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► To cite this version:

Mariam Moufaddal, Asmaa Benghabrit, Imane Bouhaddou. Industry 4.0 for PLM in Pandemics: Towards a Smart Digital Agile PLM. 18th IFIP International Conference on Product Lifecycle Management (PLM), Jul 2021, Curitiba, Brazil. pp.508-522, 10.1007/978-3-030-94335-6_36 . hal-04186159

HAL Id: hal-04186159

<https://inria.hal.science/hal-04186159v1>

Submitted on 23 Aug 2023

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Industry 4.0 in the rescue of PLM in pandemics: Towards a Smart Digital Agile PLM

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Abstract. Product Lifecycle Management (PLM) is a business strategy, aiming to streamline the flow of information about products and related processes throughout the whole product Lifecycle such that the right information in the right context at the right time can be made available. Currently, the COVID-19 pandemic meant major improvements to the way service companies operate, changing the schedule and activities of their workers. The introduction of Industry 4.0 also launched emerging technology that could promote certain operations, thus alleviating the consequences of COVID-19. The aim of this research is to, first, investigate how this pandemic has impacted the product lifecycle, and secondly, explore how industry 4.0 technologies can address these challenges by proposing a Digital Smart Agile PLM framework.

Keywords: Product Lifecycle Management, Industry 4.0, COVID-19

1 Introduction

Crisis have always allowed human organizations to progress by building on the lessons of the past. The Coronavirus pandemic is no exception. COVID-19 is “the” global crisis of our time and the biggest challenge we have faced since World War II. But the pandemic is much more than a health crisis, it is also an unprecedented socio-economic crisis putting pressure on each of the countries it affects. It has devastating social, economic and political impacts that will leave deep scars slow to fade.

For manufacturers, the health crisis has revealed the value of a lean, resilient Product Lifecycle Management, promoting responsiveness to withstand such shocks, or even become more efficient in normal times. Every product has a lifecycle from ideation to disposal. It is triggered from the design phase, runs through the phases of manufacturing, usage and recovery or disposal at the end of its life, thus creating a loop [1].

Physical products are becoming smarter because of the increased number of product embedded information devices (PEIDs) [2] and their real-time processing capabilities [3]. Indeed, the increasing use of PEIDs provides the data needed for intelligence.

The idea behind Product Lifecycle Management (PLM) in regard to data analytics is pretty simple. It’s all about collecting and managing the information and processes related to all stages of product lifecycle. PLM can then be thought of as the information

age manifestation of the cobbler model that focuses a company on its value chain and seeks to reintegrate people, processes, resources and information [4].

The efficiency of these processes can still be greatly improved. Anything that increases visibility into the reality of operations provides data, which can be used to improve these same operations. In this sense, it is important to be able to act with an actor who knows how to work on the visibility of the product lifecycle. Thus, it must be done in a secure environment for the actors, where we don't share everything with everyone.

Today, in the era of digital transformation imposed on all areas of industry, the standards have never been higher. How to adopt a global efficient approach while meeting the needs of customers? Industry 4.0 technologies are here for the rescue. Industry 4.0 factories have machines supported by wireless connectivity and sensors. These sensors are connected to a system that can visualise and monitor the entire production line and can also make its own decisions [5]. This was always considered as a disadvantage in using industry 4.0 technologies as it decreases human to human interaction. In the current situation, it has become a reason to adopt these autonomous ways of working.

The aim of this paper is to introduce industry 4.0 as a way of efficiently managing the product lifecycle in this pandemic and also the after pandemic. The rest of the paper will be structured as follows: after introductory remarks, section 2 presents a standard PLM model based on a review of other models, thus illustrating the relationship between PLM and SCM. Section 3 will recognize the position of PLM in this pandemic, highlighting the constraints it applies on products in supply chains. Section 4 proposes a framework to overcome pandemic constraints using industry 4.0 technologies. Concluding remarks and some potential-work suggestions will be given in the last section.

2 Towards a standard PLM model

2.1 The proposed model

Leonardo Da Vinci said – “Simplicity is the ultimate sophistication”. It is very true. To find simple and clear PLM definition is hard. So, how to do it anyway? Depends to whom you are talking to, engineers; managers; contractors; suppliers; customers, PLM means different things. All of them have a different perspective on PLM. But ultimately, it is about how to organize product development, manufacturing and support in the way that will make your product a first class citizen [6] that fulfills all its intended functions in an intelligent way.

The term ‘lifecycle’ generally indicates the whole set of phases, which could be recognized as independent stages to be passed/followed/performed by a product, from ‘its cradle to its grave’ [4]. Adopting an easy-to-use model, product lifecycle can be defined by three main phases: The Beginning Of Life (BOL), the Middle Of Life (MOL), and the End Of Life (EOL). In literature, many researchers agreed to this categorization of the product lifecycle, but not with the same definition.

Stark [7], Terzi et al. [4], and Kiritsis et al. [8] considered:

- In the BOL phase, the product concept is generated and subsequently physically realised. It includes design (product design, process design and plant design) and manufacturing (production of the artefacts and warehousing).
- In the MOL phase, the product is in the hands of the final customer, i.e. product user and/or some service providers, e.g. maintenance actors and logistic providers. It includes distribution, use, and support (in terms of repair and maintenance).
- The EOL is the phase where products are collected, disassembled, refurbished, recycled, reassembled, reused or disposed. It can be said that EOL starts from the time when the product no longer satisfies its users (initial purchaser, second hand owner).

Li et al. [9] had other considerations regarding the product lifecycle stages:

- BOL is the period in which the product concept is generated, designed, and subsequently physically realized. It includes design (product design, marketing) and production (procurement, product manufacturing, and equipment management).
- MOL is the period when products are distributed, used and maintained by customers or engineers. It includes logistics (warehouse management, transport), utility (customer service, support), and maintenance (corrective/preventive maintenance).
- EOL products are either recycled by manufacturers or disposed by customers.

We can see that Li et al. [9] considered warehouse management as part of the MOL phase unlike Stark [7], Terzi et al. [4], and Kiritsis et al. [8] in which it was considered as part of the BOL phase. Li et al. [9] referred to the procurement process which involves choosing the right supplier for raw materials and delivering them to the production firm. By means, the different blocks of the product supply chain are highlighted.

Bouhaddou et al. [10] had a more detailed perspective where they considered that:

- BOL phase includes Requirements' definition (customer requirements, feasibility study), Product development (design, prototyping, and testing).
- MOL phase includes Production (manufacturing, assembling, and quality control), distribution (storage, transportation and delivery), Use of the product by the customer (product usage and consumption, maintenance, and support).
- EOL includes dismiss, disposal and recycling.

We estimate that Bouhaddou et al. [10] considered BOL as the phase where the product is still a prototype not ready to be used by end users, MOL is the phase where the product is ready to be used and consumed.

In Fig.1., we propose a model where we consider:

BOL as the phase where the product is still in the hands of the company. It includes Requirements' definition (Customer requirements, environmental requirements, feasibility study), product development (Marketing, product design, prototype, test), and production (procurement, manufacturing/quality control & packaging). We exclude warehousing and distribution from the BOL phase as we estimate some organizations subcontract these activities, and we want to keep the model a standard one.

MOL as the phase where the product is no longer in the territory of the enterprise and is ready to be consumed by customers. It includes Logistics (warehousing, sales and distribution/return), utility (customer service, product support), and maintenance (preventive and corrective maintenance).

EOL as the phase where the product is no longer usable or does not satisfy the customers' need and should be either retired or recycled (partially or totally re-manufactured, re-used).

Our model is based on a combination of different perspectives. We want to keep it standard so that it can fit, with some additional specifications if needed, every company in the industrial sector.

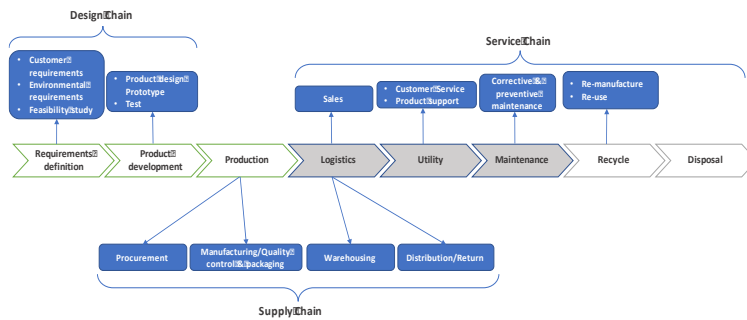


Fig. 1. The proposed PLM model

2.2 PLM AND SCM: HOW?

Instant gratification has become the norm. Customers want products delivered yesterday and are ready for the next product iteration shortly thereafter. The concept-to-delivery process in today's product manufacturing business is extraordinarily complex and fast paced. In order to respond to rapidly changing trends and meet customer expectations, companies must constantly strive to reduce product development time and increase speed to market. That's a key reason why faster time to market continues to be the number one benefit that companies hope for from their PLM investments.

But PLM alone will not deliver the expected results. Lead time, cost management, product quality, and access to raw materials force sourcing organizations into tough decisions sometimes at odds with the goals of customer-centricity.

We have identified the three chains that constitute the product lifecycle as shown in Fig.1. We are talking about:

The design chain where a prototype of the desired product is achieved, and the first tests are performed. It includes requirements definition and product development.

The supply chain where the product is being manufactured, stored, sold and distributed based on the prototype.

The service chain where extra assistance is given to consumers regarding products. Along this chain, not only product support and maintenance activities are offered whenever needed but also disposal and recycle actions are being taken care of.

We can see here that the supply chain is a component of the product lifecycle. It is an essential chain and better management of it implies better product lifecycle management. Indeed, if we are not able to predict the customers demand and deliver them the desired product as described, the work done along the design chain will not be visible to final customers. There will be also no service chain as there is no product to be used or maintained. Therefore, a company, through its supply chain, must be able to answer the design chain results/outputs and present a ready-to-use input to the service chain.

To do so, Companies must be able to give customers/consumers the right products in the most resource-effective manner, without sacrificing quality or service. If the supplier, manufacturing, and post-sales support networks are being stressed to the breaking point, if the products require excessive inventories to maintain service levels, or if costs and complexity throughout the product supply chain need to be reduced [11], then smart supply chain and product life cycle management acting together is required. Indeed, by understanding how product lifecycles in industry —and within a company — work and integrate with supply chain, managers are better equipped to optimize their supply chain accordingly, saving money and achieving customer satisfaction.

In the following, we are studying the impact of the pandemic on the product' supply chain. We conserve studying it in the design and service chains for the coming works.

3 Post-pandemic product supply chain

In "The World is Flat" (2007), his acclaimed study on the globalization of the economy, Thomas Friedman recounts a visit to an auto parts manufacturer in China, where a sign suspended above the production line displayed the following proverb: "Every morning in Africa, when the gazelle wakes up: she knows that if she wants to survive, she must run faster than the fastest lion. Every morning in Africa, when the lion wakes up: he knows that if he does not want to starve, he must run faster than the slower gazelle. Lion or gazelle, it doesn't matter, when the sun rises, it is better to start running".¹

In 2020, as the coronavirus pandemic disrupted the global activity, this Darwinian conception of competition deserves our reflection. Speed is of the essence, and companies that want to stay ahead of their competitors and survive must closely monitor the impact of the crisis and adapt quickly.

But the pandemic could also lead to deeper changes in the globalized economic models that Friedman described in his book. By drawing attention to weaknesses in supply chains, the crisis has led some international companies to place more emphasis on inventory capacity than operational efficiency, at least in the short term.

This crisis underlines the more pressing need than ever to be reactive to change. It also shows that when a crisis affects several regions, sectors and assets at the same time, it is extremely useful to be able to collaborate with other specialists.

In this context, according to experts, the integration of internet technologies, robotization and the need to have the most up-to-date and reliable data flows possible in

¹ Thomas Friedman, 'The World is Flat: The globalized world in the twenty-first century', Penguin, 2007

the industry will make it possible to gain flexibility and agility to manage the various phases linked to products lifecycle.

Thus, mastering the information related to these different phases is more essential than ever in the context of this 4th industrial revolution. The company will therefore need to have software that allows it to track this information.

Companies were already on the way to digitalizing PLM processes before the pandemic. If companies were planning on doing so gradually, then the pandemic has intensified and accelerated it. It has reinforced many trends that will enable companies to carry on their businesses despite social distancing and travel restrictions. As flexibility, productivity and efficiency are basic requirements in this era, digitalization and the automation solutions will maintain their performance levels and more. COVID may not have uncovered new challenges, but it has increased the urgency of pre-existing ones. Where brands and retailers originally expected to have 5-10 years to shift their retail and sourcing strategies, that timeline has now shifted to 5-10 weeks.

Based on our literature review, we summarized the constraints imposed by the pandemic on the product supply chain and classified them in Table 1 as follows:

Failure of supplies and uncertainty in raw material supply	(C1)
Maintain deficient machines	(C2)
Manage infection risks in plants	(C3)
Ensuring workforce capacity to assemble, store and ship products	(C4)
Loose collaboration	(C5)
Congested ports	(C6)
Integrate customer specific requirements	(C7)
Optimize decision-making	(C8)
continuous optimized production	(C9)
Manage process and data complexity	(C10)

The international demand for raw materials [12] which are exported by Africa is weakening [13], national productions which require imported inputs sometimes suffer from the breakdown of production and supply chains.

In this context, a survey [14] was carried on by Saratech Inc., an engineering organization specialized in helping customers develop better products by implementing PLM softwares and new technologies. It was conducted among a range of company sizes, during Q3 2020 with data analysis and insights extrapolation conducted in Q4 2020. Respondents of the survey, as shown in Fig.2., came from various industries; for example, 27% labeled their industry as Product Development/Engineering, and 15% came from industries described as "Other Manufacturer." Respondents also included automotive, aerospace, federal government, packaged goods, and other industries/verticals.

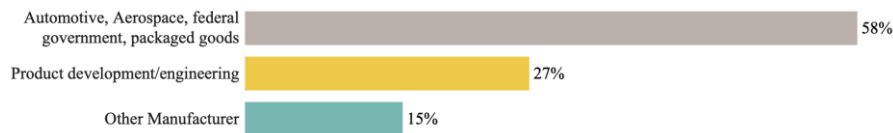


Fig. 2. Respondents of the Saratech Inc. survey

The study aimed to closely examine how organizations are adapting during the COVID-19 pandemic. It investigates how these organizations are actively transforming their supply chains and democratizing production capabilities.

To examine the potential influence of the pandemic on sourcing parts, the respondents answered, “How has the pandemic changed sourcing parts?”. 65.3% of respondents reported that nothing has changed, and it was business as usual. 16.9% of respondents stated they have started to look at new ways to insource parts instead of outsourcing. 15.1% of respondents said they have pivoted and are using new technologies.

Table 1. Constraint of the product supply chain.

Constraint	Procurement	Production	Warehousing	Distribution
C1- import raw materials	X			
C2- reduce workforce & manage plants		X	X	
C3- maintain deficient machines		X	X	
C4- manage infection risks in plants		X	X	
C5- loose collaboration	X	X	X	X
C6- congested ports	X			X
C7- integrate customer specific requirements	X	X		X
C8- optimize decision-making	X	X	X	X
C9- continuous optimized production		X		
C10- manage complexity	X	X	X	X

According to this study, fewer companies were impacted by the pandemic in terms of raw materials required for manufacturing. Companies managed to find alternative solutions to overcome this challenge. On the contrary, in another context, during the pandemic, people were trapped in their homes and their expenditure on services such as transport has fallen, while smartphones, home furnishings and many other items have risen. This meant a huge number of cargo ships floating in the sea, in conjunction with the need for urgency for supplies and protection gears to combat the pandemic. The congestion was aggravated by Covid's work schedule constraint and separation. Nevertheless, industry 4.0 technologies are promising in assisting companies to overcome these challenges by providing alternative solutions, the according knowledge and skills.

The post COVID era opens an opportunity window for sustainable business transition [15], and need to make supply and production systems more resilient [16]. COVID-19 has infected people in several countries around the world, spreading to all continents.

With this spread has come serious effects on the industry. All companies' leaders were concerned about how it will affect their sales, success metrics and most critically how would they minimize employees' interaction to fit into the new precautionary measures.

Companies should think about putting together a committed cross-functional unit. A cross-functional team will organize the efforts of various business divisions, track and provide the requisite information to senior management for more contact with staff, clients, and stakeholders. It's past time to assess vital responsibilities and main positions, as well as form a team of temporary replacements in the event of a force majeure situation, since there is a greater chance that certain workers may be unable to work due to quarantine or sickness.

Under different situations, businesses should create an efficient management decision-making mechanism. It should determine how it will guarantee the wellbeing of workers who are required to be at work and are unable to work remotely (e.g., shop assistants, cashiers, drivers, etc.). Companies are re-evaluating their strategies for ensuring proper occupational sanitation, providing disinfectants, and so on.

COVID-19 places a burden on the workforce as it tries to adapt to the current industrial process regime. To ensure social distancing at work, various reforms have been made, including improvements in manufacturing processes and, as well as standard operating procedures. This adds to the pressure on workers to meet their productivity goals when the current regime necessitates more time. Therefore, an optimal and real inventory and work allocation is required for the different phases of the pandemic [12].

Beside constraints that impact product supply chain processes directly, others have been faced once the product is ready to be delivered to clients. First, there would be no way to present what we have to offer to clients and interested parties if there are no more trade shows, in-house exhibits, or conferences. It was clear right away that something different, a new form of case, needed to be developed. It had a massive impact. The second choice is a home office. The word has been around for a long time, but only a few businesses have made it a reality.

While pandemic has made it clear that human to human interaction should be minimized, home office was adopted as the new way of working. The word has been around for a long time, but only a few businesses have made it a reality. Home office working style had emerged to be adopted by supply chains stakeholders, and it is now a reality.

The Covid-19 crisis challenges a very hierarchical managerial culture based largely on "Command and Control". While it is obviously too early to say what organizational changes will take place over time, it invites, or even forces, a price for physical and psychological distance in traditional management. It will accelerate management by objectives to the detriment of micromanagement, reinforce the importance of local management, more able to manage and raise local issues for rapid adaptation.

The health crisis calls for finding other means to ensure the cohesion of the social body, the organizer of collective intelligence in a world where remote work will be structurally more important. Questions of identity, mission and "what are we doing together?" will arise even more sharply. The technological infrastructure of firms will need to be strengthened thus, allowing remote access and collaborative work.

Consequently, PLM in collaboration with industry 4.0 technologies may be the most important piece in the architecture when companies strive for:

- Engineering collaboration for designing smart products
- Vertical integration to implement flexible and reconfigurable smart factories
- Horizontal integration to implement smart processes on extended enterprise.

4 Industry 4.0 to the rescue of PLM

4.1 Industry 4.0 answering pandemic constraints

The COVID-19 pandemic has caused lockdowns around the world, disrupted the way we work and live, and caused economic repercussions not seen since the end of World War II. The COVID-19 pandemic is fast becoming a litmus test for businesses. Its consequences could not be anticipated. To overcome them, all that matters is the ability to react quickly and adapt immediately. Moreover, in an age when smartphones, laptops, IoT, AI and other technologies are part of everyday life, increasing agility by dispensing with essential digital innovations is mission impossible.

The pandemic has demonstrated that responding to the current and evolving demands as fast and flexibly as possible is more critical than ever. In recent months, various manufacturing industries have faced a variety of challenges. Some industries, such as food and pharmaceuticals, had to rapidly scale up demand. Others, such as manufacturing and aviation industry, were forced to cut down or even cease operations. Some have even started producing other products to sustain the crisis and avoid ceasing their operations. Elavarasan and Pugazhendhi [17] have even enumerated the world's leading manufacturing companies' activity before and during COVID-19 as shown in Table 2.

Table 2. Manufacturing Industries before and during pandemic [17]

Companies	Domain	Manufacturing products	
		Before Pandemic	During Pandemic
Ford	Automotive Industry	Vehicles	Modified respirator and ventilators
Tesla - Gigafactory	Automotive Industry	PV cells	Ventilators
Airbus	Aerospace Industry	Aircraft products	Ventilators
Mercedes-AMG High Performance	Automotive Industry	Formula 1 engines	Continuous positive airway pressure (CPAP) machines
Powertrains			
Dyson	Tech company	Vacuum cleaners and hand dryers	Ventilators
Ineos	Chemical company	Oil, gas, plastics Chemicals and other products	Hand sanitizer and other healthcare products
Gucci	Fashion	Luxury clothing	Masks
Zara	Fashion	Apparel	Surgical masks
Bacardi	Alcohol based company	Rum	Hand sanitizers
Eight Oaks Farm	Distillery	Liquor	Disinfectant
LVMH and L'Oreal	Fashion	Face creams and perfumes	Medical disinfectants and sanitizer gels

There is a requirement for the introduction of various advance technologies to tackle various problems and constraints related to this viral pandemic [5]. Industry 4.0 technologies, as illustrated in Fig.3., have the capability of providing better digital solutions for our daily lives during this crisis [18–20] in many ways.

First, the cloud has taken on an extreme dynamic. Without it, the infrastructure for everything is missing. Distributed working worldwide is not new, but it has been greatly accelerated. The majority of businesses are conservative. Because of where the data is

stored. Where is my engineering job, my drawing? There are still some major corporations that say, “My records should remain in my building!”.

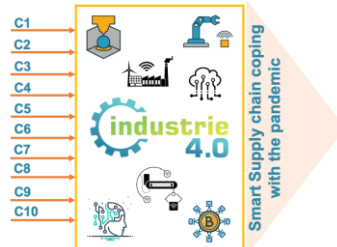


Fig. 3. Industry 4.0 as a response to pandemic constraints

Decentralized devices, such as those used in the home office, are, of course, driving cloud adoption. Otherwise, no one can operate on the same object from different locations. The Cloud is on its way. That being said, companies' conservative perspective must be respected. Their valuables, technical knowledge, and patents should not be left lying around. Many people are also unsure whether or not they can fully embrace cloud computing. One thing is sure, for the time being, anything that is in progress and contains private expertise should be kept locally. A good alternative would be to consider storing metadata in the cloud and storing data locally. This hybrid way of storing will ensure quick access to master data and metadata, as well as protection of their valuables. Corona is accelerating cloud-based distributed development worldwide. There will be a lot of activity, especially in end products with connected applications.

In addition, thanks to digital and automation of processes that can be adopted while personal access to premises is limited, certain facilities can continue to run. Machinery may also be operated remotely, commissioned, maintained or repaired. Engineers could "remotely" access a computer, system, device, or a machine and provide the same instructions as they actually stood beside the machine. Siemens, for example, offers these kinds of assistance. They use remote virtual reality to supervise desperately needed service work to support one of their clients whose company is closed to their service.

In particular, industrial 3D printing has demonstrated its utility in the crisis as it offers quick, scalable and dispersed alternatives to materials which are so desperately needed. For example, Siemens has opened her Additive Manufacturing Network to hospitals and health organizations shortly after the onset of the pandemic. Hospitals, physicians and other organizations have been able to send their medical equipment replacement parts desperately needed to third-party printing designers and 3D printing providers, thereby solving bottlenecks rapidly and without any administrative burdens.

Furthermore, thanks to Internet of Thing and Artificial intelligence (AI), a solution was developed which alerts manufacturers against the risk of infection in their facilities. It is a smart mix of modeling applications, small handheld monitoring systems and communications technologies. A Siemens production factory in Houston, Texas, already uses this functionality [21]. It will be used to refine the manufacturing processes remotely in order to make the workplace safer. The machine monitors the distances

between employees and, in cases of danger, issues a warning. Companies can also install hotspots in their factories and monitor communications with infected employees.

Accordingly, there are some companies and plants that had always been endowed with a recognizable degree of autonomy and digitalization that they were capable to face the current circumstances. For instance, the Siemens plant in Amberg is among these companies and has a degree of automation is between 75% and 80% [22]. Consequently, their efficiency had only a slight decline which they were quickly able to catch up while reorganizing their procedures to fit the new sanitary precautions.

Companies managing their own supply chains and those outsourcing to third-party logistics providers manage a massive flow of freight, goods and products on a daily basis whilst at the same time creating vast data sets especially due to the shift to e-commerce during the pandemic. Millions of shipments are tracked daily from origin to destination, indicating information such as content, weight, size, location, route, etc., of each individual shipment, across large numbers of networks [23]. It is this data tracking, providing the big data, which contains huge value which needs to be exploited [24].

Visibility is an essential necessity of tracking products in an end-to-end manner throughout the supply chain. Gartner Research [25] reported that virtually no company is able to, or will be able to, provide end-to-end supply chain visibility in the near future.

What is needed, according to Kiritsis [26], is a closed-loop PLM system that will allow all the actors who play a role during the lifecycle of a product (managers, designers, service and maintenance operators, recyclers, etc.) to track, manage and control product information at any phase of its lifecycle (design, manufacturing, MOL and EOL), at any time and any place in the world.

Although there are a lot of information flows and inter-organisational workflows, the business operations in closed-loop PLM are based on the interactions among three organisations: PLM agent, PLM system, and Product. The PLM agent can gather product lifecycle information from each product at a fast speed with a mobile device like a personal digital assistant or a laptop computer with a Product Embedded Information Device (PEID) reader. It sends information gathered at distribution sites to a PLM system through the internet. The PLM system provides lifecycle information or knowledge created by PLM agents whenever requested by individuals or organisations [26].

Through advanced analytics, it is becoming possible to provide real-time visibility across the supply chain in addition to improving distribution processes performance [24]. With this improved visibility, companies will be able to track the movements of shipments and products from the time the shipment is released until it arrives at its destination. Tracking systems will generate alerts if shipments stay at certain nodes longer than expected and prompt transportation managers to contact the freight firms involved and explore the matter to ensure timely delivery [27]. The system will be freed from the use of human labour normally deployed for handling and inspection. Lower safety stock inventory levels are expected as the products move more swiftly through inspection points. With increased information visibility throughout the supply chain, managers will be better able to respond to problematic and exception-handling cases.

To summarize, Cloud computing will allow centralized data access, Additive manufacturing will support simulation and prototyping in the design phase as well as in supplying with necessary raw materials. IoT will give a thorough insight into how the

product is being used during its lifecycle and illustrate certain components which are not of importance in terms of usage. In addition, customers require special and fast user interfaces which can be improved in conjunction with the Industrial Internet of Things (IIoT) rather than workflow-based commitments. One of the key fields is perhaps the capacity to predictively and prescriptively track and maintain, remotely or physically factories and plants. Consequently, product preferences will change with the interactive technology. Useful, autonomous and productive experience for users is to be expected.

Regardless of individual features, the PLM market is evolving quickly, and suppliers of tech solutions need to evolve solutions that address emerging demands in order to stay competitive. The biggest driving force is digitalization and Industry 4.0. Those businesses today are forced to be digital in one way or another for survival matters.

In addition, existing companies will need to combine the latest digitized approaches with what is already existing in the PLM package. The challenge is to find strategies for seamless and timely transformation coupled with the change management initiative.

4.2 The Smart Digital Agile PLM framework

Having healed its wounds, the manufacturing industry must incorporate new work habits that will undoubtedly continue for years to come. It should rely on a PLM that is:

- Remotely operated and impact resistant.
- Operating closed offices, in a network.
- Integrating security, authentication and cloud functions for remote working.
- Allowing a product to be divided into sub-assemblies that can be addressed independently, in order to operate in degraded and parallel mode, if necessary. This induces system engineering, the definition of interfaces between subsystems and mature data. But also, to structure this data to limit the dependence between disciplines (mechanics, software, electronic), and this on the different phases of the life cycle.

In order to achieve the aforementioned characteristics, companies need to operate in a crosslinked manner. In Fig. 4., each chain of the product lifecycle will be using outputs and constraints of other chains relying considerably on the emerging technologies.

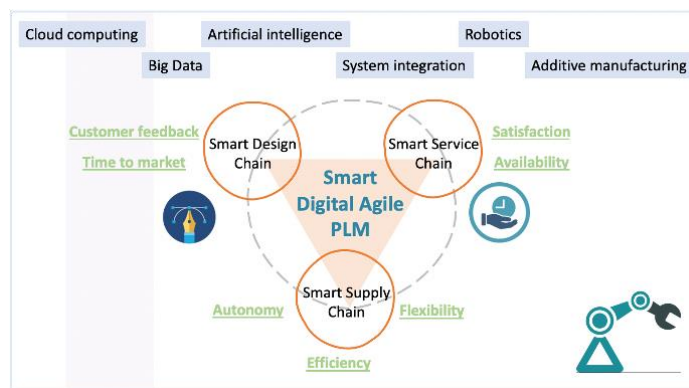


Fig. 4. The Smart Digital Agile PLM framework

In fact, the basis for progress in digital transformations is the high product data quality and the focus is on digital models for product design, product supply and service chains. They are important prerequisites for digitally optimized processes in the era of Industry 4.0. These digital models should be available at all levels of product life. They offer a comprehensively realistic visual snapshot of a machine control system that is a digital twin. It allows the designer to fully and effortlessly move his engineering method into the virtual universe. It is no longer important to work on actual hardware designs. Product development will be agile, thus only the final steps would be carried out in the real world, allowing the ecosystem to connect evolve and transform to stay competitive.

PLM in the era of industry 4.0 will be endowed of collaborative design, tapping into the creativity outside the company walls. It will engage communities and customers earlier, deeper and more often. Feedbacks will be taken into considerations on the fly as flexible manufacturing capabilities will be developed and connected services will be delivered. In accordance with this, the value proposition of the products will be extended, thus insights into how the products are performing and being used will be gained. Using these tools, we will have the essential building blocks of a resilient PLM.

5 Conclusion & future research directions

The health crisis has taught businesses how essential it is to know how to adapt quickly whether in terms of production, sourcing or even distribution. Observing what is happening in parallel in the world, given the developments in information and mobile technology, there is no doubt that we find ourselves in the era of intelligence.

Companies in many sectors are making efforts to move from 'gut-feel' decision-making to accurate data-driven insight to achieve effective business decision making. By adopting a more sustainable model, it is possible to ensure business continuity, even in the event of an unexpected and massive change in demand.

Supply chain (SC) managers need to get involved in the product development process to enable both product and process innovation. The experience of the weeks when the economy came to a screeching halt and the period of recovery should be a source of reflection and teaching for researchers and policy makers. The product lifecycle perspective becomes more important because it provides a holistic view across disparate enterprise silos to provide a coordinated response to the customer. Integration of product lifecycle and SC management can provide fresh perspectives and critical insights that are often missed due to the extreme fragmentation of functions within the firm.

Thus, supply chain professionals need to embrace these developments to remain efficient, effective and competitive. Anticipating sales volumes, customer preferences for products and optimizing work schedules are few examples where proper analysis of product data has the power to help succeed and overcome the current challenges.

The objective of this paper was to expose industry 4.0 as a rescuer of product lifecycle management (PLM) in this pandemic, having the potential of changing and impacting companies in a big way. A standard PLM model was elaborated following a review of existing PLM models. The link between PLM and SCM was outlined and the position of PLM in this pandemic was recognized, highlighting the constraints it applied on

products in supply chains. Then how industry 4.0 would address these challenges was presented and finally a smart digital PLM framework was proposed.

Along this study, we have noticed that companies lack the possibility to access product related information letting managers face the difficulty of linking together the available data and drive decisions. Therefore, we propose to investigate how to have a single point of product and process information access across multiple domains, projects, partners, suppliers and systems through the use of industry 4.0 (I4.0) technologies.

In this paper, the research mainly focused on how industry 4.0 is rescuing PLM through enumerating constraints linked to the product supply chain only. As future research direction, we propose to investigate constraints along the product lifecycle and go through each I4.0 technology to explore their opportunities and challenges for PLM.

Furthermore, the main innovation in the 4th industrial revolution is the implementation of Cyber-Physical Systems (CPS) to establish the global value creation networks. PLM enables companies to take full advantage of IT combined with CPS to make the processes highly intelligent. We propose to design a CPS combining feedback data from product usage and sending it back to constructor to take it into consideration for future advances allowing much more agility and flexibility along the product lifecycle.

Finally, most studies and proposed models concern manufacturing phase of the lifecycle. Little efforts have been devoted to the logistics (warehousing and distribution/return) phase. We propose to cover this phase so as to provide more traceability and visibility on the product while delivering it to sale points or to final costumers.

6 References

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