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. 你似乎在討論「單一批次」或生產高度定制產品的能力，這通常與精益生產原則相關。正如你所提到的，這個概念在製造業中已經被廣泛討論，特別是在工業 4.0 和精益生產方法論的背景下。

在《改變世界的機器》一書中，作者 Womack、Jones 和 Roos 確實強調了精益生產的重要性，這涉及到聘用多技能工人團隊，並利用靈活、自動化的機器高效生產各種產品。

你提供的例子，如亞馬遜的包裝系統和電子原型設計服務，展示了公司如何朝著實現這種生產靈活性的目標邁進。亞馬遜為個別客戶定制包裹的能力代表了向大規模定制的重要一步。同樣，電子原型設計服務使得快速、成本效益地交付組裝好的原型批次成為可能，這在過去是一個昂貴且耗時的過程。

電子元件的模塊化本質使得生產具有這種靈活性成為可能。像 JLCPCB 這樣的公司正在利用這種模塊化，提供快速可靠的原型設計服務，正如所示的一週內設計並生產的電源適配器電路的例子所示。

總的來說，這些例子突顯了朝著「單一批次」生產的持續演進，產品根據個別客戶需求定制，而不會犧牲效率或成本效益。這一趨勢是由自動化、模塊化和精益生產原則的進步推動的。

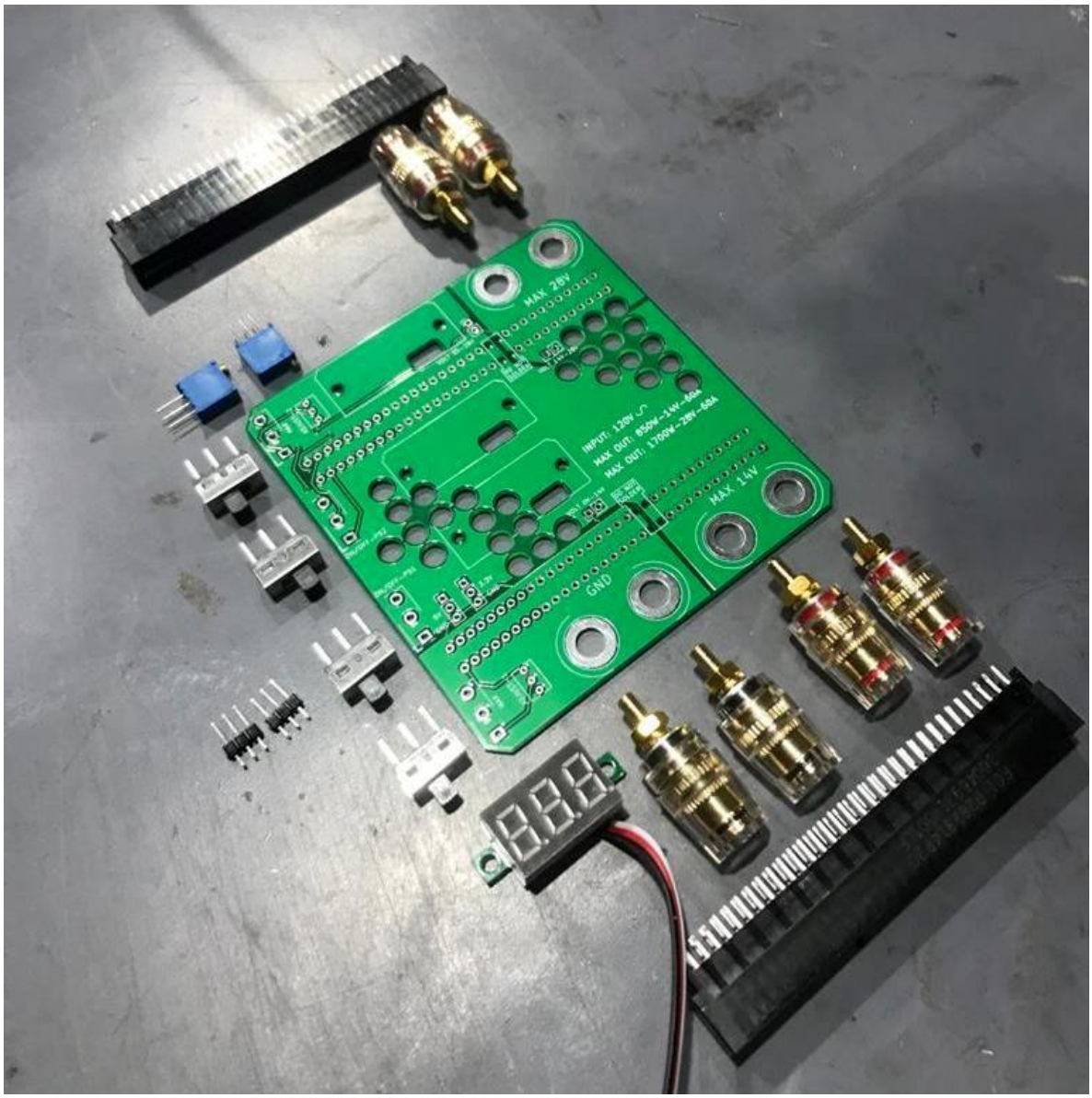

Figure 6 Example project of power supply adaptor circuit

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. 圖 6 電源適配器電路範例專案

整體而言，結果再次顯示出對變革的更大需求，需要更好地控制和管理。這意味著實施 PLM-MES 系統將會大有幫助。PLM 將被用來管理小批量產品在整個生命周期中的變革和創新，而 MES 將提供實時的反應和反饋，以減少可能導致整個批次損失的錯誤。

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. 第三章

最新技術和 PLM 與 MES 的整合

不幸的是，在 PLM 和 MES 系統整合方面並沒有太多發表的研究。但似乎對該整合最可能產生的效應存在共識。這些效應包括同步和更嚴格的容許範圍。

正如 D'Antonio 等人（2015）所解釋的，他們專注於一個關於航空應用的精密零件製造的案例研究，監控和控制系統的部署帶來的第一個預期優勢是產品質量的提升：傳感器可以檢測、測量和監控影響工藝性能或產品質量的變數、事件和情況。

關於將 PLM 與其他系統整合的核心問題之一是信息的所有權問題。一種可能的解決方案是依賴數據庫整合以及系統之間的中間件的使用。正如 Saaksvuori 和 Immonen（2008）所述。一個合理的目標是信息應該始終在一個地方更新。其他系統可以直接從 PLM 數據庫讀取信息，如果需要，所需信息可以複製到其他系統的數據庫中，如圖 7 所示。雖然它主要從 PLM-ERP 整合的角度指出了這一點，但從 PLM-MES 整合的角度來看，這仍然非常有價值，因為它展示了通過在將不同類型的文件加載到集中式 PLM-ERP 系統中運作的系統中，可以預期更好的運作。

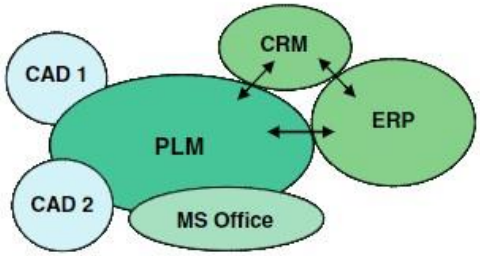

Figure 7 Diagram of PLM integration (Saaksvuori and Immonen, 2008)

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).

圖 7 PLM 整合的示意圖（Saaksvuori 和 Immonen，2008）

因此，中介軟件將是一個軟件框架，以用戶友好的方式組織和連接所有提供給系統數據庫的信息。這種應用也被稱為集成應用程序，正如 Stark（2015）所指出的，這些應用程序使產品信息在 PLM 應用程序之間進行交換（例如，在 CAD 應用程序和 CAE 應用程序之間）。它們還使產品信息在 PLM 應用程序與其他企業應用程序（如 ERP 和 CRM）之間進行交換。

在非常相關的情況下，這種中介軟件的思維方式被（Ben Khedher 等，2011）所擴展。在他們關於實施集成 MES+PLM 的不同系統架構的工作中，他們描述了在 Web 服務架構中使用調解系統。正如圖 8 所示，所提出的架構使用基於互聯網技術的數據交換，幫助公司，特別是擴展的公司，利用 Web 服務產生的機會。 "Web 服務"的概念意味著一個應用程序（程序或軟件系統），它被設計來支持在網絡上的可互操作的機器對機器交互，根據 W3C 的定義（Ben Khedher 等，2011）。

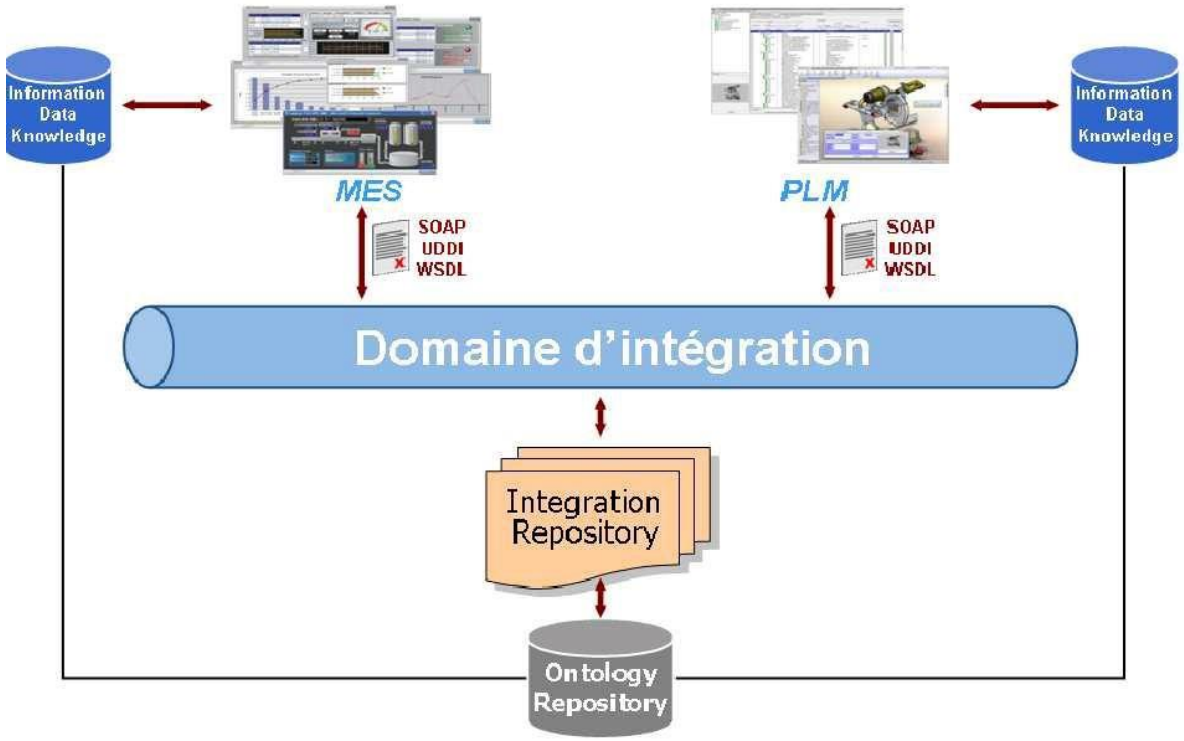

Figure 8 Diagram of Web service architecture (Adapted from Ben Khedher et al., 2011)

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.

圖 8 Web 服務架構示意圖（改編自 Ben Khedher 等，2011）

從這項工作的角度來看，這種擴展之所以如此相關，是因為 Odoo 軟件通過類似的 Web 服務架構以類似的方式工作。理論上，Odoo 軟件可以作為中介軟件在本地網絡中運作或者托管在雲端中，並實現之前提到的集成層。

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.

3.1 實際上的整合將是什麼樣子

如第 2 章所述，PLM 的主要理念是管理與產品相關的所有過程中的變化，它主要通過虛擬化來實現。這裡的虛擬化一詞表示將現實世界的物品表示到數字空間中，可以想象，有幾個抽象層次可以用來表示真實物體或過程。因此，就 PLM 而言，關於虛擬表示必須有多深和/或多詳細以達到其目的，目前沒有確切的共識。

在理想的情況下，這將是最低形式的抽象，基本上等同於在第 2 章中解釋的數字孿生。這是生產周期的每個方面的“1 對 1”數字表示，其中每個參與的部分都將有一個數字表示，不僅包含物品的物理特性，還包含其隨時間產生的所有信息。為此，正如在第 2 章中解釋的那樣，MES 在獲取所需的實時信息方面扮演了一個基本角色，甚至可能是可能的。

例如，一台 CNC 機床將具有用於模擬的數字 3D 模型，以及一個完全集成的列表，列出其生產的所有零件，有關其當前生產水平的數據，其機械零件的當前磨損情況，以及所有其他與之相關的機器，其所受到的所有變更和改進的歷史，以及許多其他方面，所有這些都以直觀的圖形用戶界面（GUI）形式打包，以允許進行最大程度的交互。

在虛構之外，我們尚未達到這種虛擬化水平。獲取和組織信息到這種細微程度需要太多的時間和金錢，特別是需要手工插入的方面，更不用說如何將這些信息集成並與之交互的主觀性了。儘管如此，確定理想狀態下最重要的方面對於此實施是有用的。

這些是：

- 虛擬化手段 - 用於構建虛擬項目的信息類型。這包括直接附加到項目的元數據和文件。在理想情況下，這將包含有關項目的所有可能信息。

- 數據輸入手段 - 如何加載和組織這些信息。理想情況下，這些信息應盡可能自動地加載到系統中，無論是通過質量控制期間的 MES 還是通過像條碼掃描器這樣的自動輸入工具。

- 訪問手段 - 如何將這些信息呈現給用戶。雖然比前述方面更主觀，但這對系統的交互方式非常重要。信息可用性的直觀程度直接影響到 PLM 的核心優勢。毕竟，如果與系統交互的唯一方式是一個命令行界面，使最終用戶難以訪問信息，那麼一切都將無用（即使其他一切都完美）。

- 整合手段 - 項目及其包含的信息如何相互交互並從彼此中受益，即與其他系統和關鍵軟件的集成。例如，如果一個項目可以訪問 CAD 文件，則應無需手工填寫元數據字段。項目如何自動影響其他項目也與此方面有關。

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:

第 4 章
公司和產品介紹

正如人們可以想象的那樣，這項工作的一個獨特之處在於它專注於一個特定的軟件解決方案，這個解決方案在實施到不同類型的企業時往往具有相當大的靈活性。這與大多數關於 PLM 實施的用例相反，其中業務案例是不變的，系統是圍繞它構建的。然而，為了評估 Odoo 作為 PLM+MES 工具，考慮一個例子是很重要的。這裡的優勢在於可以選擇一個虛構的公司作為例子，以最大程度地提高軟件在模擬期間的感知效果。

考慮到所有先前提到的系統，為了舉例說明，這家理論上的公司是按照工業 4.0 的模式組織起來的。這家公司是一家新成立的小型塑料製品製造公司，其主要生產手段是塑料射出成型，並將添加製造和快速原型制作作為其業務策略的一部分。正如第 2 章所解釋的，這些都是行業在創新方面正在採取的路徑的很好示例，其中大規模生產漸漸變得不那麼重要，而產品種類和上市時間則更為重要。

為了最大程度地追踪變化，其大多數業務都是基於主要是自動化機械的較低生產批次。這家公司專注於注塑塑料產品的生產，並且在設置生產和原型製作方面依賴於靈活的機械。考慮到這一點，應該可以對產品和流程的持續改進進行足夠簡單的模擬，以評估軟件的範圍。由於這種不斷變化的生產極大地依賴於各種信息的管理，因此它必須證明是應用 PLM+MES 的完美基礎。

在這個例子中，自從公司成立以來，公司已經實施了 Odoo 軟件，並且已經進行了所有必要的培訓和步驟來正確使用它。這使得可以消除對已有業務實施 PLM+MES 系統時常見的界限和限制，即對遺留系統的依賴、管理層的抵制變革或集成到舊流程中去。這些顯然很重要，但不在本工作的範圍內。

公司的目標是在年底之前生產一種全新的產品。在完成這個目標後，公司改進了該產品的生產過程。一旦有了產品改進的需要，就會進行相應的改進。

以下的圖表（圖 9）將作為產品開發和改進的路徑參考：

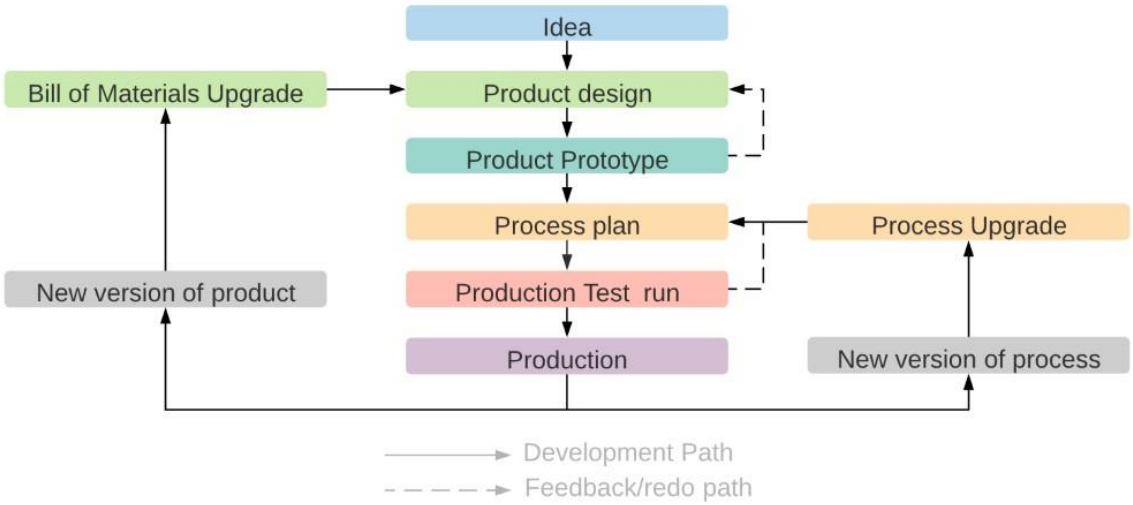

Figure 9 Development diagram

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.

圖 9 發展圖表

這條路徑旨在向讀者傳達一種對開發和改進的迭代方法。這個想法是在產品設計方面進行了循環的原型製作和重新設計，直到達到滿意的結果。然後，類似的循環也在生產過程中發生。在這個階段結束時，初步開發完成，實際生產可以開始。

在這一點上，建立持續改進的方法至關重要。在這家公司的情況下，我們只考慮兩種主要的升級路徑，分別是產品升級和過程升級。

4.1 產品和流程

變化和效果是 PLM+MES 實施的重點，因此這種變化的主題理想情況下應該是能夠提供合理自由設計的東西。儘管良好實施的 PLM+MES 的效果即使在嚴格的製造環境中，變化極其有限的情況下也應該是顯著的，但在一個以創新為主的企業中，系統將產生更為明顯的變化，因為在這種情況下，有更多的機會來改進系統並獲得反饋。

從改進的角度來看，如果將一個是通過金屬板沖壓製成的產品（圖 10）與一個相等的通過 CNC 銑削工藝製成的產品（圖 11）進行比較，就可以很容易地感受到 CNC 銑削產品更容易進行升級。雖然沖壓的成本較低（相對而言），但它依賴於昂貴的高精度金屬模具，這些模具的製作成本非常昂貴。這意味著對其進行改變的成本要高得多，因此追踪變化的系統的效果變得有限。

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.

圖 11 AK74 樣式步槍機匣的銑削示例（來自 sharpsbros.com）

對於這家虛構公司而言，已經確定了展示 PLM+MES 效果的最佳方式是設計產品時以塑料射出成型為基礎。起初可能會覺得考慮這種製造過程有些不合情理，就像之前描述的沖壓過程一樣，因為它在生產過程中也依賴於高精度模具。然而，這兩者之間的主要區別在於原型製作的便利性和升級的成本。

射出成型是一個廣泛而複雜的工程領域，涉及到各種各樣的材料和方法，但這些並不是本文關注的範圍。然而，值得指出的是，大部分情況下，射出成型中所涉及的壓力比處理鋼材時低一個量級；較軟的材料可以用於其模具，如 CNC 銑削的鋁材。與此同時，新的增材製造領域的進步使得可以將塑料部件的原型製作得更接近注塑件的最終結果。有時甚至可以使用原型模具（圖 12）進行低產量的測試運行以進行過程升級。

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.

圖 12 以 3D 打印機製作的注塑模具示例（來自 thefabricator.com）

增材製造已成為極其靈活生產的一個令人難以置信的工具。持續改進的這種思維方式，特別是在原型製作和迭代設計方面，是現代工業中非常重要的精益思維的標誌。

正如前一部分中提到的，這個案例研究考慮了虛構公司通過創建新產品及其生產過程。該產品是一個塑料小型電腦機箱，由 3 個不同的部件組成（見圖 13），預計將使用增材製造和 CNC 銑削的組合進行設計和原型製作，以實現塑料射出成型生產。

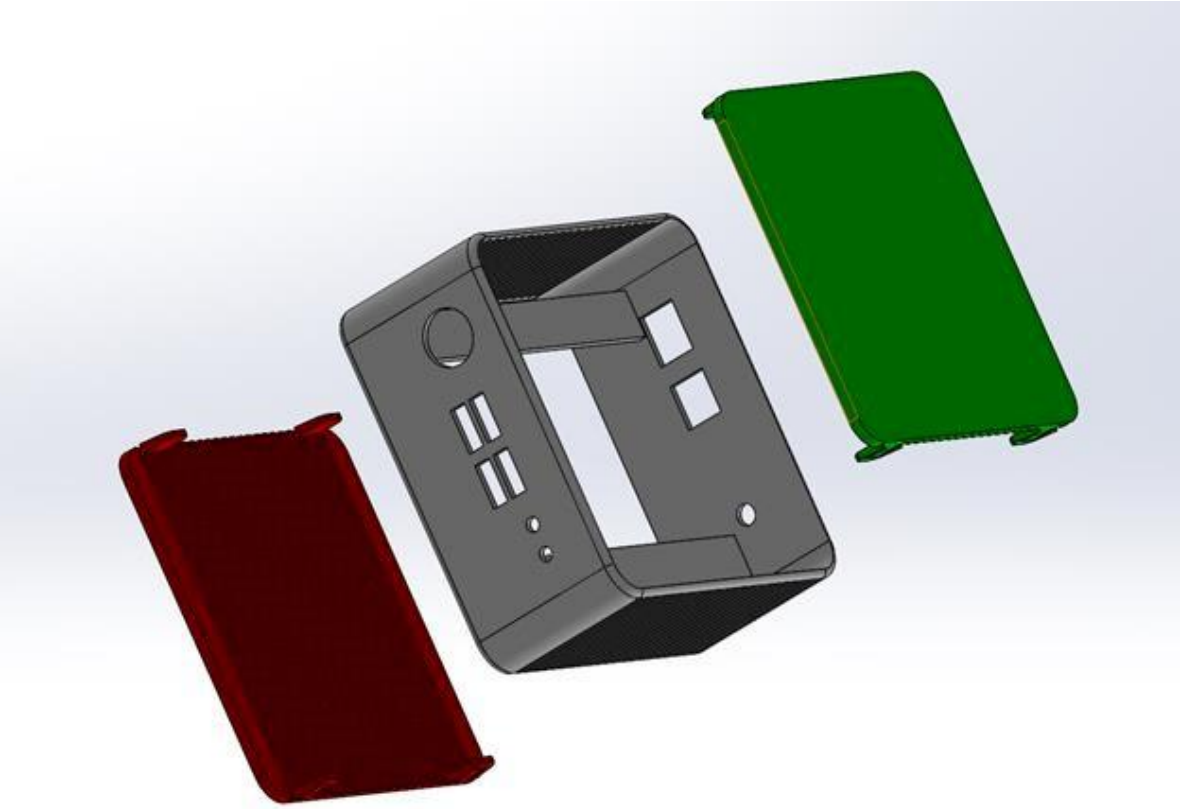

Figure 13 3D exploded view of the theoretical product

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.

圖 13 理論產品的 3D 爆炸視圖

4.1.1. 部件 A

部件 A（見圖 14）是電腦機箱的核心結構。預計它將容納所有必要的部件，以使該小型電腦正常運作。為此，選擇了一種原料 A，即丙烯腈丁二烯苯乙烯共聚物

（ABS），這是一種不透明的熱塑性聚合物和一種工程級塑料。它通常用於生產電子零件，如電話適配器、鍵盤按鍵和牆壁插座的塑料護套。

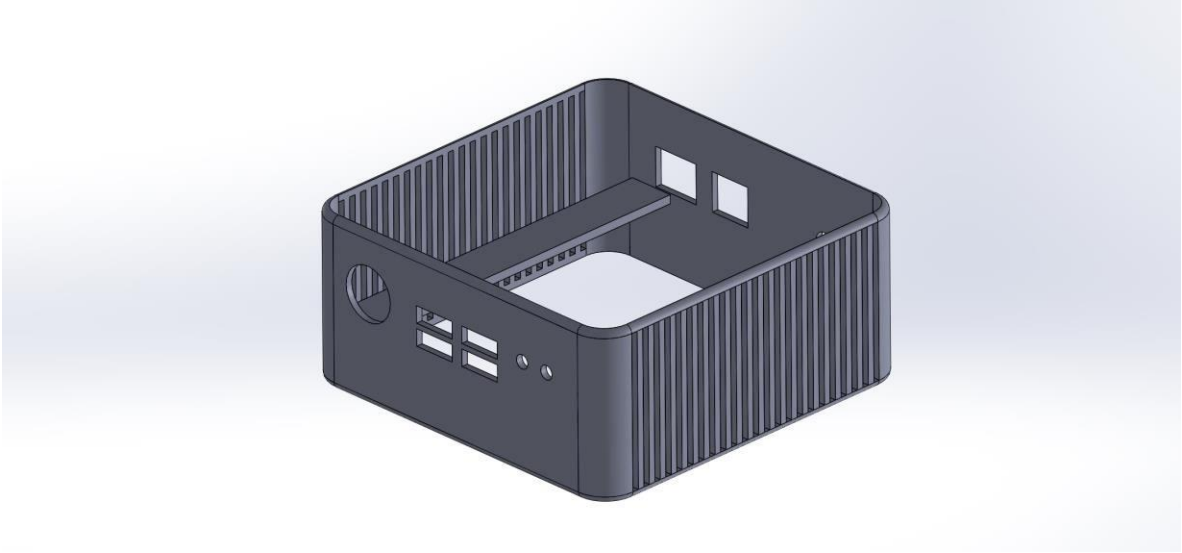

Figure 14 Isometric view of Part A

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.

圖 14 部件 A 的等角視圖

選擇這種材料的主要原因是它的韌性、良好的尺寸穩定性（冷卻後尺寸變化的抵抗力）、高抗衝擊性和表面硬度。最後，它也常以 3D 打印線的形式普遍可得，供擠出式 3D 打印機使用，在原型製作期間應該會非常有用。

4.1.2. 部件 B 和 C

部件B和C是用於密封系統的蓋子，應該能夠吸附到位。這些是非常簡單的部件，需要一定程度的彈性，以便它們能夠變形，確保無螺絲組裝。這兩個相同的部件將使用聚氨酯熱塑性彈性體（TPU）製造，因為它具有彈性，並且具有很大的拉伸和撕裂強度。這種類型的聚合物通常用於製造需要橡膠般彈性的零件。TPU 在高溫下表現良好，通常用於電動工具、電纜絕緣材料和運動用品。最後，TPU 也以 3D 打印線的形式供應，用於 3D 打印機的原型製作。

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.

圖 15 部件 B 和 C

4.1.3. 模具

理想情況下，所有模具都應該由鋼製成，以確保模具和產品質量的持久性。雖然如此，所選擇的所有部件注塑塑料對壓力的依賴性不大，它們的形式也不是很復雜，因此假設使用精密 CNC 加工的鋁模具應該足以生產這些部件。

同時假設所有模具都足夠簡單，可以使用 3D 打印進行原型製作。儘管這並不總是成立的，但確定對於這次模擬而言代表性足夠。在這些原型中使用的材料類型是使用 SLA 3D 打印機固化的高溫樹脂。此外，將考慮模具是在考慮生產過程時需要開發的主要實體方面，因為它直接影響著生產，並且可以在內部生產和跟踪，就像產品一樣。

4.2. 模擬中分析的內容

考慮到圖9所示的圖表以及在第3.1節中描述的PLM和MES成功集成的主要方面，這次實驗旨在對表 1 中列出的以下相關問題進行評論。

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 brandnew 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.

第 5 章

Odoo 軟件

5.1. Odoo 軟件介紹

Odoo 是一款商業管理軟件，與開源社區有著密切的聯繫。最初作為開源 ERP 軟件開始，因其價格實惠、直觀易用、擁有強大的集成性和可擴展性而受到廣泛歡迎。隨著公司經歷了快速增長，它將其業務模式轉變為包括企業付費版本以及在線服務。

如第 2.2 節所述，現代 ERP 系統通常是模塊化的，而在 Odoo 的情況下，由於社區開發的模塊提供了極大的擴展性，以及公司開發的高度集成的模塊，這種模塊化尤其顯著。這種可擴展性使得這款軟件在 PLM+MES 集成的話題中如此重要，因為在其製造模塊中存在用於 PLM 的模塊，以及明顯的 MES 功能。

在本論文的範圍內，目標是利用這款軟件管理之前提到的虛構公司，並就該系統中已經存在的 PLM 和 MES 集成的有效性做出結論。

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.

5.1.1. 工作原理

該軟件可以安裝在大多數 x86 計算機上，並支持包括 Windows 和所有主要 Linux 發行版在內的多個操作系統。

理想情況下，Odoo 軟件安裝在連接到本地區域網絡的計算機上，並啟動一個 SQL 數據庫，該數據庫存儲業務產生的所有必要信息和文件（見圖 16）。該計算機基本上作為服務器，由網絡中的其他計算機通過瀏覽器訪問。該計算機可以是一台專用服務器或正在使用的工作桌面，但重要的是要記住，它必須保持開機並連接到整個軟件需要運行的時間。

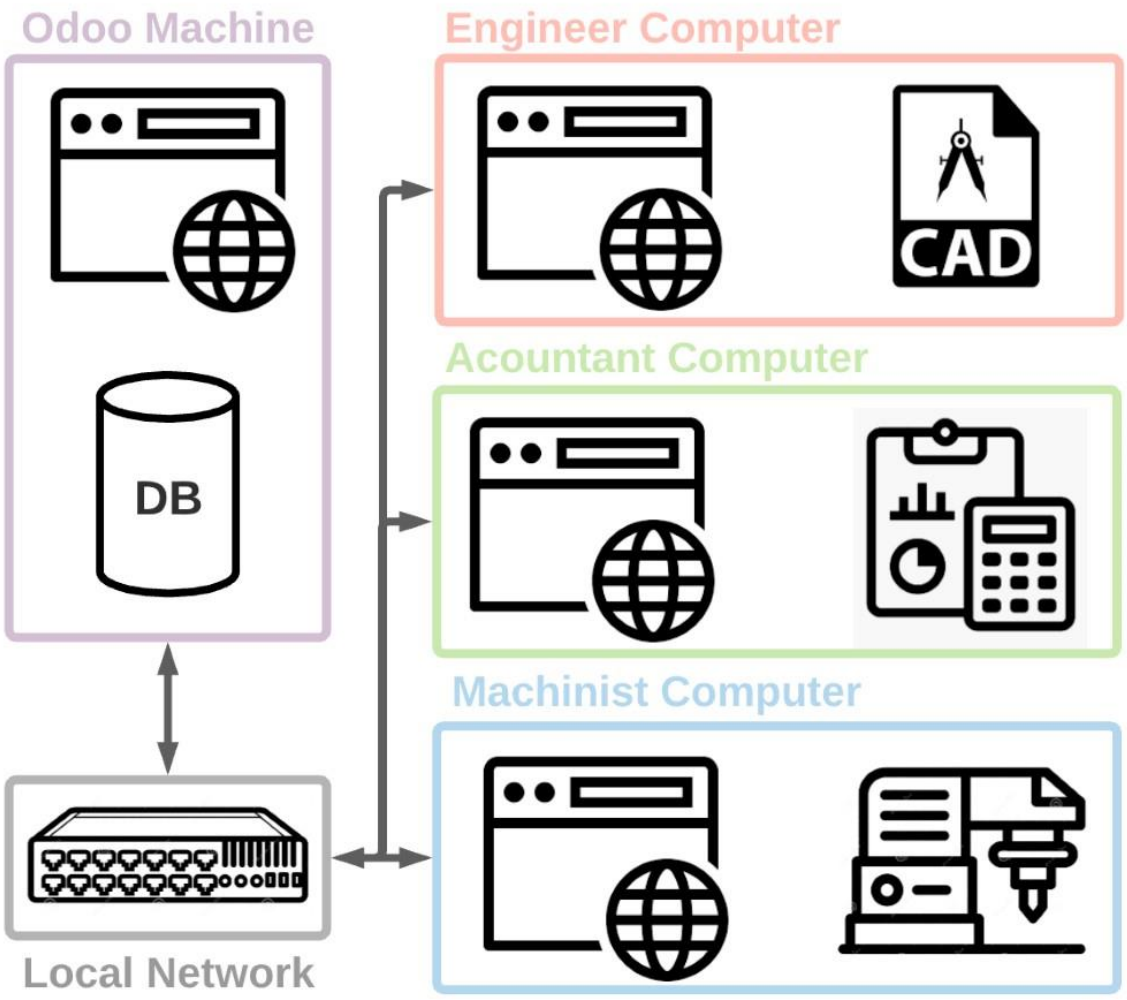

Figure 16 Function Diagram of Odoo configuration A

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.

圖 16 Odoo 配置 A 的功能圖解

另一個選項是使用 Odoo SA 提供的託管服務（見圖 17）。在這種情況下，系統將由他們來托管，數據將存儲在他們的雲端中。對許多小型企業來說，這是一個很好的選擇，特別是如果他們特別喜歡與網站相關的模塊（用於構建和管理網站和電子商店）。然而，這取決於網絡，這在某些情況下可能會造成問題。

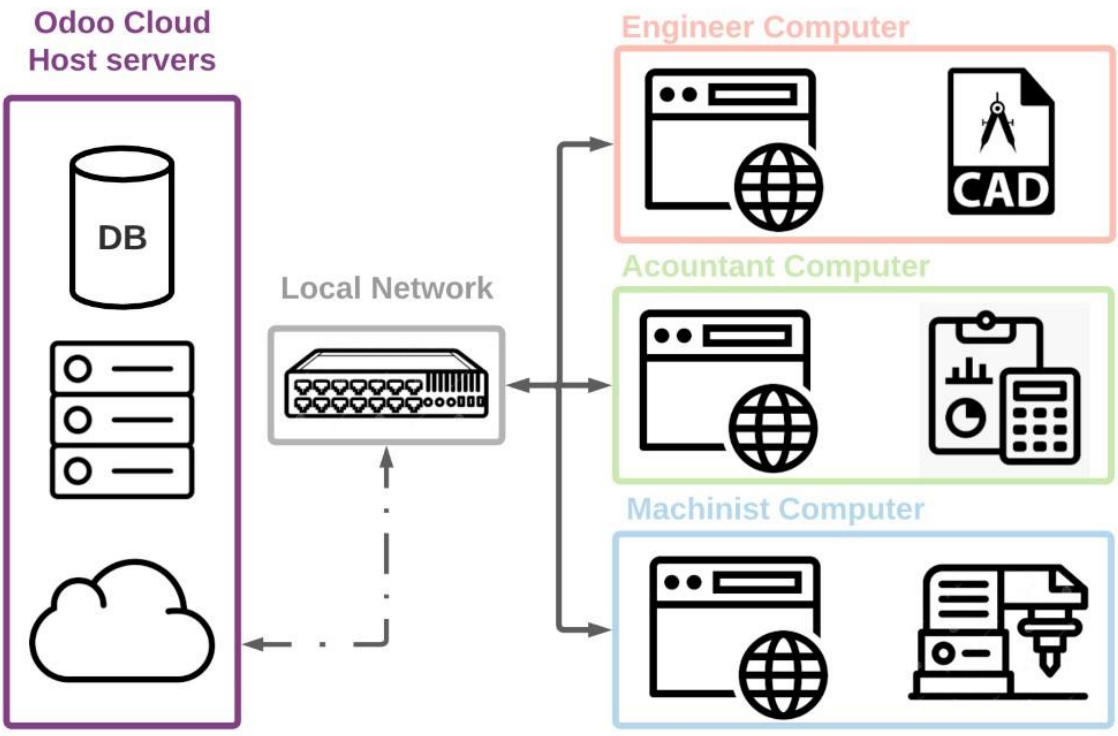

Figure 17 Function Diagram of Odoo configuration B

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 getgo, the company has available a reasonable selection of well-integrated applications not to mention a vast app store filled with community made modules.

圖 17 Odoo 配置 B 的功能圖解

用戶基本上通過圖形用戶界面（GUI）與系統交互，並使用它來根據每個用戶的需求訪問不同的模塊。這意味著可以對不同用戶施加限制，以便對業務活動的不同方面進行控制，例如，會計人員將可以訪問會計模塊、銷售模塊和庫存模塊，但他們將被限制訪問製造模塊。這種限制確保只有適當的員工才能對流程進行控制。

在該 GUI 中，不同的模塊顯示為應用程序圖標（見圖 18），公司從一開始就有一個合理的集成應用程序選擇，更不用說社區製作的大量應用程序商店了。

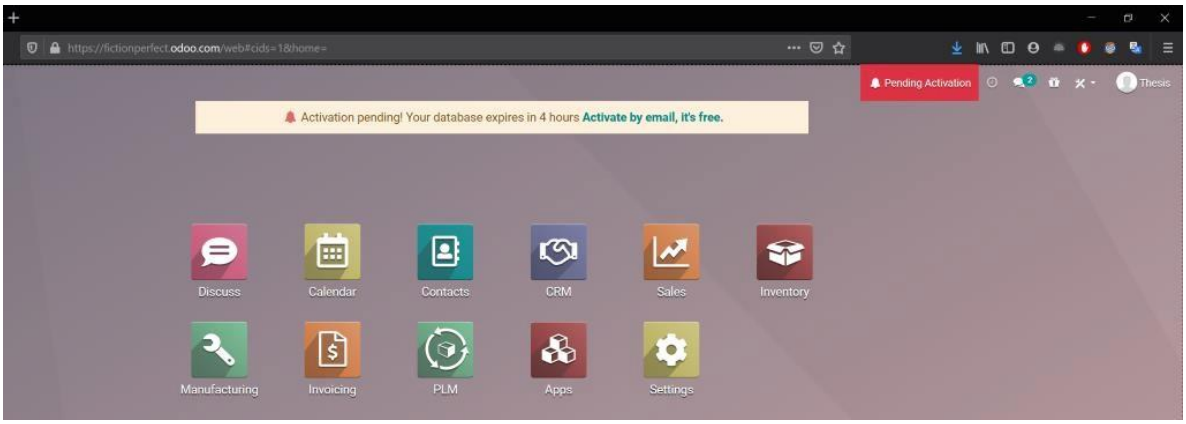

Figure 18 Screenshot of GUI from Odoo in configuration B

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.

圖 18 Odoo 配置 B 中的 GUI 截圖

5.1.2. Odoo 對製造的觀點：

Odoo 認為，關於任何事物的製造責任是分佈在不同的公司部門中的，每個部門負責特定的文件類型，並使用特定的應用程序處理（見表 2）。從 PLM 的角度來看，這是非常積極的，因為如（Saaksvuori 和 Immonen，2008）所提到的關於用戶特權管理 - PLM 系統用於定義信息訪問和維護權限。 PLM 系統定義了可以創建新信息或進行檢查和接受更改的人員，以及只允許在系統中查看信息或文檔的人員。當涉及將 PLM 與其他系統集成時，用戶特權管理通常是一個挑戰。

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’.

從 Odoo 的角度來看，在通常的製造過程中，首先是工程師使用 CAD 軟件設計產品。完成設計後，他們將創建一個物料清單（BOM），這是生產產品所需的零件或材料的列表。此時，焦點轉移到製造過程本身。

軟件對流程的觀點主要集中在路由、工作表和工作中心，這是由製造工程團隊完成的。路由是產品生產過程中經歷的一系列步驟。工作表是製造操作員的指導，而工作中心則是進行生產的地方。Odoo 認為這些是實現工程師計劃的要求。

採購部門將負責發出報價請求（RFQ）或採購訂單（PO）。庫存操作員根據這些 PO 進行收貨，通常使用 Odoo 內的條碼應用程序進行操作。正如本章的第一部分所解釋的那樣，Odoo 主要是一個 ERP 系統，此時可以注意到一些 ERP-centric 特徵，如對庫存和資源管理的關注。這將在接下來的部分進一步分析，但值得指出的是，這些 RFQ 和 PO 在數據庫中被視為項目。

只有當您有了設計、流程和所需的材料時，Odoo 才認為製造是可能的。然後，製造領班將創建一個製造訂單（MO），並通過工單（WO）和工作中心管理製造操作員的計劃。然後，製造操作員可以按照工單開始生產。產品生產完成後，它們將自動出現在庫存數據庫中，庫存部門將負責包裝和交貨。

Odoo 認為質量團隊負責分配控制/檢查點，以及識別產品或生產中可能存在的問題。這些質量控制檢查點從 MES 的角度來看非常有趣，因為它們代表著在生產過程中收集的寶貴的生產數據，即可以在每件產品生產後分配尺寸檢查，由機械師填寫尺寸以隨時間追蹤質量。

如果是設計問題或者存在改進的可能性，可以發出工程變更訂單（ECO）。這回歸到製造工程團隊手中，將集中於更新文檔和 BOM。ECO 是 Odoo 跟蹤系統內部變更的核心。這在涉及 PLM 時是關鍵的，實際上是 Odoo 名為 PLM 的應用程序的重點。該應用程序的功能將在下一節中進行探討。

5.1.3. Odoo 的信息結構

每個模塊都專注於操作特定的面向對象的類，在數據庫中保存元數據。這些是虛擬項目，負責將產品生命週期的各個方面虛擬化，如第 3.1 節所述。不同類型的項目具有不同類型的帳戶，並保存不同類型的數據，例如，產品項目代表特定產品，並保存與其交互和使用相關的

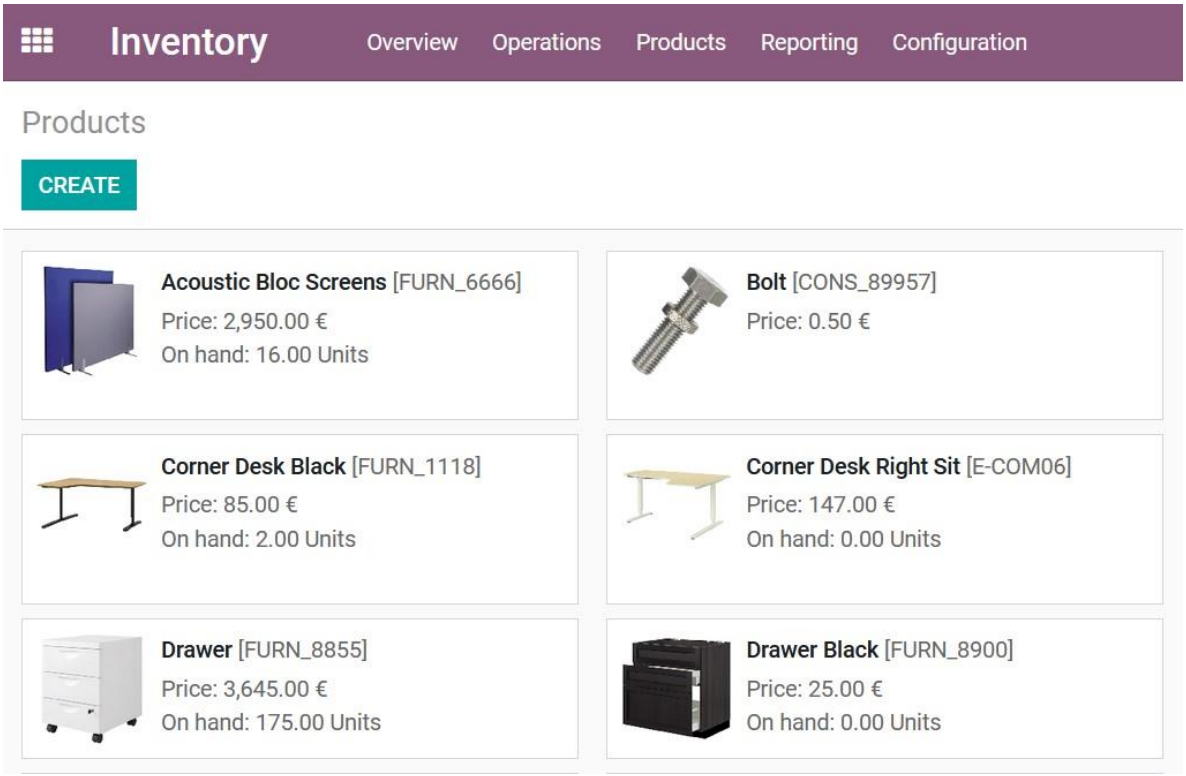

Figure 19 Example of Odoo's interface regarding items

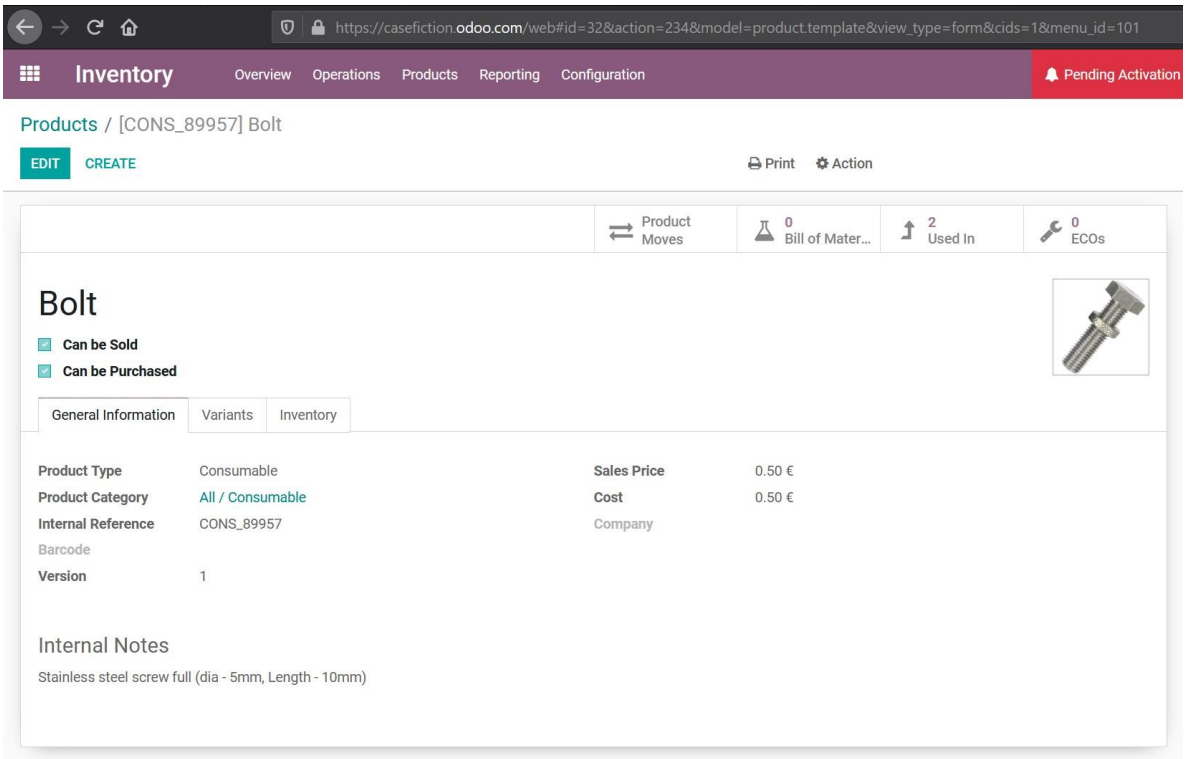

Figure 20 Example of specific item and its metadata as displayed by GUI

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.

在 Odoo 中，有幾種類型的這些項目類（有些持有大量元數據，而有些則持有非常少的）都具有不同程度的關係和集成。由於本工作的範圍僅限於 PLM 和 MES 的功能，因此重點是與之相關的項目。接下來的部分將為 Odoo 製造過程的主要 7 個項目類提供簡要說明，因為基本理解有助於讀者跟蹤模擬。這些顯示在以下圖表中（圖 21）。其他與製造過程無關的項目將在模擬中介紹。

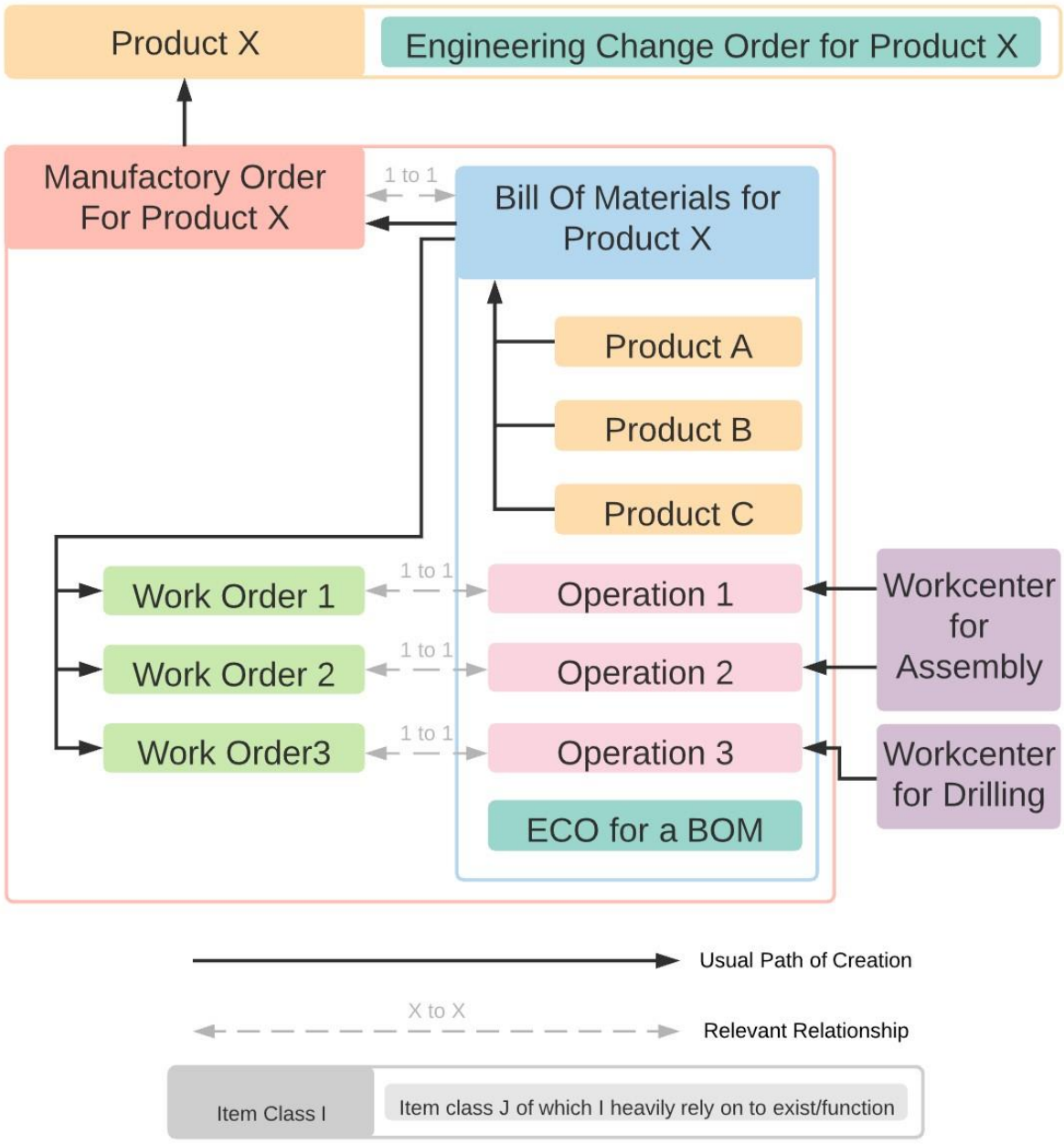

Figure 21 Simplified Item relation diagram to the manufacturing of a product X

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.

5.1.3.1. 產品項目

每種材料、零件或產品都由一個 PRODUCT 類型類別來特徵化，主要在 Odoo 的庫存應用程序中持有和管理。這意味著在系統內，產品的生產取決於其他產品的可用性，這些產品可以直接購買或從其他產品製造而來（見圖 22），即原材料也被視為產品，更具體地說是購買然後包含在 BOM 中以製造其他產品的產品。這被認為是主要的項目類別，因為它既是製造的來源也是目標。

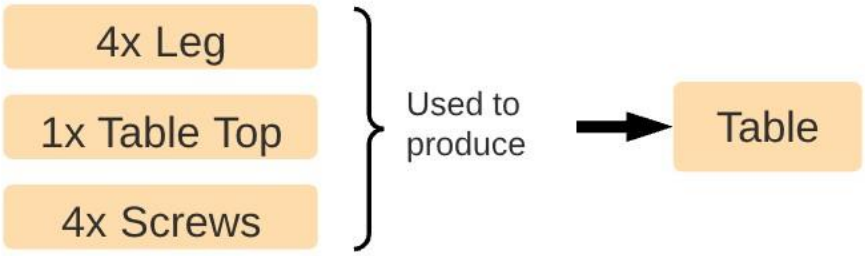

Figure 22 simplified Product relation diagram

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.

5.1.3.2. 操作項目類和工作中心項目類

操作項目代表了將零件或原材料轉化為產品或新零件所需的製造操作，而工作中心項目則代表操作發生的地點，例如，木材打磨將在具有適當設備的打磨站（見圖 23）中進行。工作中心最終在 Odoo 中用作生產計劃中的時間/設備管理工具。基本上，當生產中心達到滿負荷時，它會將後續的流程暫停或將流程重定向到替代工作中心。操作項目還負責保存在生產過程中參考的指導文件。

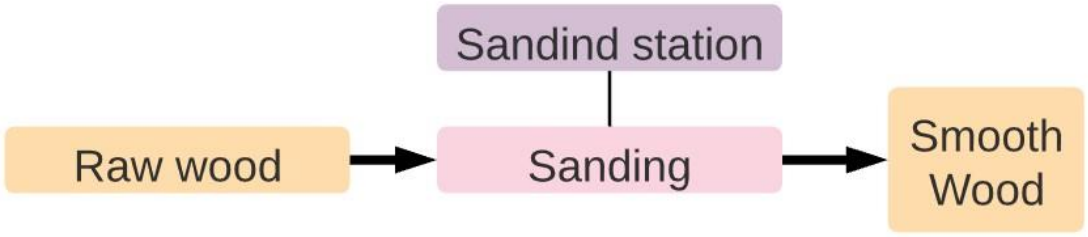

Figure 23 Simplified Operation diagram

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.

5.1.3.3. 物料清單項目類

物料清單是建造產品所需的零件清單。然而，在 Odoo 中，BOM 最好由 PLM 所考慮的生產過程的虛擬表示來描述。一開始這可能看起來有些反直覺，考慮到前面提到的操作項目類，但實際上，由於 BOM 是一個複合項目，它直接指向了生產最終產品所需的所有項目類型（見圖 24）。例如，假設要建造一個產品需要 3 個不同的部件和 4 個不同的操作；該產品的 BOM 將列出所有這些，並指定它們的使用順序。

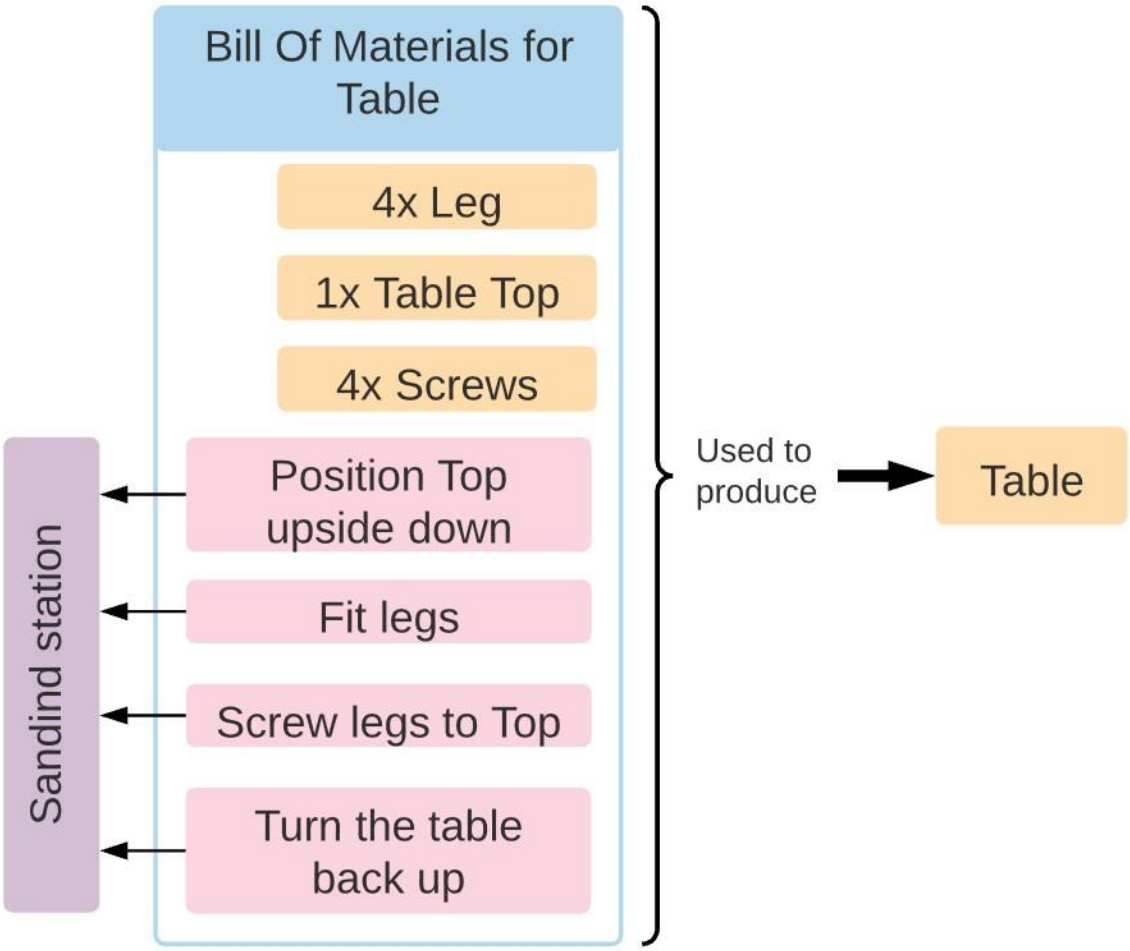

Figure 24 Simplified BOM diagram

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.

5.1.3.4. 製造訂單項目類和工作訂單項目類

在 Odoo 中考慮的標準項目之外，訂單是代表系統內開始的項目。它們表示某種變化正在發生，某處正在進行。對於製造訂單，它代表了使用其 BOM 作為基礎製造特定產品數量 N 的訂單。正是由於這個 MO，Odoo 會自動生成工作訂單（對於 BOM 中列出的每個必要操作生成一個），並分配到可用的必要工作中心中（見圖 25）。

工作訂單是製造運營商與 Odoo 互動的主要形式，它呈現了操作項目指定的所有指示，以及對其完成的控制。當 WO 發生時，運營商會通過界面信號開始，完成甚至任何質量控制檢查點，而系統則跟踪時間和性能（見圖 26）。一旦所有 WO 完成，MO 可以宣告完成，BOM 中指定的材料和零件被消耗，並且產品的 N 份副本被添加到庫存中。所有這些使工作訂單在 MES 方面成為一個中心部分。

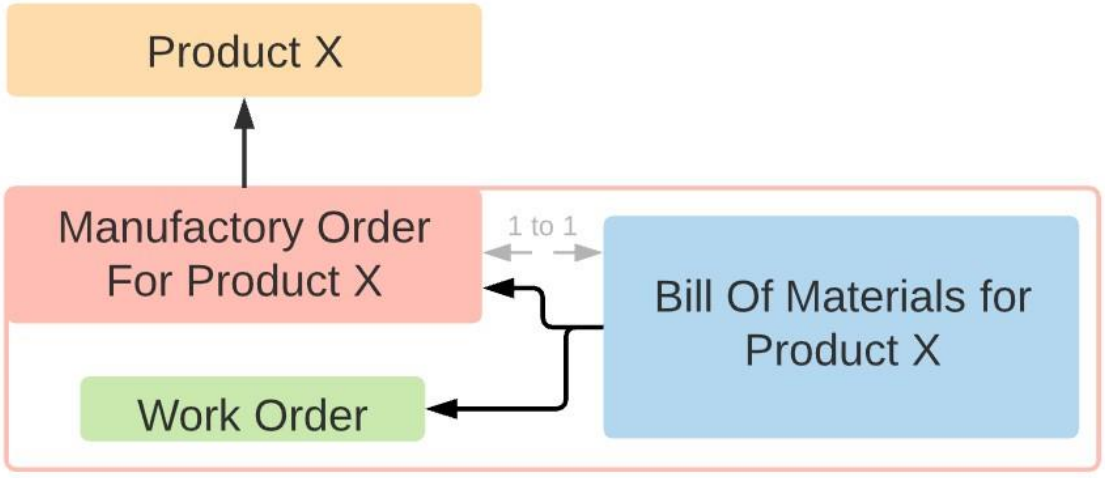

Figure 25 Simplified orders diagram

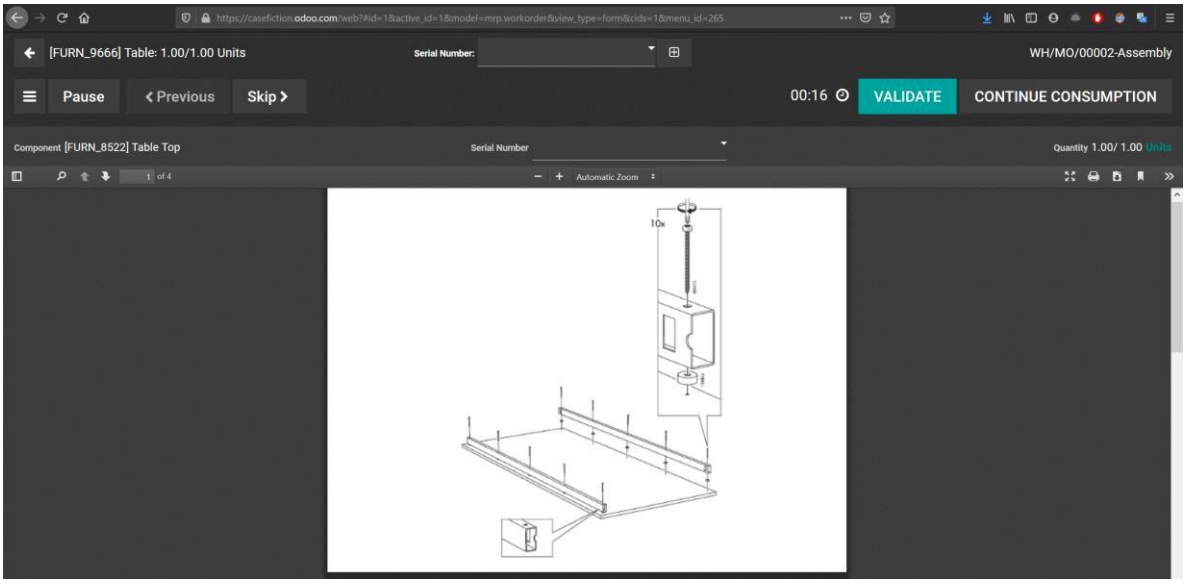

Figure 26 Operator interface during the WO

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.

5.1.3.5. 工程變更訂單

正如在第 2 章開頭解釋的那樣，Odoo 管理軟件主要將 PLM 視為跟蹤變更和改進的工具。它的應用模塊是外部的，但作為對其的擴展。其焦點項目類是工程變更訂單（ECO）。

ECO 是一種概述對產品或受到變更影響的零件提出的變更的項目類。換句話說，它是與特定產品相關的每個人的中央信息中心。

這個想法是向產品項目或 BOM 項目發出變更需求信號，保存與變更相關的文件，並應用變更，或者至少表示變更已實施，同時保留所有先前變更的歷史記錄。這在將來非常有用，可以作為簡化產品開發流程並幫助改進產品/生產的過程。

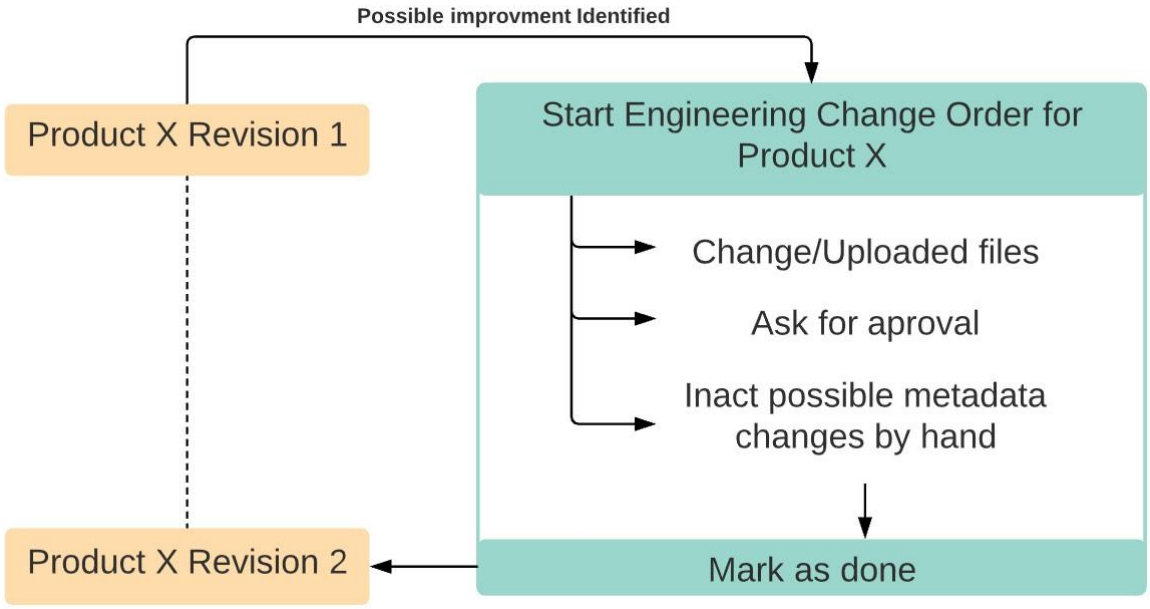

Figure 27 Simplified ECO function diagram

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).

5.2.2. 啟動模擬

5.2.2. 軟件選擇的模擬

對於這個模擬，我們決定最好的評估 Odoo 軟件的方法是通過其在線基於 Web 的服務。選擇此選項而不是使用軟件的社區版本的原因如下：

▪ 使用 Web 服務相對於在本地或遠程管理服務器更加實用。盡管社區版應用程序已經作為本研究的一部分進行了測試，並被判定為非常適合初學者的服務器應用程序，但

事實上，託管服務器本身就是一項需要經驗和知識的工作。市場對這類應用程序的態度已經發生了變化，趨向於產品作為服務，原因是顯而易見的。在撰寫本論文時，COVID-19 大流行迫使許多員工遠程工作，並讓市場清楚地認識到 IT 工作並不簡單，Web 服務是一個有吸引力的選擇。

▪ 社區版 Odoo 缺乏官方的 PLM 應用程序。盡管 Odoo 的社區版本有大量的社區製作應用程序，但這些應用程序的組織、描述、整合和支持情況至多是參差不齊的。與其依賴於可能無法跟上主軟件步伐的應用程序，不如依賴於官方應用程序，以便更公平地評估平台。也就是說，如果依靠運氣來決定將來如何支持一個免費的解決方案，那是非常不划算的。在這裡的重點是 PLM，所以這是一個不可妥協的情況。

在撰寫本文時，Odoo 允許您選擇其額外功能之一，例如 PLM，並在其雲端託管的服務器上免費使用它，時間不限。如果這份工作的唯一重點是 PLM 和製造，那麼這是一個非常有吸引力的選擇。然而，這項工作的 MES 方面高度依賴於 Odoo 的其他應用程序，這意味著幾乎沒有什麼可以做的。為此，實驗在 Odoo 企業版本的試用版中進行，該試用版允許用戶在 Odoo 雲端服務器上使用系統，沒有存儲或應用程序限制，使用期限為 14 天。

5.2.2. 相關設置細節

Odoo 的幾個設置細節與其製造功能的正常功能密切相關。尤其是在製造設置中啟用工單是正確使用工單項目、工作中心項目和操作項目的必要步驟。

本工作假設，這是軟件起源於 ERP 的遺留問題，因為如果你要在 Odoo 上進行任何嚴肅的製造控制，將此設置啟用並不直觀。無論如何，在 Odoo 企業版 v14 中，可以在「設置」>「製造」>「操作」>「工單」中設置此選項。

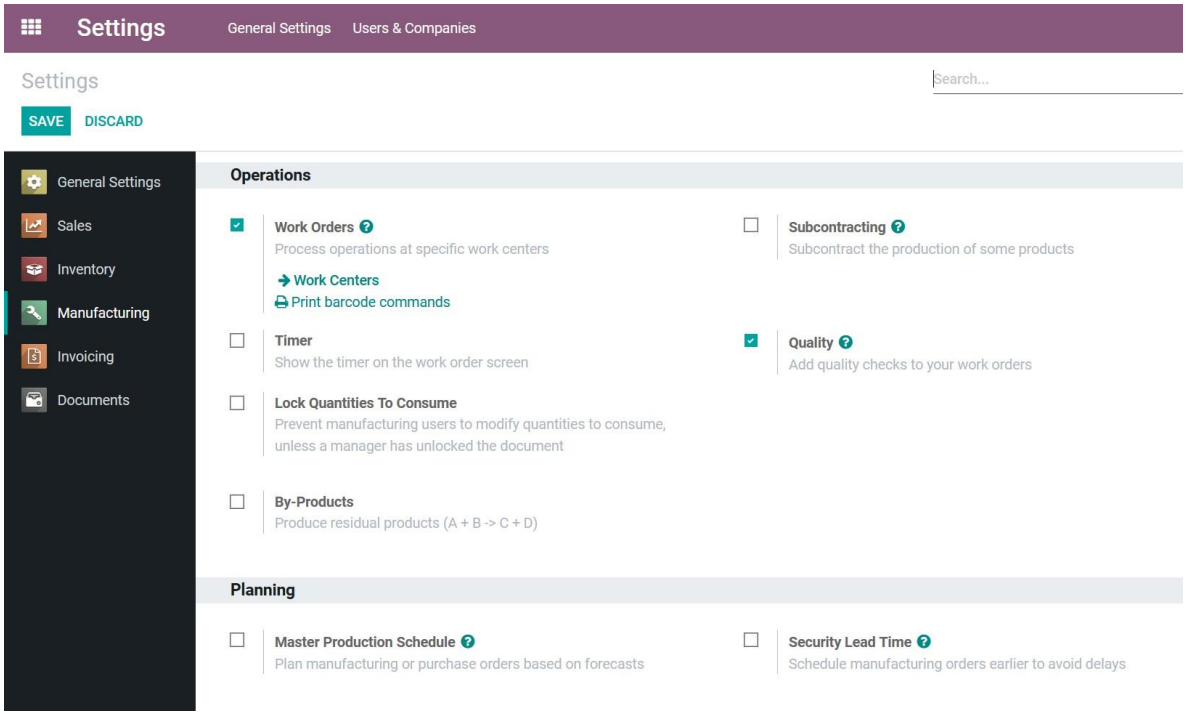

Figure 28 Screenshot of the specific setting to be enabled

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).

5.3. 構建公司結構

5.3.1. 用戶

用戶可以通過設置菜單進行設置和邀請。可以分配不同級別的權限來管理業務運營的不同方面。消息、權限、批准、責任都分配給一個用戶。這非常方便，即使在製造範圍內使用有限，也可以屬於虛擬項目類別。它們的創建並不是絕對必要的，

軟件只需要我作為具有完整管理員憑據的用戶即可運行良好，但是為了進行此模擬，創建了 5 個用戶，分別代表公司內的不同員工。以下（見圖 29）是我的用戶帳戶項目及其“訪問權限”的截圖，隨後是為公司創建的一個虛構用戶（見圖 30）。

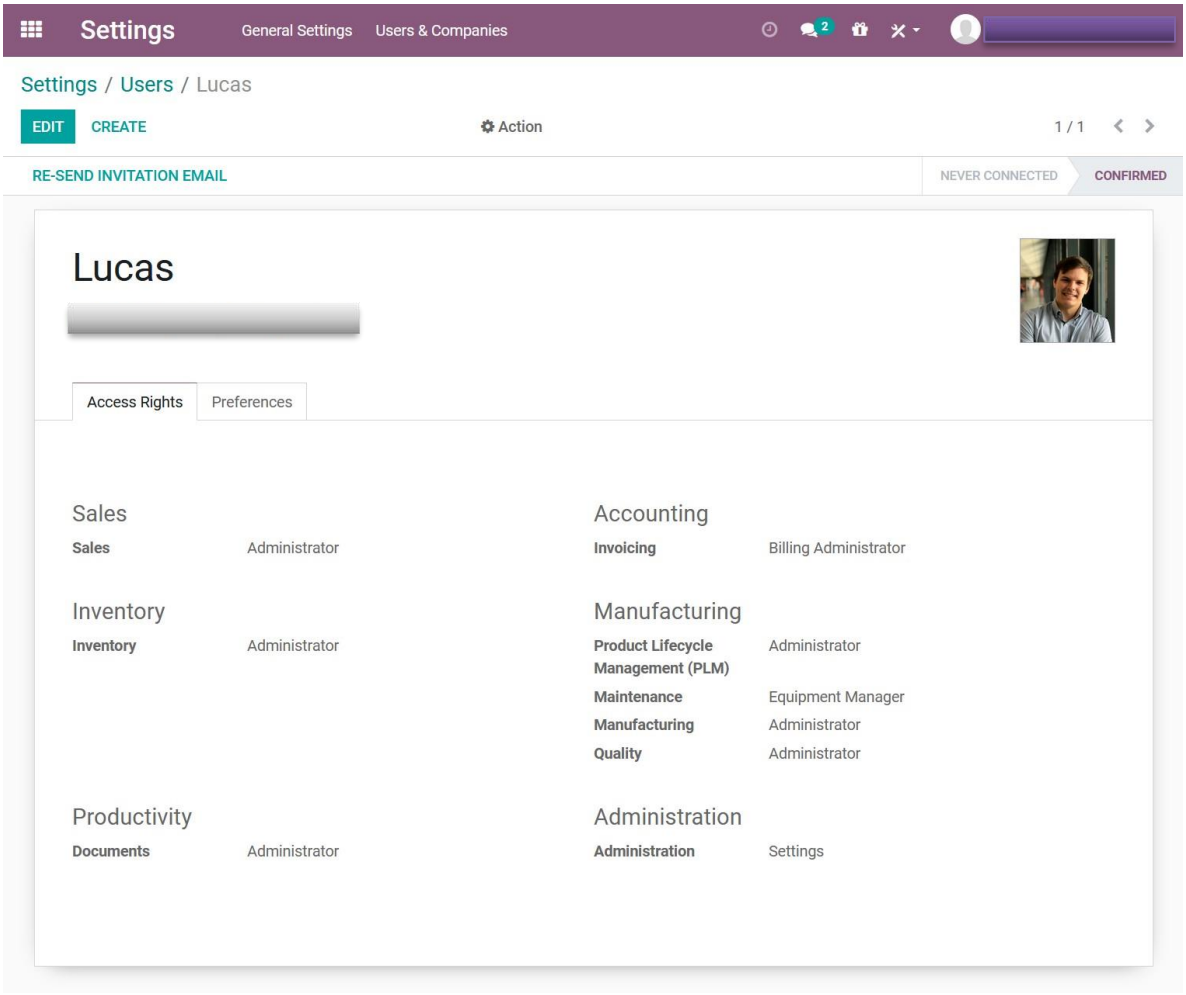

Figure 29 Screenshot of user account interface

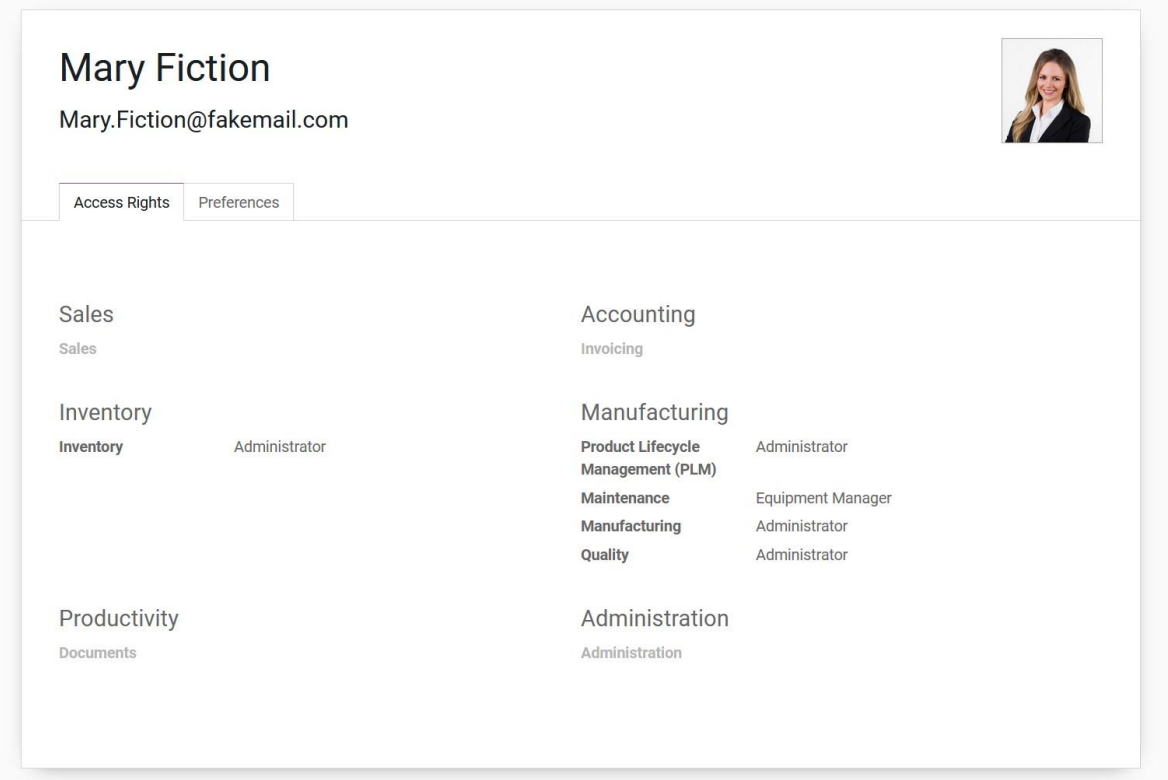

Figure 30 Screenshot of second user account interface

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).

5.3.2. 工作中心和設備

在 Odoo 中，工作中心在某種意義上是非常靈活的，因為它們可以根據需要進行更改和擴展。一個人可以在創建產品項目之後創建工作中心，以便在最終獲得一些產品的視角後重新組織車間。然而，對於大多數情況，這似乎不現實，因為工作中心在現實世界中更像是固定的結構 - 它們不像產品那樣變化，因為它們往往擁有重型機械。

在本模擬中，考慮到公司從一開始就擁有 3 個工作中心，因此工作中心和設備是事先創建的。這對於有興趣實施 Odoo 的可能讀者來說更有用，也節省了一些時間。

我們首先創建我們擁有的設備。這是一個強調維護組織的項目類別。負責管理設備的應用程序是維護應用程序。下圖是 Odoo 如何顯示一個 3D 打印機設備項目的示例（見圖 31）。

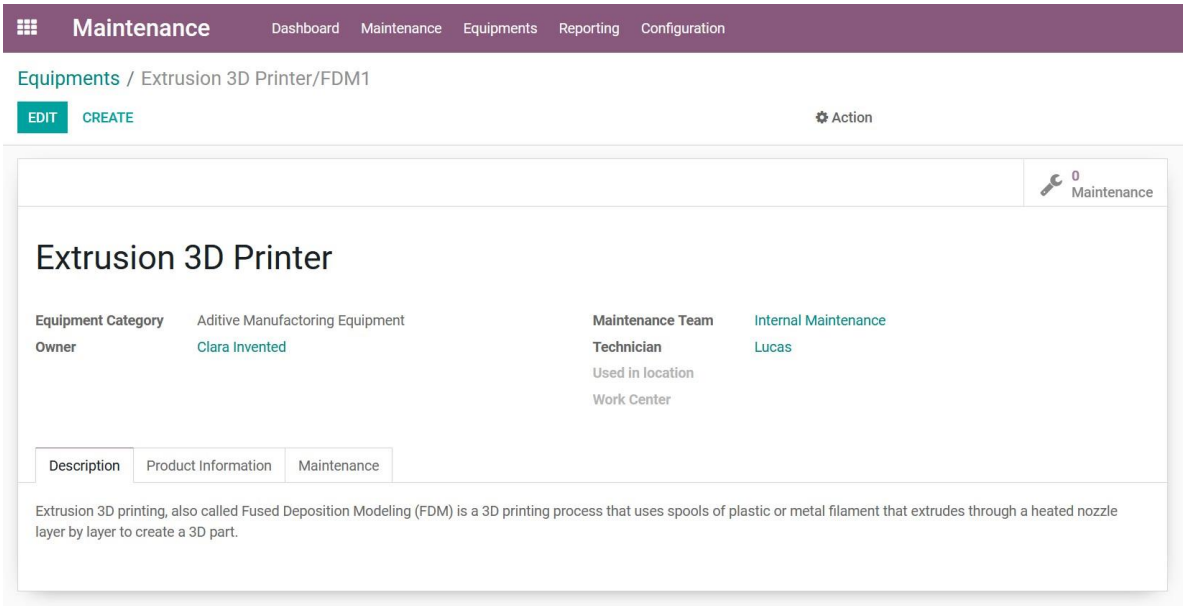

Figure 31 Odoo 3D printer equipment item

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

圖 31 Odoo 3D 打印機設備項目

除了這個 3D打印機之外，還創建了以下設備，以便在開發/生產過程中使用（見圖 32）：

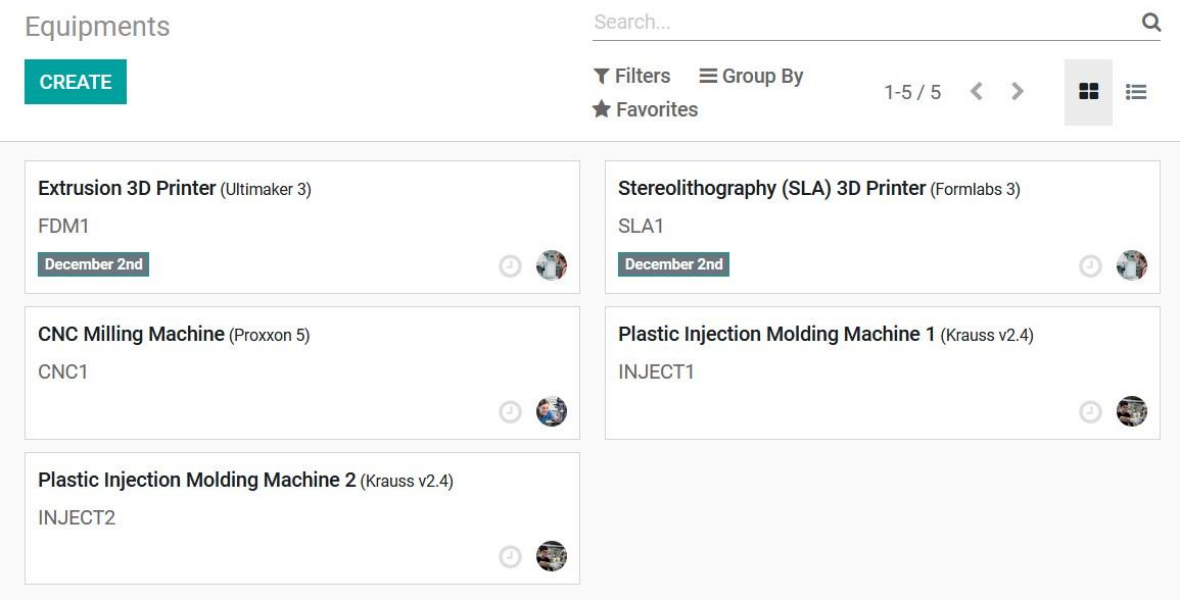

Figure 32 Overview of equipment items

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.

圖 32 設備項目概覽

這就是軟件在 PLM 方面的限制開始顯示的地方。儘管設備項目允許您一定程度的元數據（描述文本、負責用戶、維護數據和供應商），但它不允許上傳任何類型的文件來附加到該項目類別（機器手冊、報告等）。這是一個相當重要的弱點，因為文件管理被普遍認為是 PLM 的主要方面之一。這將是本次模擬的一個重要主題，因為在 Odoo 中直接允許上傳文件的項目數量有限。

現在設備已創建，它們的工作中心可以創建了。值得記住的是，工作中心項目的主要用途是管理每小時的時間和成本。理想情況下，分配給工作中心的設備不應同時使用，而且理想情況下，具有明顯不同運行成本的設備也應該位於不同的工作中心，以便更好地跟踪時間/成本。下面（見圖 33）是一個工作中心項目的示例，用於表示產品開發過程中使用的原型制作站。

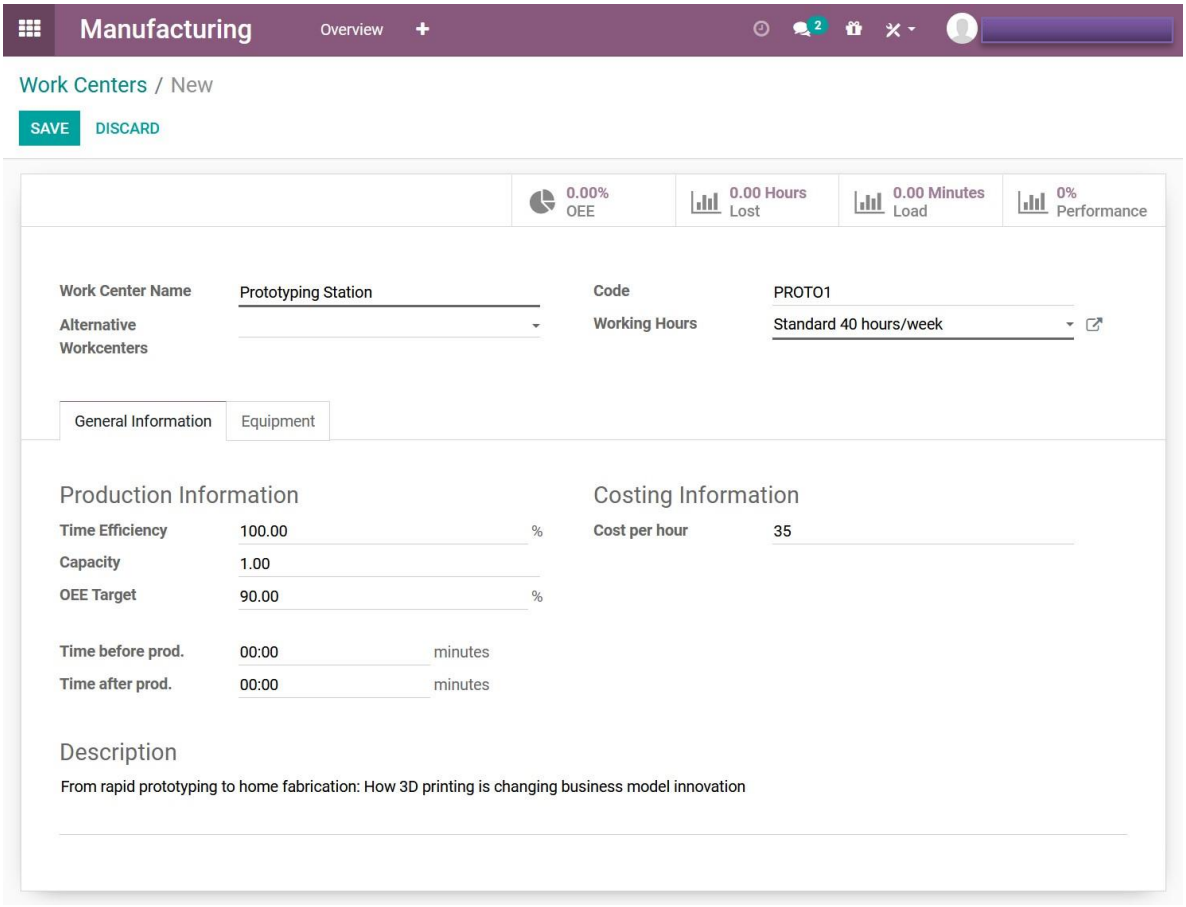

Figure 33 Odoo Prototyping Station item representation 1

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.

圖 33 Odoo 原型製作站項目表示 1

讀者會注意到這個工作站（見圖 34）是 3D 打印機和 CNC 機床所在的地方。通常，這些機器會因運行成本的不同以及它們大部分是獨立的而被分開放在單獨的工作中心中，但為了這次模擬，這被認為是足夠具有代表性的。

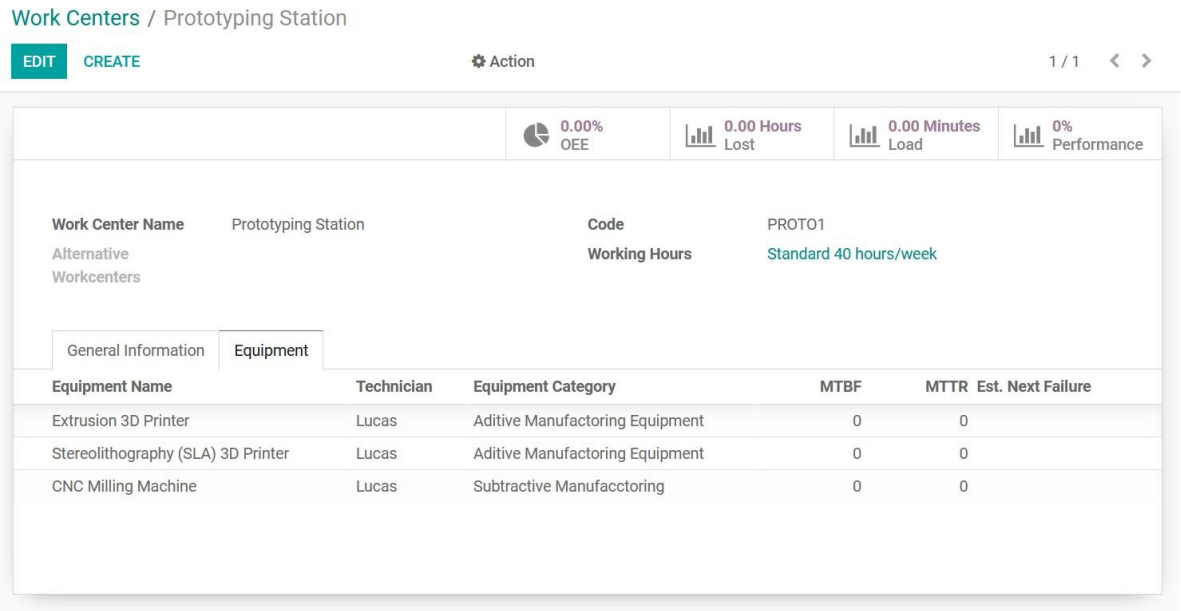

Figure 34 Prototyping Station item representation 2

The following workcenters have been also created for the simulation and filed with the necessary equipment:
圖 34 原型製作站項目表示 2

此外，以下工作中心已經為模擬而創建，並配備了必要的設備：

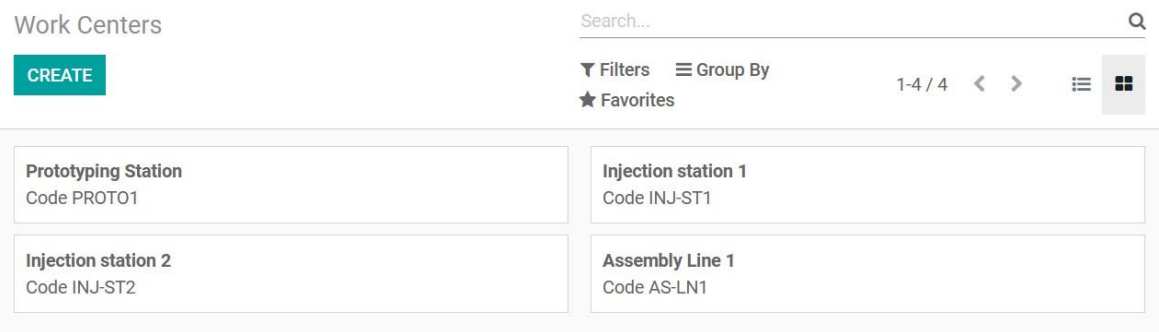

Figure 35 Overview of Workcenter items

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. 開發

現在，公司的基本結構已經在軟件中重建，可以開始進行模擬過程。首先，重點是使用 Odoo（圖 9）來開發全新產品的方面，尤其是由於這是公司第一個要創建的產品，因此評估了 Odoo 用於組織原型製作程序的可能性。這包括從想法到設計和原型生產的路徑。然後，一旦產品已經達到原型的可接受結果，將進行生產過程的開發工作。當正式進行生產運行時，將認為產品開發是成功的。