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Cloud Manufacturing: From a Concept to a Way for Being Lean

A. Hassanzadeh[1*], S. M. Razavi[2], A. Mohaghar[2], M. Houshmand[3], H. Safari[2]

[1]Department of Operations and Production Management, University of Tehran, Tehran, Iran.
[2]Department of Industrial Management, University of Tehran, Tehran, Iran.
[3]Department of Industrial Engineering, Sharif University of Technology, Tehran, Iran.

A B S T R A C T

Today, a production enterprise cannot survive without using computer-based machines. Nevertheless, not all enterprises have enough money to invest in such manufacturing resources. On the other hand, handling the resource or providing appropriate platform is not easy at all. For companies, Cloud-based strategies give them a chance to bring their inherent knowledge and intelligence to every business case and cause a quick response by reducing the cost of investment. Manufacturers know that providing capacity, according to demand will increase the profit and help them to get new work contracts. In the recent century, intelligent manufacturing would be the one in which all information is available in the most useful way, right where and when that it is needed to hold an optimum operation or response such as cloud manufacturing. This paper aims to provide a framework for how using cloud services emerge at obtaining lean concepts in the manufacturing companies. The research has conducted through semi-structured interviews among professionals in Cloud-based environments and production systems. Key managers or employees from different levels have selected. Analyzing interview transcripts using a constructivist approach to grounded theory is supposed to result in a model for how to develop cloud service models according to the lean concepts, especially in manufacturing frameworks.

Keywords: Cloud manufacturing, Lean principles, Manufacturing system, Grounded theory, Manufacturing resources.

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1. Introduction

With the emergence of a business era that constant change is its critical feature, the production success has become more difficult than the past. The key point is the ability for adaptation to

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* Corresponding author
E-mail address: a.hassanzade@ut.ac.ir
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change in the business environment and pursuing the customers' needs continuously and proactively. This change in business filed causes uncertainty in decision parameters. Therefore, being flexible in the supply chain is necessary; a flexible supply chain will adapt to changes. As Dowlatshahi and Cao [7] said, The Global competition caused evolutions, characterized by an increase in products with shorter and insecure life cycles, innovative technologies and processes and customers who expect to faster respond, lower costs and bigger customization simultaneously. The companies should effectively focus on the continuum and secure changes to be able to survive in this competitive environment. The ability to fast and effectively respond and comply with customers' needs has become the competing characteristic of manufacturing companies. Mass production apart from improvements made by just-in-time strategies and lean manufacturing necessarily is a system suitable for large-scale and hierarchical enterprise structures.

Findings show that the needs and challenges of data integration in Small-Medium sized Enterprises (SMEs) have a close relationship with the limitations of current solutions of the supply chain. Current ERP (Enterprise Resource Planning) solutions lack the wide corporate support and the shared approach based on the cloud. On the other hand, current administration system solutions could not perform distributed manufacturing processes. As a response to these requirements, a presentable offer is the next-generation architecture of administration solution for production [12]. As Song et al. [27] expressed, in recent decades, several professionals and academics such as companies globally spent considerable time on exploring and studying how to solve the problem of capital, technology, human, and equipment loss for SMEs to be able to improve their competitive power and find new markets. In this period by development of Information Technology and Internet of Things (IoT), the cloud manufacturing has emerged.

2. Literature Review

Similar to design systems, because of changing demand and emerged technologies, manufacturing systems have passed great transitions. In this section, we review similar studies in the scope of manufacturing systems. Every research has focused on a special aspect (lean or cloud). Some others tried to combine different approaches by extracting essential factors and at the same time relate these measures. In the following paragraphs, the evolution process of manufacturing systems from assembly lines to cloud manufacturing is discussed.

As Alizon et al. [2] states, Henry Ford, for example, constructed the first assembly line. Producing became more efficient and cost-effective. In the 1960s, the Toyota Manufacturing System (TPS), also known as Just-in-Time manufacturing system, had been innovated. This manufacturing system has several principles that help to eliminate waste besides reducing lead-time, inventory, and damaged goods. As Powell et al. [24] described, Lean manufacturing is referred to a combination of relevant methodologies seeking to make manufacturing processes simple and effective. Ideally, lean is "providing the exact thing that (internal\external) customers need to achieve their goals without any waste".

The alternative option for an intensive factory with mass production is the transition to a decentralized model. Management and human resource systems have changed to survive in global competition. Last developments in communication technologies have emerged team based managerial methods such as JIT and FMS. In the 1980s, to offer new types of products, the Flexible Manufacturing Systems (FMS) were developed that enabled the high operational flexibility. Especially, the main benefit of a manufacturing system is enabling change in pieces and assembly methods, although is expensive to apply [11, 15].

As Matt et al. [22] mentioned the Centralized-manufacturing structures present important cost advantages in the form of economies of scale and are less complicated than the decentralized network manufacturing plants. Nevertheless, there are strong reasons for developing the geographically distributed manufacturing structures. Certain industries have to construct their manufacturing facilities close to consumption location to benefit of a centralized production (capital advantage, the effect of scale). For rapid adaption of capacity as well as operational performance among components in response to sudden changes in the market or regulatory requirements, the Reconfigurable Manufacturing Systems (RMS) are designed for changes in structure, also in hardware/software components [34]. In this model, the manufacturing lines are modular, so single line produces different goods without any dedicated space for a special line. This modular approach makes it possible to move among products, so downtime is lower. The combination of reconfigurable manufacturing and design smooth the way for mass individualization and modular open-architecture and customer based products [15]. By the increase of markets and decrease of transportation and logistics costs as well as reduction of interaction costs by means of World Wide Web in the early 1990s, The Europe faced a globalization wave. With the growth of international trade and increment of the global need for products, companies presented the new foreign markets all over the world. Hence, it inevitably caused a high competition among foreign companies and global actors from countries with low cost and small expenditure structures. To respond to this need and certainty of competitiveness, many of firms followed the goal of distributed manufacturing structures by the transition of internal manufacturing capacity to external companies. As Matt et al. [22] mentioned, the driver for this change was the more and more important market, customer proximity and on the other side, meeting local requirements such as local factors, i.e. low labor cost.

One type of distributed manufacturing is Cloud Manufacturing (CM). The manufacturing can be as a service. Using a command embedded URL, the user can request a production operation in a special geographical place. For this system, the facilities like server farms can be located remotely [15]. This kind of manufacturing that in fact means a collective manufacturing in production labs is flexible and performed geographically by distributed manufacturing laboratories to produce different products with manufacturing processes by means of CAD data and transferred digitally from the cloud [22]. In this field of study, some researchers tried to incorporate manufacturing systems to gain better results. For example, Agarwal et al. [1] modeled criteria for lean, agile and lean-agile supply chains. They derived some criteria and concepts related to lean and agile production in the supply chain.

Among other manufacturing systems, cloud manufacturing is rather a new concept. Zhang et al. [38] introduced the manufacturing capability/resources and shared through a cloud. They stated that the specialized and customized demand could be better served at this cloud because of nature of flexible and fast accountability. Villegas et al. [31] presented a coalition among independent clouds to leverage suppliers. They studied the layer models for offering services in order to define cloud coalition based on service-oriented architecture. They believe the layered architecture leads naturally to design in which inter-cloud federation takes place at each service layer and mediated by a broker specific to the concerns of the parties at the layer. Therefore, the federation increases customer value. Xu [37] in a study presented a complete concept of cloud manufacturing based on service layers. He described the similarities and differences between cloud computing and cloud manufacturing. Wang and Xu [32] presented a full representation of architecture and performance in cloud manufacturing and finally, by using a case study, they explored integration capability of cloud manufacturing services and optimizing it from the cost perspective. They said the cloud technology brings into manufacturing industry with a number of benefits such as openness, cost efficiency, resource sharing, and production scalability. The results were quantified by OR techniques. Multi-agent is an effective tool in solving problems through sharing knowledge during the implementation of cloud manufacturing. Ferreira et al. [10] proposed a cloud-based architecture for generating dashboards and reports in cloud manufacturing setting aiming to design a managerial and supervisory software. The focus is on management information system solutions, mobile and, GIS integration. Valilai and Houshmand [8] presented a manufacturing platform based on cloud computing paradigm. In addition to developing an integrated platform called LAYMOD, a service-oriented approach for distributing the production agents is offered; they emphasized on STEP 10303.

Verl et al. [30] claimed that a cloud-based provision of control technology for machine tools eliminates the disadvantages of current integrated controls in the service area. The control Job can be centrally maintained and administered by a qualified staff. The idea of cloud manufacturing has already raised expectations to a visionary value concept. In future, the industrial production can be changed in midterm and long-term not only by wider use of 3D printers and not being necessary to sell physical products but also just product data [22].

Nowadays, the manufacturing companies try to adopt cost-efficient manufacturing systems. Reviewing recent firms show that the global manufacturing companies distribute their production abilities all over the world. The success of these companies depends on the global full integration of their product development processes and operations they perform around the world. Cooperation of distributed manufacturing agents and integration of production data play an important role in success of manufacturing companies [9].

Traditional manufacturing is obsolete and the dynamic and global model of business has changed its processes by integrating them into a global chain of resources and stakeholders. Agility, rapid reaction to market changes and proactivity, availability, and high capacity for effective response to requirements are some main principles of competitiveness and survival. Traditional manufacturing systems are built on economies of scale principles. So, the big fixed costs related to manufacturing due to huge capital investment in operation with high capacity is extremely depreciable. TPS manufacturing system principles use led to lean production which also called lean thinking. In this way of thinking, the manufacturing and assembly cells including concentrated product resources (worker, machine, shop floor, etc.) planned according to operation periods and inventory control. Economic benefits related to lean production consist of the reduction of lead-time, elimination of waste, more products, high-quality output, flexible operation, fewer middle processes, lower space requirements, and finally less cost of production unit [28].

3. Cloud Manufacturing

Today's competitive global market has changed the way that many of design and manufacturing companies work. The pressure of globalization has linked people and firms from around the world, which enables them to share data, information, and knowledge in a collective manner [32].

The main characteristics of a Cloud-Based system which makes it different from the others is presenting everything you may need as a service [10, 11, and 12]. The service is flexible, based on demand and presented on a network, provides a resource sharing opportunity for business to set information technology as a new partner for innovation [37].

Collaborative teams provide professional knowledge in the cloud that shapes the knowledge base referred by users through the internet.

Manufacturers face several important requirements that could be satisfied by cloud systems:

- Cost and production productivity: Scarce resources scaling while solving problems faster.
- Growth and innovation: Bringing new ideas to market faster than competitors.
- Customer's experiences: Providing new services for supporting customer service.
- Risk management: Keeping intellectual property and reducing global breaks in the supply chain.
- Green goals: Increasing requests for reducing energy usage and environmental effects.

The term "service" in cloud is a concept of usability good and reusable components through seller network. Offering "as a service" consists of features including:

- There are fewer barriers to enter and can be provided easily for small businesses.
- Large scalability.

- Multiple rents that allow many users to share resources.
- Device independence that allows users to access systems on different hardware.

A manufacturing system could be seen as an arrangement and operation of manufacturing tools, material, people or information for the production of physical value-added products, information or services [14]. Similar to the ICT industry, design and production have also been changed by the transition of the increasing amount of manufacturing operation to a cloud and led to the evolution of cooperative, distributed, and traditional web-based manufacturing/design to cloud-based manufacturing/design. Gradually, a global chain of resources and stakeholders becomes the alternative of traditional production industry; furthermore, a worldwide and dynamic business model emerges. Cloud manufacturing is established as a solution to address all these changes [26].

Development of cloud manufacturing is an advancement from the single adoption of cloud computing capabilities and operations to the adoption of all manufacturing resources as a service. In this scope, involving procedures in all manufacturing processes, from product/machining design parameters to equipment maintenance could be obtained by cloud-based services [11].

Decentralizing manufacturing makes the network flexible. If the existing factory is closed or not able to respond to needs, the essential components are ordered to small local manufacturing plants. In future, most of the business successes can be gained by combinatory technologies using inter-process platforms in that industry. By using JIT, it makes the production lines leaner for making parts as soon as they are needed instead of ordering or storing separately [15].

Customers can use cloud services according to their need. Cloud users can request services rating from design, manufacturing, test, management, and all other stages of a product lifecycle. Cloud manufacturing service platform performs searching, intelligent mapping, advice, and running a service. With spreading the concept of service to a wider domain, all manufacturing objects and features can be treated as service; so everything as a service emerges.

In global manufacturing networks, computing and internet-based technologies like cloud computing have the ability to respond to new challenges. This development leads to the flexible use of manufacturing resources with global, scalable, and service oriented distribution. Resource, knowledge and information sharing through geographically distributed manufacturing entities would increase cost-effectiveness and better utilization of their resources. The success of many manufacturing companies depends on the distribution of their production capacity throughout the world [11].

In some cases, instead of cloud manufacturing, the phrase "Cloud-Based Design and Manufacturing (CBDM)" is used which refers to a product diagnosis model in which group innovation and rapid product development are available with minimum cost through web-based networks and negotiation platform between a service provider and customers. In fact, it is a parallel and distributed system including a collection of physical and virtual interconnected design and manufacturing services as well as intelligent searching capabilities for design and manufacturing solutions [35, 36].

In cloud manufacturing systems, the different manufacturing resources can be diagnosed intelligently and connected in a wide internet by the help of various technologies (such as RFID, wired/wireless sensor networks, and embedded systems). Afterwards, construction resources and capabilities are virtualized and capsulated to several manufacturing clouds that can be accessed, requested and deployed according to knowledge by virtualization technologies and service-oriented technologies as well as cloud computing. Different users can search and request resources from manufacturing cloud according to their need and connect them to their virtual manufacturing environment or solution to fulfill their production task, in which case the lifecycle of whole manufacturing processes are under the support of cloud computing, service-oriented technologies, and computing technologies. After modeling manufacturing actions, the next step is the integration of their operational processes. Cloud manufacturing is not just using cloud computing in production. It is necessary to manufacturing organization and related resource/capability be described, divided, virtualized, and be integrated into a manufacturing cloud [18].

The structure of the system consists of a storage cloud that manages a manufacturing data model. Data model reserves information based on workload and facility model. An agent for versioning supports the storage cloud. This agent checks the changes in the inventory history of material bill structure and prevents disparity in logged data. This environment enables maintenance, synchronization and version control among users and the multiple companies potentially sharing manufacturing resources. Finally, schedule and performance indicators are available [23].

In cloud manufacturing systems, the key objective is relating users to resource suppliers who could provide their needs with acceptable cost, schedule, and quality. Cloud manufacturing platform compromises these features:

- Every resource and task belongs to an unknown entity.
- In cloud manufacturing system, manufacturing resources are changeable. The platform can increase or decrease the resources dynamically and instantly according to cloud users' requirements.
- For cloud user not only there is no concern about the reliability of entities and resources, but also it is attractive that resource supplier can offer manufacturing capabilities with high trustworthiness and successful task accomplishment [17].

According to Xu [37], the cloud manufacturing layers include:

- Application layer: It acts as an interface between users and system. For service providers, application layer provides a customized interface for management of manufacturing resource. The information about service history, resource workload, market forecast, and proposals for service improvement and customer feedback is transmitted to the service provider [18]. This layer is responsible for connecting user and cloud manufacturing resources; the user can define and produce a new product by the help of virtual resources [32].

- Global service layer: This layer is related to agent's requirements in cloud computing model. It is equivalent to the platform as a service and formed based on these platforms. Offering agile and dynamic cloud services to agents by cloud service is the most important thing all agents want and it has to be considered in designing this layer. Accordingly, two kinds of action can be offered by cloud services: Full service and local service situations. In the former, the global service layer is responsible for all operational activities of the cloud. These services may be monitored dynamically and managed how they are assigned. They are also able to balance themselves simply with their congener components according to requests load. Global service layer has the responsibility for location, assignment, costing, and remote monitoring of resources. These all need enough knowledge about optimization. This layer should process requests for service as well as managing capsulated services.
- Virtual service layer: In service provider domain of the cloud manufacturing, there are virtual service layer and manufacturing resource layer. Virtual service layer is responsible for an affair like manufacturing resource detection, virtualizing, and grouping them as cloud service package [33].

Manufacturing resources consist of material and non-material resources, including equipment, machines, tools, intelligent assets, and etc. From the perspective of resources, every manufacturing capability requires supporting from related manufacturing resource that is in two types of soft and hard resources [13].

Xu [37] applied two important concepts to describe cloud manufacturing: "integration of distributed resources" and "distribution of integrated resources". Suppliers release their resources into this cloud manufacturing platform and then distributed resources are capsulated to cloud services and managed in a focused approach. Consumers use cloud services according to their requirements. They can request services rating from product design to production, test, management, and other steps of a product lifecycle. As the system includes groups of devices such as robots, CNCs, sensors, and so on, keeping operation at high performance is a tough work. Ren et al. [26] classified cloud services in two types: Services running completely on the cloud and out-of-cloud services, which need additional operation by an operator through the cloud platform.

High-performance services need effective resource and appropriate methodology for applying them. Manufacturing capability facing the need of the cloud user can be provided by a single service provider or a collection of them. In the transformation from the current manufacturing state to cloud manufacturing, the manufacturing capabilities and resources should be integrated and applied in a cloud manufacturing context [32].

According to cloud manufacturing idea, the platform of cloud manufacturing services for SMEs depend on IOT[1] and information technology to promote combination and conversion of manufacturing and services; the social resource integration in manufacturing processes and the improvement of resource utilization like decrease of resource consumption is checked to provide new way for companies to guide them from manufacturing type to service type.

When accessing to the platform for the first time, corporate users should write in their information for enrollment. At the same time, their primary validity would be assessed according to registration information. If enrollment is successful, users will be able to login to platform by importing username and password accordingly. The First thing corporates users should do after logging successfully is presenting service resource information (supply side) or demand information (demand-side) and then can customize their related manufacturing processes through the management tools of the business process.

Demand-side searches service resources through intelligent adaption motor for supply and demand to find supplier companies in accordance with service capability, reasonable rate, easy transfer, and higher validity. The Demand side registers orders in platform system and signs the contracts with the supply side offline. Then, the platform system accepts these orders and sends them to the motor of transaction coordination logic to implement. Logic motor tracks and manages the coordination of orders transaction and then guides both sides for the accomplishment of the whole process including online payment, procedure feedback, delivery, and reception. Corporate users can log in to check transaction process and order status or to deal with incomplete orders in real time [25]. Intelligent manufacturing in this century is a manufacturing system in which all information is available when and where needed and in the most useful type to lead the operation and optimum response [16].

Features of this manufacturing system offer companies the flexibility to manage their business. By cloud approach, there is no need for costly investment in purchasing manufacturing equipment, maintaining production line, and even hiring professional engineers. Instead, they can have quick access to the most efficient and innovative business technology solutions based on pay as use model, so, cloud use can make business agile. Especially in SMEs, the transition to cloud leads monetary and intellectual capital to focus on innovation and technology instead of buying or maintaining expensive resources [18]. Agile producers know that providing capacity based on demand can increase profit and help them to get new contracts. Cloud platform brings virtualization and automation power to the whole supply chain. Manufacturers can dynamically add new resources to a certain project without the need to additional investment on hardware or human resource [29].

[1] Internet of Things

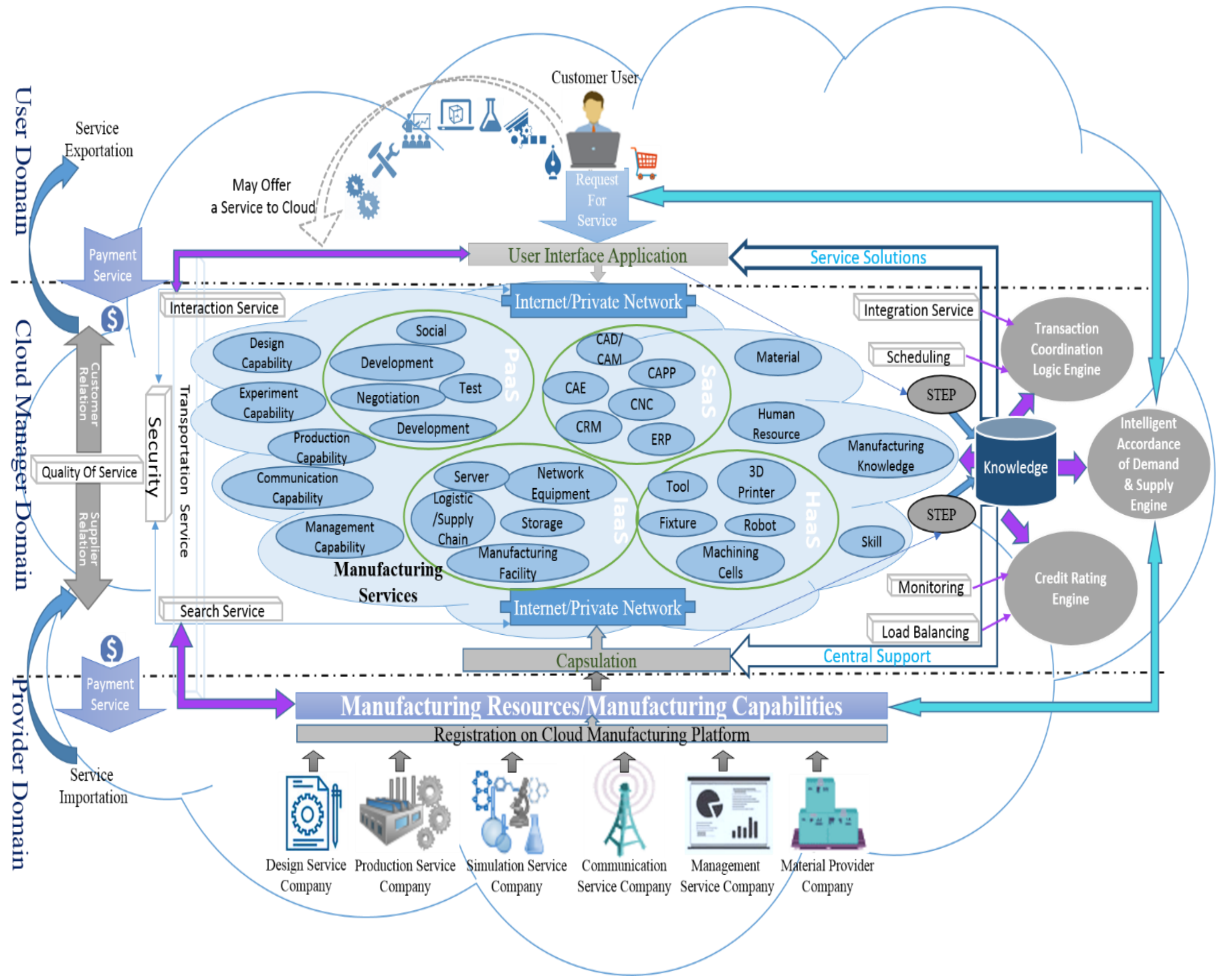

Figure 1. Cloud Manufacturing.

As Lutz et al. [19] said, in modern manufacturing systems, information technology has a strong relation with operational performance of the production. To provide reliable service, IT departments should have appropriate IT infrastructure to support industrial actions now and in the future. Advanced manufacturing depends on acquiring, disseminating and using on time information about machines and processes over local limitations. These activities can enhance the accuracy and reliability to forecast resource requirements and assignments, maintenance and scheduling, and preserve the lifetime of the equipment. These are all reasons why Gao et al. [11] claim that using cloud platforms provides new opportunities for gaining advanced manufacturing goals.

Industrial producers try to achieve the lean philosophy but find it difficult. Most of them withdraw with a sketchy understanding of this system and fail to implement a part of system pulled out of its original context. Lean production is not only a series of techniques and principles but also a new vision for manufacturing. The real lean move is about learning and experiencing, not just a collection of projects.

The strategy of lean production in an organization insists on efficiency increase and quality improvement by eliminating no value-added activities. To survive in today's competitive market, the most important challenge is providing products with maximum quality and minimum cost. The lean approach can be used for appraisal of a company's success level in implementing lean culture compared with other similar organizations. On the other hand, migrating to the world of lean in short term is risky [3].

Utilizing lean production includes important organizational changes requiring the organization to manage key factors which may influence the success of applying. Lean production is a management system focused on the elimination of every kind of waste. So. The main goal of this system is attaining maximum efficiency by performing at minimum cost and zero waste [20]. In the other word, lean is the elimination of everything adding no value to product or service. Although this group of actions may exist, in all areas, most of the models refer to manufacturing activities. The reason is that industrial companies usually eliminate waste activities in manufacturing area first. Another feature of lean is continuous improvement of products and process. Multi-functional teams are the other feature that insists on training and capital facilities to make teams work better.

Introducing and applying lean principles during last twenty years have strongly influenced so many companies. Experiences show that methods and tools are not applicable for big and small companies evenly. To reduce waste, improve quality, satisfy customers, and so on, we certainly need good design, fluent manufacturing, better assembly lines, experienced workforce, quality control knowledge, and facilities. Implementing lean concepts in manufacturing companies often needs huge investment in equipment and qualified staff. Most of the fear about implementation lean production is because it is costly and time-consuming. In comparison to big enterprises, small firms have fewer resources and usually less access to capital, which leads to lower level of utilizing cost sensitive packages. Matt and Rauch [21] Claim that SMEs using lean production mostly benefit from competitiveness improvement caused by innovation and faster production, flexibility increase, and cost reduction. However, it is not easy, especially for SMEs to reach leanness. SMEs can utilize cloud-based services since the services provide usability of software and solutions, which could be so complicated or expensive or designed for most of organizations. Gao et al. [11] enumerate advantages of the cloud platform for companies. Pay per use model with low cost of use and maintenance eliminate the economic limitations such as huge investments in IT systems and manufacturing equipment that are rarely used and rapidly depreciated. The philosophy of JIT shows delivery of every part on accurate quantity and in the exact time. In this way, an important factor is the integration degree between the plan of suppliers and manufacturers. To achieve this degree of flexibility, important changes are needed and as mentioned before, the cloud brings all these changes rapidly and with cost efficiency. Castro et al. [4] studied the benefits of Web 3.0 for manufacturing virtual companies. The main goal is applying communication technologies and social media in developing manufacturing processes of SMEs.

4. Research Methodology

This research has conducted through semi-structured interviews. The data are analyzed through discourse analysis and a constructivist approach is applied to interpret the data and to generate a grounded theory describing how cloud services should be presented to get close to the lean system. To validate this performance, a criterion for the interviewees' selection is the practical experience in presenting production or cloud-based services or being decision references for cloud regulatory in Iran.

For each company/organization, a key manager associated with cloud has identified. These individuals have contacted, interviewed, and asked to provide the name of one person who had been involved in presenting cloud services. Through this process, one to three individuals per company/organization have identified. The process of the sampling and interviewing with the new ones continues until no more concepts or code extracts; overall, 22 persons participated in the study. Interviews with these people have conducted between September 2016 and March 2017. Among the interviewees, five are professors of industrial engineering/management familiar with new manufacturing systems, five are industrial factory managers/experts, ten are consultant or managers of cloud service companies and two are managers of the Information Technology organization.

Two semi-structured interview guides have developed: One for the participants who had been involved in cloud-based services; the other for the participants involved in manufacturing projects. Consistent with a qualitative methodology, interview questioning during later rounds of interviews changed as new data emerged [6]. Selection of the companies and research study participants was through a snowball sampling technique. Professional contacts provided access to the first study participants. Those participants are then able to provide access to other cloud or lean development teams and companies. Early phases of the study focuses on university professors specialized in lean concepts to extract the main perspectives of a lean production system and then, how these aspects can match up with cloud manufacturing models. The Combination of various participant sampling provides insights into both aspects of the study, lean frameworks and cloud services.

Face-to-face recorded interviews have conducted with 22 practitioner interviewees and these recordings have transcribed. An open-ended semi-structured interview approach has adopted which gives respondents the opportunity to raise any topics, issues, and concerns outside the scope of interview questions. Probing questions have used to elicit more detail about topics raised by interviewees. This approach generates detailed descriptions from each participant and enables integration of the varying interviewee perspectives. The audio interviews and associated written transcripts have carefully reviewed to ensure consistency. The transcript text has imported into a qualitative data analysis software tool, ATLAS. ti.

The analysis has begun with the identification of concepts within the data. Grounded theory is an analytical process for discovering theory through the analysis of data. The new theories arise from the data being analyzed and are thus grounded in that data. The interview concepts have coded and then compared within and between interviewees. These interview concepts have then iteratively grouped and refined into selected categories. The categories become saturated as data collection progresses and this process forms the basis of the grounded theory. Two independent coders have used at the beginning and middle stages of coding to provide verification and reliability for the codes being used [5].

5. Results

This section describes the evolution of the framework extracted from several coding steps. The interviews were analyzed on a line-by-line basis using open coding. Some of the interviewees, who were in the cloud service sector, propounded a need for increasing the efficiency of the Cloud. For instance, a part of the discourse was as:

[. . .] the trust management system is necessary for the cloud.

[. . .] the security can be defined as a spectrum according to what extent the customer tends to pay in this scope.

The others who were in the manufacturing sector, expressed the capital issues associated with small-medium sized companies that want to be lean:

[. . .] the cloud use is a technological solution to overcome the lack of capital issues in small-medium sized enterprises.

[. . .] receiving customers' ideas and comments can improve processes.

Open coding was conducted on a sentence-by-sentence basis of the interview transcripts. Short descriptive phrases were used as codes, such as “uncertainty about business scope”, “integrated product design”, and “elimination of waste”. Constant comparison was used to refine and sharpen the categories emerging from data in this research.

Over 280 key sentences generated sixty concept labels, which were then collapsed into 16 major categories, each one presents a perspective of presenting cloud-based manufacturing services (see Table I).

Table 1. Major categories and lower level concepts.

Major categories	Lower level concepts
Cloud framework role players	The Government, Macro policymaking, regulatory, business owners, owner of an idea
Cloud manufacturing existence reason	Uncertainty about business scope, indistinctive demand level, machinery and labor idle time, Maintenance and control costs, resource buying cost, loss of capital
Cloud manufacturing benefits	Decrease infrastructure cost, Continuous improvement, process betterment, decrease cost and trouble associated with Maintenance and control, setup cost reduction, work station design according to tasks, pull manufacturing system, Just in Time(JIT), custom product manufacturing
Cloud manufacturing service levels	General service, professional service
Service improvement factors in Cloud manufacturing	Demand management, Supplementary technologies, free flow of information in the cloud, standard
Cloud manufacturing selection factors	Calculation of RIO, NPV, TCO, Brand, demand accordance with presented service, service flexibility, professional service
Cloud manufacturing development	Conceit elimination, price difference, increase of social capital, determination of service level agreement (SLA) , public training, culture
Cloud manufacturing obstacles	Traditional work force, loss of the technical workforce, loss of infrastructure, privacy resistance, policy limitations
Trusting in cloud	Quality, security, trust
Service cost	Cloud licensing models, discount in general service, Billing, intelligent system
Communication portal characteristics	Customizable, forum, critics and suggestions, opinion survey, Ticketing, online dashboards
Cloud manufacturing business model	Cost reduction, efficiency improvement, elimination of waste, making value flow, elimination of the process with no value added, scalability, demand matching service, service measurability, Production without a factory
Presentable resources in Cloud manufacturing	Material as a Service, Manufacturing Equipment as a Service, Business Process as a Service, Finished Product as a Service, Logistics as a Service, Skill as a Service, Business Council as a Service, Market Growth Center as a Service, Idea as a Service
Characteristics of a lean cloud manufacturing systems	Cloud management, optimization, technology infrastructure, the software platform
Attaining lean goals through Cloud	Integrated product design, lean organization, lean workflow, just in time delivery, demand meet in supply chain, lean technology, standard piece and template, integration of information with suppliers, lean administration
Making a manufacturing cloud lean	Making platform, according to demand, determination of standards by the cloud, commitment to service request time, demand liquidity management, logistic as a service, reconfiguration instead of customization, multitask agents, Cloud service provider and Customer at the same time, visibility of supplier inventory for cloud manager, not storing resources by cloud, assignment management by the cloud manager through overbooking, resource aggregation by cloud

By continuing the coding process through axial coding and then selective coding, this research raises four sectors for the Lean-cloud framework in manufacturing systems as shown below.

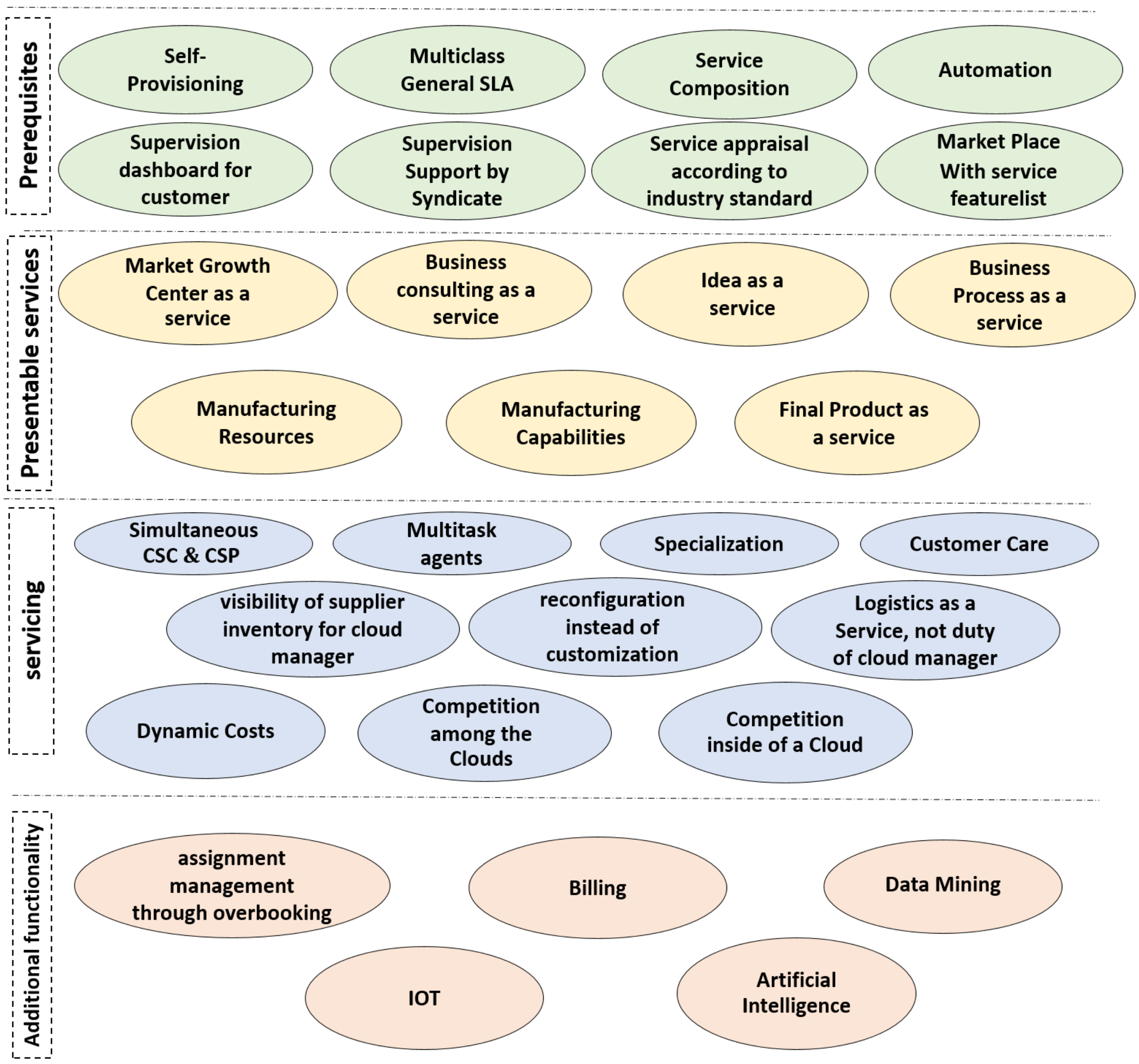

Figure 2. Lean-cloud framework in manufacturing systems.

6. Conclusion

Today, the production context is totally competitive and uncertain. A manufacturing system should be flexible or reconfigurable to adapt to the dynamic environments. As the other word, a manufacturing system should have a goal of operational performance improvement and production of high-quality goods without failure or aggregation. The main contribution of this research was to derive the characteristics, which made a manufacturing cloud to be lean. The basis of this research was the trying to explore principles of lean concept in cloud manufacturing and present a lean-cloud framework. The main problem in studying manufacturing approaches was that each one as an independent paradigm had certain properties. In this study, we tried to extract lean production concepts as well as cloud manufacturing components, and then the relationship between them was explored and investigated whether lean principles are met by using cloud manufacturing. Therefore, by adding dimensions of lean to related sections of cloud manufacturing, we can have a lean cloud covering both paradigms. Cloud manufacturing establishes a unique solution that can be adapted easily to business companies of all sizes. In the cloud environment, the first step of being lean is to have a lean cloud.

In order to improve the efficiency of cloud manufacturing, some additional functionalities such as using artificial intelligence and data mining were proposed. To calculate the cost of the service in a manufacturing cloud, a billing system was necessary. By this approach, all sectors of the organization negotiate together with the language of service. Equipping the logistic vehicles by IOT technologies can improve the visibility. To ensure that resources are not idle, the assignments can be managed by overbooking. It is not necessary to divide the members of the cloud to customers and suppliers. Instead, every supplier may offer several professional manufacturing services and on the other hand be a customer for a special service itself. By using professional forums in the user interface in cloud, customers can share their experience about the services. In addition to manufacturing capabilities and resources, presenting idea as a service, market growth center as a service, and business consulting as a service, enhance the cloud to support all the services needed in a manufacturing company.

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