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POLITECNICO DI TORINO

對於 ODOO 軟體在產品生命周期管理、製造執行系統及其整合能力的分析

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

AND THEIR INTEGRATION

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0.2 摘要

ABSTRACT

ODOO 軟件在產品生命周期管理和製造執行系統方面的能力及其整合分析

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

20 世紀下半葉以電腦技術在生產的各個方面的進步而著稱

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

該陳述的關鍵特徵是，隨著計算能力的增加所帶來的複雜性增加，信息量也越來越龐大

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要，出現了幾個系統，重點是利用這些寶貴的數據資源

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.

從管理角度來看，ERP (企業資源規劃)、從生產角度來看 MES (製造執行系統)，以及更近期的 PLM (從戰略發展/重新開發角度來看) 等，作爲信息解決方案，從不同角度解決這一問題。然而，這些解決方案雖然有效，但始終受到實施這些系統的工具之間基本不兼容性的困擾

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.

本文的目標是從理論角度分析 PLM 和 MES 系統的整合，並評論使用 Odoo 軟件工具來實現該整合

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.

Odoo 軟件被詳細描述了 (關於其在製造環境中的使用)，包括它如何實現 PLM 和 MES。然後，軟件被用於模擬一個虛構的公司，該公司設計符合工業 4.0 的模式。這家公司是一家虛構的新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爲其業務策略的一部分

The Odoo software was described in detail (regarding its use for manufacturing environment) 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. 關鍵字: 產品生命週期管理

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

Contents

0.3 縮寫詞列表

LIST OF ACRONYMS
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：智能製造系統 (Cyber Physical System)
IoT：物聯網 (Internet of Things)
DT：數字孿生 (Digital Twin)
GUI：圖形用户界面 (Graphical User Interface)
CNC：電腦數控 (Computer Numerical Control)

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0.4 引言

INTRODUCTION
1. 章節
1. CHAPTER

0.4.1 目標

1.1. Objective

本論文的目標是通過分析不同概念和動態來找出可以使用現成的 Odoo 軟件實現 PLM+MES 系統的程度，並應用虛構情境來確定這些概念中是否包含在該套裝解決方案中

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.

爲了將情況置於背景中，Odoo 軟件在實施和商業模式上與市場上的其他解決方案有著顯著的不同。簡而言之，Odoo 軟件最初是作爲開源的 ERP 軟件而非 PLM 或 MES 軟件而產生的，因此其可用性和模塊化程度都得到了合理的擴展。不用說，這種情況的反面是，它在 PLM 或 MES 領域的可用性是不確定的，因此本工作的價值就在於此。

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

具體而言，從小型製造企業和初創企業的角度來看，實現 PLM-MES 系統的全面 ERP 概念非常有價值。儘管 ERP 系統在某種程度上是可用的，但它們很少深入到製造領域以擴展成 PLM 或 MES 解決方案。此外，另一個方向也很重要，因爲 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

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.

雖然修改軟件不在本工作的範圍內，但該軟件有開源社區版本的事實意味著即使對於最特定的情況，也可能更容易且成本更低地適應軟件，進一步強調了這款軟件在小型企業背景下的可能實用性。

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.

最終，論文將就如何進一步開發該系統提供理論和實踐建議。它還將爲未來對 Odoo 軟件的研究奠定基礎，通過確定 PLM-MES 集成和實施的特定關鍵方面，檢查解決方案的表現。

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.

0.4.2 結構

1.2. Structure

這項工作可以作爲小型製造企業中所描述解決方案的實際實施的參考，並且它可以被視爲 PLM-MES 及其實施的入門材料，以及對其首要原則和對 Odoo 軟件當前狀態的審查。爲此，本論文提供了以下結構：

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:

Chapter 1 - 引言介紹了本論文的內容和目標。此外，它提供了簡要解釋，說明爲什麼這種軟件解決方案首先需要這種分析，以及如何組織這種分析。

Chapter 2 - 本章介紹了 PLM、MES、ERP 和工業 4.0 的基本理論背景。這些理論被提出，以便在進行這種分析時做出有意義的貢獻，同時爲如果讀者是小型企業代表，提供有意義的背景。

Chapter 3 - 本章涉及 PLM 和 MES 系統之間的整合，這是根據先前的研究討論的，也是本論文所分析的內容。這對於確立在分析 Odoo 軟件時所涉及的概念和動態是有用的。

Chapter 4 - 介紹了虛構公司和產品，這些產品是基於工業 4.0 的模型選擇的，將用於對 Odoo 軟件進行進一步分析和評估。

Chapter 5 - 介紹了 Odoo 軟件，並更深入地解釋了其用途和功能。考慮到所有前幾章的描述，詳細描述了對 Odoo 軟件的實驗。

Chapter 7 - 結論：最後一章描述了工作的要點：中型企業如何通過知情地使用 Odoo 軟件實施 PLM+MES 系統來改善其流程。

Chapter 1 - Introduction to this work and its objectives. Furthermore, it provide a succinct explanation of why this software solution requires this sort of analysis in the first place and how it was be structured. Chapter 2 —This chapter introduce the

basic theoretical background to PLM, MES,

ERP and Industry 4.0. These are presented in order to create the grounds to a meaningful contribution in this kind of analysis as well as providing meaningful context for its implementation in case the reader is a small business representative.

Chapter 3 —This chapter is all about the integration between PLM and MES systems as discussed by previous works and as was be analyzed in this work. This is useful to

stablish the concepts and dynamics that are the subject when analyzing the Odoo software.

Chapter 4 —Introduction to the fictional company and products chosen in the molds

of Industry 4.0 to be used in the further analysis and evaluation of the Odoo software.

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

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

0.5 理論背景

THEORETICAL BACKGROUND
2. CHAPTER
第二章

本章是對於圍繞著生產數據收集和處理概念的不同系統進行簡要介紹，這些系統被學術界以及當前和未來工業認爲是不可或缺的，因爲它們旨在增強生產的各個方面。

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.

從這部分很重要的一點是，這些系統並不是完全獨立的信息系統。它們從不同的角度開始，並試圖解決不同的問題，但由於廣泛的定義，它們不可避免地會相互擴展。這本身就是一個問題，因爲從現有的文獻中很難確定一個系統的邊界在哪裡，另一個系統從哪裡開始。

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.

Odoo 管理軟件（本文的研究對象）主要將 PLM 視爲跟踪變更和改進的工具，而 PLM 的其他關鍵特徵，例如使用數字項目（稍後在第 2.1 節詳述），是物料需求計劃的基本特徵，這也是一種涉及 MES 的工具。

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.

0.5.1 產品生命周期管理

2.1. Product lifecycle management 任何個人或團隊所產生的信息都是通過一個實證

創造過程完成的。一個任務需要先前的知識/經驗，否則它將不可避免地受到錯誤和更正的困擾，這反過來又需要時間和資源來獲得相應的經驗。傳統上，這種經驗通常嵌入在首次生成信息的人力資源（員工）中。

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.

產品生命周期管理（PLM）是一個組織過程，旨在控制產品在整個生命周期中的所有方面的信息流動。正如大家可以想像的，這個定義及其廣泛的範圍並不會讓人更容易理解 PLM。對於所有目的來說，重點是 PLM 眞正的價值在於涉及變化的方面。

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

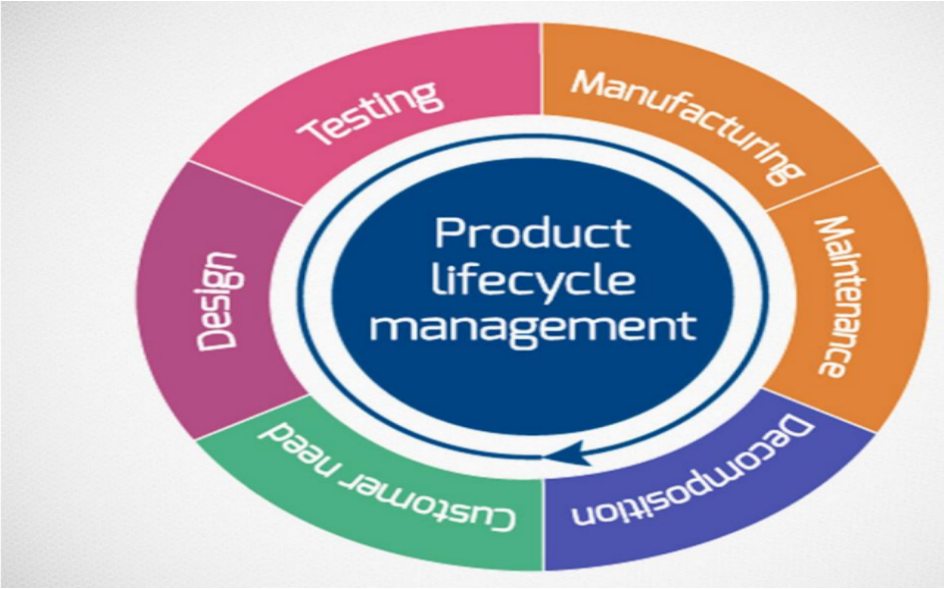

Figure 1 Product lifecycle stages (Tripaldi, 2019)
圖 1 產品生命周期階段（Tripaldi，2019）

PLM 最重要的是一種連接技術，而不是一個獨立的技術島或信息處理系統（Saaksvuori 和 Immonen，2008）。其理念是公司人員生成的每一個信息都具有相當於所投入時間和金

錢的價值。利用這些信息可以省錢，不利用這些信息會浪費金錢。這一點在設計過程中更容易理解。

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

例如，如果一位工程師設計了一個電子電路，保存 CAD 圖紙的文件的價值等同於投入其中的時間和金錢。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，其中包含的內容以及可能的用途的程度。然而，從公司其他部門的角度來看，這只是數據庫中的一個文件，與其他成千上萬個文件並列。結果是，單獨看來，這些信息的用途有限。

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

如果偶然有另一位工程師在進行類似設計，他/她將極其難以找到該文件並將其應用於自己的設計中。最終，這將導致浪費，因爲工程師 2 將不得不花費更多的時間和金錢去做一些已經完成的工作，只是因爲該信息不容易獲得或組織得不好。

If by any chance there is another engineer working in a similar design it will become extremely difficult for him/her to find that file and use it in his own design. Ultimately this results in waste because Engineer2 will have to spend more time and money doing something that was already made just because that information was not easily available or well organized.

這種情況不僅限於產品設計，還涉及產品生命周期的所有方面，隨著時間的推移而產生變化。必須有人來組織該產品如何生產、如何移動、包裝、分發和處置。當發現問題或存在改進時，這些變化也會產生信息並消耗資源。如果公司無法利用有關產品構思各個階段的現有信息，則每次重新設計都會浪費資源。

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

產品生命周期管理包括一個信息系統，允許在組織內部和組織之間進行信息和知識共享 (Sudarsan 等，2005)，通過控制和組織那些信息，否則將僅由生成這些文件的人力資源所承擔的文件。它實現這一目標的方式是通過在對象導向架構中以數字“項目”的形式虛擬化產品生命周期的所有組件。正如 (Saaksvuori 和 Immonen，2008) 所解釋的，項目是一種系統化和標準化的方式，用於識別、編碼和命名產品、產品元素或模塊、組件、材料或服務。

Product Lifecycle Management consists of an information system that allows information and knowledge sharing within and between organizations (Sudarsan et al., 2005) minimizing the waste by controlling and organizing those files with information that would otherwise be carried only by the human resource that produced said files. The way it accomplishes that is by virtualizing all components of the product life-cycle in the form of digital “items” in an object oriented architecture. As explained by

(Saaksvuori and Immonen, 2008),an item is a systematic and standard way to identify, encode and name a product, a product element or module, a component, a material or a service.

這些項目對象無疑是虛擬表示，它們保存有關其所嘗試表示的信息，並允許連接和鏈接信息。如 (D'Antonio 等，2015) 所述，產品信息應與其生產過程相關聯。PLM 允許將定義的流程與產品相關聯，並對流程執行的順序提供限制。例如，電路原理圖的 CAD 圖紙附加到虛擬電路對象上，該對象保存有關文件內容的基本信息，以及該文件隨時間的推移的所有先前版本，以及與其所屬的材料清單 (BOM)、製造它所需的機器、組裝它所需的流程等項目的鏈接，更重要的是所有這些項目隨著每個改進的迭代而發生的變化。

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

這種全方位的虛擬化使得信息在其自身的複雜性中得以珍貴的背景。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。這是將現有數據組織成未來參考的最佳方式，因爲它允許結構和透明度。

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

總之，作爲一個系統，PLM 的目標是跟踪與產品生命週期有關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。它通過將眞實事物虛擬化爲數字項目的形式來實現這一目標，這些項目存儲有關該項目所代表的信息的文件。這些文件又可以使用元數據相關聯並隨時間跟踪。

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

0.5.2 企業資源規劃

Enterprise Resource Planning

在資訊系統的早期階段，其中一種最早得到廣泛實施的系統被稱爲 MRP (物料需求規劃)。儘管不一定基於軟體，但這種系統的廣泛實施是計算技術的自然結果，旨在通過計算生產所需的材料來解決物資供應和產品產出方面的瓶頸問題。隨著它在企業中的普及，到了 70 年代末和 80 年代初，該系統逐漸發展演變。這導致了 MRP II (製造資源規劃) 的產生，更重要的是，對本文範圍的 ERP (企業資源規劃) 的產生。

In the early days of information systems, one of the first systems to find wide implementation was the called MRP (Material Requirements Planning). Although not necessarily software based, this system wide implementation was a natural consequence of computing technology and it aimed to solve bottlenecks regarding the material sup-

plying and product output by calculating the material needs for production. As it became more ubiquitous in the enterprise in the late 70 ' s and early 80 ' s the system evolved. This gave origin to MRP II (Manufacturing Resource Planning) and, more important to the scope of this paper, ERP (Enterprise Resource Planning).

大多數現代企業資源規劃系統擴展了原始的 MRP 功能，包含了企業運營的許多其他方面，同時對系統添加了模塊化。

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

現代 ERP 系統通常是基於模塊的；不同的模塊具有不同的用户界面和不同的用户群組。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 and Immonen, 2008)。這些模塊橫跨許多知識領域，但大多數情況下，它們都是從生產、銷售和服務的角度來擴展的。圖 2 顯示了 ERP 系統的範圍與其他信息系統的比較。

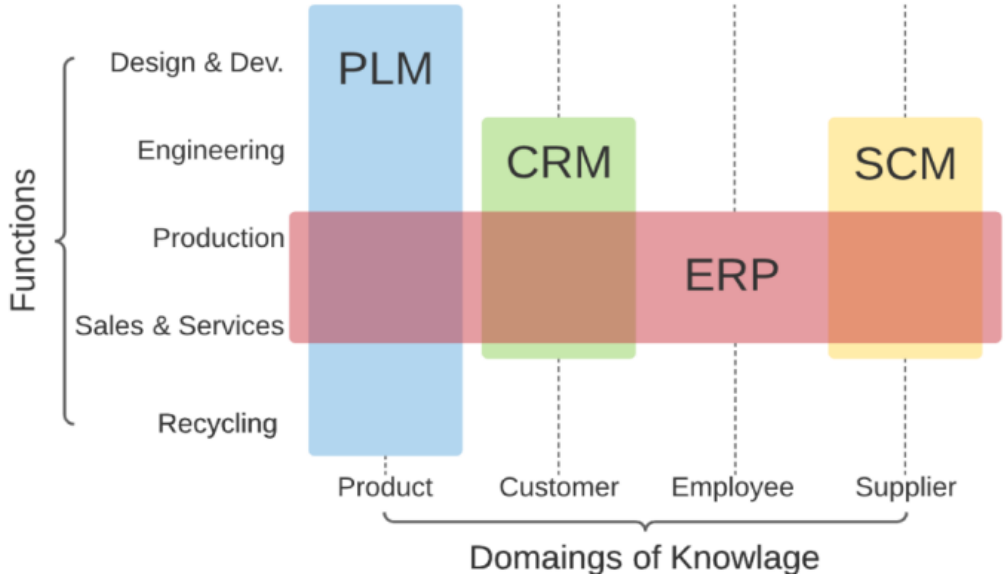

Figure 2 Visual representation of the scope of different information systems (Adapted from Stark 2015)

圖 2 不同信息系統範圍的視覺化呈現

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

Visual representation of the scope of different information systems (Adapted from Stark 2015) 不同信息系統範圍的視覺表示 (根據 Stark 2015 進行了調整)

這種跨領域的廣泛覆蓋是合理的，因爲像 MRP 一樣，ERP 操作的重點是處理交易和訂單。ERP 的重點是控制資源的輸入、保留和輸出對公司的變化，無論是產品、原材料還是包裝。

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.

從同一張圖中，可以看到 PLM 和 ERP 之間的理論對比，儘管它們都非常廣泛。儘管 ERP 擴展了知識領域，但它局限於少數功能；而 PLM 則擴展到涉及產品的所有功能。如圖 3 所示，另一個代表兩者之間良好差異的觀點是關於 ERP 和 PLM 影響行業的規模或細節水平缺乏重疊 (即這兩個系統的細微程度)。

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).

Visual comparison of ERP and PLM concerning granularity (Adapted from Stark, 2015) 對於 ERP 和 PLM 的粒度的視覺比較 (根據 Stark，2015 年進行了調整)

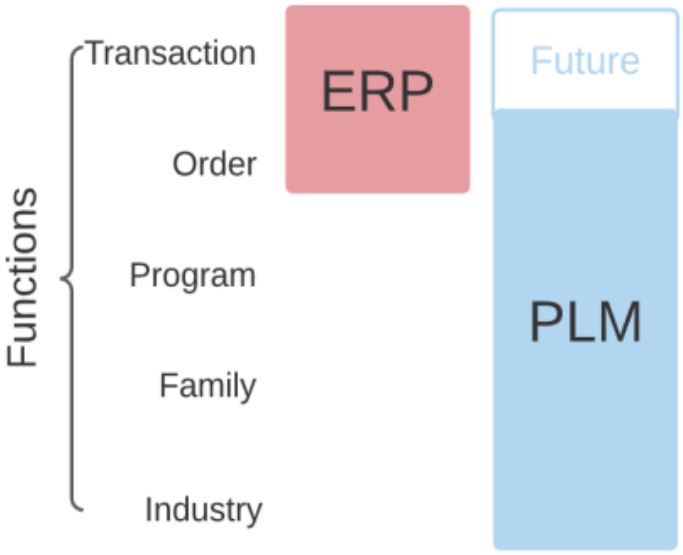

Figure 3 Visual comparison of ERP and PLM concerning granularity (Adapted from Stark, 2015)
□ 3 ERP 和 PLM 在粒度方面的□□比□

如我們所看到的，ERP 主要關注交易和訂單。一旦訂單完成，ERP 系統就會針對該訂單處理相關的交易，但在此之後並不會過多關注該訂單。另一方面，PLM 的細微程度則關注產品的訂單，並延伸至程式、系列甚至整個產業 (Stark，2015 年)。

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

這尤其引人注目，因爲它展示了這兩個系統如何在領域中互補。ERP 的一個方面值得指出的是，它相對容易與其他系統集成。例如，ERP-MES 集成已被廣泛研究和實施，甚至制定了相應的標準 (ISA 95 - IEC 62264)。其中一個原因是 ERP 系統的模塊化性質，這在本文中進一步討論 (第 5 章) 並且通過對 Odoo 軟體的分析加以確認。這是因爲 Odoo 軟體最初是從一個開源的 ERP 系統演變而來的。

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

ERP 系統的本質最好由 (Umble 等，2003 年) 總結：ERP 提供了一個統一的企業視圖，涵蓋了所有功能和部門，並且在企業數據庫中追踪了所有涉及財務、銷售、營銷、採購和人力資源的行動。這一目標的實現是爲了擴大客户目標，並在市場逐漸轉向創新的情況下增加客户的份額 (Vásquez 和 Escribano，2017 年)。

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

0.5.3 製造執行系統

Manufacturing Execution System

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通信的一個層面；它是一種軟體，允許組織層與通常由 ERP 支援的工廠控制系統之間進行數據交換，在這些系統中，使用了多種不同的、高度定制的軟體應用 (Meyer 等，2009 年)。圖 4 是對不同系統如何適應製造和開發範圍的清晰描述。

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.

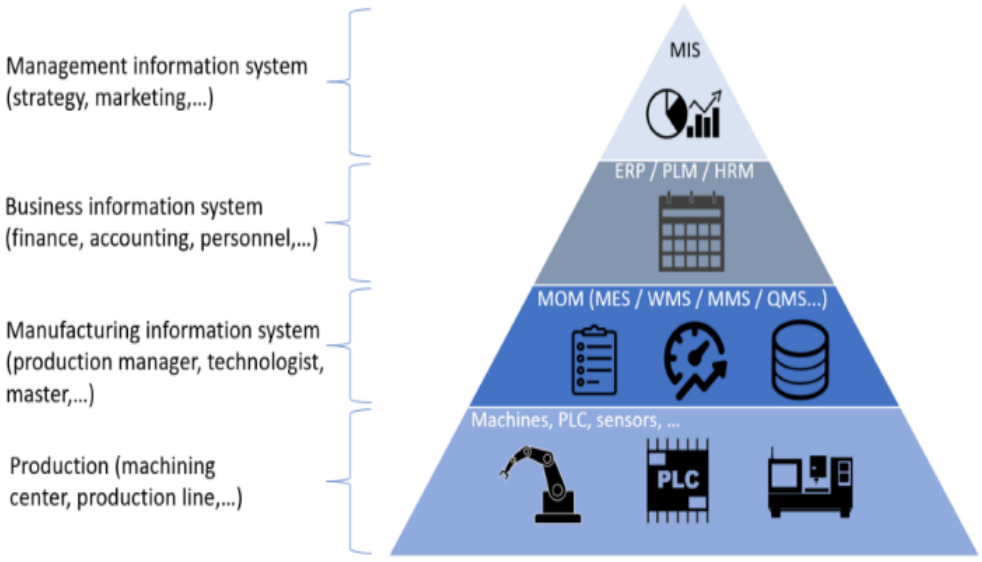

Figure 4 Visual representation of the roll of different systems including MES

□ 4 包括 MES 在□的不同系□角色的□□表□

就所有目的而言，MES 的主要目標是提供數字和數據，最終用於確定不僅產品的狀況和質量，還包括影響生產的所有過程。機器、感應器以及與產品接觸並提供任何類型輸出的任何東西，基本上將這些數據交給 MES 進行即時排序和處理。例如，如果經理想要即時了解生產數字或查看拒收率的圖形表示，該數據將從 MES 軟件中獲得。

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.

傳統上，管理層將從這種類型的信息中評估工作並做出決策。正如前面提到的，這種數據收集完全適用於 ERP 的使用，不僅因爲如果配合實時生產數據，資源管理可以更加詳細，而且還因爲 ERP 的模塊化通常意味著無縫集成。MES (就像 ERP 一樣) 也已被證明並實施了數十年，它們的實施已經被合理地標準化。

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.

MES 的功能被 MESA International (1997 年) 分爲 11 個類別；此外，ISA95-IEC62264 (2013 年) 標準列出了每個企業層面以及每種類型的信息系統的任務。該標準還爲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性；然而，它主要集中在 ERP-MES-車間集成上 (D ' Antonio 等，2015 年)。

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).

相比之下，PLM 研究要新得多，而 PLM-MES 集成，這是本工作的主要焦點，更是如此。這種集成的挑戰以及與之相關的最新技術在第 3 章中已經涉及，以及背後的理論結構。暫時只需指出，由於 MES 提供了通過其組織變更並通過生成文件形式的信息來驗證結果的反饋，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。

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.

0.5.4 工業 4.0

Industry 4.0

在現代文獻中，"Industry 4.0" 這個術語一再被提及，它代表著生產演進的下一步或當前步驟。它代表了第四次工業革命，其中第一次革命以蒸汽動力的採用爲特徵，第二次革命主要使用電力，而第三次革命則以數字技術的實施爲特徵。圖 5 很好地表示了工業革命的進展。

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.

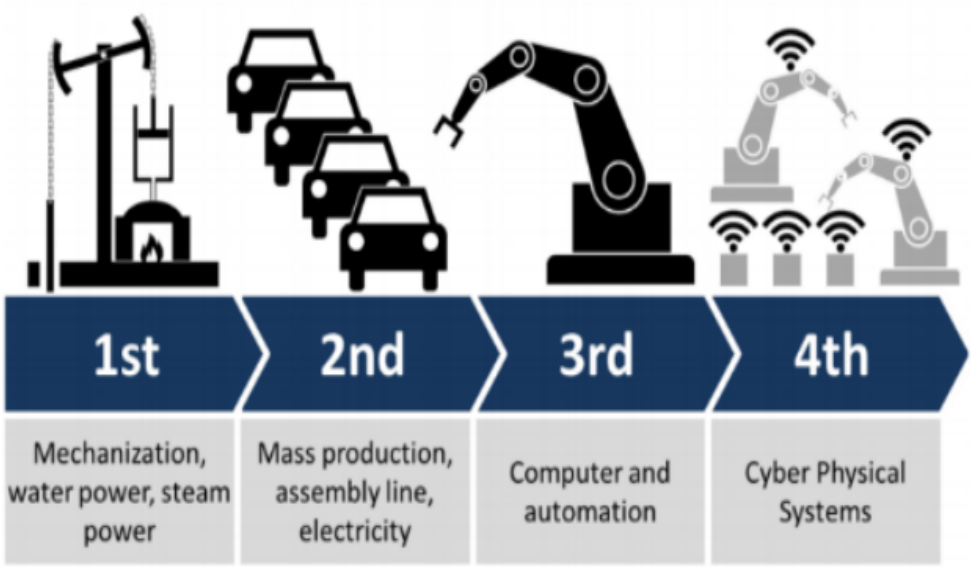

Figure 5 The industry evolution

□ 5 行□演□

以廣泛的視角來看，第四次工業革命最終將以數字連接和生產之間的完全整合爲特徵。眾所周知，數字網絡的發展是支撐現代世界的關鍵技術。它已經改變了人類的互動方式和商業運作方式。然而，目前應用於工業的水平是否構成了一次工業革命仍然不確定，因爲在其他所有革命中，都有一個生產暴增的現象，而這一次尚未出現。事實上，我們尚未達成對“Industry 4.0”的共識定義。然而，已被廣泛接受的是，Industry 4.0 至少具有 3 種技術特徵。這些是物聯網 (IoT)、雲計算和 Cyber-Physical Systems (CPS) 的發展，後者對於本文的背景尤爲重要。

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.

CPS 是由眞實實體 (例如機器) 和其相應的虛擬模型組成的系統，嵌入了模擬眞實對應物行爲的所有模型，這些系統能夠相互通信 (D'Antonio 等，2017 年)。其理念是，如

果對一個系統中有關流程的所有物理儀器開發數字孿生體 (DT)，使得數字對應物之間可以互相交互以及與物理世界進行互動，則該流程的創新或變更將會更快速、更有效地發生。例如，工程師可以使用 DT 的互動模擬一個變更，然後，如果成功，即可將該變更自動應用於實時生產線上，執行測試，收集數據並將其反饋給系統，而無需通過手動輸入完成，所有這些都是通過網絡完成的。

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.

從所有這些中可以得出的主要觀點是，PLM-MES 系統可能是實現適當 CPS 的第一步，因爲它提供了虛擬化和必要的控制，以達到接近虛擬孿生體的程度。爭議的問題是，它目前對工業應用的影響有多深。

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.

然而，" Industry 4.0 " 這個術語，如果可以這麼說的話，是對數字連接、網絡發展和互聯網應用於工業的不斷增長的一個有用標誌。在 " Industry 4.0 " 的範圍內常常提到的另一個術語是所謂的 " Lot Size One " 或 " Lot 1 "。這是每個項目都根據買家的個別規格定制的概念，其中客户訂單不是開始供應鏈設備運動的開始；而是啓動製造機器。

Nonetheless, the term Industry 4.0 is, if anything, a useful denotation to the increasing application of digital connectivity, network development and the internet to industry. Another term often included within the scope of Industry 4.0 is the called Lot Size One or Lot 1. This is the idea of each item customized to the individual specifications of the buyer in a system in which a customer order does not start supply chain equipment moving; it turns on manufacturing machines. The theory behind it is that as production and development becomes more and more flexible as this sort of manufacturing becomes not only viable but also attractive. Having a tailored requested product means that there are no storage requirements, no inventory overhead, and of course a 100fact 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.

它的理論基礎是，隨著這種類型的製造變得越來越靈活，這種製造不僅是可行的，而且也是有吸引力的。擁有定制的產品意味著沒有儲存要求、沒有庫存開支，當然也保證了 100

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.

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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.

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這個概念並不新鮮，事實上，它在工業 4.0 之前就已存在了很長時間。在書籍《改變世界的機器》中，作者 (Womack 等人，1990 年) 討論了爲實現這一目標，精益生產者在組織的各個層面都使用多技能工人團隊，並使用高度靈活、日益自動化的機器生產各種產品的大量產品。

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.

一批一件" 的概念其實就是這種思維的延伸。儘管工業尚未完全實現如此靈活的生產水平，但在更模塊化的生產中已經可以看到這種思維的一些體現，比如亞馬遜的包裝系統。顧客從亞馬遜收到的包裹裡可能裝著一系列根據他們具體訂單特別打包的產品，儘管看似簡單，但卻代表了對顧客的高度定制化。

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.

另一個很好的例子是電子原型製作。目前有些公司可以接收你的印刷電路板設計和 BOM 清單，以低成本提供少量組裝好的原型。電子設備的原型製作曾經是一個非常昂貴的過程，但一些公司已經將他們的生產過程變得靈活化到可以快速可靠地交付的程度。這種可能性再次出現是因爲電子元件本身就是模塊化系統，即使具有高複雜性。下面的圖片 (圖 6 電源適配器電路示例專案) 是一個由這位學生設計並在一周內由 JLCPCB 製造的電子電路的示例。

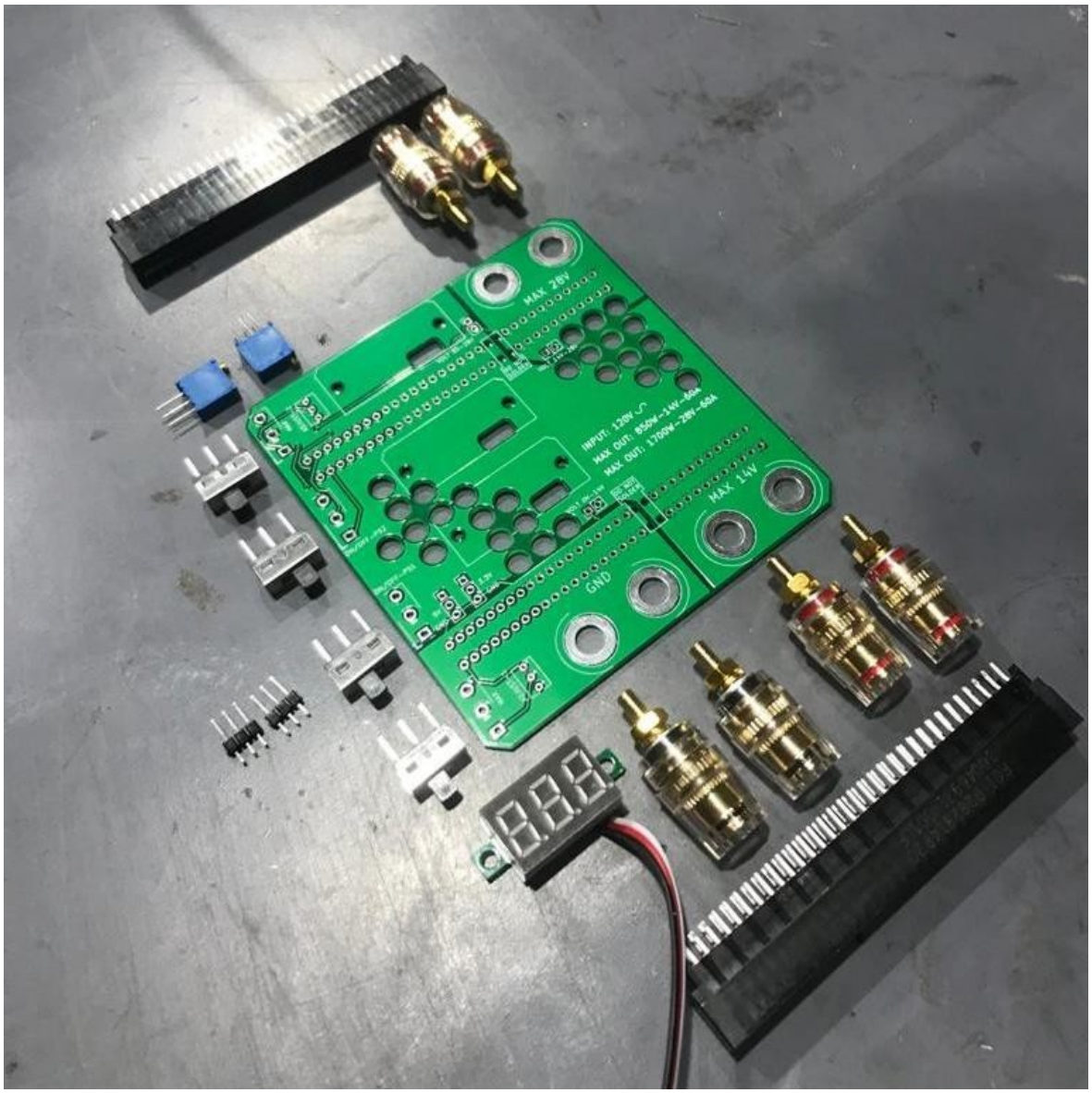

Figure 6 Example project of power supply adaptor circuit
圖 6：電源適配器電路示例專案

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.

整體來說，結果再次顯示對於控制和管理變化的需求更爲迫切。這意味著實施一個產品生命周期管理（PLM）-製造執行系統（MES）系統將會大有幫助。PLM 將需要用來管理小批量產品的變化和創新，而 MES 將提供即時的反應和反饋，以減少可能導致整批產品損失的錯誤。

3. CHAPTER
第三章
THE STATE OF THE ART AND THE INTEGRATION OF PLM AND MES
「PLM 和 MES 的最新技術及整合」

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.

不幸的是，在 PLM 和 MES 系統整合方面，目前沒有太多已發表的研究。但似乎對於該整合可能產生的最可能效應存在共識。這些效應包括同步和更嚴格的容許範圍。

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.

正如 D ' Antonio 等人 (2015 年) 所解釋的，該研究聚焦於一個涉及航空應用精密零件製造的案例研究，部署監控和控制系統的首個預期優勢是產品質量的提升：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。

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.

將 PLM 與任何其他系統整合的核心問題之一圍繞著信息的擁有權。一種可能的解決方案依賴於數據庫集成以及在系統之間使用中間件。正如 Saaksvuori 和 Immonen (2008 年) 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，所需信息可以在其他系統的數據庫上複製，如圖 7 所示。儘管它主要是從 PLM-ERP 整合的角度來指出這一點，但從 PLM-MES 整合的角度來看，它仍然非常有價值，因爲它是一個示例，說明通過繞過文件類型不同的系統將文件載入到集中式 PLM-ERP 系統中可以期望更好地運作。

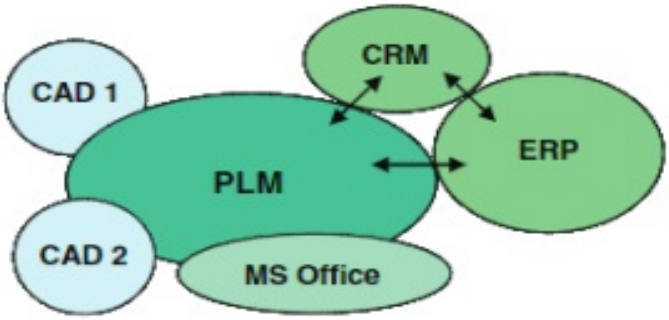

Figure 7 Diagram of PLM integration (Saaksvuori and Immonen, 2008)

第 7 圖 PLM 整合示意圖 (Saaksvuori 和 Immonen，2008 年)

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 applications15 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.

因此，中間件將是一個軟件框架，以用户友好的方式組織和連接所有提供給系統數據庫的信息。這種應用程序也被稱爲集成應用程序，正如 Stark (2015 年) 所指出的，這些應用程序使得產品信息在 PLM 應用程序之間進行交換 (例如，在 CAD 應用程序和 CAE 應用程序之間)。它們還使得產品信息在 PLM 應用程序和其他企業應用程序 (如 ERP 和 CRM) 之間進行交換。

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

在 (Ben Khedher 等，2011 年) 中，對這種中間件思維方式進行了擴展。在他們關於不同系統架構用於實現集成的 MES+PLM 的工作中，他們描述了在 Web 服務架構中使用調解系統。如圖 8 所示，所提出的架構使用基於 Internet 技術的數據交換，幫助公司，尤其是擴展型公司，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)，其設計用於支持網絡上的可互操作的機器對機器交互，根據 W3C 的定義 (Ben Khedher 等，2011 年)。

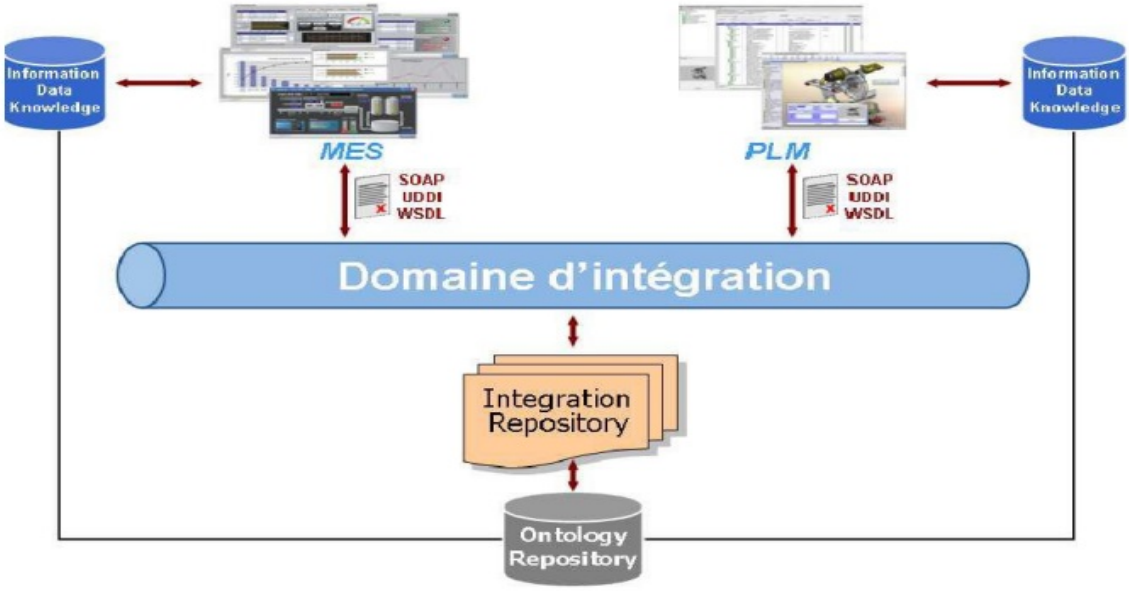

Figure 8 Diagram of Web service architecture
(Adapted from Ben Khedher et al., 2011)

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

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

這種擴展之所以在這項工作的角度上如此相關，是因爲 Odoo 軟件通過類似的 Web 服務架構以類似的方式工作。從理論上講，Odoo 軟件可以通過本地網絡或托管在雲端來充當中間件，並實施之前提到的整合層。

3.1. How would this integration look like in practical terms
在實際情況下，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.

正如在第 2 章中提到的，PLM 的主要理念是管理與產品相關的所有流程中的變化，它主要通過虛擬化來實現。這裡的虛擬化一詞表示將現實世界中的物品表示爲數字空間中的物品，正如人們可以想像的那樣，有幾個抽象層次可以通過這些層次來表示實物或過程。因此，關於 PLM，對於虛擬表示必須有多深和/或多詳細以發揮其作用，目前並沒有確切的共識。

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.

在理想情況下，這將是最低層次的抽象，本質上將等同於在第 2 章中所解釋的數字孿生。這是生產周期的每個方面的「1 對 1」數字表示，其中每個涉及的部分都將具有數字表示，不僅携帶了物品的物理特徵，還携帶了其隨時間產生的所有信息。爲此，正如在第 2 章中解釋的，MES 在獲取 DT 所需的實時信息方面扮演了一個基本角色，甚至可以說是可能的。

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 機床將具有一個數字 3D 模型，用於模擬，以及一個完全集成的零件列表，列出了它生產的所有零件，包括關於它目前生產水平的數據，機械零件的當前磨損程度，以及與其相關的所有其他機器，以及所有曾經影響過它的變更和改進的歷史，以及許多其他方面，所有這些都在直觀的圖形用户界面 (GUI) 中良好地打包，允許進行最大程度的交互。

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，我們還沒有達到這種虛擬化的水平。獲取和組織信息到如此細微的程度需要太多的時間和金錢，尤其是需要手動插入的方面，更不用説如何將這些信息整合和互動的主觀性。儘管如此，在理想狀況下，識別對於這種實現最重要的方面是有用的。

Those are:

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

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

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

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

包括:

- 虛擬化的手段涉及使用各種信息來構建虛擬項目。這包括與項目直接附加的元數據和文件。在理想情況下，這將包含有關項目的所有可能信息。

- 數據輸入的手段包括如何將這些信息載入和組織到系統中。理想情況下，這些信息應該盡可能自動地載入系統中，無論是通過 MES 在質量控制期間還是通過使用自動輸入工具，如條碼掃描器。

- 訪問的手段指的是信息如何呈現給用户。雖然比前面的方面更主觀，但這對系統的互動方式非常重要。信息的可用性有多直觀，這直接影響到 PLM 系統的核心優勢。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，使最終用户難以訪問信息，那麼一切都將是徒勞的。

- 整合的手段指的是項目及其包含的信息如何相互作用並從彼此中受益，即與其他系統和關鍵軟件的整合。例如，如果一個項目可以訪問 CAD 文件，則不需要手動填寫元數據字段。項目如何自動影響其他項目也涉及到這一方面。

4. CHAPTER
第四章
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.

正如人們可以想像的那樣，這項工作的獨特之處之一是其專注於一個特定的軟件解決方案，這個解決方案在實施方面往往相當靈活，適用於不同類型的業務。這與大多數關於 PLM 實施的用例相反，其中業務案例是固定的，而系統是圍繞它建立的。儘管如此，爲了評估 Odoo 作爲 PLM+MES 工具，考慮一個示例是很重要的。這裡的優點在於可以選擇一家虛構的公司作爲示例，從而最大程度地提高軟件在模擬過程中的感知效果。

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.

考慮到之前提到的所有系統，爲了舉例說明，這個理論上的公司是按照工業 4.0 的模式組織的。這家公司是一家新成立的小型箱式製造公司，主要使用塑料射出成型作爲其主要生產手段，並將增材製造和快速原型製作作爲其業務戰略的一部分。正如在第 2 章中解釋的那樣，這些都是行業在創新方面所走的道路的很好示例，其中大規模生產正在逐漸變得不那麼重要，而產品多樣性和上市時間則變得更加重要。

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.

爲了最大程度地追踪變化，該公司的大多數業務都基於主要是自動化機械的小批量生產。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，應該很容易模擬產品和流程的持續改進，以評估的軟件的程度。由於這種不斷變化的生產極其依賴各種信息管理，因此它必須證明是應用 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，自從成立以來，該公司已經實施了 Odoo 軟件，並且已經接受了所有必要的培訓和步驟以正確使用它。這使得可以消除關於將 PLM+MES 系統實施到已經存在的業務中的界限和限制，例如對遺留系統的依賴、管理層對變革的抵制以及與舊流程的整合。這些顯然是重要的，但這不在本工作的範圍內。

公司的目標是在年底之前生產一種全新的產品。在這樣做之後，公司改進了該產品的生產流程。一旦需要產品改進，相應的改進也會進行。

下面的圖表（圖 9）將被視爲產品開發和改進的路徑：

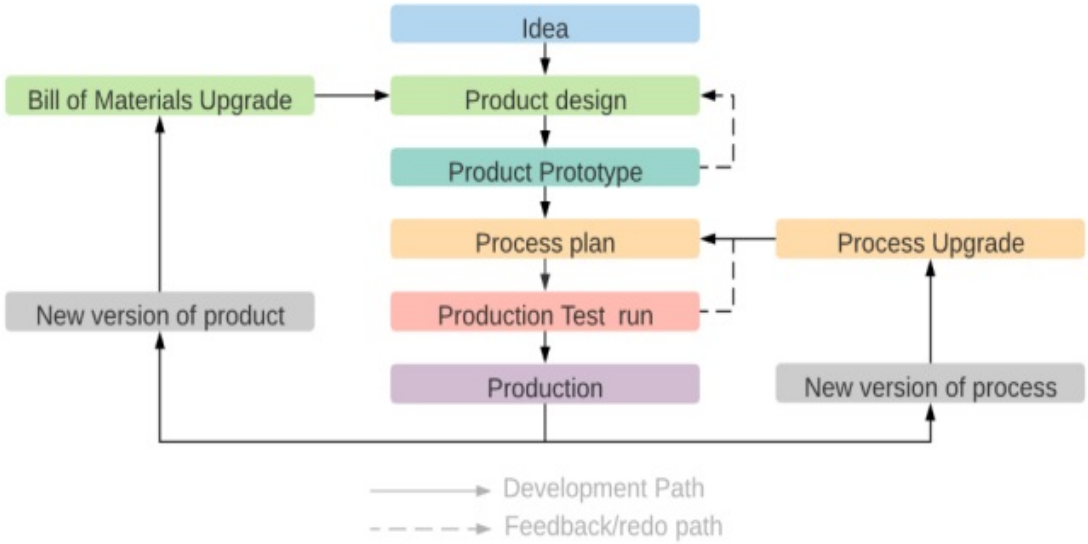

Figure 9 Development diagram
第 9 圖發展圖

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遞一種迭代的開發和改進方法。這個想法是通過產品設計，然後進行原型設計和重新設計的循環，直到達到滿意的結果。然後，類似的循環也會發生在生產過程中。在這個階段結束時，初步的開發工作完成，實際的生產可以開始。

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是很重要的。在這家公司的情況下，我們只考慮兩種主要的升級路徑，分別是產品升級和流程升級。

4.1.The products and processes

4.1. 產品和流程

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.

變化和效果是 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自由度的設計。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，但在一個以創新爲主的企業中，這種變化會更爲明顯，因爲這裡會有更多改進系統和獲得反饋的機會。

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 20 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，如果將一個由鍍鋼板金工製作而成的產品 (見圖 10) 與一個相當產品進行對比，該產品是通過 CNC 銑削程序製作而成的 (見圖 11)，可以很容易地感受到 CNC 銑削的產品更適合進行升級。雖然鍍鋼板金加工成本較低 (相對而言)，但它依賴於昂貴的高精度金屬模具，而這些模具的生產成本極高。這意味著對其進行改變的成本要高得多，因此對於追踪變化的系統的影響變得有限。

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

圖 10 鍍鋼板金加工的 AK74 型槍機匣示例 (Brownnells.com)

Figure 11 Example of milled AK74 pattern rifle receiver (sharpsbros.com)
圖 11 AK74 型槍機匣的銑削加工示例 (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.

在這個虛構的公司案例中，已經確定最好的方式來說明 PLM+MES 的效果是設計基於塑料射出成型的產品。乍一看，考慮這種製造過程可能看起來有點不直觀，就像之前描述的鍍鋼板金加工一樣，因爲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 21 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，涉及了各種各樣的材料和方法，這些大多數對本工作來說不太重要。然而，值得指出的是，對於射出成型，大部分時間所涉及的壓力比處理鋼材時低一個數量級；較軟的材料可以用於它們的模具，如 CNC 銑削鋁。與此同時，增材製造領域的新進展使得可以用具有更接近最終注射件的物理特性的原型來製作塑料部件。有時甚至可以使用原型模具 (見圖 12) 進行較低容量的測試運行，進行流程升級。

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

圖 12 使用 3D 打印機製作的射出模具示例 (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.

增材製造已成爲超靈活生產的一個不可思議的工具。這種對持續改進的思維，特別是在原型製作和迭代設計方面，是現代工業中如此重要的精益思維的一個標誌。

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.

如前一部分所述，在這個案例研究中，考慮了虛構公司對新產品及其生產過程的創建。該產品是一款塑料小型計算機機箱，由 3 個不同的部件組成 (見圖 13)，預計將通過增材製造和 CNC 銑削的組合來設計和製作原型，以用於塑料射出成型生產。

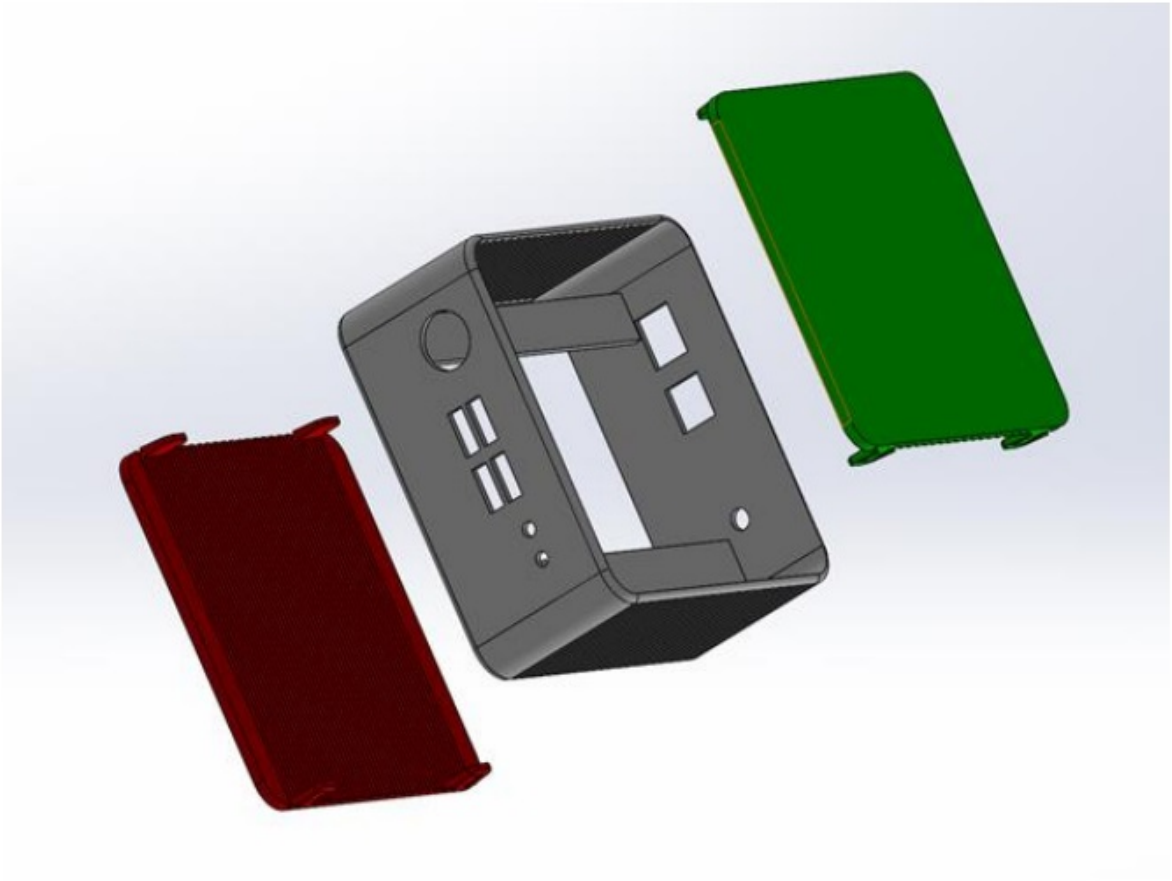

Figure 13 3D exploded view of the theoretical product
圖 13 理論產品的 3D 爆炸視圖

4.1.1. Part A

4.1.1. 部件 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.

部件 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，以確保所述小型計算機的正常運行。爲此，選擇了原材料 A 爲丙烯□丁二烯苯乙烯共聚物 (ABS)，這是一種不透明的熱塑性聚合物，是一種工程級塑料。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罩。

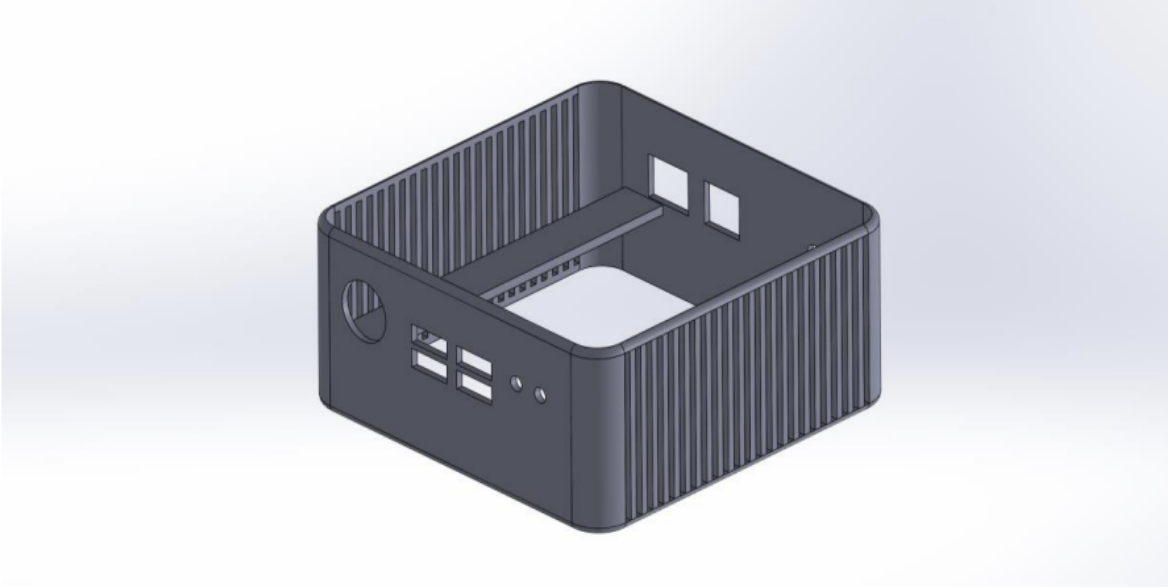

Figure 14 Isometric view of Part A
圖 14 部件 A 的等距視圖

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.

選擇這種特定材料的主要原因是其韌性、良好的尺寸穩定性 (冷卻後尺寸變化的抵抗力)、高衝擊抗性和表面硬度。最後，它還常見於 3D 列印絲材料，可用於擠出式 3D 列印機，這在原型製作過程中應該非常有用。

4.1.2. Parts B and C
4.1.2 部件 B 和 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 sim-

ulation, will be used for prototyping.
B 和 C 部件是盖子，應該能夠卡入位，關閉系統。這些是非常簡單的部件，需要一定程度的彈性，以便能夠變形以確保無螺紋組裝。這兩個相同的部件將使用聚氨酯彈性體 (TPU) 製造，因爲其具有彈性和出色的拉伸和撕裂強度。這種聚合物通常用於生產需要橡膠樣彈性的部件。TPU 在高溫下表現良好，通常用於電動工具、電纜絕緣和體育用品。最後，TPU 也可以作爲 3D 列印機的絲材料，用於模擬中的原型製作。

Figure 15 Parts B and C
圖 15 零件 B 和 C

4.1.3. Molds
4.1.3. 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，所有模具應該由鋼材製成，以確保模具和產品質量的持久性。雖然如此，所選擇的注塑塑料對所有零件的壓力要求不那麼高，它們的形式也不那麼復雜，因此可以假設用精密 CNC 加工的鋁模具應該足以生產所述的零件。

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.
還假設所有模具都足夠簡單，可以使用 3D 列印進行原型製作。儘管這並非始終如此，但已確定對於本次模擬來說具有代表性。這些原型使用的材料類

型是使用 SLA 3D 打印機固化的高溫樹脂。此外，模具將被視爲在生產過程中需要開發的主要實體方面，因爲它直接影響生產，同時可以在內部生產並跟踪其作爲產品的情況。

4.2.What is analized during the simulation
4.2. 模擬過程中的分析

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 中所示的圖表，以及在第 3.1 節中描述的 PLM 和 MES 成功整合的主要方面，此實驗旨在就表 1 中所描述的以下相關問題進行評論。

Table 1 Summary of questions to be answered
表 1 需要回答的問題摘要

Category 類別	Questions 問題
[l]How does the software deals with items? 軟體如何處理項目 所有產品生命周期的方面都有被代表嗎？ How well are each of those items represented? 每個方面的代表程度如何？	[l]Are all aspects of the product lifecycle represent
[l]How easy it is to create a brandnew product? 創建一個全新的產品有多容易 產品如何描述？ How does the product integrate and reference relevant files? 產品如何整合和參考相關文件？ Does changing one affects the other? 更改一個是否會影響另一個？	[l]How the product is depicted?
[l]How easy it is to create a brand-new production process? 創建全新的生產過程有多容易 生產過程是如何描述的？ How does the process integrate and reference the product it produces? 生產過程如何整合和參考其所生產的產品？ Does changing one affects the other? 更改其中一個是否會影響另一個？	[l]How the process is depicted?
[l]How easy is to improve an existing product 改善現有產品有多容易 更新其元數據有多容易？ How easy it is to determine the effects of the change 確定更改的影響有多容易？ How does the software deals with different product revisions? 軟體如何處理不同的產品修訂版本？	[l]How easy it is to update its metadata
[l]How easy it is to improve an existing production process 改善現有的生產流程有多容易 更新其元數據有多容易 How easy it is to determine the effects of the change 確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？	[l]How easy it is to update its metadata

第五章

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，與開源社區關係密切。最初作爲開源 ERP 軟體開發，因其價格實惠、直觀且擅長整合和擴展而受到廣泛歡迎。隨著公司業務的迅速增長，其商業模式逐漸轉變，包括提供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.

如第 2.2 節所述，現代 ERP 系統通常是模塊化的，而在 Odoo 的情況下，這種模塊化特別明顯，因爲社區開發的模塊和公司開發的高度集成的模塊提供了令人難以置信的擴展。正是這種可擴展性使得這款軟體對 PLM+MES 整合這一主題如此重要，因爲在其製造模塊中存在用於 PLM 以及顯著的 MES 功能的模塊。

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.

在本論文的範圍內，目標是利用這款軟體管理先前提到的虛構公司，並得出關於 PLM 和 MES 整合在該系統中已經存在的有效性的結論。

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，並啓動一個 SQL 數據庫，該數據庫包含企業生成的所有必要信息和文件 (見圖 16)。該電腦基本上作爲服務器工作，其他位於網絡中的機器通過瀏覽器訪問它。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，它必須在軟體需要運行的整個時間內保持開機並連接著。

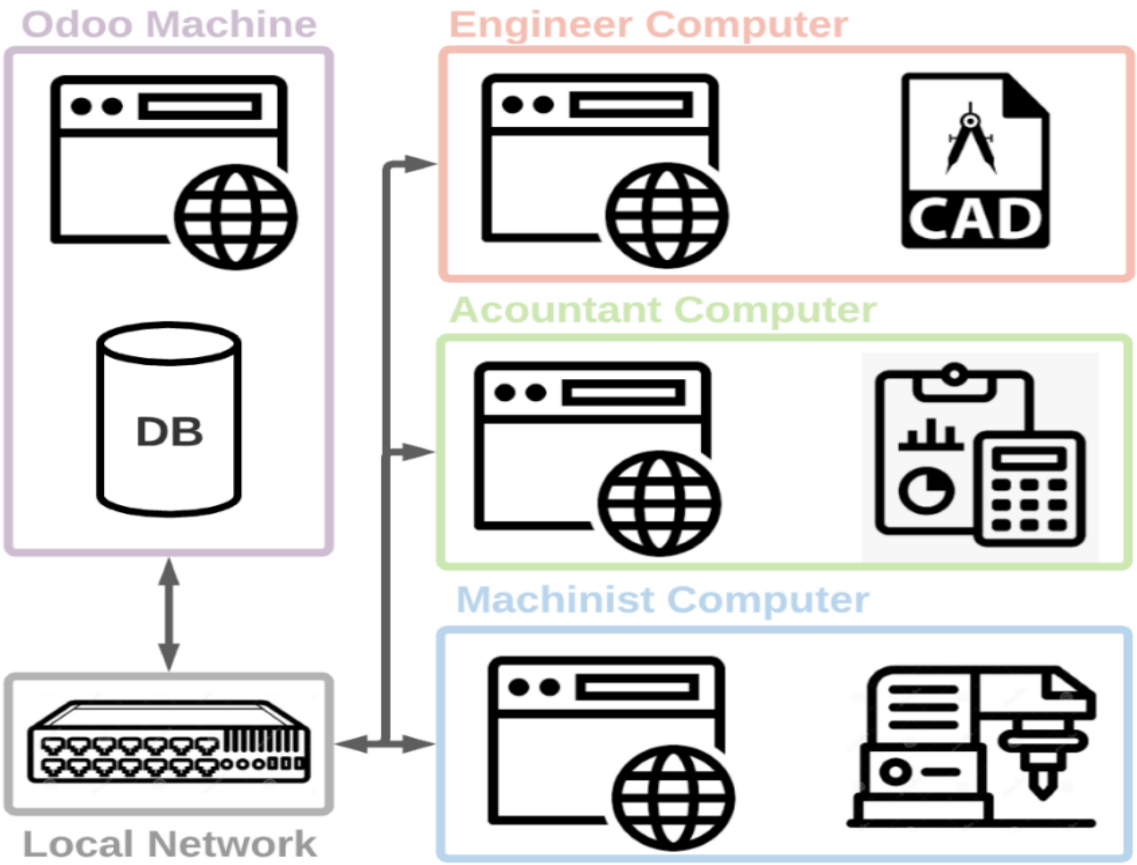

Figure 16 Function Diagram of Odoo configuration A
圖 16 Odoo 配置 A 的功能圖

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端。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塊 (用於構建和管理網站和電子商店)。然而，這取決於網絡，這在某些情況下可能會造成問題。

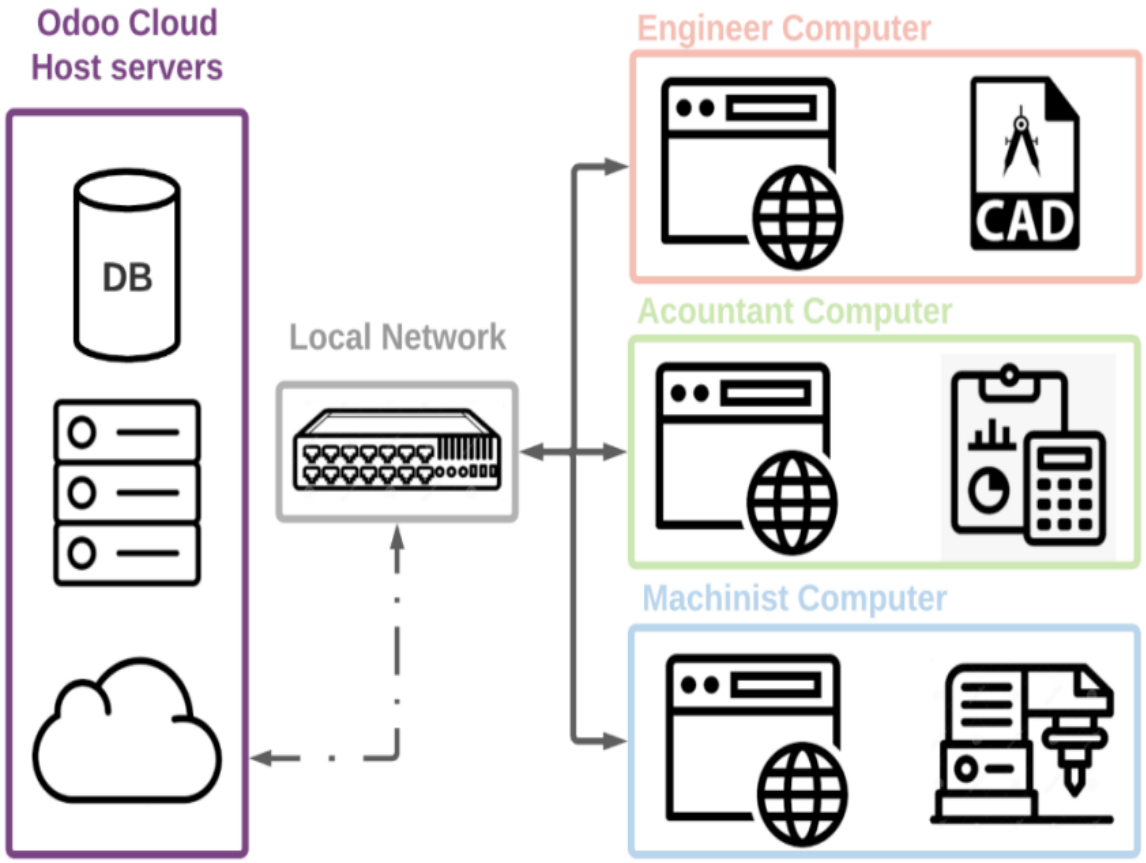

Figure 17 Function Diagram of Odoo configuration B

圖 17 Odoo 配置 B 的功能圖

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.

用户基本上通過圖形用户界面 (GUI) 與系統互動，並使用它來根據每個用户的需要訪問不同的模塊。這意味著可以對不同的用户施加限制，以便對業務活動的不同方面進行控制，例如，會計人員將可以訪問會計模塊、銷售模塊和庫存模塊，但將被限制訪問製造模塊。這種限制確保了只有適當的員工才能對流程進行控制。

Within said GUI the different modules appear as app icons (Figure 18) and, from the getgo, the company has available a reasonable selection of well-integrated applications not to mention a vast app store filled with community made modules.
在該 GUI 中，不同的模塊顯示爲應用程式圖標 (見圖 18)，從一開始，公司就可以使用合理選擇的經過良好整合的應用程式，更不用說有一個充滿社區製作的模塊的龐大應用程式商店。

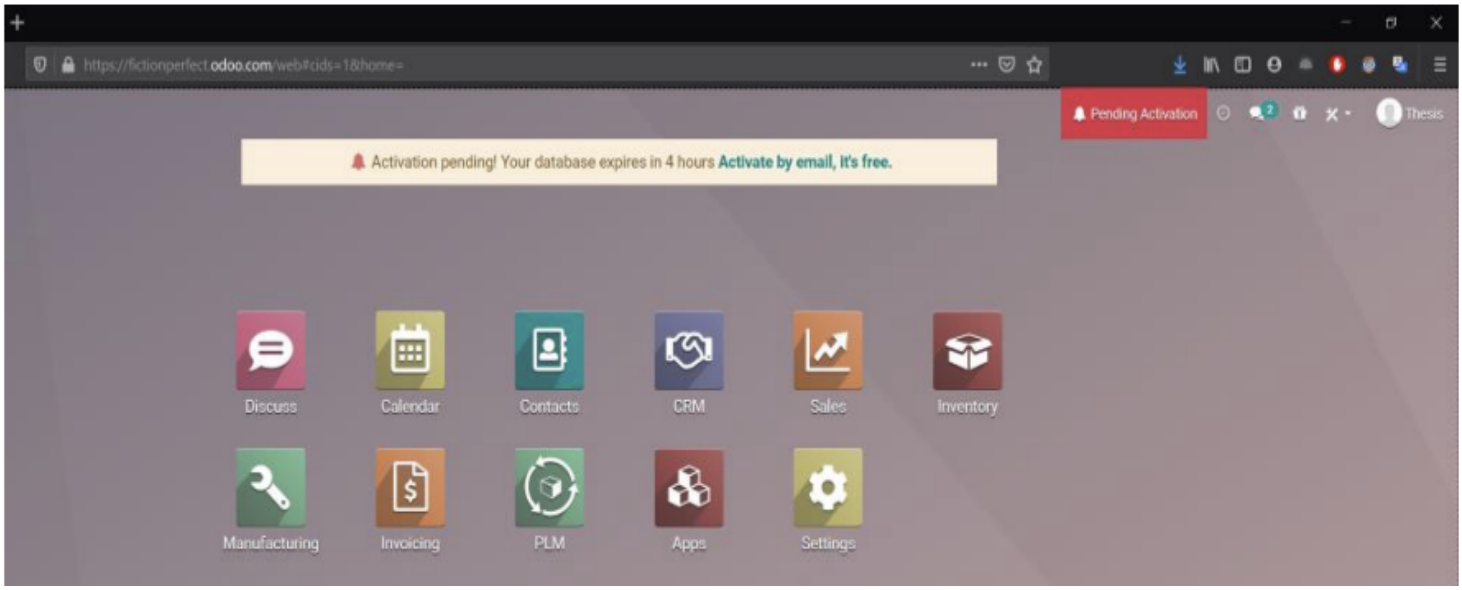

Figure 18 Screenshot of GUI from Odoo in configuration B

圖 18 Odoo 在配置 B 中的 GUI 截圖

5.1.2. Odoo ' s view on manufacturing:
5.1.2. Odoo 對製造的看法:

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 認爲任何製造工作的責任都分散在不同的公司部門中，每個部門

負責特定的文件類型，並使用特定的應用程式進行處理 (見表 2)。從 PLM 的角度來看，這非常積極，因爲如 (Saaksvuori 和 Immonen，2008) 所述，關於用户權限管理 - PLM 系統用於定義信息訪問和維護權限。PLM 系統定義了誰可以創建新的信息或進行製作、檢查和接受變更，以及那些僅允許查看系統中的信息或文檔的人。當涉及將 PLM 與其他系統集成時，用户權限管理通常是一個挑戰。

Table 2 Correlation between department and Documents/Apps

表 **2** 部門與文件/應用程式的相關性

[l]**Department** 部門 文件/應用程式	[l]**Documents/Apps**
[l]Engineering 工程 CAD 和 BOM	[l]CAD and BOM
[l]Manufacturing Engineering 製造工程 工藝路線、工作表、工作中心	[l]Routings, Worksheets, Workcenters
[l]Purchase/Procurement 採購/採購 採購訂單、報價請求	[l]Procurement order, Request for quotation
[l]Inventory Operators 庫存操作員 收貨、條碼	[l]Receipt, Barcode
[l]Manufacturing Foreman 製造主管 製造訂單、計劃	[l]Manufacturing order, Planning
[l]Manufacturing Operators 製造操作員 工作訂單	[l]Work order
[l]Inventory Operators 庫存操作員 交貨	[l]Delivery
[l]Quality 品質 警報、分析、控制點	[l]Alert, Analysis, Control points
[l]Engineering 工程 工程變更訂單	[l]Engineering change order
[l]Maintenance 維護 預防性/矯正性	[l]Preventive/Corrective

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

從 Odoo 的角度來看，在通常的製造過程中，首先是工程師使用 CAD 軟件設計產品。一旦完成，他們將創建一個物料清單 (BOM)，這是生產產品所需的零件或材料的清單。此時，重點轉移到製造過程本身。

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

軟體對過程的視角主要集中在工藝路線、工作表和工作中心，這由製造工程團隊負責。工藝路線是產品在生產過程中所經歷的一系列步驟。工作表是針對製造操作員的指示，而工作中心則是生產活動進行的地方。Odoo 認爲這些是將工程師的計劃付諸實施所需的要求。

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.

採購部門將負責請求報價 (RFQ) 或採購訂單 (PO)。庫存操作員根據這些 PO 負責收貨，通常在 Odoo 中使用條碼應用程式完成。正如本章的第一節所解釋的，Odoo 主要是一個 ERP 系統，正是在這一點上可以注意到一些 ERP 中心化的特徵，比如對庫存和資源管理的關注。這將在接下來的章節中進一步分析，但值得指出的是，這些 RFQ 和 PO 被視爲數據庫中的項目。

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.

只有在擁有設計、流程和所需材料時，Odoo 才認爲製造是可能的。然後，製造主管將創建一個製造訂單 (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，它們將自動出現在庫存數據庫中，並由庫存部門負責包裝和交貨。

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 認爲品質團隊負責指定控制/檢查點，以及識別產品或生產中可能存在的問題。這些品質控制檢查點從 MES 的角度來看非常有趣，因爲它代表著寶貴的生產數據，該數據在生產過程中實時收集，即在每個產品生產後，可以指定一個尺寸檢查點，加工人員將填寫尺寸以隨時間跟踪品質。

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 31 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.

如果存在設計問題或有改進的可能性，可以發出工程變更訂單 (ECO)。這將回到製造工程團隊手中，並將專注於更新文件和 BOM。ECO 是 Odoo 跟踪系統內變更的核心。這在考慮 PLM 時非常重要，實際上也是 Odoo 名爲 PLM 的應用程式的重點。該應用程式能夠實現到什麼程度，將在下一節中進行討論。

5.1.3. The information structure of Odoo
5.1.3. 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 ’.

每個模塊都專注於操作特定的面向對象的類，這些類在數據庫中保存元數據。這些是虛擬項目，負責將產品生命周期的各個方面虛擬化，正如 (第 3.1 節) 所述。不同類型的項目具有不同類型的賬户，保存不同類型的數據，例如，產品項目代表特定產品，保存與其互動和使用相關的元數據，以及與其密切相關的其他可能項目的鏈接，如負責的用户或製造所需的材料清單。Odoo 通過其瀏覽器界面使所有這些信息都可以訪問和交互 (見圖 19 和圖 20)。爲了保持一致，本文將特定項目表示 (例如，螺栓) 稱爲“ 項目 ”，將項目類型 (產品) 稱爲“ 項目類 ”。

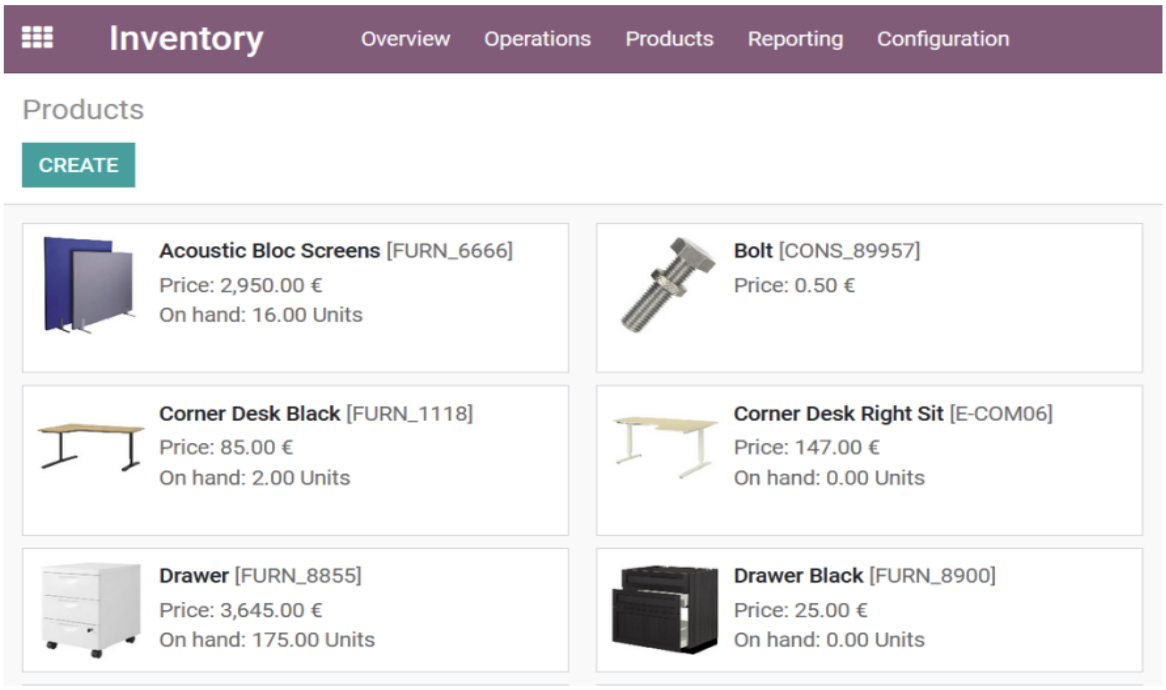

Figure 19 Example of Odoo's interface regarding items
圖 19 Odoo 界面示例，涉及項目

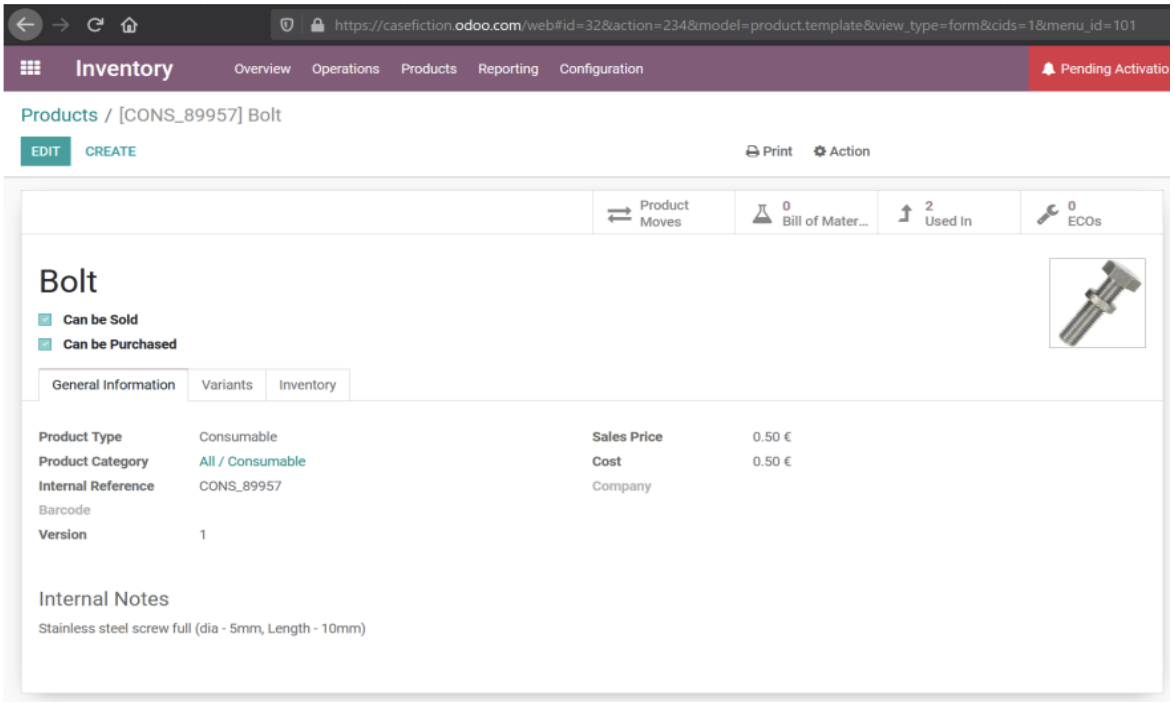

Figure 20 Example of specific item and its metadata as displayed by GUI

圖 20 由 GUI 顯示的特定項目及其元數據的示例

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，有幾種類型的項目類 (一些保存了大量的元數據，一些保存了很少)，它們之間有不同程度的關係和整合。由於本工作的範圍僅限於 PLM 和 MES 的功能，因此重點放在與它們相關的項目上。下面的章節將對 Odoo 製造過程的主要 7 個項目類進行簡要解釋，因爲基本的理解有助於讀者跟隨模擬。這些在以下圖 (圖 21) 中表示。其他與製造過程無關的項目將在模擬過程中介紹。

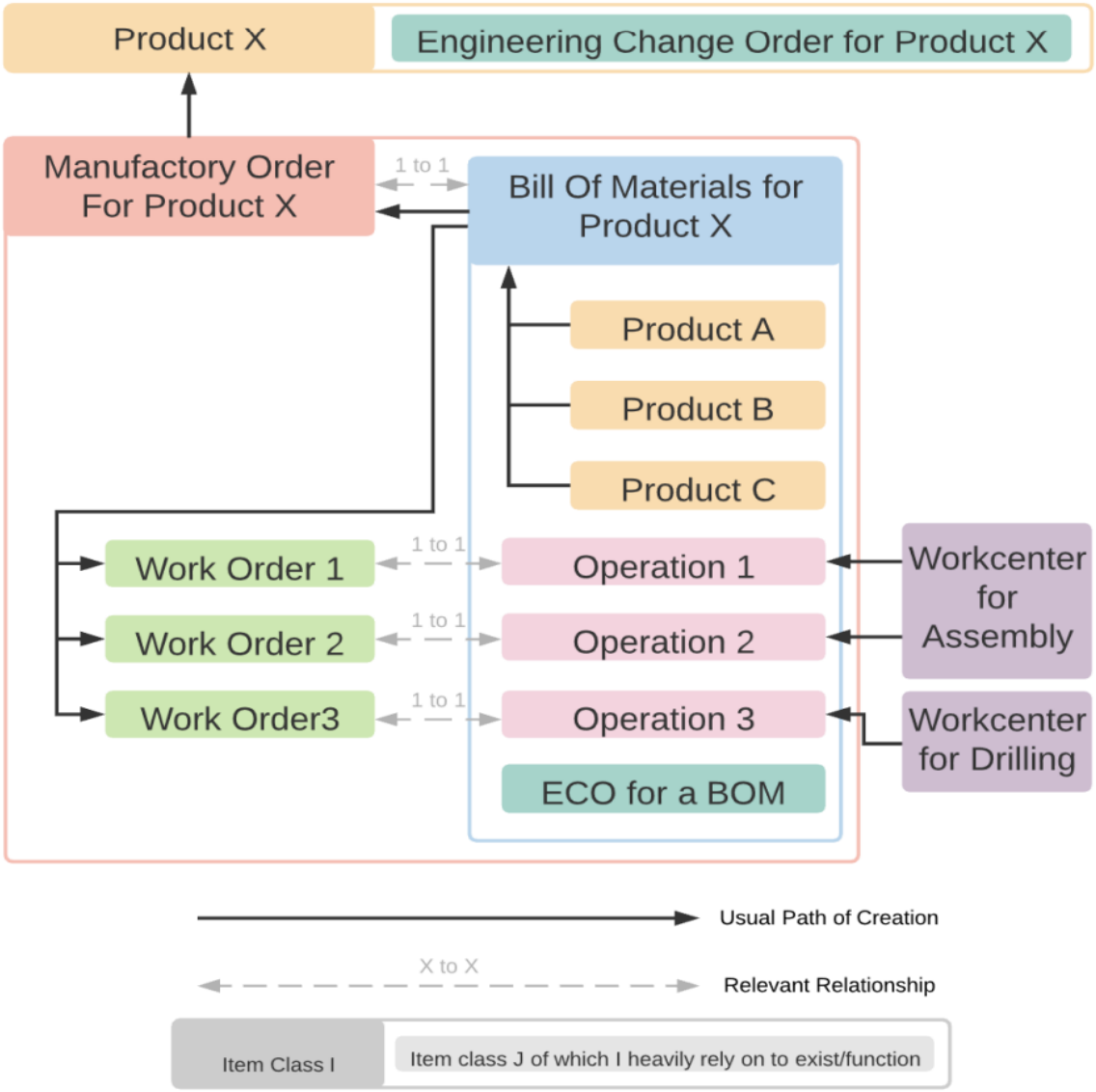

Figure 21 Simplified Item relation diagram to the manufacturing of a product X

圖 21 產品 X 製造的簡化項目關係圖

Operation item class and workcenter item class

5.1.3.2. 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爲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。

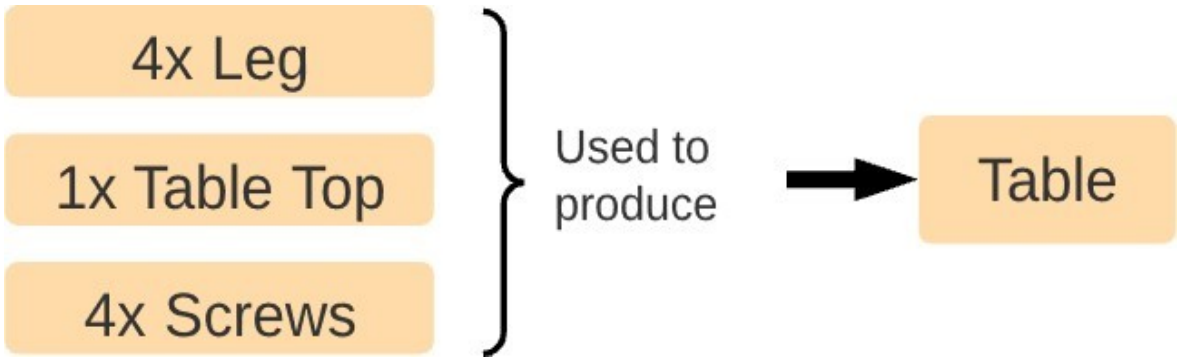

圖 23 操作簡化圖

The Bill of Materials item class

5.1.3.3 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 35 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 認爲生產過程的虛擬表示來描述。考慮到前面提到的操作項類，乍一看這似乎有悖常理，但實際上，由於 BOM 是一個複合項，因此它直接指向生產最終產品所需的所有項目類型 (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。

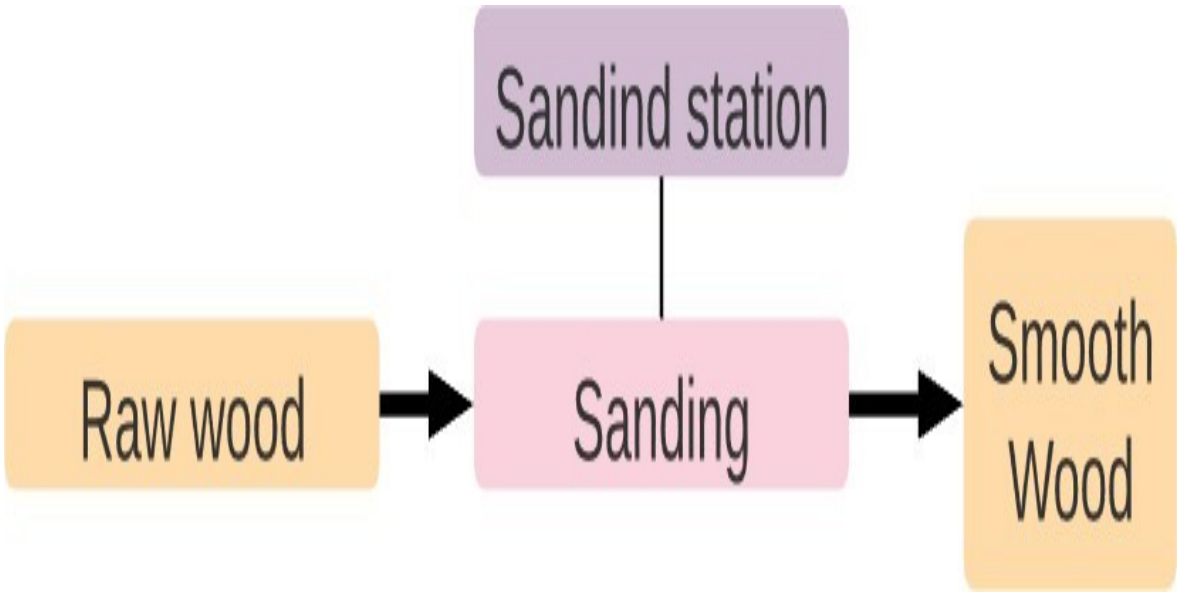

圖 24 簡化的 BOM 圖

Manufacturing order item class and work order item class

5.1.3.4 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). 36 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.

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爲基礎製造 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)。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爲 MES 的核心部分。

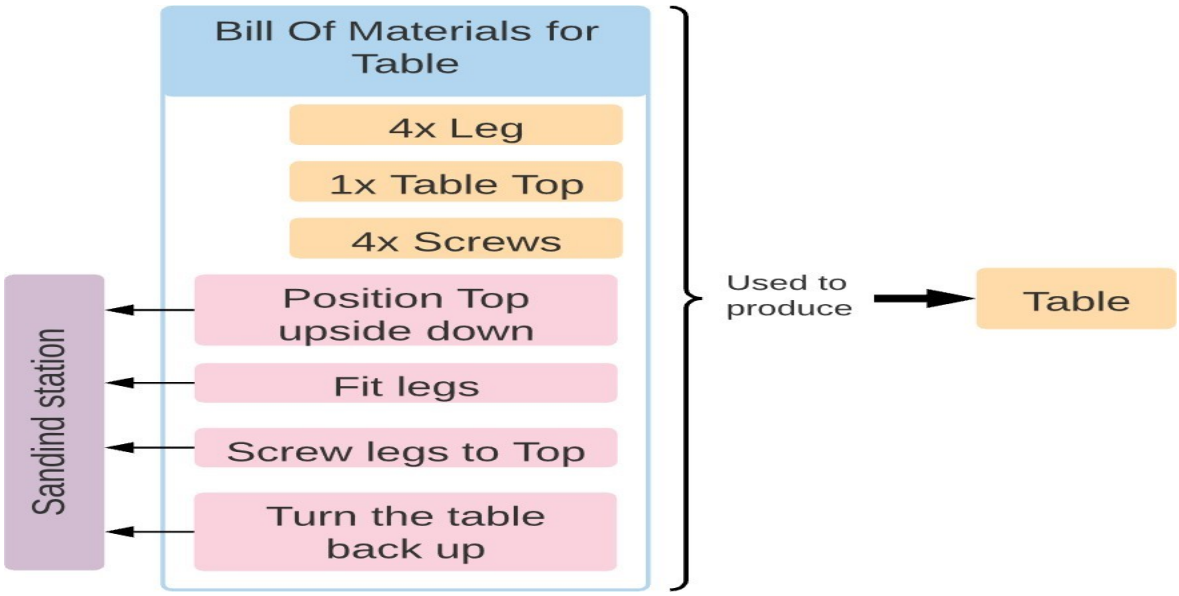

圖 25 簡化訂單圖

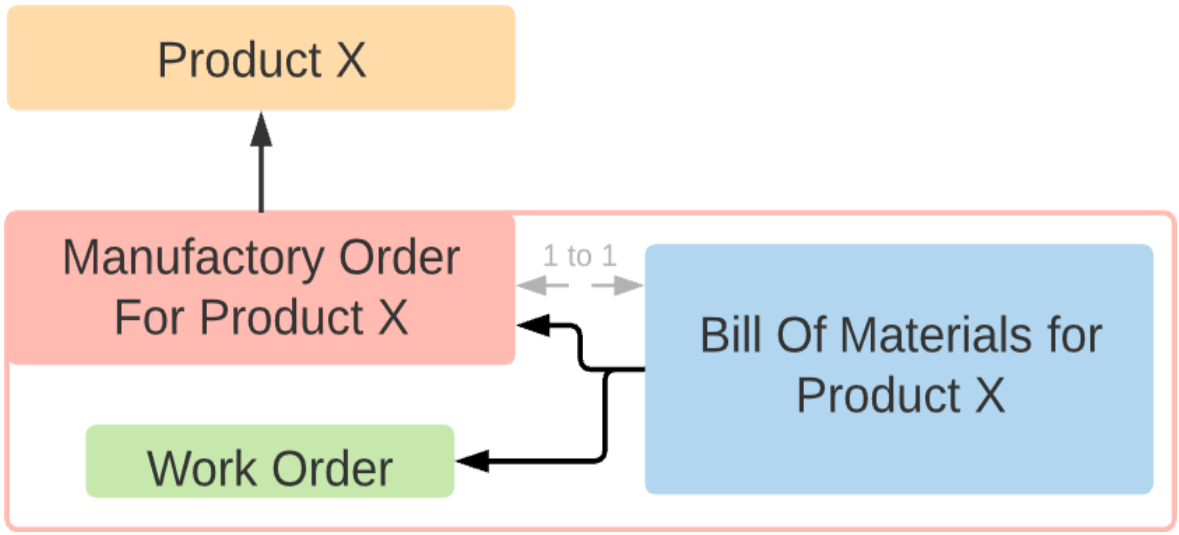

圖 26 WO 操作介面

The engineering change order

5.1.3.5 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). An ECO is an item class that outlines the proposed changes to the product or the parts that would be affected by the change. In other words, is a central information hub for everyone associated with a given product. The idea is to signal the need for change to a product item or a BOM item, hold the files that are relevant to the change and apply the change or at least signal that the change has been implemented, all while keeping the history of al the previous changes. All very useful in the future and serve as a process to streamline product development and help improve products/production.

如第 2 章開頭所述，Odoo 管理軟體主要將 PLM 視爲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)。

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。

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，並作爲簡化產品開發和□明改進產品/生產的過程。

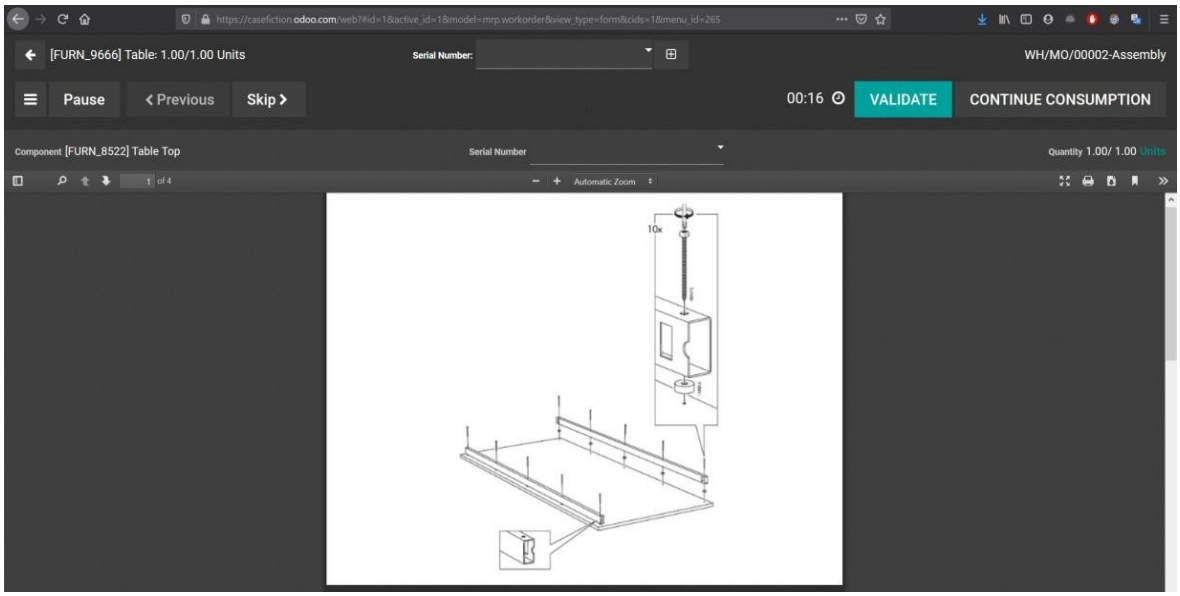

圖 27 簡化的 ECO 功能圖

Starting the simulation

5.2 開始類比

Software option chosen for the simulation

5.2.1 爲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:

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

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

At the time of writing this work, Odoo allows you to select one of its extra features like PLM and use it for free for an indefinite amount of time on their cloud hosted servers. This is a very attractive option if the only focus of this work was PLM and manufacturing. However, the

MES aspect of this work is highly dependent of other applications of Odoo which means that there is very little that can be done. To this end the experiment was carried out in the trial version of Odoo enterprise which allow the user to use the system without storage or application limitations for a period of 14 days all hosted in Odoo cloud servers (Figure 17).

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：

- 使用基於 Web 的服務作爲本地或遠端管理伺服器的實用性。儘管社區應用程式作爲這項工作研究的一部分進行了測試，並且被認爲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。

- 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。

在撰寫本文時，Odoo 允許您選擇其額外功能之一，如 PLM，并在其雲端托管的服務器上免費無限期使用。如果本文的唯一重點是 PLM 和製造，這是一個非常吸引人的選擇。然而，這項工作的 MES 方面高度依賴於 Odoo 的其他應用，這意味著幾乎沒有什麼可以做。爲此，實驗是在 Odoo 企業試用版中進行的，該試用版允許用户在 Odoo 雲端服務器上無限制地使用系統，但僅限於 14 天 (見圖 17)。

5.2.2. 相關的設置細節

Odoo 的設置中有一些細節與其製造功能的正確運作密切相關。具體而言，在製造設置中啓用工單是使用工單項目、工作中心項目和操作項目的正確步驟。

本工作的假設是，這是該軟件 ERP 起源的殘留，因爲如果您要在製造上嚴格控制，那麼預設情況下不啓用此設置相當不直觀。儘管如此，從 Odoo 企業版 v14 開始，此選項可在「設置」>「製造」>「操作」>「工單」中設置 (見圖 28)。

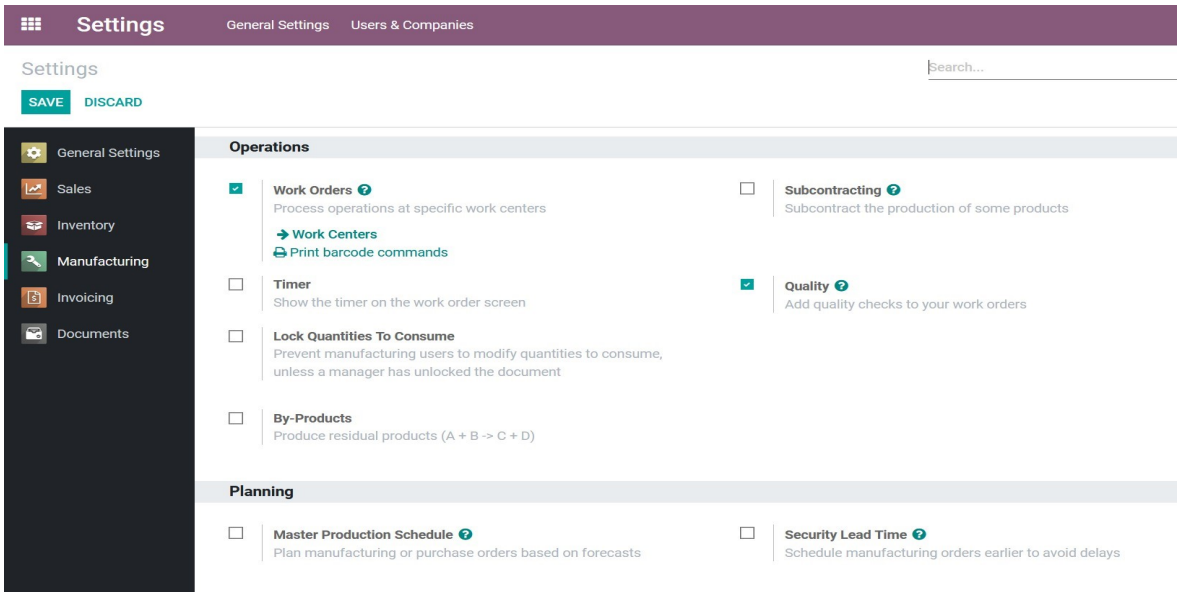

圖 28 啓用特定設置的截圖

Building the company structure

5.3. 建立公司結構

Users

5.3.1. 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, 40 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).

使用者通過設置菜單設置並邀請。可以分配不同級別的權限，涉及業務操作的不同方面。消息、權限、批準、責任都分配給一個使用者。這非常方便，即使在製造範圍內使用有限，也可以屬於虛擬項目類別。它們的建立並非絕對必要，軟體只需我作爲具有完整管理員憑據的使用者即可正常執行，但爲了這個模擬，建立了 5 個使用者，列舉如下，以代表公司內不同的員工。以下 (見圖 29) 是我的用户帳户項目及其“訪問權限”的截圖，接著是爲公司建立的虛構使用者之一 (見圖 30)。

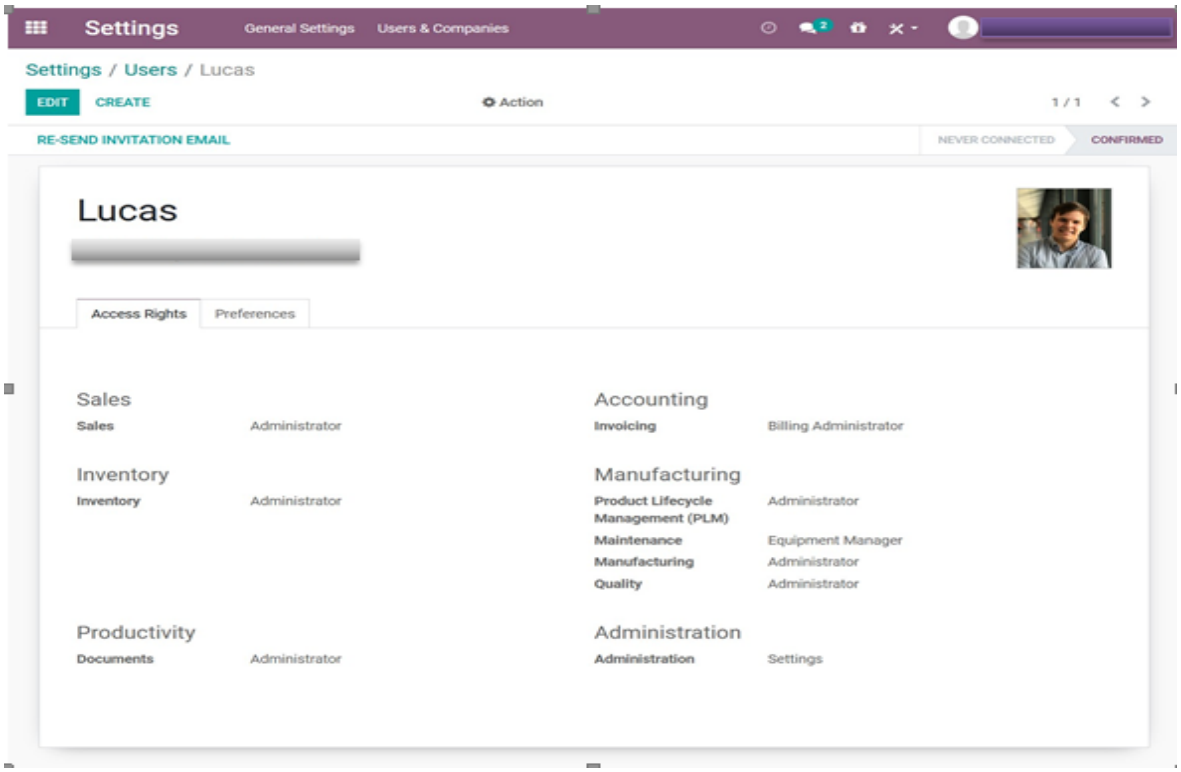

圖 29 用户帳户界面的截圖

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

很高興指出這兩者在訪問權限方面的差異。在這個例子中，Mary Fiction 被創建爲一名工程師，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。

Workcenters and Equipement

5.3.2. 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. In this simulation it was considered that the company already has 3 workcenters from the get-go and therefore the

workcenters and machinery were created beforehand. This is more useful for possible readers interested in implementing Odoo as well as saving sometime. We begin by creating the equipment we have. This is an item class that emphasizes in maintenance organization. The application responsible for managing equipment is the Maintenance App. The following image is an example of how Odoo portrays a 3D printer equipment item (Figure 31).

在 Odoo 中，工作中心在某種程度上非常靈活，因爲它們可以根據需要進行更改和擴展。一個人可以在創建產品項目後創建工作中心，以便在最終獲得對產品的一些了解後重新組織車間。然而，對於大多數情況，這似乎是不現實的，因爲在現實世界中，工作中心是更爲固定的結構 - 它們不像產品那樣經常變化，因爲它們往往擁有重型機械。

在這個模擬中，考慮到公司從一開始就已經擁有了 3 個工作中心，因此工作中心和機械是提前創建的。這對於可能對實施 Odoo 感興趣的讀者來說更加有用，同時也節省了一些時間。

我們首先創建我們擁有的設備。這是一個強調維護組織的項目類別。負責管理設備的應用程序是維護應用程序。下圖是 Odoo 如何呈現一個 3D 打印機設備項目的示例 (見圖 31)。

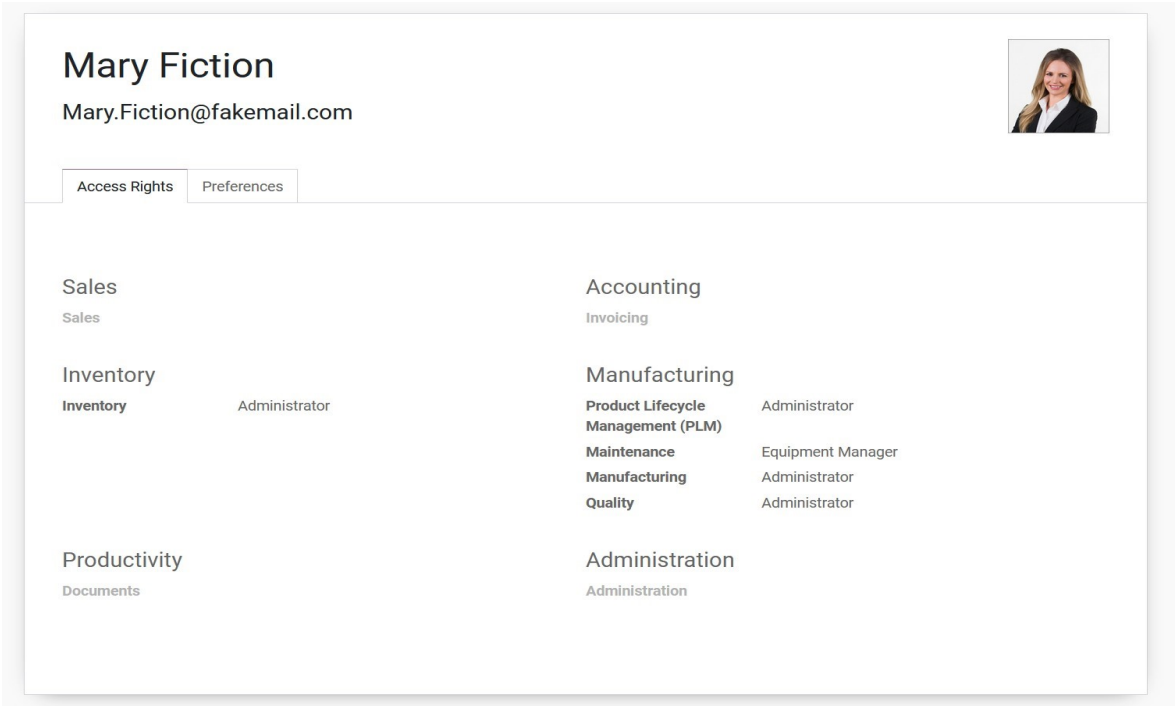

圖 30 第二個用户帳户界面的截圖

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
很好地指出了兩者在訪問權限方面的不同之處。在這個例子中，Mary Fiction 被創建爲一名工程師，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。

Workcenters and Equipement

5.3.2. 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. In this simulation it was considered that the company already has 3 workcenters from the get-go and therefore the workcenters and machinery were created beforehand. This is more useful for possible readers interested in implementing Odoo as well as saving sometime. We begin by creating the equipment we have. This is an item class that emphasizes in maintenance organization. The application responsible for managing equipment is the Maintenance App. The following image is an example of how Odoo portrays a 3D printer equipment item (Figure 31).
在 Odoo 中，工作中心在某種程度上非常靈活，因爲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，以便在最終獲得對產品的一些了解後重新組織車間。但是，對於大多數情況來說，這似乎是不現實的，因爲在現實世界中，工作中心是更爲固定的結構 - 它們不像產品那樣經常變化，因爲它們往往擁有重型機械。
在這個模擬中，考慮到公司從一開始就已經擁有了 3 個工作中心，因此工作中心和機械是提前創建的。這對於可能對實施 Odoo 感興趣的讀者來說更加有用，同時也節省了一些時間。
我們首先創建我們擁有的設備。這是一個強調維護組織的項目類別。負責管理設備的應用程序是維護應用程序。以下圖片是 Odoo 如何呈現一個 3D 打印機設備項目的示例 (見圖 31) :

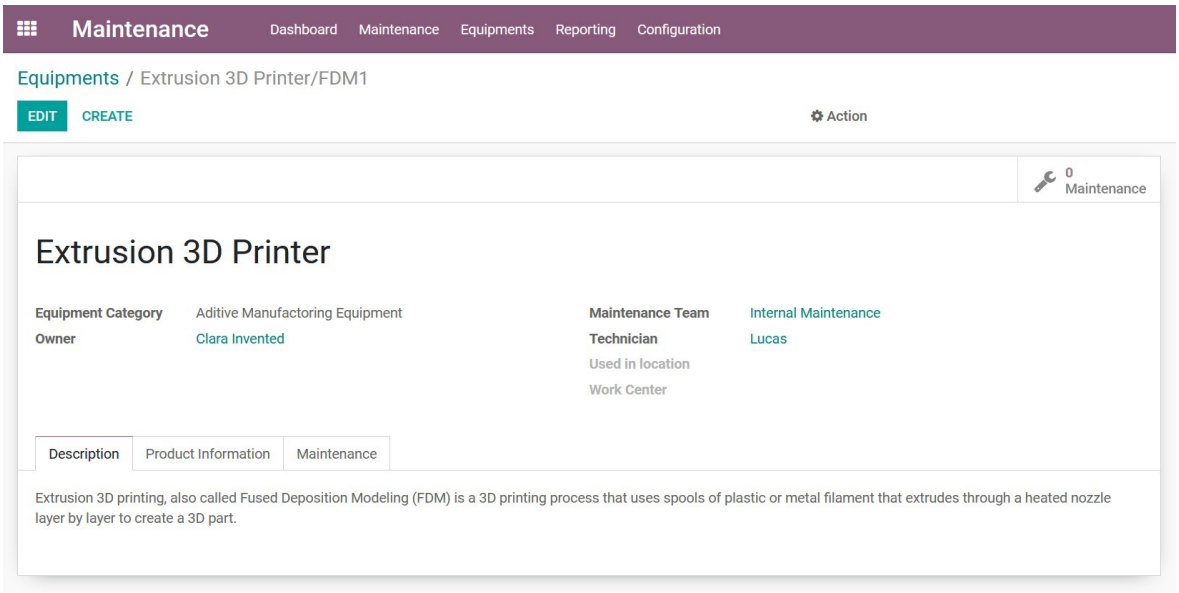

圖 31 Odoo 3D 打印機設備項目

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 打印機之外，還創建了以下設備，以在整個開發/生產過程中使用 (見圖 32):

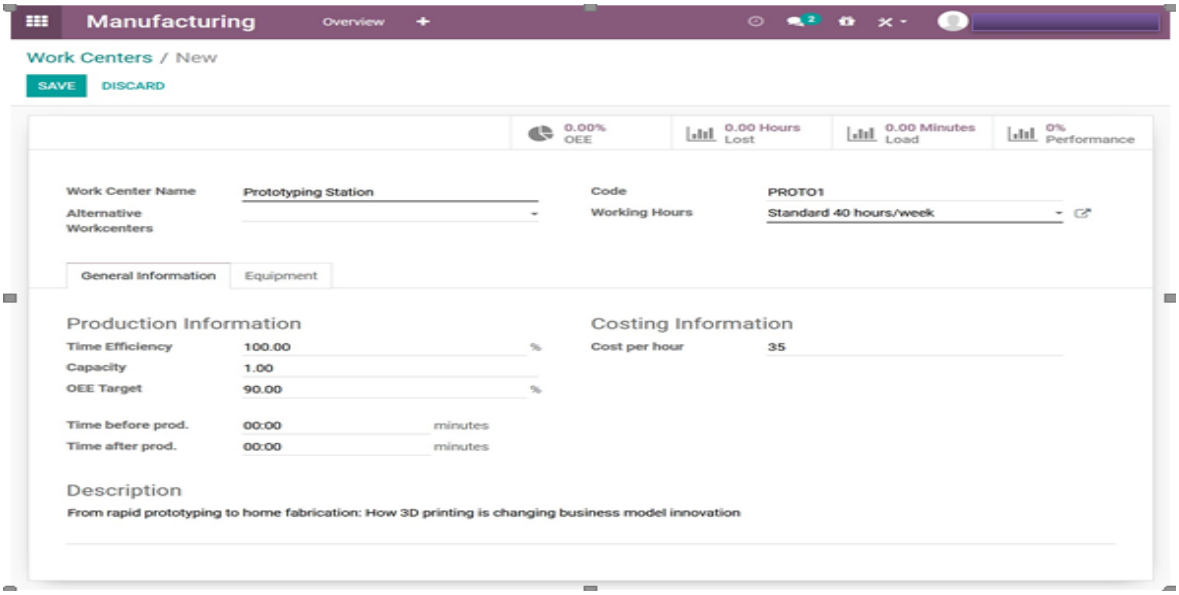

圖 32 設備項目概覽

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.

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

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

這是軟件在 PLM 方面開始顯示限制的地方。雖然設備項目允許一定程度的元數據 (描述文本、負責用户、維護數據和供應商),但它不允許上傳任何類型的文件以附加到該項目類別 (機器手册、報告等)。這是一個相當重要的弱點，因爲文件管理被普遍認爲是 PLM 的主要方面之一。這將是這個模擬的一個重要主題，因爲在 Odoo 中，允許直接向其上傳文件的項目數量是有限的。

現在設備已經創建，它們的工作中心可以被創建。值得注意的是，工作中心項目的主要用途是按小時管理時間和成本。想法是分配給工作中心的設備不應該同時使用，理想情況下，具有極不同運行成本的設備也應該在不同的工作中心，以便更好地跟蹤時間/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 (見圖 33) 是一個工作中心項目的示例，用來代表在產品開發過程中使用的原型製作站。

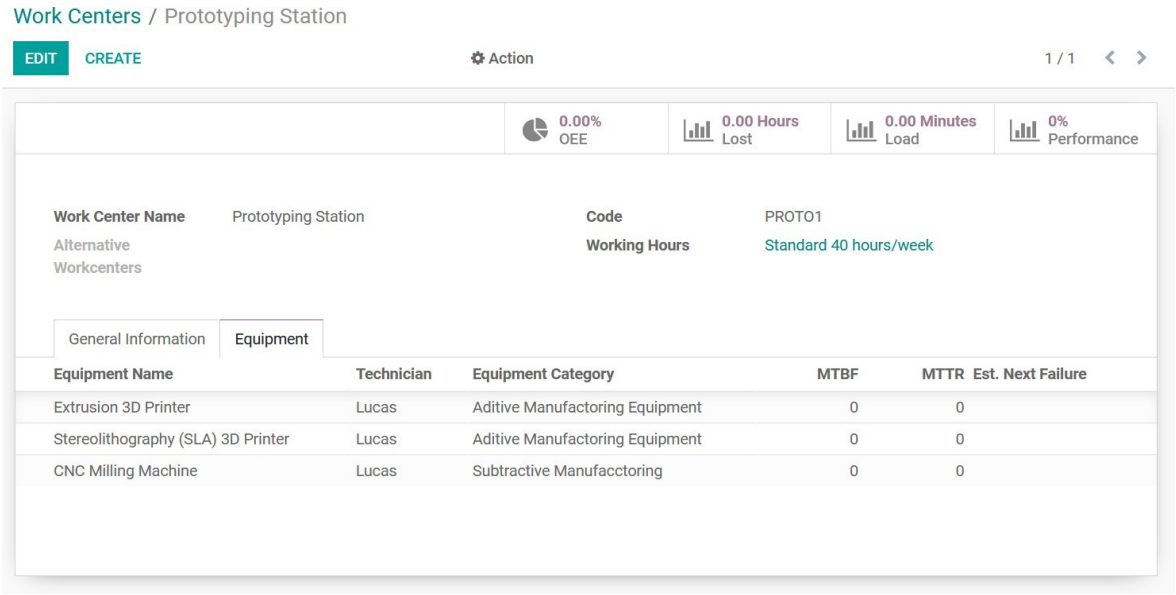

圖 33 Odoo 原型製作站項目表示 1

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.

讀者會注意到這個工作站 (見圖 34) 是 3D 打印機和 CNC 機床所在的地方。通常，由於操作成本的差異以及它們在很大程度上是獨立的，這些機器會被分開放置在單個的工作中心中。然而，出於本模擬的目的，這被認爲是足夠具有代表性的。

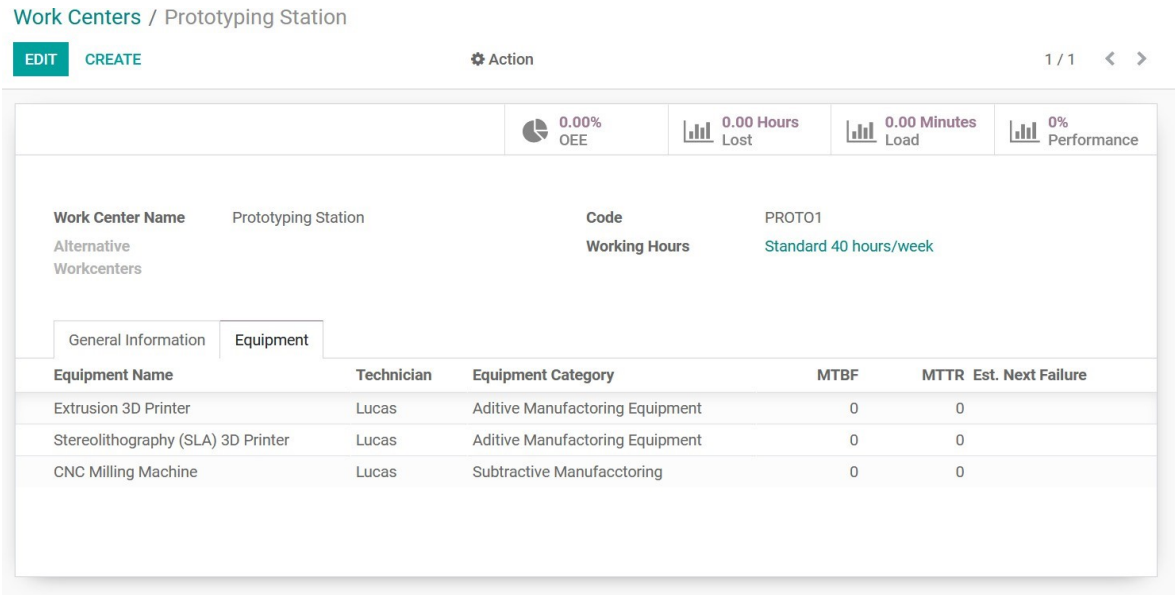

圖 34 原型製作站項目表示 2

5.1.3.1. Product Item
5.1.3.1. 產品項目

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 34 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、零件或產品都由一個 PRODUCT 類型的類別來描述，這個類別主要保存和管理在 Odoo 的庫存應用中。這意味著在系統中，產品的生產取決於其他產品的可用性，這些產品要麼是按原樣購買的，要麼是從其他產品中製造出來的 (見圖 22)，即原材料也被視爲產品，更具體地說，是購買的產品，然後包含在 BOM 中以製造其他產品。這被認爲是主要的項目類別，因爲它既是製造的來源，也是目標。

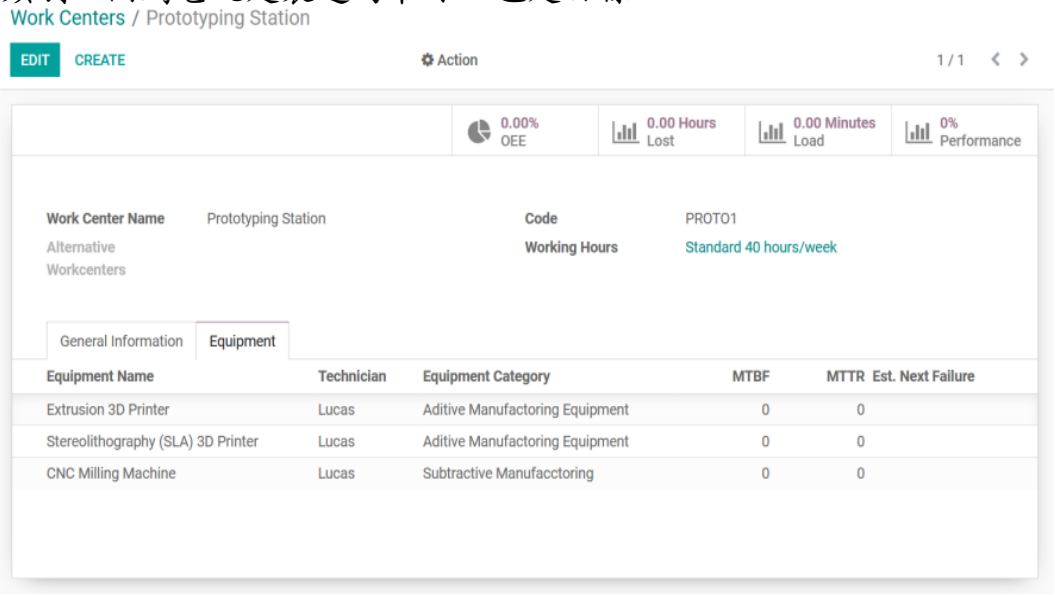

Figure 34 Prototyping Station item representation 2
圖 34 原型製作站物品表現 2

The following workcenters have been also created for the simulation and filed with the necessary equipment:
以下工作中心也已爲模擬建立並填入所需的設備：

Figure 35 Overview of Workcenter items
圖 35 工作中心項目概覽

5.4. Development
5.4. 發展

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，重點是使用 Odoo (見圖 9) 的全新產品開發方面，因爲這是公司第一個要創建的產品，因此評估了使用 Odoo 組織原型製作流程的可能性。這包括從想法到設計和原型製作的過程。然後，一旦產品已經達到可接受的原型結果，將進行關於生產過程開發的工作。當正式生產完成後，產品開發被認爲是成功的。

5.4.1. Idea - design - product prototype
5.4.1. 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，並且已經進行了初始設計特徵和基本產品研究。這代表了 Odoo 軟件在現實世界中的實際應用，因爲雖然 Odoo 具有良好的項目管理和通信應用程序，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 軟件沒有集成。在這個模擬中，將想法紙上實現，並使用 Solidworks 軟件將其轉化爲 CAD 設計，生成一個在工程師計算機上本地存儲的 CAD 文件。

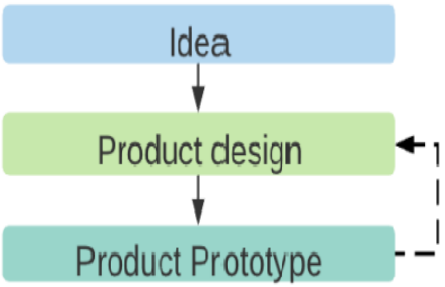

Figure 36 Sectioned diagram regarding product development
圖 36 產品開發剖面圖

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，可以正式開始利用 Odoo 軟件。第一步是了解產品項目的生產主題是什麼。在如何做到這一點方面有兩種方法：

- 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爲最終產品的早期版本，即在開發過程中對原型進行修訂後，Odoo 中創建的原型項目將與最終產品項目相同。如果原型是通過與最終生產相同的方法實現的，那麼這將是推薦的做法。這種方法的一個例子是，如果產品足夠簡單，使得產品和生產方面的開發可以一起進行。

- 第二種方法是將原型視爲與最終產品分開的項目 - 這是本次模擬所採取的方法。做出這個決定的主要原因是，我們的原型製作方式與最終生產方式不同，因爲我們使用了 3D 打印技術來製作原型。

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.
從根本開始，創建了一個名爲”PROTO Alpha Case” 的產品項目 (見圖 37)(Alpha Case 是產品的名稱)。從這一點開始，我們將將原型產品稱爲’proto 項目’。正如我們所看到的，這使得 proto 項目能夠得到良好的表現。由於這是一個原型，它不會被標記爲可以出售或購買的東西，銷售價格將設置爲 0 美元，因爲這不重要。這個 proto 項目將用於連接其開發的不同方面，但目前它被獨自留下。

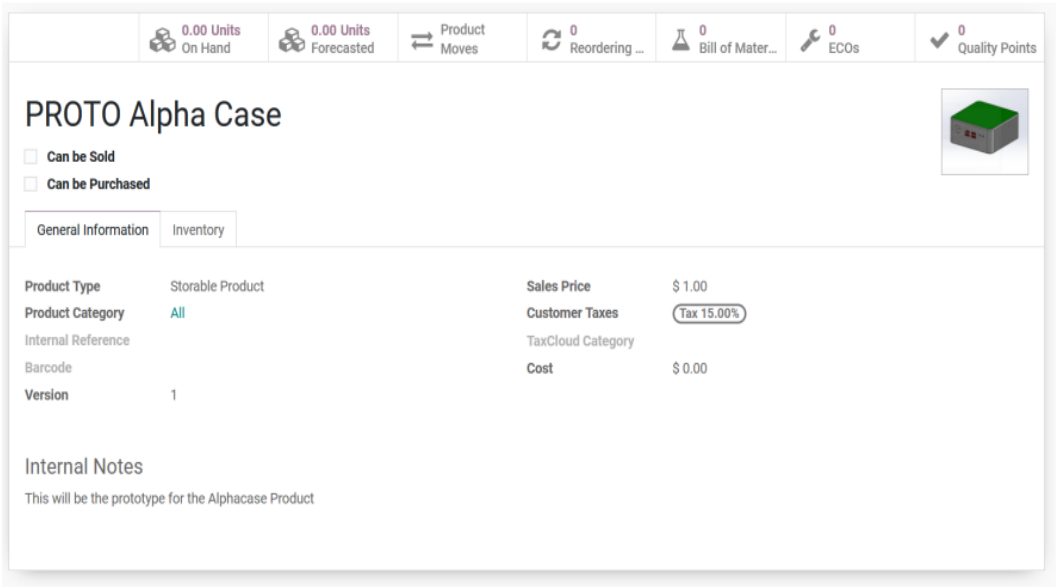

Figure 37 Image of the prototype product item
圖 37 原型產品項目的圖像

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 章中先前所建立的，產品將由 3 個部件 Part A、Part B 和 Part C 組成。這些部件也需要進行原型製作，並且被創建爲產品，以便它們可以添加到 PROTO Alpha Case 的物料清單中。最後，決定使用特定的塑料填充物 (見第 4.1.1 節) 來進行 PROTO Part A、PROTO Part B 和 PROTO Part C 的 3D 打印，這些也需要被添加爲產品 (見圖 38)。

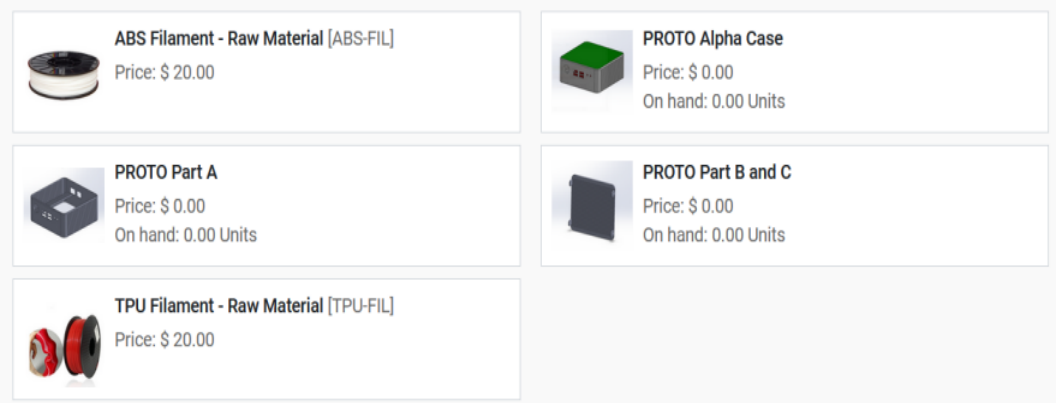

Figure 38 Overview of Product class items for prototype
圖 38 原型產品類項目概覽

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):

在這一點上，與 Alpha Case 的原型製作相關的產品項目已經完成，這使得可以創建其相應的 BOM (物料清單)。共有 3 個 BOM，它們遵循 (圖 39) 中的結構：

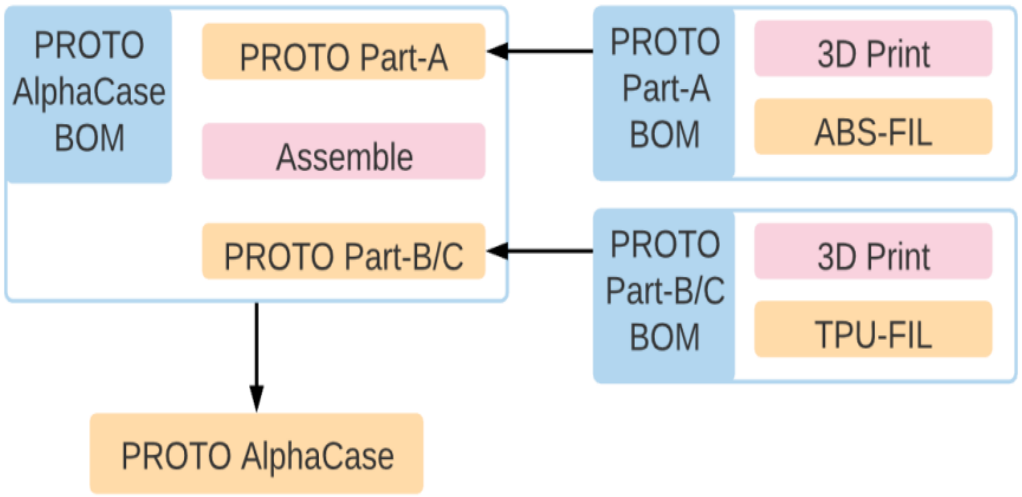

Figure 39 BOM diagrams for prototyping
圖 39 原型製作的 BOM 圖示

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 在產品項目上使用了套件選項 (見圖 40)，以推斷該產品是另一個產品的組件。這非常有趣，因爲它自動創建了生產中產品項目之間的依賴關係。

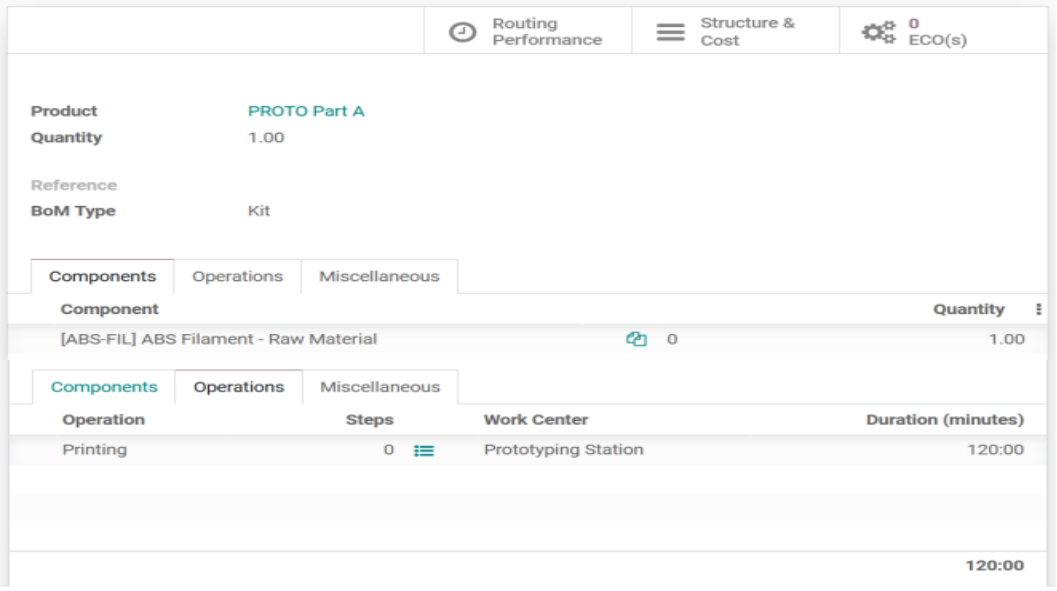

Figure 40 Image of the prototype product BOM (Part-A)
圖 40 原型產品 BOM (Part-A)

As the reader can see (Figure 41), while making the BOMs it is simple to create the specific operation items necessary for the manufacturing procedure and specify its

work center. One of the best functionalities regarding MES in Odoo is the ability to track the time of operations based on default duration. This can be dynamically changed based on tracked time or set manually. It is also in the operation item that we can add instruction files for the operation. Even though it is limited to PDF text or a link to a google slides file, this is one of the few opportunities presented by Odoo for file management connected directly to an item.

正如讀者所見 (見圖 41)，在製作 BOM 時，很容易創建製造程序所需的具體操作項，並指定其工作中心。關於 Odoo 中 MES 的最佳功能之一是能夠基於默認持續時間追踪操作的時間。這可以根據追踪的時間動態更改，也可以手動設置。在操作項中，我們還可以添加操作的指示文件。儘管這僅限於 PDF 文本或連接到 Google 幻燈片文件的鏈接，但這是 Odoo 爲直接連接到項目的文件管理提供的少數機會之一。

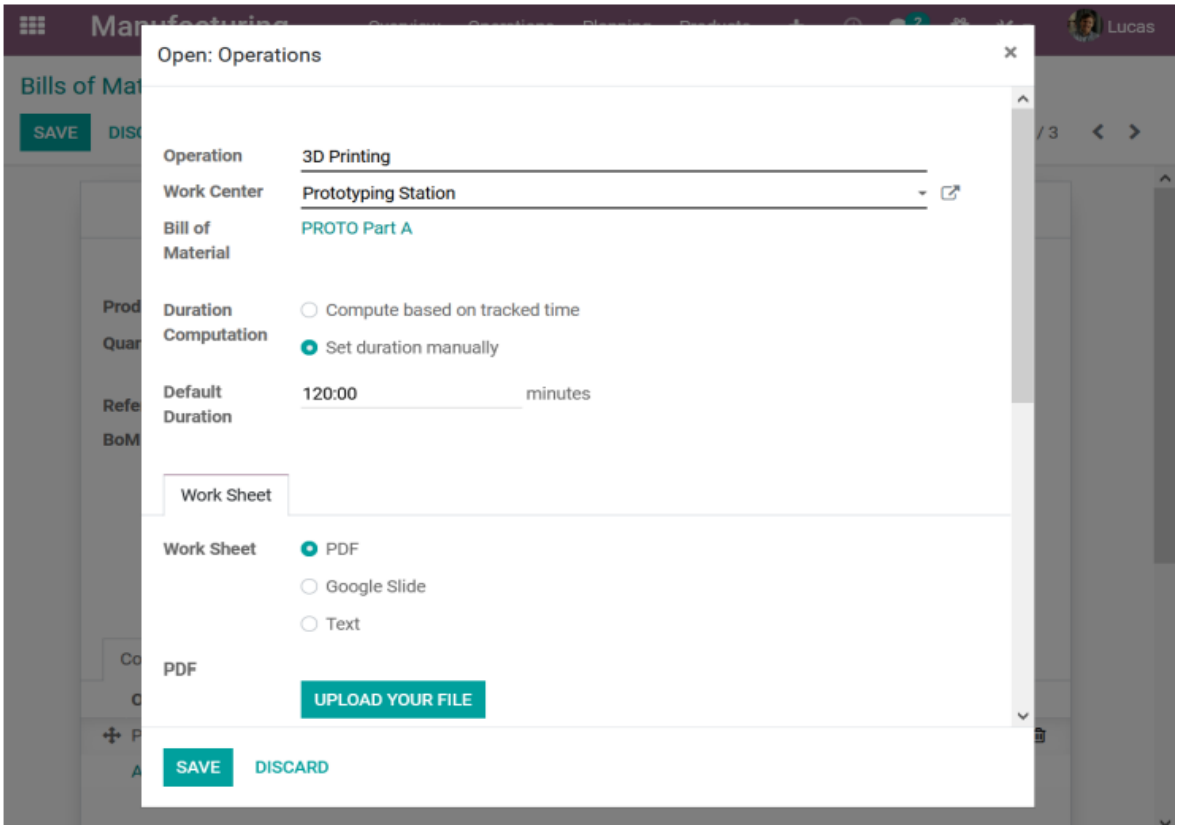

Figure 41 Image of operation item as presented by Odoo (BOM Part-A)

圖 41 Odoo 呈現的操作項圖像 (BOM Part-A)

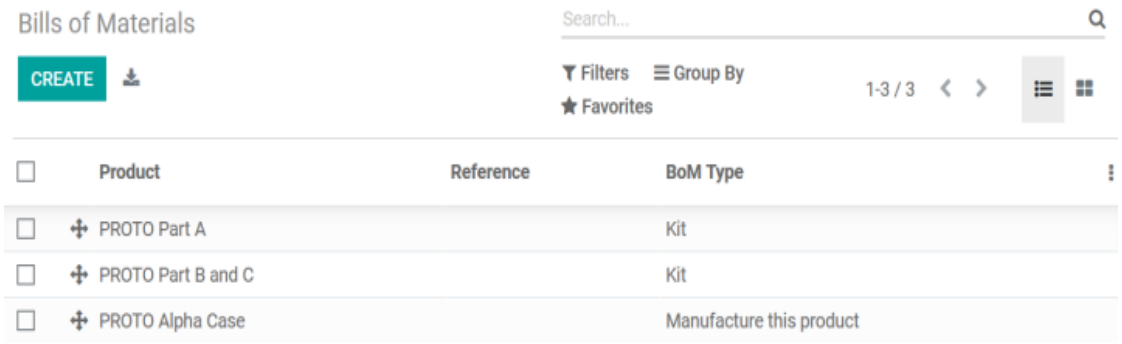

Figure 42 Overview of BOMs created for prototyping

圖 42：用於原型製作的 BOM 概觀

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到該項目的方法。在我們的情況下，我們有關於我們正在原型製作的零件的 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 節中所解釋的那樣，ECO 是一個與產品項目或 BOM 相關聯的項目，允許上傳的文件附加到它。這是一個次要的解決方法，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。

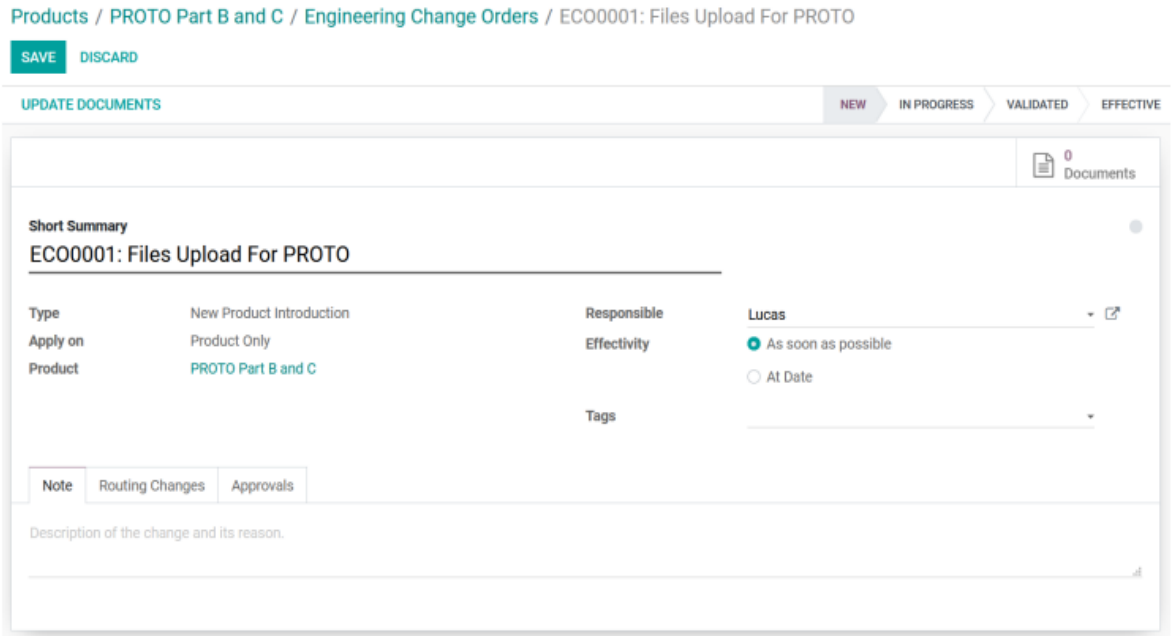

Figure 43 ECO example
圖 43 ECO 示例

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 團隊在其 ERP 基礎上實施 PLM 作爲外部應用程序的戰略的一部分。這是合理的，但仍然，這是該軟件界面中少數幾個不那麼直觀的方面之一。這是一個非常有價值的功能，但它有些隱藏。在創建並保存 ECO 之後，文件圖標才會出現在右上角 (見圖 43)。

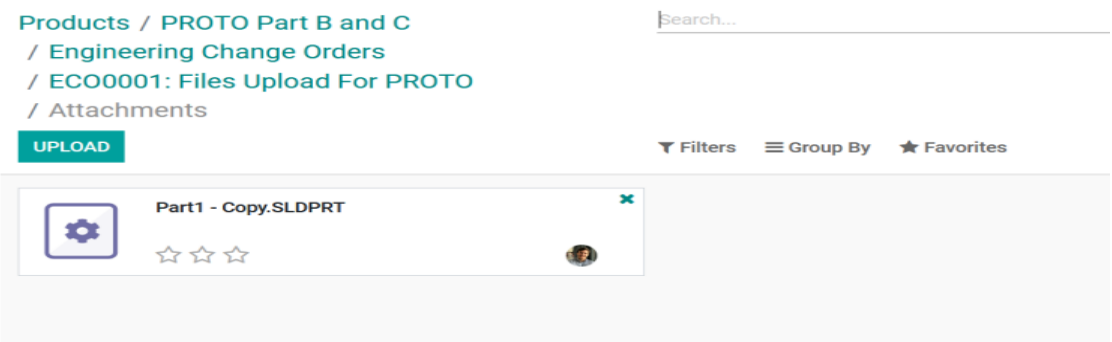

Figure 44 Overview of attached files to ECO

圖 44: ECO 附加文件概觀

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，上傳文件不會自動更改產品元數據。從 PLM 的角度來看，這不是理想的情況，但這是一個良好實施的功能。通過允許產品項目直接鏈接到不僅是一個現有的 ECO，而是到過去應用於該項目的所有 ECO 的列表，軟件在跟蹤版本控制和開發方面做得很好。

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.

爲了進行過程控制，可以做一些有趣的事情，例如將質量控制點添加到操作中。這允許負責人員在生產過程中就工程團隊關注的點提供反饋。在我們的案例中，我們擔心的是 3D 打印變形。當 3D 打印過程中溫度變化太大時，就會發生這種情況。爲此，將創建一個質量控制點項目 (見圖 45)，該項目將要求操作員檢查零件是否存在變形，並標記通過或不合格。

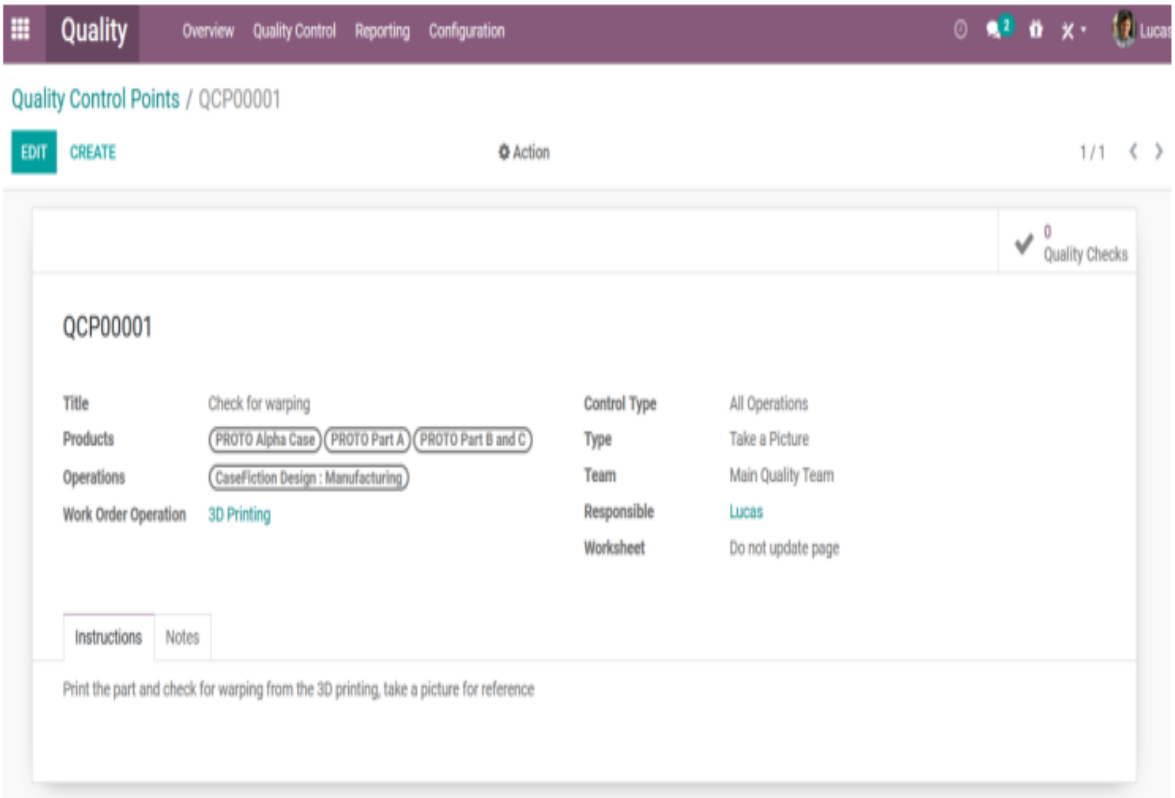

Figure 45 Quality Control Point item for the prototype production

圖 45：用於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.

原型週期的最後一步將是生產原型進行測試和評估。在 Odoo 中，生產是非常直觀的，也是我們之前所做的一切結合在一起的地方。已經創建的元數據和項目允許我們啓動製造訂單 (MO)(見圖 46)。這反過來從 BOM 中列出的操作和組件中提取必要的工單。工單出現在製造操作員面前，生產可以開始/被跟踪。

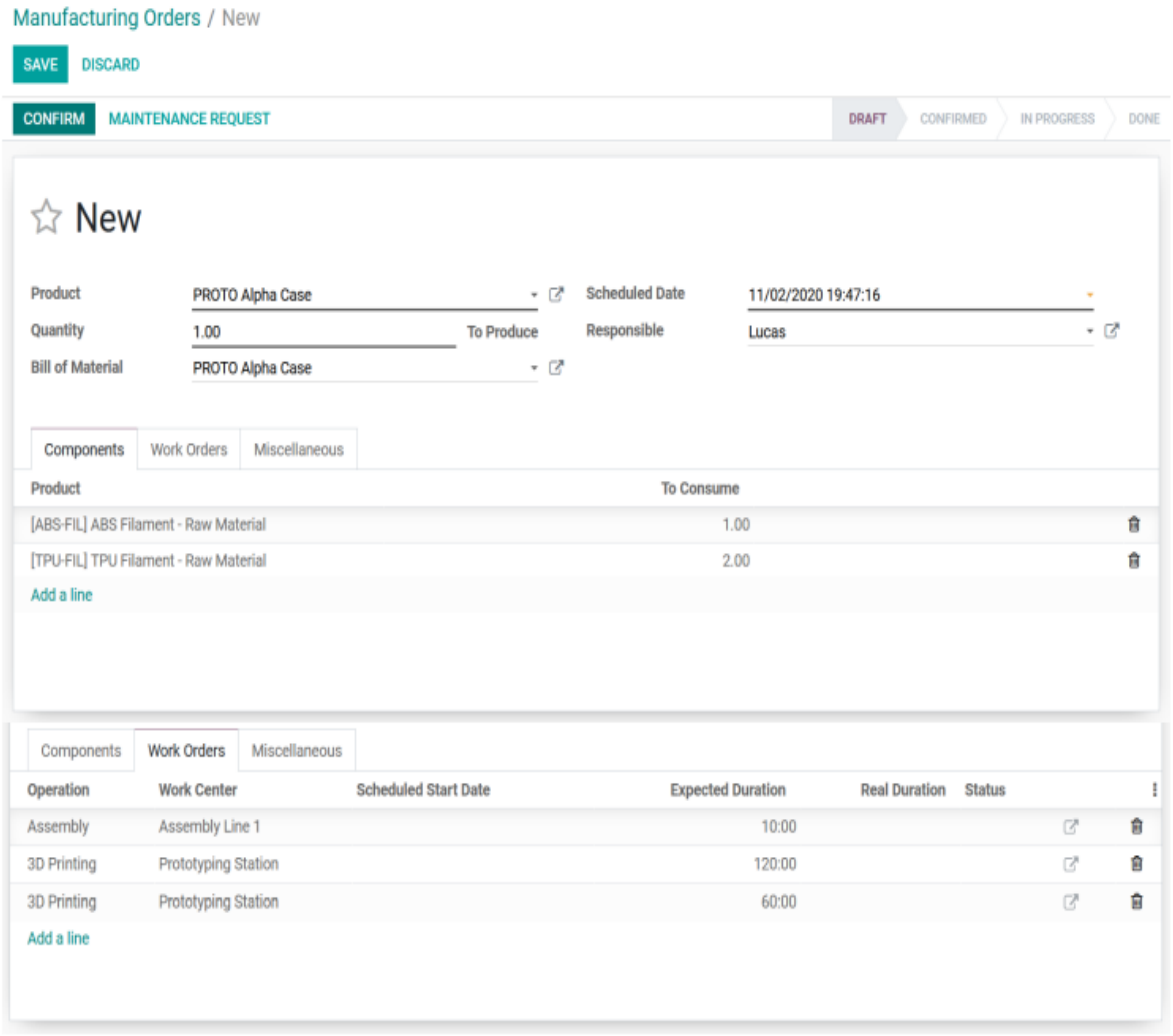

Figure 46 Depiction of the manufacturing order 圖 46：製造訂單的描繪

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且清晰。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，軟件通過使用一個名爲“路線 (Route)”的額外項目類來指示進行操作。這些是產品在庫存和製造過程中移動的基本部分，但出於某種原因，在新版本的製造方面，傾向於在 BOM 中內置簡化的序列數據，而放棄了這些路線。截至撰寫本文時，已有報告稱該功能存在問題和混亂，這一問題加劇了使用該功能的解釋材料要麼不存在，要麼仍在引用舊版本的軟件 (其中“路線”仍在使用)。

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 only solution is to count on the awareness of the operators regarding the order of production or manually scheduling the operations in the plan tab. During the period of research for this work (before Odoo V14) familiarization experiments were made in which there were no problem of this nature. In addition, there are examples online even from Odoo website demonstrating the use of routes and how they are useful for this exact situation.
熱心的讀者會注意到圖 47 中操作可用的順序並不正確。這正是由於這個問題，目前唯一的解決方法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。在進行本文研究期間 (Odoo V14 之前)，曾進行過熟悉化實驗，並未出現此類問題。此外，甚至在 Odoo 網站上也有示例，展示了路線的使用以及它們在這種情況下的用處。

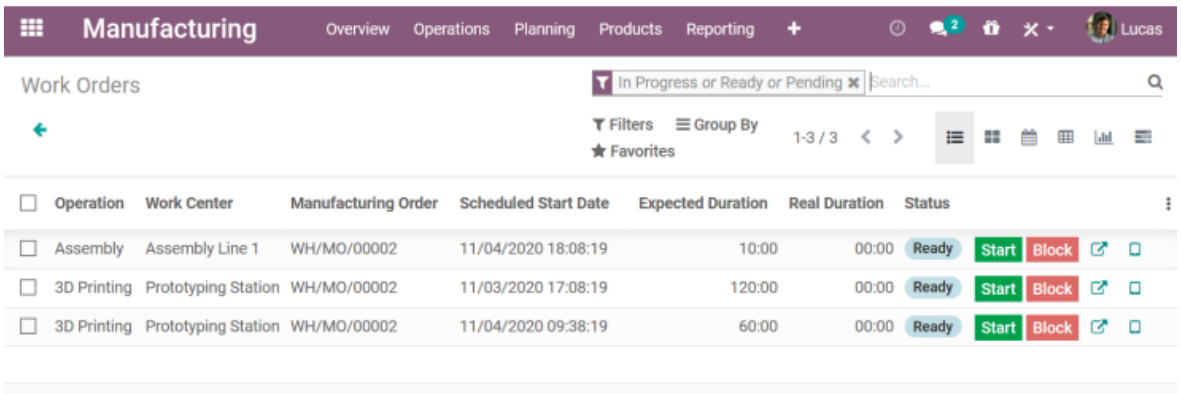

Figure 47 Overview of the resulted Work Orders
圖 47: 結果工單概述

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.
問題已被其他人 (見圖 48) 報告給 Odoo 公司，並且正在進行解決，希望很快能解決 (畢竟這是軟件的一個非常新的版本)。話雖如此，這仍然是一個問題，即使它只是一個小問題。

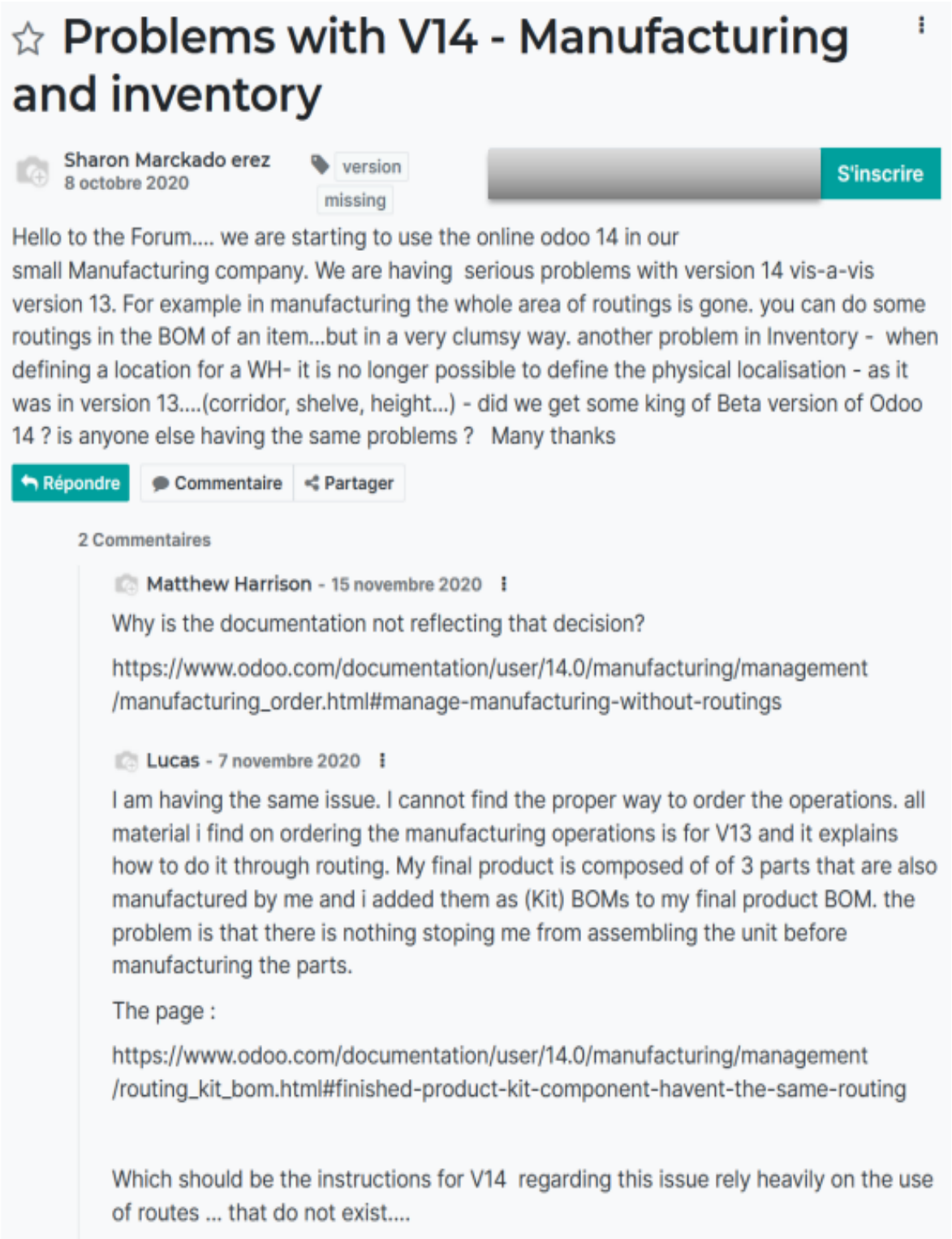

Figure 48 Image of Odoo forum question regarding routes

圖 48：關於路線的 Odoo 論壇問題的圖像

The manufacturing process was repeated 7 times (Figure 49) to simulate a small batch of prototypes for testing and tolerance checking. It is rare to get a perfect prototype in the first batch, for this reason it was chosen to represent correction

through the simulation. In this simulation this problem was a fit problem that resulted in a change of dimension of PROTO Part A.
製造過程被重複了 7 次 (見圖 49)，以模擬一小批原型進行測試和容差檢查。很少能在第一批中獲得完美的原型，因此選擇通過模擬來表示修正。在這個模擬中，問題是一個適合問題，導致 PROTO Part A 的尺寸變化。
Figure 49 Overview of the products after manufacturing
圖 49 產品製造後概覽
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，建立和控制更改爲產品項。要執行的更改在 CAD 檔上，涉及產品項。和以前一樣，我們可以啓動 ECO 並填寫描述，然後檔是上傳，ECO (圖 50) 在進行之前經過必要的驗證有效。

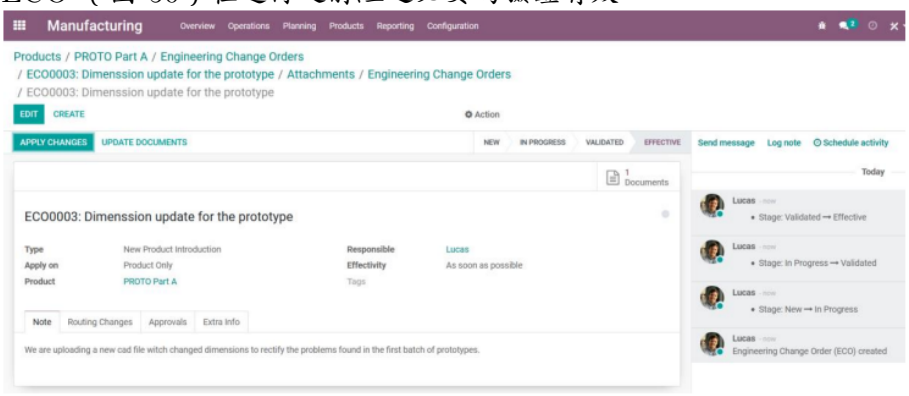

Figure 50 Depiction of the validation of the ECO
圖 50 ECO 驗證說明

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
驗證程式基本上是設置爲要求對某人進行適當的驗證存取權限或特定人員。在本例中，主帳户用於驗證並使其有效，從圖像右側的日誌中可以看出。一旦改變

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).
應用後，您可以看到產品項版本已反覆運算到版本 2 以及與該專案連結的 ECO 清單中添加了一個新的 ECO (圖 51)。

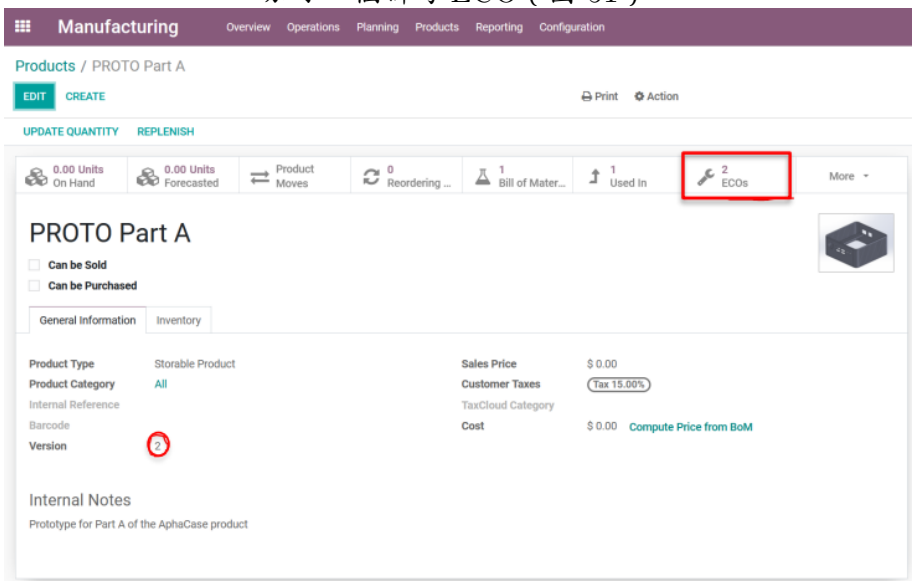

Figure 51 Depiction of changes provoked by the ECO to product item
圖 51 ECO 對產品專案引起的變化的描述

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.
該更新之後是另一批原型，該週期將持續到生產的原型符合設計團隊制定的標準。在這種情況下模擬假設一個修正足以代表這個過程。這完成從想法到原型的開發。

5.4.2. Process Plan - Production Test Run - Production
5.4.2. 工藝計畫-生產試運行-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，重點將轉移到流程上。已確定以前，決定將原型產品與最終產品專案分開進行隔離產品從生產過程中的開發過程開始。這樣一來，很多方面產品的開發可以有序地進行評估。現在，該過程被開發出來，創建將代表最終的產品專案似乎是合理的產品由於產品成功運行的過程將準備好生產它的樣本 (圖 52)。

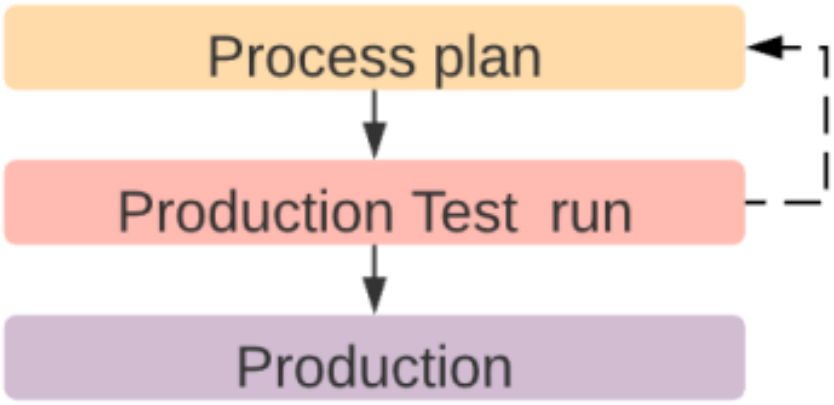

Figure 52 Sectioned diagram regarding Process development
圖 52 工藝開發剖面圖

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).
創造的其他產品專案是注塑成型的原材料 (其中是送入機器進行熔化和注射的塑膠顆粒)。所有這一切都完成了以與我們創建原型產品時相同的方式，除了 Alpha 案例 (圖 53) 現在被標記爲可售，其銷售成本現在相關 (圖 54).

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

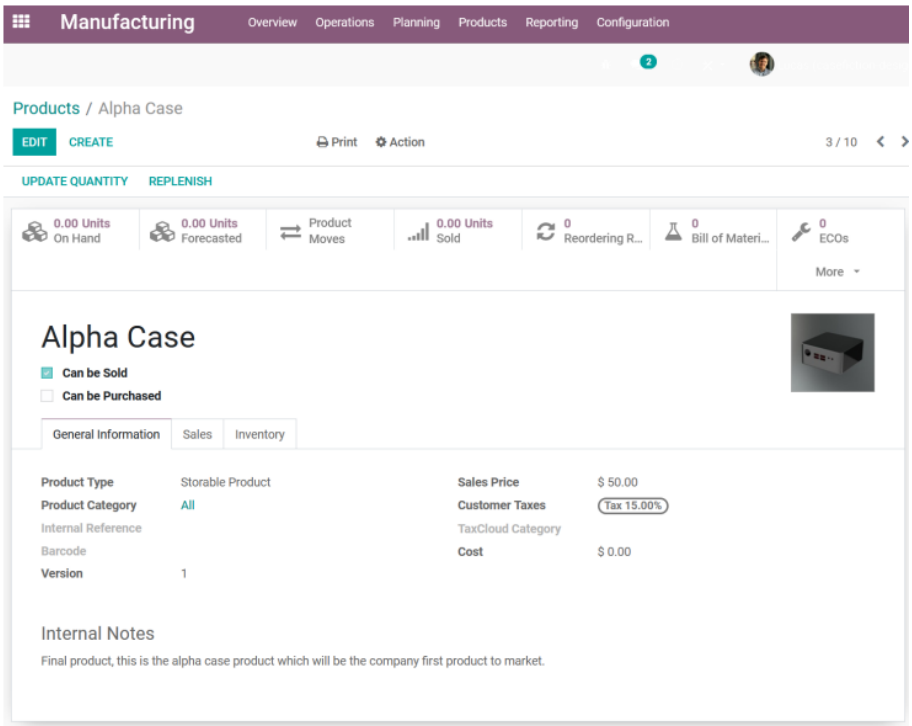

Figure 54 Product Item of the Alpha Case
圖 54 Alpha 案例的產品項

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).

一旦產品專案得到處理，我們需要回到流程的哪個方面將在此模擬的上下文中使用 Odoo 進行跟蹤。正如之前暗示的那樣，當談到注塑成型，工藝變化的關鍵方面是模具機器用來製造零件。對於這個模擬，認爲模具開發將遵循與產品開發非常相似的程式，這從下圖（圖 55）中應該更清楚。

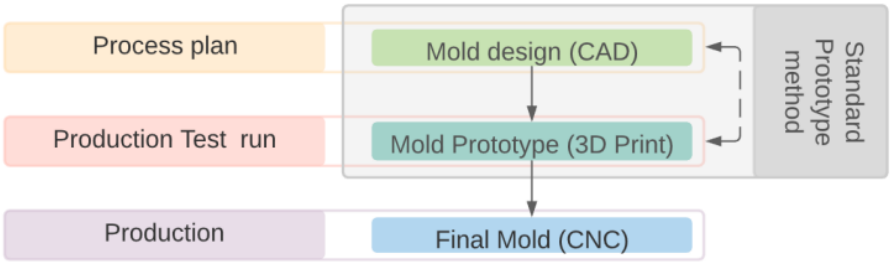

Figure 55 Diagram regarding process development for mold
圖 55 模具工藝開發示意圖

The production of a prototype mold by 3D printing follows the same standard procedure for prototyping used for the product. So far, the mold is considered a product like any other, this reveals another small weakness regarding Odoo ability to represent the totality of the process. The reader will notice that although the mold is been treated as a product (because it is been manufactured) it should in fact be considered a tool or piece of equipment as well.
通過 3D 列印生產原型模具遵循相同的標準程式用於產品原型設計。到目前爲止，模具與其他任何產品一樣被認爲是一種產品，這揭示了 Odoo 表示整體能力的另一個小弱點過程。讀者會注意到，儘管模具被視爲產品 (因爲它被製造出來) 實際上也應該被視爲一種工具或設備。

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 確實在設備和產品之間進行了這種區分，但它沒有關於兩者兼而有之的情況的整合。此外，如前所述，還有無法將 CAD 檔上傳到設備專案或將設備連結到範圍的工具。即 Odoo 不考慮使用具有 x 個鑽頭的立式鑽頭來製造不同尺寸的孔。從設備/維護的角度來看，它能做的最接近的是將立式鑽機視爲一個工作站，每個鑽機尺寸都是一個單獨的設備。具有指定設置時間的工作站。如果您忽略鑽頭是產品，則沒關係。

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 ERP 系統的角度來看並不理想。PLM 的視角，因爲它顯示了應該代表相同的項目之間的差距東西。在生產中，從製造應用程式開始，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，與事實沒有聯繫該工具是消耗品，您可以考慮維護計畫，甚至做一個有用的壽命參數，但因爲它是設備，你不能有備用工具就像庫存中的鑽頭一樣，就像消耗品一樣。

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，用原型模具表示測試變得非常困難。如果您可以按照軟體的設計進行操作，您需要創建一個單獨的 ECO 來應用每個對模具開發的每次不同反覆運算進行操作，以達到必

要的 BOM 和進行測試運行 (圖 56)。在這一點上，考慮模具的維護方面爲一個工具是沒有意義的，因爲它需要在維護中歸檔中繼資料手動應用程式用於每個原型模具反覆運算，而不會與製造業視角。PROTO 模具項目最終僅用於隨著模具的改進，跟蹤材料並保持檔。

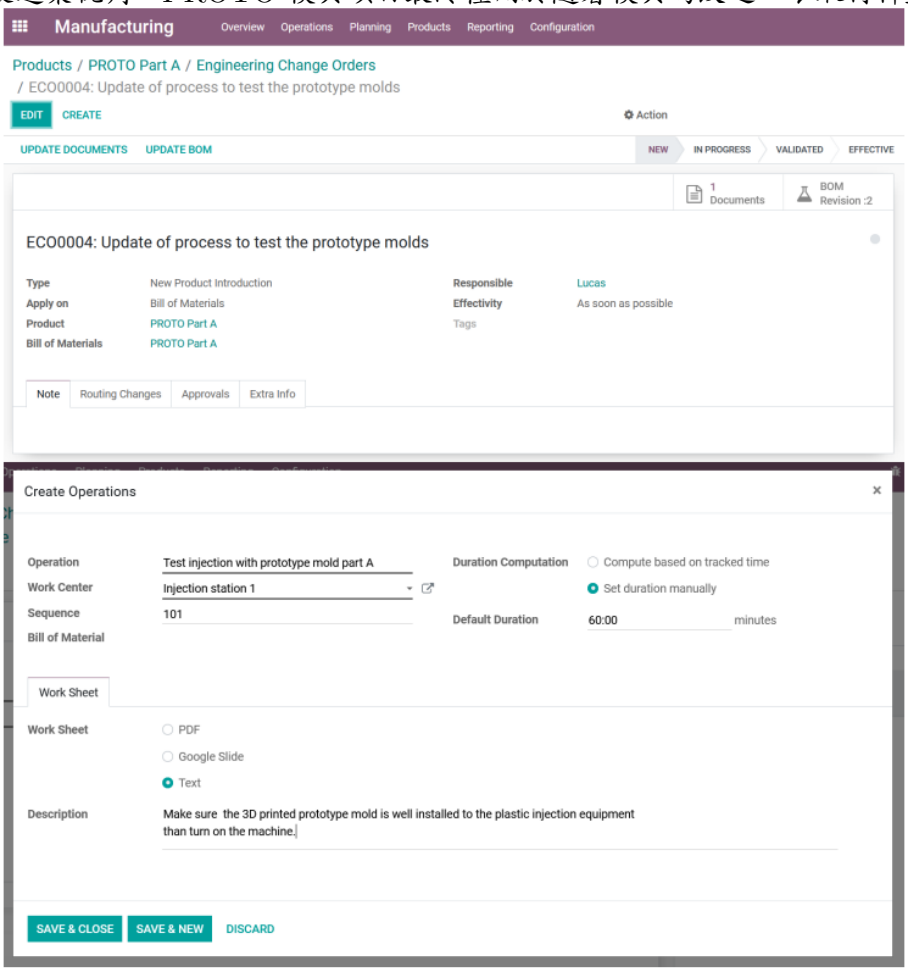

Figure 56 ECO example of update procedure of BOM
圖 56 BOM 更新程式的 ECO 示例

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，它將生產一個 3D 列印模具用於 Alpha 案例的每個部分。然後，將創建案例原型部件的 ECO 以應用於零件 BOM，將操作從 3D 列印更新爲注塑成型使用原型模具進行試運行。

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
在這一點上，我們可以將產品原型與測試運行原型區分開來然而，考慮到我們快速增長的清單，製作一個新的原型產品專案產品專案 (圖 57) 得出的結論是，最好在此進行描述努力修改以前生產的產品原型 (用 3D 列印製成)，然後

use the same items. We can do this because those prototypes have already served their purpose.
只是使用相同的項目。我們可以這樣做，因爲這些原型已經爲他們的目的。

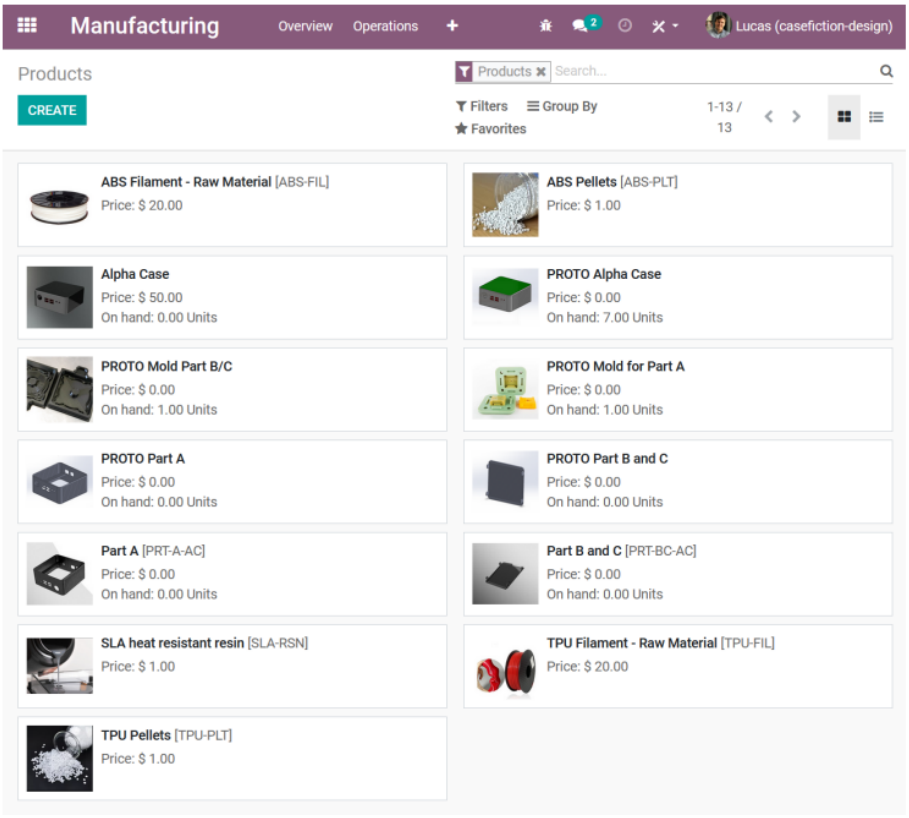

Figure 57 Overview of product items at this stage of the simulation
圖 57 類比此階段的產品專案概覽

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).
創建模具後，原型的 BOM 將更新爲包括注塑站和正確操作（指定模具的使用）下一步就是做原型的生產試運行。同樣，這是通過發出 MO 完成來完成的生成的 WO（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擬合度（如果校正是需要再次排放 ECO，如圖 56 所示，並且將進行生產和測試。此過程將重複，直到產品令人滿意，足以證明將使用的 CNC 加工模具的生產是合理的在批量生產中。

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，這是下一步的發展。程式基本相同和以前一樣，除了需要爲原材料（鋁）創建產品專案塊）和製造前的 CNC 模具。創建 BOM 表和上傳相關檔。

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，可以開始新模具的實際生產。表示創建了 100 個 Alpha 案例的製造訂單。這標誌著主路徑的結束從構思到生產的發展（圖 58）。

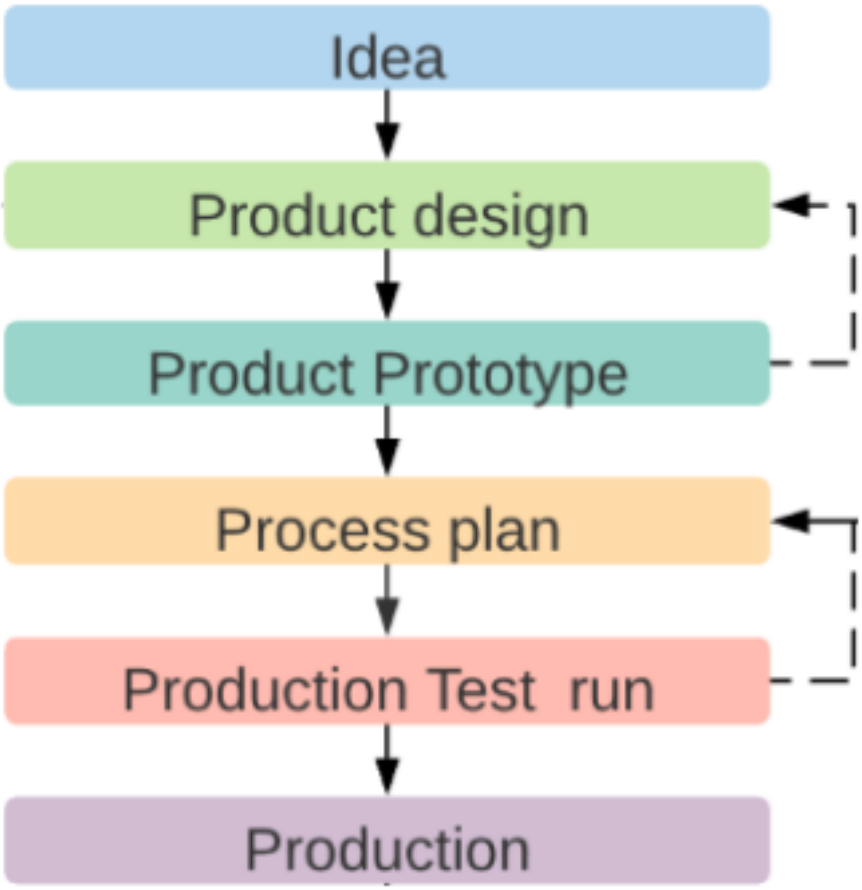

Figure 58 Main path of development from idea to production
圖 58 從構思到生產的主要發展路徑

5.4.3. Process upgrade procedure
5.4.3. 進程升級過程

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 utilizing items like Products, BOMs, ECOs, MOs, WOs and Operations.

This section will be different in the sense that now we have a production being carried out and the idea is to test Odoo in its capabilities of performing upgrades (Figure 59 and Figure 60). In other words, performance and feedback of information (and of course MES) becomes the main subject.

前面的部分是關於使用 Odoo 所需的程式用於跟蹤產品主要開發過程中變化的軟體。因此，大部分是重點介紹了 PLM 的使用以及創建和利用的標準程式產品、物料清單、ECO、MO、WO 和運營等專案。此部分將有所不同從某種意義上說，現在我們正在進行生產，我們的想法是測試 Odoo。其執行升級的能力 (圖 59 和圖 60)。換言之，資訊 (當然還有 MES) 的性能和回饋成爲主要主題。

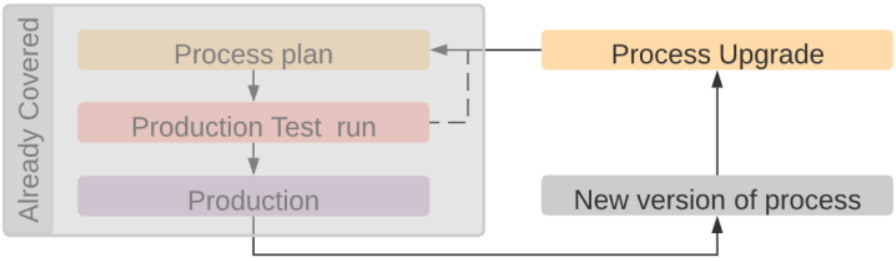

Figure 59 Sectioned diagram regarding Process upgrade procedure
圖 59 進程升級過程剖面圖

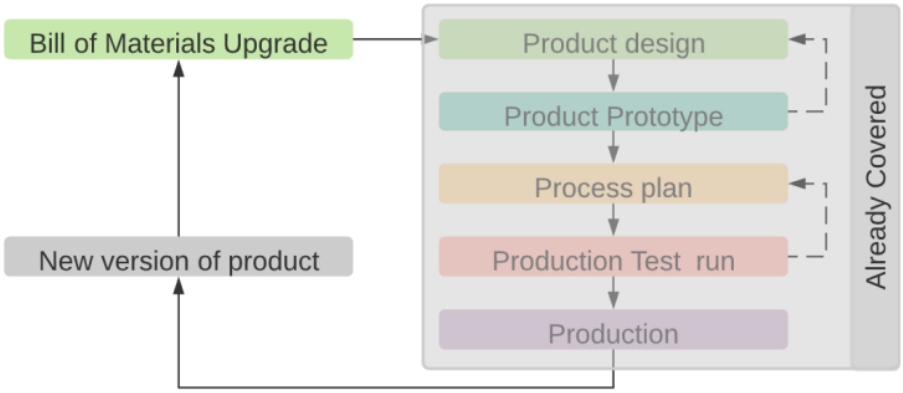

Figure 60 Sectioned diagram regarding Process development
圖 60 工藝開發剖面圖

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 功能進行更改。提醒讀者，應用此更改的情況 (圖 61) 是產品概述相關產品專案。該清單中的每個產品專案 (不是原材料) 都擺出姿勢至少一個 BOM 和兩個 ECO 已經應用於它們，以表示初始狀態每個產品專案 (圖 62)。每個專案的第一個 ECO 都會影響產品及其保存初始相關檔，第二個應用於產品的 BOM 以保存與過程的初始狀態相關的檔，以及記錄 BOM 的初始狀態。如果沒有這些 ECO (圖 62)，當我們應用改進時，初始狀態產品檔或 BOM 將丟失。

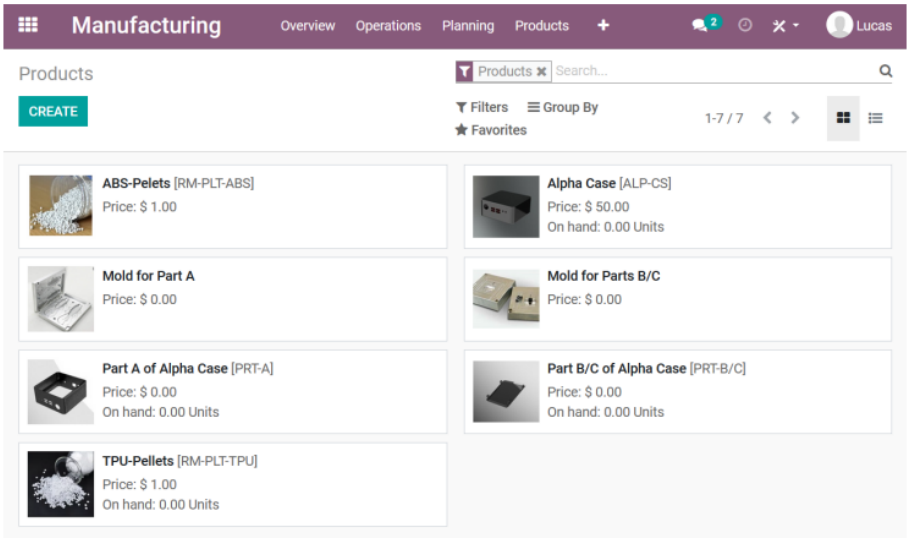

Figure 61 Relevant product items overview
圖 61 相關產品項概覽

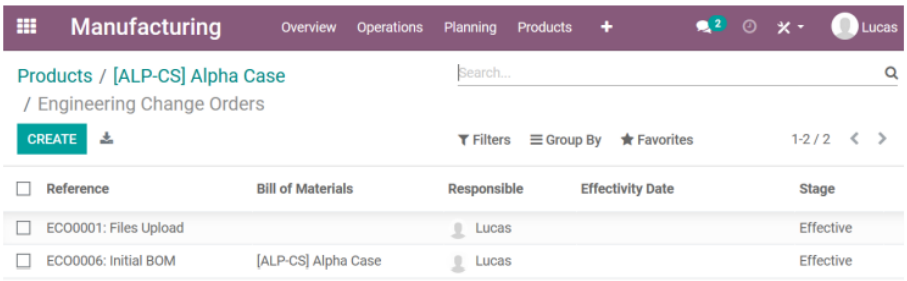

Figure 62 Example of ECOs of a product item
圖 62 某產品項的 ECO 示例

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).
這個時間大約是生產持續時間和過程的估計持續時間需要考慮的事情，這樣我們才能感知到應用的變化對工藝影響生產。爲此，將創建一個 50 個單位的 Alpha Case 的 MO 每個操作估計需要 30 秒 (部件 B/C 爲 15 秒，因爲有需要其中的 2 個)。這意味著在理想情況下，總長度爲 50 分鐘 (25 分鐘並行進行注塑生產，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.
在這個類比製造運行中，選擇注射操作將需要稍多一點的時間才能完成，以代表次優性能。這這樣做是爲了查看 Odoo 如何反應並即時通知手頭的情況。

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).

在注射過程中的第一階段生產，並行進行注射站 1 和 2 上的 A 和 B/C 部分。下面 (圖 64) 顯示了如何在流程開始時，生產站的概覽以綠色表示圈。這些通告在被稱爲 Andon 中，儘管它並不總是被考慮作爲 MES 的一部分，它通常是許多 MES 系統中的集成功能。生產後過程進行得稍有延遲，圓圈變灰，整體效率高在工作站標籤上標記爲紅色 (圖 64)。

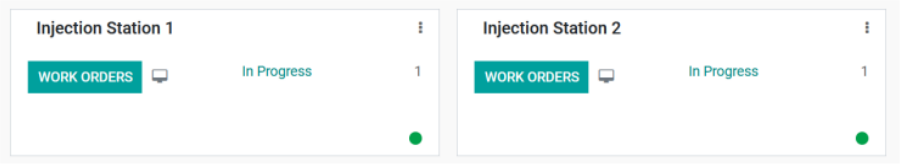

Figure 63 Workcenter overview 1
圖 63 工作中心概覽 1

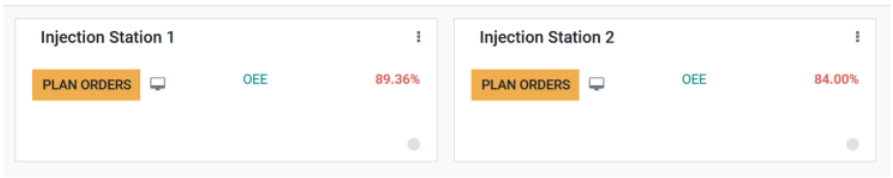

Figure 64 Workcenter overview 2
圖 64 Workcenter 概覽 2

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).

在進行任何改進之前，生產進行了兩次。第一個要進行的改進是對生產過程、操作和原始使用的材料。更具體地說，是代表設備升級的新操作在注塑機和塑膠顆粒的替代品牌上使用注射過程 (圖 65)。

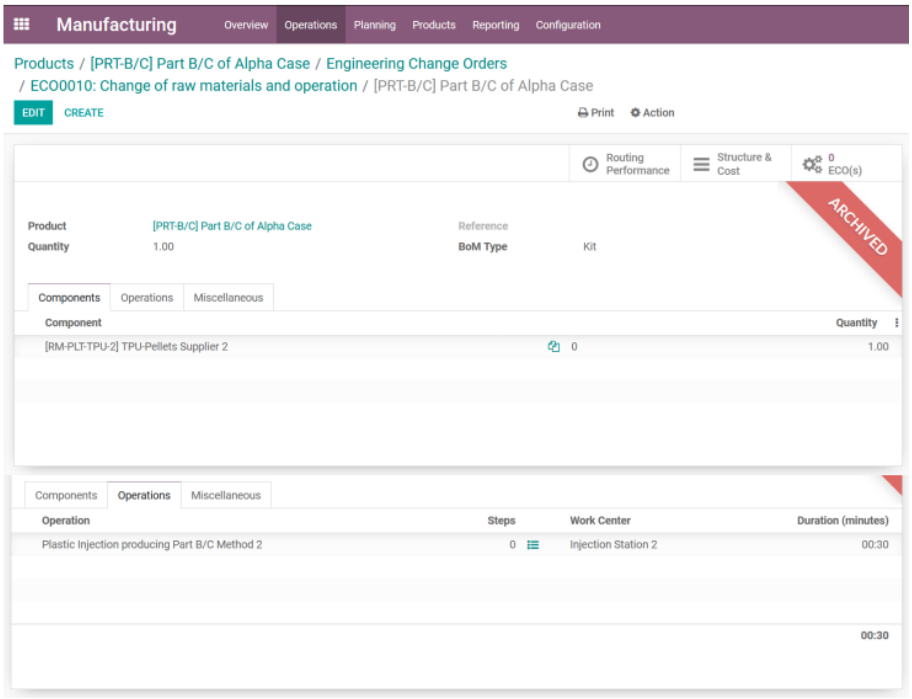

Figure 65 ECO applied to BOM
圖 65 應用於 BOM 的 ECO

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):
這些升級應用於 Alpha 外殼的 A 和 B 部件的 BOM，並且重新開始生產。在另外兩個 MO 生產 50 個產品後，每個 MO 類比改進流程自動提供以下類型的資料通過 Odoo (表 3):

Table 3 Types of data output
表 3 資料輸出類型

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

It should be commented that the data regarding MOs is unfortunately captured in a monthly basis as opposed to the other two categories that process data per order executed. This means that since this simulation is using a trial version of the software that lasts only 14 days the graphical representation of that data offers an unimpressive view of a single point or a single column. In the long run this is a great way to display performance over time but in the case of this simulation not so much (Figure 66).
應該評論的是，不幸的是，有關 MO 的資料被捕獲在按月計算，而不是其他兩個類別，即處理每個執行的訂單的資料。這意味著，由於此模擬使用的是僅持續 14 的軟體試用版天該資料的圖形表示提供了單個點的不起眼的視圖或單列。從長遠來看，這是顯示性能隨時間推移的好方法，但在這種類比的情況下，沒有那麼多 (圖 66)

Figure 49 Overview of the products after manufacturing
圖 49 產品製造後概覽

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，建立和控制更改爲產品項。要執行的更改在 CAD 檔上，涉及產品項。和以前一樣，我們可以啓動 ECO 並填寫描述，然後檔是上傳，ECO （圖 50）在進行之前經過必要的驗證有效。

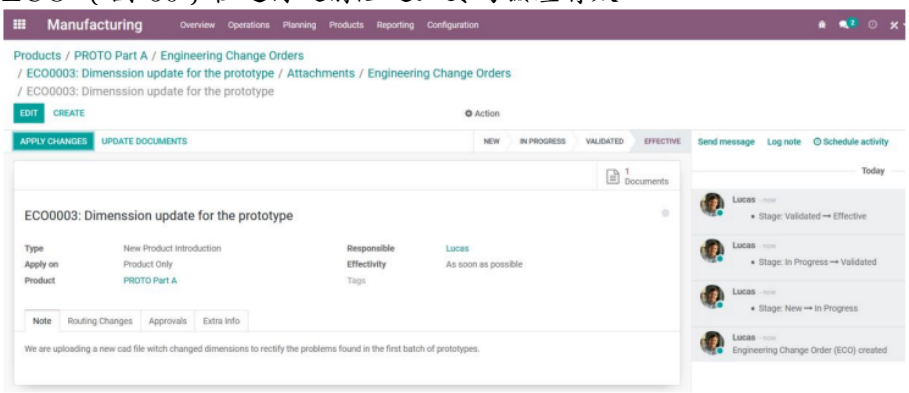

Figure 50 Depiction of the validation of the ECO
圖 50 ECO 驗證說明

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
驗證程式基本上是設置爲要求對某人進行適當的驗證存取權限或特定人員。在本例中，主帳户用於驗證並使其有效，從圖像右側的日誌中可以看出。一旦改變

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).
應用後，您可以看到產品項版本已反覆運算到版本 2 以及與該專案連結的 ECO 清單中添加了一個新的 ECO (圖 51)。

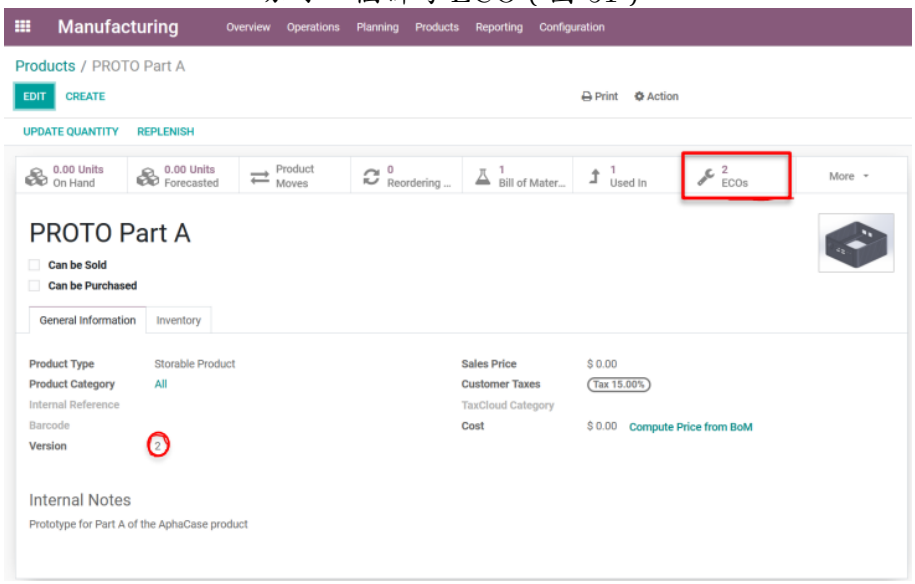

Figure 51 Depiction of changes provoked by the ECO to product item
圖 51 ECO 對產品專案引起的變化的描述

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.
該更新之後是另一批原型，該週期將持續到生產的原型符合設計團隊制定的標準。在這種情況下模擬假設一個修正足以代表這個過程。這完成從想法到原型的開發。

5.4.2. Process Plan - Production Test Run - Production
5.4.2. 工藝計畫-生產試運行-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，重點將轉移到流程上。已確定以前，決定將原型產品與最終產品專案分開進行隔離產品從生產過程中的開發過程開始。這樣一來，很多方面產品的開發可以有序地進行評估。現在，該過程被開發出來，創建將代表最終的產品專案似乎是合理的產品由於產品成功運行的過程將準備好生產它的樣本 (圖 52)。

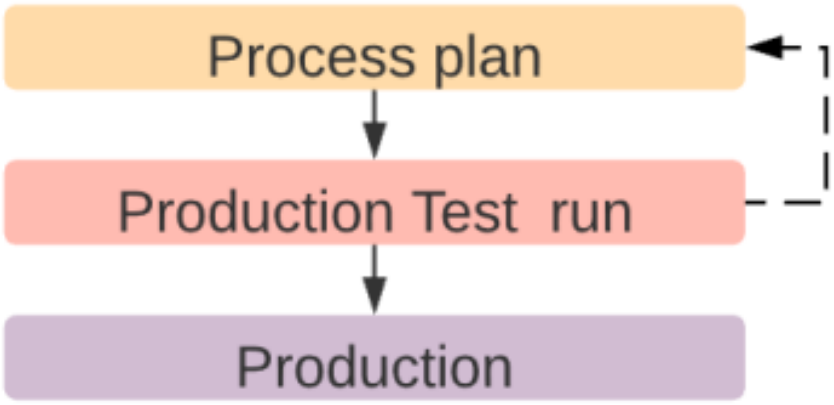

Figure 52 Sectioned diagram regarding Process development
圖 52 工藝開發剖面圖

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).
創造的其他產品專案是注塑成型的原材料 (其中是送入機器進行熔化和注射的塑膠顆粒)。所有這一切都完成了以與我們創建原型產品時相同的方式，除了 Alpha 案例 (圖 53) 現在被標記爲可售，其銷售成本現在相關 (圖 54).

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

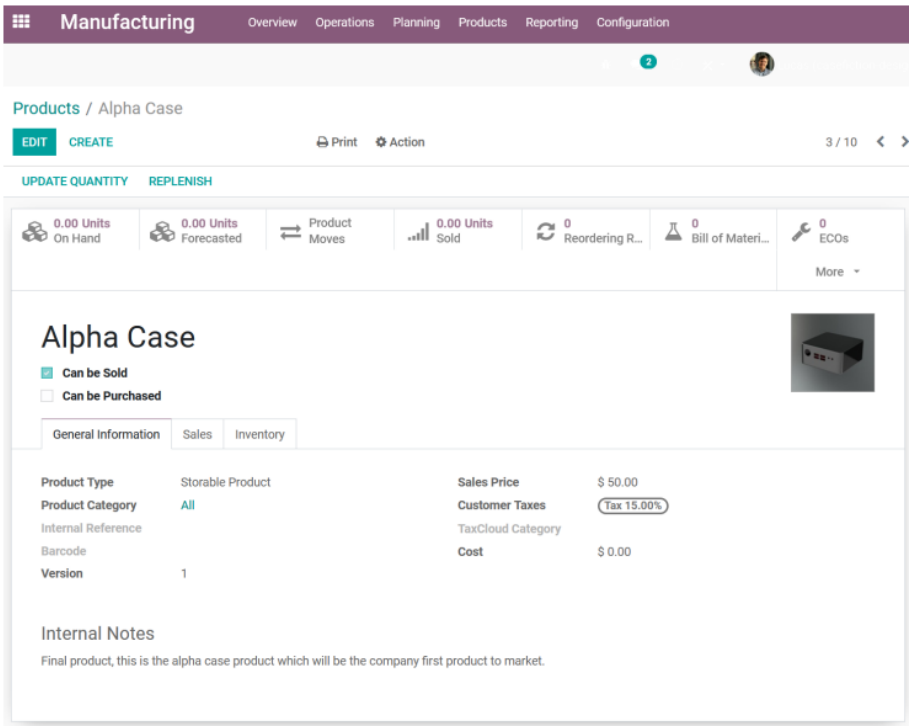

Figure 54 Product Item of the Alpha Case
圖 54 Alpha 案例的產品項

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).

一旦產品專案得到處理，我們需要回到流程的哪個方面將在此模擬的上下文中使用 Odoo 進行跟蹤。正如之前暗示的那樣，當談到注塑成型，工藝變化的關鍵方面是模具機器用來製造零件。對於這個模擬，認爲模具開發將遵循與產品開發非常相似的程式，這從下圖（圖 55）中應該更清楚。

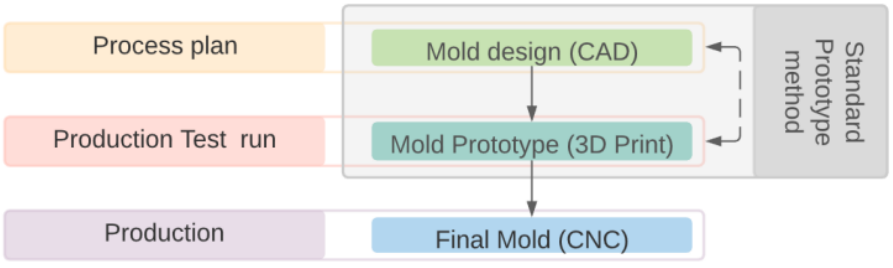

Figure 55 Diagram regarding process development for mold
圖 55 模具工藝開發示意圖

The production of a prototype mold by 3D printing follows the same standard procedure for prototyping used for the product. So far, the mold is considered a product like any other, this reveals another small weakness regarding Odoo ability to represent the totality of the process. The reader will notice that although the mold is been treated as a product (because it is been manufactured) it should in fact be considered a tool or piece of equipment as well.
通過 3D 列印生產原型模具遵循相同的標準程式用於產品原型設計。到目前爲止，模具與其他任何產品一樣被認爲是一種產品，這揭示了 Odoo 表示整體能力的另一個小弱點過程。讀者會注意到，儘管模具被視爲產品 (因爲它被製造出來) 實際上也應該被視爲一種工具或設備。

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 確實在設備和產品之間進行了這種區分，但它沒有關於兩者兼而有之的情況的整合。此外，如前所述，還有無法將 CAD 檔上傳到設備專案或將設備連結到範圍的工具。即 Odoo 不考慮使用具有 x 個鑽頭的立式鑽頭來製造不同尺寸的孔。從設備/維護的角度來看，它能做的最接近的是將立式鑽機視爲一個工作站，每個鑽機尺寸都是一個單獨的設備。具有指定設置時間的工作站。如果您忽略鑽頭是產品，則沒關係。

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 ERP 系統的角度來看並不理想。PLM 的視角，因爲它顯示了應該代表相同的項目之間的差距東西。在生產中，從製造應用程式開始，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，與事實沒有聯繫該工具是消耗品，您可以考慮維護計畫，甚至做一個有用的壽命參數，但因爲它是設備，你不能有備用工具就像庫存中的鑽頭一樣，就像消耗品一樣。

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，用原型模具表示測試變得非常困難。如果您可以按照軟體的設計進行操作，您需要創建一個單獨的 ECO 來應用每個對模具開發的每次不同反覆運算進行操作，以達到必

要的 BOM 和進行測試運行 (圖 56)。在這一點上，考慮模具的維護方面爲一個工具是沒有意義的，因爲它需要在維護中歸檔中繼資料手動應用程式用於每個原型模具反覆運算，而不會與製造業視角。PROTO 模具項目最終僅用於隨著模具的改進，跟蹤材料並保持檔。

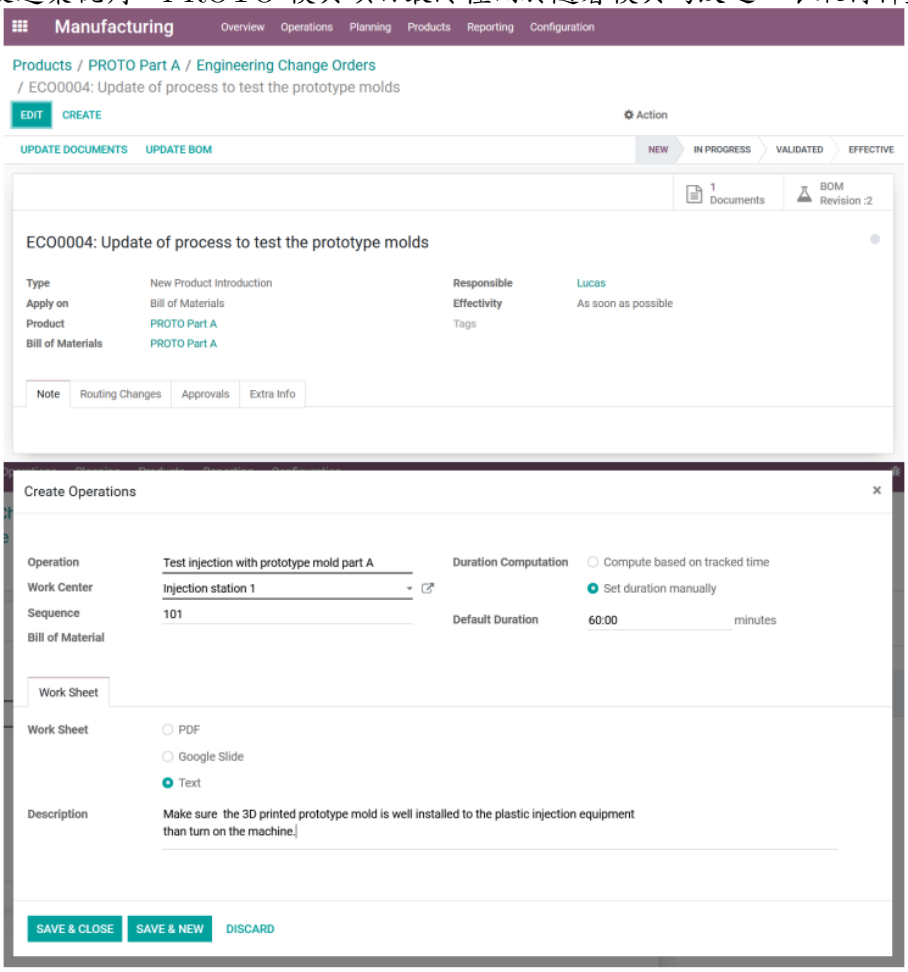

Figure 56 ECO example of update procedure of BOM
圖 56 BOM 更新程式的 ECO 示例

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，它將生產一個 3D 列印模具用於 Alpha 案例的每個部分。然後，將創建案例原型部件的 ECO 以應用於零件 BOM，將操作從 3D 列印更新爲注塑成型使用原型模具進行試運行。

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
在這一點上，我們可以將產品原型與測試運行原型區分開來然而，考慮到我們快速增長的清單，製作一個新的原型產品專案產品專案 (圖 57) 得出的結論是，最好在此進行描述努力修改以前生產的產品原型 (用 3D 列印製成)，然後

use the same items. We can do this because those prototypes have already served their purpose.
只是使用相同的項目。我們可以這樣做，因爲這些原型已經爲他們的目的。

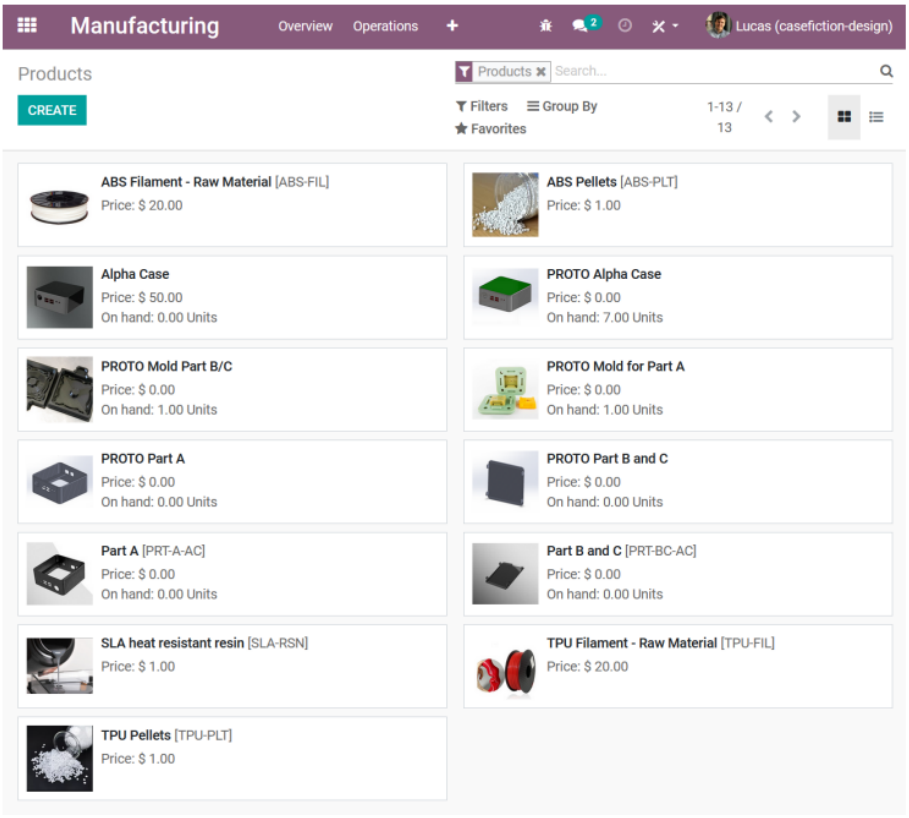

Figure 57 Overview of product items at this stage of the simulation
圖 57 類比此階段的產品專案概覽

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).
創建模具後，原型的 BOM 將更新爲包括注塑站和正確操作（指定模具的使用）下一步就是做原型的生產試運行。同樣，這是通過發出 MO 完成來完成的生成的 WO（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擬合度（如果校正是需要再次排放 ECO，如圖 56 所示，並且將進行生產和測試。此過程將重複，直到產品令人滿意，足以證明將使用的 CNC 加工模具的生產是合理的在批量生產中。

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，這是下一步的發展。程式基本相同和以前一樣，除了需要爲原材料（鋁）創建產品專案塊）和製造前的 CNC 模具。創建 BOM 表和上傳相關檔。

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，可以開始新模具的實際生產。表示創建了 100 個 Alpha 案例的製造訂單。這標誌著主路徑的結束從構思到生產的發展（圖 58）。

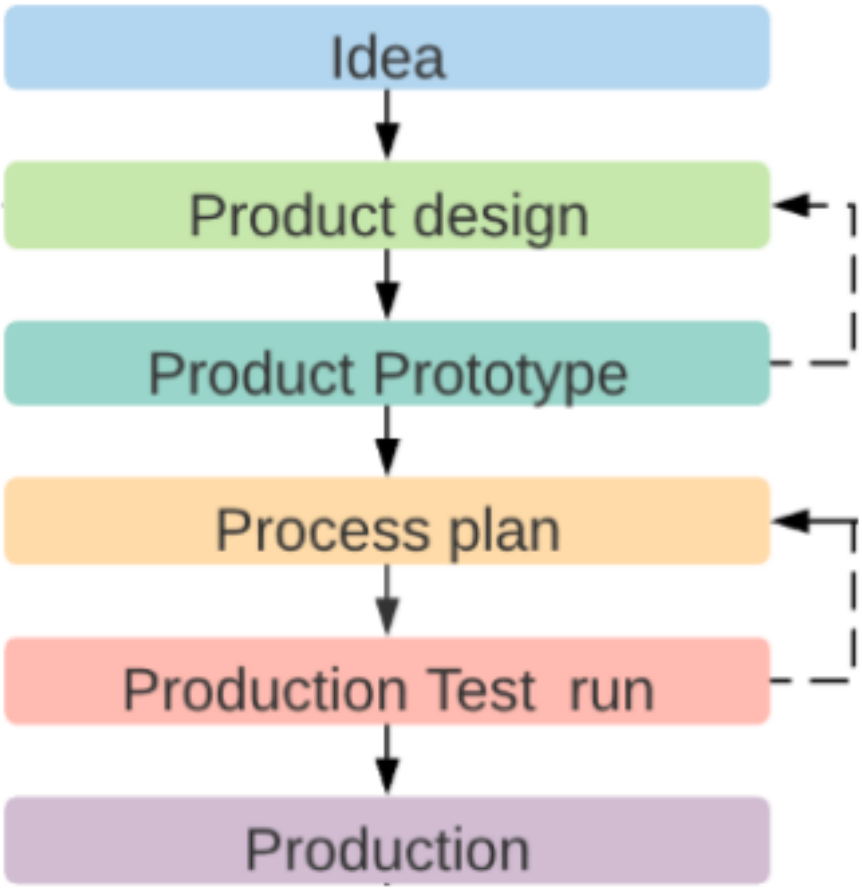

Figure 58 Main path of development from idea to production
圖 58 從構思到生產的主要發展路徑

5.4.3. Process upgrade procedure
5.4.3. 進程升級過程

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 utilizing items like Products, BOMs, ECOs, MOs, WOs and Operations.

This section will be different in the sense that now we have a production being carried out and the idea is to test Odoo in its capabilities of performing upgrades (Figure 59 and Figure 60). In other words, performance and feedback of information (and of course MES) becomes the main subject.

前面的部分是關於使用 Odoo 所需的程式用於跟蹤產品主要開發過程中變化的軟體。因此，大部分是重點介紹了 PLM 的使用以及創建和利用的標準程式產品、物料清單、ECO、MO、WO 和運營等專案。此部分將有所不同從某種意義上說，現在我們正在進行生產，我們的想法是測試 Odoo。其執行升級的能力 (圖 59 和圖 60)。換言之，資訊 (當然還有 MES) 的性能和回饋成爲主要主題。

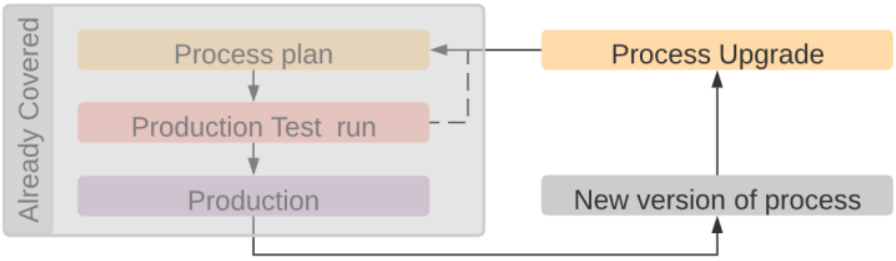

Figure 59 Sectioned diagram regarding Process upgrade procedure
圖 59 進程升級過程剖面圖

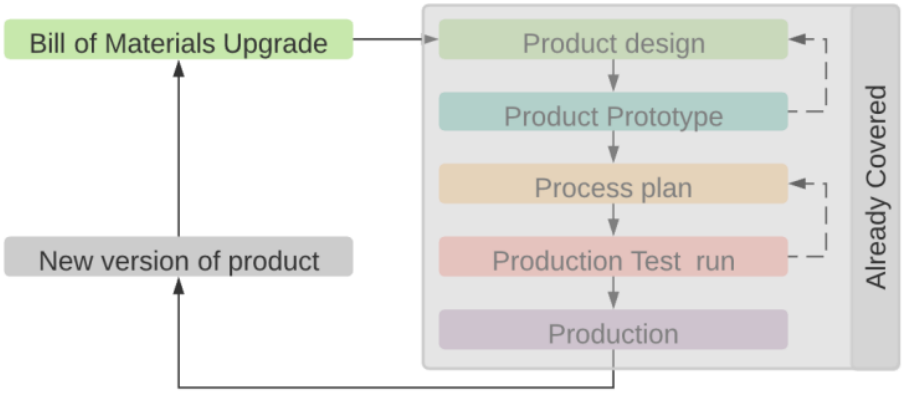

Figure 60 Sectioned diagram regarding Process development
圖 60 工藝開發剖面圖

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 功能進行更改。提醒讀者，應用此更改的情況 (圖 61) 是產品概述相關產品專案。該清單中的每個產品專案 (不是原材料) 都擺出姿勢至少一個 BOM 和兩個 ECO 已經應用於它們，以表示初始狀態每個產品專案 (圖 62)。每個專案的第一個 ECO 都會影響產品及其保存初始相關檔，第二個應用於產品的 BOM 以保存與過程的初始狀態相關的檔，以及記錄 BOM 的初始狀態。如果沒有這些 ECO (圖 62)，當我們應用改進時，初始狀態產品檔或 BOM 將丟失。

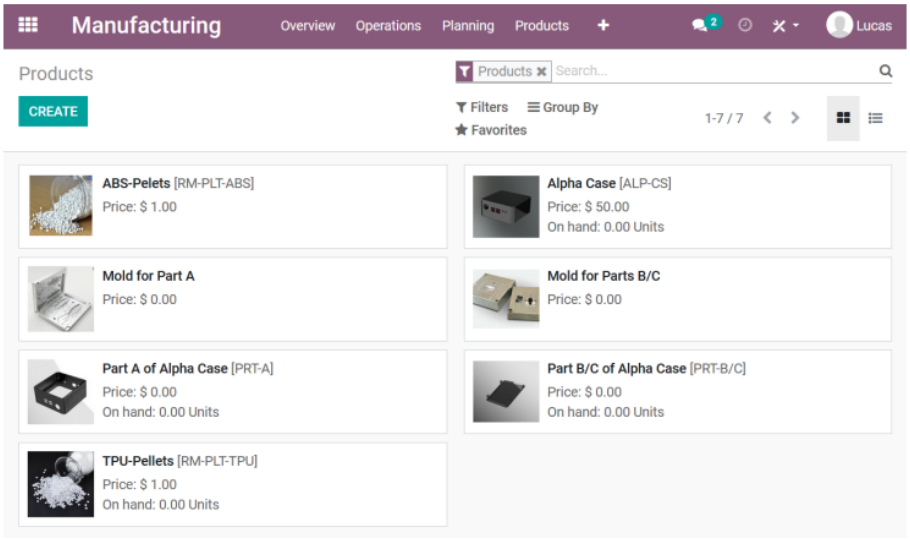

Figure 61 Relevant product items overview
圖 61 相關產品項概覽

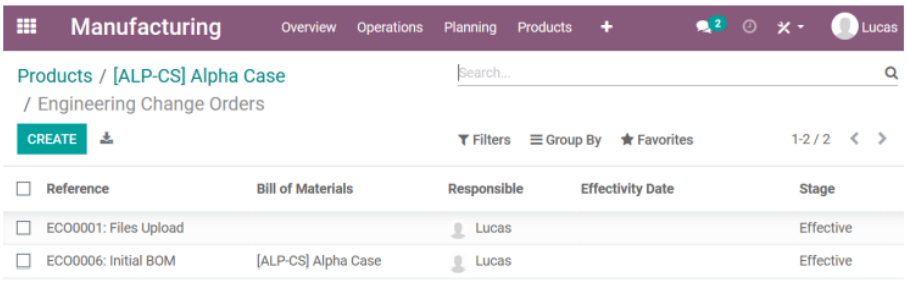

Figure 62 Example of ECOs of a product item
圖 62 某產品項的 ECO 示例

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).
這個時間大約是生產持續時間和過程的估計持續時間需要考慮的事情，這樣我們才能感知到應用的變化對工藝影響生產。爲此，將創建一個 50 個單位的 Alpha Case 的 MO 每個操作估計需要 30 秒 (部件 B/C 爲 15 秒，因爲有需要其中的 2 個)。這意味著在理想情況下，總長度爲 50 分鐘 (25 分鐘並行進行注塑生產，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.
在這個類比製造運行中，選擇注射操作將需要稍多一點的時間才能完成，以代表次優性能。這這樣做是爲了查看 Odoo 如何反應並即時通知手頭的情況。

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).

在注射過程中的第一階段生產，並行進行注射站 1 和 2 上的 A 和 B/C 部分。下面 (圖 64) 顯示了如何在流程開始時，生產站的概覽以綠色表示圈。這些通告在被稱爲 Andon 中，儘管它並不總是被考慮作爲 MES 的一部分，它通常是許多 MES 系統中的集成功能。生產後過程進行得稍有延遲，圓圈變灰，整體效率高在工作站標籤上標記爲紅色 (圖 64)。

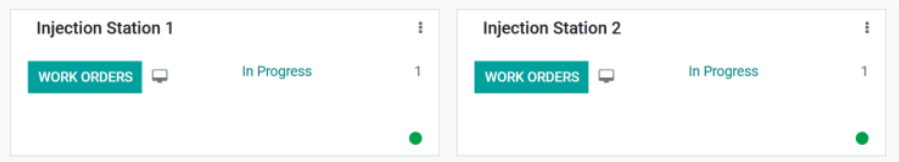

Figure 63 Workcenter overview 1
圖 63 工作中心概覽 1

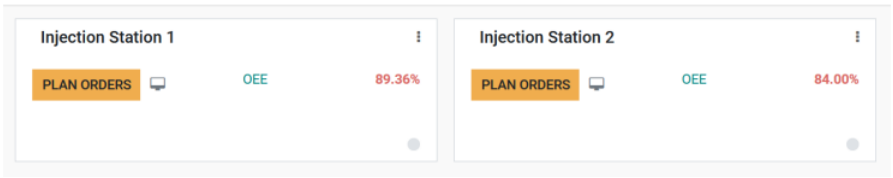

Figure 64 Workcenter overview 2
圖 64 Workcenter 概覽 2

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).

在進行任何改進之前，生產進行了兩次。第一個要進行的改進是對生產過程、操作和原始使用的材料。更具體地說，是代表設備升級的新操作在注塑機和塑膠顆粒的替代品牌上使用注射過程 (圖 65)。

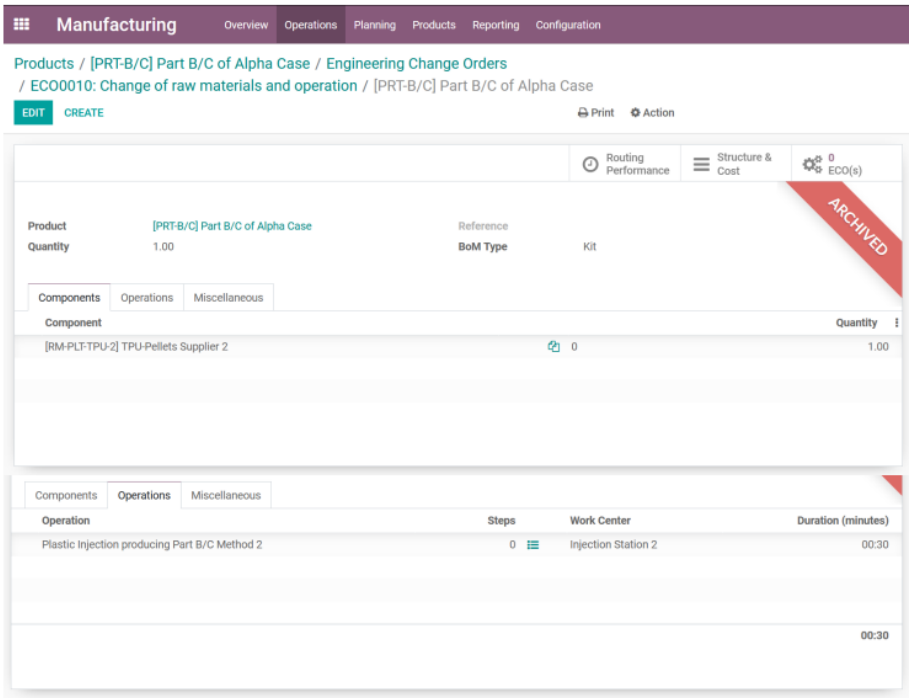

Figure 65 ECO applied to BOM
圖 65 應用於 BOM 的 ECO

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):
這些升級應用於 Alpha 外殼的 A 和 B 部件的 BOM，並且重新開始生產。在另外兩個 MO 生產 50 個產品後，每個 MO 類比改進流程自動提供以下類型的資料通過 Odoo (表 3):

Table 3 Types of data output
表 3 資料輸出類型

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

It should be commented that the data regarding MOs is unfortunately captured in a monthly basis as opposed to the other two categories that process data per order executed. This means that since this simulation is using a trial version of the software that lasts only 14 days the graphical representation of that data offers an unimpressive view of a single point or a single column. In the long run this is a great way to display performance over time but in the case of this simulation not so much (Figure 66).
應該評論的是，不幸的是，有關 MO 的資料被捕獲在按月計算，而不是其他兩個類別，即處理每個執行的訂單的資料。這意味著，由於此模擬使用的是僅持續 14 的軟體試用版天該資料的圖形表示提供了單個點的不起眼的視圖或單列。從長遠來看，這是顯示性能隨時間推移的好方法，但在這種類比的情況下，沒有那麼多 (圖 66)