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

對於Odoo軟件在產品生命週期管理（PLM）、製造執行系統（MES）以及它們的整合方面的能力進行分析。

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Academic Year 2020 – 2021

2020年至2021年學年

ACKNOWLEDGMENTS

鳴謝

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.

我想感謝朱莉亞·布魯諾博士對這個項目的專業建議和邀請，以及 Emiliano Traini 在這個論文過程中給予的非凡支持。

最誠摯地感謝我的父母 Julio 和 Michelle，他們給了我一切，從我的生命到他們廣泛而無條件的支持和鼓勵；同樣地，也感謝我的兄弟和我的未婚妻 Ana，在這些年裡一直激勵著我。

我最深切的感謝和欣賞送給 Icaro、Matt 和 Maz，感謝他們在這個項目中以及其他時刻給予我的無盡幫助和支持，他們一直推動著我不斷進步。同樣地，對於那些影響了我的生命，成為我最大禮物的人，你們都知道自己是誰，我真心感謝與你們分享我生命中特別時刻。

ABSTRACT
摘要

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

對於 Odoo 軟體在產品生命週期管理（PLM）、製造執行系統（MES）及其整合方面的能力進行分析

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

二十世紀下半葉以電腦技術在生產的各個方面的進步為特徵。

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.

該說法的關鍵特徵在於無可否認的事實，即隨著計算能力所允許的增加的複雜性，將不斷產生龐大的信息量。

從工業景觀的不同角度來看，由於對組織、自動化和減少浪費的迫切需求，一些系統應運而生，這些系統專注於有用數據的這一領域。

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.

從工業景觀的不同角度來看，由於對組織、自動化和減少浪費的迫切需求，一些系統應運而生，這些系統專注於有用數據的這一領域。

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.

從管理的角度來看，ERP（企業資源計劃）、從生產的角度來看，MES（製造執行系統），以及最近從戰略發展/再開發的角度來看，PLM（產品生命週期管理）等信息解決方案從不同角度解決了這一問題。然而，這些解決方案，儘管有效，卻總是受到實施這些系統的工具之間根本不相容的困擾。

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.

本文的目標圍繞著從理論角度分析 PLM 和 MES 系統的整合，並評論使用 Odoo 軟體工具來實現該整合。

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.

對 Odoo 軟體進行了詳細描述（關於其在製造環境中的使用），包括它如何實現 PLM 和 MES。然後，對該軟體進行了一個虛構公司的模擬，這家公司是一家虛構的最近成立的小型製造公司，其主要生產手段是塑料射出成型，並將增材製造和快速原型製作作為其業務策略的一部分。

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

關鍵詞：產品生命周期管理、製造執行系統、Odoo

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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

ERP - 企業資源規劃（Enterprise Resource Planning）

MES - 製造執行系統（Manufacturing Execution System）

PLM - 產品生命周期管理（Product Lifecycle Management）

MRP - 物料資源規劃（Material Resource Planning）

WO - 工作訂單（Work Order）

BOM - 物料清單（Bill of Materials）

MO - 製造訂單（Manufacturing Order）

ECO - 工程變更訂單（Engineering Change Order）

CPS - 智慧物理系統（Cyber Physical System）

IoT - 物聯網（Internet of Things）

DT - 數位孿生（Digital Twin）

GUI - 圖形使用者介面（Graphical User Interface）

CNC - 電腦數值控制（Computer Numerical Control）

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1. CHAPTER章

INTRODUCTIO

引言

1.1. Objective 1.1. 目標

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.

論文的目標是通過分析不同的概念和動態，找出使用現有的Odoo軟件能實施PLM+MES系統到什麼程度，並且應用虛構情景來確定該集成中是否包含這些概念中的哪些。

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.

為了提供背景，Odoo軟件在實施和商業模式方面與市場上的其他解決方案有很大不同。簡而言之，Odoo軟件最初是一款開源的ERP軟件，而不是PLM或MES軟件，因此其可用性和模塊化程度相對擴展。顯而易見的是，與此相對應的是，它在PLM或MES領域的可用性是不確定的，因此這項工作的價值就體現出來了。

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.

具體來說，從小型製造業和初創企業的角度來看，實現一個全方位的ERP，並實施PLM-MES系統是非常有價值的。儘管ERP系統在一定程度上是可用的，但它們很少深入製造

業，以擴展到PLM或MES解決方案。此外，另一個方向也很重要，因為PLM解決方案往往缺乏ERP的可擴展性，這通常意味著任何集成都需要專門的特定工作。

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.

雖然修改軟件不在本工作的範圍內，但軟件具有開源社區版本的事實意味著即使是對最特定的情況進行適應也可能更容易，經濟上的障礙對於接受率更低的採用者來說可能更低，進一步強調了在小企業環境中這款軟體的可能效用。

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.

最終，該論文將就如何進一步利用這個系統提供理論和實踐建議。它還為未來對Odoo軟件的工作奠定基礎，並通過識別PLM-MES集成和實施的具體關鍵方面來檢查該解決方案的性能。

1.2. Structure 1.2. 結構

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:

這份工作可以作為小型製造企業中所描述解決方案的實際實施的參考，並且可以被視為PLM-MES及其實施的入門材料，以及對Odoo軟件目前狀態的基本原則和評論。為此，本論文提出以下結構：

- 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.
- 第1章 - 介紹本工作及其目標。此外，它提供了為什麼這種軟件解決方案需要這種分析以及如何結構化的簡明解釋。

- 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.

- 第2章 - 本章介紹PLM、MES、ERP和工業4.0的基本理論背景。這些被呈現出來，以便為這種分析做出有意義的貢獻，同時為其在小企業代表讀者的情況下提供有意義的上下文。

- 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.

- 第3章 - 本章將討論先前研究中關於PLM和MES系統之間的集成，並將分析這項工作。這有助於確立在分析Odoo軟件時涉及的概念和動態。

- 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.

- 第4章 - 介紹了以工業4.0模式為基礎的虛構公司和產品，這些將在進一步分析和評估Odoo軟件中使用。

- 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

- 第5章 - 介紹Odoo軟件以及更深入解釋其使用和功能。描述了對Odoo軟件的實驗，考慮了所有前面的章節。

- 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.

- 第7章 - 結論。最後一章描述了工作的收穫：中型企業如何通過明智地使用Odoo軟件實施PLM+MES系統來改善其流程。

2. CHAPTER

THEORETICAL BACKGROUND

章 理論背景

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.

本章是對處理數據生產收集和處理的不同系統進行簡要介紹，這些系統圍繞著增強所有生產方面的概念，這些概念受到學術界以及當前和未來工業狀態的青睞，這些系統應該被證明是不可或缺的。

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.

值得注意的是，這些系統並不是完全獨立的信息系統。它們從不同的角度出發，嘗試解決不同的問題，但由於廣泛的定義，它們不可避免地相互擴展。這本身就是一個問題，因為從現有文獻中很難準確指出一個系統的邊界在哪裡，另一個系統開始。

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.

Odoo管理軟件（本文的主題之一）主要將PLM視為跟踪變更和改進的工具，而PLM的其他關鍵特性，如使用數字項目（稍後在第2.1節詳細介紹），則是物料需求計劃的基本特徵，而後者也涉及MES。

2.1. Product lifecycle management 2.1. 產品生命周期管理

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.

任何個人或團隊所產生的信息都是通過經驗主義的創造過程完成的。一項任務要求要么具有先前的知識/經驗，否則將不可避免地受到錯誤和更正的困擾，這反過來又消耗了時間和資源來獲取這種經驗。傳統上，這種經驗嵌入在首次產生信息的人力資源（員工）中。

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.

產品生命周期管理（PLM）是一個組織過程，旨在控制產品在其整個生命周期中的所有方面的信息流。正如人們可以想像的那樣，這個定義及其廣泛的範圍並不會使理解PLM變得更容易。對於所有目的來說，要關注的是PLM在變化方面的真正價值

Figure 1 Product lifecycle stages (Tripaldi, 2019)

圖1 產品生命周期階段（Tripaldi，2019）

PLM is above all a connecting technology, not an individual technology islet orinformation processing system (Saaksvuori and Immonen, 2008). The idea is that everyinformation produced by company personnel holds value equivalent to the time and moneyinvested. Using that information saves money, not using that information wastes money. Thisis 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 anequivalent value to the time and money invested in it. The problem comes from the fact thatin a traditional system only the engineer knows the design process behind the file, the extentof 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 becomeextremely difficult for him/her to find that file and use it in his own design. Ultimately this5results in waste because Engineer#2 will have to spend more time and money doingsomething that was already made just because that information was not easily available orwell organized.

PLM 最重要的是一種連接技術，而不是一個獨立的技術小島或信息處理系統（Saaksvuori 和 Immonen，2008）。這個想法是，公司人員生產的每一條信息都具有相當於投資的時間和金錢的價值。利用這些信息可以節省金錢，不利用這些信息會浪費金錢。當觀察設計過程時，這一點更容易理解。例如，如果一個工程師設計了一個電子電路，保存 CAD 繪圖的文件就具有等同於投資的時間和金錢的價值。問題在於，傳統系統中只有工程師知道文件

背後的設計過程，其中的內容及其可能的用途的程度。而對於公司的其他人來說，這只是數據庫中的另一個文件。結果是，單獨的信息僅具有有限的用途。如果碰巧有另一位工程師在進行類似的設計，那麼他/她將極難找到該文件並將其用於自己的設計中。最終，這將導致浪費，因為工程師#2 將不得不花更多的時間和金錢做一些已經完成的事情，只是因為該信息不容易獲得或組織得不好。

This scenario is not limited to product design, but also to all aspects of the productlifecycle that produces change over time. Someone had to orchestrate how that piece will beproduced , how that piece will be moved,packed , distributed and disposed of. When aproblem is found or improvements are possible those changes also produce information andconsume resources. If the company cannot take advantage of that existing information aboutall those phases of the product conception it will waste resources at every single redesign.Product Lifecycle Management consists of an information system that allows informationand knowledge sharing within and between organizations (Sudarsan et al., 2005) minimizingthe waste by controlling and organizing those files with information that would otherwisebe carried only by the human resource that produced said files. The way it accomplishes thatis by virtualizing all components of the product life-cycle in the form of digital “items” in anobject oriented architecture. As explained by (Saaksvuori and Immonen, 2008),an item is asystematic and standard way to identify, encode and name a product, a product element ormodule, a component, a material or a service.These item objects are, by all means, virtual representations that hold metadata regardingwhat 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 orderof process execution. E.g. a CAD drawing for a circuit schematic is attached to a virtualcircuit object that holds basic information about what is contained in the file and all theprevious iterations of that file over time as well as links to items representing which bill ofmaterials (BOM) it belongs to, the machines necessary to manufacture it, the processesnecessary to assemble it and more importantly how all those items changed over eachimproving iteration.This all-around virtualization gives precious context to information otherwise lost on itsown complexity. It allows for faster access, easier understanding of the whole and theconsequences of what happens when there is change for each part. This is the best way oforganizing the existing data for future reference because it allows for structure as well astransparency.To sum up, PLM as a system aims to track functional change in all aspects regarding theproduct life, in a way that the company can benefit strategically from it by avoidinginformational waste. It does so by virtualizing the real thing in the form of digitalitems that6store the files regarding what the item is supposed to represent. These can in turn becorrelated and tracked over time using metadata.

這種情況不僅限於產品設計，還涵蓋了在產品生命周期的所有方面隨時間產生變化的過程。某人必須協調如何生產這個部件，如何移動、包裝、分配和處置這個部件。當發現問題或可以進行改進時，這些變化也會產生信息並消耗資源。如果公司無法利用關於產品概念各個階段的現有信息，它將在每次重新設計時浪費資源。產品生命周期管理包括一個信息系統，允許組織內部和組織之間共享信息和知識（Sudarsan 等，2005），通過控制和組織那些具有信息的文件，減少浪費，否則這些信息將僅由生產這些文件的人力資源所持有。它實現這一目標的方式是通過以數字“項目”的形式將產品生命周期的所有組件虛擬化，以對象導向的架構。正如（Saaksvuori 和 Immonen，2008）所解釋的那樣，項目是識

別、編碼和命名產品、產品元素或模塊、零件、材料或服務的系統化和標準化方式。這些項目對象無疑是虛擬表示，其中包含有關其所試圖表示的信息的元數據，並允許連接和鏈接信息。正如（D'Antonio 等，2015）所描述的，產品信息應與其生產過程相關聯。PLM 允許將定義的過程鏈接到產品，並對過程執行的順序提供約束。例如，電路原理圖的 CAD 繪圖附加到一個虛擬電路對象，該對象包含有關文件內容的基本信息以及該文件的所有先前迭代，以及與項目相關聯的鏈接，這些項目表示它屬於哪個材料清單（BOM）、製造它所需的機器、組裝它所需的過程，更重要的是所有這些項目如何在每個改進迭代中發生變化。這種全面的虛擬化為本來就很複雜的信息提供了寶貴的上下文。它允許更快地訪問，更容易理解整個過程以及每個部分發生變化時的後果。這是組織現有數據以便未來參考的最佳方式，因為它允許結構和透明度。總而言之，PLM 作為一個系統旨在追踪關於產品生命周期的所有方面的功能變化，以使公司能夠從戰略上受益，避免信息浪費。它通過將真實物件虛擬化為數字項目，存儲有關該項目應該代表什麼的文件來實現。這些項目可以透過元數據相互關聯和追踪。

2.2. Enterprise Resource PlaningIn the early days of information systems, one of the first systems to find wideimplementation was the called MRP (Material Requirements Planning). Although notnecessarily software based, this system wide implementation was a natural consequence ofcomputing technology and it aimed to solve bottlenecks regarding the material supplying andproduct output by calculating the material needs for production. As it became moreubiquitous in the enterprise in the late 70's and early 80's the system evolved. This gaveorigin to MRP II (Manufacturing Resource Planning) and, more important to the scope ofthis paper, ERP (Enterprise Resource Planning).For the most part modern Enterprise Resource Planning expands the original MRPfunction to encompass many other aspects of enterprise operations all while addingmodularity to the system.Modern ERP systems are often module based; different modules have different userinterfaces and different user groups. For example, Manufacturing module, Procurementmodule, Logistics module, Financial module, Maintenance module, Sales module.(Saaksvuori and Immonen, 2008). These modules expand across many domains ofknowledge but for the most part they do so always from the perspective of Production, Salesand Service. Figure 2 depicts the scope of the ERP system in comparison to other Informationsystems.

2.2. 企業資源規劃在信息系統的早期，其中一個最早被廣泛實施的系統是所謂的 MRP（物料需求計劃）。雖然不一定基於軟件，但這個系統的廣泛實施是計算技術的自然結果，它旨在通過計算生產所需的材料來解決物料供應和產品產出方面的瓶頸。隨著它在 70 年代末和 80 年代初在企業中變得更加普遍，這個系統不斷發展演變。這導致了 MRP II（製造資源規劃）的出現，更重要的是本文範圍內的 ERP（企業資源規劃）。在很大程度上，現代企業資源規劃擴展了原始 MRP 的功能，以包含企業運營的許多其他方面，同時為系統增加了模塊化。現代 ERP 系統通常是基於模塊的；不同的模塊具有不同的用戶界面和不同的用戶群體。例如，製造模塊、採購模塊、物流模塊、財務模塊、維護模塊、銷售模塊。(Saaksvuori 和 Immonen，2008)。這些模塊跨越許多知識領域，但在很大程度上，它們總是從生產、銷售和服務的角度進行擴展。圖 2 描述了 ERP 系統的範圍，以便與其他信息系統進行比較。

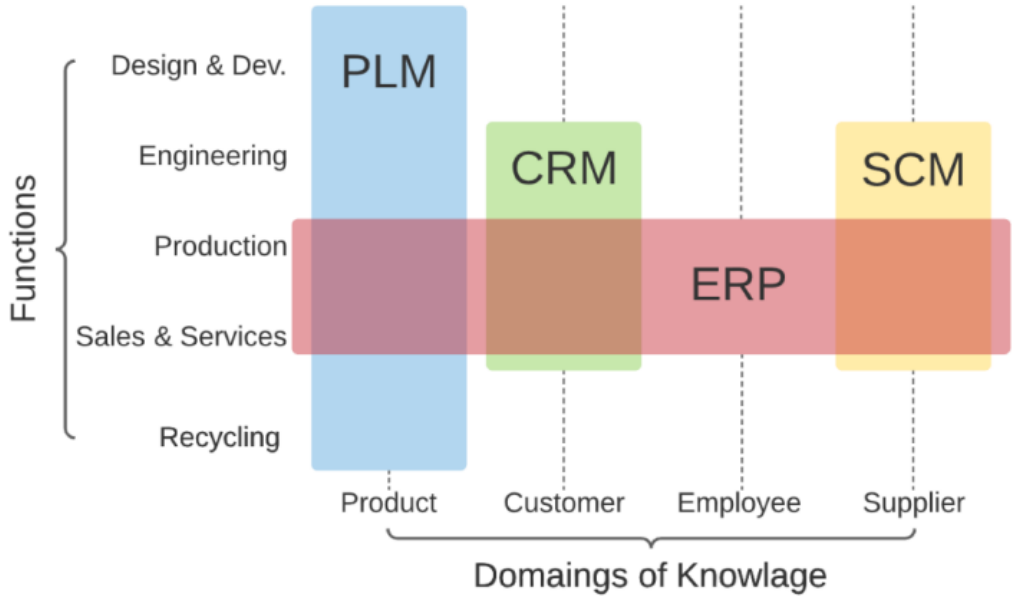

Figure 2 Visual representation of the scope of different information systems (Adapted from Stark 2015)

圖 2: 不同信息系統範圍的視覺表示（改編自 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).

這種跨領域的廣泛覆蓋是有道理的，因為像 MRP 一樣，ERP 操作的重點是處理交易和訂單。 ERP 的重點是控制公司資源的輸入、保留和輸出的變化，無論是產品、原材料還是包裝。從同一張圖像中，可以看到 PLM 和 ERP 之間的理論對比，即使它們都非常廣泛。雖然 ERP 擴展到知識領域，但它限制自己僅涉及少數功能；PLM 則擴展到涉及產品的所有功能。正如圖 3 所描繪的，另一個代表兩者之間良好區別的觀點是關於 ERP 和 PLM 對行業影響的尺度或細節層面的重疊之處的缺乏（即這兩個系統的細粒度）。

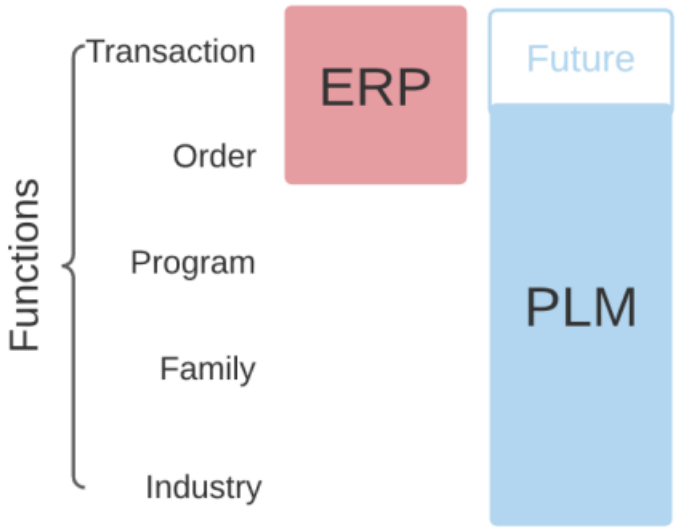

Figure 3 Visual comparison of ERP and PLM concerning granularity(Adapted from Stark, 2015)

圖 3 ERP 和 PLM 之間的粒度比較（摘自 Stark，2015）

As we can see, ERP is primarily concerned with the transaction and the order. Once anorder is closed out, the ERP system processes the transactions with respect to that order butis 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 intothe family and the entire industry (Stark, 2015).This is particularly interesting because it demonstrates how the two systems can and docomplement each other in the field. One of the aspects of ERP that should point out is that itis comparatively easier to integrate with other systems. ERP-MES integration for instancehas been widely studied and implemented to the point where standards have been developedfor it (ISA 95 - IEC 62264). One argument for this is the modular nature of the ERP systemwhich 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 aunified 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 thecustomers target and increase customers share in a market that slowly pivots to innovation(Vásquez and Escribano, 2017).

正如我們所看到的，ERP 主要關注交易和訂單。一旦一個訂單結束，ERP 系統就會針對該訂單處理交易，但對訂單本身的關注程度不是很高。另一方面，PLM 的粒度關注的是產品的訂單，不僅延伸到程序，還包括家族和整個行業（Stark，2015）。這尤其有趣，因為它展示了這兩個系統在該領域中如何可以互補。 ERP 的一個方面值得指出的是，它與其他系統相對容易集成。例如，ERP-MES 集成已被廣泛研究和實施，甚至已經為其開發了標準（ISA 95 - IEC 62264）。其中一個理由是 ERP 系統的模塊化性質，這在本文中（第 5 章）進一步討論了對 Odoo 軟件的分析中。這是因為 Odoo 軟件最初是從一個開源 ERP 系統發展而來的。ERP 系統的性質最好由（Umble 等，2003）總結：ERP 提供了業務的統一企

業視圖，包括所有功能和部門，以及一個企業數據庫，其中追蹤了所有關於財務、銷售、市場營銷、採購和人力資源的操作。實現這一目標的目的是擴大客戶目標，增加客戶在一個逐漸轉向創新的市場中的份額（Vásquez 和 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.

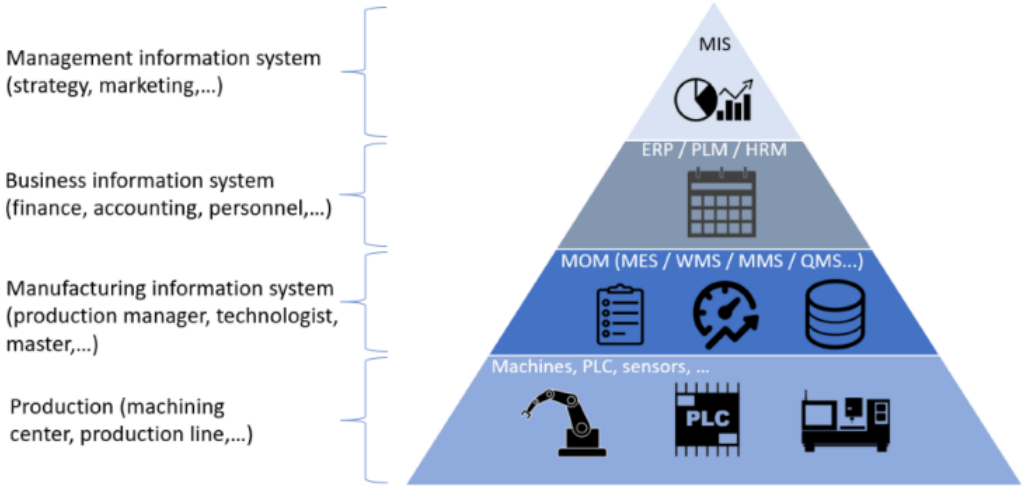

Figure 4 Visual representation of the roll of different systems including MES(Adapted from mescenter.org)

圖4 包括MES在內的不同系統的滾動視覺化表示（改編自 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.

2.3. 製造執行系統完全集成系統的最後一個關鍵是製造執行系統（MES）。MES 是管理層和生產層之間的通信層；它是一種軟件，允許組織層級（通常由 ERP 支持）與車間控制系

統之間進行數據交換，其中使用了多種不同的、高度定制的軟件應用（Meyer 等，2009）。 圖 4 是不同系統如何適用於製造和開發範圍的良好描述對於所有目的來說，MES 的主要目標是提供數據和數字，最終用於確定不僅產品的狀態和質量，還包括影響生產的所有流程。機器、傳感器以及與產品接觸並提供任何類型輸出的任何東西，基本上都將該數據傳遞給 MES 進行即時排序和處理。例如，如果一位經理想要知道即時的生產數字或查看拒收率的圖形表示，該數據將可從 MES 軟件獲取。傳統上，管理層將根據這類信息評估工作成效並做出決策。如前所述，這類數據收集非常適合於 ERP 的使用，不僅因為如果結合實時生產數據，資源管理可以更加詳細，還因為 ERP 的模塊化通常意味著無縫集成。MES（像 ERP 一樣）也已經證明並實施了幾十年，它們的實施已經相當標準化。
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 4 th industrial revolution where the first was marked the adoption of steam power, the second was marked mainly using electrical power and the 3 rd was characterized by the implementation of digital technology. Figure 5 nicely represents the progression of industrial revolutions.
MES 的功能已被 MESA International（1997）分為 11 個類別；此外，ISA95-IEC62264（2013）標準還列出了每個企業層面以及每種類型的信息系統的任務。該標準還為要在信息系統之間交換的數據結構提供了定義，旨在增強它們的集成；然而，它主要聚焦於 ERP-MES-車間一線的集成（D'Antonio 等，2015）。相比之下，PLM 的研究要新得多，而 PLM-MES 集成，這份工作的主要焦點，更是如此。這種集成的挑戰以及與之相關的技術水平將在（第 3 章）中進行探討，同時也會探討其背後的理論結構。暫且可以指出，由於 MES 提供了通過生成文件形式的信息來編排變更並通過反饋驗證結果，而 PLM 則專注於通過文件組織跟踪變更，因此 PLM-MES 集成確實具有價值。2.4. 工業 4.0 工業 4.0 這個術語在現代文獻中一再被提及，被認為是生產演進的下一步或當前步驟。它代表著第四次工業革命，其中第一次革命是以蒸汽動力的應用為標誌，第二次主要以電力使用為標誌，而第三次則以數字技術的實施為特徵。圖 5 很好地展示了工業革命的進展。

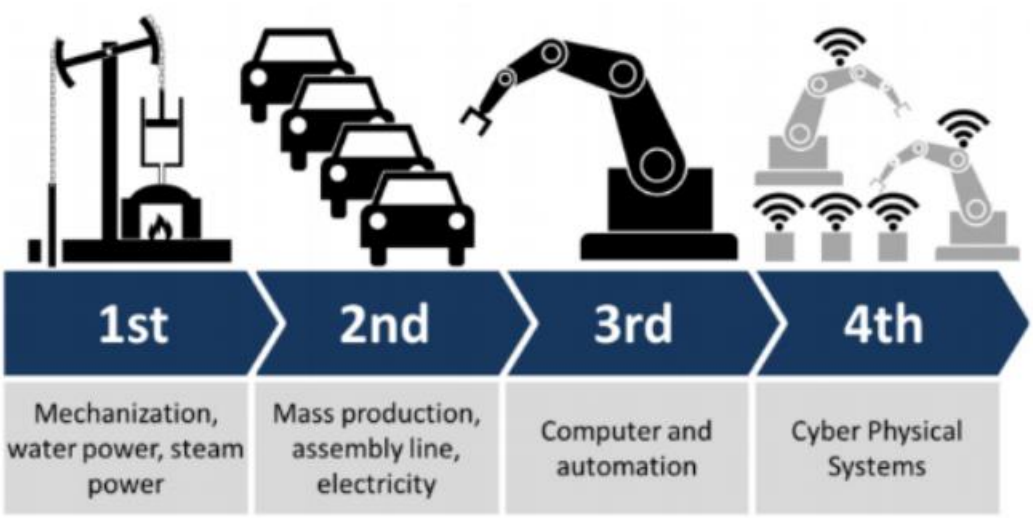

Figure 5 The industry evolution (Adapted from STANCIOIU Alin, 2017)

圖5 產業演變（改編自 STANCIOIU Alin，2017 年）

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 12 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.

概括而言，第四次工業革命最終將以數字連接和生產的完全整合為標誌。眾所周知，數字網絡的發展是維持現代世界的關鍵技術。它改變了人類的互動方式和商業模式。然而，目前應用於工業的水平是否構成了一場工業革命仍然不確定，因為在所有其他革命中，生產的暴增都尚未發生。事實上，我們仍然沒有達成關於工業 4.0 的共識定義。然而，被廣泛接受的是，工業 4.0 至少有三項技術特徵。這些技術是物聯網（IoT）、雲計算和物理-數字系統（CPS）的發展，後者對於本論文的背景尤其重要。CPS 是由真實實體（例如，一台機器）及其相應的虛擬模型組成的系統 - 其中包含了模仿真實對應物行為的所有模型 - 能夠相互通信（D’Antonio 等，2017）。其核心理念是，如果開發一個關於系統中所有與某一過程有關的物理儀器的數字孿生體（DT），允許數字對應物件彼此互動，以及與物理世界互動，則該過程的創新或變革將更快更有效。例如，工程師可以使用 DT 的互動模擬變更，然後在實時中自動應用變更到生產線上，執行測試，收集數據並將其反饋到系統中，無需手動輸入，所有這些都通過網絡完成。從所有這些中得出的主要觀點是，PLM-MES 系統可能是實現適當 CPS 的第一步，因為它提供了虛擬化和必要的控制，以實現接近虛擬孿生體的情況。值得爭議的問題是它目前在工業應用中的影響程度如何。儘管如此，無論如何，工業 4.0 這個詞彙是對數字連接、網絡發展和互聯網應用於工業的日益增長的一個有用標誌。工業 4.0 範圍內經常包含的另一個術語是所謂的 Lot Size One 或 Lot 1。這是將每個項目定制為買家個人規格的想法，在這樣的系統中，客戶訂單不會啟動供應鏈設備運動；它啟動了製造機器。其背後的理論是，隨著生產和開發變得越來越靈活，這種類型的製造不僅變得可行，而且也變得吸引人。定制的產品意味著沒有庫存要求，沒有庫存成本，當然也有 100％的銷售保證。這個概念並不新穎，事實上，它比工業 4.0 早得多。在書籍《改變世界的機器》中，作者們（Womack 等，1990）討論了瘦生產者向這個目標邁進的過程，他們在組織的所有層次都使用多技能工人團隊，並使用高度靈活，越來越自動化的機器生產大量產品。

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.

在某種程度上，“Lot Size One”不過是這種思維的延伸。當然，工業還沒有達到這種生產靈活性的水平，但這種思維的一瞥已經在更模塊化的生產中得以體現。亞馬遜的包裝系統是其中最好的例子之一。例如，一位客戶從亞馬遜收到一個包裹，其中包含了根據他/她的特定訂單而為他/她包裝的各種產品混合物。儘管表面上看似乎簡單，但這對客戶來說代表了高度的定制。另一個很好的例子是電子原型製作。目前有一些公司接受您的印刷電路板設計和 BOM，以低成本交付少量組裝好的原型樣品。電子設備的原型製作曾經是一個成本高昂的過程，但一些公司已經將其生產模式靈活化到了能夠快速且可靠地交付的程度。這是可能的，因為電子元件本質上是模塊化系統，即使復雜性很高。下面的圖片（圖 6：電源適配器電路示例項目）是一個示例，顯示了這個學生設計的電路，並在一個星期內由 JLCPCB 公司製造。

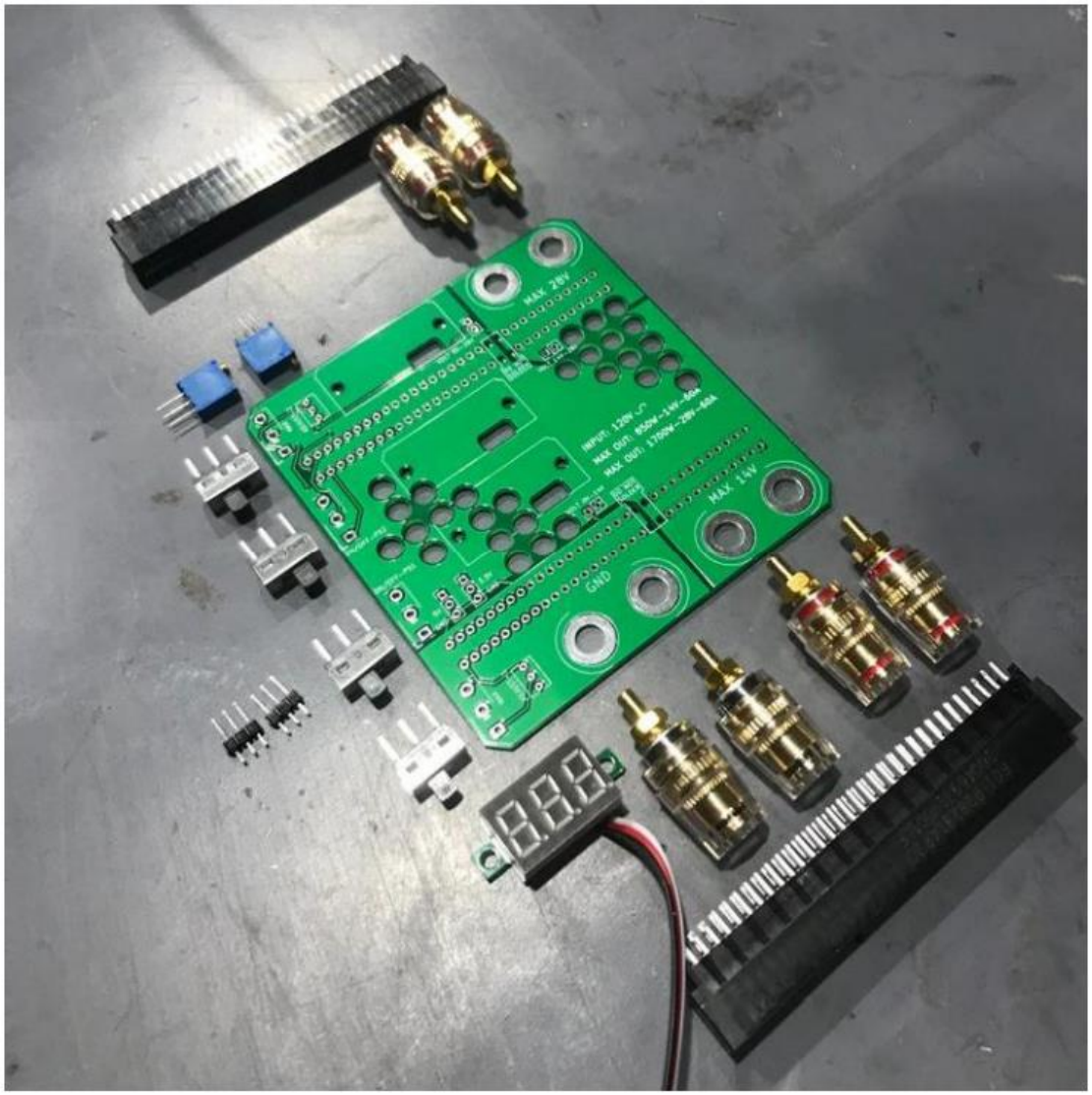

Figure 6 Example project of power supply adaptor circuit

圖6 電源適配器電路範例工程

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.
總的來說，這一切再次表明了對變化的控制和管理的更大需求。這意味著實施 PLM-MES 系統將是非常有幫助的。PLM 將需要在小批量產品的整個生命周期中管理變化和創新，而 MES 將提供實時的反應和反饋，以減少可能導致整批損失的錯誤。
3. CHAPTER THE STATE OF THE ART AND THE INTEGRATION OF PLM AND MES Unfortunately, there are not many published studiesin 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.

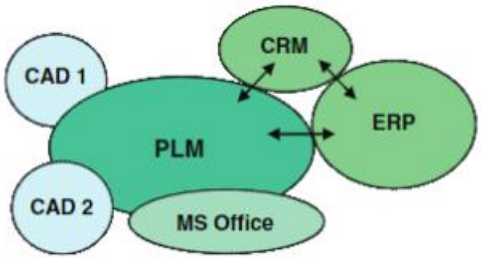

Figure 7 Diagram of PLM integration(Saaksvuori and Immonen, 2008)
圖7 PLM整合示意圖（薩克斯沃里和伊莫寧，2008）

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 15 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.
第 3 章 現有技術與 PLM 和 MES 的整合不幸的是，在 PLM 和 MES 系統整合方面，並沒有太多已發表的研究。但似乎對於該整合最可能產生的影響存在共識，即同步和更緊密的容忍

度。正如 D'Antonio 等人（2015 年）所解釋的，他們聚焦於航空應用中精密零部件的製造案例研究，監控和控制系統部署帶來的第一個預期優勢是產品質量的提高：儀器可以檢測、測量和監控影響流程性能或產品質量的變量、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。一個可能的解決方案依賴於數據庫集成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，如果必要，所需的信息可以在其他系統的數據庫中複製，如圖 7 所示。儘管它主要是從 PLM-ERP 整合的角度指出這一點，但從 PLM-MES 整合的角度來看，它仍然非常有價值，因為它是如何期望通過在文件性質不同的系統中工作，進而實現更好操作的示例，這些系統將文件加載到集中的 PLM-ERP 系統中。因此，中間件將成為一個軟件框架，以用戶友好的方式組織和連接系統數據庫中提供的所有信息。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 PLM 應用程序之間的產品信息交換成為可能（例如，在 CAD 應用程序和 CAE 應用程序之間）。它們還實現了 PLM 應用程序與其他企業應用程序（如 ERP 和 CRM）之間的產品信息交換。

In a very relevant fashion, this middleware line of thinking is expanded upon by (BenKhedher et al., 2011).

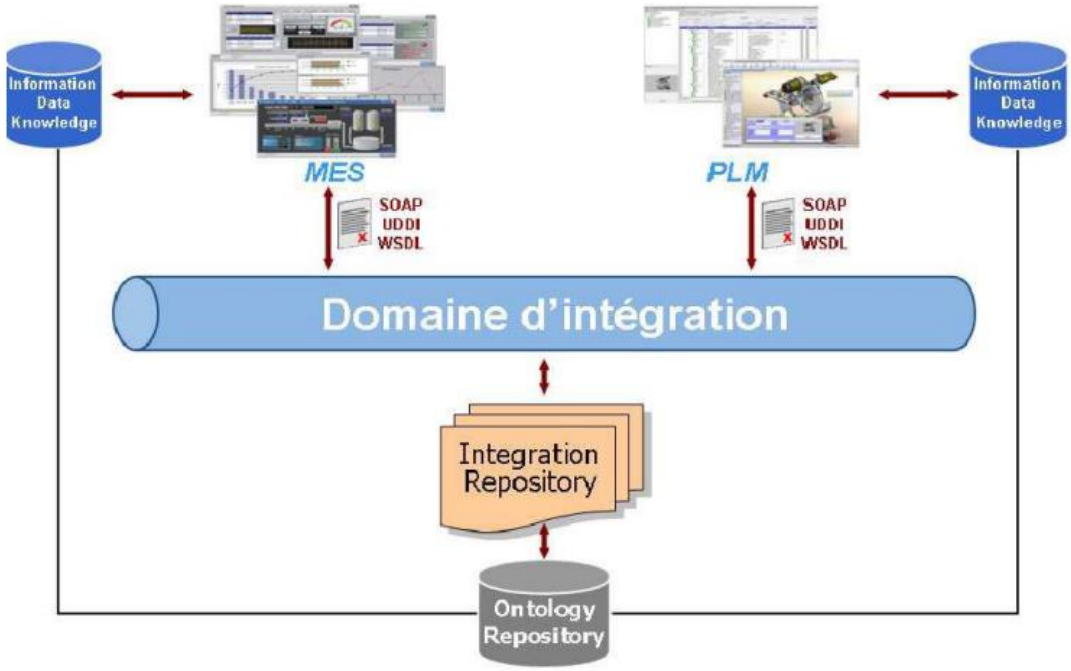

Figure 8 Diagram of Web service architecture (Adapted from Ben Khedher et al., 2011)

圖8 Web服務架構圖

（改編自 Ben Khedher 等人，2011 年）

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 he cloud and enacting the layer of integration that was previously mentioned.

在（Ben Khedher 等人，2011）的研究中，這種中間件思維的擴展方式非常相關。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的使用。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，以幫助公司，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），它旨在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 等人，2011）。這種擴展之所以如此重要，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 軟件可以通過本地網絡或在雲端中托管，並實施先前提到的集成層作為中間件。

3.1. How would this integration look like in practical terms
3.1.在實際應用中，這種整合會是什麼樣子呢？

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.

如第2章所述，PLM的主要思想是管理與產品相關的所有流程中的變化，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為數位空間中的物品，可以想象，有多種抽象層次可以表示真實對象或流程。因此，就PLM而言，對於虛擬表示必須有多深入和/或詳細以發揮其作用，沒有確切的共識。

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.

在理想的情況下，最低程度的抽象將是基本上相當於第2章中所解釋的數位孿生。這是生產周期的每個方面的"1對1"數位表示，涉及的每個部分都將具有數位表示，不僅攜帶物品的物理特性，還包含其隨時間產生的所有信息。為此，正如第2章所解釋的，MES在獲取所需的實時信息方面起著基本作用，甚至使數位孿生成為可能。

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.

例如，一台CNC機器將具有數位3D模型用於模擬，以及一個完全集成的列表，其中包含它生產的所有零件，關於它目前生產水平的數據，機械零件的當前磨損情況，以及與其相關的所有其他機器，以及它所受影響的所有更改和改進的歷史記錄等等，所有這些都被很好地打包在直觀的圖形用戶界面（GUI）中，使其可以進行最大程度的互動。

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.

在現實中，我們尚未達到這種程度的虛擬化。獲取和組織信息到這種極細節的水平需要太多的時間和金錢，特別是需要手工插入的方面，更不用說這些信息如何集成和互動的主觀性了。儘管如此，在理想情況下，識別對於這種實施最重要的方面是有用的。

Those are:

這些方面包括：

- 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.
  虛擬化的手段 - 用於建立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。

- 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.
  數據輸入的方式 - 這些信息如何被載入和組織。理想情況下，這些信息應盡可能自動地載入系統，無論是通過MES在質量控制期間還是通過使用條碼掃描儀等自動輸入工具。

- 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.

  訪問手段 - 這些信息如何呈現給用戶。儘管比前面的方面更主觀，但這對系統的交互方式非常重要。信息可用性有多直觀直接影響到PLM的核心優勢。畢竟，即使其他方面都完美，如果與系統互動的唯一方式是一個命令行界面，使最終用戶難以訪問信息，那麼一切都將是徒勞的。

- 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.

  整合手段 - 項目及其包含的信息如何互動並相互受益，即與其他系統和關鍵軟體的整合。例如，如果一個項目可以訪問CAD文件，就不需要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相關。

4. CHAPTER

章節四

INTRODUCTION TO THE COMPANY AND PRODUCT

公司和產品介紹

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.

正如大家可以想象的，這項工作的獨特之處之一是它專注於一個特定的軟體解決方案，這在實施到不同類型的企業時往往相當靈活。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，系統是圍繞它建立的。儘管如此，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為此目的挑選一家虛構公司，在模擬過程中最大程度地提高軟體的感知效果。

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.

考慮到所有先前提到的系統，為了舉例說明，理論上的公司被組織成了工業4.0的模式。這家公司是一家最近成立的小型案例製造公司，以塑料射出成型作為他們的主要生產手段，並將增材製造和快速原型製作作為他們的業務策略的一部分。正如第2章中所解釋的，這些是工業在創新方面所採取的路徑的很好的例子，其中大規模生產正在慢慢變得不那麼重要，而產品多樣性和上市時間變得更加重要。

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.

為了最大程度地跟蹤變化，這家公司的大部分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非常依賴靈活的機械。考慮到這一點，應該相當簡單地模擬產品和流程的持續改進，以評估軟體的範圍。由於這種不斷變化的生產極度依賴於各種信息的管理，它必須被證明是應用PLM+MES的完美基礎。

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.

在這個例子中，公司自從成立以來已經實施了Odoo軟體，並採取了所有必要的培訓和步驟來正確使用它。這消除了對於已經存在的企業實施PLM+MES系統時如此普遍的界限和限制，即對於遺留系統的依賴、管理層對變革的阻力或對舊流程的整合。這些顯然很重要，但這不在本工作的範圍內。

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.

該公司的目標是在年底前生產一個全新的產品。完成後，該公司改進了該產品的生產過程。一旦有產品改進的需要，該改進也會被執行。

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

以下圖表（圖9）將作為產品開發和改進的路徑。

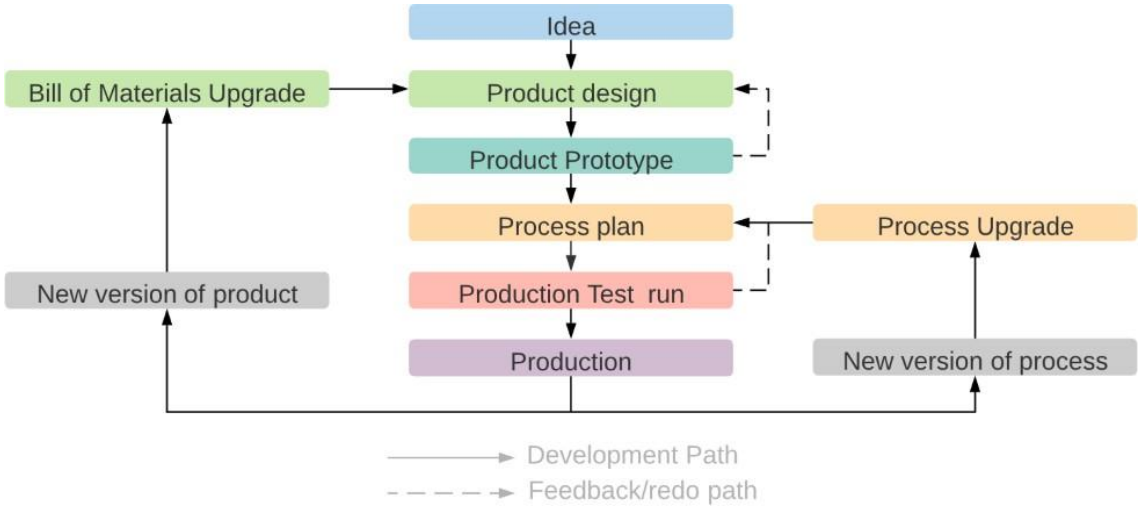

Figure 9 Development diagram
產品開發圖解9

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.

這條路徑旨在向讀者傳達一種對開發和改進的迭代方法。該想法是先進行產品設計，然後進行一個原型製作和重新設計的循環，直到達到滿意的結果。然後，類似的循環在生產過程中發生。在這個階段結束時，初始開發完成，實際生產可以開始。

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.

在這一點上，確立持續改進的方式就顯得很重要。對於這家公司，我們只考慮兩種主要的升級途徑，分別是產品升級和流程升級。

4.1. The products and processes
4.1. 產品與流程

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.

變化和影響是PLM+MES實施的重點，因此理想情況下，變化的主題應該是能夠提供合理的設計自由度的事物。儘管在嚴格的製造環境中，變化非常有限，一個良好實施的PLM+MES系統的效果應該是顯著的，但在一個擅長創新的企業中，系統會產生更加明顯的變化，因為在這裡會有更多改進系統並獲得反饋的機會。

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.

從改進的角度來看，如果將通過板金沖壓製造的產品（圖10）與通過數控銑削程序製造的相等產品（圖11）進行比較，可以很容易地感受到數控銑削產品更容易進行升級。儘管沖壓成本較低（相對而言），但它依賴於昂貴的高精度金屬模具，生產成本極高。這意味著對其進行改變的成本要高得多，因此，一個依賴追踪變化的系統的效果會受到限制。

Figure 10 Example of stamped AK74 pattern rifle receiver (Brownnells.com)
圖10 針對AK74樣式步槍機匣的沖壓示例（來自Brownnells.com）

Figure 11 Example of milled AK74 pattern rifle receiver (sharpsbros.com)
圖11 針對AK74樣式步槍機匣的銑削示例（來自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.

對於這家虛構公司來說，已經確定了最好的方式來說明PLM+MES的效果是設計基於塑料射出成型的產品。一開始考慮這種製造程序可能看起來有些不合常理，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。

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.

射出成型是一個廣泛而複雜的工程領域，涉及各種各樣的材料和方法，其中大部分與本工作無關。然而，值得指出的是，射出成型所涉及的壓力大部分情況下比處理鋼材時低一個數量級；可以在其模具上使用較軟的材料，如數控銑削鋁。同時，增材製造領域的新進展使得可以製作出與注塑件最終結果非常接近的塑料零件原型。有時甚至可以使用原型模具（圖12）進行低容量測試運行，以進行流程升級。

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

圖12 通過3D打印製作的注塑模具示例（來自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.

增材製造已成為極具靈活性生產的不可思議工具。尤其是在原型製作和迭代設計方面，這種持續改進的思維模式是現代工業中非常重要的精益理念的典範。

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.

正如前一節所提到的，在這個案例研究中，考慮到了這家虛構公司對一個新產品及其生產過程的創建。該產品是由3個不同部分組成的塑料小型電腦機箱（見圖13），預計將通過增材製造和數控銑削的結合來進行設計和原型製作，以達到塑料射出成型的生產目標。

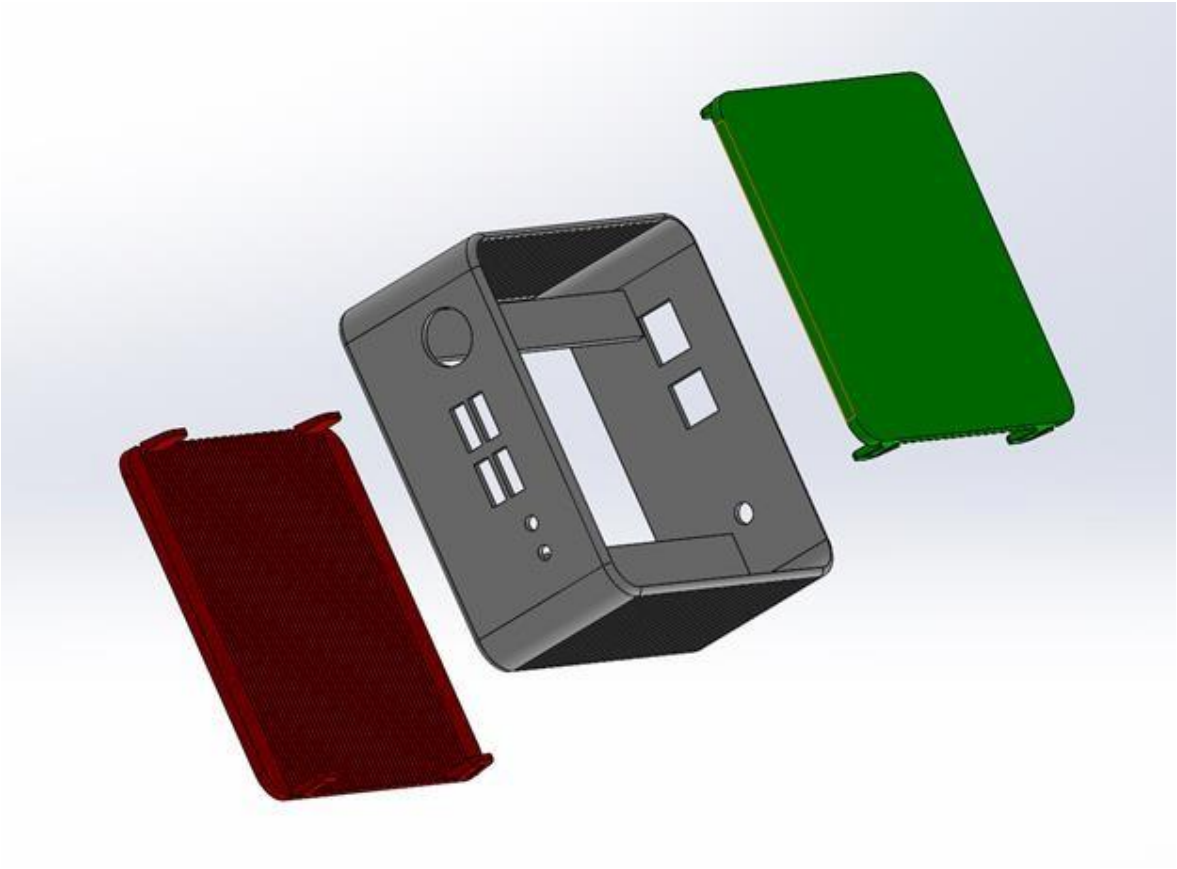

Figure 13 3D exploded view of the theoretical product
圖13 理論產品的三維分解視圖

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.

PART-A（見圖14）是計算機機箱的核心結構。預計它將包含所有必要的零件，以使所需的小型電腦正常運作。為此，選擇了一種原材料A，即丙烯腈丁二烯苯乙烯（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，如手機適配器、鍵盤按鍵和牆壁插座塑料護套。

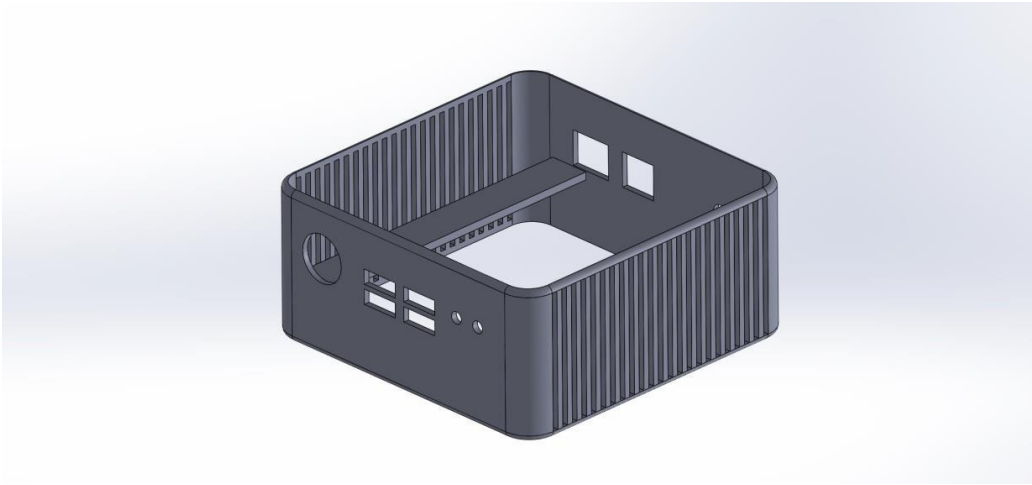

Figure 14 Isometric view of Part A
圖14 Part A的等角視圖

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.

選擇這種材料的主要原因是它的耐用性、良好的尺寸穩定性（冷卻後尺寸不易變化）、高衝擊抗性和表面硬度。最後，它還常常以3D打印的形式作為擠出式3D打印機的材料供應，這在原型製作過程中應該非常有用。

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.

部件B和C是蓋子，應該能夠啪地一聲合上，封閉系統。這些是非常簡單的零件，需要一定程度的彈性，以便在無螺絲的情況下變形，確保組裝。這兩個相同的零件將使用聚氨酯熱塑性彈性體（TPU）製造，因為它具有彈性和出色的拉伸和撕裂強度。這種類型的聚合物通常用於生產需要橡膠般彈性的零件。TPU在高溫下表現良好，常用於電動工具、電纜絕緣和運動用品。最後，TPU也以3D打印的方式供應，因此，在模擬中，將用於原型製作。

Figure 15 Parts B and C
圖15 零件B和C

4.1.3. Molds 模具

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.

理想情況下，所有模具都應該使用鋼材製造，以確保模具和產品質量的持久性。儘管如此，所選擇的所有部件所使用的注塑塑料並不如此依賴壓力，它們的形式也不是很複雜，因此可以假設使用精密數控加工製作的鋁模具足以生產這些部件。

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.

同時也假設所有的模具都足夠簡單，可以使用3D打印技術進行原型製作。儘管這不一定總是正確的，但確定對於這個模擬來說具有代表性。這些原型所使用的材料類型是使用SLA 3D打印機固化的高溫樹脂。此外，將模具視為生產過程中要開發的主要物理方面，因為它直接影響生產，並且可以在內部製造和跟踪，就像產品一樣。

4.2. What is analized during the simulation
4.2. 模擬過程中分析的內容

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.

考慮到圖9中的圖表以及在第3.1節中描述的PLM和MES成功整合的主要方面，本實驗旨在對表1中提出的以下相關問題進行評論。

Table 1 Summary of questions to be answered

Table 1 要回答的問題摘要

Category 類別	Questions 問題
How does the software deals with items? 軟體如何處理物品？	Are all aspects of the product lifecycle represented? 產品生命周期的所有方面都有所代表嗎？
	How well are each of those items represented? 這些項目被多好地呈現了？
How easy it is to create a brand-new product? 創建全新產品有多容易？	How the product is depicted? 產品如何描述？
	How does the product integrate and reference relevant files? 產品如何整合並參考相關文件？
	Does changing one affects the other? 更改其中一個是否會影響另一個？
How easy it is to create a brand-new production process? 創建全新的生產流程有多容易？	How the process is depicted? 流程如何呈現？
	How does the process integrate and reference the product it produces? 流程如何整合和參考其產出的產品？
	Does changing one affects the other? 改變其中一個是否會影響另一個？
How easy is to improve an existing product? 改進現有產品有多容易？	How easy it is to update its metadata? 更新其元數據有多容易？
	How easy it is to determine the effects of the change? 決定變更的影響有多容易？
	How does the software deals with different product revisions? 軟體如何處理不同的產品修訂？
How easy it is to improve an existing production process?改進現有的生產流程有多容易？	How easy it is to update its metadata? 更新其元數據有多容易？
	How easy it is to determine the effects of the change?決定變更的影響有多容易？
	How does the software deals with different production process revisions? 軟體如何處理不同的生產流程修訂？
How easy is to find data related to product or process? 找到與產品或流程相關的數據有多容易？	How easy is find production numbers? 找到生產數據有多容易？
	How does Odoo generate performance data? Odoo如何生成性能數據？
	How does the software present performance change as a result of a upgrade? 軟體如何呈現升級後的性能變化？

5. CHAPTER

第五章

THE ODOO SOFTWARE
Odoo 軟體

5.1. Introduction to the Odoo software
5.1. Odoo軟體介紹

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.

Odoo是一款商業管理軟體，與開源社區有著密切的聯繫。最初作為開源ERP軟體開始，因其價格實惠、直觀易用、且擅長整合和擴展而受到廣泛歡迎。隨著公司快速增長，他們調整了商業模式，包括推出企業付費版本和在線服務。

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.

正如在第2.2節中提到的，現代ERP系統通常是模塊化的。在Odoo的情況下，這種模塊化特別明顯，因為社區開發的模塊以及公司開發的模塊提供了大量的擴展功能，並且高度集成。這種可擴展性使得這款軟體與PLM+MES整合的話題密切相關，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。

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.

在這個論文的範圍內，目標是利用這款軟體來管理之前提到的虛構公司，並得出關於PLM和MES整合在這個系統中的效果如何的結論。

5.1.1. How it works
5.1.1. 它是如何運作的

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

該軟體可以安裝在大多數x86架構的電腦上，並支援多個操作系統，包括Windows和所有主要的Linux發行版。

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.

理想情況下，Odoo軟體安裝在連接到本地區域網絡的電腦上，並啟動一個SQL數據庫，該數據庫保存了企業產生的所有必要信息和文件（見圖16）。該電腦基本上充當服務器，可以通過網絡中的其他機器使用瀏覽器訪問。這台電腦可以是專用服務器，也可以是正在使用的工作桌面，但重要的是要記住，軟體需要正常運行期間，它必須保持開啟並連接。

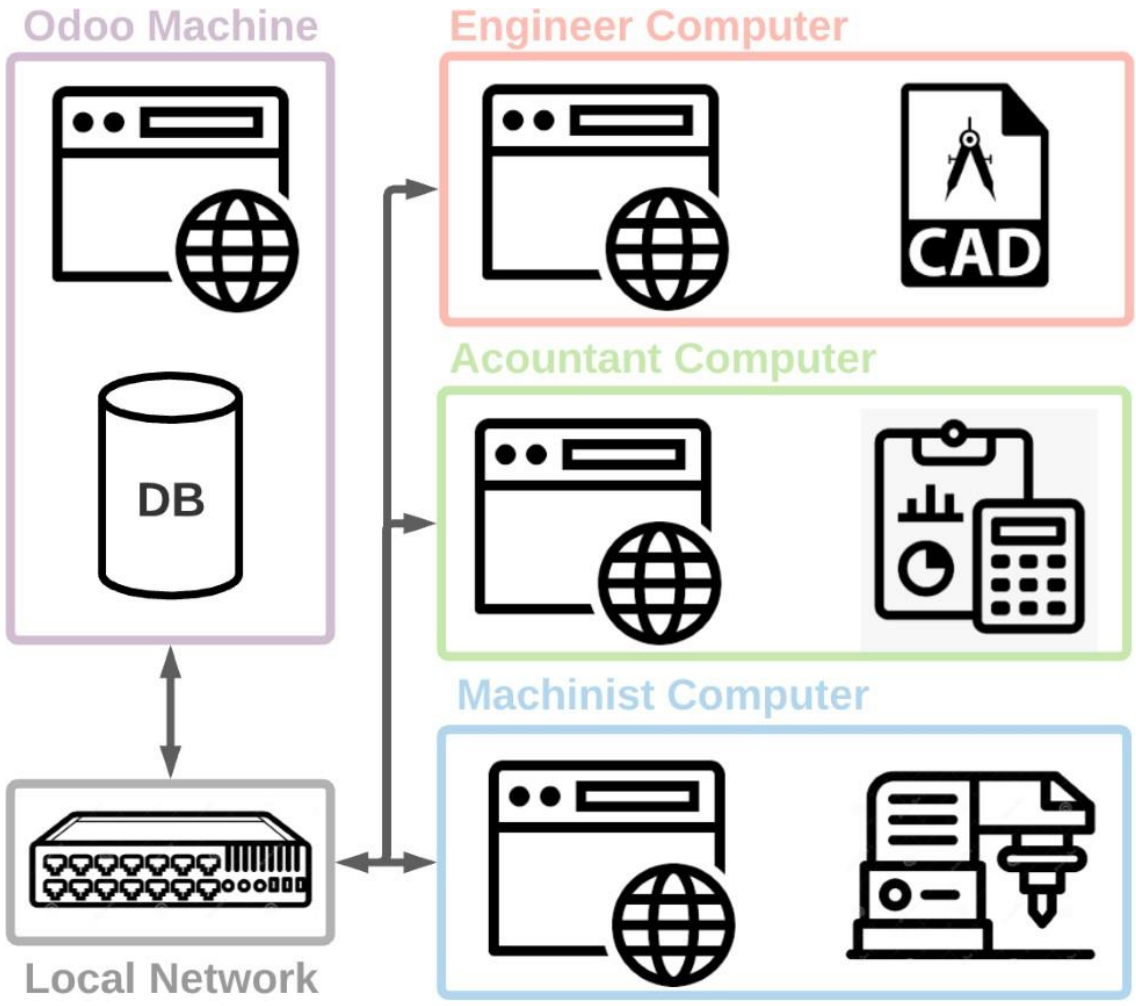

Figure 16 Function Diagram of Odoo configuration A

圖16：Odoo配置A的功能圖解

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.

另一個選擇是使用Odoo SA提供的托管服務（見圖17）。在這種情況下，系統將由他們托管，數據將存儲在他們的雲中。對於許多小型企業來說，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組（用於構建和管理網站和電子商店）。然而，這是依賴於網絡的，這在某些情況下可能會存在問題。

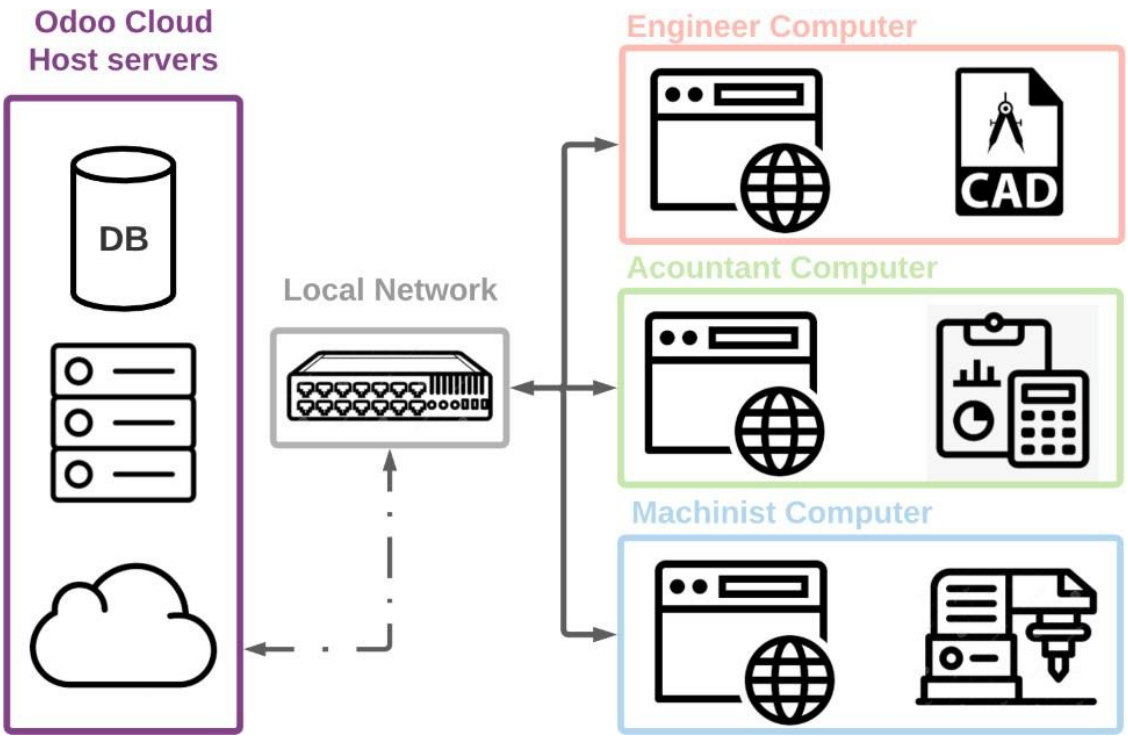

Figure 17 Function Diagram of Odoo configuration B

圖17 Odoo配置B功能圖

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.

使用者基本上通過圖形使用者介面（GUI）與系統交互，並使用它來訪問每個用戶根據需要提供的不同模組。這意味著可以對不同的使用者施加限制，以保持對商務活動不同方面的控制，例如，會計師可以訪問會計模組、銷售模組和庫存模組，但他們將受到製造模組的限制。這種限制保證了對流程的控制只對適當的員工。

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.

在上述 GUI 中，不同的模組顯示為應用程式圖示（圖 18），並且從一開始，該公司就提供了合理選擇的集成良好的應用程式，更不用說充滿社區製作模組的龐大應用商店了。

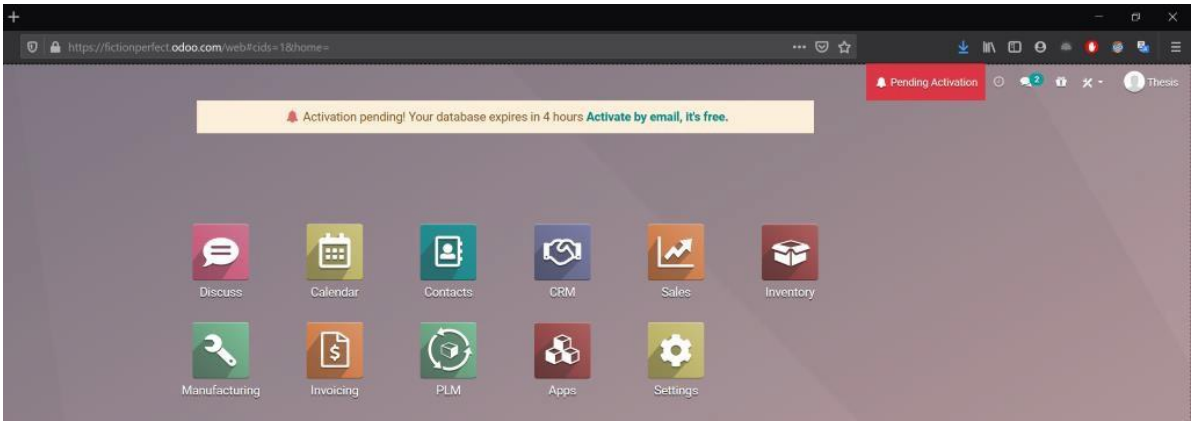

Figure 18 Screenshot of GUI from Odoo in configuration B

圖 18 配置 B 中 Odoo 的 GUI 螢幕截圖

1.1.1. Odoo's view on manufacturing: Odoo對製造業的看法：

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.

Odoo 認為，製造任何產品的責任都分佈在不同的公司部門，每個部門負責特定的檔類型，並使用特定的應用程式進行處理（表 2）。從 PLM 的角度來看，這是非常積極的，因為正如（Saaksvuori 和 Immonen，2008）關於用戶許可權管理所提到的，PLM 系統用於定義資訊訪問和維護許可權。PLM 系統定義了可以創建新資訊或進行、檢查和接受更改的人員，以及僅允許查看系統中的資訊或文檔的人員。在將 PLM 與其他系統整合時，用戶許可權管理通常是一個挑戰。

Table 2 Correlation between department and Documents/Apps
表2部門與文檔/應用程式的相關性

Department 部門	Documents/Apps 文件/應用程式
Engineering 工程	CAD & BOM CAD 和 BOM
Manufacturing Engineering 製造工程	Routings, Worksheets, Workcenters 工藝路線、工作表、工作中心
Purchase/Procurement 採購/採購	Procurement order, Request for quotation 採購訂單， 詢價
Inventory Operators 庫存操作員	Receipt, Barcode 收據、條碼
Manufacturing Foreman 製造工頭	Manufacturing order, Planning 製造訂單、計劃
Manufacturing Operators 製造運營商	Work order 工作訂單
Inventory Operators 庫存操作員	Delivery 交貨
Quality 品質	Alert, Analysis, Control points 警報、分析、控制點

Department 部門	Documents/Apps 文件/應用程式
Engineering 工程	Engineering change order 工程變更單
Maintenance 保養	Preventive/Corrective 預防/糾正

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.

從Odoo的角度來看，在任何常規製造過程的開始，第一步將是工程師通常使用CAD軟體設計產品。完成後，他們將創建物料清單（BOM），這是生產產品所需的元件或材料清單。在這一點上，重點放在製造過程本身。

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

流程的軟體檢視側重於工藝路線、工作表和工作中心，這是由製造工程團隊完成的。工藝路線是產品在生產過程中經歷的一組步驟。工作表是製造操作員的指令，工作中心是進行生產的地方。Odoo認為這些是將工程師計劃付諸實施的要求

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.

採購部門將負責詢價 （RFQ） 或採購訂單 （PO）。庫存操作員根據這些採購訂單處理收據，這通常是使用Odoo中的條碼應用程式完成的。如本章第一節所述，Odoo主要是一個ERP系統，在這一點上，可以注意到一些以ERP為中心的特徵，例如對庫存和資源管理的關注。這將在以下各節中進一步分析，但公平地指出，這些 RFQ 和 PO 被視為資料庫中的專案。

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.

只有當您擁有所需的設計、工藝和材料時，Odoo才會考慮製造。然後，製造領班將創建製造訂單 （MO） 並通過工作訂單 （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作訂單開始生產。產品生產完成後，它們會自動出現在庫存資料庫中，該資料庫與包裝和交付一起由庫存部門管理。

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.

Odoo認為質量團隊負責分配控制/檢查點，並識別產品或生產中可能存在的問題。從MES的角度來看，這些品質控制檢查點非常有趣，因為它代表了在生產過程中即時收集的有價值的生產數據，即，可以在每件作品生產後分配尺寸檢查，機械師將填寫尺寸以跟蹤品質隨時間推移。

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.

如果是設計問題或有改進的可能性，可以發出工程變更單 （ECO）。這又回到了製造工程的手中 團隊，並將專注於更新文檔和 BOM。ECO是Odoo處理系統內跟蹤變化的核心。在PLM方面，這是關鍵，事實上，這是Odoo應用程式PLM的重點。所述應用程式能夠執行到什麼程度是下一節的主題。

1.1.2. The information structure of Odoo
Odoo的信息結構

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’.

每個模組都側重於操作在資料庫中保存元數據的特定面向物件類。這些是負責虛擬化產品生命週期各個方面的虛擬專案，如（第3.1節）中所述。不同類型的專案具有不同類型的帳戶並持有不同類型的數據，即產品專案代表特定產品，並包含與其交互和使用相關的元數據，以及指向其他可能專案的連結，這些專案密切相關，例如其責任使用者或製造所需的物料清單。Odoo使所有這些資訊都可以通過其瀏覽器介面訪問和交互（圖19和圖20）。為了保持一致性，本文檔將特定專案表示（例如Bolt）稱為“專案”，並將專案類型（產品）稱為“專案類”。

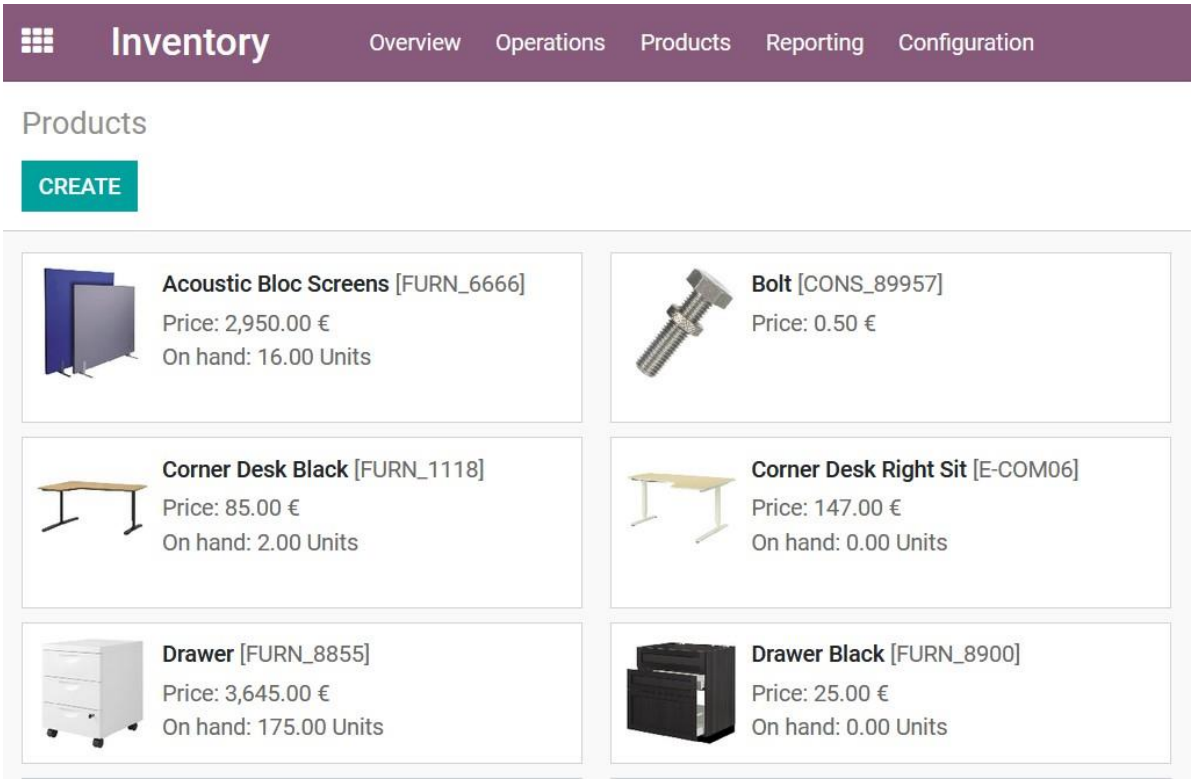
Inventory
Overview
Operations
Products
Reporting
Configuration
Products
CREATE
Acoustic Bloc Screens [FURN_6666]
Price: 2,950.00 €
On hand: 16.00 Units
Bolt [CONS_89957]
Price: 0.50 €
Corner Desk Black [FURN_1118]
Price: 85.00 €
On hand: 2.00 Units
Corner Desk Right Sit [E-COM06]
Price: 147.00 €
On hand: 0.00 Units
Drawer [FURN_8855]
Price: 3,645.00 €
On hand: 175.00 Units
Drawer Black [FURN_8900]
Price: 25.00 €
On hand: 0.00 Units

Figure 19 Example of Odoo's interface regarding items

圖19 Odoo關於專案的介面示例

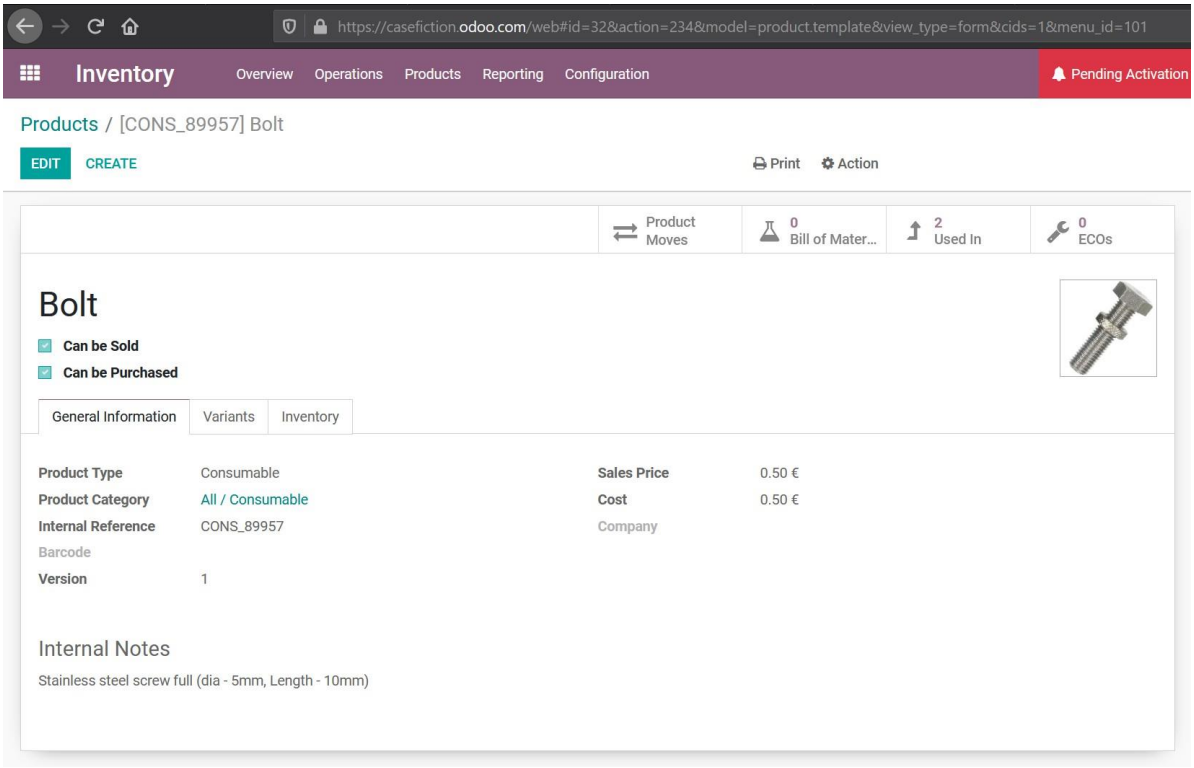

Figure 20 Example of specific item and its metadata as displayed by GUI
圖20 GUI顯示的特定專案及其元數據示例

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，有幾種類型的專案類（有些包含大量元數據，有些保存很少），它們都具有不同程度的關係和集成。由於這項工作的範圍僅限於 PLM 和 MES 功能，因此重點放在與之相關的專案上。以下各節將對Odoo製造過程的主要7個專案類別進行簡短的解釋，因為它的基本理解有助於讀者遵循類比。如下圖所示（圖 21）。製造過程外部的其他專案將在整個模擬過程中呈現。

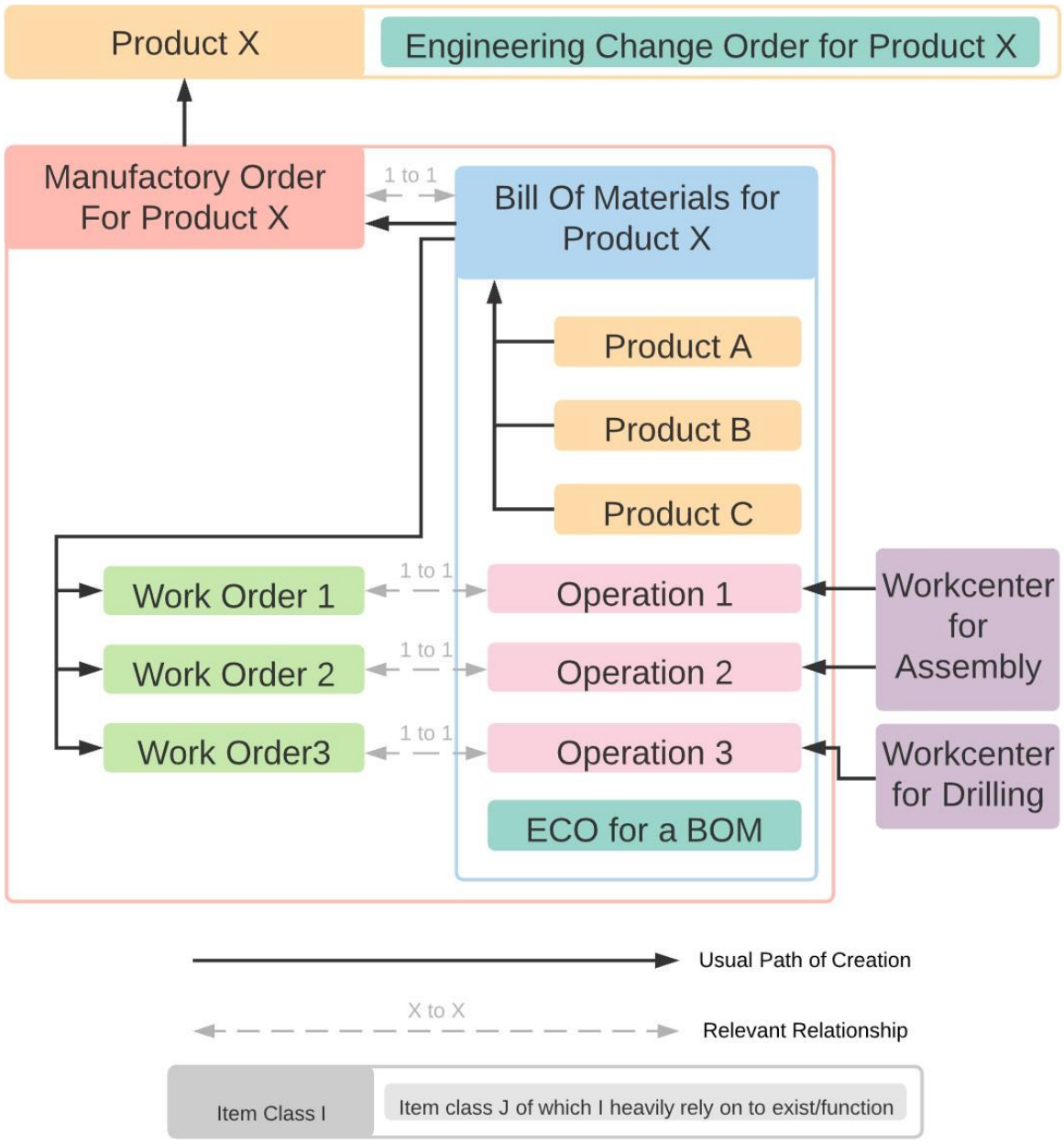

Figure 21 Simplified Item relation diagram to the manufacturing of a product X
圖 21 簡化物料與產品製造的關係圖 X

1.1.2.1. Product Item
產品專案

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.

每種材料、元件或產品都以產品類型類為特徵，該類主要在Odoo的庫存應用程式中保存和管理。這意味著在系統內，產品生產取決於其他產品的可用性，這些產品要麼按原樣購買，要麼從其他產品製造（圖22），即原材料也被視為產品，更具體地說，是購買的產品和 然後包含在 BOM 中以製造其他產品。這被認為是主要專案類，因為它既是製造的來源，也是製造的目標。

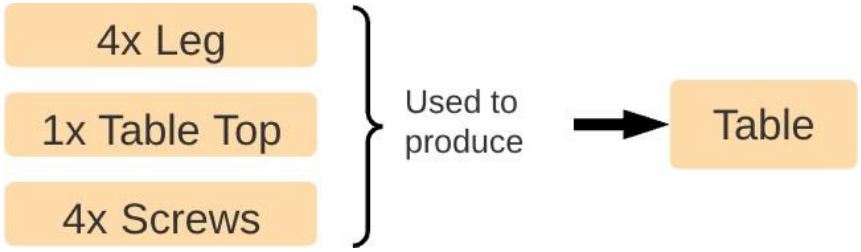

Figure 22 simplified Product relation diagram

圖22簡化產品關係圖

1.1.2.2. Operation item class and workcenter item class 工序物料類和工作中心物料類

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.

工序專案代表將元件或原材料轉化為產品或新元件所需的製造工序，而工作中心專案則代表工序發生的地方，例如，在具有適當設備的砂光站（圖 23）中進行打磨木材。該工作中心最終在Odoo中用作其生產計劃中的時間/設備管理工具。基本上，當生產中心滿負荷運轉時，它會暫停後續流程或將流程重定向到備用工作中心。操作項還負責保存生產過程中查閱的指令檔。

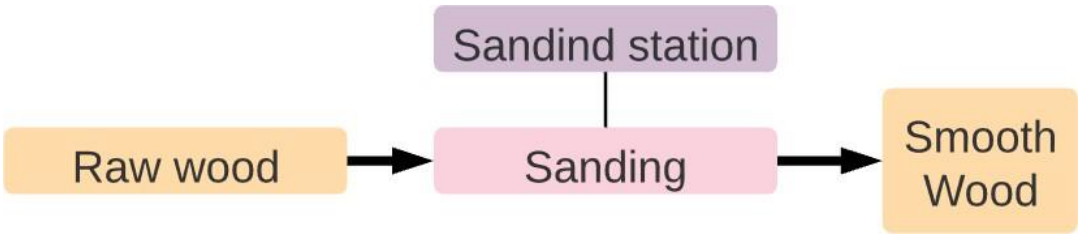

Figure 23 Simplified Operation diagram
圖23簡化操作圖

1.1.2.3. The Bill of Materials item class
物料清單項類

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.

物料清單是構建產品所需的元件清單。然而，在Odoo中，BOM最好用PLM認為生產過程的虛擬表示來描述。考慮到前面提到的工序物料類，乍一看似乎有悖常理，但實際上，由於物料清單是複合物料，它直接指向生產最終產品所需的所有物料類型（圖 24）。例如，假設要構建一個產品，需要 3 個不同的部件和 4 個不同的操作;所述產品的BOM將列出所有這些產品，並指定它們的使用順序。

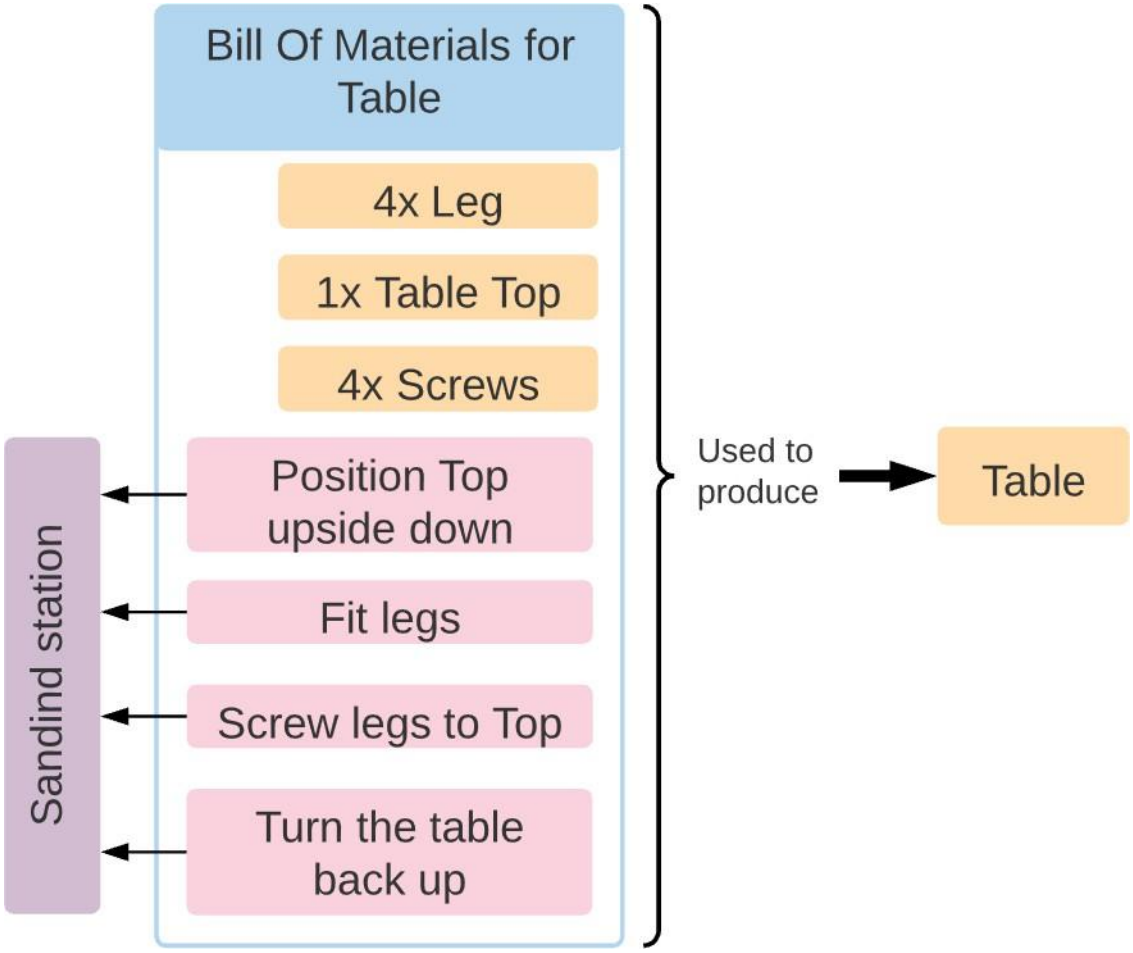

Figure 24 Simplified BOM diagram

圖 24 簡化的 BOM 圖

1.1.2.4. Manufacturing order item class and work order item class 製造訂單項類和工作訂單項類

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).

在 Odoo 中考慮的標準專案中，訂單是代表系統內開始的訂單。他們發出信號，表明正在以某種方式和某個地方發生變化。對於製造訂單，它表示使用其物料清單作為基礎製造 N 個特定產品的訂單。正是由於該 MO，Odoo 會自動生成工單（BOM 中列出的每個必要操作一個），並在整個可用的必要工作中心分配（圖 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.

工單是製造操作員與 Odoo 交互的主要形式，它呈現操作項指定的所有指令，以及對其完成的控制。當 WO 發生時，操作員通過介面發出信號，發出信號，發出信號，完成所有 WO 后，可以聲明 MO 完成，並消耗 BOM 中指定的材料和元件，並將產品的 N 份添加到庫存中。所有這些都使工單成為 MES 的核心部分。

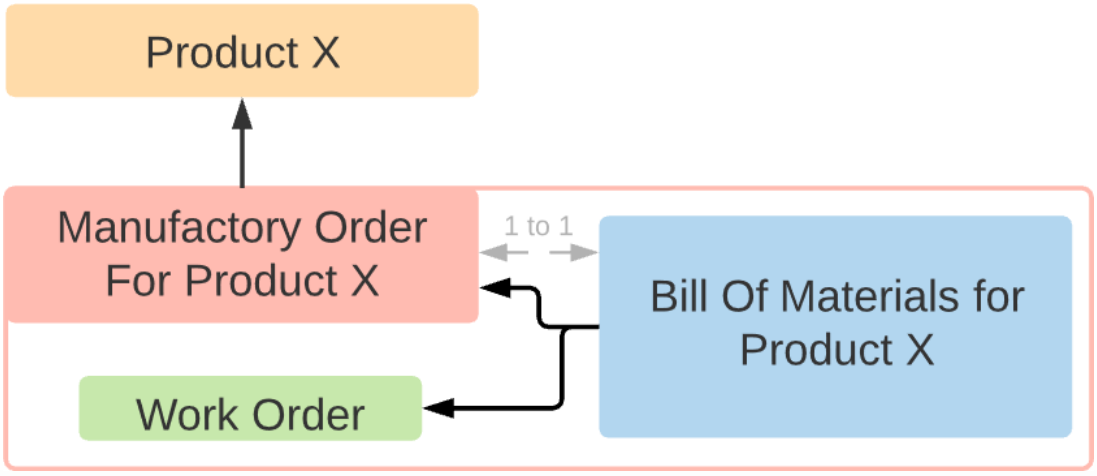

Figure 25 Simplified orders diagram
圖25簡化訂單圖

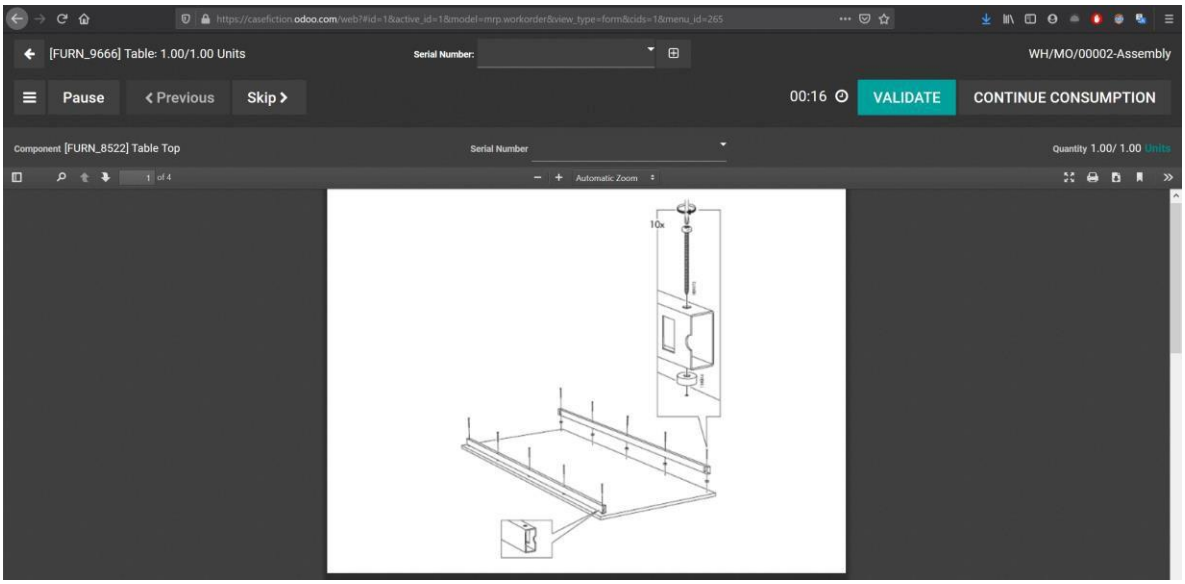

Figure 26 Operator interface during the WO

圖26 WO操作介面

1.1.2.5. The engineering change order 工程變更單

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).

如第2章開頭所述，Odoo管理軟體主要將PLM視為跟蹤變更和改進的工具。它的應用模組是正常製造流程的外部，但充當其擴展。其重點專案類是工程變更單（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.

ECO 是一個專案類，它概述了對產品或將受更改影響的部件的擬議更改。換句話說，是與給定產品相關的每個人的中央資訊中心。

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.

這個想法是發出需要更改產品項或 BOM 項的信號，保留與更改相關的檔並應用更改，或者至少發出已實施更改的信號，同時保留所有先前更改的歷史記錄。所有這些都在未來非常有用，並作為簡化產品開發和說明改進產品/生產的過程。

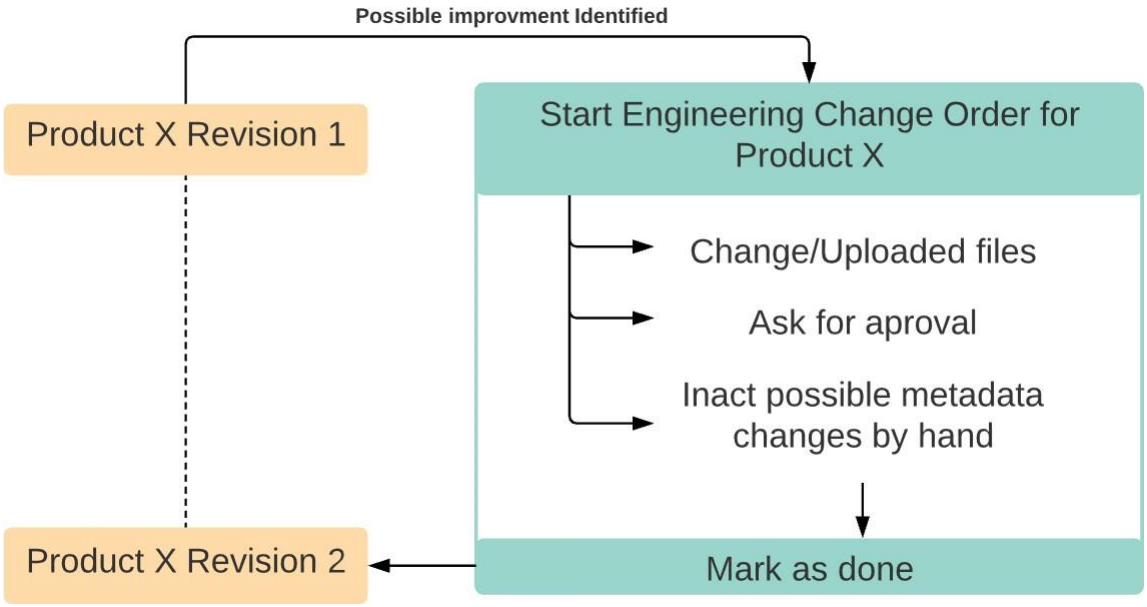

Figure 27 Simplified ECO function diagram
圖27簡化的ECO功能圖

1.2. Starting the simulation
開始類比

1.2.1. Software option chosen for the simulation
為模擬選擇的軟體選項

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:

對於此類比，已決定通過其基於Web的在線服務對Odoo軟體進行最佳評估。選擇不使用該軟體的社區版的原因如下

- 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.
使用基於 Web 的服務作為本地或遠端管理伺服器的實用性。儘管社區應用程式作為這項工作研究的一部分進行了測試，並且被認為是一個非常初學者友好的伺服器應用程式，但事實是，託管伺服器本身就是一項需要經驗和知識的工作。關於這種應用，市場已經轉向產品即服務，這是有充分理由的。在撰寫本文時，COVID-19 大流行迫使許多員工遠端工作，並向市場表明 IT 不是一項簡單的工作，Web 服務是一個有吸引力的選擇

- 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.
缺少Odoo社區版的官方OdooPLM應用程式。儘管Odoo的社區版有大量的社區應用程式，但這些應用程式的組織、描述、集成和支援充其量只能被發現。與其依賴可能跟不上主要軟體的應用程式，不如決定如果基於官方應用程式，對平臺評估會更公平。也就是說，僅僅依靠運氣來決定未來如何支援它，就拼湊出一個免費的解決方案是非常徒勞的。PLM 是這裡的重點，所以這是一個不容置疑的情況。

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).

在撰寫本文時，Odoo允許您選擇其額外功能之一，例如PLM，並在其雲託管伺服器上無限期免費使用它。如果這項工作的唯一重點是 PLM 和製造，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，這意味著可以做的很少。為此，實驗是在Odoo企業版的試用版中進行的，它允許使用者在14

天內使用系統，而沒有存儲或應用程式限制，全部託管在Odoo雲伺服器中（圖17）。

1.2.2. Setings details that are relevant
相關的設置細節

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.

有關Odoo設置的一些細節與其製造功能的正常功能有關。也就是說，在製造設置中啟用工作訂單是正確使用工作訂單項、工作中心項和工序項的必要步驟。

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).

為這項工作所做的一個假設是，這是軟體ERP起源的保留，因為如果您要使用Odoo對製造進行任何嚴格的控制，那麼默認情況下不啟用此設置是相當不直觀的。從 Odoo enterprise v14 開始，可以在 Settings > Manufacturing > Operations > Work Orders 中設置此選項（圖 28）。

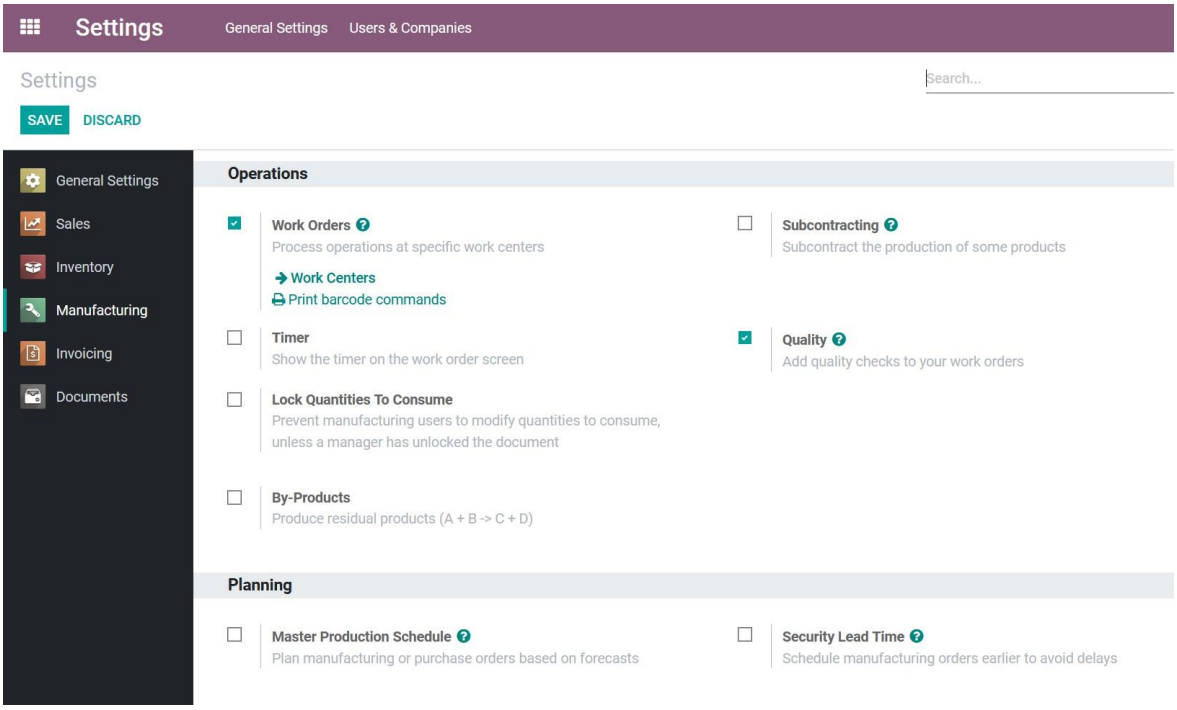

Figure 28 Screenshot of the specific setting to be enabled
圖28 要啟用的特定設置截圖

1.3. Building the company structure
構建公司結構

1.3.1. Users
使用者

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,

通過設置功能表設置和邀請使用者。可以針對業務運營的不同方面分配不同級別的許可權。消息傳遞、許可權、

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).

核准、責任都指派給一個使用者。這非常方便，即使在製造範圍內的使用有限，它也可以屬於虛擬項目類別。它們的創建並非絕對必要，軟件只需我一個使用者具有完整的管理員權限即可運行良好，但是為了這個模擬，創建了5個使用者，如下列舉的那樣，代表公司內不同的員工。下面（圖29）是我的用戶帳戶項目的屏幕截圖及其"評估權利"，隨後是為公司創建的一個虛構用戶的屏幕截圖（圖30）。

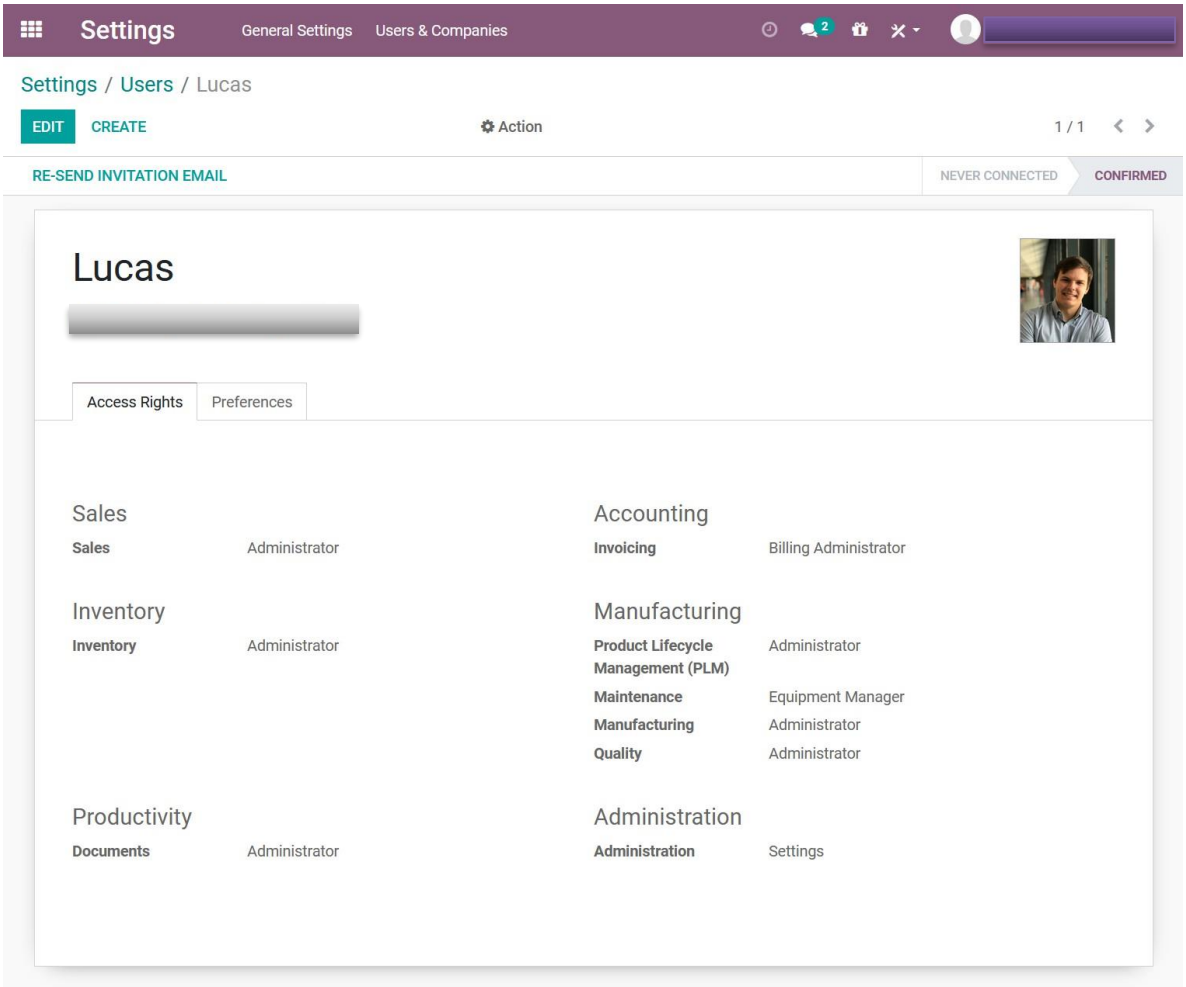

Figure 29 Screenshot of user account interface

圖29 用戶帳戶界面截圖

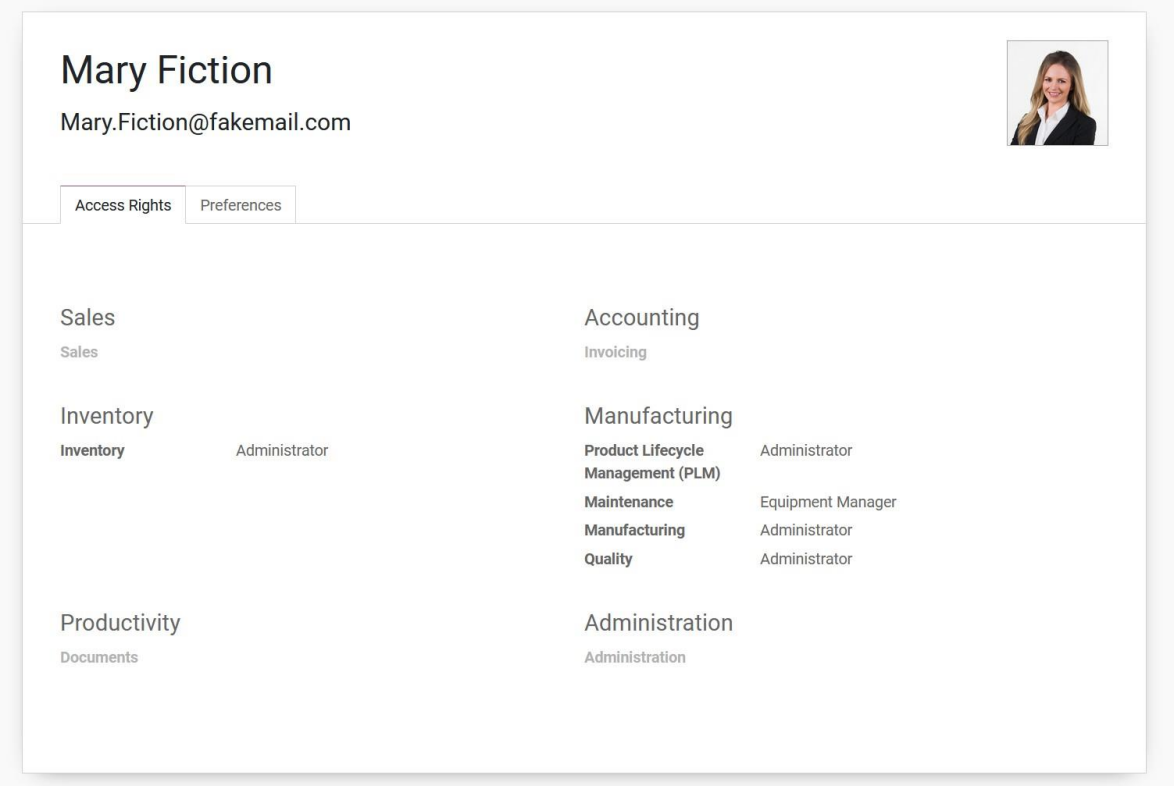

Figure 30 Screenshot of second user account interface

圖 30 第二個使用者介面截圖

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.

很高興指出兩者在訪問權限上的差異。在此示例中，Mary Fiction 被創建為一名工程師，因此她的大部分權限都圍繞著製造程序，同時她被拒絕訪問其他部分，如銷售或會計。

1.1.1. Workcenters and Equipement
工作中心和設備

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.

工作中心在Odoo中非常靈活，因為它們可以根據需要進行更改和擴展。可以在創建產品項目之後創建工作中心，以便在獲得一些關於最終產品的遠景後重新組織車間。然而，對於大多數情況來說，這似乎不太現實，因為工作中心在現實世界中是比較固定的結構——它們不像產品那樣經常變化，因為它們往往容納著重型機械。

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.

在這個模擬中，假設公司從一開始就已經擁有3個工作中心，因此工作中心和機械都是事先創建的。這對於有興趣將Odoo實施的可能讀者來說更有用，同時也節省了一些時間。

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).

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式是維護應用程式。下面的圖片是Odoo展示3D打印機設備項目的示例（圖31）。

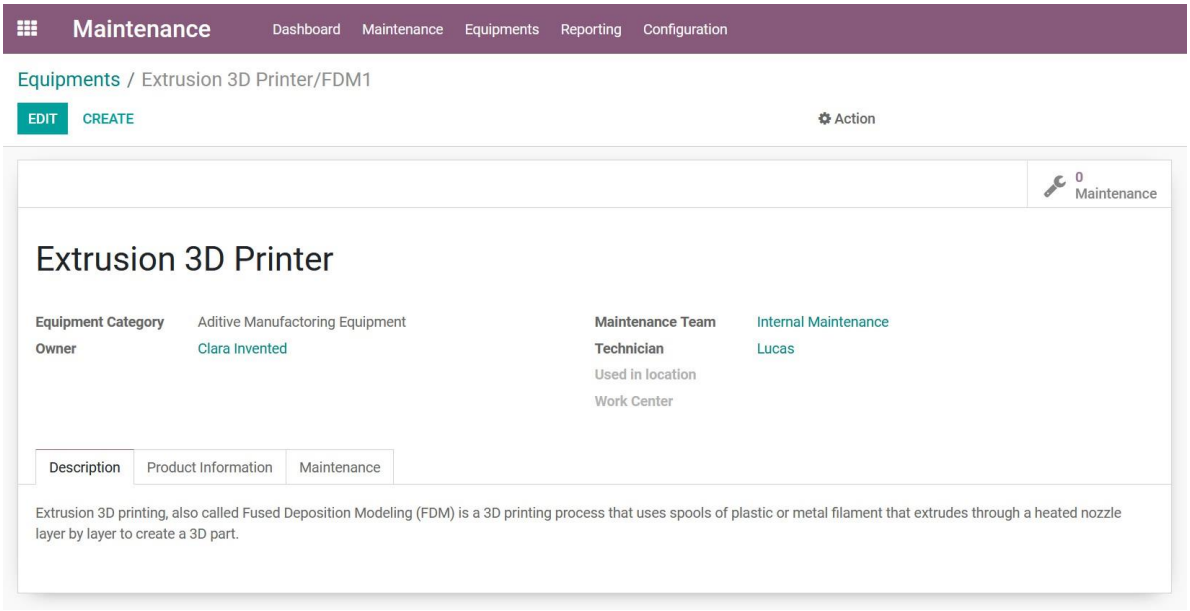

Figure 31 Odoo 3D printer equipment item
圖31 Odoo 3D打印機設備項目

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

除了這台3D打印機外，還創建了以下設備，用於整個開發/生產過程中的使用（圖32）：

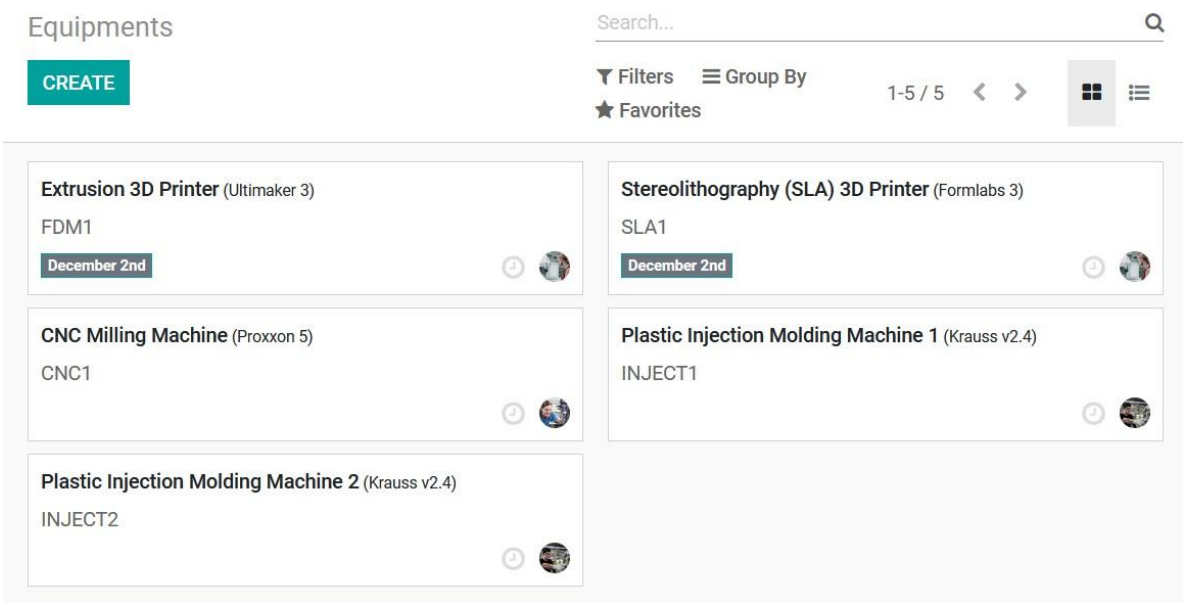

Figure 32 Overview of equipment items
圖32 設備項目概覽

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.

這是軟件在產品生命週期管理（PLM）方面的限制開始展示的地方。儘管設備項目允許您進行一定程度的元數據（描述文本、負責用戶、維護數據和供應商），但它不允許附加任何類型的文件到該項目類別（機器手冊、報告等）。這是一個重大的弱點，因為文件管理被普遍認為是PLM的主要方面之一。這將是這次模擬的一個反覆出現的主題，因為在Odoo中，允許直接上傳文件的項目數量有限。

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.

現在設備已創建，可以創建它們的工作中心。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。理念是分配給工作中心的設備不應該同時使用，並且理想情況下，運行成本差異很大的設備也應該位於不同的工作中心，以便更好地追蹤時間/成本。

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.

以下（圖33）是一個工作中心項目的示例，用於代表整個產品開發過程中使用的原型製作站。

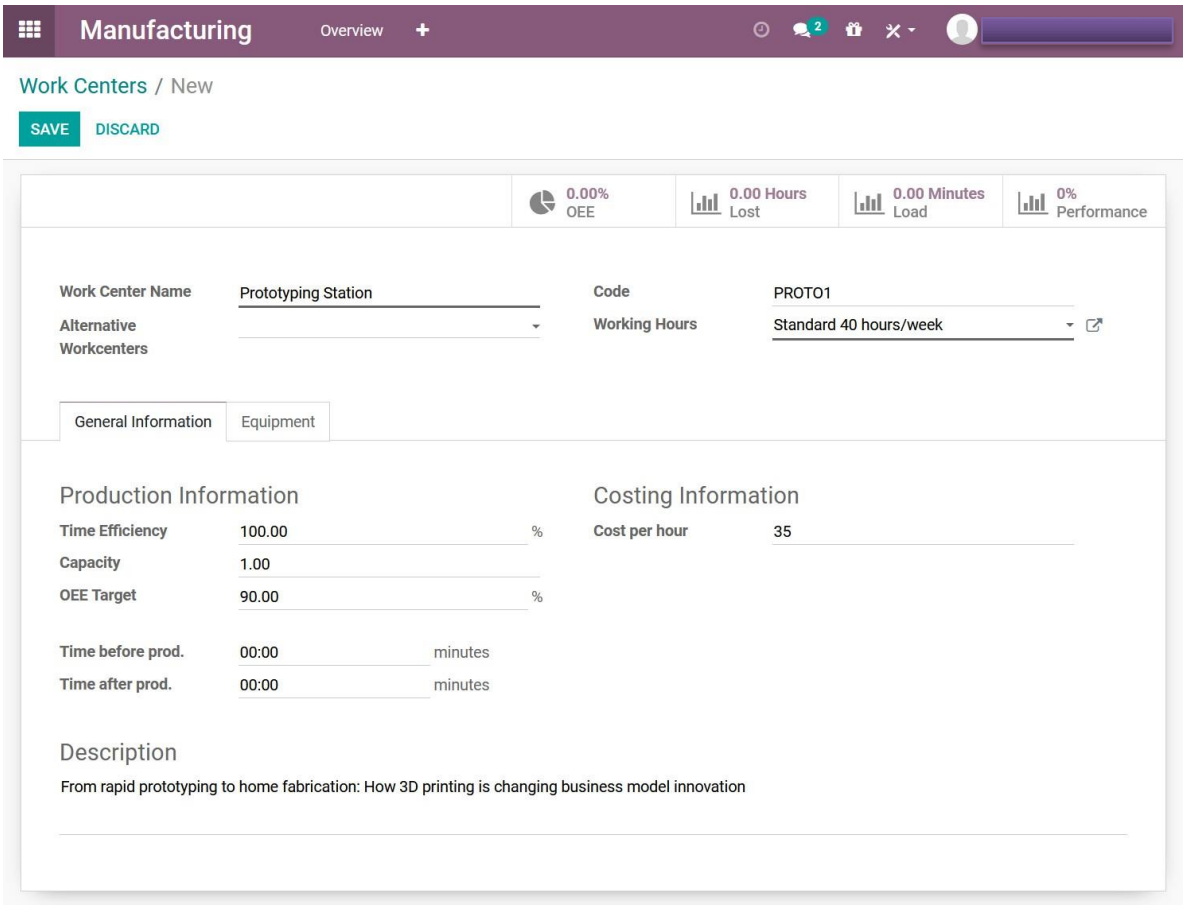

Figure 33 Odoo Prototyping Station item representation 1

Figure 33 Odoo原型製作站項目表示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.

讀者會注意到這個站點（圖34）是3D打印機和CNC機床的所在地。通常，這些機器會因為操作成本的差異以及它們大部分是獨立的而被分開放在不同的工作中心中，但是為了這次模擬的目的，這被認為已經足夠代表性了。

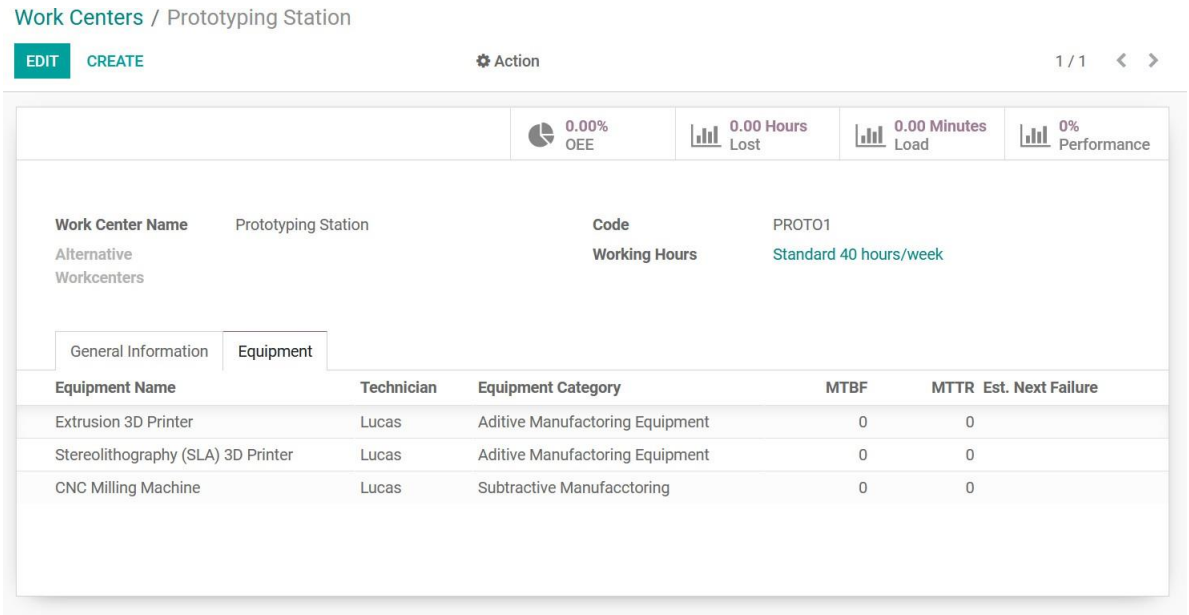

Figure 34 Prototyping Station item representation 2

Figure 34 原型製作站項目表示2

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

同時，以下工作中心也已經為模擬創建並裝備了必要的設備：

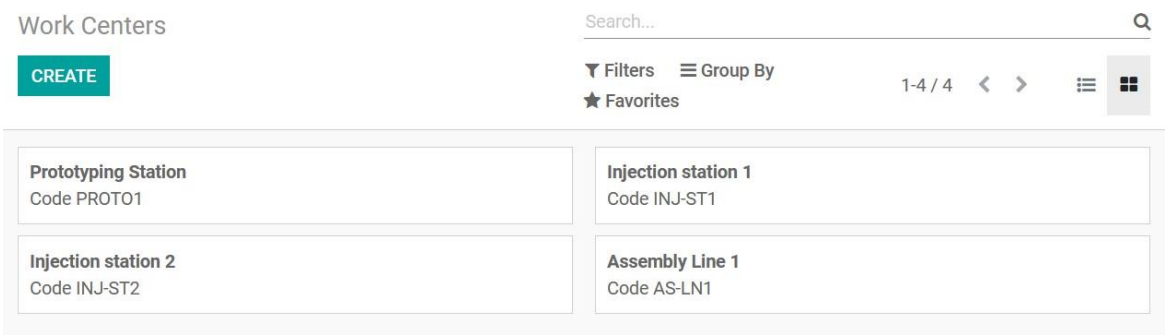

Figure 35 Overview of Workcenter items

圖35 工作中心項目概覽

1.2. Development
開發

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.

現在，公司的基本結構已經在軟件中重新建立，可以開始模擬過程。首先，重點放在使用Odoo進行全新產品開發的方面，特別是因為這是公司創建的第一個產品，因此對於組織原型製作程序的可能使用進行了評估。這包括從想法到設計和原型生產的過程。然後，一旦產品作為原型達到了可接受的結果，就會進行生產過程的開發工作。一旦完成正式生產運行，產品開發就被認為是成功的。

1.2.1. Idea - design - product prototype
想法 - 設計 - 產品原型

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.

正如在（第4章）中所解釋的，產品的想法已經確立，初始設計特徵和基本產品研究已經進行。這代表了Odoo軟件在現實世界中的實際應用，因為儘管Odoo具有良好的項目管理和通訊應用程序，但這些應用程序是外部的庫存和製造應用程序，更重要的是，它們與工程設計CAD軟件沒有任何集成。在這個模擬中，想法已經被紀錄下來，並且已經被轉化為使用Solidworks軟件生成的CAD設計，將CAD文件存儲在工程師的計算機上。

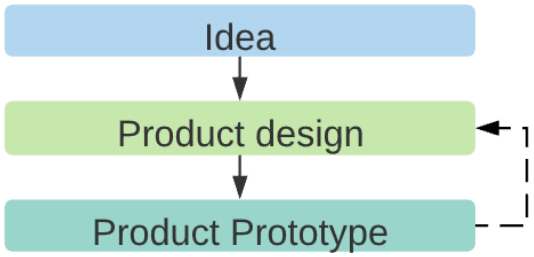

Figure 36 Sectioned diagram regarding product development
Figure 36 關於產品開發的分段圖示

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:

在這一點上，Odoo軟件的利用正式開始。第一步是了解就產品項目而言生產主題是什麼。有兩種方法來做到這一點：

- 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.

- 第一種方法是將原型視為最終產品的早期版本，即在開發過程中對原型進行修訂的原型項目在Odoo中創建的將與最終產品項目相同。如果原型是通過與最終生產使用相同的方法來實現的，這將是推薦的方法。這種方法的一個例子是，如果產品足夠簡單，開發的產品和生產方面可以一起進行。

- 第二種方法是將原型視為與最終產品不同的單獨項目-這是此模擬中採取的路徑。做出這個決定的主要原因是，我們的原型生產方式與最終生產方式不同，因為原型使用了3D打印。

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.

從根源開始，創建了一個名為PROTO Alpha Case（圖37）的產品項目（Alpha Case是產品的名稱）。從這一點開始，我們將將原型產品稱為"proto item"。正如我們所看到的，這允許對proto項目進行良好的表示。由於這是一個原型，因此它不會被標記為可以出售或購買的物品，銷售價格將設置為0美元，因為這不重要。這個proto項目將用於連接其開發的不同方面，但目前它被單獨留下。

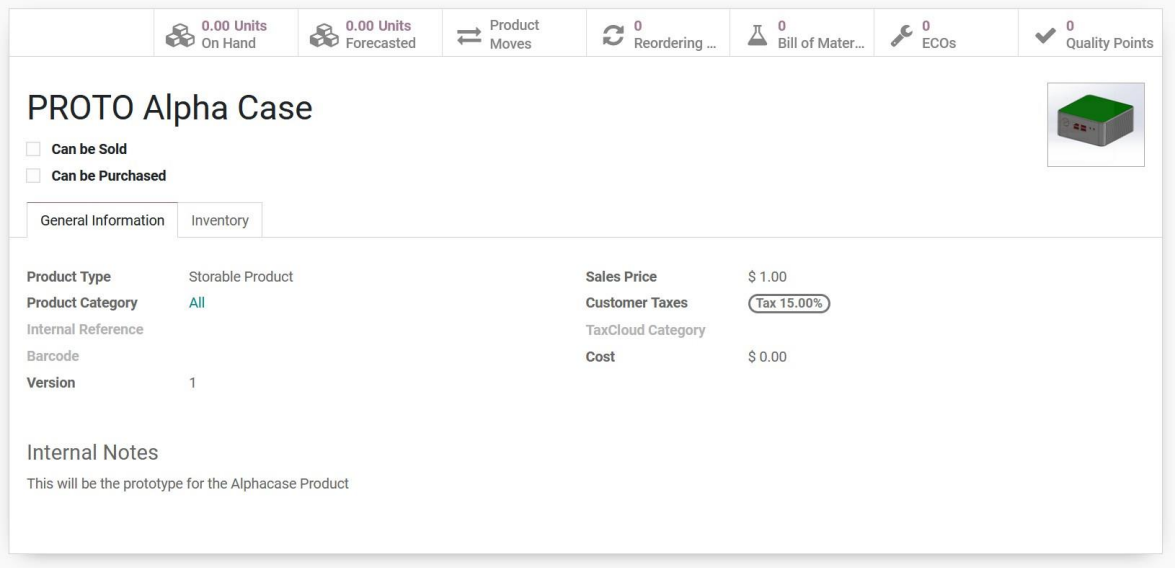

Figure 37 Image of the prototype product item
Figure 37 原型產品項目的圖片

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).

正如我們在第3章中先前確定的，產品將由3個零件組成，即A零件、B零件和C零件。這些零件需要被製作成原型並作為產品創建，以便它們可以被添加到PROTO Alpha Case的物料清單中。最後，決定使用特定的塑料填充物（參見4.1.1節）來進行PROTO Part A和PROTO Part B和C的3D打印，這些也需要被添加為產品（圖38）。

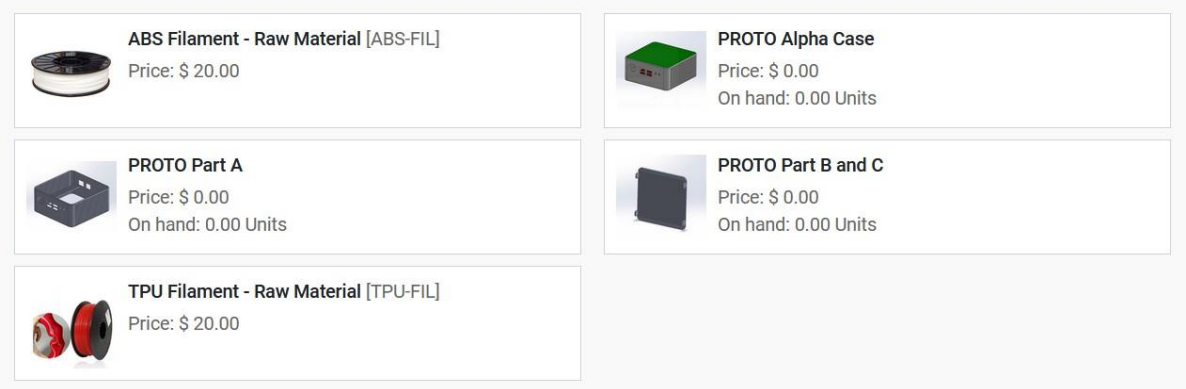

Figure 38 Overview of Product class items for prototype
Figure 38 原型產品類項目概覽

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):

此時，用於Alpha Case原型的相關產品項目已經完成，這使得可以創建相應的物料清單。它們有3個，並且遵循如（圖39）中的結構：

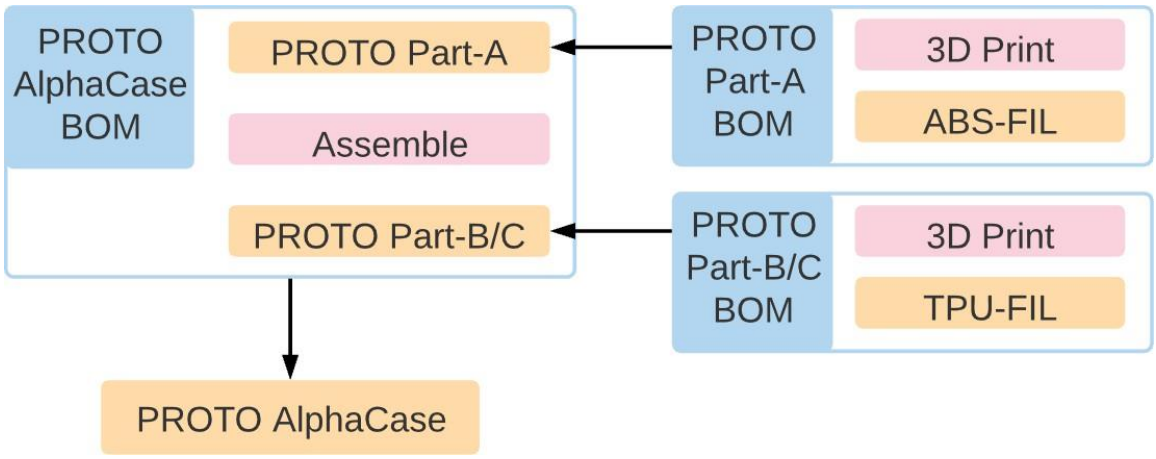

Figure 39 BOM diagrams for prototyping

Figure 39 用於原型的物料清單圖表

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.

值得一提的是，Odoo在該項目上使用了套件選項（圖40），以推斷該產品是另一個產品的組件。這非常有趣，因為它自動在產品項目之間創建了生產依賴關係。

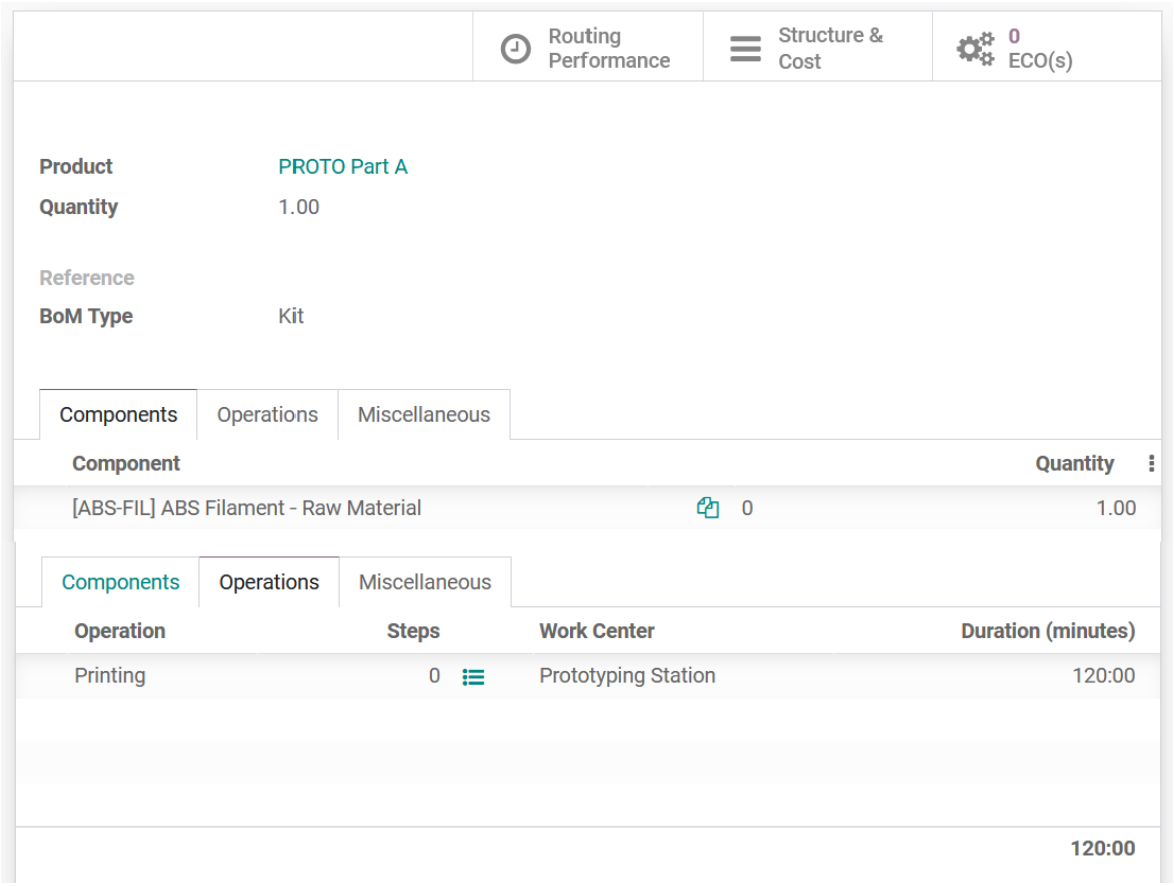

Figure 40 Image of the prototype product BOM (Part-A)

Figure 40 原型產品BOM的圖片（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.

如讀者所見（圖41），在製作物料清單時，可以輕鬆地創建必要的製造過程的具體操作項目並指定其工作中心。Odoo中關於MES的最佳功能之一是根據默認持續時間跟踪操作時間的能力。這可以根據跟踪的時間動態更改，也可以手動設置。同時，在操作項目中，我們可以添加操作的指示文件。儘管它僅限於PDF文本或鏈接到Google幻燈片文件，但這是Odoo為與項目直接相連的文件管理提供的少數機會之一。

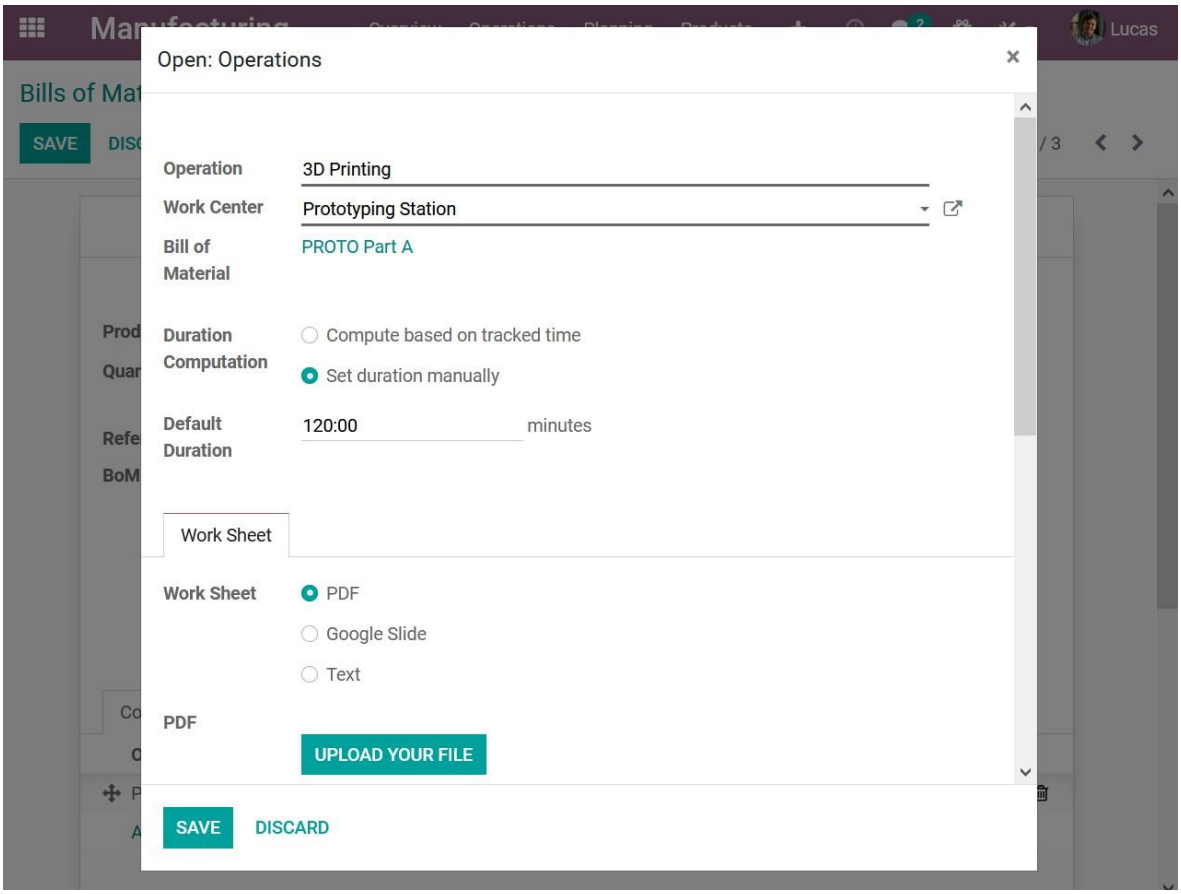

Figure 41 Image of operation item as presented by Odoo (BOM Part-A)
Odoo呈現的操作項目圖片（BOM Part-A）。

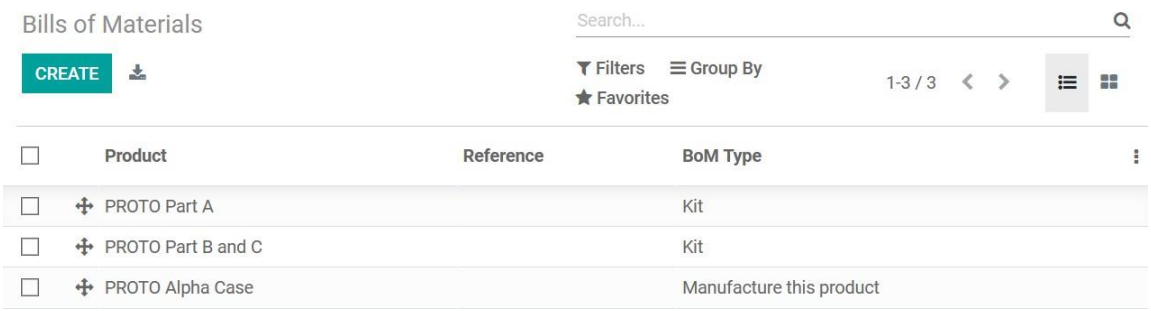

Figure 42 Overview of BOMs created for prototyping

Figure 42 原型製作的物料清單概覽

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.

提到這種缺乏上傳機會，我們可以注意到，在製作產品項目時，沒有直接上傳與產品相關的文件的方式。在我們的情況下，我們有關於我們正在原型的部件的CAD文件，無法以任何方式上傳這些文件將從PLM的角度來看會是完全失敗的。幸運的是，有一個解決方法。正如在第5.1.3.5節中所解釋的，ECO是與產品項目或物料清單相關聯的項目，並允許上傳文件附加到它。這是一個小的解決方法，但基本上意味著如果我們想以任何重要的方式上傳我們的CAD文件到項目中，即使沒有進行“更改”，我們也需要發出一個ECO。

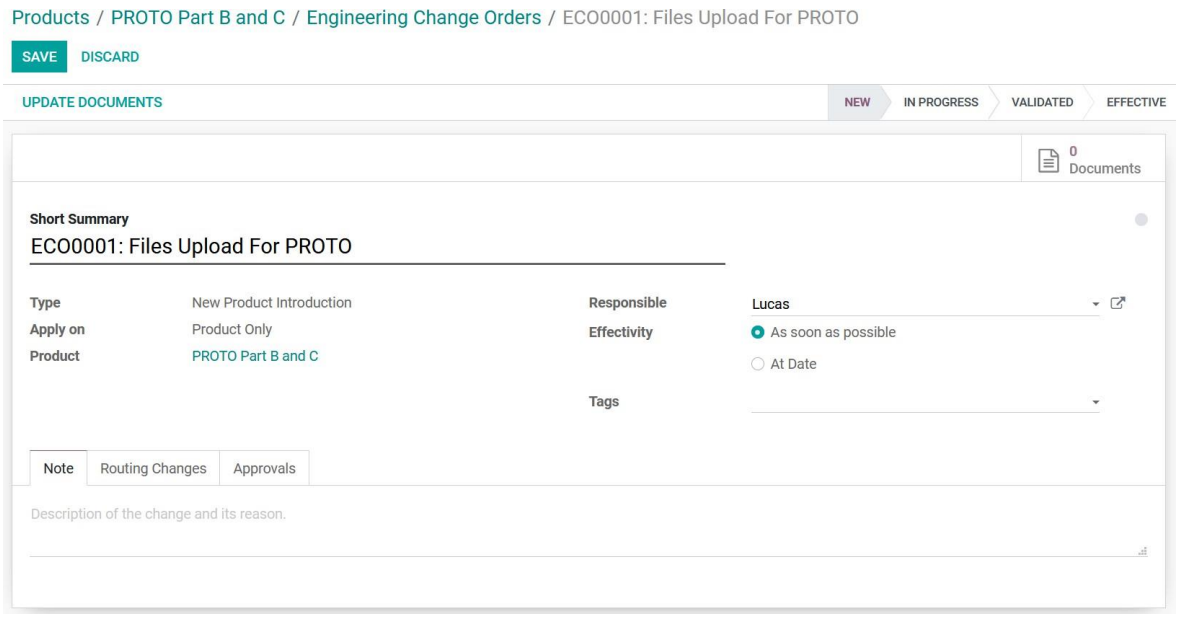

Figure 43 ECO example

Figure 43 ECO範例

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.

可以假設這是Odoo團隊在實施PLM作為其ERP基礎的外部應用程序時的策略之一。這是合理的，但是，這仍然是這個軟件界面中少數不太直觀的方面之一。這是一個非常有價值的功能，但它有些隱藏。只有在創建和保存ECO之後，文檔圖標才會出現在右上角（圖43）。

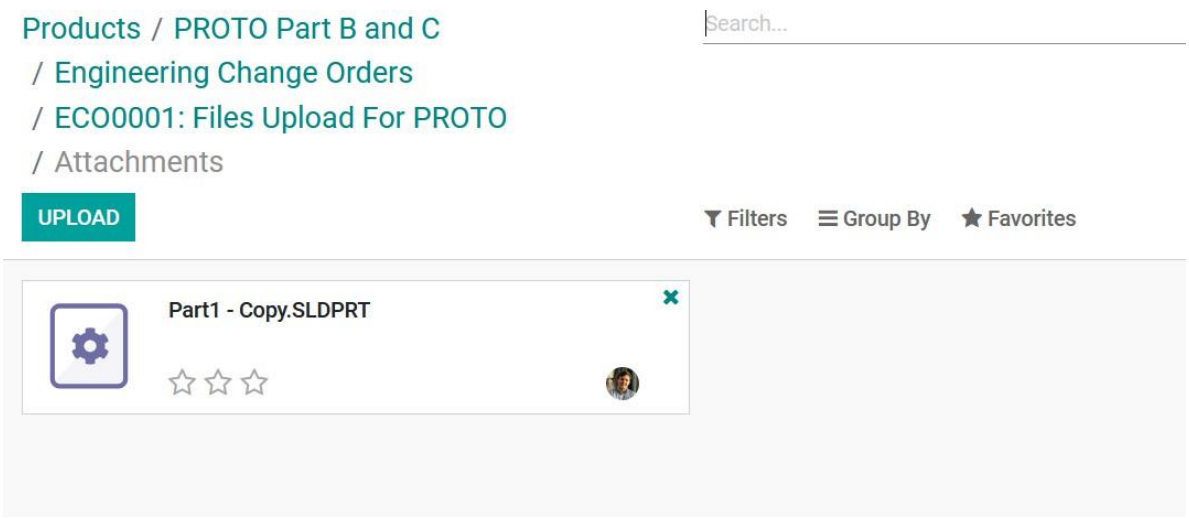

Figure 44 Overview of attached files to ECO
Figure 44 附加到ECO的文件概覽

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.

由於Odoo與CAD軟件之間沒有直接集成，因此上傳文件不會導致產品元數據的自動更改。從PLM的角度來看，這並不理想，但它是一個實現良好的功能。通過允許產品項目直接鏈接到不僅是一個現有的ECO，而且是產品項目曾經應用過的所有ECO的列表，軟件在跟踪版本控制和開發方面表現良好。

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.

為了流程控制的目的，可以做一些有趣的事情是在操作中添加質量控制點。這使得負責人員可以在生產過程中就工程團隊關注的問題提供反饋。在我們的案例中，我們關注的是3D打印扭曲。這是在3D打印過程中溫度變化太大時發生的情況。為此，將創建一個質量控制點項目（圖45），該項目將要求操作員檢查零件是否扭曲並標記通過或失敗。

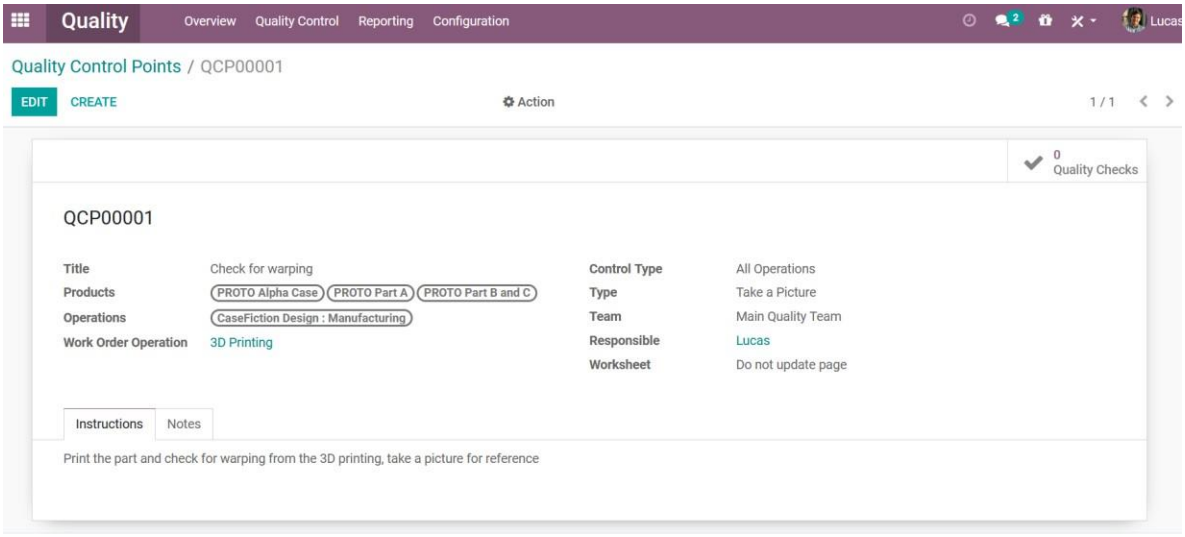

Figure 45 Quality Control Point item for the prototype production

Figure 45 原型生產的質量控制點項目

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.

原型循環的最後一步將是生產用於測試和評估的原型。在Odoo中，生產是一個非常直觀的過程，也是我們之前所做的一切集合的地方。已經創建的元數據和項目使我們能夠開始製造訂單（MO）（圖46）。這反過來從BOM中列出的操作和組件中拉出必要的工單。工單出現在製造操作員的工作中，生產可以開始/被跟蹤。

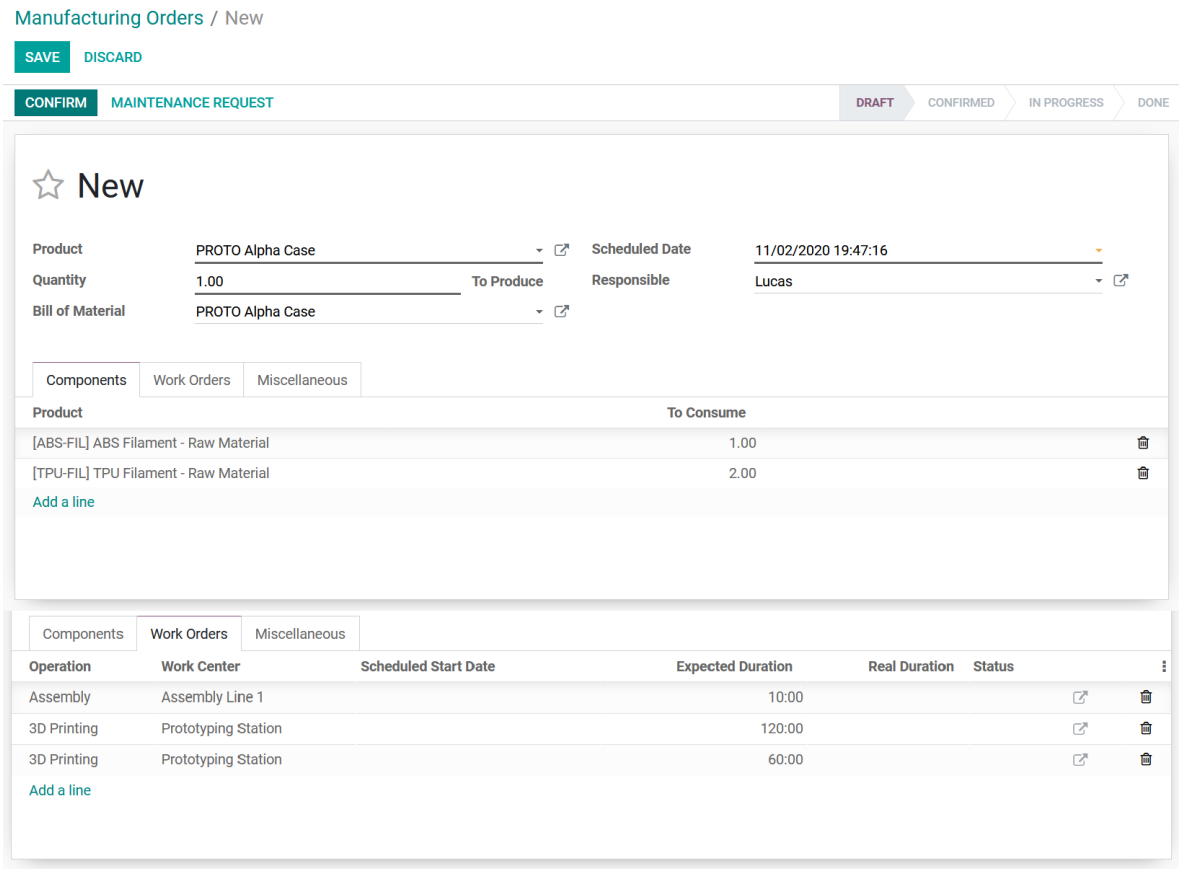

Figure 46 Depiction of the manufacturing order

Figure 46 製造訂單的描述

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).

在很大程度上，這個操作非常自動化和清晰。然而，由於從Odoo V13到Odoo V14的結構性變化，存在一些問題。很長一段時間以來，軟件使用了一個名為“路線”的額外項目類來指定要執行的操作。這些是產品在庫存和製造中移動的基本部分，但出於某種原因，在新版本的製造方面放棄了這一功能，而是改為在BOM中內置了簡化的順序數據。截至撰寫本文時，有報告稱對此功能的使用存在問題和困惑，這些問題更加惡化的原因是解釋這一功能的資料要麼不存在，要麼仍然在參考舊版本的軟件（在這些版本中，“路線”仍然在使用）。

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

熱心的讀者將會注意到在圖47中，操作的提供順序並不正確。這正是由於這個問題，目

only solution is to count on the awareness of the operators regarding the order of productionor manually scheduling the operations in the plan tab. During the period of research for thiswork (before Odoo V14) familiarization experiments were made in which there were noproblem of this nature. In addition, there are examples online even from Odoo websitedemonstrating the use of routes and how they are useful for this exact situation.

唯一的解決方案是依賴操作員對生產順序的認識，或者在計劃選項卡中手動安排操作。在進行此項研究期間（Odoo V14之前），進行了熟悉化實驗，並未出現這種性質的問題。此外，甚至在Odoo網站上都有示例，展示了路線的使用以及它們對於這個確切情況的有用性。

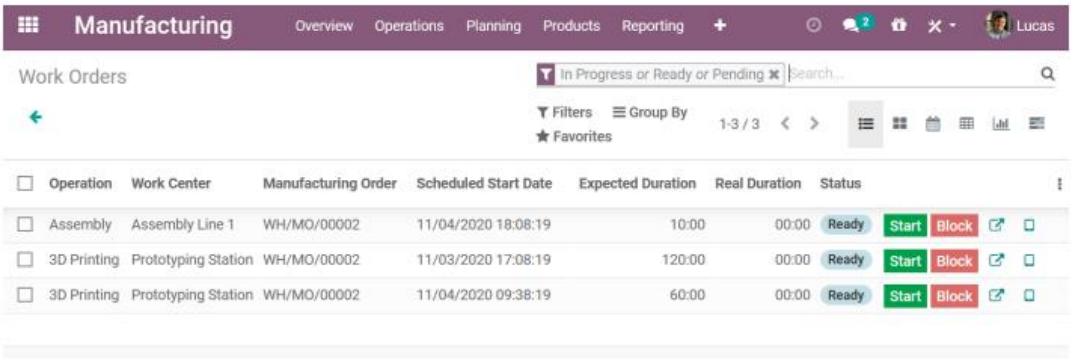

Figure 47 Overview of the resulted Work Orders
圖47 工作訂單結果概觀

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.

這個問題已被其他人（圖48）報告給Odoo公司，希望它會很快得到解決（畢竟這是一個非常新的軟件版本）。儘管如此，即使它只是一個小問題，這仍然是一個問題。

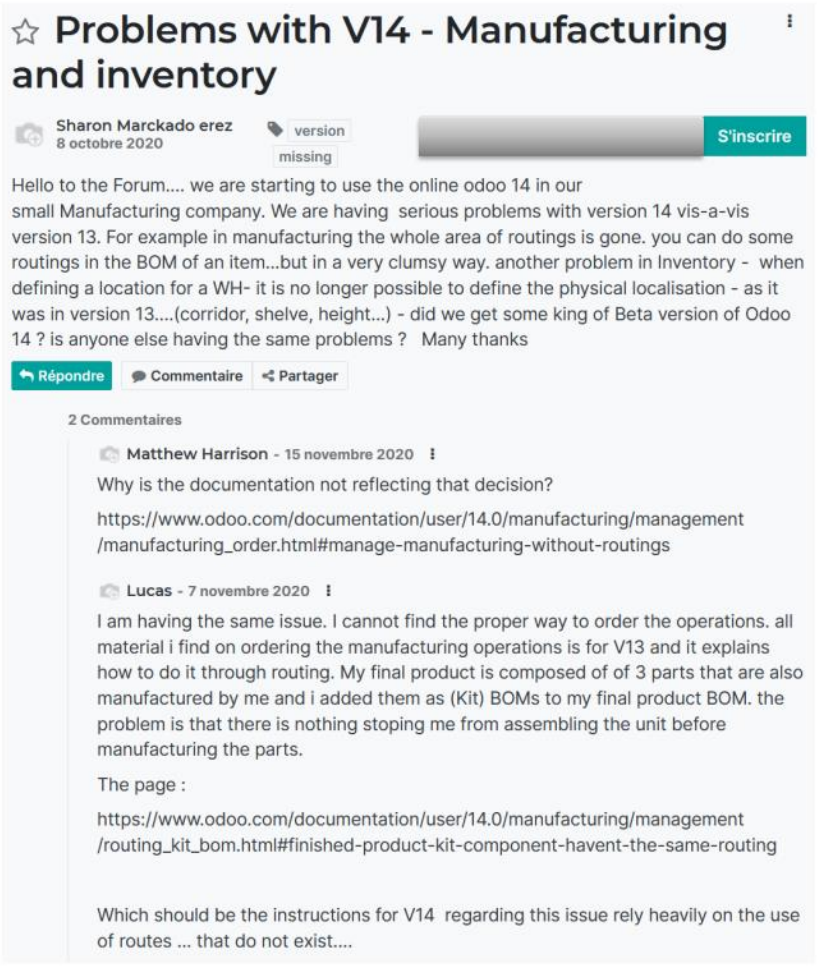

Figure 48 Image of Odoo forum question regarding routes
圖 48 Odoo 論壇有關路線問題的圖片

The manufacturing process was repeated 7 times (Figure 49) to simulate a small batch ofprototypes 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.

製造過程重複 7 次（圖 49），以模擬小批量原型進行測試和公差檢查。
在第一批中獲得完美原型的情況很少見，因此選擇它來代表透過模擬進行修正。
在此模擬中，該問題是一個擬合問題，導致原型 A 部分的尺寸發生變化。

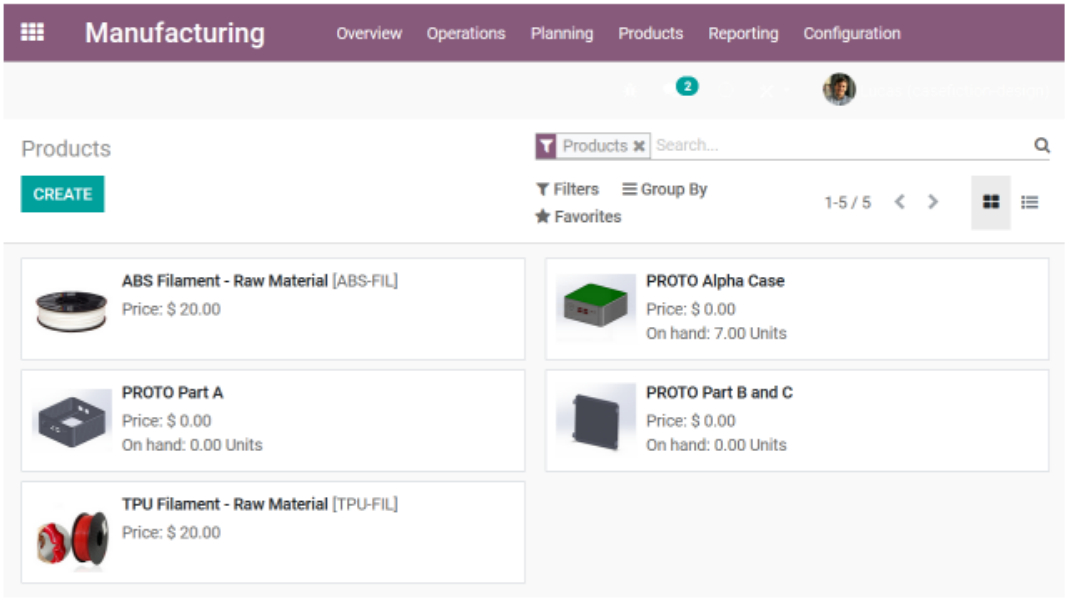

Figure 49

Overview of the products after manufacturing
圖49 製造後的產品概覽

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.

這使我們有機會將 ECO 用於其實際目的、建立和控制產品項目的變更。要進行的變更是在有關產品項目的 CAD 檔案上進行的。 與之前一樣，我們可以啟動 ECO 並填寫描述，然後上傳文件，ECO（圖 50）經過必要的驗證後才會生效。

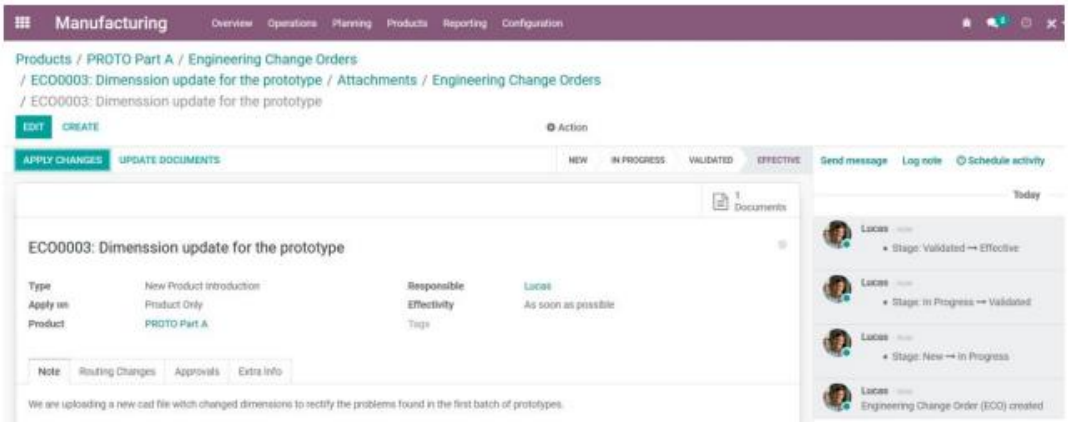

Figure 50 Depiction of the validation of the ECO
圖 50 ECO 驗證描述

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).

驗證程序基本上設定為要求具有適當存取權限的人員或特定人員進行驗證。

在本例中，主帳戶用於驗證並生效，從圖像右側的日誌可以看出。
套用變更後，您可以看到產品項目版本已迭代至版本 2，並且新的 ECO 已新增至連結至該專案的 ECO 清單（圖 51）。

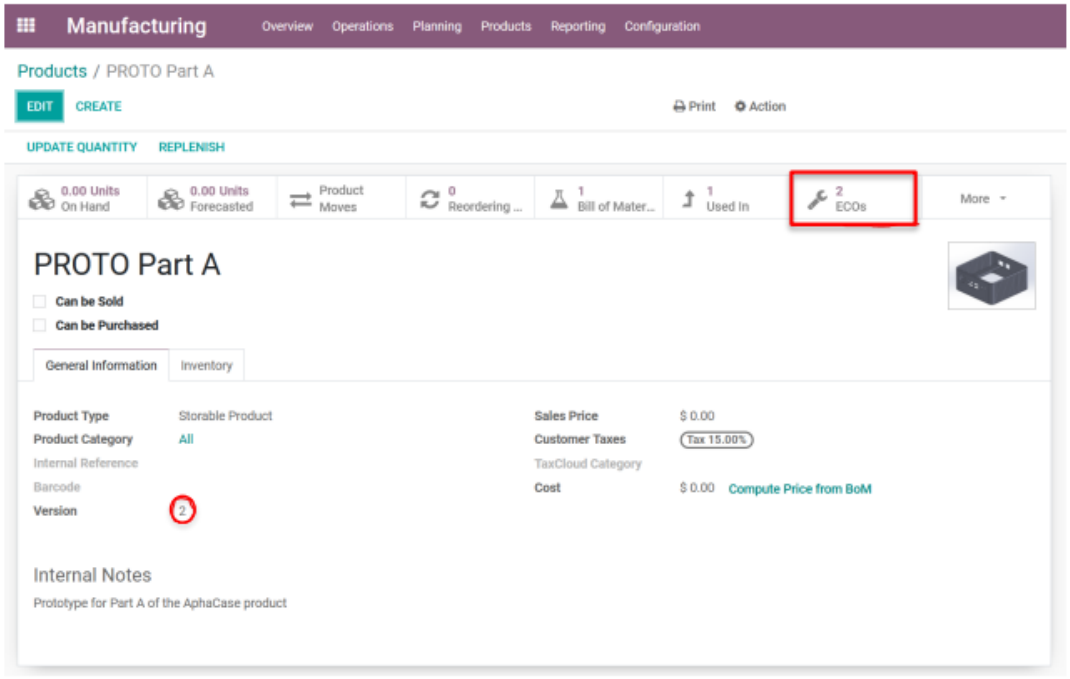

Figure 51 Depiction of changes provoked by the ECO to product item
圖 51 ECO 對產品項引起的變化的描述

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.

更新之後是另一批原型，循環將繼續，直到生產的原型滿足設計團隊制定的標準。
在此模擬的情況下，假設一次校正足以代表該過程。 這就完成了從想法到原型的開發。

5.4.2. Process Plan - Production Test Run – Production
5.4.2. 製程計劃 - 生產 試運轉 - 生產

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).

現在原型階段已經完成，重點將轉移到流程。
如前所述，決定將原型產品與最終產品分開，以將產品與開發過程中的生產流程隔離。
這樣，產品開發的許多方面都可以按順序進行評估。
既然流程已經開發完畢，創建代表最終產品的產品專案似乎是合理的，因為流程成功運作的產品將是其生產就緒的樣品（圖 52）。

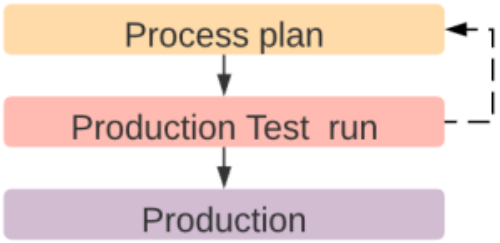

Figure 52 Sectioned diagram regarding Process development
圖 52 製程開發剖面圖

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).

創建的其他產品項目是注塑成型的原料（這些塑膠顆粒被送入機器進行熔化和注射）。所有這些都以與我們創建原型產品時相同的方式完成，除了 Alpha 案例（圖 53）現在被標記為可銷售並且其銷售成本現在是相關的（圖 54）。

Figure 53 Render of how the final product should look like
圖 53 最終產品的渲染圖

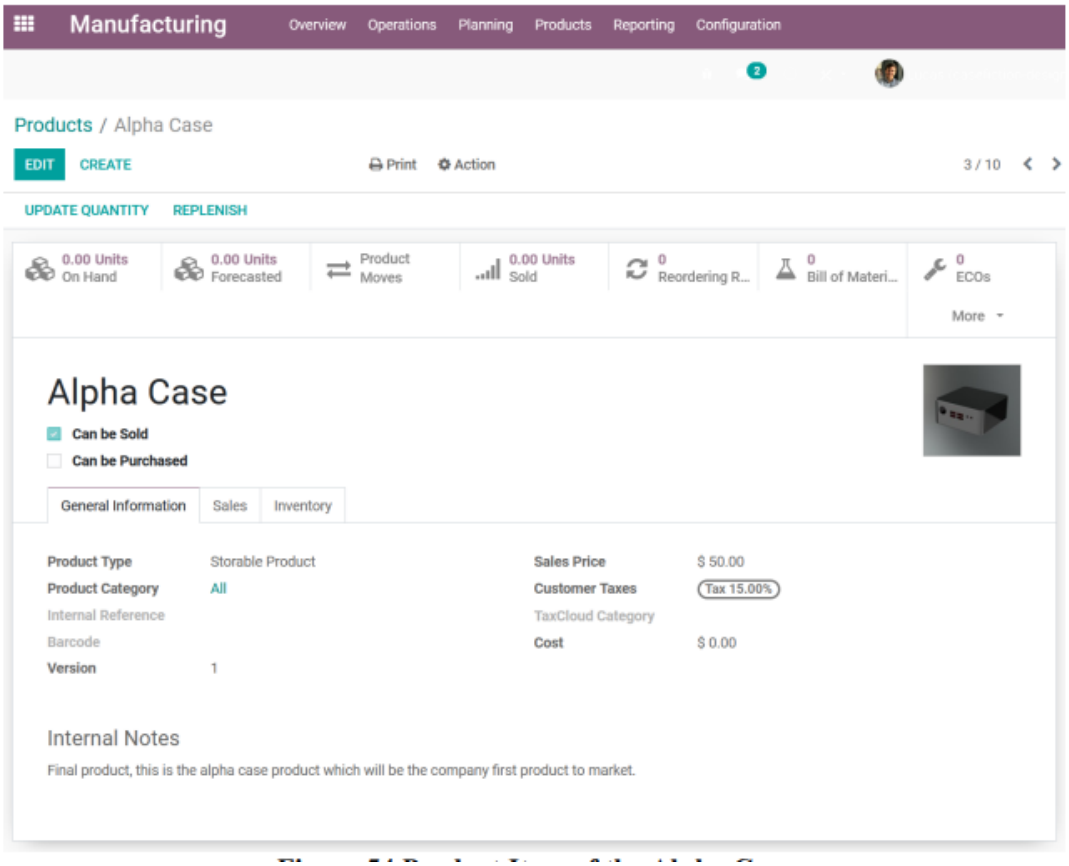

Figure 54 Product Item of the Alpha Case
圖 54 Alpha 案例的產品項目

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).
一旦處理完產品項目，我們需要回到在此模擬的背景下使用 Odoo 追蹤流程的哪些方面。正如之前在談論注塑成型時所暗示的那樣，工藝變化的關鍵方面是機器用來製造零件的模具。對於此模擬，我們認為模具開發將遵循與產品開發非常相似的程序，這一點從下圖中應該更清楚（圖 55）。

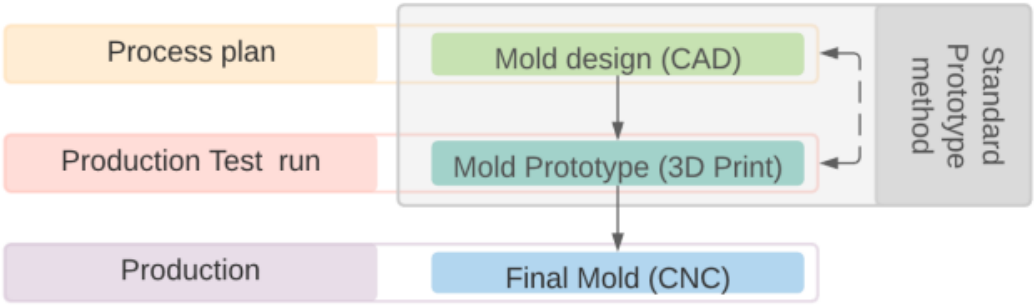

Figure 55 Diagram regarding process development for mold
圖55 模具製程開發圖

The production of a prototype mold by 3D printing follows the same standard procedurefor 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.

透過 3D 列印生產原型模具遵循與產品原型製作相同的標準程序。
到目前為止，模具被認為是與任何其他產品一樣的產品，這揭示了 Odoo
代表整個過程的能力的另一個小弱點。
讀者會注意到，雖然模具被視為一種產品（因為它是製造出來的），但實際上它也應該被視為一種工具或設備。

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.

儘管 Odoo 確實對設備和產品進行了區分，但對於兩者兼而有之的情況，它沒有進行整合。
此外，如前所述，無法將 CAD 檔案上傳到裝置項目或將裝置連結到一系列工具。 IE。 Odoo
不考慮使用具有 x 個鑽頭的垂直鑽頭來製作不同尺寸的孔。
從設備/維護的角度來看，它可以做的最接近的事情是將立式鑽機視為工作站，並且每個鑽機尺寸都是工作站內的單獨設備，並具有指定的設置時間。
如果你忽略了鑽頭是一種產品，這也沒關係。

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.

從 ERP 系統的角度來看，所有這些都是合理的，但從 PLM
的角度來看並不理想，因為它顯示了應該代表同一件事的項目之間的差距。
在製造應用程式的生產中，設置的是工作中心站而不是設備（見圖 41）。
在維護應用程式中，與該工具是消耗品這一事實無關，您可以考慮維護計劃，甚至可以製定使用壽命參數，但因為它是設備，所以您不能在庫存中保留鑽頭等工具像消耗品。

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.

結果是用原型模具來表示測試變得非常困難。

如果您按照軟體設計的方式進行操作，則需要建立一個單獨的
ECO，將模具開發的每個不同迭代的每個操作應用到必要的 BOM 並進行測試運行（圖 56）。
在這一點上，將模具的維護方面視為一種工具是沒有意義的，因為這需要為每個原型模具迭代手動在維護應用程式中歸檔元數據，而從製造角度來看，這不會造成任何差異。
隨著模具的改進，原型模具專案最終僅用於追蹤材料和保存文件。

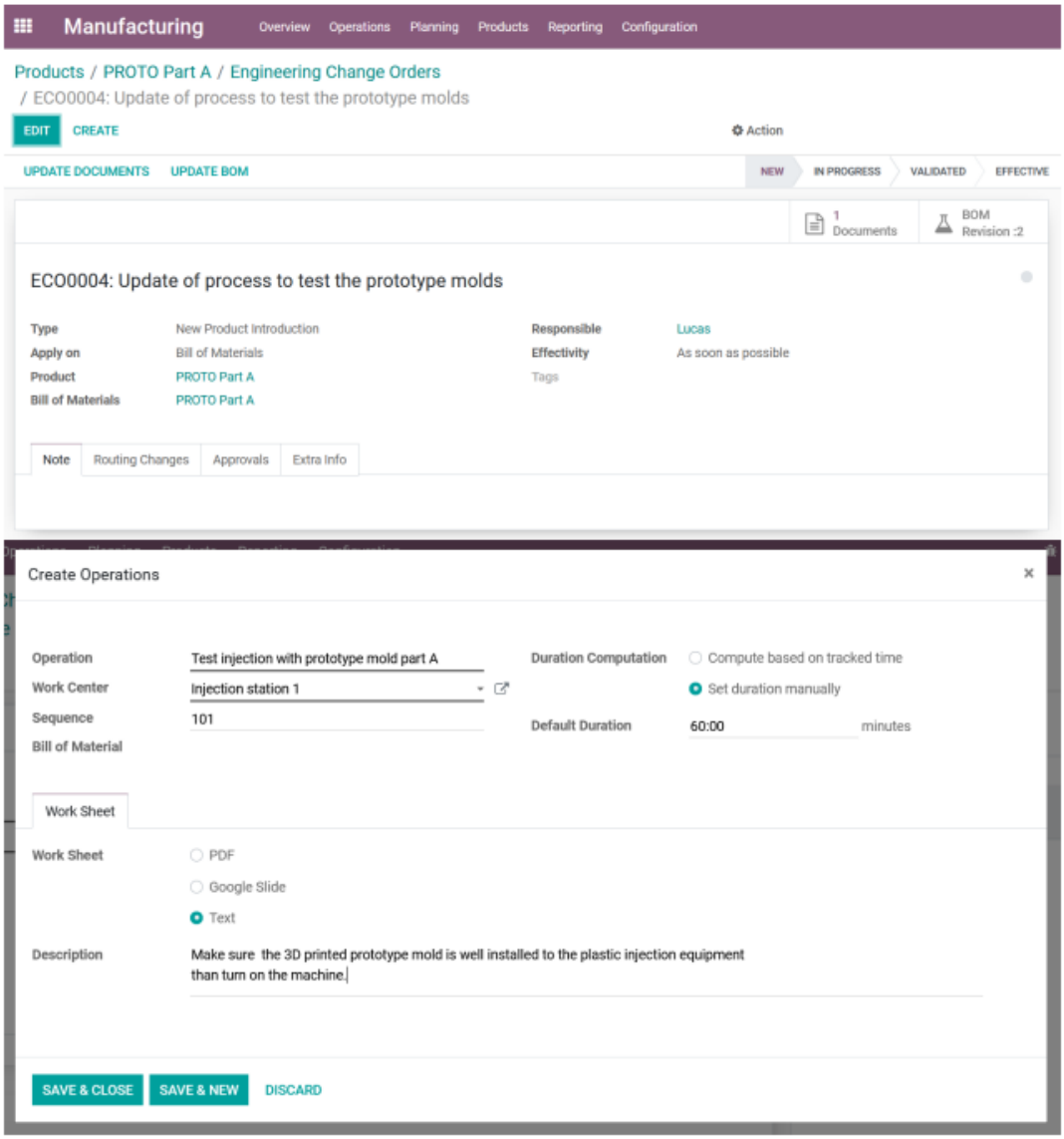

Figure 56 ECO example of update procedure of BOM
圖56 BOM更新流程ECO範例

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

考慮到這一點，在模擬中將為 alpha 外殼的每個部分製作 3D 列印模具。
然後，將創建案例原型零件的 ECO，並將其應用於零件 BOM，更新從 3D

列印到原型模具注塑試運行的操作。

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 60 use the same items. We can do this because those prototypes have already served their purpose.

此時，我們可以透過製作新的原型產品項目來區分產品原型與測試運行原型，但是考慮到我們快速增長的產品項目清單（圖57），我們得出的結論是，在本工作中進行描述會更好修改先前生產的產品原型（透過 3D 列印製作），只有 60 個使用相同的物品。
我們可以做到這一點，因為這些原型已經達到了它們的目的。

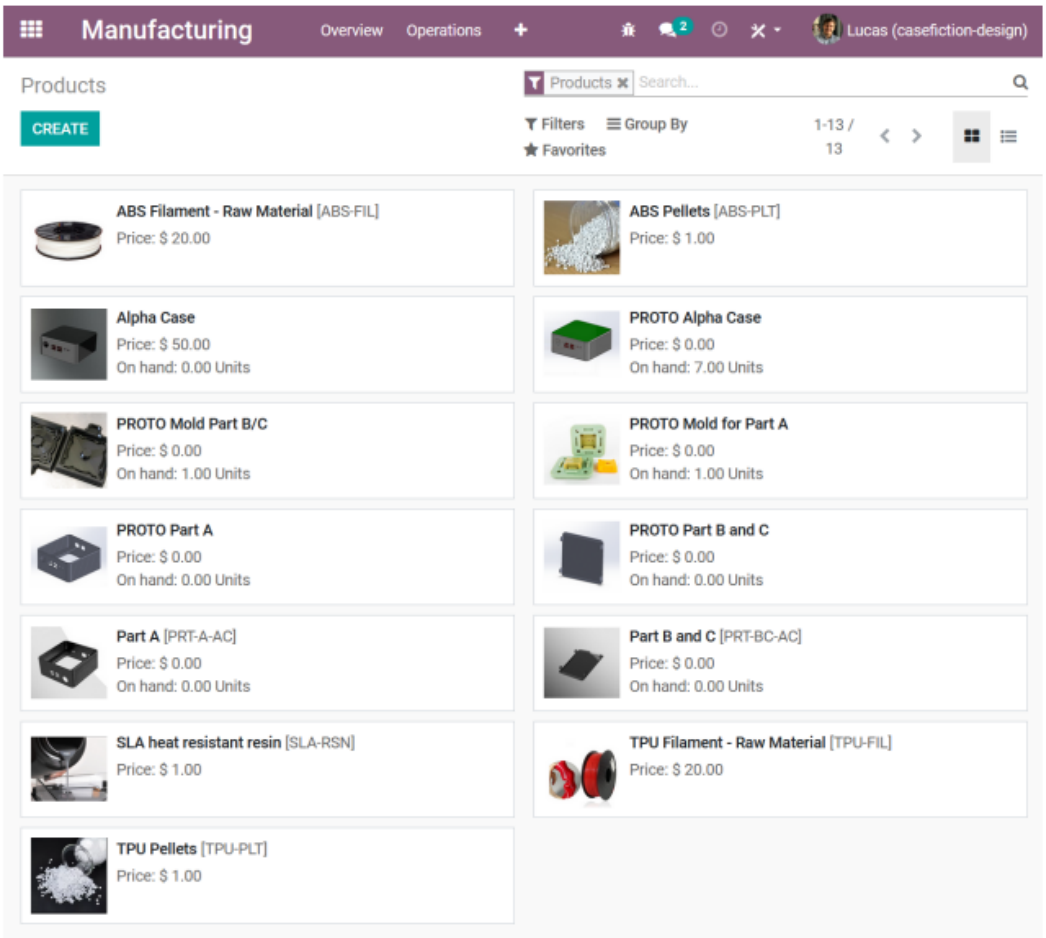

Figure 57 Overview of product items at this stage of the simulation
圖 57 模擬此階段的產品專案概覽

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).

創建模具並更新原型的 BOM

以包括注射站和正確的操作（指定模具的使用）後，下一步是對原型進行生產測試運行。
這也是透過發出完成生成的 WO 的 MO 來完成的（參見上一節的圖 46 和圖 47）。

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.

生產結果用於檢查尺寸和裝配，如果需要修正，將再次發出 ECO，如圖 56 所示，並且將進行新的生產和測試迭代。
這個過程將重複進行，直到產品足夠令人滿意，足以證明用於大規模生產的 CNC 加工模具的生產是合理的。

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.

由於在此模擬中選擇最終模具（由鋁製成）也將在內部生產，因此這是開發的下一步。
程序與以前基本相同，只是需要在製造之前為原材料（鋁塊）和 CNC 模具創建產品項目。 建立 BOM 並上傳相關文件。

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).

最後，新模具可以開始實際生產。 表示創建了 100 個 Alpha Case 的製造訂單。
這標誌著從創意到生產的主要發展路徑的結束（圖58）。

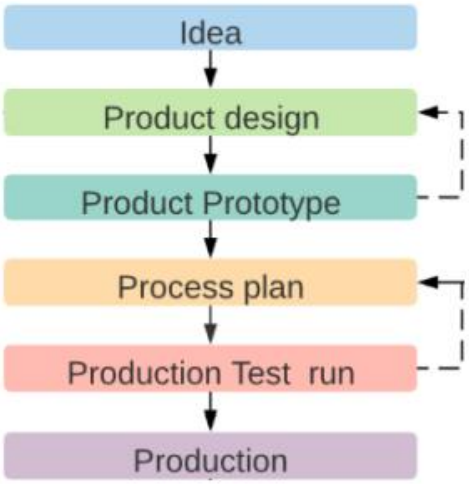

Figure 58 Main path of development from idea to production
圖58 從創意到生產的主要發展路徑

5.4.3. Process upgrade procedure
5.4.3. 製程升級流程

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 utilizingitems 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.

前面的部分介紹了在產品主要開發過程中使用 Odoo 軟體追蹤變更所需的程序。因此，所描述的大部分內容都集中在 PLM 的使用以及創建和利用產品、BOM、ECO、MO、WO 和營運等專案的標準程序。 本節將有所不同，因為現在我們正在進行生產，目的是測試 Odoo 執行升級的能力（圖 59 和圖 60）。
換句話說，訊息（當然還有MES）的表現和回饋成為主要課題。

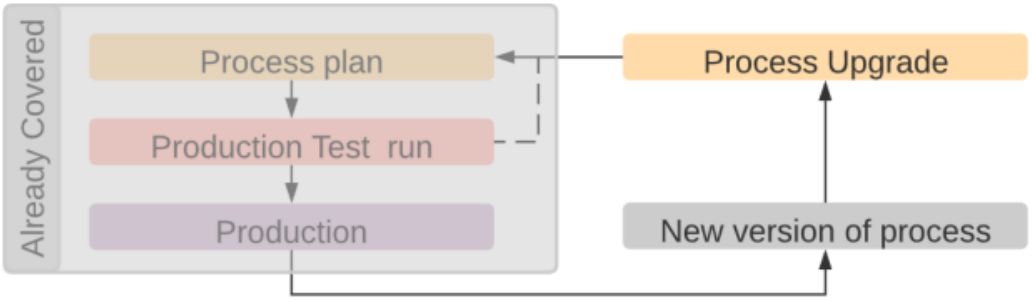

Figure 59 Sectioned diagram regarding Process upgrade procedure
圖 59 製程升級流程剖面圖

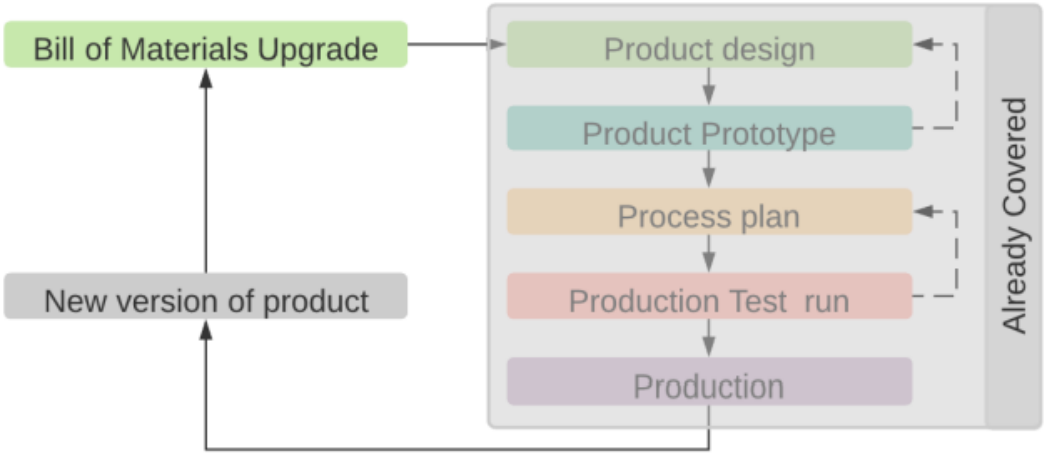

Figure 60 Sectioned diagram regarding Process development
圖 60 製程開發剖面圖

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.

即使在這種情況下，也始終使用 ECO 功能來實施變更。

為了提醒讀者將套用此變更的情況（圖 61）是相關產品項目的產品概述。
此清單中的每個產品項目（不是原材料）至少包含一個 BOM 和兩個已應用於它們的
ECO，以表示每個產品項目的初始狀態（圖 62）。 每個專案的第一個 ECO
影響產品並保存初始相關文件，第二個 ECO 應用於產品的
BOM，以便保存與流程初始狀態相關的文件並記錄 BOM 的初始狀態。 如果沒有這些 ECO（圖
62），當我們應用改進時，產品檔案或 BOM 的初始狀態將會遺失。

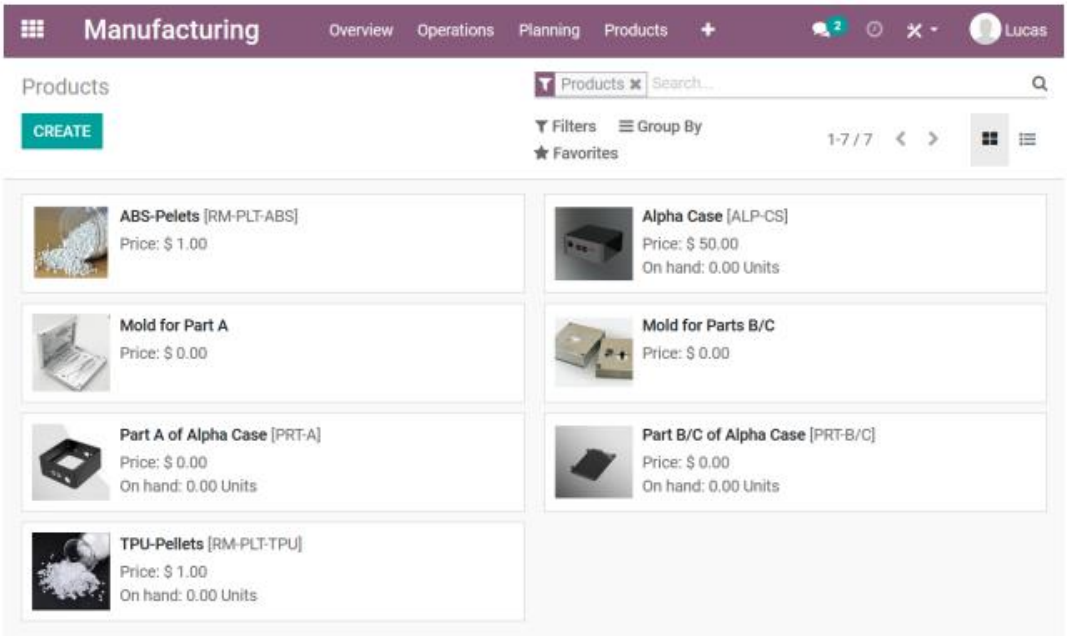

Figure 61 Relevant product items overview
圖 61 相關產品項目概覽

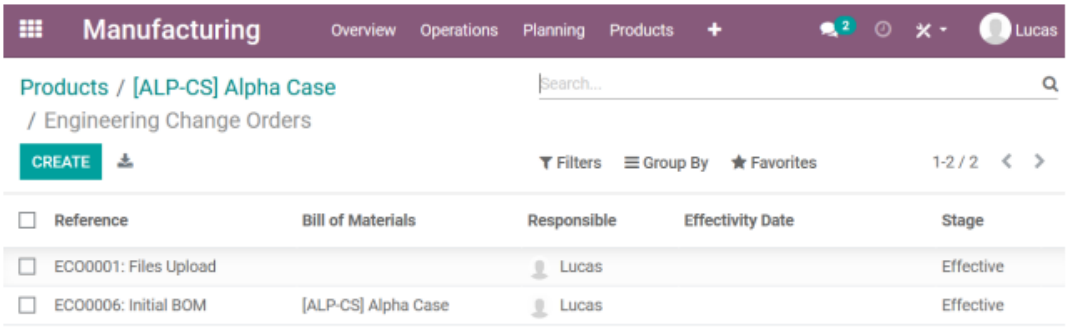

Figure 62 Example of ECOs of a product item
圖 62 產品項的 ECO 範例

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).

這次需要考慮生產持續時間和流程的估計持續時間，以便我們能夠了解流程中應用的變更如

何影響生產。 為此，將建立 50 個 Alpha Case 單元的 MO，每個操作預計需要 30 秒（B/C 部分需要 15 秒，因為需要其中 2 個）。 這意味著在理想情況下，總長度為 50 分鐘（25 分鐘的注射生產並行完成，25 分鐘用於最終組裝）。

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.

在此模擬製造運行中，選擇注射操作需要稍長的時間才能完成，以代表次優性能。 這樣做是為了了解 Odoo 如何反應並即時告知當前情況。

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).

第一階段是在注塑過程中進行的生產工作，同時在注塑站1和2上進行A部件和B/C部件的平行生產。如下圖所示，在過程開始時，生產站的概覽以綠色圓圈表示。這些圓圈的信號被稱為安東（Andon），儘管它並不總是被視為MES的一部分，但它通常是許多MES系統中集成的一個特徵。在生產過程稍有延遲後，圓圈變成了灰色，並且在站點標籤上標記了整體效率為紅色。

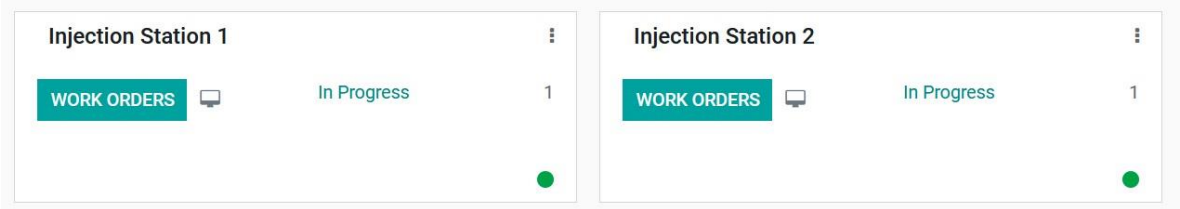

Figure 63 Workcenter overview 1

圖63 工作中心概覽 1

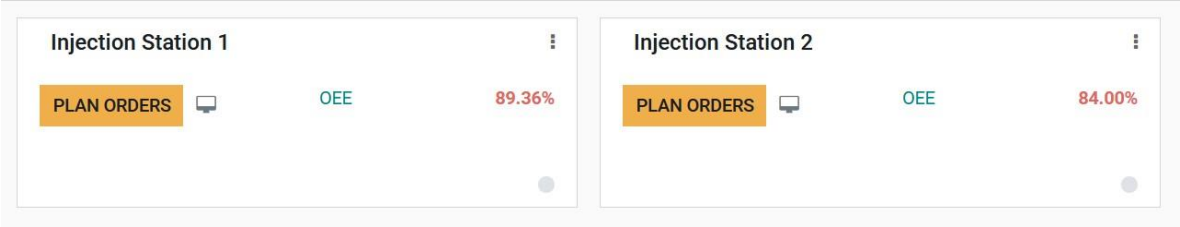

Figure 64 Workcenter overview 2

圖64 工作中心概覽 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).

在進行任何改善之前，生產進行了兩次。首先要進行的改進是在操作和使用的原材料上進行生產過程。更具體地說，是對注塑機進行設備升級的新操作，以及更換注塑過程中使用的塑料顆粒品牌（圖65）。

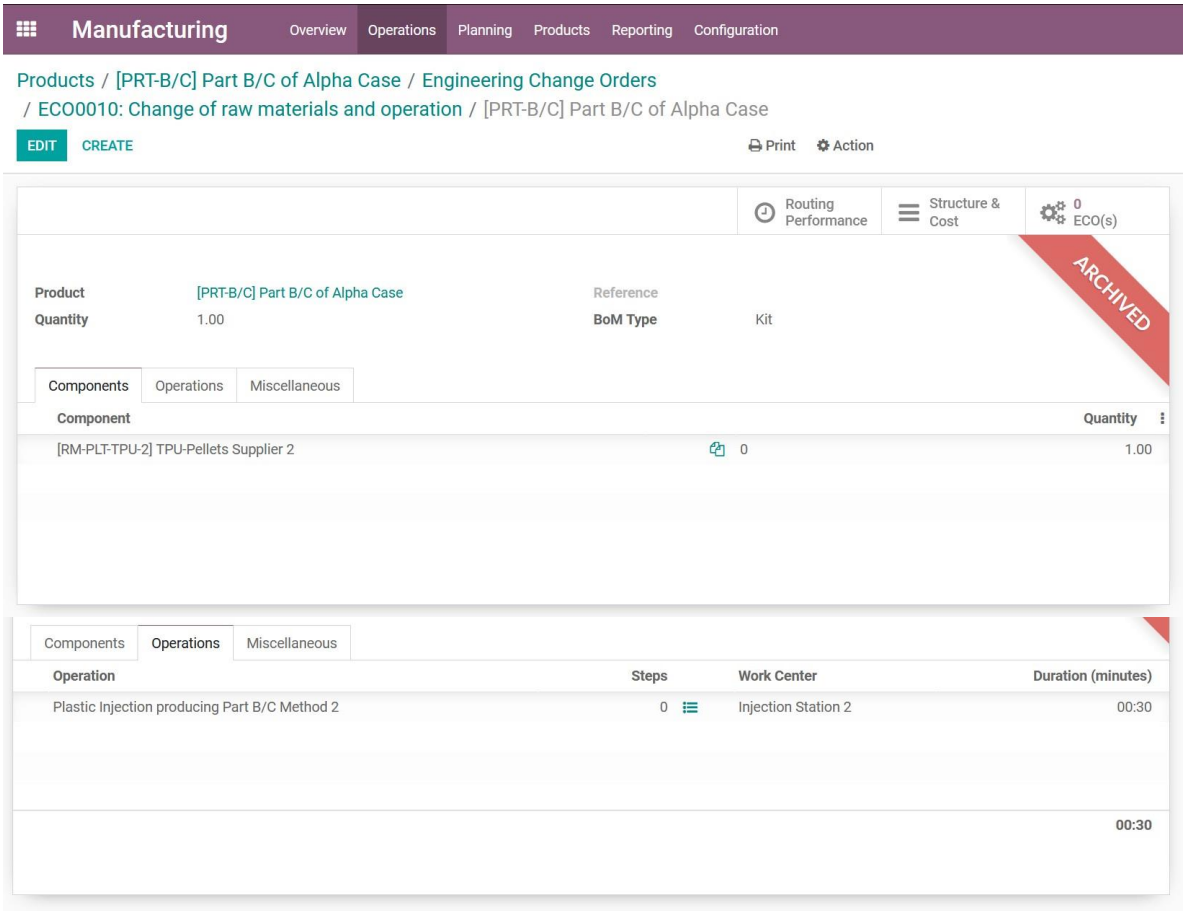

Figure 65 ECO applied to BOM

圖65 對BOM應用的ECO

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):

這些升級措施被應用於Alpha案件的A部分和B部分的BOM，生產重新開始。在進行了另外兩個MOs，每個生產50個產品，模擬對過程進行改善之後，Odoo自動提供了以下類型的數據（表3）：

Table 3 Types of data output

表3：數據輸出類型

Regarding WOs:	Regarding MOs:	Overall Equipment Effectiveness:
-Duration deviation	-Backorder sequence	

-Duration per unit -Expected duration -Quantity -Real duration	-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).

"需要指出的是，關於MO（製造指令）的數據不幸地是按月捕獲的，而不像其他兩個類別那樣按執行的訂單處理數據。這意味著由於這個模擬使用的軟件試用版本僅為14天，該數據的圖形表示提供了一個令人印象深刻的單點或單列的觀點。從長遠來看，這是一種很好的顯示隨時間推移的性能的方式，但在這個模擬的情況下則不然（見圖66）。

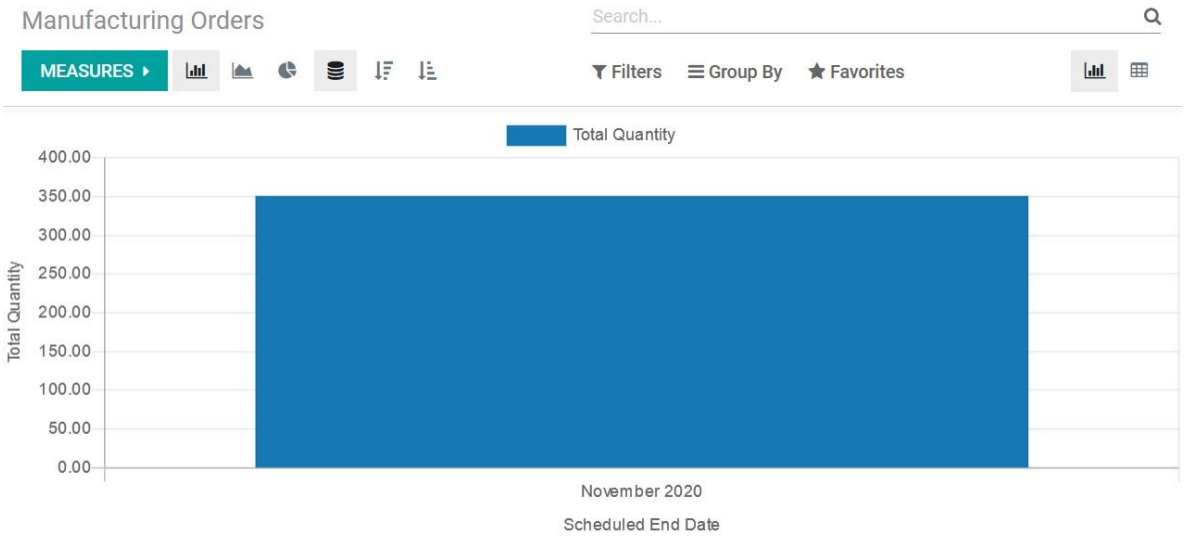

Figure 66 Total quantity regarding MO
圖66：有關MO的總數量

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:

所有可用的數據都可以以柱狀圖、折線圖或餅圖的形式查看，這些圖表是在時間性能被記錄後自動生成的（這發生在對工單進行任何操作的任何時刻）。圖67、圖68和圖69是5個生產運行的結果的示例：

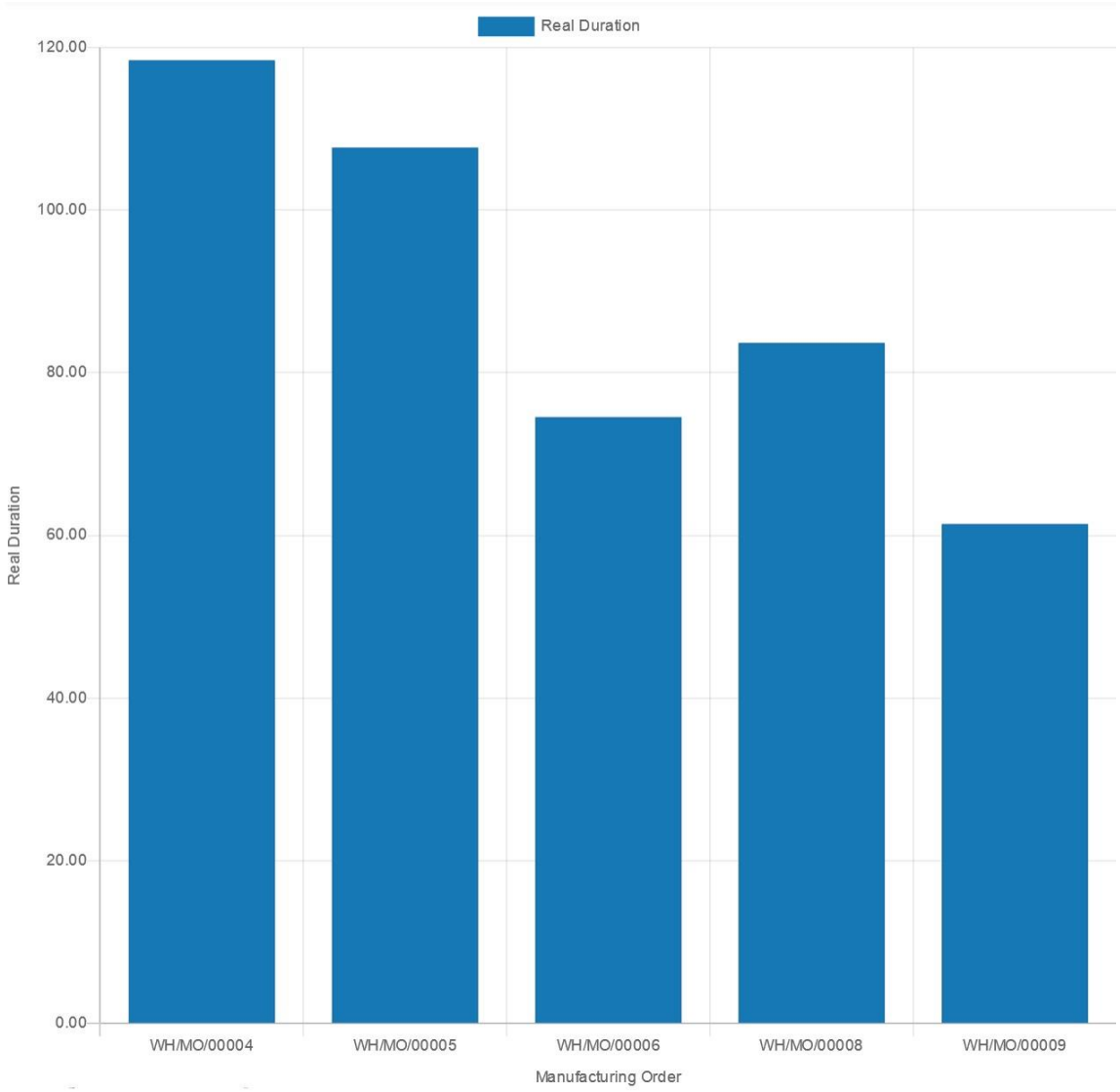

Figure 67 Real duration regarding work orders

圖67：關於工單的實際持續時間

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.

值得一提的是，每當Odoo提到數量或持續時間時，它指的是每個工單的總數量或持續時間（系統不關心操作是否在平行進行）。因此，在我們的模擬中，使用3個操作製造50個單位，每個操作應該需要30秒，理想情況下應該記錄的“持續時間”為每個MO 75分鐘。

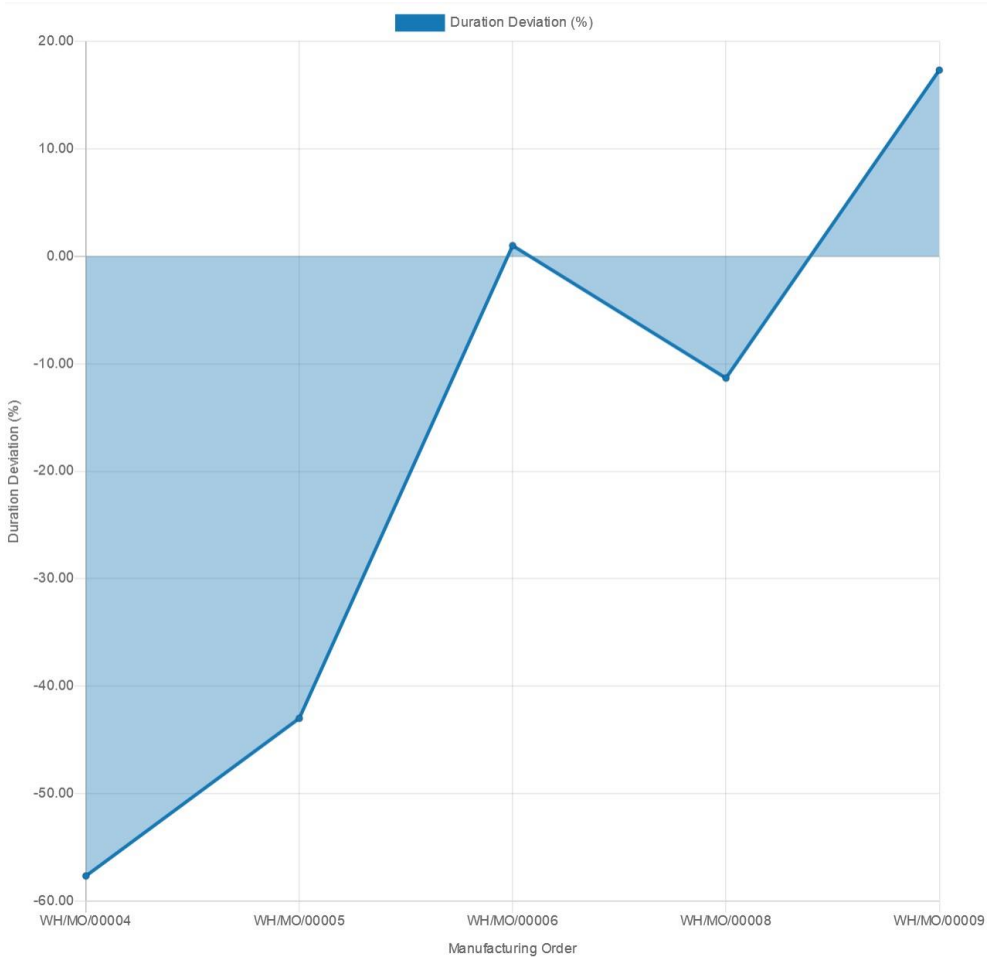

Figure 68 Duration variation regarding work orders

圖68：關於工單的持續時間變化

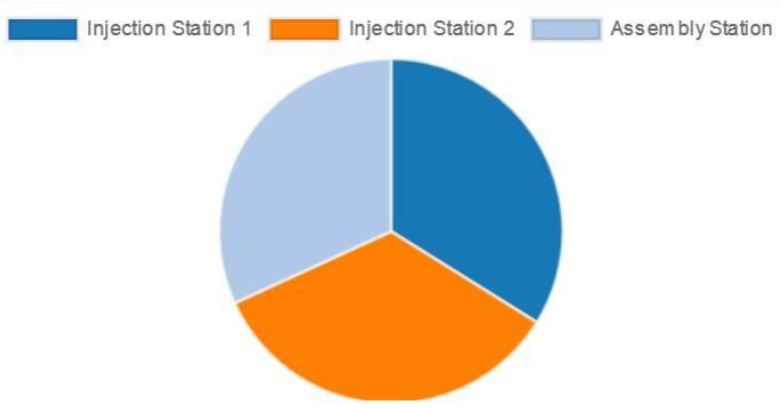

Figure 69 Overall equipment effectiveness

圖69：整體設備效率

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.

細心的讀者會注意到，到目前為止提到的所有數據都是從操作完成所需的時間、MO相關的數量和使用的工作中心中獲得的。儘管如此，仍然令人印象深刻的是可以獲得多少信息，尤其是考慮到這些信息都是自動生成的。

6. CHAPTER

第6章

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.

這一章旨在總結Odoo軟件在產品生命週期管理（PLM）和製造執行系統（MES）方面的優勢和劣勢，重點討論第4.2節提出的問題。它還將評論Odoo在模擬過程中注意到的功能或缺失，同時考慮到這些問題。

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. 該軟件如何處理物品？

總體而言，Odoo軟件向用戶提供了多種數字化物品，可以用來表示製造的各個方面以及業務的其他方面。這主要是由於Odoo ERP功能使用物品來跟蹤其使用過程中的拉動和推動行為，這也是軟件實現自動化的方式。

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.

6.1.1. 產品生命周期的各個方面是否都有所代表？

由於Odoo是從ERP系統衍生出來的一個缺點是，它專注於ERP的主要範圍（見圖2），即生產和銷售。Odoo中的物品反映了這一點。例如，在模擬中的開發生命周期部分，儘管表示是可能的，但肯定感覺像是為生產階段而非開發本身設計的功能拉伸（見圖70）。例如，當開發原型時，許多步驟，例如創建一個早期僅用於攜帶文件的ECO，並且每次對原型進行調整時都要經過許多步驟，這種感覺過於官僚或者說是一種繞道行事的方式。

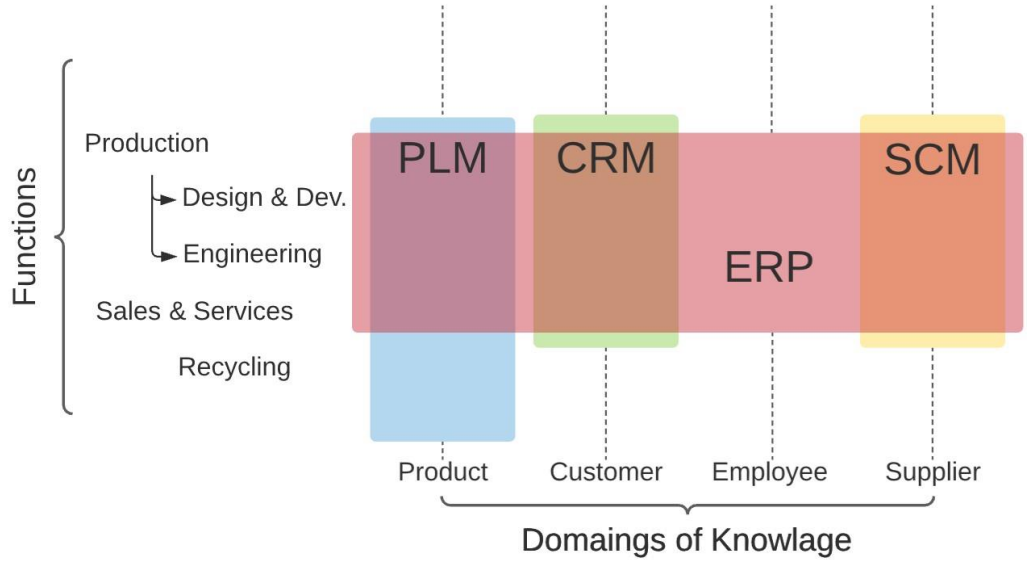

Figure 70 Diagram representing Odoo scope of ERP

圖70：代表Odoo 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

6.1.2. 每個項目的代表程度如何？

這些項目的代表程度取決於該項目的使用方式。產品項目的材料焦點是一個很好的例子。從產品原型或原材料之間幾乎沒有區別的角度來看，一切都被視為產品。產品項目或BOM項目的代表程度非常高，具有大量的元數據和與其他項目的有用連接。然而，即使在製造應用程序中，也有一些項目缺乏關注。例如，操作項目是可以從更多上傳功能中受益的項目，比如3D打印或CNC文件。隨著自動化在生產中變得更加普及，僅具有PDF或幻燈片說明已不再足夠。此外，其他項目甚至無法保存文件，即使使用ECOs也無法。

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. 創建全新產品有多容易？

在Odoo中，產品創建是最直接的程序之一，它主要是使用庫存應用程序或製造應用程序來

創建新產品，然後填寫其元數據。

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.

6.2.1. 產品如何描述？

產品描述清晰而簡潔，產品項目允許上傳圖像並將其用作圖標。Odoo中產品項目的ERP性質意味著元數據基本上偏向於用於管理存儲和庫存的信息（重量、體積、數量等），但該項目還允許編寫描述，並提供與產品相關的BOMs和ECOs的鏈接。

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.

6.2.2. 產品如何整合和參考相關文件？

在允許最有價值的項目（產品和BOMs）管理和參考相關文件方面，Odoo確實做了合理的努力。然而，Odoo在文件管理方面實施的幾乎僅限於最低限度。它最多只能允許手動上傳和下載文件。這意味著每當有人更改文件時，需要手動將其上傳到ECO中。與大多數文件的整合幾乎不存在，除了操作項目外，因為在生產過程中可以在Odoo中打開並與之交互的指示文件。

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.

6.2.3. 改變一個是否會影響另一個？

不會，Odoo主要將文件視為以後參考的文件。任何添加文件的操作，如果可能會導致產品或BOM元數據的變化，都需要有人意識到這一變化並手動更新信息。

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. 創建全新生產流程有多容易？

如前所述，最能代表流程的項目是物料清單（BOM）。此項目類別需要與現有產品關聯，除此之外，創建BOM並不比產品項目更難。

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.

6.3.1. 流程如何描述？

流程在BOM中被描述為一系列組件（其他產品項目）和按特定順序進行的操作，以生產一定數量的最終產品。這種表示似乎與生產程序相得益彰。元數據被保持在最低限度，但仍具有提供文本描述的能力。

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.

6.3.2. 流程如何整合並參考其所產生的產品？

在Odoo中，BOM和產品項目之間的整合是最好的。對BOM所做的更改會影響生產並直接關聯到產品。每當元數據的更改是可能的且該方面也在產品項目中表示時，一個的更改會被另一個繼承。

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.

6.3.3. 改變一個是否會影響另一個？

就庫存和製造而言，整合和參考都實施得很好。生產在庫存的變化和GUI的導航路徑上都無懈可擊。從一個產品到另一個產品或導航到其他相關項目不需要超過3或4次點擊。

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. 改善現有產品/生產流程有多容易？

如前所述，Odoo中的所有改進都是使用工程變更訂單進行的。這些應用於產品項目或物料清單。創建ECOs相當容易且有組織性，ECO本身代表著一個創建變更的信號，一旦生效，它就代表著對產品或流程的增量。

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.

6.4.1. 更新其元數據有多容易

在Odoo中更新任何項目的任何元數據都很容易；但是，值得指出的是，由於ECOs是單獨的項目，僅僅是副產品或BOM，許多變更並不是自動的，需要手動干預。例如，ECO不會更改產品的文本描述。如果新更新需要更改該描述，則需要用戶手動在產品項目中進行干預。這樣做很容易，但這是一項額外的任務，並不會被ECO跟踪。

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.

6.4.2. 確定變更影響有多容易？

Odoo的信息反饋主要是基於製造訂單的。可用的信息很清晰，而且ECO不會影響已經進行中的MOs，因此應用ECO的影響不難察覺。然而，值得指出的是，在性能信息顯示的方式中，沒有顯示產品版本或應用的ECO的指示。這意味著用戶首先需要確定應用ECO的時間，然後才能在數據中找到相應的MO來做出結論。雖然對於最近的更改並不是問題，但如果有人想要分析舊更改的影響，這就變得有問題了。

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.

6.4.3. 軟體如何處理不同的產品版本？

版本控制是通過產品/BOM和相關ECOs之間的1到N關係很好地解決的。每個產品都將有一個標籤，其中包含按時間順序應用於它的所有ECOs，有效地作為代表項目演變的時間軸。

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).

6.5. 找到與產品或流程相關的數據有多容易？

關於生產的性能相關數據大多集中在報告選項卡下，如前一章中

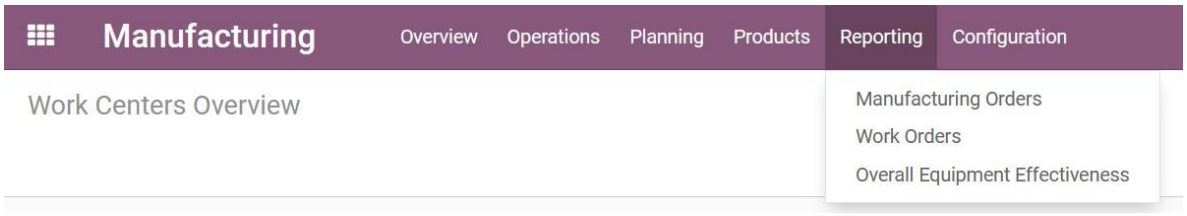

Figure 71 GUI Options of data reporting

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

Figure 72 關於產品項目的MO總數

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.

6.5.1. 找到生產數字有多容易？

除了之前提到的方法外，Odoo還提供了一個單位預測圖，記錄庫存的進出情況。這對於估計銷售並平衡存儲和需求特別有用（見圖73）。這個功能在這份工作中沒有被提到太多，因為供應和需求不是MES功能的重點，但是這對於獲得生產概況非常有用。

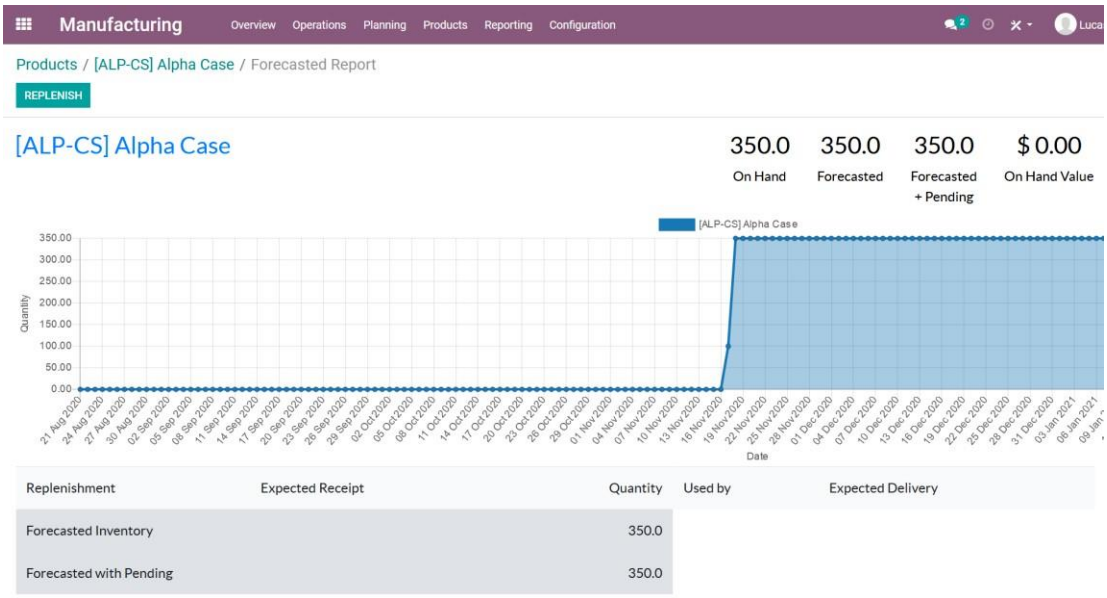

Figure 73 Unit forecast overview

Figure 73 單位預測概況

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.

6.5.2. Odoo是如何生成性能數據的？

細心的讀者會注意到，到目前為止提到的所有數據都來自於操作完成所需的時間，與MO相關的數

量以及使用的工作中心。即便如此，尤其考慮到所有數據都是自動生成的，可以得出如此多的信息仍然令人印象深刻。

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.

6.5.3. 軟件如何展示升級導致的性能變化？

為了識別變化，用戶必須在變化後識別MO，然後根據此來查看差異。理想情況下，如果圖形信息顯示了產品的修訂，那將會很好，但是截至Odoo V13，這一點尚未實現。

CONCLUSION

結論

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.

在第二章中，我引用了一幅圖表，代表了PLM與其他系統整合的理想模式（見圖74）。在該圖中，讀者可以注意到，理想情況下，PLM應該是系統的中心，其他系統（包括ERP）附加在其上。與該圖不同，Odoo軟件將ERP視為中心，其他系統附加在其上。這項工作顯示，確實可以使用Odoo進行PLM和MES，但也顯示了PLM和MES實施存在一些弱點。

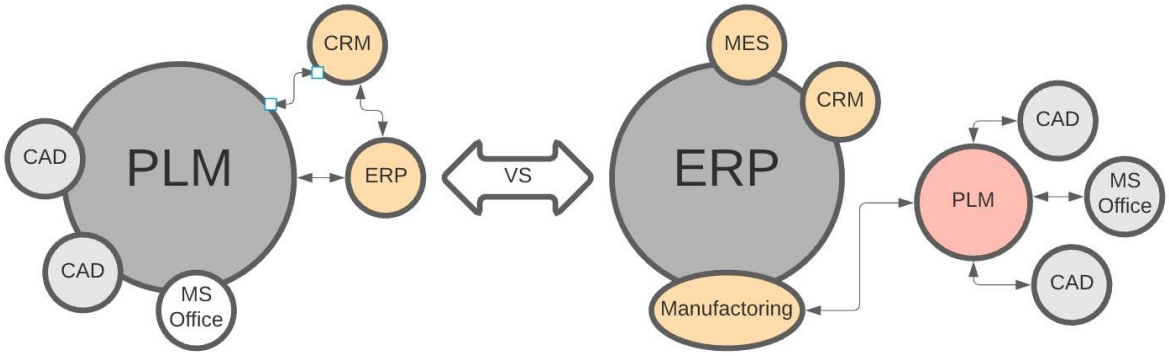

Figure 74 Comparison to the left the adapted diagram as theorized by Saaksvuori, A. and Immonen, A. (2008), to the right Odoo take on how systems interact.

圖74比較左邊是Saaksvuori, A.和Immonen, A.（2008）理論化的調整後圖表，右邊是Odoo對系統互動的看法。

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).
在操作項目、工作中心或設備等方面缺乏文件上傳支持，尤其是考慮到3D打印或CNC時，對CAD文件的訪問將對操作員有所幫助是一個值得關注的問題。此外，當公司自行開發和生產工具（類似情況發生在模擬中開發模具時）時，產品和工具之間存在一個差距。
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.
此外，雖然MES提供了有關其數據集的詳細圖形表示，但僅限於從完成操作所需的時間中衍生的數據。例如，如果關於質量控制的圖形表示也容易獲得，那將非常有價值。

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.
總之，在Odoo中將ECOs應用於BOMs是值得稱讚的程序。ECO保持信息，直到準備應用並且由負責人員驗證ECO後，它會自動更新BOM。現在可能看起來不像什麼很重要，因為這個模擬正在處理非常簡單的產品，但隨著複雜性的增加，它變得越來越重要。例如，擁有數千個零件和數百個嵌套BOMs的汽車，如果沒有此類系統，將被視為難以控制且難以追踪變更的噩夢。

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.

這個軟件在PLM或MES的實施方面並不完美，但在可用性和與其他系統的整合方面具有價值。特別是在產品和流程方面，軟件具有極具吸引力的整合性，與其自然的ERP功能相結合。所有這些都構成了一個更適合的系統：
- 小型企業可以在較小的規模上使用PLM和MES。
- 那些處理較少製造而更多組裝或分銷的公司，可以利用軟件的一體化特性。

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.

值得一提的是，Odoo的限制不在於產品本身的複雜性，而在於其開發周圍操作的複雜性。綜合考慮所有因素，如果裝配包含的僅是簡單的製造操作，或者更複雜的工程任務由供應商完成，那麼你可以追踪一個大型而複雜的裝配。換句話說，在Odoo中輕鬆追踪摩托車的裝配，但PLM功能不夠完善，無法追踪其動力傳動系統的完整演變/開發。當然可以做到這一點，但從工程團隊的角度來看，為了獲得一個全方位的解決方案並帶有ERP功能，這將需要太多的時間和精力，而不值得僅僅為了這個目的而這樣做。

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