Figure 1 Product lifecycle stages (Tripaldi, 2019)

圖 1 產品生命周期階段（Tripaldi，2019）

PLM is above all a connecting technology, not an individual technology islet orinformation processing system (Saaksvuori and Immonen, 2008). The idea is that everyinformation produced by company personnel holds value equivalent to the time and moneyinvested. Using that information saves money, not using that information wastes money. Thisis easier to understand when looking to a design process.E.g. if an engineer designs an electronic circuit, the file holding the CAD drawing has anequivalent value to the time and money invested in it. The problem comes from the fact thatin a traditional system only the engineer knows the design process behind the file, the extentof what is inside and its possible uses. While, from the perspective of the rest of the company,that is just a file in the database alongside thousands of others. The result is that, on its own,the information is of limited use.If by any chance there is another engineer working in a similar design it will becomeextremely difficult for him/her to find that file and use it in his own design. Ultimately this5results in waste because Engineer#2 will have to spend more time and money doingsomething that was already made just because that information was not easily available orwell organized.

PLM 最重要的是一種連接技術，而不是一個獨立的技術小島或信息處理系統（Saaksvuori 和 Immonen，2008)。這個想法是，公司人員生產的每一條信息都具有相當於投資的時間和金錢的價值。利用這些信息可以節省金錢，不利用這些信息會浪費金錢。當觀察設計過程時，這一點更容易理解。例如，如果一個工程師設計了一個電子電路，保存 CAD 繪圖的文件就具有等同於投資的時間和金錢的價值。問題在於，傳統系統中只有工程師知道文件背後的設計過程，其中的內容及其可能的用途的程度。而對於公司的其他人來說，這只是數據庫中的另一個文件。結果是，單獨的信息僅具有有限的用途。如果碰巧有另一位工程師在進行類似的設計，那麼他/她將極難找到該文件並將其用於自己的設計中。最終，這將導致浪費，因為工程師#2 將不得不花更多的時間和金錢做一些已經完成的事情，只是因為該信息不容易獲得或組織得不好。

This scenario is not limited to product design, but also to all aspects of the productlifecycle that produces change over time. Someone had to orchestrate how that piece will beproduced , how that piece will be moved,packed , distributed and disposed of. When aproblem is found or improvements are possible those changes also produce information andconsume resources. If the company cannot take advantage of that existing information aboutall those phases of the product conception it will waste resources at every single redesign.Product Lifecycle Management consists of an information system that allows informationand knowledge sharing within and between organizations (Sudarsan et al., 2005) minimizingthe waste by controlling and organizing those files with information that would otherwisebe carried only by the human resource that produced said files. The way it accomplishes thatis by virtualizing all components of the product life-cycle in the form of digital “items” in anobject oriented architecture. As explained by (Saaksvuori and Immonen, 2008),an item is asystematic and standard way to identify, encode and name a product, a product element ormodule, a component, a material or a service.These item objects are, by all means, virtual representations that hold metadata regardingwhat it tries to represent and allows to connect and link the information. As described by(D’Antonio et al., 2015) product information should be connected to its production process.PLM allows to link defined processes to the product and to provide constraints on the orderof process execution. E.g. a CAD drawing for a circuit schematic is attached to a virtualcircuit object that holds basic information about what is contained in the file and all theprevious iterations of that file over time as well as links to items representing which bill ofmaterials (BOM) it belongs to, the machines necessary to manufacture it, the processesnecessary to assemble it and more importantly how all those items changed over eachimproving iteration.This all-around virtualization gives precious context to information otherwise lost on itsown complexity. It allows for faster access, easier understanding of the whole and theconsequences of what happens when there is change for each part. This is the best way oforganizing the existing data for future reference because it allows for structure as well astransparency.To sum up, PLM as a system aims to track functional change in all aspects regarding theproduct life, in a way that the company can benefit strategically from it by avoidinginformational waste. It does so by virtualizing the real thing in the form of digitalitems that6store the files regarding what the item is supposed to represent. These can in turn becorrelated and tracked over time using metadata.

這種情況不僅限於產品設計，還涵蓋了在產品生命周期的所有方面隨時間產生變化的過程。某人必須協調如何生產這個部件，如何移動、包裝、分配和處置這個部件。當發現問題或可以進行改進時，這些變化也會產生信息並消耗資源。如果公司無法利用關於產品概念各個階段的現有信息，它將在每次重新設計時浪費資源。產品生命周期管理包括一個信息系統，允許組織內部和組織之間共享信息和知識（Sudarsan 等，2005），通過控制和組織那些具有信息的文件，減少浪費，否則這些信息將僅由生產這些文件的人力資源所持有。它實現這一目標的方式是通過以數字“項目”的形式將產品生命周期的所有組件虛擬化，以對象導向的架構。正如（Saaksvuori 和 Immonen，2008）所解釋的那樣，項目是識別、編碼和命名產品、產品元素或模塊、零件、材料或服務的系統化和標準化方式。這些項目對象無疑是虛擬表示，其中包含有關其所試圖表示的信息的元數據，並允許連接和鏈接信息。正如（D'Antonio 等，2015）所描述的，產品信息應與其生產過程相關聯。PLM 允許將定義的過程鏈接到產品，並對過程執行的順序提供約束。例如，電路原理圖的 CAD 繪圖附加到一個虛擬電路對象，該對象包含有關文件內容的基本信息以及該文件的所有先前迭代，以及與項目相關聯的鏈接，這些項目表示它屬於哪個材料清單（BOM)、製造它所需的機器、組裝它所需的過程，更重要的是所有這些項目如何在每個改進迭代中發生變化。這種全面的虛擬化為本來就很複雜的信息提供了寶貴的上下文。它允許更快地訪問，更容易理解整個過程以及每個部分發生變化時的後果。這是組織現有數據以便未來參考的最佳方式，因為它允許結構和透明度。總而言之，PLM 作為一個系統旨在追踪關於產品生命周期的所有方面的功能變化，以使公司能夠從戰略上受益，避免信息浪費。它通過將真實物件虛擬化為數字項目，存儲有關該項目應該代表什麼的文件來實現。這些項目可以透過元數據相互關聯和追踪。

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

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

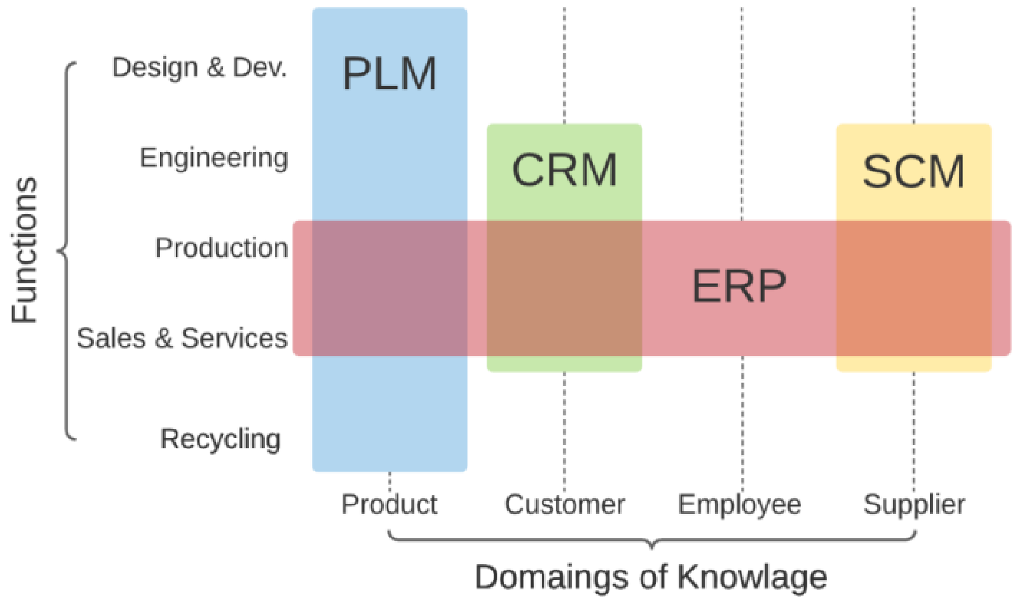

Figure 2 Visual representation of the scope of different information systems (Adapted from Stark 2015)

圖 2: 不同信息系統範圍的視覺表示（改編自 Stark，2015）

This sort broad reach across the domains makes sense because the ERP operations, as were in the case of MRP, focus on handling transactions and orders. The focus of the ERP is controlling the change in input, retention and output of resources to the company, be of products, raw materials or packing.From the same image, it is possible to see the theoretical contrast between PLM and ERP even though they are both extremely broad. While ERP expands across the domains of knowledge but limits itself to a few functions, PLM expands across all functions that involve the product. As portrayed by Figure 3, another point of view that represents a good difference between the two is the lack of overlap in what concerns the scale or level of detail in which ERP and PLM affects the industry (i.e. the granularity of the two systems).

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

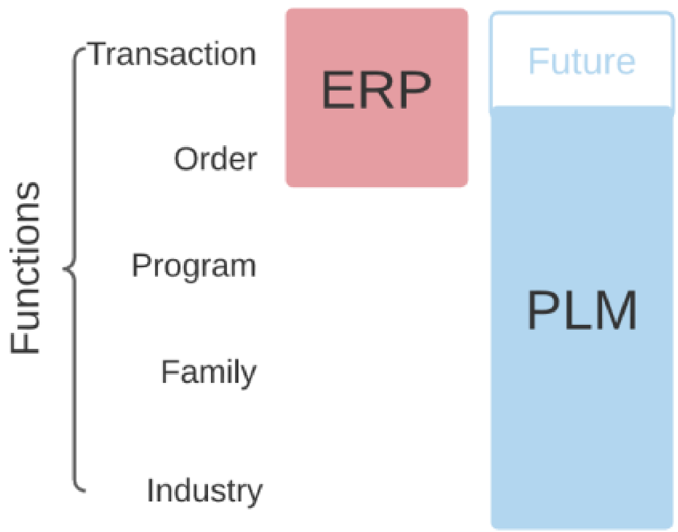

Figure 3 Visual comparison of ERP and PLM concerning granularity(Adapted from Stark, 2015)

圖 3 ERP 和 PLM 之間的粒度比較（摘自 Stark，2015）

As we can see, ERP is primarily concerned with the transaction and the order. Once anorder is closed out, the ERP system processes the transactions with respect to that order butis not very much concerned with the order beyond that. On the other hand, PLM's granularity is concerned with the order for the product and extends not only into the program, but intothe family and the entire industry (Stark, 2015).This is particularly interesting because it demonstrates how the two systems can and docomplement each other in the field. One of the aspects of ERP that should point out is that itis comparatively easier to integrate with other systems. ERP-MES integration for instancehas been widely studied and implemented to the point where standards have been developedfor it (ISA 95 - IEC 62264). One argument for this is the modular nature of the ERP systemwhich is discussed further in the paper in (Chapter 5) with the analysis of the Odoo software.That is because the Odoo software evolved originally from an open-source ERP system.The nature of the ERP system is best summed up by (Umble et al. 2003): ERP provides aunified enterprise view of the business which encompasses all functions and departments,and an enterprise database in which all actions concerning finance, sales, marketing,purchasing and human resources are traced. The aim of this achieving is to expand thecustomers target and increase customers share in a market that slowly pivots to innovation(Vásquez and Escribano, 2017).

正如我們所看到的，ERP 主要關注交易和訂單。一旦一個訂單結束，ERP 系統就會針對該訂單處理交易，但對訂單本身的關注程度不是很高。另一方面，PLM 的粒度關注的是產品的訂單，不僅延伸到程序，還包括家族和整個行業（Stark，2015）。這尤其有趣，因為它展示了這兩個系統在該領域中如何可以互補。 ERP 的一個方面值得指出的是，它與其他系統相對容易集成。例如，ERP-MES 集成已被廣泛研究和實施，甚至已經為其開發了標準（ISA 95 - IEC 62264）。其中一個理由是 ERP 系統的模塊化性質，這在本文中（第 5 章）進一步討論了對 Odoo 軟件的分析中。這是因為 Odoo 軟件最初是從一個開源 ERP 系統發展而來的。ERP 系統的性質最好由（Umble 等，2003）總結：ERP 提供了業務的統一企業視圖，包括所有功能和部門，以及一個企業數據庫，其中追蹤了所有關於財務、銷售、市場營銷、採購和人力資源的操作。實現這一目標的目的是擴大客戶目標，增加客戶在一個逐漸轉向創新的市場中的份額（Vásquez 和 Escribano，2017）。

2.3. Manufacturing Execution System The final key of a fully integrated system would be the Manufacturing Execution System(MES). A MES is a layer of communication between the management and the production levels; it is a software that allows data exchange between the organizational level, usually supported by an ERP, and the shop-floor control systems, in which several, different, very customized software applications are employed (Meyer et al., 2009). Figure 4 is a nice depiction of how different systems fit within the scope of manufacturing and development.

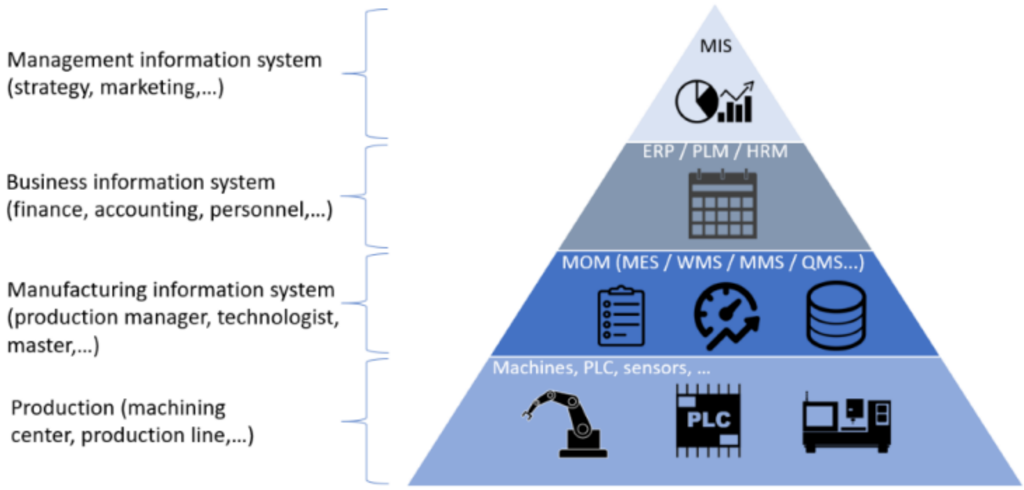

Figure 4 Visual representation of the roll of different systems including MES(Adapted from mescenter.org)

圖 4 包括 MES 在內的不同系統的滾動視覺化表示

（改編自 mescenter.org）

For all purposes MES main goal is to provide the numbers and data that ultimately is used to ascertain the condition and quality of not only the products but also all the processes that affect production. Machines, sensors, and anything that comes in contact with the product and provides output of any kind, basically, handing said data to the MES for sorting and processing in real time. E.g. if a manager wants to know the instant production numbers or to see a graphical representation of the rejection rate, that data will be available from a MES software. Traditionally it is from this sort of information that management will evaluate efforts and make decisions. As mentioned before this sort of data collection fits perfectly to the use of ERP not only because the management of resources can be much more detailed if complemented by real time production data but also because the modularity of ERP usually means a seamless integration. MES (like ERP) has also been proven and implemented for decades and their implementation have already been standardized to a reasonable degree.

2.3. 製造執行系統完全集成系統的最後一個關鍵是製造執行系統（MES）。MES 是管理層和生產層之間的通信層；它是一種軟件，允許組織層級（通常由 ERP 支持）與車間控制系統之間進行數據交換，其中使用了多種不同的、高度定制的軟件應用（Meyer 等，2009）。 圖 4 是不同系統如何適用於製造和開發範圍的良好描述對於所有目的來說，MES 的主要目標是提供數據和數字，最終用於確定不僅產品的狀態和質量，還包括影響生產的所有流程。機器、傳感器以及與產品接觸並提供任何類型輸出的任何東西，基本上都將該數據傳遞給 MES 進行即時排序和處理。例如，如果一位經理想要知道即時的生產數字或查看拒收率的圖形表示，該數據將可從 MES 軟件獲取。傳統上，管理層將根據這類信息評估工作成效並做出決策。如前所述，這類數據收集非常適合於 ERP 的使用，不僅因為如果結合實時生產數據，資源管理可以更加詳細，還因為 ERP 的模塊化通常意味著無縫集成。MES（像 ERP 一樣）也已經證明並實施了幾十年，它們的實施已經相當標準化。

The functionalities of a MES have been grouped in 11 categories by MESA International(1997); furthermore, the tasks for each enterprise layer and, in turn, for each kind of information system are listed in the ISA95 – IEC62264 (2013) standard. This standard also provides definitions for the data structures to be exchanged among information systems aiming to enhance their integration; however, it mainly focuses on ERP-MES-Shop floor integration (D’Antonio et al., 2015). PLM studies by comparison are much more recent and PLM-MES integration, a main focus of this work, even more so. The challenge of this sort of integration and the state of the art regarding it was be covered in (Chapter 3) as well as the theoretical structure behind it. For now, suffice to point out that since MES provides the feedback by which changes are orchestrated and results are validated by generating information in the form of files and PLM focus on the tracking change by file organization there sure is value in the PLM-MES integration. 2.4. Industry 4.0 The term Industry 4.0 is one mentioned time and time again in modern literature as the next or current step in the evolution of production. It represents what is the 4 th industrial revolution where the first was marked the adoption of steam power, the second was marked mainly using electrical power and the 3 rd was characterized by the implementation of digital technology. Figure 5 nicely represents the progression of industrial revolutions.

MES 的功能已被 MESA International（1997）分為 11 個類別；此外，ISA95-IEC62264（2013）標準還列出了每個企業層面以及每種類型的信息系統的任

務。該標準還為要在信息系統之間交換的數據結構提供了定義，旨在增強它們的集成；然而，它主要聚焦於 ERP-MES-車間一線的集成（D'Antonio 等，2015)。相比之下，PLM 的研究要新得多，而 PLM-MES 集成，這份工作的主要焦點，更是如此。這種集成的挑戰以及與之相關的技術水平將在（第 3 章）中進行探討，同時也會探討其背後的理論結構。暫且可以指出，由於 MES 提供了通過生成文件形式的信息來編排變更並通過反饋驗證結果，而 PLM 則專注於通過文件組織跟踪變更，因此 PLM-MES 集成確實具有價值。2.4. 工業 4.0 工業 4.0 這個術語在現代文獻中一再被提及，被認為是生產演進的下一步或當前步驟。它代表著第四次工業革命，其中第一次革命是以蒸汽動力的應用為標誌，第二次主要以電力使用為標誌，而第三次則以數字技術的實施為特徵。圖 5 很好地展示了工業革命的進展。

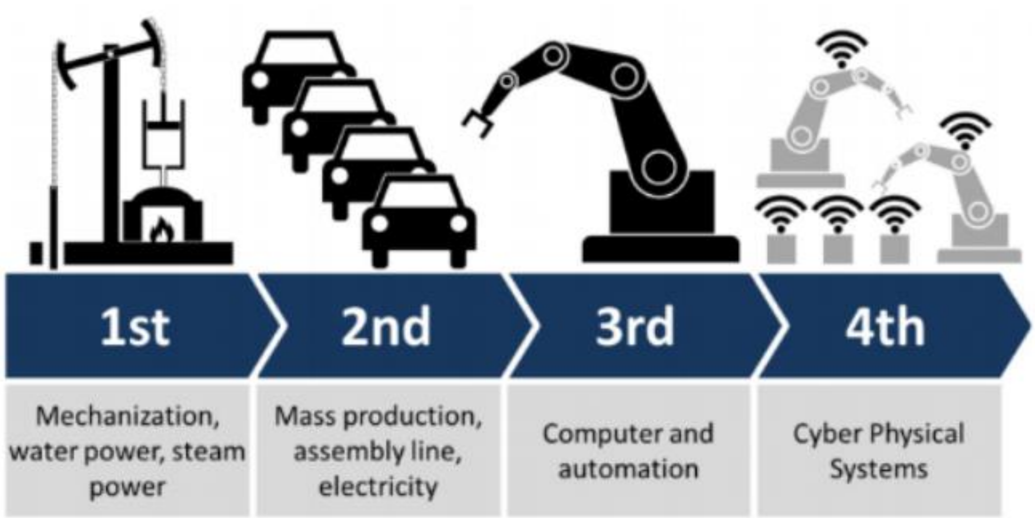

Figure 5 The industry evolution (Adapted from STANCIOIU Alin, 2017)

圖 5 產業演變（改編自 STANCIOIU Alin，2017 年）

In broad strokes the 4th industrial revolution is (or will be) ultimately marked by the full integration between digital connectivity and production. As it is well known that the development of digital networks is the pivotal technology that sustain the modern world. It has changed the way humans interact and do business. However, whether the current level in which it is applied to the industry constitutes an industrial revolution is still uncertain because in all other revolutions have been marked by a violent increase in production that is yet to happen this time around. In fact, we are still to reach a shared definition of Industry 4.0. What has been widely accepted however is that there are at least 3 technologies that characterize Industry 4.0. Those are the Internet of things (IoT), Cloud computing and the development of Cyber-Physical Systems (CPS), the last of which is particularly important for the context of this thesis.CPS are systems consisting in a real entity (for example, a machine) and its corresponding virtual model – embedding all the models for mimicking the behavior of the real counterpart – capable to communicate with each other (D'Antonio et al., 2017). The idea is that, if one were to develop a digital twin (DT) of all physical instruments regarding a process in a system that allows for the digital counterparts to interact with each other as well as interacting with the physical world, innovation or change of said process would occur much faster and effectively. E.g., an engineer could simulate a change using the DT's interaction, then, if successful, apply the change automatically to the production line in real time, execute tests, gather data and feed it back to the system without the need of manual input with all being done through the network.The main point to be derived from all this is that PLM-MES systems possibly are the first step to achieve a proper CPS since it provides for the virtualization and necessary control to reach something near a virtual twin. The debatable matter is how deep is its current effect in industrial application.Nonetheless, the term Industry 4.0 is, if anything, a useful denotation to the increasing application of digital connectivity, network development and the internet to industry. Another term often included within the scope of Industry 4.0 is the called Lot Size One or Lot 1. This is the idea of each item customized to the individual specifications of the buyer in a system in which a customer order does not start supply chain equipment moving; it turns on manufacturing machines. The theory behind it is that as production and development becomes more and more flexible as this sort of manufacturing becomes not only viable but also attractive. Having a tailored requested product means that there are no storage requirements, no inventory 12 overhead, and of course a 100% guaranteed sell. This concept is not new by any means, in fact it predates Industry 4.0 quite a lot. In the book "The machine that changed the world" the authors (Womack et al., 1990) discuss that toward this end, lean producers employ teams of multiskilled workers at all levels of the organization and use highly flexible, increasingly automated machines to produce volumes of products in enormous variety.

概括而言，第四次工業革命最終將以數字連接和生產的完全整合為標誌。眾所周知，數字網絡的發展是維持現代世界的關鍵技術。它改變了人類的互動方式和商業模式。然而，目前應用於工業的水平是否構成了一場工業革命仍然不確定，因為在所有其他革命中，生產的暴增都尚未發生。事實上，我們仍然沒有達成關於工業 4.0 的共識定義。然而，被廣泛接受的是，工業 4.0 至少有三項技術特徵。這些技術是物聯網（IoT）、雲計算和物理-數字系統（CPS）的發展，後者對於本論文的背景尤其重要。CPS 是由真實實體（例如，一台機器）及其相應的虛擬模型組成的系統 – 其中包含了模仿真實對應物行為的所有模型 – 能夠相互通信（D' Antonio 等，2017）。其核心理念是，如果開發一個關於

系統中所有與某一過程有關的物理儀器的數字孿生體（DT），允許數字對應物件彼此互動，以及與物理世界互動，則該過程的創新或變革將更快更有效。例如，工程師可以使用 DT 的互動模擬變更，然後在實時中自動應用變更到生產線上，執行測試，收集數據並將其反饋到系統中，無需手動輸入，所有這些都通過網絡完成。從所有這些中得出的主要觀點是，PLM-MES 系統可能是實現適當 CPS 的第一步，因為它提供了虛擬化和必要的控制，以實現接近虛擬孿生體的情況。值得爭議的問題是它目前在工業應用中的影響程度如何。儘管如此，無論如何，工業 4.0 這個詞彙是對數字連接、網絡發展和互聯網應用於工業的日益增長的一個有用標誌。工業 4.0 範圍內經常包含的另一個術語是所謂的 Lot Size One 或 Lot 1。這是將每個項目定制為買家個人規格的想法，在這樣的系統中，客戶訂單不會啟動供應鏈設備運動；它啟動了製造機器。其背後的理論是，隨著生產和開發變得越來越靈活，這種類型的製造不僅變得可行，而且也變得吸引人。定制的產品意味著沒有庫存要求，沒有庫存成本，當然也有 100%的銷售保證。這個概念並不新穎，事實上，它比工業 4.0 早得多。在書籍《改變世界的機器》中，作者們（Womack 等，1990）討論了瘦生產者向這個目標邁進的過程，他們在組織的所有層次都使用多技能工人團隊，並使用高度靈活，越來越自動化的機器生產大量產品。

In a way 'Lot Size One' is nothing more than the extrapolation of this sort of thinking. Of course, the industry is yet to reach such level of production flexibility, but glimpses of this sort of mentality can already be seem on more modular productions. One of the best examples is amazon packing systems. E.g. a customer receives a package from Amazon containing a mix of products that has been packaged just for him/her according to their specific order.Although superficial in nature, this represents a high level of customization for the customer.Another great example is electronics prototyping. Currently there are companies that take your printed circuit board designs and BOM, delivering small batches of assembled prototypes at a low cost. Prototyping of electronical devices used to be a highly expensive process, but some companies have flexibilized their production to the degree where they are able to deliver it fast and reliably. Again, that is possible because electronics components are inherently modular systems even if of high complexity. The following image (Figure 6 Example project of power supply adaptor circuit) is an example of an electronic circuit that was designed by this student and manufactured by JLCPCB within a single week.

在某種程度上，“Lot Size One”不過是這種思維的延伸。當然，工業還沒有達到這種生產靈活性的水平，但這種思維的一瞥已經在更模塊化的生產中得以體現。亞馬遜的包裝系統是其中最好的例子之一。例如，一位客戶從亞馬遜收到一個包裹，其中包含了根據他/她的特定訂單而為他/她包裝的各種產品混合物。儘管表面上看似乎簡單，但這對客戶來說代表了高度的定制。另一個很好

的例子是電子原型製作。目前有一些公司接受您的印刷電路板設計和 BOM，以低成本交付少量組裝好的原型樣品。電子設備的原型製作曾經是一個成本高昂的過程，但一些公司已經將其生產模式靈活化到了能夠快速且可靠地交付的程度。這是可能的，因為電子元件本質上是模塊化系統，即使復雜性很高。下面的圖片（圖 6：電源適配器電路示例項目）是一個示例，顯示了這個學生設計的電路，並在一個星期內由 JLCPCB 公司製造。

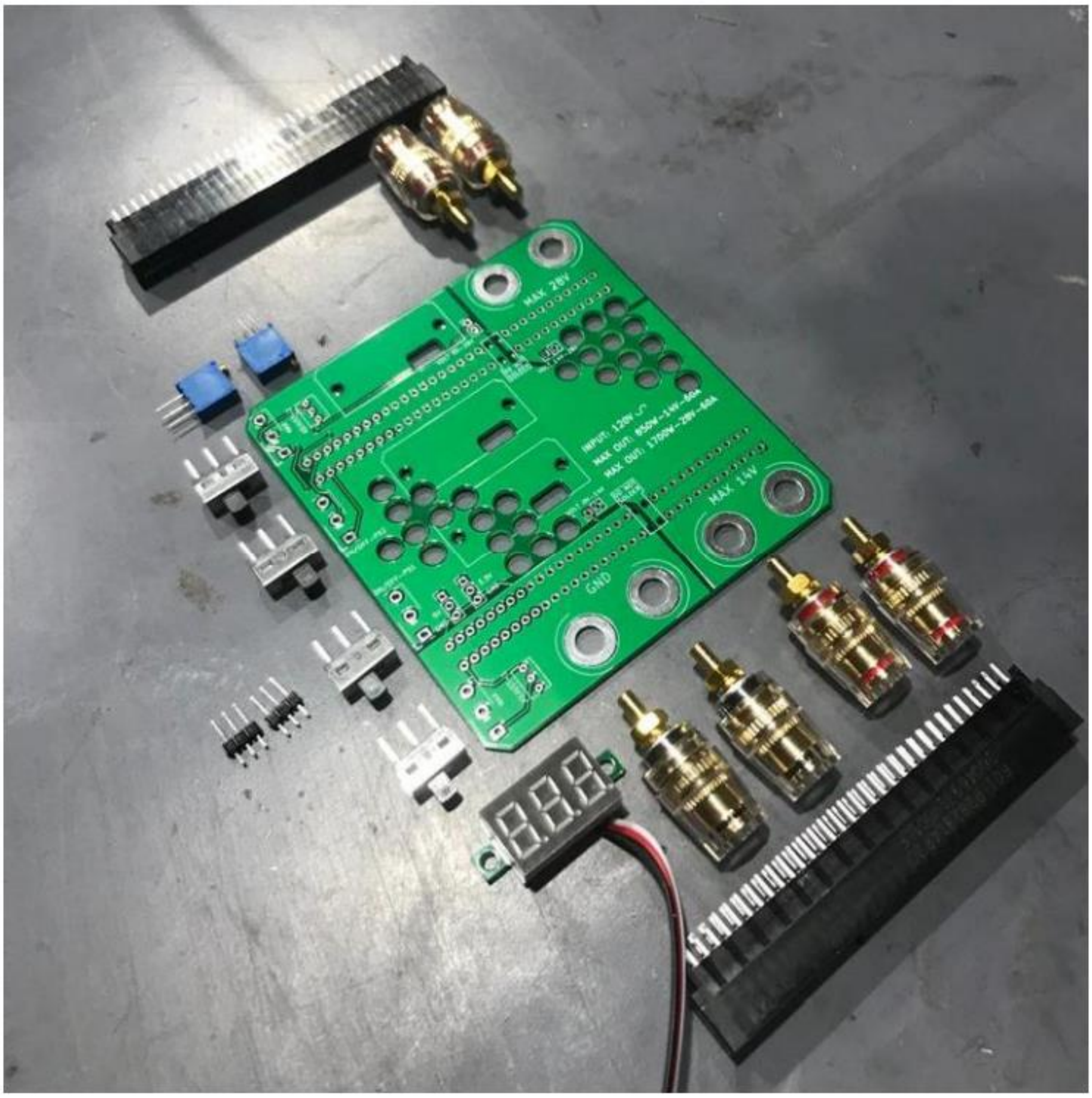

Figure 6 Example project of power supply adaptor circuit

圖 6 電源適配器電路範例工程

All and all, the result is again a greater need for control and management of change. Which means the implementation of a PLM-MES system would be of great help. PLM

would be required to manage change and innovation throughout the lifecycle of small batch products and MES would provide the real time reaction and feedback necessary to reduce errors that could cause losing a whole batch.
總的來說，這一切再次表明了對變化的控制和管理的更大需求。這意味著實施 PLM-MES 系統將是非常有幫助的。PLM 將需要在小批量產品的整個生命周期中管理變化和創新，而 MES 將提供實時的反應和反饋，以減少可能導致整批損失的錯誤。
3. CHAPTER THE STATE OF THE ART AND THE INTEGRATION OF PLM AND MES
Unfortunately, there are not many published studiesin the matter of integration between PLM and MES systems. But there seems to be a consensus in the most probable effects of said integration. Those being synchronization and tighter tolerances. As explained by D'Antonio et al. (2015), which focus on a case study involving the manufacturing of precision components for aeronautical applications, the first advantage expected by the deployment of the monitoring and control system is product quality improvement: sensors allow to detect, measure and monitor variables, events and situations that affect process performance or product quality. One of the central problems regarding integrating PLM with any other system revolves around the ownership of information. A possible solution relies on database integration as well as the use of middleware between systems. As is written in Saaksvuori and Immonen,(2008). A reasonable objective is that information should always be updated in one place.Other systems can read information directly from the PLM databases, and if necessary, the required information can be replicated on the databases of other system, as depicted in Figure 7. Although it points this out mainly from the perspective of PLM-ERP integration, it is still very valuable from the perspective of PLM-MES integration because it is an example of how the better operation can be expected by working around systems in which files of different nature are loaded into a centralized PLM-ERP system.

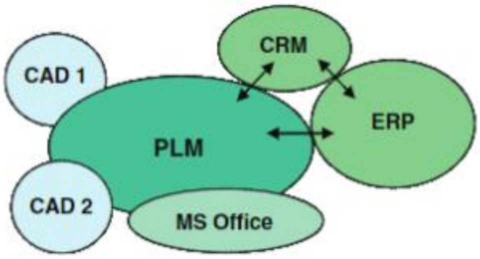

Figure 7 Diagram of PLM integration(Saaksvuori and Immonen, 2008)

圖 7 PLM 整合示意圖（薩克斯沃里和伊莫寧，2008）

The middleware would therefore be a software framework to organize and connect all the information given to the system database in a user-friendly way. This sort of application is also referred to as integration application and, as specified by Stark (2015), these applications 15 enable exchange of product information between PLM applications (for example, between a CAD application and a CAE application). They also enable exchange of product information between PLM applications and other enterprise applications such as ERP and CRM.

第 3 章 現有技術與 PLM 和 MES 的整合不幸的是，在 PLM 和 MES 系統整合方面，並沒有太多已發表的研究。但似乎對於該整合最可能產生的影響存在共識，即同步和更緊密的容忍度。正如 D'Antonio 等人（2015 年）所解釋的，他們聚焦於航空應用中精密零部件的製造案例研究，監控和控制系統部署帶來的第一個預期優勢是產品質量的提高：儀器可以檢測、測量和監控影響流程性能或產品質量的變量、事件和情況。關於將 PLM 與其他系統整合的核心問題之一是信息的所有權。一個可能的解決方案依賴於數據庫集成以及系統之間的中間件的使用。正如 Saaksvuori 和 Immonen（2008）所述。一個合理的目標是信息應該始終在一個地方更新。其他系統可以直接從 PLM 數據庫讀取信息，如果必要，所需的信息可以在其他系統的數據庫中複製，如圖 7 所示。儘管它主要是從 PLM-ERP 整合的角度指出這一點，但從 PLM-MES 整合的角度來看，它仍然非常有價值，因為它是如何期望通過在文件性質不同的系統中工作，進而實現更好操作的示例，這些系統將文件加載到集中的 PLM-ERP 系統中。因此，中間件將成為一個軟件框架，以用戶友好的方式組織和連接系統數據庫中提供的所有信息。這種應用也被稱為集成應用程序，正如 Stark（2015）所指出的，這些應用程序使 PLM 應用程序之間的產品信息交換成為可能（例如，在 CAD 應用程序和 CAE 應用程序之間）。它們還實現了 PLM 應用程序與其他企業應用程序（如 ERP 和 CRM）之間的產品信息交換。

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

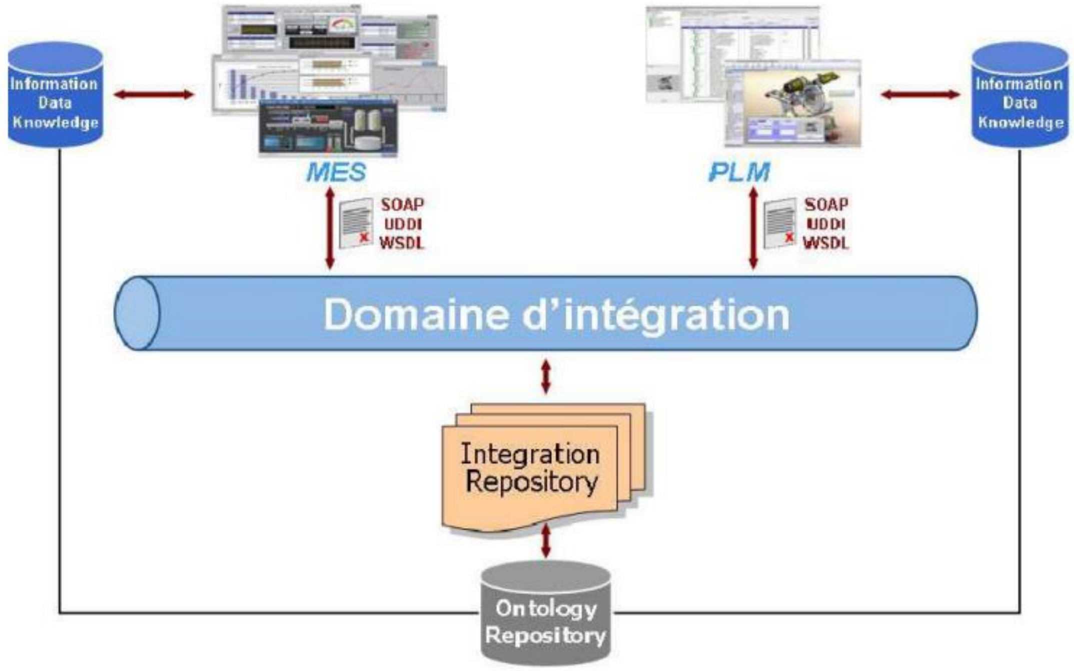

Figure 8 Diagram of Web service architecture (Adapted from Ben Khedher et al., 2011)

圖 8 Web 服務架構圖

（改編自 Ben Khedher 等人，2011 年）

In their work regarding different systems architectures for the implementation of an integrated MES+PLM they describe the use of a mediation system in web service architecture. As depicted in Figure 8, the proposed architecture uses data exchange based on internet technologies to help companies, especially expanded companies, to take advantage of opportunities generated by the Web Services. The concept of "web service" means an application (program or software system) which is designed to support interoperable machine-to-machine interactions over a network, according to the definition of W3C (Ben Khedher et al., 2011). Figure 8 Diagram of Web service architecture(Adapted from Ben Khedher et al., 2011) The reason this expansion is so relevant from the perspective of this work is that the Odoo software works in a similar fashion through a similar web service architecture. In theory the Odoo software could act as the middleware working through the local network or hosted in he cloud and enacting the layer of integration that was previously mentioned.

在（Ben Khedher 等人，2011）的研究中，這種中間件思維的擴展方式非常相關。在他們關於實施集成 MES+PLM 的不同系統架構的工作中，他們描述了在 Web 服務架構中使用調解系統的使用。如圖 8 所示，所提出的架構使用基於互聯網技術的數據交換，以幫助公司，特別是擴展的公司，利用 Web 服務產生的機會。 "Web 服務"的概念意味著一個應用程序（程序或軟件系統），它旨在支持在網絡上的可互操作的機器對機器交互，根據 W3C 的定義（Ben Khedher 等人，2011）。這種擴展之所以如此重要，是因為 Odoo 軟件通過類似的 Web 服務架構以類似的方式工作。理論上，Odoo 軟件可以通過本地網絡或在雲端中托管，並實施先前提到的集成層作為中間件。