systems administrative resistance to change or integration to old procedures. These are obviously important, but it is not within the scope of this work.

The company aims to produce a completely new product by the end of the year. After doing so, the company improved the process of production for said product. Once there is the need for product improvement, said improvement was performed as well.

The following diagram (Figure 9) will be taken into consideration as the path of product development and improvement:

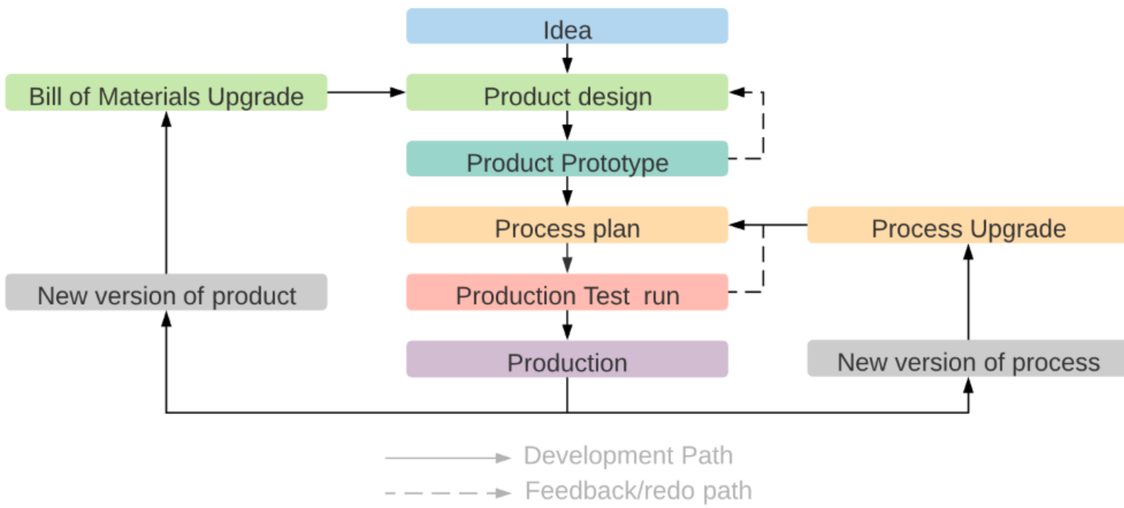


Figure 9 Development diagram

This path aims to transmit to the reader an iterative approach towards development and improvement. The idea is followed by a product design for which a cycle of prototyping and redesign takes effect until satisfactory result is achieved. Then a similar cycle takes place regarding the production process. At the end of this stage initial development is done and the actual production can begin.

It is at this point that ways of stablishing the continuous improvement is important. In the case of this company, we are only considering two main types of upgrade paths, those being, product upgrade and process upgrade respectively.

4.1.The products and processes

Change and effect are the focus of the PLM+MES implementation as such the subject of said change would ideally be something that could afford a reasonable amount of freedom of design. Although the effects of a well implemented PLM+MES should be substantial even in rigid manufacturing environments, where the change is extremely limited, the system will produce much more perceivable change in an enterprise that thrives in innovation because there will be more opportunities to improve the system and gain feedback.

From the perspective of improvement, if you compare a product that is a result from sheet metal stamping (Figure 10) to an equivalent product that is the result of a CNC milling procedure (Figure 11) it is easy to perceive that the CNC milled product is more welcoming to upgrades. While the stamping is low cost (by comparison) it depends on heavy high precision metal dyes that are extremely expensive to produce. This means that the cost of enacting change to it is much higher and thus the effect of a system that thrives on tracking change becomes limited.

Figure 10 Example of stamped AK74 pattern rifle receiver (Brownnells.com)

Figure 11 Example of milled AK74 pattern rifle receiver (sharpsbros.com)

In the case of this fictional company, it has been determined that the best way to exemplify the PLM+MES effects would be to have products designed around plastic injection molding. It might seem unintuitive at first to consider this manufacturing procedure, like the stamping procedure previously described, since it too depends on high precision molds during production. However, the main differences between the two is regarding ease of prototyping and the cost of upgrading.

Injection molding is a broad and complex field of engineering that involves a huge variety of materials and methods, little of which is of the concern of this work. It is however relevant to point out that for the most part, the pressures involved in the injection molding are one order of magnitude lower than the when we are dealing with steel; softer materials can be used on their molds like CNC milled aluminum. At the same time, new advancements in the field of additive manufacturing have made possible to prototype plastic parts with much closer physical characteristics to the end result of a injected piece. Sometimes even prototype molds (Figure 12) can be used for a lower volume test runs during process upgrades.

Figure 12 Example of injection mold made using a 3D printer (thefabricator.com)

Additive manufacturing has become an incredible tool for ultra-flexible production. This mindset of continuous improvement, especially when regarding prototyping and iterative design, is a hallmark of the lean mentality that is so relevant in the modern industry.

As mentioned in the previous section, in this case study it is considered the creation of a new product and its production process by the fictional company. This product consists in a plastic small form factor computer case, composed of 3 different parts (Figure 13) that are expected to be designed and prototyped considering combination of additive manufacturing and CNC milling towards a plastic injection molding production.

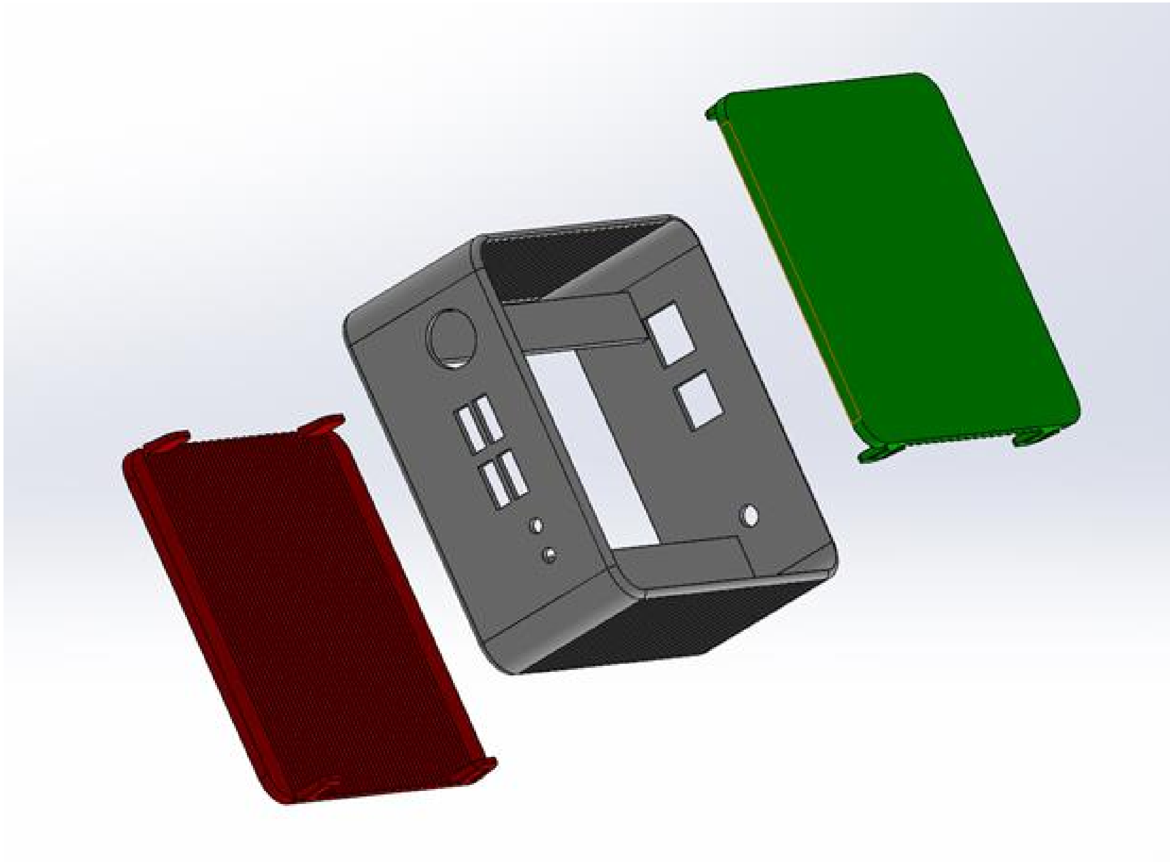


Figure 13 3D exploded view of the theoretical product

4.1.1. Part A

PART-A (Figure 14) is the core structure of the computer case. It is expected to comport all the pieces necessary for the proper function of the small form factor computer in question. To this end a raw material A was selected to be Acrylonitrile Butadiene Styrene (ABS) this is an opaque thermoplastic polymer and an engineering grade plastic. It is commonly used to produce electronic parts such as phone adaptors, keyboard keys and wall socket plastic guards.

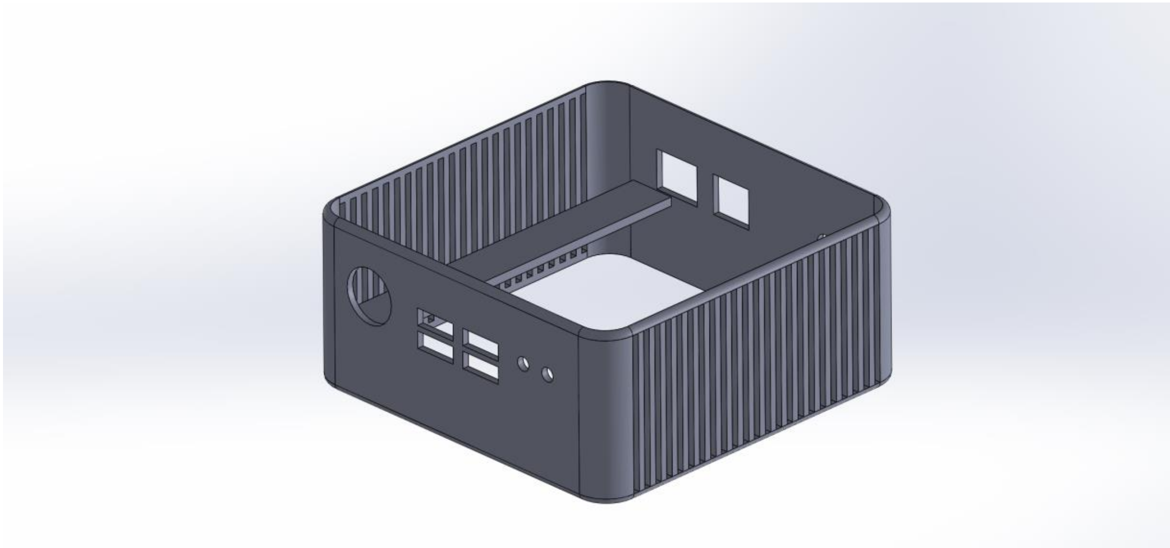


Figure 14 Isometric view of Part A

The main reasons for choosing this material specifically are its toughness, its good dimensional stability (resistance to change dimensions after cooling), its high impact resistance and surface hardness. Finally, it is also commonly available in the form of 3D printing filament for extrusion 3D printers which should prove to be quite useful during prototyping.

4.1.2. Parts B and C

Parts B and C are lids that should snap into place, closing the system. These are very simple pieces and require a certain level of elasticity so it can deform to assure a screwless assembly. These two identical parts are going to be made with Thermoplastic Polyurethane (TPU), because of its elastic nature and great tensile and tear strength. This sort of polymer is often used to produce parts that demand a rubber-like elasticity. TPU performs well at high temperatures and is commonly used in power tools, cable insulations and sporting goods. Finally, TPU is also available in the form of filament for 3D printers which, for the simulation, will be used for prototyping.

Figure 15 Parts B and C

4.1.3. Molds

Ideally all molds should be made of steel, for longevity of the mold and product quality. That being said, the injected plastics that are being selected for all parts are not so pressure dependent and their forms are not so complex, so it is assumed that aluminum molds made with a precision CNC machining should suffice to produce said parts.

It is also assumed that all molds are simple enough to be prototyped using 3D printing. Although this is not always true, it was determined representative enough for this simulation. The type of material used in those prototypes is high temperature resign cured using an SLA 3DPrinter. Additionally, the mold will be considered the main physical aspect to be developed when regarding the production process because it something that directly affects the production as well as something that can be produced in house and tracked as a product would.

4.2. What is analized during the simulation

Taking into consideration the diagram, shown in Figure 9, as well as the main aspects of a successful integration of PLM and MES as described in the section 3.1, this experiment aims to produce commentary regarding the following relevant questions in Table 1.

Table 1 Summary of questions to be answered

Category	Questions
How does the software deals with items?	Are all aspects of the product lifecycle represented?
	How well are each of those items represented?
How easy it is to create a brand-new product?	How the product is depicted
	How does the product integrate and reference relevant files?
	Does changing one affects the other?
How easy it is to create a brand-new production process?	How the process is depicted?
	How does the process integrate and reference the product it produces?
	Does changing one affects the other?
How easy is to improve an existing product	How easy it is to update its metadata
	How easy it is to determine the effects of the change
	How does the software deals with different product revisions?
How easy it is to improve an existing production process	How easy it is to update its metadata
	How easy it is to determine the effects of the change
	How does the software deals with different production process revisions?
How easy is to find data related to product or process?	How easy is find production numbers?
	How does Odoo generate performance data?
	How does the software present performance change as a result of a upgrade?

5. CHAPTER

THE ODOO SOFTWARE

5.1. Introduction to the Odoo software

Odoo is a commercial business management software with strong ties to the open source community. Initially started as open source ERP software becoming well received as an affordable and intuitive package that thrived on integration and expandability. Since then, as the company experienced accelerated growth, it shifted their business model to include an enterprise paid version as well as an online service.

As mentioned in the section 2.2, modern ERP systems are usually modular and, in the case of Odoo, this modularity is particularly evident due to the incredible amount of expansion provided by community developed modules as well as company developed modules that are highly integrated. This extendibility is what makes this software so relevant to the topic of PLM+MES integration since there are present modules for PLM as well as noticeable MES functionalities within their manufacturing modules.

Within the scope of this thesis, the objective is to utilize this software on the management of the previously mentioned fictional company and draw conclusions regarding how effective the integration of PLM and MES is already present within this system.

5.1.1. How it works

The software can be installed in most x86 computers and it supports several operating systems including windows and all the main Linux distributions.

Ideally, the Odoo software is installed in a computer connected to a local area network and starts a SQL database that holds all the necessary information and files produced by the business (Figure 16). Said computer works essentially as a server and accessed via a browser by the other machines present in the network. This computer can be a dedicated server or a working desktop in use, but it is important to remember that it must remain ON and connected throughout the entire time the software is required to function.

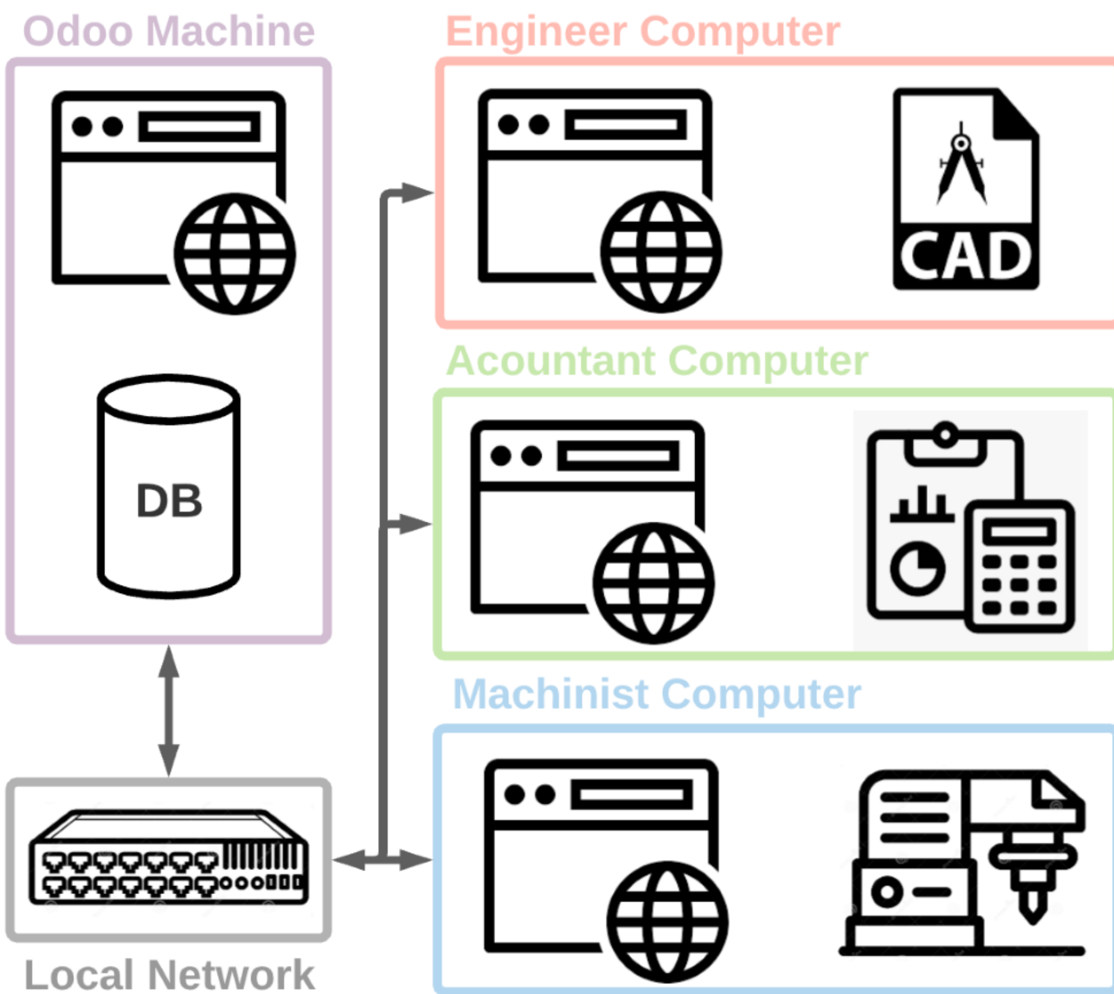


Figure 16 Function Diagram of Odoo configuration A

Another option is to use the hosting service provided by Odoo SA (Figure 17). In this case the system would be hosted by them and data would be stored in their cloud. This is a good fit for many small businesses specially if they are particularly fond of the website related modules (used to build and manage web sites and e-stores). It is however network dependent which may pose a problem in some instances.

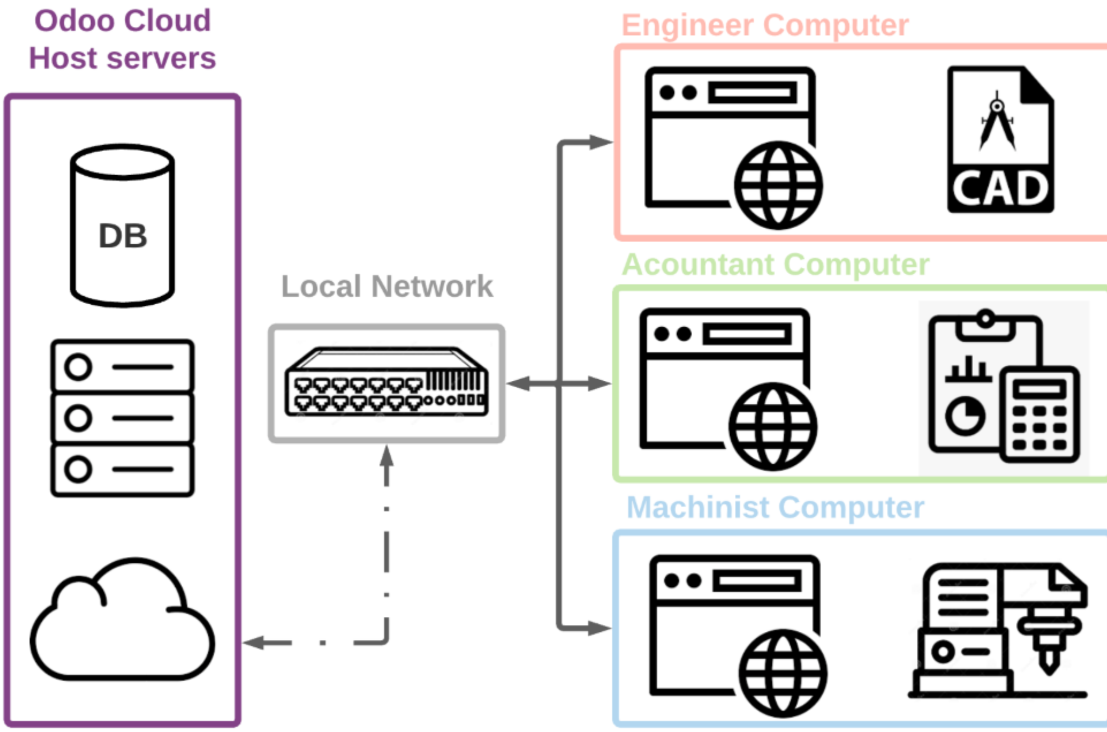


Figure 17 Function Diagram of Odoo configuration B

Users essentially interact with the system through the graphical user interface (GUI) and use it to access the different modules available as need by a per user basis. This means that restrictions can be applied to different users in order to maintain control over the different aspects of the business activity, e.g., accountants would get access to accounting module, sales module and inventory module but they would be restricted from the manufacturing module. This sort of restriction guarantees control over the processes only to the proper employees.

Within said GUI the different modules appear as app icons (Figure 18) and, from the get-go, the company has available a reasonable selection of well-integrated applications not to mention a vast app store filled with community made modules.

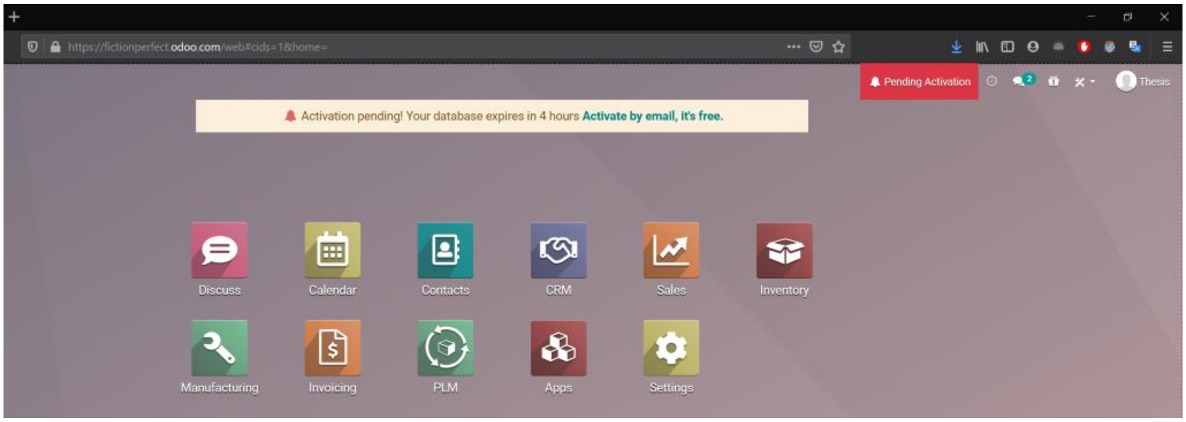


Figure 18 Screenshot of GUI from Odoo in configuration B

5.1.2. Odoo's view on manufacturing:

Odoo considers that the responsibilities regarding manufacturing of anything is distributed throughout different company departments, each of which is responsible for specific file types and dealt with using specific apps (Table 2). From the perspective of PLM this is very positive because as mentioned by (Saaksvuori and Immonen, 2008) about User privilege management – the PLM system is used to define information access and maintenance rights. The PLM system defines the people who can create new information or make, check and accept changes, and those who are allowed only to view the information or documents in the system. user privilege management is usually a challenge when regarding integration of PLM with other systems.

Table 2 Correlation between department and Documents/Apps

Department	Documents/Apps
Engineering	CAD & BOM
Manufacturing Engineering	Routings, Worksheets, Workcenters
Purchase/Procurement	Procurement order, Request for quotation
Inventory Operators	Receipt, Barcode
Manufacturing Foreman	Manufacturing order, Planning
Manufacturing Operators	Work order
Inventory Operators	Delivery
Quality	Alert, Analysis, Control points

Department	Documents/Apps
Engineering	Engineering change order
Maintenance	Preventive/Corrective

From Odoo's perspective in the beginning of any usual manufacturing process, the first step will be the engineers designing the product usually using a CAD software. Once that is done, they will create a Bill of materials (BOM) this is a list of components or materials necessary to produce the product. At this point the focus goes to the manufacturing process itself.

The software view of process is focused on routings, worksheets and work centers this is done by the manufacturing engineering team. A routing is a set of steps a product goes through for production. Worksheets are the instructions for the manufacturing operator, and work centers are the places where the production is being conducted. Odoo considers that these are the requirements for putting engineers plans in motion

A procurement department will be responsible for requesting for quotations (RFQ) or purchase orders (PO). Inventory operators take care of receipts based on those POs, which is usually done using a barcode application within Odoo. As explained in the first section of this chapter Odoo is primarily an ERP system and it is at this point that it is possible to notice some ERP centric characteristics like the focus on inventory and management of resources. This will be further analyzed in the following sections, but it is fair to point out that those RFQ and PO are considered items within the data base.

Only when you have the design the process and the materials required Odoo considers manufacturing possible. Then the manufacturing foreman will create a manufacturing order (MO) and manage the planning of the manufacturing operators through work orders (WO) and work centers. Then the manufacturing operators can start production following a work order. After the products are produced, they automatically appear in the inventory database which alongside packaging and delivery is managed by the Inventory department.

Odoo considers that quality team is responsible for assign control/check points as well as identify possible issues within the product or production. These quality control check points are very interesting from the MES perspective because it represents valuable production data that is collected in real time as production occurs, i.e., it is possible to assign a dimension check after the production of every piece where the machinist will fill in the dimensions to track quality over time.

If it's a problem of design or if there is possibility for improvement an engineering change order (ECO) can be issued. This falls back to the hands of the manufacturing engineering team and will focus on updating documents and the BOM. The ECO is the heart of how Odoo deals with tracking change within the system. That is key when regarding PLM and in fact is the focus of the Odoo application called PLM. To which lengths said application is capable to perform is the subject of the next section.

5.1.3. The information structure of Odoo

Each module focuses in the manipulation of specific object-oriented classes that hold metadata within the database. These are the virtual Items that are responsible for virtualizing the aspects of the product lifecycle as referred by in (Section 3.1). Different types of items have different types of accounts and hold different sorts of data, i.e., a product item is representative of a certain product and holds metadata that is relevant to its interactions and use as well as links to other possible items that are closely relevant like their responsible user or the bill of materials necessary to its manufacturing. Odoo them makes all that information accessible and interactable through its browser interface (Figure 19 and Figure 20). For the sake of consistency this document will refer to specific item representations (E.g. Bolt) as 'item' and refer to a type of item (Product) as 'item class'.

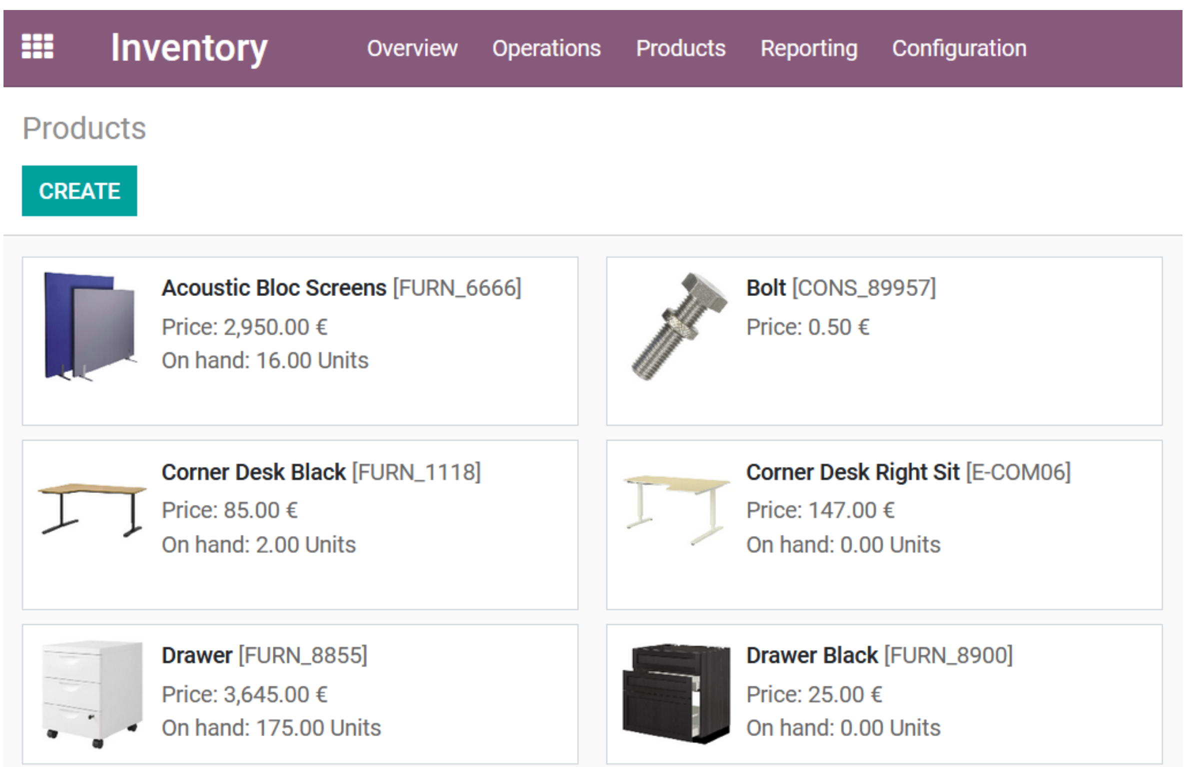


Figure 19 Example of Odoo's interface regarding items

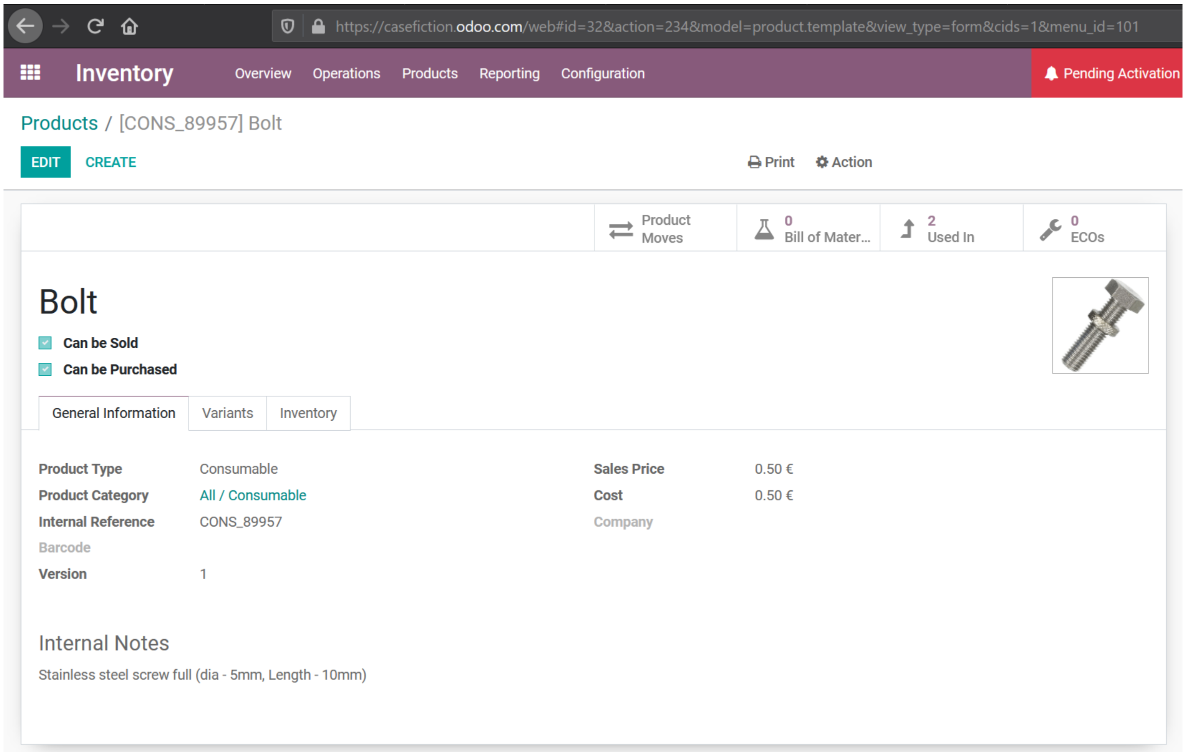


Figure 20 Example of specific item and its metadata as displayed by GUI

Within Odoo, there are several types of those item classes (some holding a lot of metadata and some holding very little) all with a varying degree of relationships and integration. Since the scope of this work is limited to the PLM and MES capabilities, the focus is on the items that are related to it. The following sections will provide short explanations for the main 7 item classes of Odoo's manufacturing process since its basic understanding is helpful for the reader to follow the simulation. These are represented in the following diagram (Figure 21). Other items that are external to the manufacturing procedure will be presented throughout the simulation.

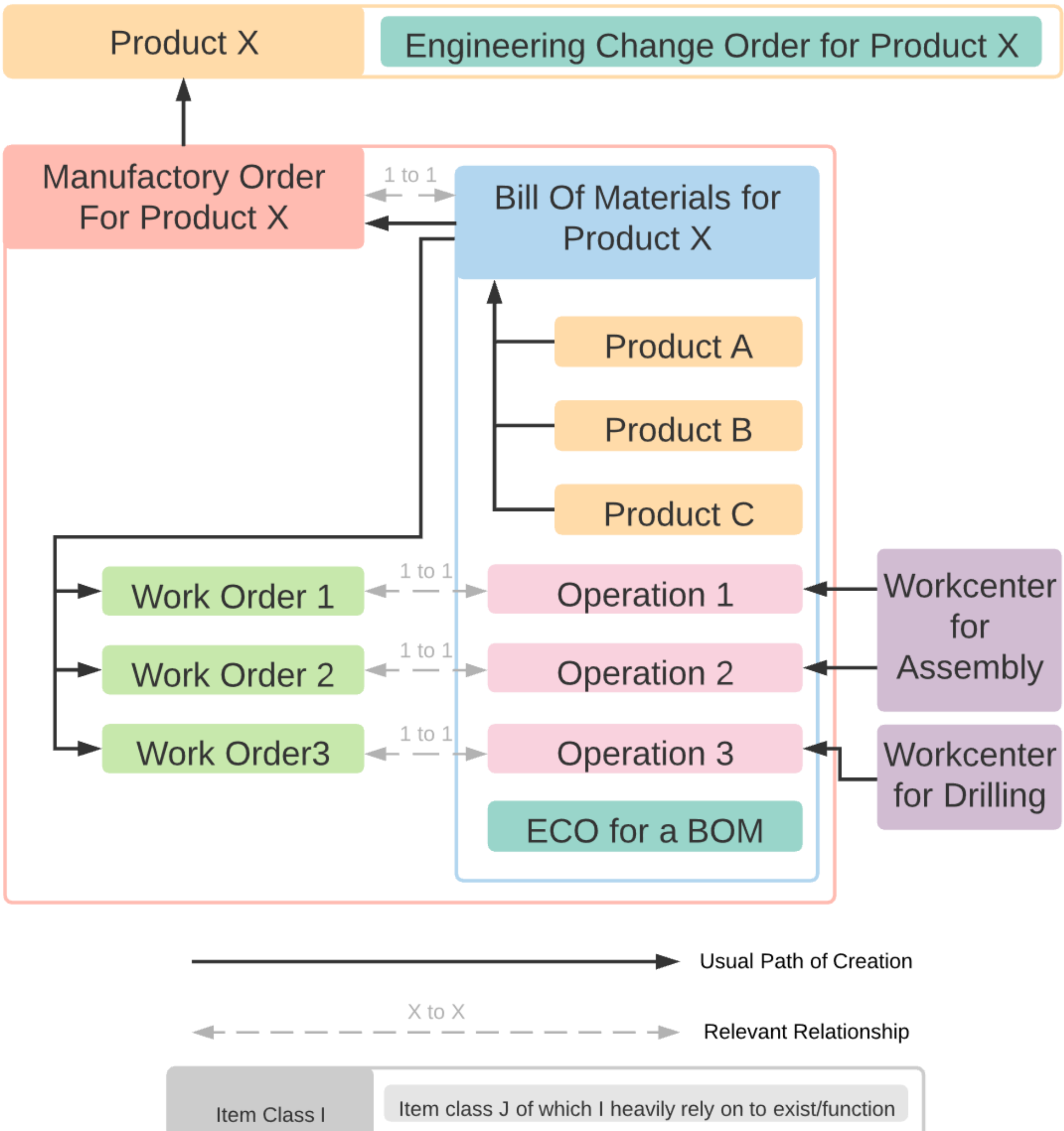


Figure 21 Simplified Item relation diagram to the manufacturing of a product X

5.1.3.1. Product Item

Every material, component or product is characterized by a PRODUCT type class that is held and mainly managed within the Inventory application of Odoo. That means that within the system product production is dependent on the availability of other products that are either bought as they are or manufactured from another products (Figure 22), i.e., raw materials are considered products as well, more specifically products that are purchased and then included in the BOM's to manufacture other products. This is considered the main item class since it is both the source and the goal of manufacturing.

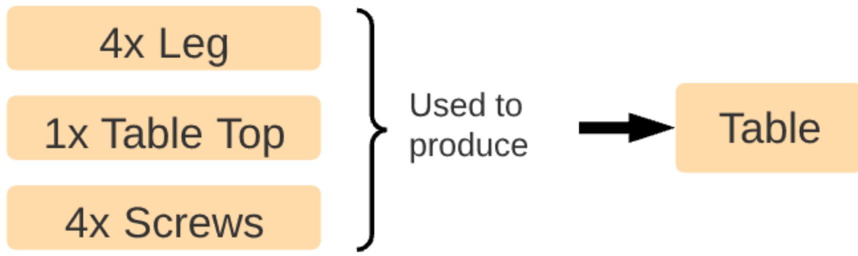


Figure 22 simplified Product relation diagram

5.1.3.2. Operation item class and workcenter item class

The operation item is representative of a manufacturing operation that is required to transform components or raw materials into a product or new component while the workcenter item represents the place at which the operation takes place, e.g., a sanding wood will be carried out in a sanding station (Figure 23) that has the proper equipment. The workcenter is eventually used in Odoo as a time/equipment management tool in its production planning. Basically, when the production center is at full capacity it puts following processes on hold or redirects the processes to an alternative workcenter. The operation item is also responsible for holding the instruction files that are consulted during production.

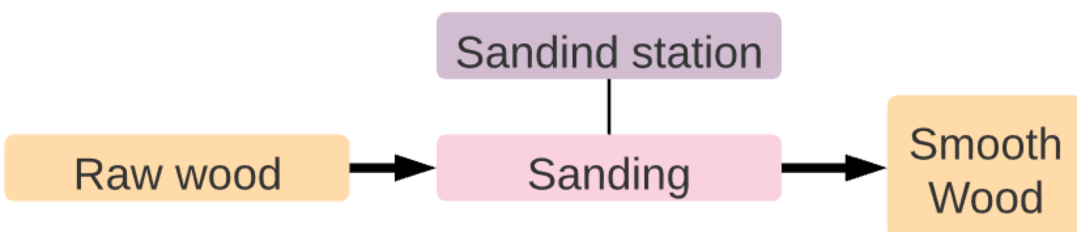


Figure 23 Simplified Operation diagram

5.1.3.3. The Bill of Materials item class

The Bill of Materials is a list of components necessary to build a product. In Odoo, however, the BOM is best described by what PLM would consider the virtual representation of the production process. That might seem counter intuitive at first considering the previously mentioned operation item class, but in fact since the BOM is a compound item it points directly to all item types necessary to produce the end product (Figure 24). For example, let's say that to build a product it is required 3 different parts and 4 different operations; the BOM of said product would list all of them as well as specify the order in which these are utilized.

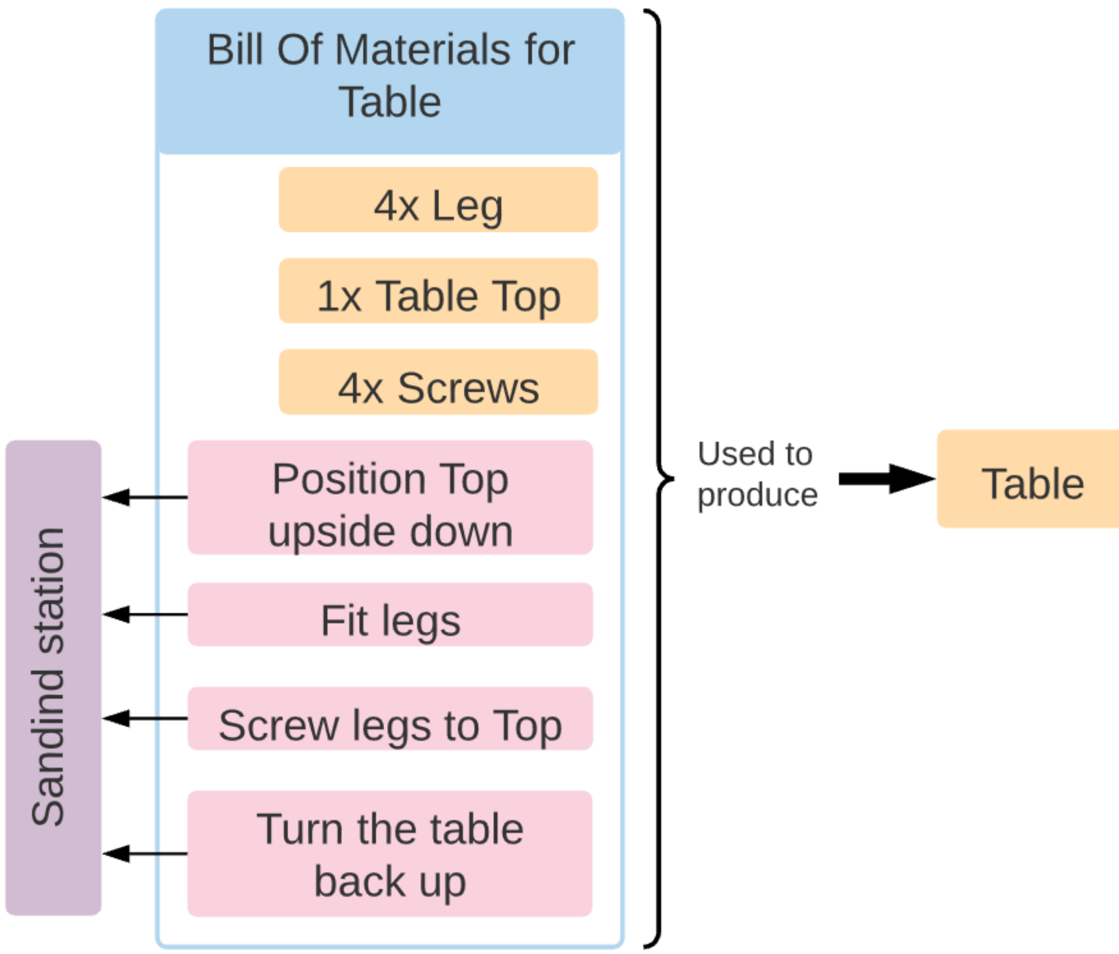


Figure 24 Simplified BOM diagram

5.1.3.4. Manufacturing order item class and work order item class

Along the standard items that are considered within Odoo, orders are the ones that represent commencement within the system. They are signaling that a change is taking place somehow and somewhere. In the case of a manufacturing order it represents the order to manufacture N number of specific products using it's BOM as a base. It is as consequence of that MO that work orders are automatically generated by Odoo (one for each necessary operation listed in the BOM) and allocated throughout available necessary workcenters (Figure 25).

The work order is the main form in which the manufacturing operators interact with Odoo, it presents all the instructions specified by the operation item, as well as control towards its completion. When a WO takes place the operator signals through the interface its beginning, its completion and even any quality control check points required while the system keeps track of timing and performance (Figure 26). Once all WO are done the MO can be declared done and the materials and components specified in the BOM are consumed and the N copies of the product is added to inventory. All that makes the work order a central piece as far as MES is concerned.

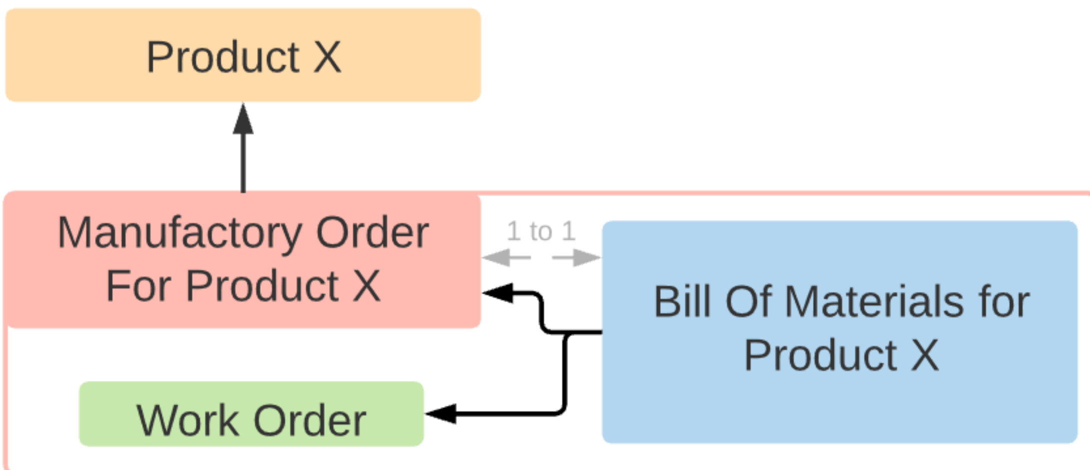


Figure 25 Simplified orders diagram

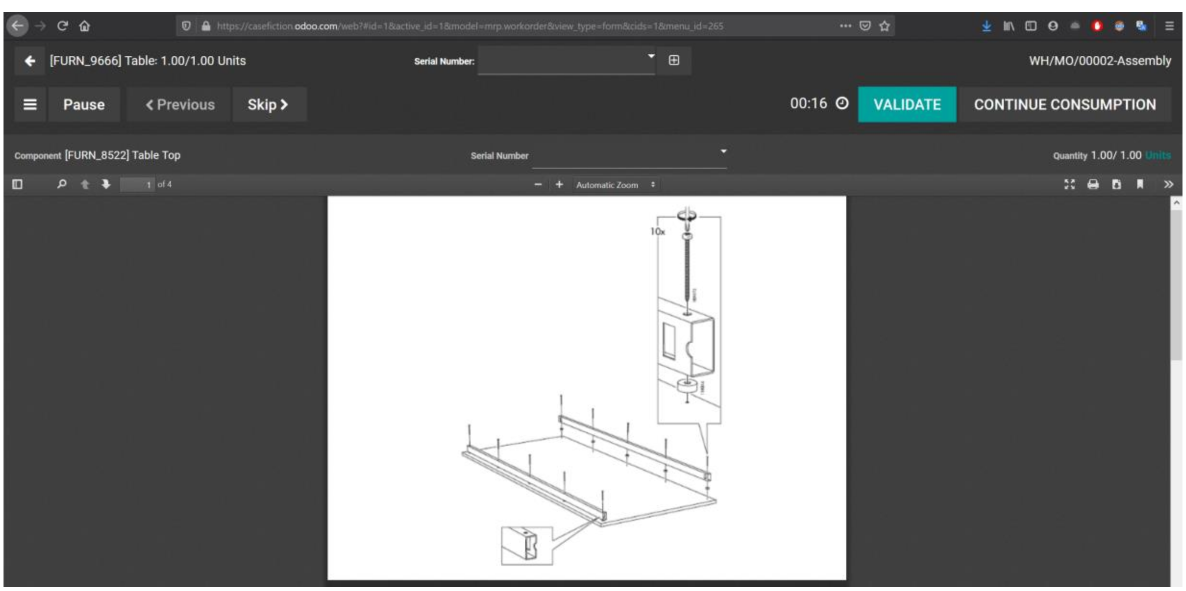


Figure 26 Operator interface during the WO

5.1.3.5. The engineering change order

As explained in the beginning of chapter 2 the Odoo management software considers PLM mainly as a tool for tracking change and improvements. Its application module is external to the normal flow of manufacturing but acts as an expansion to it. Its focal item class is the Engineering Change Order (ECO).

An ECO is an item class that outlines the proposed changes to the product or the parts that would be affected by the change. In other words, is a central information hub for everyone associated with a given product.

The idea is to signal the need for change to a product item or a BOM item, hold the files that are relevant to the change and apply the change or at least signal that the change has been implemented, all while keeping the history of al the previous changes. All very useful in the future and serve as a process to streamline product development and help improve products/production.

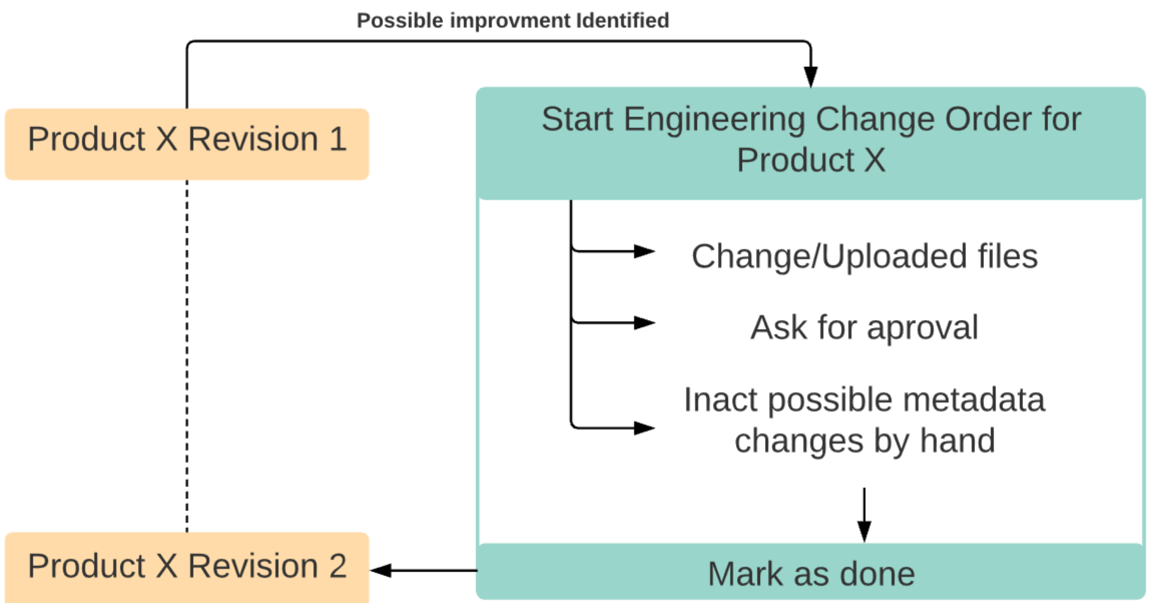


Figure 27 Simplified ECO function diagram

5.2.Starting the simulation

5.2.1. Software option chosen for the simulation

For this simulation, it has been decided that the best evaluation of the Odoo software would be through its online web-based service. The reasons for such choice instead of using the community edition of the software are as follows:

- The practicality of using a web-based service as oppose to administrate a server locally or remotely. Although the community application was tested as part of the research for this work and has been judged to be a very beginner friendly server application the fact of the matter is that hosting a server is, on its own, a job that requires experience and knowledge. There has been a shift of the market regarding this sort of application towards product as a service and with good reason. At the time this thesis is being written the COVID-19 pandemic is forcing a lot of employees to work remotely and making clear to the market that IT is not a simple job and that a web service is an attractive option.

- Lack of official Odoo PLM application for the community edition of Odoo. Although there is a substantial repertoire of community made applications for the community edition of Odoo the organization, description, integration, and support of this applications are spotted at best. Rather than rely on applications that might not keep up with the main software it was decided that it would be a fairer to the platform evaluation if it was based on official applications. I.e. it would be very unproductive to slap together a free solution just to depend on luck regarding how it is supported on the future. PLM is the focus here, so this is an unnegotiable situation.

At the time of writing this work, Odoo allows you to select one of its extra features like PLM and use it for free for an indefinite amount of time on their cloud hosted servers. This is a very attractive option if the only focus of this work was PLM and manufacturing. However, the MES aspect of this work is highly dependent of other applications of Odoo which means that there is very little that can be done. To this end the experiment was carried out in the trial version of Odoo enterprise which allow the user to use the system without storage or application limitations for a period of 14 days all hosted in Odoo cloud servers (Figure 17).

5.2.2. Setings details that are relevant

A few details regarding the settings of Odoo are relevant to the proper function of its manufacturing functionalities. Namely enabling work orders in the manufacturing settings is an obligatory step for proper use of both work order items, workcenter items and operation items.

An assumption made for this work is that this is a holdover of the ERP origins of the software because it is rather unintuitive to not have this setting enabled by default if you are going to use Odoo to make any serious control on manufacturing. Regardless as of Odoo enterprise v14 this option can be set in the Settings > Manufacturing > Operations > Work Orders (Figure 28).

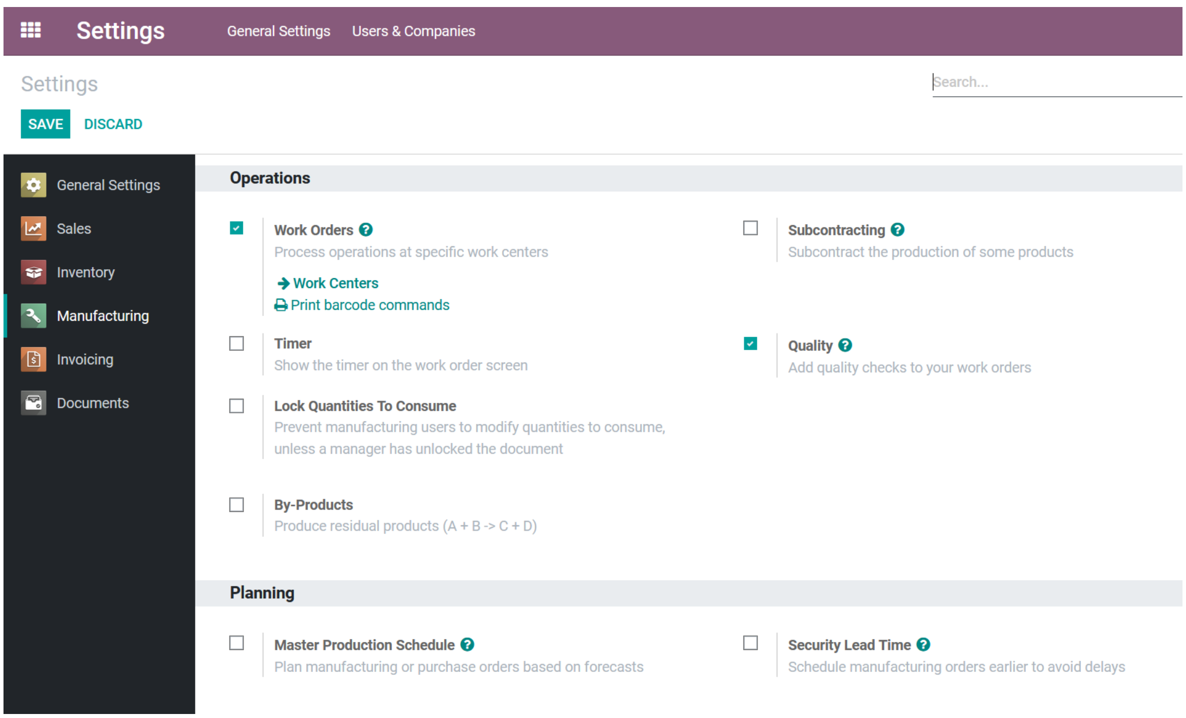


Figure 28 Screenshot of the specific setting to be enabled

5.3. Building the company structure

5.3.1. Users

Users are set and invited through the setting menu. It is possible to assign different levels of permissions regarding different aspects of the business operation. Messaging, permissions, approvals, responsibilities are all assigned into a user. This is very convenient and can fall within the category of virtual item class even if it has limited use in the scope of manufacturing. Their creation is not strictly necessary, the software would run just fine having just me as a user with full administrator credentials, but for this simulation, 5 users were created as listed below to represent different employees within the company. The following (Figure 29) is a screenshot of my user account item and its 'Asses Rights' followed by one of the fictional users being created for the company (Figure 30).

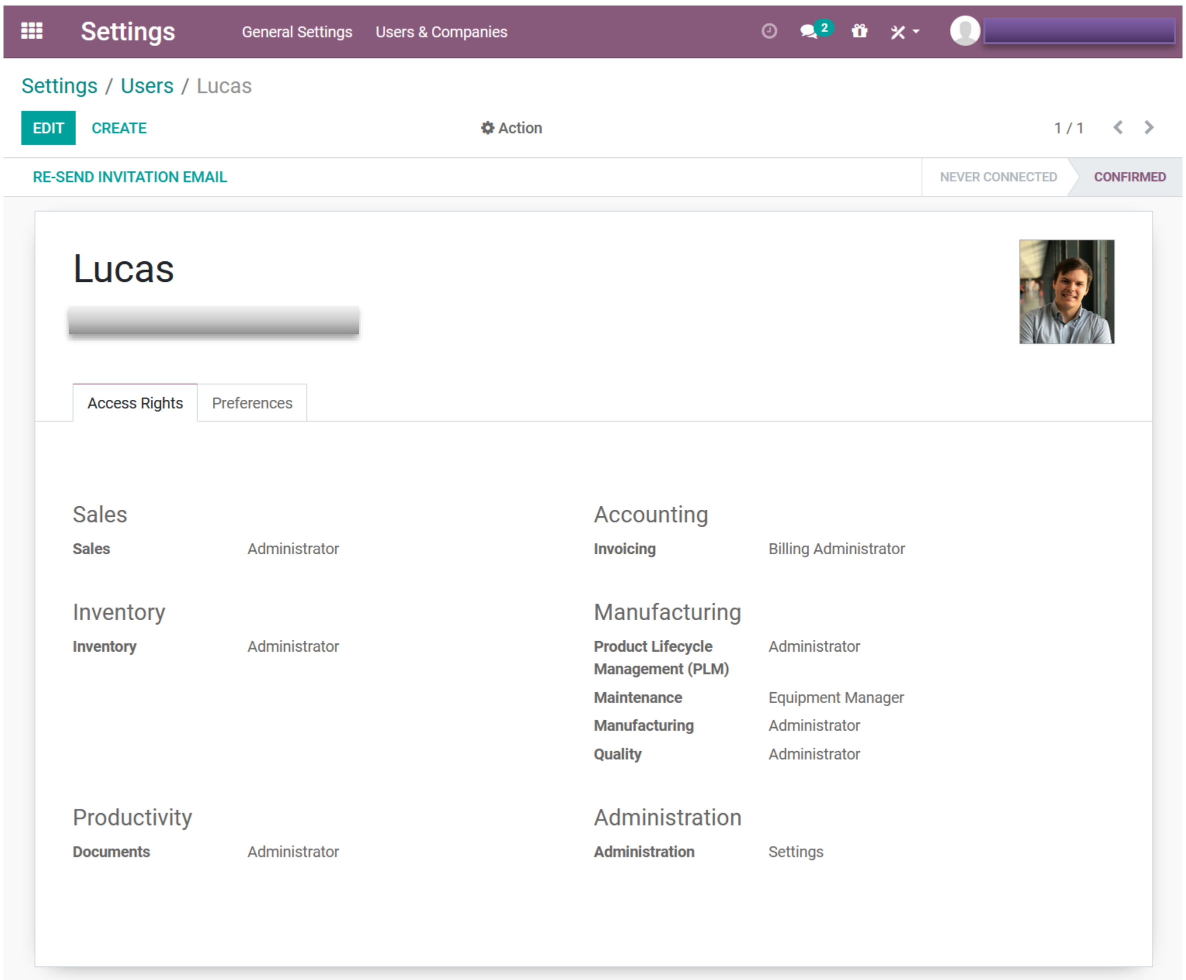


Figure 29 Screenshot of user account interface

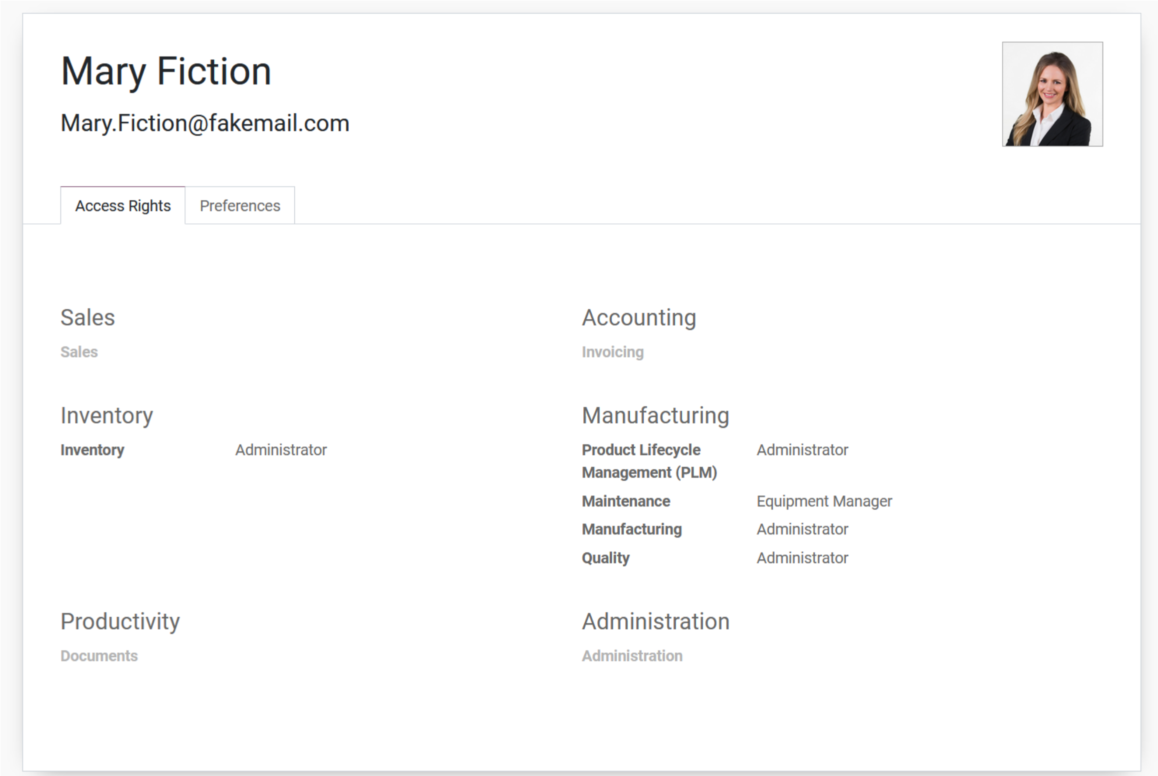


Figure 30 Screenshot of second user account interface

It is nice to point out how the two differ in access rights. Mary Fiction has been created in this example as an engineer and therefore most of her permissions are around the manufacturing procedure while she is denied access to other parts like Sales or Accounting.

5.3.2. Workcenters and Equipement

Workcenters are quite flexible within Odoo in the sense that they can be changed and expanded as needed. One could create the workcenters after creating the product items to allow for reorganization of the shop floor once you gained some perspective on what the products will be in the end. However, for most scenarios this seems unrealistic since the workcenters are more rigid structures in the real world - they don't change as much as the products since they tend to hold heavy machinery.

In this simulation it was considered that the company already has 3 workcenters from the get-go and therefore the workcenters and machinery were created beforehand. This is more useful for possible readers interested in implementing Odoo as well as saving sometime.

We begin by creating the equipment we have. This is an item class that emphasizes in maintenance organization. The application responsible for managing equipment is the Maintenance App. The following image is an example of how Odoo portrays a 3D printer equipment item (Figure 31).

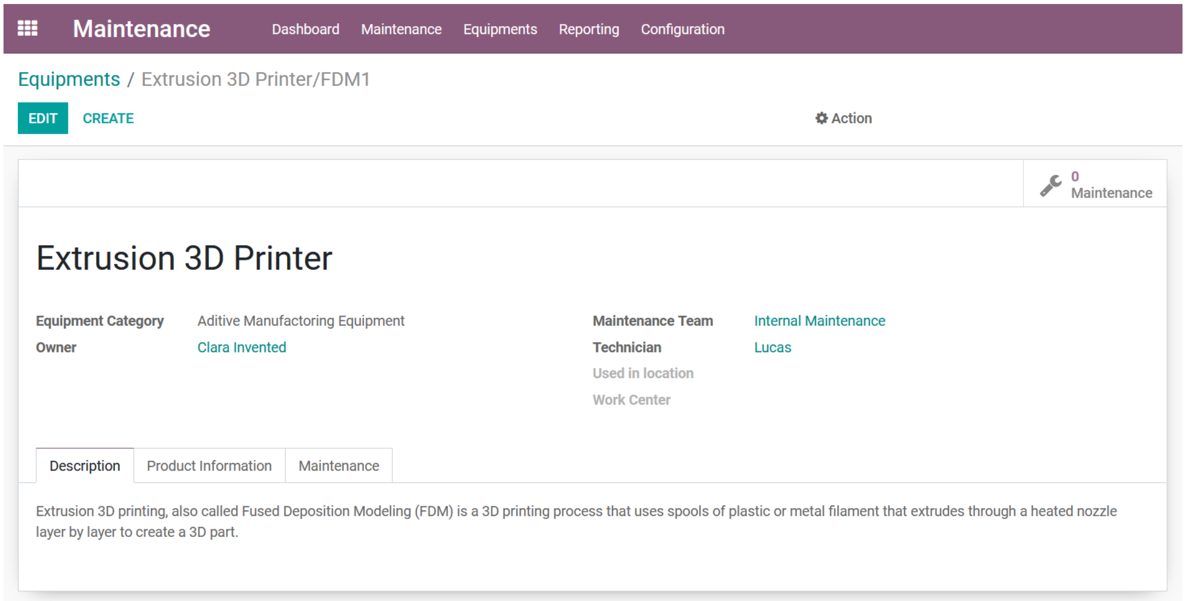


Figure 31 Odoo 3D printer equipment item

In addition to this 3D printer the following equipment were created to be used throughout the development/production process (Figure 32):

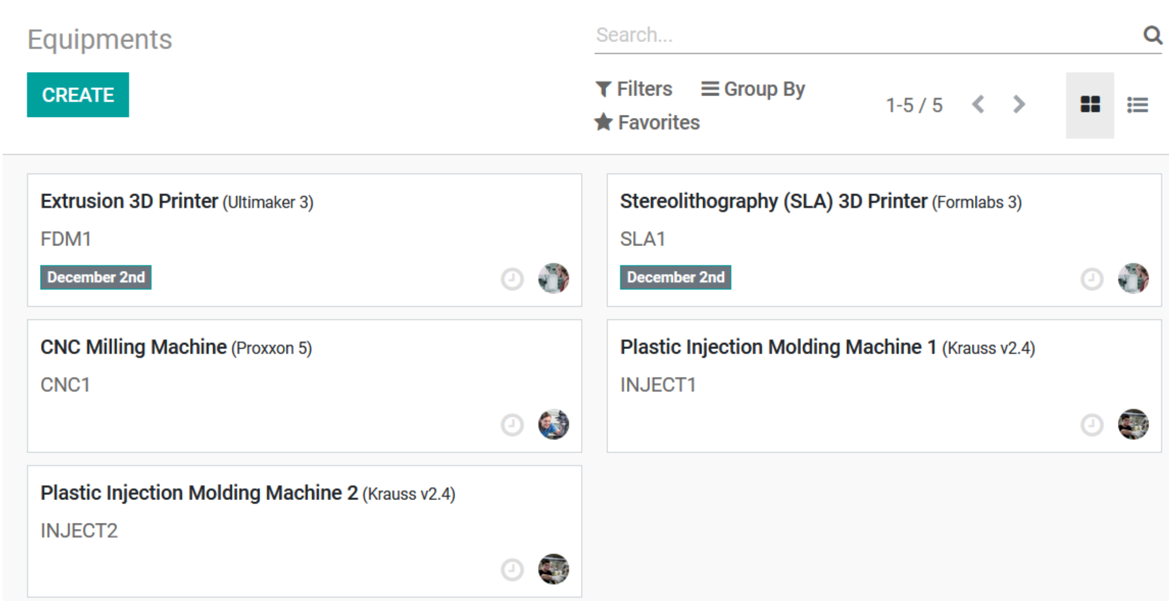


Figure 32 Overview of equipment items

This is where software limitations regarding PLM start to show. Although equipment items allow you some level of metadata (description text, responsible user, maintenance data and vendor). It does not allow for the uploading of files of any kind to be attached to the item class (machine manuals, reports etc). This is a substantial weakness, since file management is something quite unanimously considered a main aspect of PLM. This will be a recurring subject of this simulation since the number of Items that allow upload of files directly to them is limited in Odoo.

Now that the equipment has been created, their workcenters can be created. It is interesting to remember that the main use of the workcenter item is management of time and cost per hour. The idea is that equipment assigned to a WC should not be used at the same time and that ideally equipment that have widely different running costs should also be in different workcenters to allow for better time/cost tracking.

The following (Figure 33) is a an example of a workcenter item made to represent the prototyping station that is used throughout the development of the product.

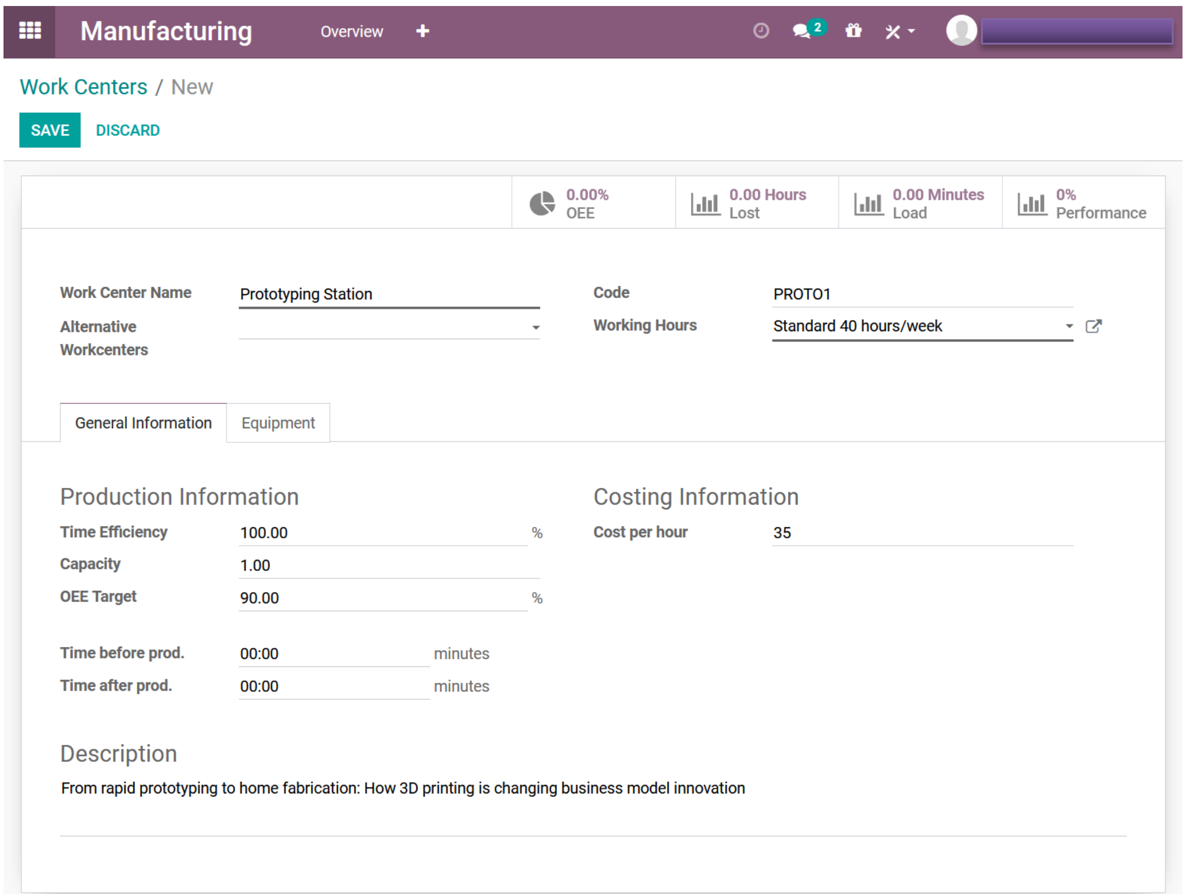


Figure 33 Odoo Prototyping Station item representation 1

The reader will notice that this station (Figure 34) is where the 3D printers and CNC machine are located. Usually these machines would be separated in singular workcenters because of difference in operation costs and because they are for the most part independent however for the sake of this simulation this has been considered representative enough.

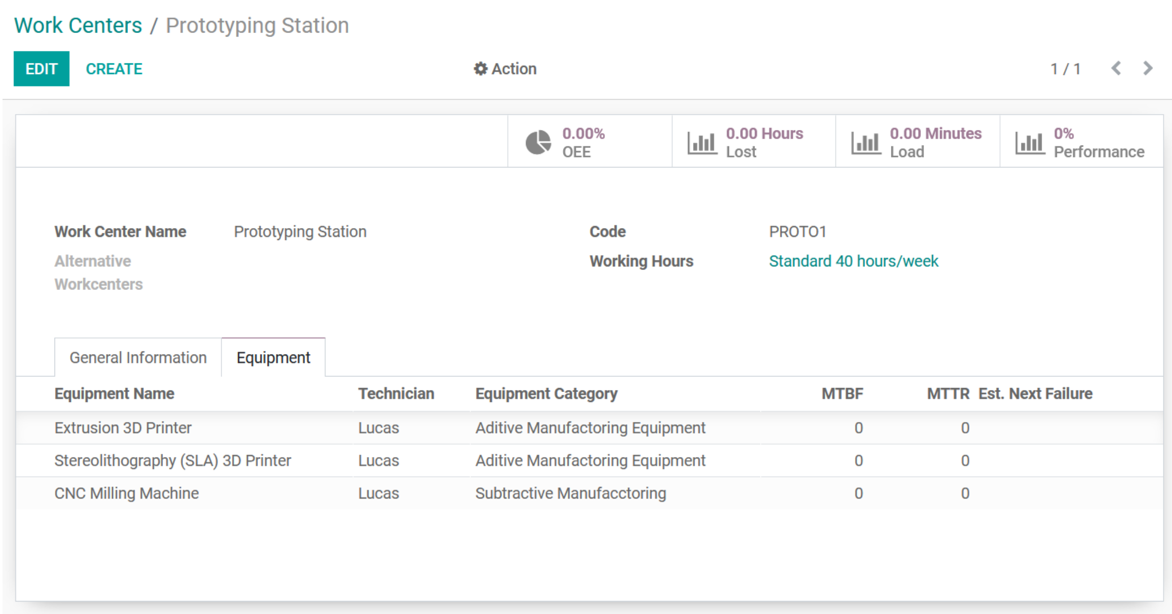


Figure 34 Prototyping Station item representation 2

The following workcenters have been also created for the simulation and filed with the necessary equipment:

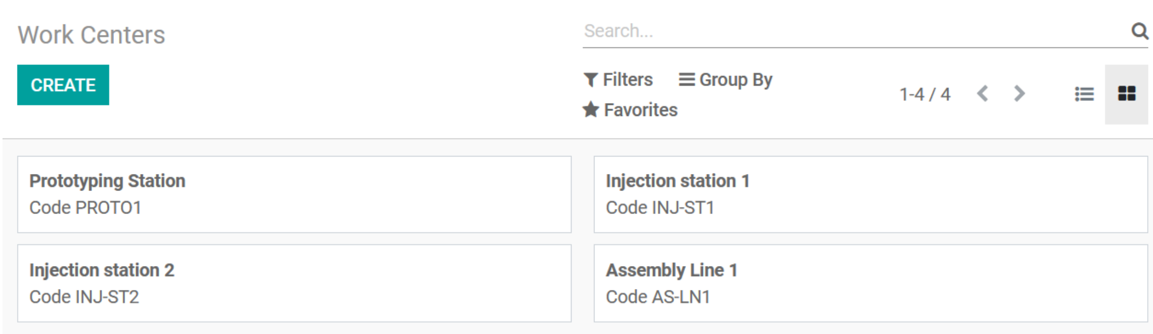


Figure 35 Overview of Workcenter items

5.4. Development

Now that the basic structure of the company has been recreated in the software, it is possible to commence the simulation process. At first, the focus is on the development aspect of a brand new product using Odoo (Figure 9) most noticeably, since this is the company first product to be created, a possible use of Odoo for organizing prototyping procedure is evaluated. This include the path from idea to design and prototype production. Then once the product has reached an acceptable result as a prototype, the work regarding the development of the production process will take place. The product development is considered successful once an official production run is done.

5.4.1. Idea - design - product prototype

As explained in (Chapter 4) the idea for the product has already been stablished and initial design characteristics and basic product research have already been carried out. This is representative of an actual implementation of the Odoo software in the real world because although Odoo have good project management and communication applications, those are external to the inventory and manufacturing applications and, more importantly, share no integration with the engineering design CAD software. In this simulation, the idea has been put to paper and have been turned into a CAD design using the Solidworks software generating a CAD file locally stored in the engineer computer.

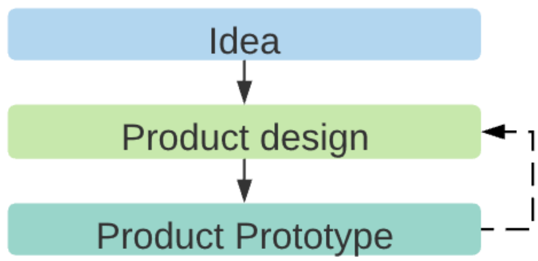


Figure 36 Sectioned diagram regarding product development

It is at this point that the utilization of the Odoo software can officially take place. The first step is to understand what the subject of production is as far as product items are concerned. There are two takes in how to do this:

- The first is to consider the prototype an early revision of the final product, that is the prototype item created in Odoo would be the same as the final product item with revisions been carried out during development. That would be the recommended if the prototype is achieved by identical means to the ones used in the final production. An example of this approach would be if the product is simple enough that product and production aspects of development can be carried out together.

- The second one is to consider the prototype as a separate item from the final product - this is the path was taken in this simulation. The main reason for this decision was that the ways in which our prototype production were carried out differed from the final production since 3D printing was used for the prototypes.

Starting from the root, a product item called PROTO Alpha Case (Figure 37) was created (Alpha Case being the name of the product). From this point on we will refer to prototype products as ‘proto item’. As we can see, this allows for a nice representation of the proto item. Since it is a prototype, it will not be marked as something that can be sold or purchased, and sales price will be set to 0$ since it is unimportant. This proto item will be used to connect the different aspects of its development but for now it is left alone.

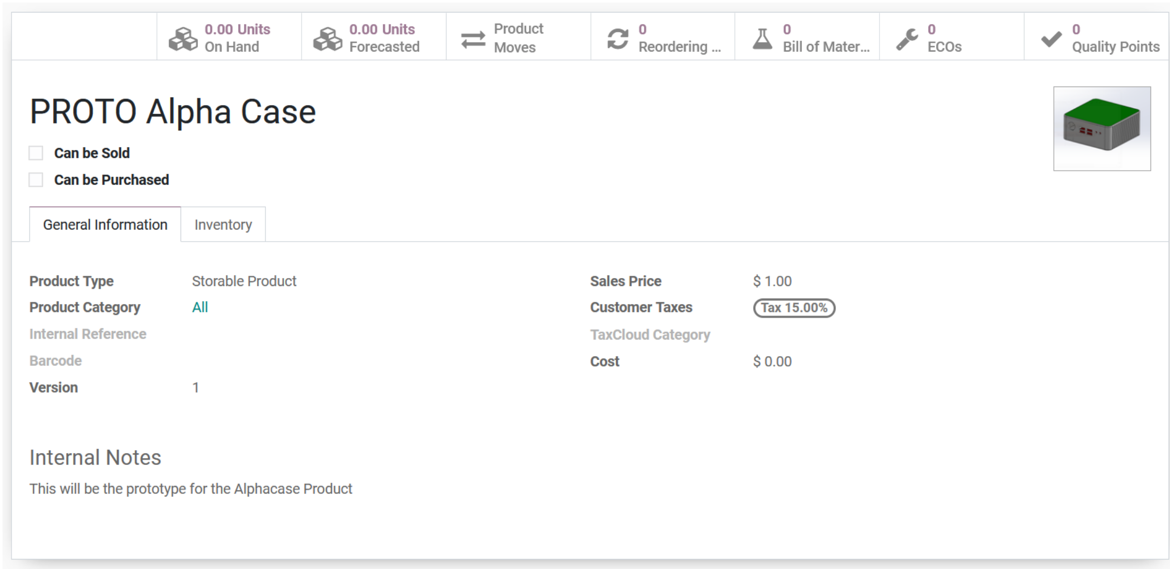


Figure 37 Image of the prototype product item

As we have previously stablished in chapter 3, the product will consist of 3 pieces Part A, Part B and Part C. These need to be prototyped and created as products as well so that they can be added to the bill of materials of the PROTO Alpha Case. Finally, it was decided to use specific plastic filaments (see section 4.1.1) for the 3D printing of PROTO Part A and PROTO Part B and C and these need to be added as products as well (Figure 38).

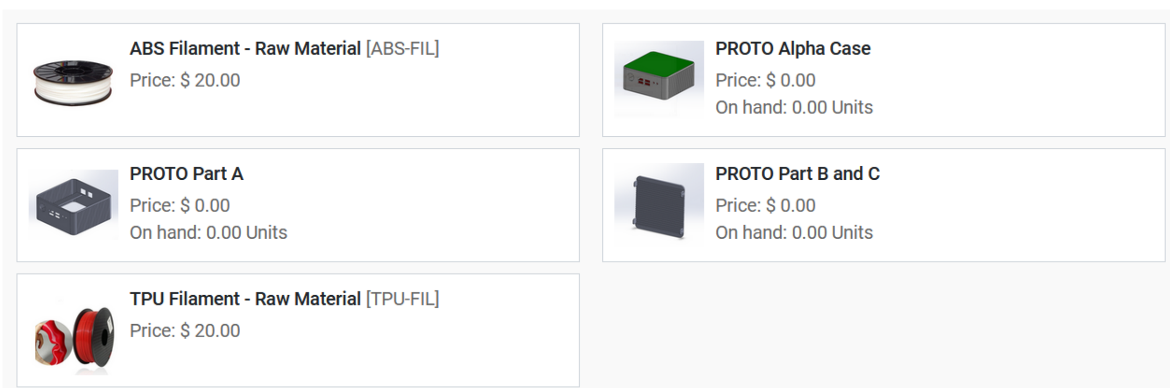


Figure 38 Overview of Product class items for prototype

At this point, the relevant product items for the prototyping of the Alpha Case were finished, which makes possible the creation of the its relevant BOMs. There are 3 of them and they follow the structure in (Figure 39):

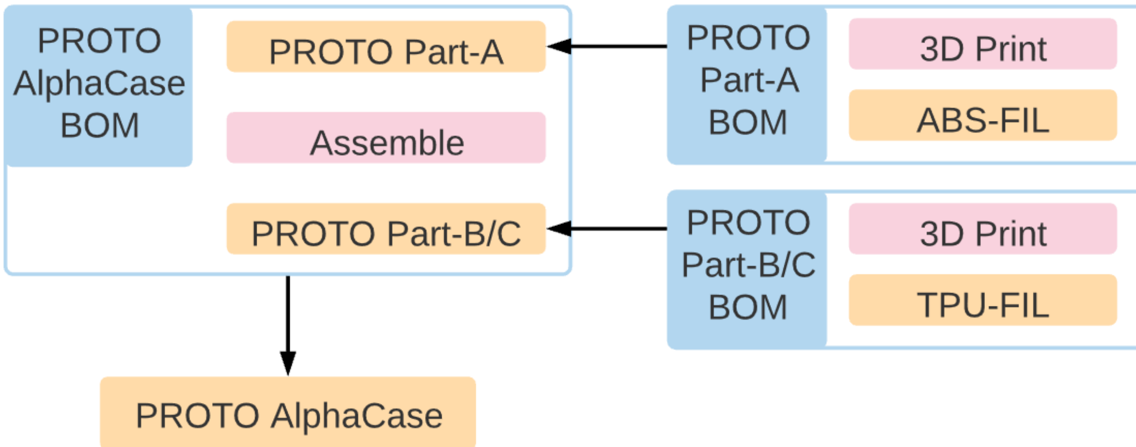


Figure 39 BOM diagrams for prototyping

Something worth mentioning is that Odoo used the kit option (Figure 40) on the item to infer that this product is a component of another product. This is very interesting because it automatically creates dependencies between the product items for production.

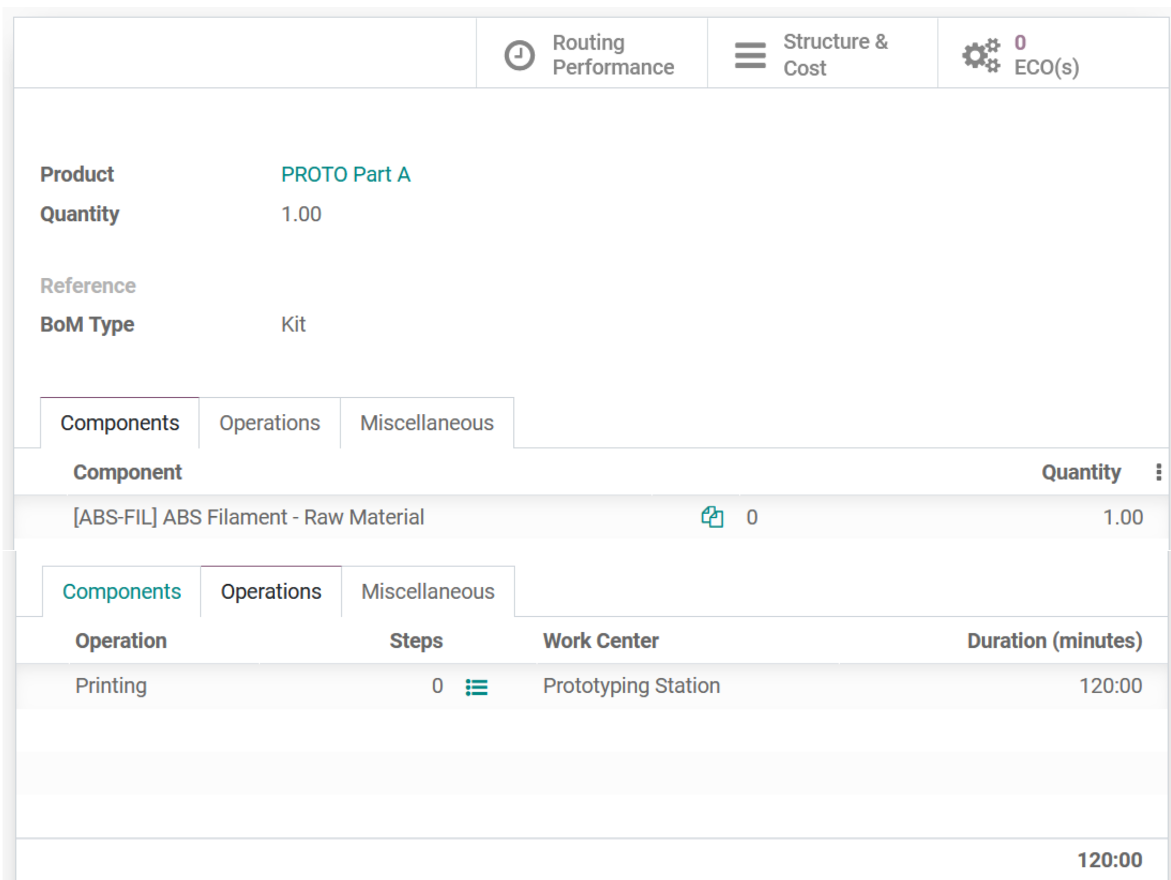


Figure 40 Image of the prototype product BOM (Part-A)

As the reader can see (Figure 41), while making the BOMs it is simple to create the specific operation items necessary for the manufacturing procedure and specify its work center. One of the best functionalities regarding MES in Odoo is the ability to track the time of operations based on default duration. This can be dynamically changed based on tracked time or set manually. It is also in the operation item that we can add instruction files for the operation. Even though it is limited to PDF text or a link to a google slides file, this is one of the few opportunities presented by Odoo for file management connected directly to an item.

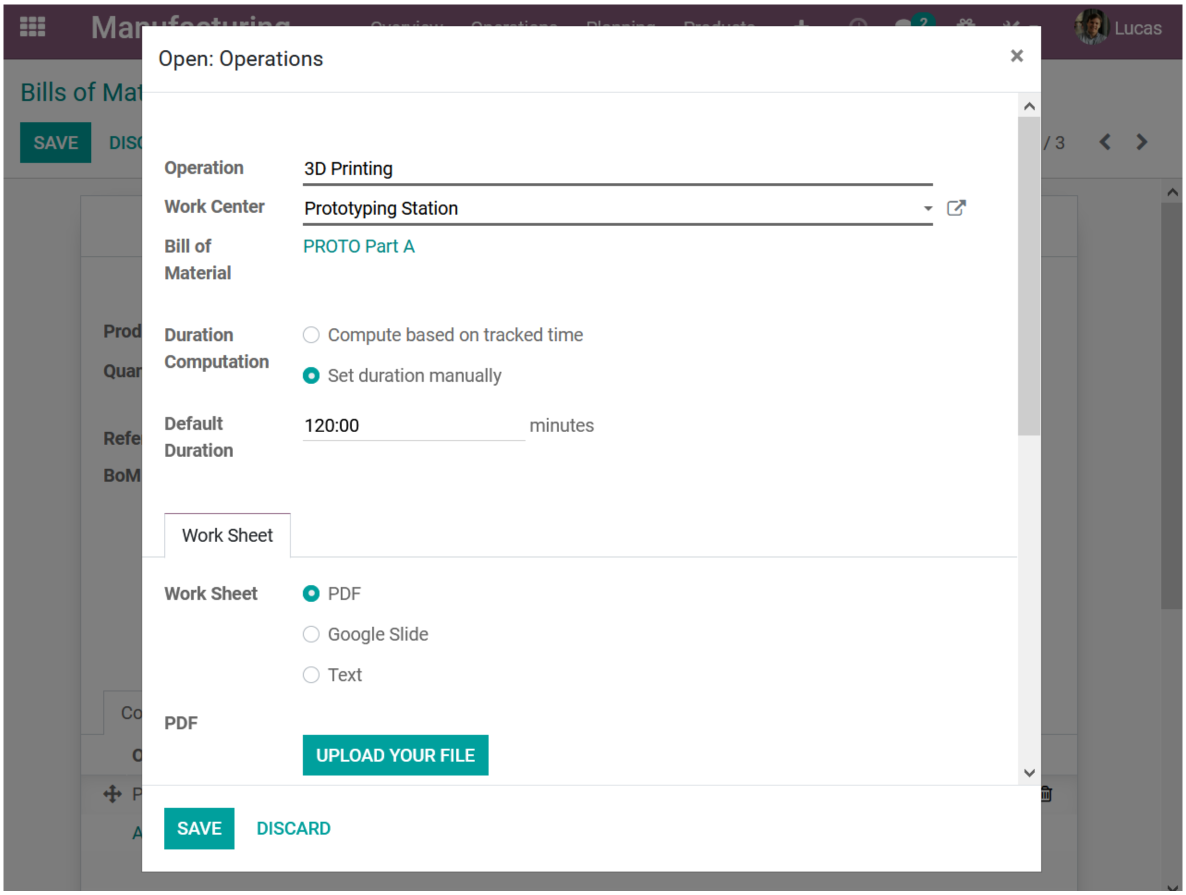


Figure 41 Image of operation item as presented by Odoo (BOM Part-A)

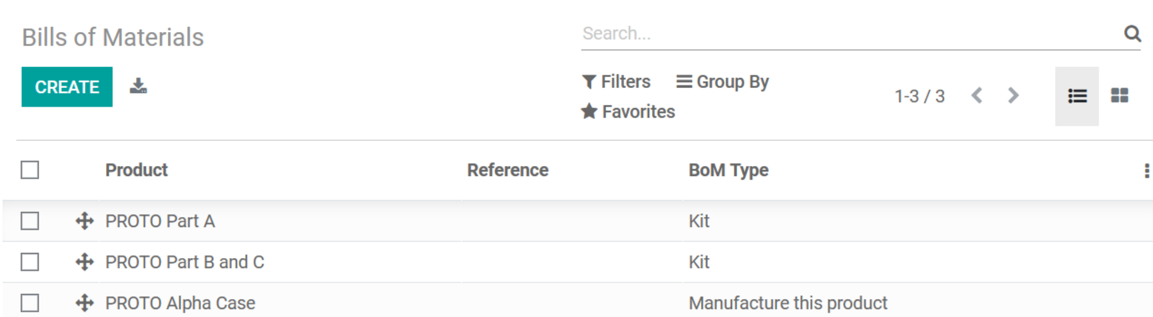


Figure 42 Overview of BOMs created for prototyping

Speaking of this lack of upload opportunities, we can notice that while making the product item there was no way to directly upload files regarding the product to the item. In our case, we have the CAD files regarding the parts that we are prototyping, to not be able to upload these files in any way would be a complete failure from a PLM perspective. Thankfully there is a workaround. As explained in section 5.1.3.5, the ECO is an item that is linked to either product items or BOMs and allow uploaded files to be attached to it. It is a minor workaround but basically means that if we want to upload our CAD files to the items in any significative manner, we need to emit an ECO even if there is no "change" being made.

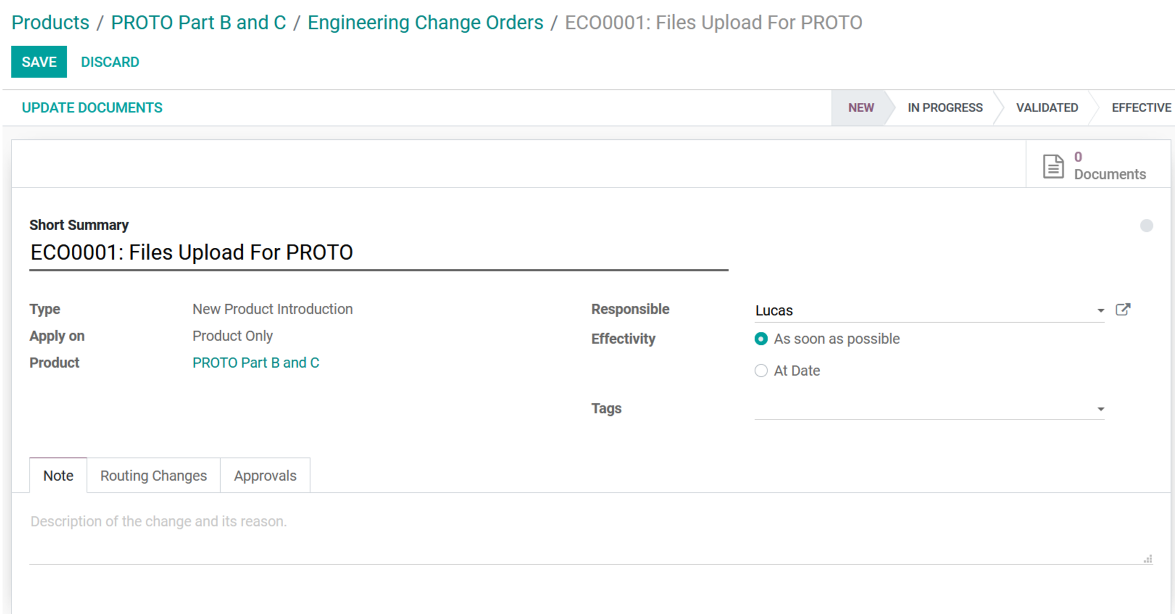


Figure 43 ECO example

It can only be assumed that this was part of Odoo's team strategy to implement PLM as an external application in its ERP base. It is reasonable, but still, this is one of the few aspects of this software interface that is not as straightforward. It is an extremely valuable feature, but it is somewhat hidden. The documents icon appears in the top right corner (Figure 43) only after the ECO is created and saved.

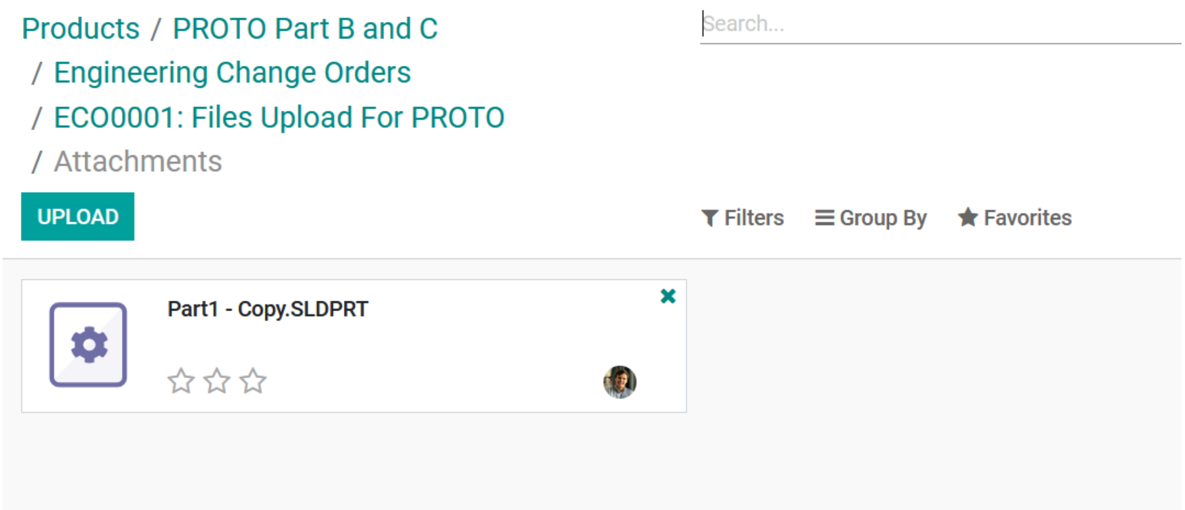


Figure 44 Overview of attached files to ECO

Since there is no direct integration between Odoo and the CAD software, uploading the file do not cause any automatic change to the product metadata. This is not ideal from the PLM perspective, still, it is a well implemented feature. By allowing product items to link directly to not only one existing ECO but to the list of all ECOs ever applied to the item, the software does well in tracking version control and development.

Something interesting that can be done for the sake of process control is adding quality control points to operations. This allows the responsible personnel to give feedback during the production regarding concerning points to the engineering team. In our case, we are concerned about 3D printing warping. This is something that happens when temperature varies to much during the 3D printing procedure. To this end a Quality Control Point item will be created (Figure 45) that will enquire with the operator to check if there is warping in the piece and mark pass or fail.

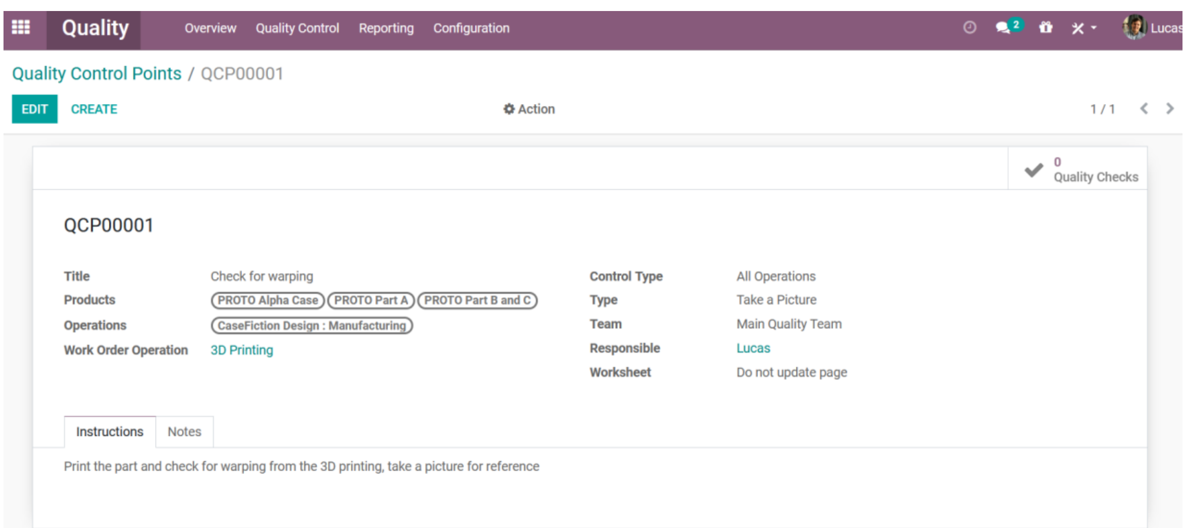


Figure 45 Quality Control Point item for the prototype production

The last step of a prototype cycle would be the production of prototypes for testing and evaluation. Production is something quite straightforward in Odoo and really the point where everything we have done before come together. The metadata and the items that have been created allow us to start the Manufacturing Order (MO) (Figure 46). This, in turn, pull the necessary workorders from the operations and components listed in the BOM. The workorders appear for manufacturing operators and production can commence/be tracked.

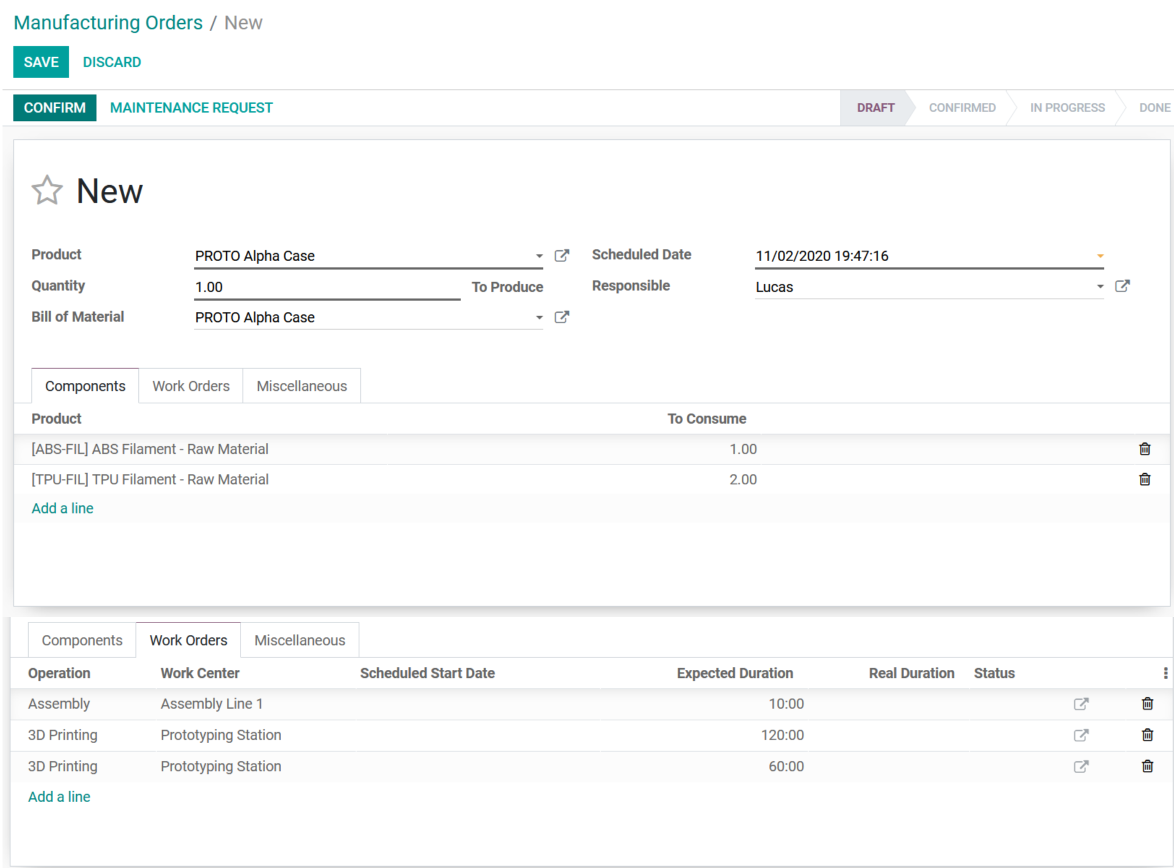


Figure 46 Depiction of the manufacturing order

For the most part this operation is very well automated and clear. There are however a few problems that are result of structural changes from Odoo V13 to Odoo V14. For a long time, the software ordered the operations to be carried out using an extra item class called ‘Route’. These were a fundamental part of how the product moved within the inventory and manufacturing, but for some reason, was dropped in the manufacturing aspect of the new version in favor of a simplified sequence data built into the BOM. As of the writing of this work, there have been reports of problems and confusions regarding how that works, which are aggravated by the fact that material explaining the use of this functionality are either nonexistent or still referencing old versions of the software (in which ‘routes’ are still in use).

The avid reader will notice in Figure 47 that the order in which operations are being made available are not in the correct sequence. This is due to exactly this problem and for now the only solution is to count on the awareness of the operators regarding the order of production or manually scheduling the operations in the plan tab. During the period of research for this work (before Odoo V14) familiarization experiments were made in which there were no problem of this nature. In addition, there are examples online even from Odoo website demonstrating the use of routes and how they are useful for this exact situation.

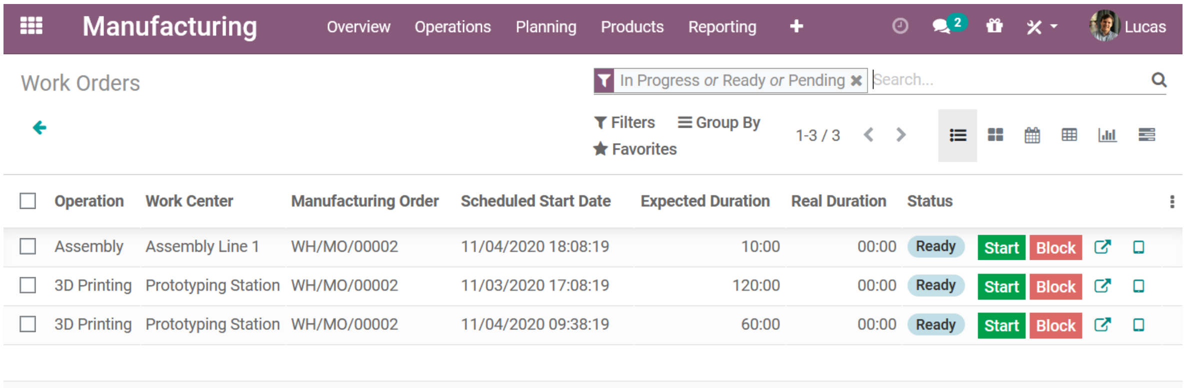
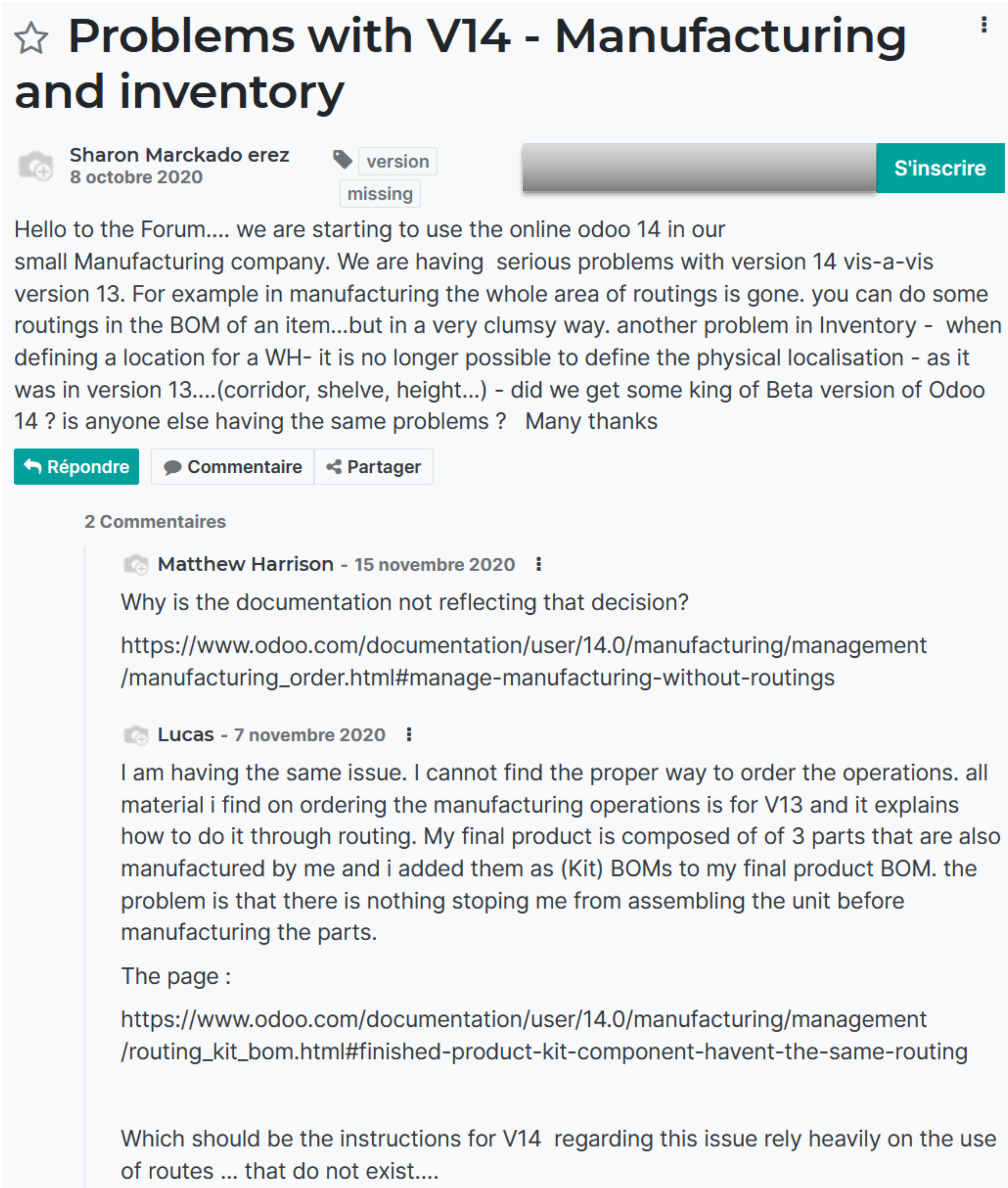


Figure 47 Overview of the resulted Work Orders

The problem has been reported by other people (Figure 48) to the Odoo company and is been and hopefully it will be resolved shortly (this is after all a extremelly recent version of the software). That been said, it is a problem even if it is a minor one.


Problems with V14 - Manufacturing and inventory

Sharon Marckado erez
8 octobre 2020

version
missing

S'inscrire

Hello to the Forum.... we are starting to use the online odoo 14 in our small Manufacturing company. We are having serious problems with version 14 vis-a-vis version 13. For example in manufacturing the whole area of routings is gone. you can do some routings in the BOM of an item...but in a very clumsy way. another problem in Inventory - when defining a location for a WH- it is no longer possible to define the physical localisation - as it was in version 13....(corridor, shelve, height...) - did we get some king of Beta version of Odoo 14 ? is anyone else having the same problems ? Many thanks

Répondre | Commentaire | Partager

2 Commentaires

Matthew Harrison - 15 novembre 2020

Why is the documentation not reflecting that decision?

https://www.odoo.com/documentation/user/14.0/manufacturing/management/manufacturing_order.html#manage-manufacturing-without-routings

Lucas - 7 novembre 2020

I am having the same issue. I cannot find the proper way to order the operations. all material i find on ordering the manufacturing operations is for V13 and it explains how to do it through routing. My final product is composed of of 3 parts that are also manufactured by me and i added them as (Kit) BOMs to my final product BOM. the problem is that there is nothing stoping me from assembling the unit before manufacturing the parts.

The page :

https://www.odoo.com/documentation/user/14.0/manufacturing/management/routing_kit_bom.html#finished-product-kit-component-havent-the-same-routing

Which should be the instructions for V14 regarding this issue rely heavily on the use of routes ... that do not exist....

Figure 48 Image of Odoo forum question regarding routes

The manufacturing process was repeated 7 times (Figure 49) to simulate a small batch of prototypes for testing and tolerance checking. It is rare to get a perfect prototype in the first batch, for this reason it was chosen to represent correction through the simulation. In this simulation this problem was a fit problem that resulted in a change of dimension of PROTO Part A.

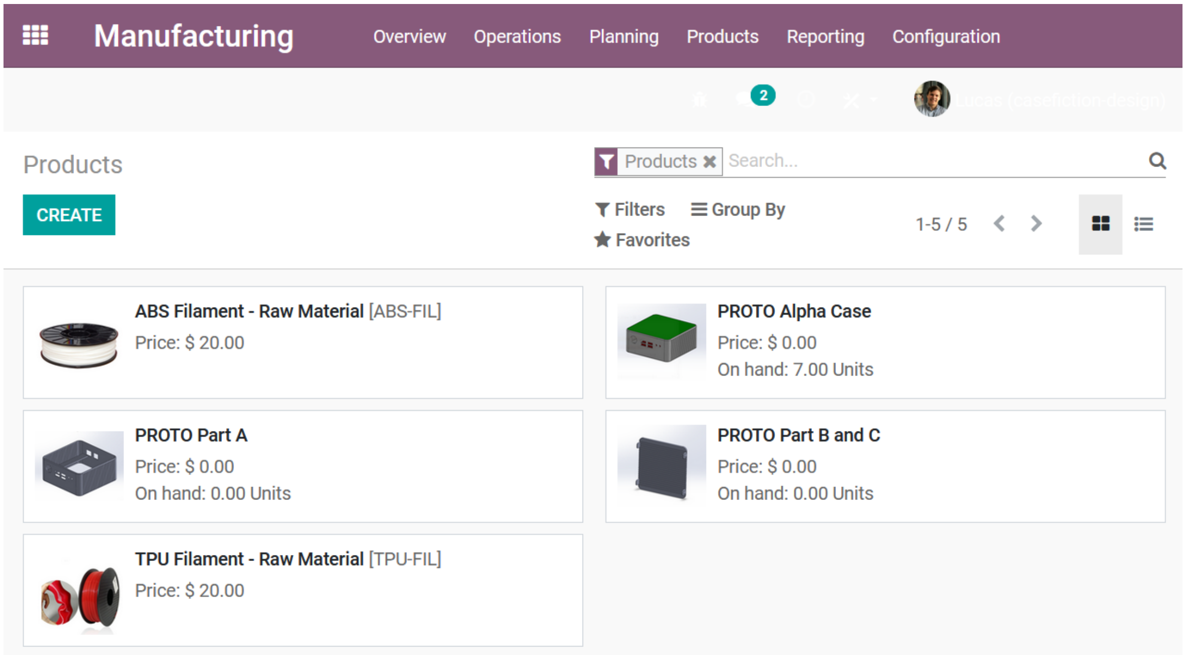


Figure 49 Overview of the products after manufacturing

This give us the opportunity to use ECOs for their actual purpose, stablish and control a change to the product item. The changes to be carried out were on the CAD file regarding the product item. As before we can start the ECO and fill in the description, then the files are uploaded, and the ECO (Figure 50) goes through necessary validation before been made effective.

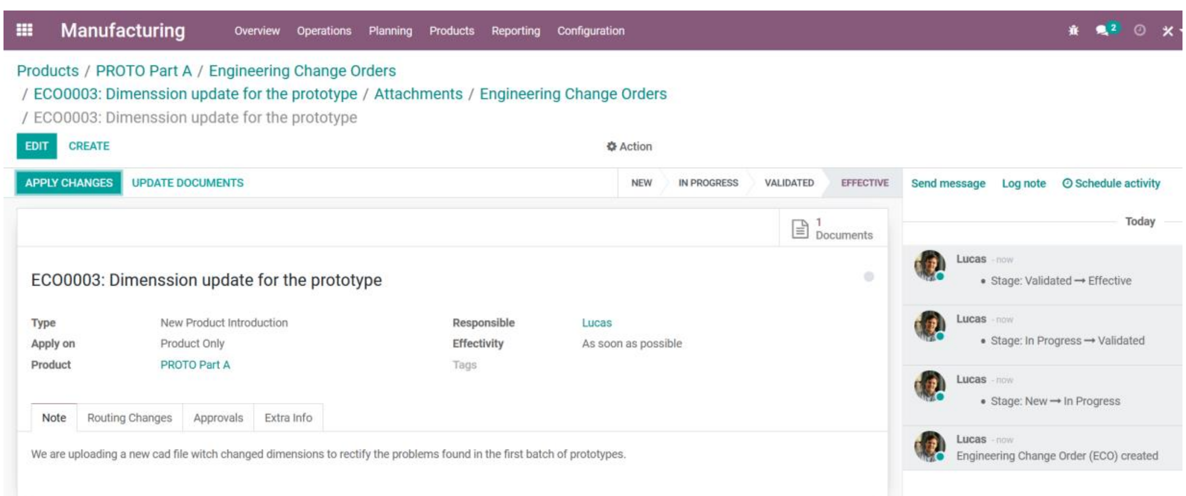


Figure 50 Depiction of the validation of the ECO

The validation procedure basically is set to ask for validation of someone with proper access permissions or specific personnel. In this case, the master account was used to validate and make effective as can be seen from the log in the right side of the image. Once the change is applied you can see that the product item version has been iterated to version 2 as well as a new ECO has been added to the list of ECOs linked to the item (Figure 51).

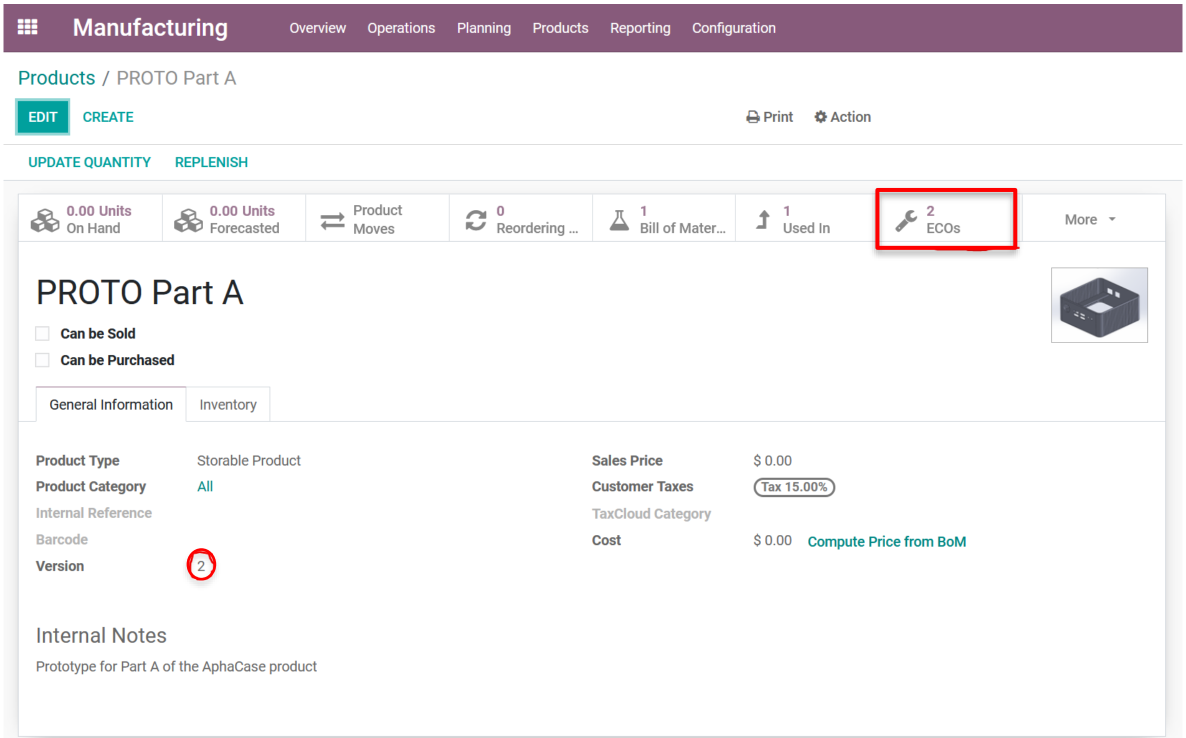


Figure 51 Depiction of changes provoked by the ECO to product item

That update is followed by another batch of prototypes, the cycle would continue until the prototypes produced satisfy the criteria stablished by the design team. In the case of this simulation it was assumed that one correction was representative enough of this process. This finalizes the development from idea to prototype.

5.4.2. Process Plan - Production Test Run - Production

Now that the prototype phase is complete the focus will shift to the process. As stablished before, it was decided to separate the prototype products from the final product item to isolate the product from the production process during the development. This way many aspects of development of the product could be evaluated in an ordered manner. Now that the process is been developed it seems reasonable to create the product items that will represent the final products since the product of a successful run of the process will be the production ready samples of it (Figure 52).

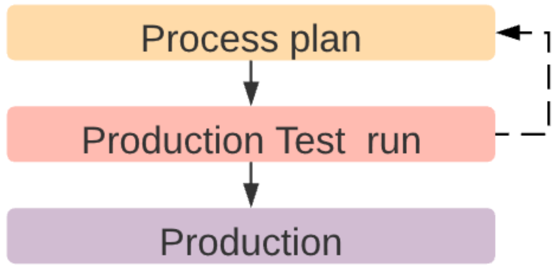


Figure 52 Sectioned diagram regarding Process development

Other product items that created were the raw materials for the injection molding (which are plastic pellets that are fed into the machine to be melted and injected). All that was done in identical manner to when we create the prototype products with the exception that the Alpha case (Figure 53) now is marked as sellable and its sale costs are now relevant (Figure 54).

Figure 53 Render of how the final product should look like

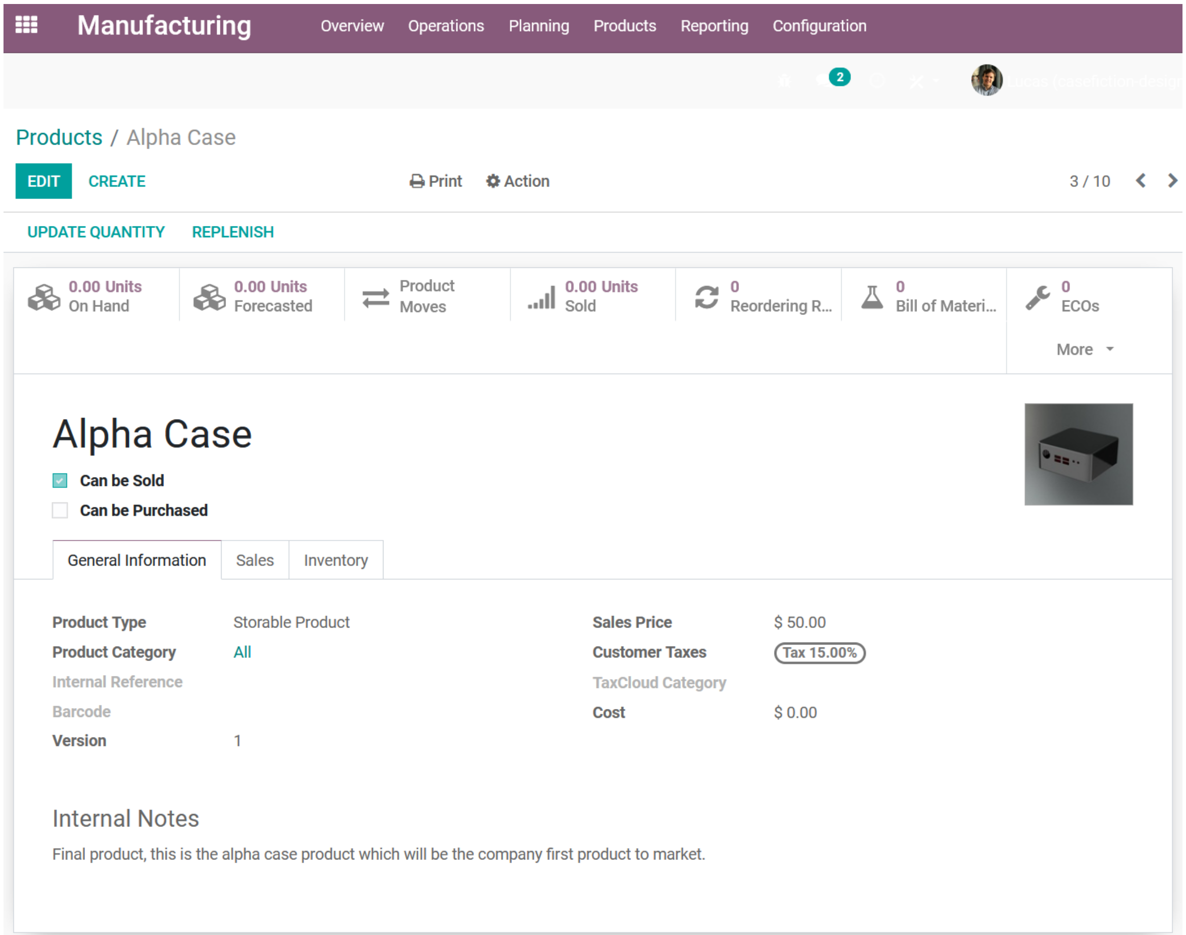


Figure 54 Product Item of the Alpha Case

Once the product items are taken care of, we need to go back to what aspect of the process will be tracked using Odoo in the context of this simulation. As it was hinted previously when talking about injection molding the key aspect of change regarding the process are the molds used by the machines to create the parts. For this simulation it was considered that the mold development will follow a very similar procedure of the development of the product, this should be more clear from the following diagram (Figure 55).

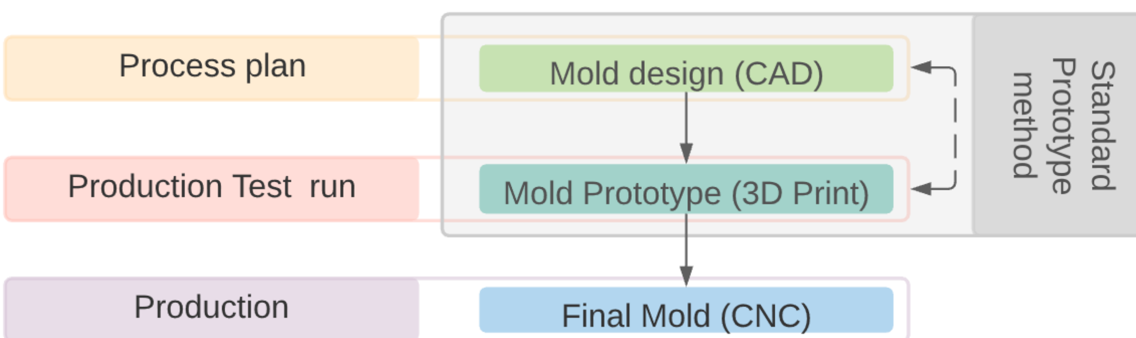


Figure 55 Diagram regarding process development for mold

The production of a prototype mold by 3D printing follows the same standard procedure for prototyping used for the product. So far, the mold is considered a product like any other, this reveals another small weakness regarding Odoo ability to represent the totality of the process. The reader will notice that although the mold is been treated as a product (because it is been manufactured) it should in fact be considered a tool or piece of equipment as well.

Although Odoo does makes this distinction between equipment and products, it has no integration regarding the situations where one is both. In addition, as explained before, there is no way of uploading CAD files to an equipment item or linking an equipment to a range of tools. I.e. Odoo does not consider a vertical drill with x number of drill bits to make different size holes. The closest it can do from the perspective of equipment/maintenance is consider the vertical drill a workstation and each drill size a separate equipment within the station with an assigned set up time. This is ok if you ignore that the drill bit is a product.

All of this is reasonable from the perspective of an ERP system but not ideal from the perspective of PLM because it shows gaps in between items that should represent the same thing. In production from the manufacturing application what is set is the work center station not the equipment (see Figure 41). In the maintenance app there is no connection to the fact that the tool is a consumable product, you can consider a maintenance schedule and even make a useful life parameters but because it is an equipment you can’t have reserve tools like drill bits in inventory like consumables.

The result is that it becomes very difficult to represent testing with a prototype mold. If you do as the software is designed for you need to create a separate ECO to apply every operation for each different iteration of the mold development to the necessary BOMs and make a test run (Figure 56). At this point, considering the maintenance aspect of the mold as a tool just does not make sense because it would entails filing in metadata in the maintenance App by hand for every prototype mold iteration all without causing any difference from the manufacturing perspective. The PROTO mold item ends up been used only for the sake of tracking material and holding files as the mold is improved.

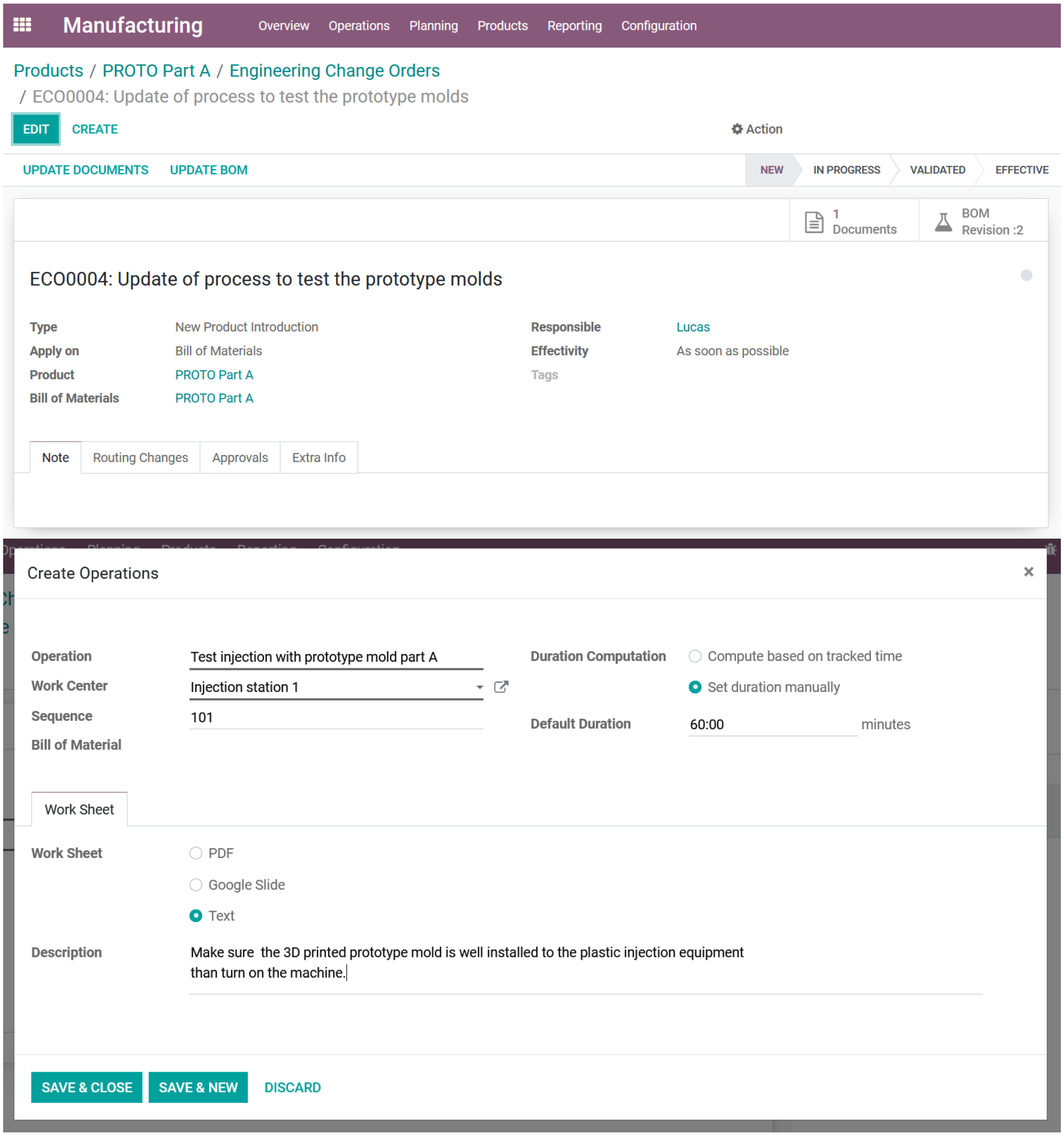


Figure 56 ECO example of update procedure of BOM

Taking this in consideration, in simulation it will be produced one 3D printed mold for each part of the alpha case. Then ECOs for the prototype parts of the case will be created to be applied to the parts BOMs updating the operation from 3D printing to injection molding test run with prototype molds.

At this point we could differentiate the product prototype from the test run prototype by making a new prototype product item, however considering our rapidly growing list of product items (Figure 57) it was concluded that it would be just better for depiction in this work to modify the previously produced product prototypes (made with 3D printing) and just use the same items. We can do this because those prototypes have already served their purpose.

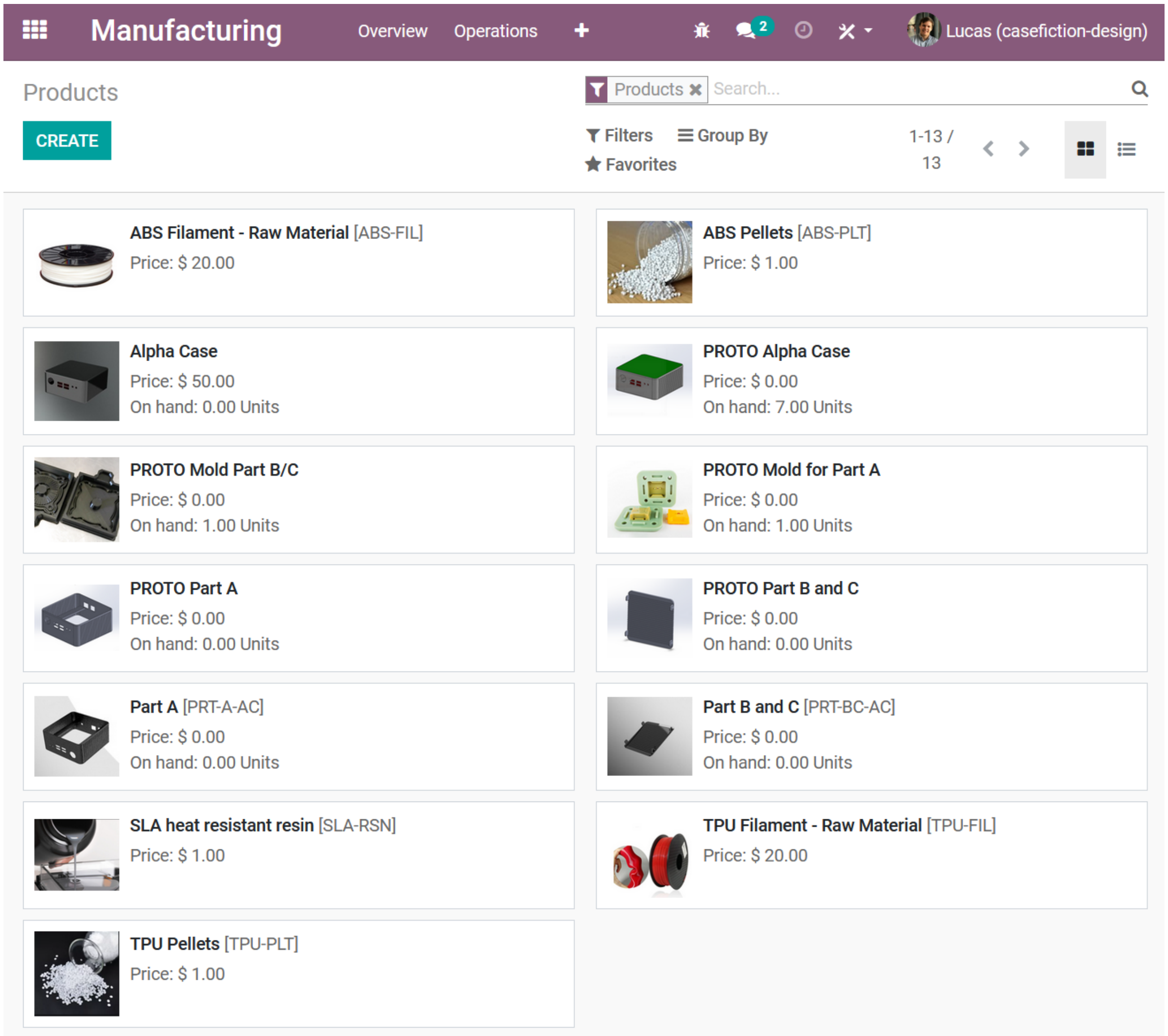


Figure 57 Overview of product items at this stage of the simulation

After the mold have been created and the BOMs for the prototypes are updated to include the injection stations and the proper operations (specifying the use of the molds) the next step is to do a production test run of prototype. Again that is done by emitting the MO completing the generated WOs (see Figure 46 and Figure 47 of previous section).

The result of the production is used to check for dimension and fitting, if correction is needed the ECOs would be emitted again as seen in Figure 56, and a new iteration of production and testing would be carried out. This process would repeat until the product is satisfactory enough to justify the production of the CNC machined molds that would be used in mass production.

Since in this simulation it was chosen that the final mold (made of aluminum) would also be produced in house, this is the next step of development. Procedure is basically the same as before except that it is needed to create product items for both the raw material (aluminum block) and the CNC molds prior to their manufacturing. Creating BOMs and uploading relevant files.

Finally, the actual production on the new molds can begin. To represent that a manufacturing order of 100 Alpha Cases were created. This marks the end of the main path of development from idea to production (Figure 58).

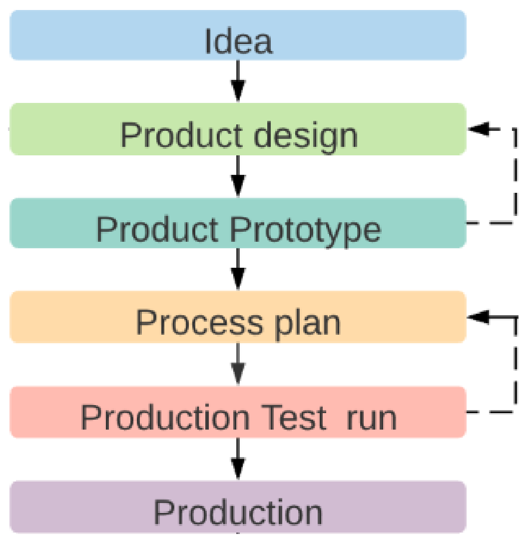


Figure 58 Main path of development from idea to production

5.4.3. Process upgrade procedure

The previous sections were about the procedure that would be necessary to use the Odoo software to track change during the main development of product. As such, most of what was described focused in the use of PLM and the standard procedure of creating and utilizing items like Products, BOMs, ECOs, MOs, WOs and Operations. This section will be different in the sense that now we have a production being carried out and the idea is to test Odoo in its capabilities of performing upgrades (Figure 59 and Figure 60). In other words, performance and feedback of information (and of course MES) becomes the main subject.

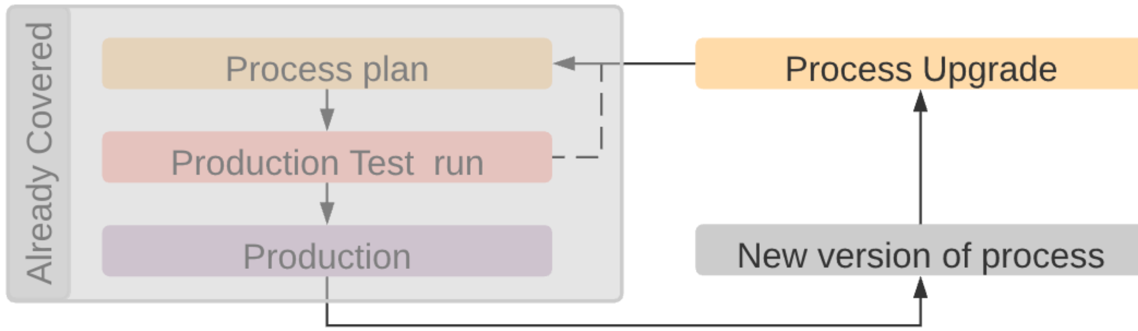


Figure 59 Sectioned diagram regarding Process upgrade procedure

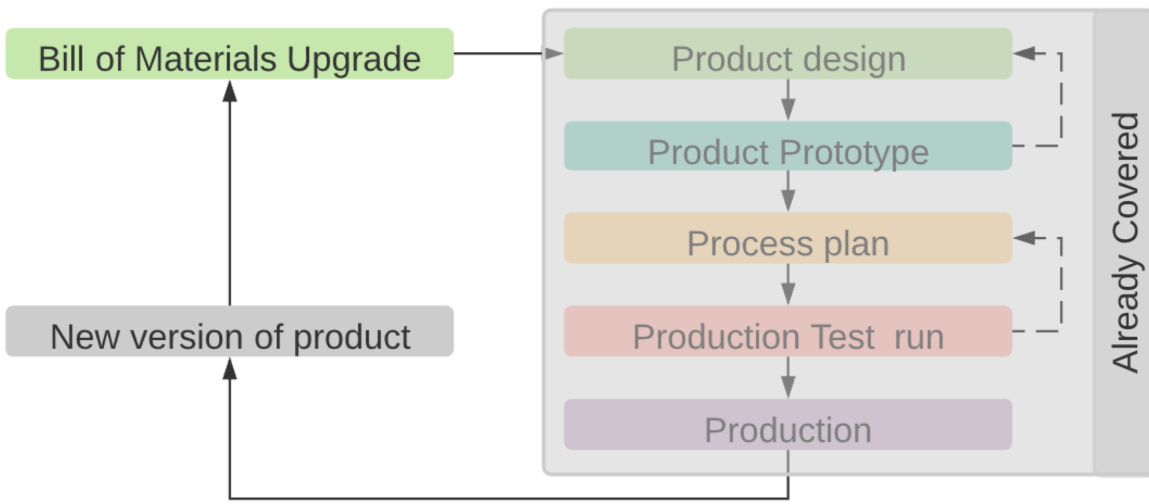


Figure 60 Sectioned diagram regarding Process development

Change is always enacted using the ECO functionality even in this case. To remind the reader the situation in which this change will be applied (Figure 61) is the product overview of the relevant product items. Every product item in that list (that is not a raw material) poses at least one BOM and two ECOs already applied to them in order to signify the initial state of every product item (Figure 62). The first ECO of every item affects the product and it holds the initial related files, the second is applied to the BOM of the product in order to hold files related to the initial state of the process as well as record the initial state of the BOM. Without these ECOs (Figure 62), when we ever applied an improvement, the initial state of the product files or BOMs would be lost.

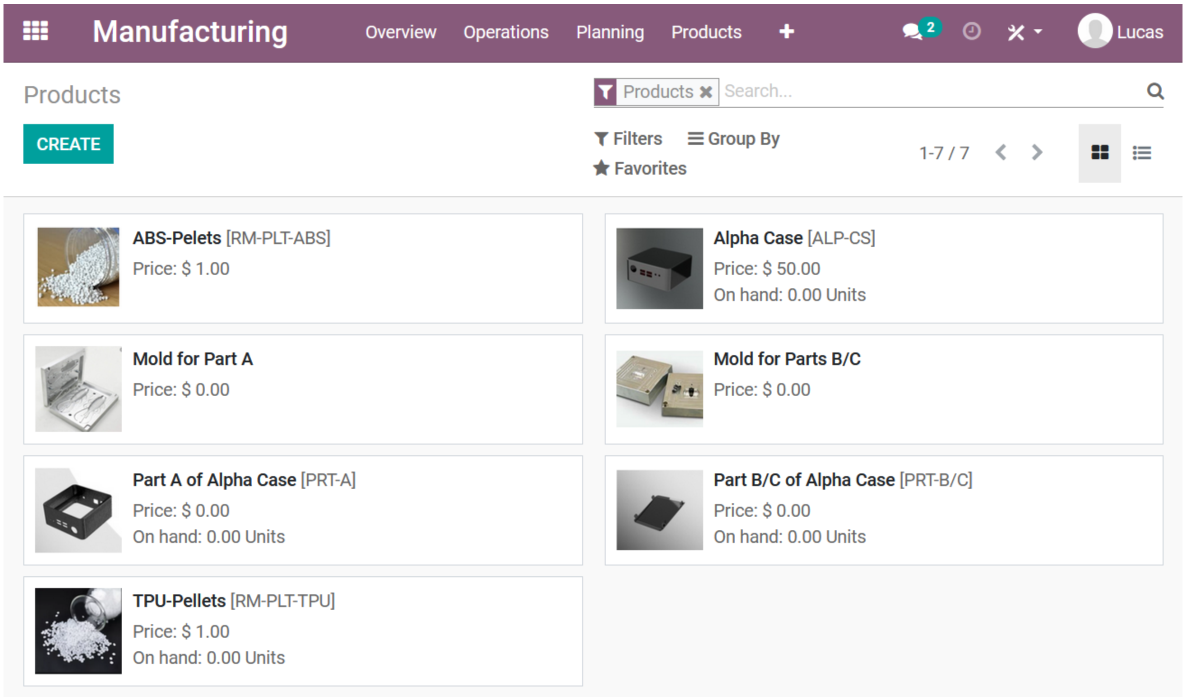


Figure 61 Relevant product items overview

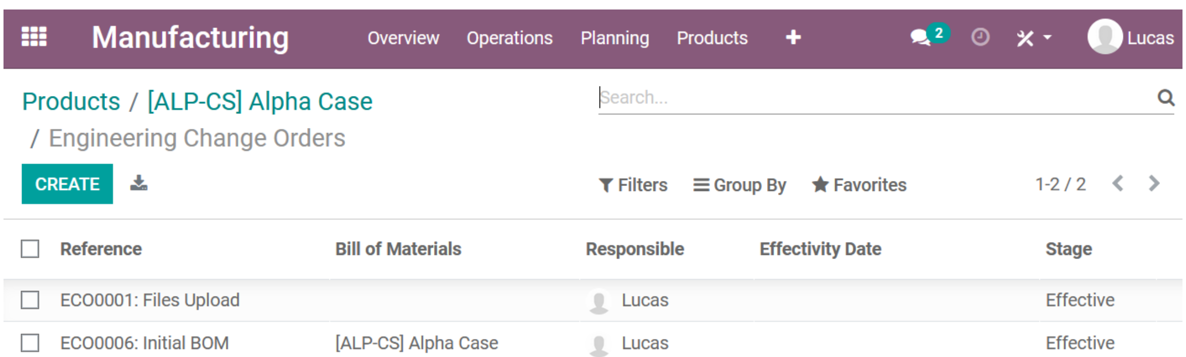


Figure 62 Example of ECOs of a product item

This time around the production duration and the estimated duration of the process is something that need to be taken in consideration so we can perceive how that applied change on the process affect production. To this end a MO of 50 units of Alpha Case will be created with each operation being estimated to take 30 seconds (15s for parts B/C because there is the need for 2 of them). Meaning that in an ideal situation the total length would be 50 minutes (25 of injection production being done in parallel and 25 for final assembly).

In this simulated manufacturing run it was chosen that the injection operations would take slightly more time to complete to be representative of a suboptimal performance. This is been done to see how Odoo reacts and informs in real time the situation in hand.

The first phase of the production in the injection process that is carried out in parallel for parts A and B/C on the injection stations 1 and 2. The following (Figure 64) shows how in the beginning of the process the overview of the productions stations indicate with green circles. These circulars signaling in known as Andon and although it is not always considered part of MES it is commonly an integrated feature in many MES systems. After the production process have been carried out with a little delay the circle turned gray and overall efficiency has been marked red on the station tabs (Figure 64).

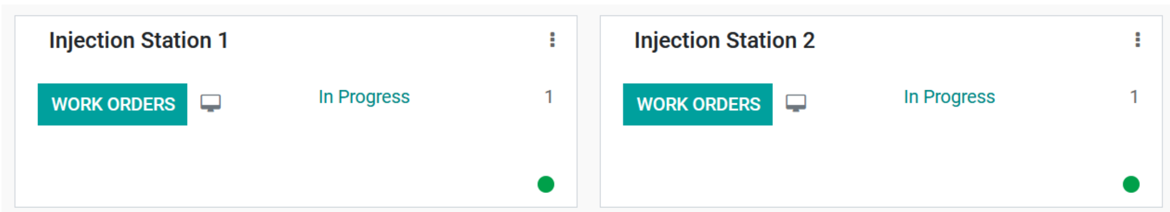


Figure 63 Workcenter overview 1

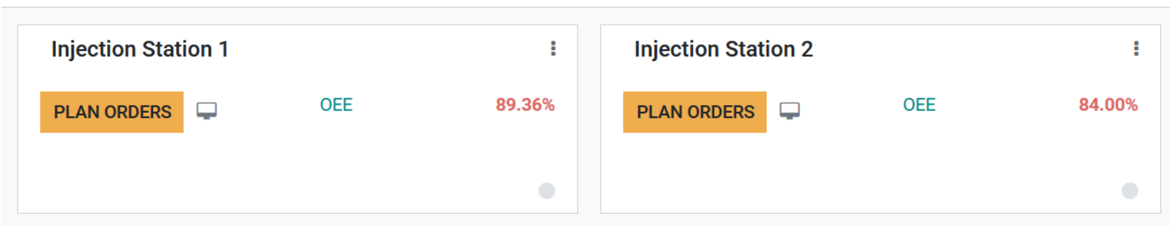


Figure 64 Workcenter overview 2

The production was carried out twice before any improvement was applied. The first improvement to be carried out were on the production process on the operation and the raw materials used. More specifically, a new operation representative of an equipment upgrades on the injection machines and the replacement of the brand of plastic pellets use in the injection process (Figure 65).

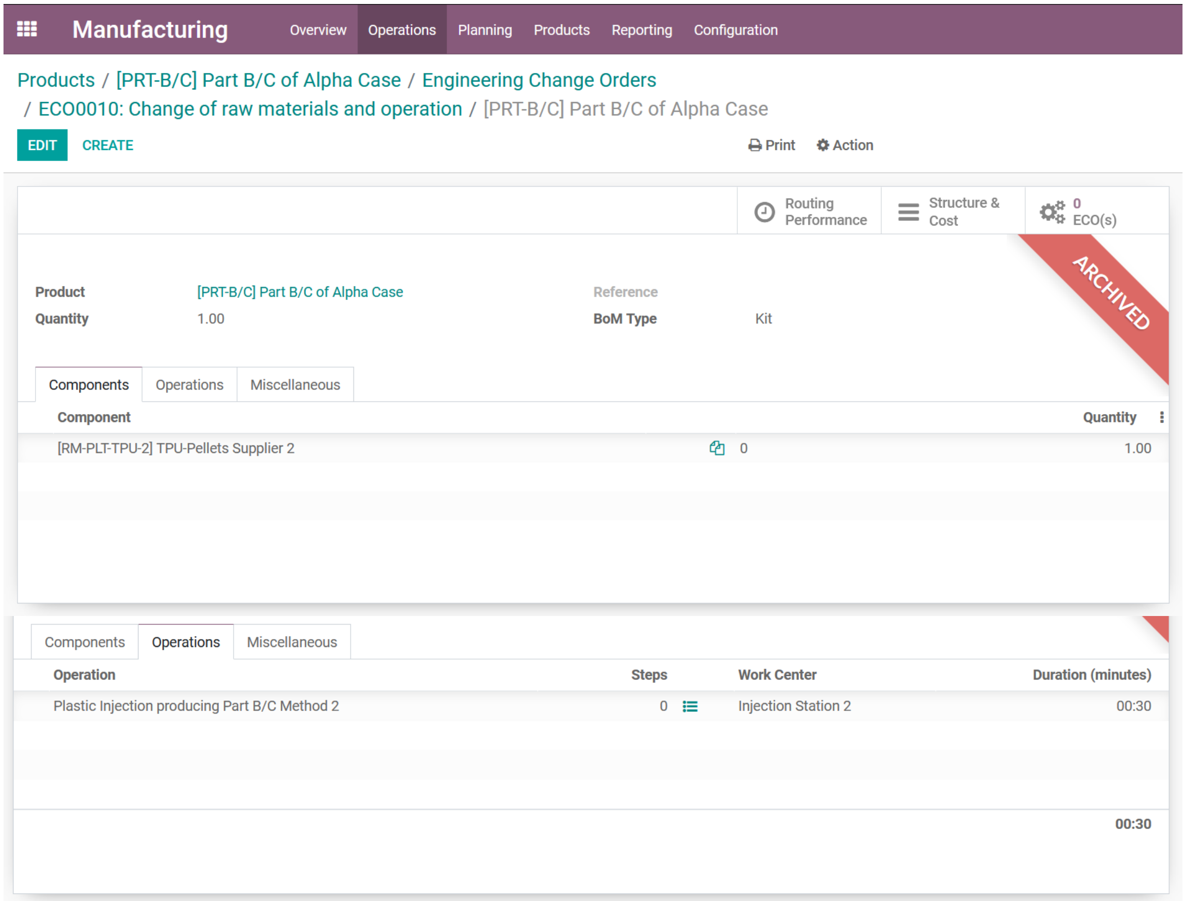


Figure 65 ECO applied to BOM

These upgrades were applied to the BOMs of parts A and B of the Alpha case and production recommenced. After two other MOs producing 50 products each simulating an improvement to the process the following types of data were automatically made available by Odoo (Table 3):

Table 3 Types of data output

Regarding WOs:	Regarding MOs:	Overall Equipment Effectiveness:
-Duration deviation -Duration per unit -Expected duration -Quantity -Real duration	-Backorder sequence -Extra cost -Quantity to produce -Total quantity	-Quantity

It should be commented that the data regarding MOs is unfortunately captured in a monthly basis as opposed to the other two categories that process data per order executed. This means that since this simulation is using a trial version of the software that lasts only 14 days the graphical representation of that data offers an unimpressive view of a single point or a single column. In the long run this is a great way to display performance over time but in the case of this simulation not so much (Figure 66).

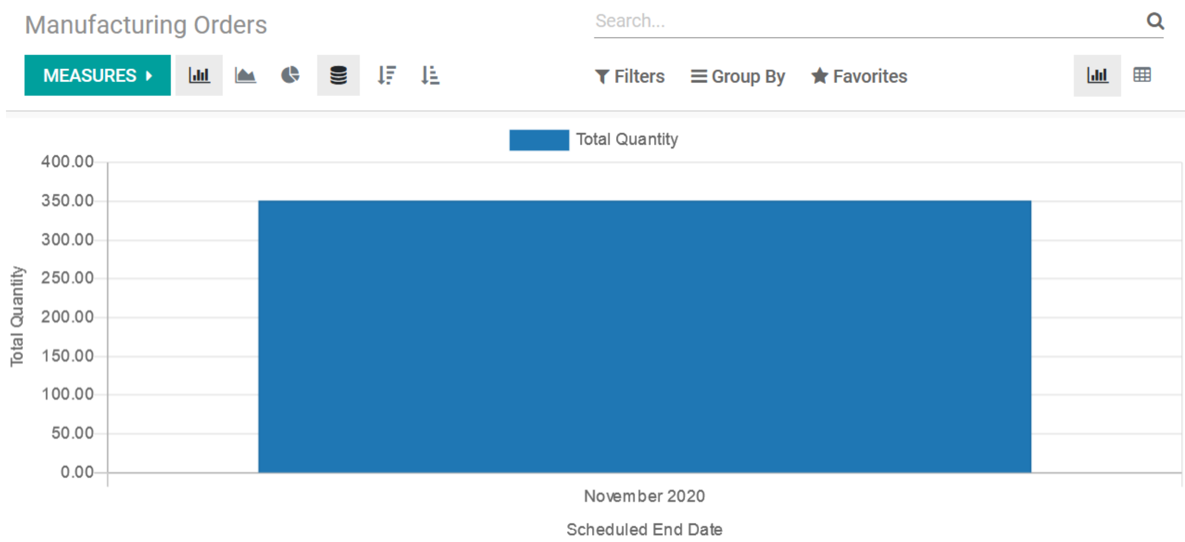


Figure 66 Total quantity regarding MO

All the data available can be seen in the form of bar charts, line charts or pie charts automatically generated after the time performance is registered (which happens at any moment an action is performed in a work order). Figure 67, Figure 68 and Figure 69 are examples of the results of the 5 production runs:

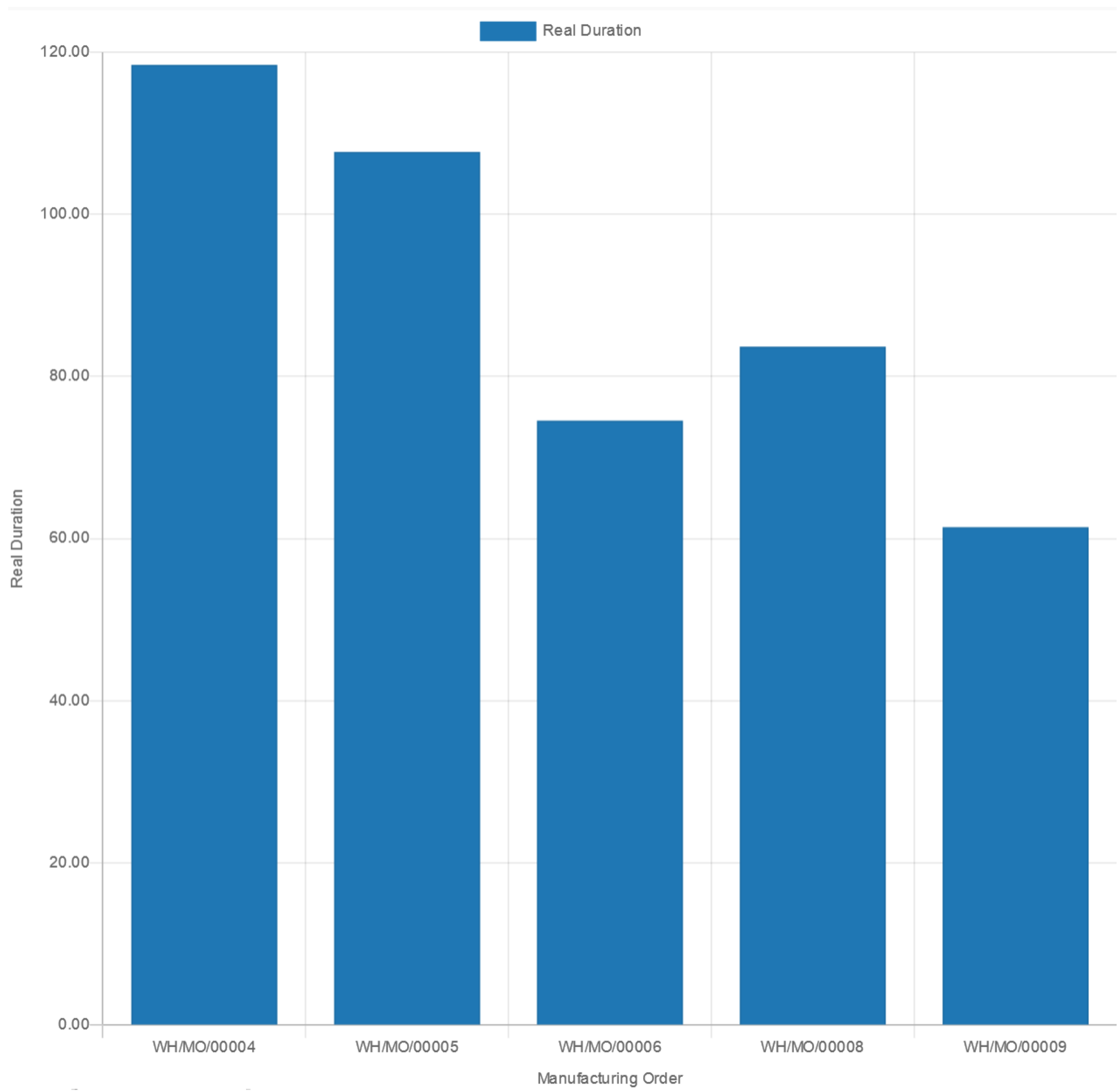


Figure 67 Real duration regarding work orders

Something worth mentioning here is that whenever Odoo mentions quantity or duration it is referring to amount per workorder summed (the system does not care if the operations are being carried in parallel). So, on our simulation, making 50 units using 3 operations that should take 30 seconds each the estimated "duration" to be recorded ideally here is 75 minutes per MO.

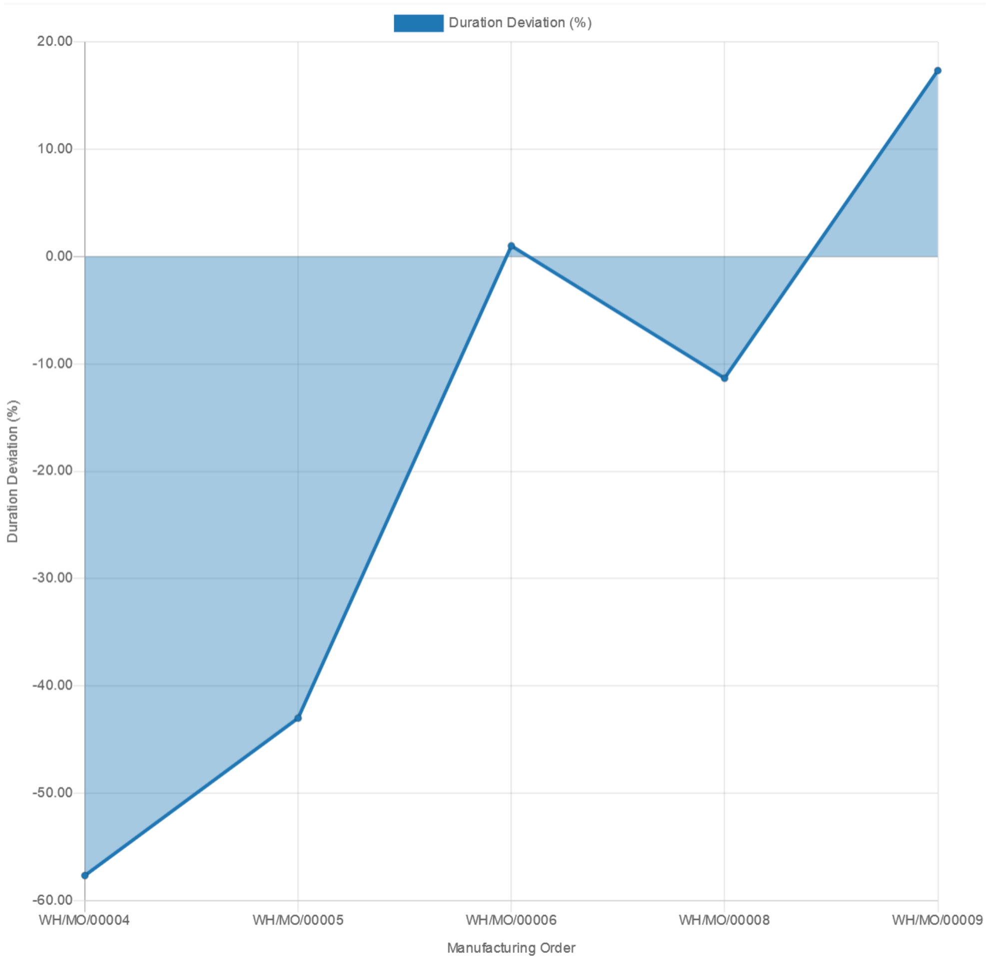


Figure 68 Duration variation regarding work orders

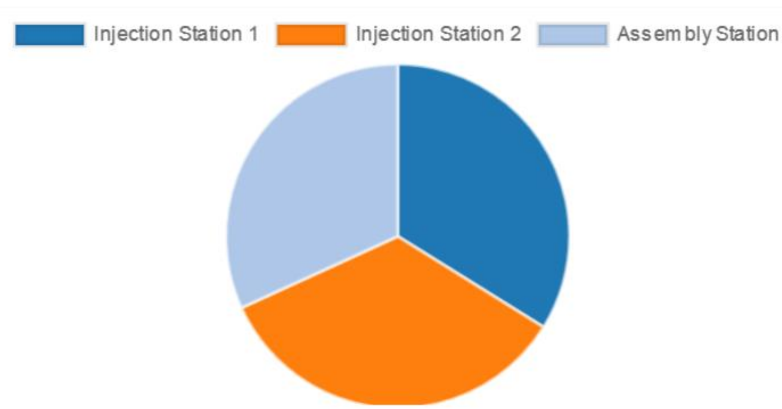


Figure 69 Overall equipment effectiveness

The astute reader will notice that all the data mentioned so far is derived from the time to completion of the operations been carried out, the related amount to the MO and the workcenter utilized. Even so it is impressive how much information can be drawn especially considering that it is all generated automatically.

6. CHAPTER

ODOOS ACOMPLISHMENTS REGARDING PLM AND MES

This chapter aims to summarize the strengths and weaknesses of the Odoo software focusing on the questions raised on section 4.2. It will also comment Odoo functionalities or lack thereof noticed throughout the simulation also taking the questions into account.

6.1.How does the software deals with items?

Overall, the Odoo software presents the user with a wide variety of digital items that can be used to represent several aspects of manufacturing as well as other aspects of business. This is mainly due to the way the Odoo ERP functionality uses items to track the pull and push actions throughout its use, that is also how automation is achieved in the software.

6.1.1. Are all aspects of the product lifecycle represented?

One of the disadvantages of being derived from a ERP system is that it focus on the primary scope of ERP (Figure 2) ,that is, production and sales. The Items in Odoo reflect that. For instance, the development part of the life cycle during the simulation, although the representation was possible it certainly felt like a stretch of functionalities made for the production phase rather than development is self (Figure 70). When developing prototypes for instance many of the steps like creating an ECO just to carry files in the beginning and going through many steps every time an adjustment in the prototype was made felt too bureaucratic or too much of a workaround.

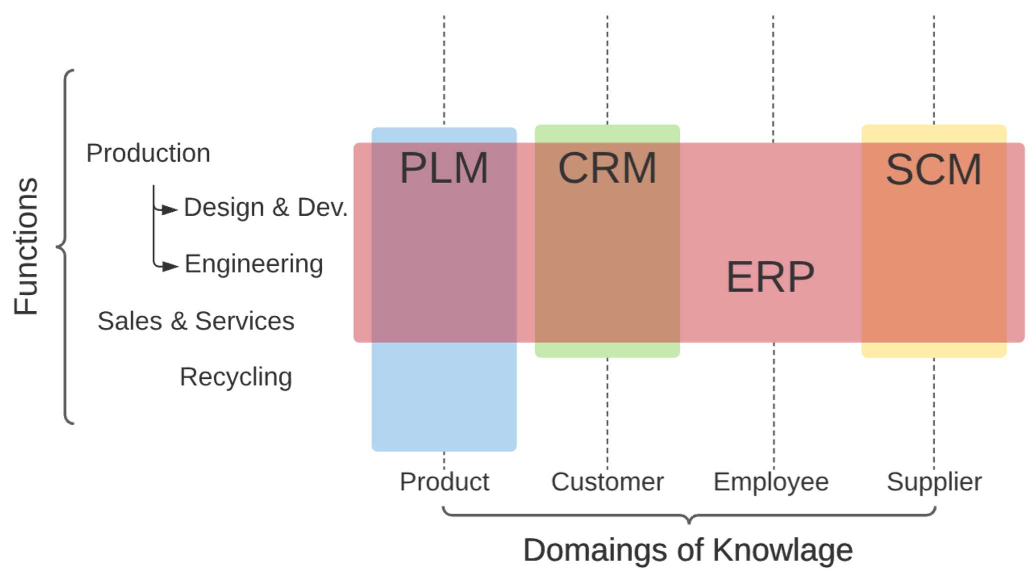


Figure 70 Diagram representing Odoo scope of ERP

6.1.2. How well are each of those items represented?

Representation levels of the items vary depending on how the item is used. A good example of that is the material focus of product items. In the sense that everything is considered a product with very little distinction between prototypes or raw materials. The representation of product items or BOM items is very high with a lot of metadata and useful connections to other items. However, even within the manufacturing application there are some items that lack attention. Operations for instance are items that could benefit greatly from more upload capabilities like 3D printing or CNC files. As automation is becoming more widespread in production it is no longer enough to have only PDF or slide instructions. Additionally, other items do not have the ability of holding files not even with the use of ECOs

6.2. How easy it is to create a brand-new product?

Product creation is one of the most straightforward procedures in Odoo, it really comes down to using either the Inventory application or the Manufacturing application to create a new Product and then fill in its metadata.

6.2.1. How is the product depicted?

The product depiction is clear and concise, the product item allows for an image to be uploaded to the item and used as an icon. The ERP nature of the product items in Odoo means that the metadata is reasonably bias toward information that is used to manage storage and inventory (Weight, Volume, Quantity etc.) but the item also allows for written description as well as providing links to the BOMs and ECOs related to the product.

6.2.2. How does the product integrate and reference relevant files?

There is surely a reasonable attempt in allowing the most valuable items (Product and BOMs) to be able to manage and reference relevant files. However, Odoo does not implement much more than the bare minimum as far as file management goes. The most it can do is allow for files to be uploaded and download manually. This means that whenever someone makes a change in a file it needs to be manually uploaded in ECO. Integration with most files is inexistent except for operation items because the instruction files can be opened and interacted within Odoo during the production.

6.2.3. Does changing one affects the other?

It does not, files are mostly dealt by Odoo as paperwork for later reference. Anything added file wise that could entail a change in the product or BOM metadata will require someone to be aware of the change and update the information manually.

6.3.How easy it is to create a brand-new production process?

As mentioned before the item the best represents the process is the bill of materials. This item class requires an existing product to be associated with, other that the BOM is no harder to create than a product item.

6.3.1. How the process is depicted?

The process is depicted in the BOM as a list of components (other product items) and operations that are carried out in as specific order to produce a number of end products. This representation seems to sit well with the production procedure. Metadata is kept to a minimum but there is still the capability to offer a text description.

6.3.2. How does the process integrate and reference the product it produces?

The integration between the BOM and the product items is by far the most well done in Odoo. Changes made in the BOM affect production and are directly linked to the product. Whenever metadata changes are possible and said aspect is represented in the product item as well the change of one is inherited by the other.

6.3.3. Does changing one affects the other?

As far as inventory and manufacturing is concerned integration is and referencing is well implemented. Production results flawlessly in the resulting changes in inventory and the navigation path of the GUI is very well optimized. It does not take more than 3 or 4 clicks to get from one product to another or to navigate to other relevant items.

6.4.How easy is to improve an existing product/ production process?

As mentioned previously, all improvements in Odoo are performed using engineering change orders. These are applied to product items or bill of materials. Creating ECOs is quite easy and organized, the ECO is an item on itself that symbolizes a signal given to create change, once effective, it symbolizes an increment on the product or process.

6.4.1. How easy it is to update its metadata

It is easy to update any metadata regarding any item in Odoo; however, it is wise to point out that since the ECOs are separate items that are just point by products or BOMs many of the changes are not automatic and require manual intervention. I.e. an ECO will not change the text description of the product for instance. If the new update were to require a change on that description it would require a manual intervention from the user in the product item. Doing that is easy, but it is an extra task that will not be tracked by the ECO.

6.4.2. How easy it is to determine the effects of the change?

Odoo feedback of information is mainly done in a manufacturing order basis. The information available is clear and ECOs do not affect MOs that are already under way so the effects of an applied ECO would not be hard to notice. However, it is good to point out that in the way the performance information is displayed there is no indication of the product revision or the ECO applied. This means that the user would need to first figure when the ECO was applied, then navigate to the equivalent MO in the data to draw its conclusions. Although not a problem for recent changes this does becomes problematic if someone want to analyze effects of old changes.

6.4.3. How does the software deals with different product revisions?

Version control is something well covered by the 1 to N relation between product/BOM and linked ECOs. Every product will have a tab containing all the ECOs applied to it in chronological order effectively working as a timeline representing the item evolution.

6.5. How easy is to find data related to product or process?

Most of the data related to performance regarding production is concentrated under the reporting tab as mentioned in the previous chapter (Figure 71).

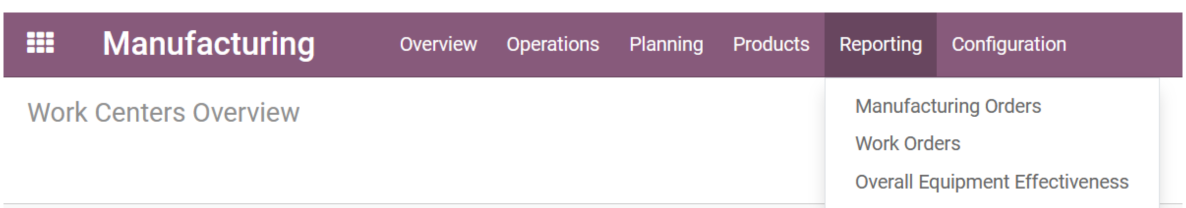


Figure 71 GUI Options of data reporting

This means that as far as performance is concerned it is quite easy to find the data. The previous chapter will show examples of possible information that are available within those tabs.

In addition to using this path the UI of the product item also has a tab that point to the monthly comparison of production volume regarding the product (Figure 72). Which would be more impressive if there was more than one month in the trial version of Odoo.

Figure 72 Total quantity regarding MO from product item

6.5.1. How easy is find production numbers?

In addition to the previously mentioned ways, Odoo also makes available a unit forecast graph that records the ins and outs of the inventory. This is particularly useful to estimate sales and balance storage with demand (Figure 73). This feature is not mentioned to much in this work because supply and demand is not so much a MES functionality, but it is to useful to have an overview of the production.

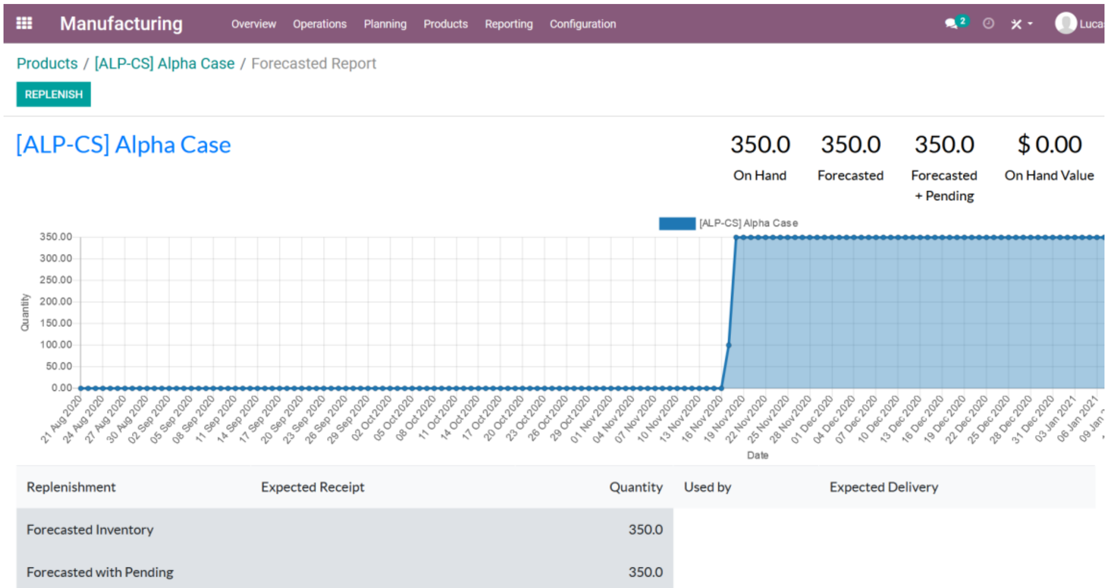


Figure 73 Unit forecast overview

6.5.2. How does Odoo generate performance data?

The astute reader will notice that all the data mentioned so far is derived from the time to completion of the operations been carried out, the related amount to the MO and the workcenter utilized. Even so it is impressive how much information can be drawn especially considering that it is all generated automatically.

6.5.3. How does the software present performance change as a result of a upgrade?

In order to identify the change, the user must identify the MOs following the change and see the difference based on that. Ideally it would be nice if the graphical information showed the revision of the product, but this is not present as of Odoo V13.

CONCLUSION

In chapter 2 I referenced a diagram that represents a theoretical ideal of how the integration of PLM with other systems should be (Figure 74). In that diagram the reader can notice that ideally PLM would be the center of the system with other systems (Including ERP) attached to it. Different from said diagram the Odoo software takes ERP as the center with other systems attached to it. This work has shown that it is certainly possible to use Odoo for PLM and MES however it has also shown that the PLM and MES implementation presents some weaknesses.

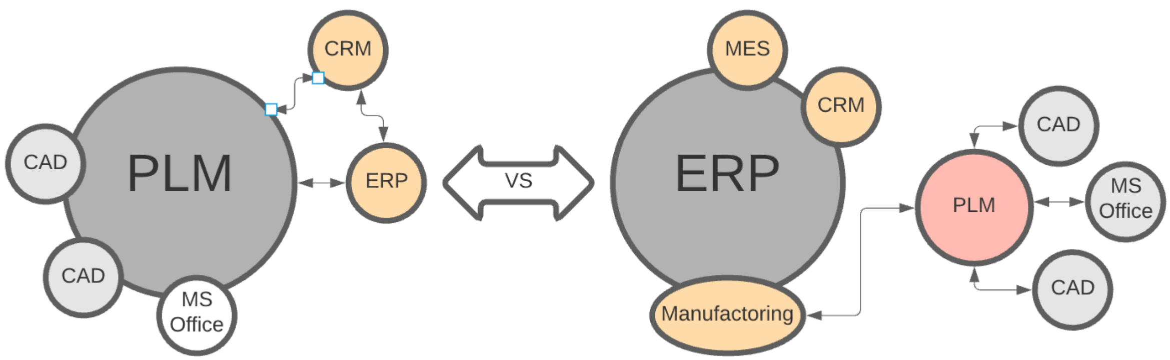


Figure 74 Comparison to the left the adapted diagram as theorized by Saaksvuori, A. and Immonen, A. (2008), to the right Odoo take on how systems interact.

The lack of file upload support on things like operation items, work centers or equipment is something of some concern especially considering 3D printing or CNC because access to the CAD files would prove helpful to the operators. Also, there is a gap in between the facets of product and tool when the company is taking upon themselves to develop and produce said tooling (similar situation founded when developing the molds in the simulation).

In addition, although MES provide detailed graphical representation regarding the dataset that it has, it is limited to data derived from the time to completion of the operations been carried out. For instance, it would be very valuable if graphical representation regarding quality control was easily available as well.

All that said, applying ECOs to BOMs in Odoo is a procedure deserving of praise. The ECO holds the information until it is ready to be applied and then it updates the BOM automatically once the ECO is validated by responsible personnel. It might not look like something so important now because this simulation is dealing with very simple products, but it becomes exponentially more important as complexity increases. E.g. A car with thousands of parts and hundreds of nested BOMs would be considered a nightmare to control and keep track of change if a system like this was not present.

This software is not perfect for PLM or MES implementation, but it does hold value in the sense of availability and integration with other systems. The functionality is there specially regarding product and process and the software has an extremely interesting integration with its natural ERP functionalities. All this makes up for a system that would suit better:

- Small business that could use PLM and MES in a smaller scale.
- Companies that deal with less manufacturing and more assembly or distribution taking advantage of the All in One nature of the software.

It is important to mention that the limitations of Odoo are not in the complexity of the product itself but in the complexity of the operations that surround its development. All things considered you could track a large and complex assembly if it includes only simple manufacturing operations or if more complex engineering tasks are done by suppliers. I.e. you could track the assembly of a motorcycle with ease in Odoo, but the PLM features are not polish enough to track the full evolution/development of its powertrain. It is certainly possible to do so but it would take too much time and effort from the engineering team to be considered worth it just for the sake of having an all in one solution with ERP features.

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