Manufacturing-as-a-Service (MaaS): state-of-the-art of up and running solutions and a framework to assess the level of development of a Cloud Manufacturing platform

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Abstract: During the last decades manufacturers tried to find new sources of flexibility because of the uncertainty of the market. Both practitioners and academics started to study new paradigms aiming to make companies more flexible up and downstream of their value chains leveraging on suppliers and customers. Cloud Manufacturing (CM) is certainly one of the most interesting concepts because it comes from the success of Cloud Computing and belongs to the complex fourth industrial revolution (i.e. Industry 4.0 paradigm). It has been introduced in 2010, defined as the "manufacturing version of cloud computing" where manufacturing resources are available to users on-demand, with outstanding flexibility. CM pursues the idea of creating Manufacturing as-a-Service (MaaS) leveraging on the benefits of the platform economy. In spite of its interest, after ten years debate there is not consensus on the essential characteristics of this paradigm because of the very limited number of real applications (prototypes excluded). In this paper we explore 6 cases of up and running platforms which resemble some of the characteristics of CM, define them as "CM Early adopters" and inductively propose a framework to assess the level of development of a CM platform. This study contributes to theory as it shows that CM is already arising in some businesses, the approach to the paradigm can vary significantly from one case to another, and different levels of development can be assessed. From a managerial point of view, this paper helps to understand the CM paradigm as it shows concrete examples of real companies pursuing the MaaS idea. In conclusion, MaaS seems ready to land on some industrial sectors and this can be either a new opportunity for competitiveness or a serious threat.

Keywords: Manufacturing-as-a-Service (MaaS); Platform Economy; Cloud Manufacturing; Industry 4.0

1. Introduction

Flexibility is a key word for competitiveness. It is widely accepted as one of the four operational capabilities of a firm amongst quality, dependability, and costs (Ferdows and De Meyer 1990) and becomes fundamental for business strategy (Gerwin 1993). (Naim et al. 2016) distinguish different types of "internal" flexibility of a company resulting into 4 different types of "external flexibility", i.e. product, volume, mix, and delivery. It is acknowledged that always more frequently the dynamics and turbulence of the context require companies to be flexible on these four principles.

Thus, in order to develop the concept of flexibility, manufacturers and researchers work in two directions: internally and externally of the enterprise. In the "internal" track we have the achievements of the flexible manufacturing systems FMSs (1980s) and therefore reconfigurable manufacturing systems RMSs (Moriwaki et al. 1999). Externally, from 1990 onwards the debate on different paradigms to find new sources of flexibility gets beyond the limited barrier of the enterprise.

Externally: Agile, Multi-agent based, Holonic and Grid manufacturing paradigms arise with this aim. According to the Agile manufacturing vision, enterprises should be able to establish a network of resources shared that can be used by virtual enterprises which born and die to answer rapidly and effectively upon market request (Gunasekaran 1998). Multi-agent based and Holonic manufacturing paradigms propose agile manufacturing control systems. Agents or Holons (manufacturing systems that can be defined as "Whole" or "part of a whole" manufacturing system) cooperate, decentralize decisions (heterarchical structure) on distributed resources by providing autonomy and intelligence to the individual parties involved. They differ from traditional control approaches because they do not have a top-down approach characterized by centralization of planning, scheduling and control function decisions. Instead, they involve a "bottom up" approach because the control is devolved to intelligent, autonomous, and integrated manufacturing components (Leita 2009). Lastly, in Manufacturing Grid (MGrid) companies cooperate through the coordinated (but not centralized) sharing, integration and interoperability of a system of resources that are spatially distributed. This should be possible through the interconnection of resources and the use of advanced IT and management techniques (Tao, Zhang, and Nee 2011).

All the paradigms previously described leverage on cooperation among enterprises where a network of resources is somehow shared. The main challenge for them is having a network of resources with no centralized management. Multi-agent based and Holonic industrial implementations are rare because the investments required are high, they are complex system to design and manufacturers are sceptical about "local autonomous entities" (Leita 2009).

Cloud Manufacturing (CM) is another interesting paradigm arisen recently (firstly introduce by Li et al. in 2010) which derives from the success of Cloud Computing (CC) (Xu 2012). CM is the manufacturing counterpart of CC; it doesn't mean to apply Cloud Computing within manufacturing operations but it is a model to enable convenient, on-demand network access to a shared pool of manufacturing services (Liu et al. 2019). It mainly differs from "traditional" paradigms introduced before because it requires centralized management of resources/services through the development of a platform managed by a "Cloud Operator" who set the rules of the "game". Today, after a ten-years debate, there is not consensus on the CM definition because of the scarcity of empirical examples.

Nevertheless, during the last years several platforms arose and now they are operating, pursuing the goal of MaaS and they resemble the characteristics of CM paradigm as envisioned by academics but in different ways. Thus, we wonder whether is possible to define them as "CM Early Adopters" and identify different development levels for CM platforms. Starting from the literature of MaaS, CM and Platform economy, we perform a multiple-case study research to build a framework highlighting different development levels of CM platforms.

The present paper is organized as follows: in the second chapter a literature review of Manufacturing as-a-Service (MaaS) and CM is performed, followed by a deepening study on the platform economy. Chapter 3 presents the objective and the methodology used, and Chapter 4 shows the findings of the research. The framework to assess the level of development of CM platforms is introduced in Chapter 5 and Chapter 6 concludes the paper and suggests future research directions.

2. Theoretical Background

2.1 Manufacturing-as-a-Service (MaaS)

"Manufacturing as-a-service" (MaaS) is related to the trend of servitization within manufacturing sector. Servitization refers to the business trend where companies find a new source of competitiveness in adding services to their traditional offerings (Vandermerwe and Rada 1988).

The Maas conceptualization appears in literature when (Goldhar and Gelinek 1990) describe the characteristics of a new flexible sourcing method characterized by peculiar features, e.g. high variety to the extent of customization of product design, customer participation in the design of the product, fast response time, flexible contractual relationship, high information content transactions where vendors and customers "learn" and transactions become more efficient over time. Although the concept was extremely interesting, it did not attract the attention of practitioners and academics because of the lack of enabling technologies to sustain such a paradigm.

During the last ten years the maturity of technologies such as Internet of Things (IoT), CC and the achievements of the Platform Economy pushed academics and practitioners to experiment solutions to bring MaaS to life. In particular, the success of CC gave birth to CM which aims to realize MaaS.

2.2 From Cloud Computing to Cloud Manufacturing

To better understand the CM paradigm this sub-chapter briefly runs through the history of CC and its development trajectory.

During the last ten years CC has deeply changed the way we make use of computing resources as they have been servitized: we can now get computing services on-demand, with pay-as-you-go/pay-per-performance models. This idea was not new: "creating a distributed computing infrastructure" and transforming computing as a "fifth utility" - after water, gas, electricity and telephony - was discussed already 30 years ago (Clark and McMillin 1992) (Foster et al. 1997). Grid Computing is certainly the most known distributed computing paradigm pursuing the objective introduced above. It should enable a federation of shared computing resources resulting in a dynamic, distributed environment (Foster et al. 2008). Foster explains that Grid Computing should have these two characteristics (Foster 2002):

1. coordinating resources that are not subject to centralized control;
2. using standard, open, general-purpose protocols and interfaces.

Nevertheless, Grid Computing did not succeed because of the never solved issues about coordinated resource sharing and problem solving in dynamic, multi-institutional organizations (Foster, Kesselman, and Tuecke 2001).

The history shows that among distributed computing paradigms, only CC (Mell and Grance 2011) succeeds in delivering computing services as they were an utility and it has been unexpectedly characterized by opposite characteristics with respect to the Grid paradigm (Rajan 2011):

1. involving computing resources which are pooled and centrally managed by the service provider;
2. using proprietary protocols and interface.

CM was naturally born from the concept of CC and this is why the debate on this topic started around 2010 (Li et al. 2010) and why the interest increased over the last years. Many authors have tried to give a comprehensive definition of the CM paradigm (Xu 2012) and to describe the architecture of such a system (Huang et al. 2013). Although several literature reviews have been produced by academics (e.g. Adamson et al. 2017; Henzel and Herzwurm 2018), today there is not full consensus on the conceptualization of this paradigm. Nevertheless, we decide to provide the reader with one of the most recent CM definitions given by (Liu et al. 2019):

"A model for enabling aggregation of distributed manufacturing resources (e.g. manufacturing software tools, manufacturing equipment, and manufacturing capabilities) and ubiquitous, convenient, on-demand network access to a shared pool of configurable manufacturing services that can be rapidly provisioned and released with minimal management effort or service operator and provider interaction".

The system involves mainly three participants: the User, the Cloud Operator and the Resource Provider. A CM system acts as a platform as it facilitates the relationship between two distinct group of users (we'll see better in next Chapter 2.3).

Among the advantages for Users we find MaaS, guaranteed by the pool of available resources. In a CM environment, the supply chain is characterised by enhanced efficiency, increased flexibility (Wu et al. 2013).

Resource Providers mainly benefits from CM systems as they increase efficiency of their production systems (e.g. reducing idle capacity, and getting in contact with a higher number of customers through the internet network).

According to the literature of CM we are quite far from seeing a completed implemented CM platform because of many unsolved technical and business issues (Lu and Xu 2019). Most prominent academic authors in this field recognize we are still in a liquid phase because we do not know how CM will be successfully implemented (Liu et al. 2019).

The characteristics of CM (Liu et al. 2019) aiming to realize MaaS can be resumed as follows (Tedaldi and Miragliotta 2020):

1. Centralized management: resources are centrally managed by the Cloud Operator (i.e. turning User requirements into tasks, allocating them, scheduling them)
2. High-information sharing: resource providers and users communicate a great quantity of information with the Cloud Operator;
3. On-demand: resources appear to be immediately available to provide the User with services;
4. Service-oriented: great flexibility in sourcing (high customization level for Users in product, delivery date, volumes, mix), fast response time, flexible contractual relationship;
5. Resource pooling: resources are pooled and generally the User could have no control or knowledge over the exact location of the provided resources;
6. Ubiquitous manufacturing & broad network access: services are anywhere available and accessible through standard devices (e.g. smartphone, laptop)
7. Dynamism with uncertainty, rapid elasticity and scalability: resources can be elastically provisioned (and released) to scale rapidly outward (and inward) as it is requested.

2.3 Platform Economy

With the term "Platform Economy" or "Digital Platform Economy" we refer to the economy generated by platforms which are dramatically changing our lives, e.g. socializing with Facebook.com, shopping on Alibaba.com, finding accommodations with Aribnb.com, moving thanks to Uber.com drivers) (Kenney and Zysman 2016). There is not consensus neither on the definition of this phenomenon, nor on its name. Many authors label this economy as "Sharing Economy", others as "Creative Economy", other distinguish "Gig Economy". Regardless of the terminology used, all of us agree in recognizing that it is certainly one of the most impactful trend of the last twenty years.

Platforms are usually two-sided and aim at facilitating the interaction between two groups of users: demand-side Users and supply-side Providers (Ardolino, Saccani, and Perona 2016) (Eisenmann, Parker, and Van Alstyne 2008). One of the main problems of platforms is creating a business model to get both sides of the platform on-board (Eisenmann, Parker, and Van Alstyne 2006), taking into account network externalities which affect this kind of platforms and impact on their success (Rochet and Tirole 2003, Eisenmann, Parker, and Van Alstyne 2006).

3. Methodology

Since the number of platforms implementing solutions closed to the MaaS concept are a few, we could not perform any quantitative analysis. Qualitative research (Glaser and Strauss 1967) was a suitable option, thus we decided to perform multiple case-studies (Yin 2003) on enterprises which have developed platforms which increase sourcing flexibility and somehow resemble the MaaS characteristics.

In light of the emerging Platform Economy and theoretical developments on the CM topic introduced in Chapter 2, we use the case studies to describe different maturity levels for each of the CM characteristics. In fact, Yin states (2003) that "existing theories are the starting point of case study research, (…) propositions provide direction, reflect theoretical perspective and guide the search for relevant evidence".

First, we carefully select the cases and we choose 6 companies which can be regarded as representative of the heterogeneity of the platforms in this field. The unit of analyses is represented by the web-based platform and its users, i.e. the CM system. Sources of data are represented by interviews with people from the companies, websites of the companies and available online material (e.g. online video interviews and demo video). Since some of them are funded startup we have also sourced data from crunchbase.com, which collects info about innovative companies (e.g. founders, foundation year, funding).

We carefully analyzed the web-based platforms making simulations of Request for Quotations (RFQ) to better qualify the platforms characteristics from a user perspective. Then we have observed what happens beyond the platform, i.e. on the provider-side, and detailed the operational flows from RFQ to product delivery.

Finally we perform a cross-case analyses which enables us to obtain a framework which extends the theory in this field: it identifies possible different levels of development for each one of the characteristics of a CM platform.

4. Findings

In this chapter we introduce the companies analyzed and describe the features of the platforms developed.

Orderfox

Orderfox is a German company founded in 2017 and arisen to facilitate the relationship customer-supplier by creating a portal supporting the exchange of information. The platform basically offers two kind of services: (I) suppliers search and (II) RFQs publication in a marketplace.

Users at the demand-side of the platform can register for free, it means Orderfox chooses the strategy to subsidize the demand-side of the platform also to attract user to the supplier-side. The "suppliers search" tool allows to select attributes of the desired supplier (e.g. capabilities, nationality, dimension, certifications) and shows the results on a map. As "buyer" of the platform the User creates an RFQ and details it (adding drawing, any kind of documents and notes). After having decided whether to select specific recipients or publish worldwide, the RFQ is shared with resource providers selected. The option of selecting specific recipients can be interesting if we are going to submit sensitive data through the RFQ (e.g. drawings).

Resource Providers at the supplier-side can access the marketplace (a registration fee is required to have unlimited access) where all the RFQs are listed and detailed. In this case, we note the provider knows who submitted the RFQ and decides whether to apply or not for specific jobs; in case of acceptation, she/he answers to the RFQ.

Weerg

Weerg is an Italian company founded in 2015 and offers Additive Manufacturing (AM) and CNC machining services through a web-based platform which provides instant quoting to RFQs. The platform is open both to business customers and consumers.

To submit an RFQ the process is guided by the rules of the platform. The User uploads CAD drawings, selects the technology, the material, finishing services and instantly visualizes prices on the basis of the delivery date (the sooner it is, the higher is the cost). Eventually, the User places the order and the product is finally delivered to the customer.

Resource Providers are represented by the single facility owned by the Cloud Operator, i.e. Weerg. As the founder says, their strength reckons on "transparency of prices, speed of execution, certainty of deliveries".

247TailorSteel

This company is one of the eldest analyzed (founded in 2007), but it has started an interesting project in 2015 resulting in a platform offering metal sheet and tube processing (e.g. laser cutting, bending services). As in the Weerg case, the Cloud Operator is the same entity owning the resources providing the manufacturing services. It differs from Weerg because the platform is not web-based but works on a Software (namely, "Sophia") to be installed on a laptop. As for Weerg, the User uploads the CAD drawing and after having selected the specs she/he receives the quote, almost instantly. Even in this case, the delivery options are fully customizable and the price takes into account of that.

One of the most interesting things of this case is that Sophia is totally integrated with the production site. Once the order is confirmed, the production plan is updated and the CAM instructions are directly delivered to the machine which will realize the parts ordered (Scholten 2017). This is possible because they developed Sofia together with machinery manufacturers providing the resources owned by 247TailorSteel (Tedaldi and Miragliotta 2020).

Sculpteo

The company was founded in 2009 and it has been acquired by Basf (www.basf.com) in 2019. Sculpteo is specialized in providing Users with additive manufacturing services (i.e. design and production for several additive manufacturing technologies and materials available).

Sculpteo developed a web-based platform to provide Users with instant price and fast delivery times of parts desired. The User simply drags and drops 3D files (.stl or .obj files are suggested but others are allowed) in the window and configures the material and finishing options. It is possible to choose among three delivery options (i.e. "standard", "economic", "express") with different lead times (1-3, 7, 14 days).

Manufacturing resources are mainly represented by 20 3D printers owned by the company and distributed in 2 factories settled in San Francisco (USA) and Paris (France).

Fractory

Fractory is a startup providing manufacturing services for sheet metal fabrication (e.g. plasma, laser cutting) and CNC machining. It has been founded in 2017 in Estonia, moved in UK in 2019 and raised $ 0.35 million from investors.

As other companies, they have built a web-based platform equipped with an instant quoting engine providing quotes in real time to RFQs. From the User perspective, the operational flow is quite similar to the previous cases, as it requires CAD drawings, to specify the technology and the materials desired. Deliveries are not customizable but more than 100 different colours as coating options are available (e.g. matte or glossy).

Differently from the previous cases, Fractory does not own any manufacturing facility. It sells manufacturing services leveraging on a network of about 25 manufacturers distributed mainly in UK. The company simplifies the sourcing process as it answers almost instantly to Users RFQs, takes care about the production, as well as the shipping/delivery.

Once the order is received, the algorithm finds the most suitable suppliers (among the registered Fractory providers) and the production is entrusted to the one which can respect the delivery date promised to the customer. On the one hand, the process is highly automated to the User side of the platform, on the other hand the providers side relationships with resource providers is managed almost manually.

Xometry

Xometry is an American company founded in 2013 and headquartered in Geithersburg, Maryland (USA). It has attracted great attention of investors and raised a total of $ 197 million of funding received. Recently it has acquired Shift, (a German company which was working on the concept of "on-demand" manufacturing), and the European expansion has officially started. It offers CNC Machining, sheet metal processing (e.g. waterjet, laser, plasma cutting), injection moulding, 3D printing services, as well as other ones like urethane casting and finishing services.

The business model and operational flow are quite similar to those ones of Fractory. The company does not own any manufacturing asset but guarantees product quality of its suppliers through the use of employees which control parts before the final shipping to the customer.

On the one hand, Xometry can be compared to Fractory, on the other hand we observe Xometry capabilities, materials are more extended and the level of service customization is much higher (e.g. thread, part marking, inserts). Moreover, it allows to get different prices on the basis of the delivery options, which are three: "Expedite" (2 days), "Standard" (7 days) and "Economy" (12 days) but in some regions of US are available shipping in 1 day.

A network of more than 5.000 manufacturers guarantees to this platform a higher level of elasticity with respect to the other cases and, consequently, a higher flexibility to Users.

5. Cross-case analysis

In this chapter we refer to the characteristics of CM presented in Chapter 2 and - from a comparison of the cases we selected - we draw different levels of development for each one, considering max 4 levels (L1, L2, L3, L4).

Centralized Management

We identified 4 levels of centralized management.

L1. Resources are not managed by the Platform Operator. The Platform Operator just describes the Resource Providers in term of capabilities. The User finds the right Provider in less time, looking at the online "providers catalogue".

L2. The Platform Operator creates a marketplace where RFQs are published. Resource Providers can answer to them, connect to the Users and start a relationship.

L3. The Platform Operator directly answers to the RFQs while the Resource Provider loses the contact with the final User. When the Order is confirmed, the Platform Operator select the Resource Providers who would fulfil the order. The Resource Provider can accept/deny the allocation suggested by the Platform Operator and it does not lose the control of its own resources.

- L4. The Platform Operator turns the Order into tasks to be performed and unilaterally decides where to allocate them. Here, the Resource provider loses control of its own resources.

High information sharing

Information sharing between the platform and the other CM participants allow CM system to reach different level of automation of their processes:

L1. The Platform Operator is a traditional intermediary and just starts the relationship between customers and suppliers.

L2. The Platform is equipped with a repository of the RFQs. At this level, services are not requested by Users through standardized mechanisms, thus the response to the RFQ cannot be automated. Nevertheless, the platform centralizes the communication, supports the negotiation with web-based tools (e.g. chat tools, repository of drawings, customers categories);

L3. The services are requested through standardized mechanisms and read by the Platform Operator (e.g. drawing with specific file formats). The response to the RFQs is automated. Nevertheless, once the order is confirmed, the allocation of the tasks to the resources is managed by human interactions between the Platform Operator and the Resource Providers. This happens because the Platform Operator has no visibility on the availability of the resources (i.e. resources are not connected and virtualized).

L4. The information transactions are managed almost automatically. Resources are equipped with sensors which communicate data to the Platform Operator. The RFQs are requested through standardized mechanism and the response to the RFQs is automated by the Platform. Once the order is confirmed, the Platform automatically turns them into tasks to be performed by the resources and allocates them to the most suitable ones.

On-Demand

For this feature we can just specify whether a platform is immediately available to produce a service on request. Thus we have only two levels:

L1. No: the platform just offers a marketplace where RFQ are published at any time but delivery of services are not guaranteed by the Cloud Operator.

L4. Yes: the Platform is available at any time and Cloud Operators guarantees the delivery of the manufacturing services whenever requested.

Service-oriented

This characteristic is focused on the relationship customer-supplier and 4 different levels of flexibility are found:

L1. The relationship with suppliers is traditional;

L2. Fast response time to RFQs, highly customized product. Users cannot change the delivery date suggested. A limited set of materials and finishing services (e.g. coating, colours) are available;

L3. Like "L2" but 3-5 delivery options are available with different pricing (e.g. "Economy", "Express");

L4. The relationship with suppliers is new (e.g. highly customized product, flexible relationship). It allows to customize materials, lead times, finishing and selecting other services.

Resource Pooling

Here we specify whether the resources are pooled and we measure the level of distribution of the resources:

L1. Resources are not pooled and it is not present a network of physically distributed resources;

L2. Resources are pooled but owned by a single Provider which manage them;

L3. Resource are pooled and owned by a group of enterprises or a group of enterprises belonging to a parent company;

L4. Resources are pooled by a great number of enterprises and the platform is "open" to the Resource Provider side.

Ubiquitous and broad network access

Manufacturing ubiquity means the User easily access the manufacturing network and can receive the service wherever she/he is (i.e. this is related to the worldwide presence of manufacturing resources):

L1. The platform runs on standard devices (e.g. web-based applications running on laptops, tablets, smartphones). Resource providers are located in one country and Users from other countries feel the distance from the manufacturer (e.g. longer lead time);

L2. Broad network access as for "L1" but here services comes from an international network, even if still limited to 1 continent;

L3. As for L2 but Services comes from 2 continents; Users from worldwide can still suffer the distance from manufacturers of the network;

L4. As for L3 but "Ubiquitous manufacturing" here is a customer experience, because resources are dispersed in 3 or more continents (e.g. North America, Europe, Asia).

Dynamism, rapid elasticity and scalability

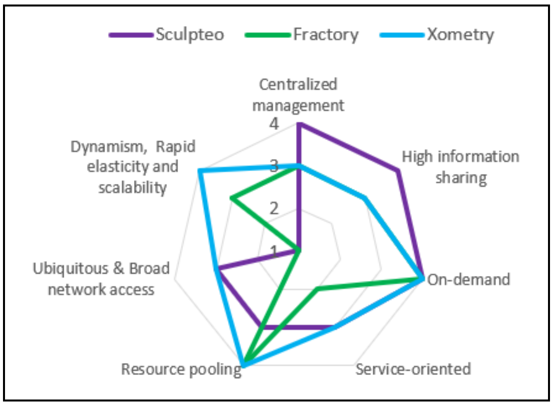
These characteristics depend on the amount of resources beyond the platform. From the cases analysed, we can identify 4 different levels:

L1. The system is static and works with a very limited capacity. This level refers to platforms leveraging on just a couple of production facilities.

L2. The Platform responds to demand variations leveraging on a limited number of pooled resources, at the expense of the speed of response to the change. Here we find platforms leveraging on less than 10 production sites;

L3. At this level the system better responds to demand variations because a wide network of resources, but less than 50, is available;

L4. A great amount of resources are available and resources appear to be unlimited to the user.



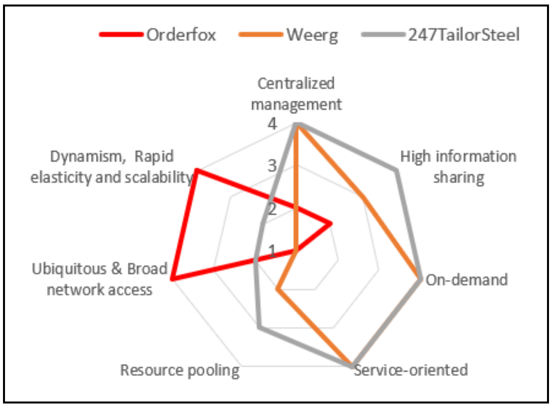


Figure 1: Cross-case analyses

After having proposed a framework to measure different development levels of CM platforms, we can visualize on a spider chart the differences between the cases analysed (Fig.1). Companies like Orderfox are further away from the realization of a CM system, while other seems to be closer but follow different approaches. 247TailorSteel aims to achieve full integration of IT systems and equipment while Xometry clearly aims at increasing the number of manufacturing providers as much as possible to guarantee full scalability.

6. Conclusion & Future Research

CM promises to give birth to Manufacturing-as-a-Service, a way to increase companies flexibility. The recent success of platform economy has pushed professionals to create platforms aiming to facilitate the procurement of mechanical parts with unprecedented benefits in term of flexibility. We think these platforms are – consciously or not - Early Adopters of CM and empirical evidences has been carried out in this paper.

This study firstly contributes to theory as it explores real cases of CM Early Adopters which help academics for future studies in this field. Secondly, the framework we propose derives from the empirical cases and shows that the approach to the paradigm can vary significantly from one case to another. From a managerial perspective, we show to manufacturers that MaaS is arising; Cloud Operators in this field could use this framework to evaluate themselves with reference to other players.

With regard to future research, it should be interesting to enlarge the empirical base of our results and to discover whether - on the way to CM implementation - multiple development paths are possible to follow for those companies aiming at realizing a full CM system.

References

Adamson, G., L. Wang, M. Holm, and P. Moore. 2017. "Cloud Manuf.–a Critical Review of Recent Development and Future Trends." *Int. J. of Computer Integrated Manuf.* 30 (4–5): 347–80.

Ardolino, Marco, Nicola Saccani, and Marco Perona. 2016. "The Rise of Plat. Economy: A Framework to Describe Multisided Plat.." *Proc. of the Summer School F. Turco* 13-15-September-2016: 257–61.

Baines, T. S., H. W. Lightfoot, S. Evans, A. Neely, R. Greenough, J. Peppard, R. Roy, et al. 2007. "State-of-the-Art in Product-Service Systems." *J. of Eng. Manufacture* 221 (10): 1543–52.

Broberg, James, Srikumar Venugopal, and Rajkumar Buyya. 2008. "Market-Oriented Grids and Utility Computing: The State-of-the-Art and Future Directions." *J. of Grid Computing* 6 (3): 255–76.

Clark, Henry, and Bruce McMillin. 1992. "DAWGS—A Distributed Compute Server Utilizing Idle Workstations." *J. of Parallel and Distributed Computing* 14 (2): 175–86.

Eisenmann, Thomas, Geoffrey Parker, and M. W. Van Alstyne. 2008. "Opening Plat.: How, When, Why?"

Eisenmann, Thomas, Geoffrey Parker, and Marshall W. Van Alstyne. 2006. "Strategies for Two-Sided Markets." *Harvard Business Review* 84 (10).

Ferdows, Kasra, and Arnoud De Meyer. 1990. "Lasting Improvements in Manuf. Performance: In Search of a New Theory." *J. of Operations Mgmt* 9 (2): 168–84.

Foster, Ian. 2002. "What Is the Grid? A Three Point Checklist." ThreePoint-Check. Pdf. 2002.

Foster, Ian, J. Geisler, C. Kesselman, and S. Tuecke. 1997. "Managing Multiple Communication Methods in High-Performance Networked Computing Systems." *J. of Parallel and Distributed Computing* 40 (1): 35–48.

Foster, Ian, and Carl Kesselman. 2003. *The Grid: Blueprint for a New Computing Infrastructure. San Francisco. Morgan Kaufmann Publishers, C1999.*

Foster, Ian, Carl Kesselman, and Steven Tuecke. 2001. "The Anatomy of the Grid." *Int. J. of Supercomputer Applications* 15 (3): 200–222.

Foster, Ian, Yong Zhao, Ioan Raicu, and Shiyong Lu. 2008. "Cloud Computing and Grid Computing 360-Degree Compared." In *Grid Computing Environments Workshop, GCE*. IEEE.

Gerwin, Donald. 1993. "Manuf. Flexibility: A Strategic Perspective." *Mgmt Science* 39 (4): 395–410.

Glaser, Barney G, and Anselm L. Strauss. 1967. *The Discovery of Grounded Theory: Strategies for Qualitative Research*. Aldine Transaction.

Goldhar, J.D., and M. Jelinek. 1990. "Manuf. as a Service Business: CIM in the 21st Century." *Comp. in Industry* 14 (1–3): 225–45.

Gunasekaran, A. 1998. "Agile Manuf.: Enablers and an Implementation Framework." *Int. J. of Prod. Research* 36 (5): 1223–47.

Henzel, Robert, and Georg Herzwurm. 2018. "Cloud Manuf.: A State-of-the-Art Survey of Current Issues." In *Procedia CIRP*, 72:947–52. Elsevier B.V.

Huang, B., C. Li, C. Yin, and X. Zhao. 2013. "Cloud Manuf. Service Plat. for Small- and Medium-Sized Enterprises." *Int. J. of Adv. Manuf. Tech.* 65 (9–12): 1261–72.

Kenney, M., and J. Zysman. 2016. "The Rise of the Plat. Economy." *Issues in Science and Tech.* 32 (3): 61–69.

Leita, Paulo. 2009. "Eng. Applications of Artificial Intelligence Agent-Based Distributed Manuf. Control : A State-of-the-Art Survey" 22: 979–91.

Li, B.-H., L. Zhang, S.-L. Wang, F. Tao, J.-W. Cao, X.-D. Jiang, X. Song, and X.-D. Chai. 2010. "Cloud Manuf.: A New Service-Oriented Networked Manuf. Model." *CIM Systems,* 16 (1).

Liu, Y., L. Wang, X.V. Wang, X. Xu, and P. Jiang. 2019. "Cloud Manuf.: Key Issues and Future Perspectives." *Int. J. of CIM* 32 (9): 858–74.

Lu, Yuqian, and Xun Xu. 2019. "Cloud-Based Manuf. Equipment and Big Data Analytics to Enable on-Demand Manuf. Services." *Robotics and CIM.* 57: 92–102.

Mell, Peter, and Timothy Grance. 2011. "The NIST Definition of Cloud Computing Recommendations of the National Institute of Standards and Tech.." *Nist Special Publication* 145: 7.

Moriwaki, T., U. Heisel, G. Pritschow, H. Van Brussel, F. Jovane, Y. Koren, and G. Ulsoy. 1999. "Reconfigurable Manuf. Systems." *CIRP Annals - Manuf. Tech.* 48 (2): 527–40.

Naim, Mohamed M., Andrew T. Potter, Robert J. Mason, and Nicola Bateman. 2006. "The Role of Transport Flexibility in Logistics Provision." *The Int. J. of Logistics Mgmt* 17 (3): 297–311.

Rajan, Sameer. 2011. "Cloud Computing : The Fifth Generation of Computing."

Rochet, Jean-Charles, and Jean Tirole. 2003. "Plat. Competition in Two-Sided Markets." *J. of the European Economic Association* 1 (4): 990–1029.

Scholten, Chiel. 2017. "Industrial Internet of Things: Digitisation, Value Networks and Changes in Work." http://www.technopolis-group.com/wp-content/uploads/2018/08/wpfomeef18006.pdf.

Tedaldi, G., and G. Miragliotta. 2020. "The Role of ETO Machinery Manufacturers in Future Cloud Manuf. Supply Chains: A Business Case and a Strategic Perspective." *Prod. Plan. and Control* (online).

Vandermerwe, Sandra, and Juan Rada. 1988. "Servitization of Business: Adding Value by Adding Services." *European Mgmt J.* 6 (4): 314–24.

Wu, D., M.J. Greer, D.W. Rosen, and D. Schaefer. 2013. "Cloud Manuf.: Strategic Vision and State-of-the-Art." *J. of Manuf. Systems* 32 (4): 564–79.

Wu, D., D.W. Rosen, L. Wang, and D. Schaefera. 2014. "Cloud-Based Manuf.: Old Wine in New Bottles?" In *Procedia CIRP*, 17:94–99.

Xu, Xun. 2012. "From Cloud Computing to Cloud Manuf.." *Robotics and CIM.* 28 (1): 75–86.

Yin, Robert K. 2003. *Case Study Research: Design and Methods*. Ed. by Thousand Oaks. SAGE.