Cloud Manufacturing: An Approach to Strengthen Global Competitiveness of the Indonesian Small and Medium Manufacturing Enterprises

Khamdi Mubarok and Mahrus Khoirul Umami
Department of Mechanical Engineering, University of Trunojoyo Madura, Bangkalan, Indonesia

Keywords: Industry 4.0, Making Indonesia 4.0, Small and Medium Manufacturing Enterprises, E-Smart IKM, Cloud Manufacturing

Abstract: The World is moving into a new industrial revolution era and new industrial competition. Driven by the advanced development of computer science and information and communication technologies (ICT), the German strategic initiative Industry 4.0 has triggered many countries to establish their national strategies. Responding to this trend, the Indonesian government launched “Making Indonesia 4.0” as a roadmap to strengthen industrial competitiveness. Focusing on small and medium manufacturing enterprises (SMMEs) or IKM, the Ministry of Industry released E-Smart IKM to help them improve their productivity and expand their market. However, these initiatives paid less attention to the collaboration worth among companies. In order to build a close relationship and strong collaboration among SMMEs, cloud manufacturing concept is adopted in this research. By utilizing the Internet of things (IoT), service-oriented architecture (SOA) technologies and cloud computing technologies, a cloud manufacturing platform for the Indonesian SMMEs is developed. First, Making Indonesia 4.0 initiative and E-Smart program as the background of this research are observed. Second, cloud manufacturing definition and basic concept are discussed. Finally, three supporting conditions for the adoption of cloud manufacturing and nine implementation strategies for the Indonesian context are proposed. The initial work of this implementation is also presented.

1 INTRODUCTION

Industry 4.0 (or Industrie 4.0) refers to the fourth industrial revolution in which manufacturing industries will be occupied by intelligent machines and products to create intelligent systems and networks which can communicate each other autonomously (Oztemel and Gursev, 2020). This concept was first introduced by National Academy of Science and Engineering (Acatech) Germany at Hannover Messe trade fair in 2011 as the strategic initiative to secure Germany position as the world leader in manufacturing industries (Kagermann et. al., 2013). Industry 4.0 can be seen as a collection of emerging information and communication technologies (ICT) that drive future manufacturing. Those technologies include Internet of Things (IoT), cloud computing (CC), big data and analytics (BDA), system integration, advanced robotics, additive manufacturing or 3D printing, augmented reality (including virtual reality and mixed reality), advanced simulation, knowledge graph, blockchain, digital twin, and cyber secrity (Mubarok, 2020).

Initiated from the manufacturing domain, the application of Industry 4.0 technologies gain more and more attention from both industry experts and academic researchers. Those technologies have to improve manufacturing life cycle processes in the most suitable areas of application (Zheng et al., 2020). Additive manufacturing is one of the newly technologies taking fast advantages in this new era enabling rapid product development by utilizing IoT technologies (Wang et al., 2019).

Similar to Industry 4.0, General Electric and other leading industries in the United States also introduced the concept of Industrial Internet, putting intelligent machines, advanced analytics and connected people as the key elements of future manufacturing (Evans and Annunziata, 2012). Other countries also develop their unique strategies for future manufacturing competition. Made in Sweden 2030 (Ersson and Sagström, 2013), Smart Industry – Dutch Industry fit for the future (FME, 2014) and

Mubarok, K. and Umami, M.
Cloud Manufacturing: An Approach to Strengthen Global Competitiveness of the Indonesian Small and Medium Manufacturing Enterprises.
DOI: 10.5220/0010305900003051
In *Proceedings of the International Conference on Culture Heritage, Education, Sustainable Tourism, and Innovation Technologies (CESIT 2020)*, pages 185-192
ISBN: 978-989-758-501-2

Made in China 2025 (Liu, 2016) are some of the examples.

Following this trend, on April 4th, 2018, the government of Indonesia launched “Making Indonesia 4.0” (Kemenperin, 2018a) as a roadmap for guiding the reinforcement programs to boost national industries globally. This is the way how Indonesia revitalize the manufacturing sector to achieve the vision to be among the tenth largest world economy in 2030. Another initiative, focusing on IKM or small and medium manufacturing industries (SMMEs), the Indonesian Ministry of Industry also created a digital technology project called “E-Smart IKM” (Kemenperin, 2017). E-Smart IKM is a government exertion to SMMEs to enter online marketplace so that their product can reach global markets.

Both initiatives, however, still lack focus on strengthening the relationship and collaboration between industries or among similar industries. Even though those similar industries have been placed in certain location forming an industrial cluster, the collaboration between those industries is still very low. As a result, they only able to undertake a small project individually. They are incapable of accomplishing big projects. Close collaboration between those industries will allow them to overcome this challenge. Based on this conditions, a close collaboration network program applying a new manufacturing paradigm called cloud manufacturing (CMfg) is proposed. Cloud manufacturing platform enable diverse industries to access and use manufacturing resources from a pool of resources provided by other companies (Ghami et al., 2019). This approach will enable SMMEs to build a close collaboration with other companies to carry big projects together and enhance their global competitiveness.

To enable on-demand access, manufacturing equipment need to be connected to the Internet and provide required data analytics tools as to assess their capabilities and availabilities (Lu and Xu, 2019). These technologies will benefit Small and Medium Sized Enterprises (SMEs) in term of competitive advantage, flexibility, efficiency, and quality. However, most of the SMEs have financial and knowledge constaints to adopt those typical Industry 4.0 technologies (Masood and Sonntag, 2020). Therefore, before integrate modern and smart manufacturing equipment, SMEs are required to analyze technological, organizational, and environmental determinants of digital technology adoption and implementation (Ghobakhloo and Ching, 2019). In addition, other critical factors comprised in this implementation are the support and involvement of SME managers, training support from expertise and academic researchers, also the collaboration among SMEs in the industrial network (Moeuf et al., 2020).

The main objective of this paper is to develop a cloud manufacturing platform for Indonesian SMMEs based on their typical characteristics. The rest of this paper is organized as follow. Section II highlights the new Indonesian government initiative “Making Indonesia 4.0” and “E-Smart IKM” program scheme as the background of this research. Section III discusses the basic concept of cloud manufacturing and its suitability for Indonesian context. Section IV describes the adoption process and the implementation strategy. Finally, Section V concludes the paper and define future work.

2 MAKING INDONESIA 4.0 AND E-SMART IKM

This section describes Making Indonesia 4.0, the Indonesian national strategy to compete in today’s global market, and “E-Smart IKM’ project. Following that, we identify some beneficial factors as well as some drawbacks of government programs.

2.1 Making Indonesia 4.0

The main contents of Making Indonesia 4.0 roadmap are five industrial sectors as the pillars and ten national development priorities (Kemenperin, 2018a). Based on the real condition of the Indonesian manufacturing environment, the Ministry of Industry has selected five leading industries that have enormous potential to be expanded globally. Those leading industries are the main strength of future Indonesian manufacturing. Those five sectors are food and beverage, textile and apparel, automotive, electronics and chemical. Figure 1 shows the five industry pillars and the main enabling technologies such as artificial intelligence (AI), IoT, wearables, advanced robotics and 3D printing. However, other Industry 4.0 technologies as mentioned on the first section will also be utilized.

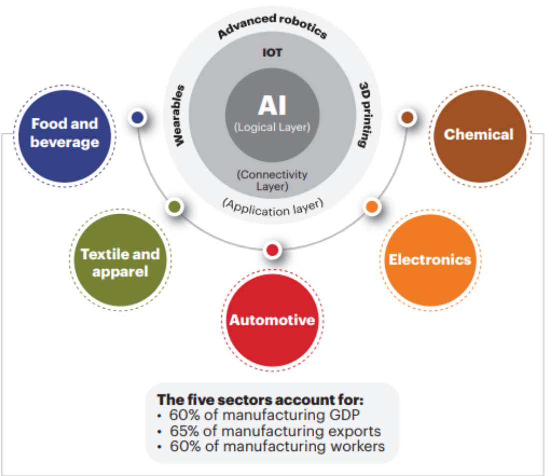

Figure 1: Five main industrial sectors (Kemenperin, 2018a)

Based on the study of the obstacle factors to the development of manufacturing industries in Indonesia, the government has placed ten national priorities that urgently required to faster industrial growth. Those ten priorities are fixing material supply chain, redesigning industrial zone, accommodating sustainability standards, empowering SMEs, building national digital infrastructure, attracting foreign investments, improving human resource skills, forming innovation-based ecosystems, offering incentives for technological investments, and harmonization of rules and policies (Kemenperin, 2018a). In this research, the empowering SMEs (SMMEs) and redesigning industrial zone or industrial cluster are highlighted. Re-design industrial cluster can be referred to re-managing industries within a cluster for close collaboration.

2.2 E-Smart IKM Project

E-Smart IKM is a Ministry of Industry project to improve the productivity of small and medium-sized enterprises by introducing digital technology. The government encourages SMMEs to trade their products through the online marketplace on the Internet that the government has created or collaborated. Within this project, the government also offer help and support on capital investment, process and product standardization, intellectual property right, raw material access, human resource development, etc. This Internet-based project is a good start. To this end, many SMMEs have joined and experienced the benefits. To further improve their global competitiveness, this project can be improved further by building cloud manufacturing platform to support collaboration.

Another government scheme to support SMMEs is the industrial machinery restructuration project that has been run since 2009. In this project, the Ministry of Industry reimburses 25-30% of the total money a company spent on purchasing new machines or equipment (Kemenperin, 2018b). Although this project can augment SMMEs production capability, enlarge their production capacity, and improve their competitiveness, this project is less effective. This is because only the companies which receive the grant can take benefits. Other industries still suffer from their restricted capability. Therefore, it is necessary for the government to review this scheme as to have more companies take benefits. Cloud manufacturing approach holds this potential to share the use of machines or equipment in a community or public-based. On the other way, the Ministry of Industry can manage under cloud manufacturing platform in which machinery and equipment in one company can be accessed by other companies. As a result, many companies will benefit from access to that machinery and equipment. This will be more effective and efficient to improve global competitiveness for many SMMEs.

3 CLOUD MANUFACTURING

Cloud manufacturing is a collaborative manufacturing concept based on cloud computing technology and service-oriented architecure (Li et al., 2010). Hundreds of papers have been published on this topic. In addition, several research projects in Europe and China have also toughened the foundation of this concept. However, the real implementation of this concept still scarce.

3.1 Definition and Basic Concept

Cloud manufacturing is a cloud computing application in manufacturing. Before cloud computing technology introduced, software installer was provided on compact disc (CD). Also, files were stored on PC hard disk which holds a certain capacity. Since cloud computing is introduced, software installer, storage, and other services are available in the cloud which can be accessed from everywhere as long as internet connection are available. Similarly, in cloud manufacturing, machines, robots, and other manufacturing facilities are virtualized and offered as a service that can be accessed or used by anyone (cloud users).

One of the formal definition of cloud manufacturing is mirroring the definition of cloud computing. Cloud manufacturing is ''*a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable manufacturing resources (e.g., manufacturing software tools, manufacturing equipment, and manufacturing capabilities) that can be rapidly provisioned and released with minimal management effort or service provider interaction*.''(Xu, 2012).

In cloud manufacturing, companies that have idle resources, such as machines, equipment, and other manufacturing facilities register their virtualized resources in the cloud via cloud operator and offer them as services. This means other companies can access and use their resources on "pay as you go" bases. The benefit of this concept, among other benefits, is the users do not need to purchase resources. They can use other companies' resources (cloud providers) and pay based on how long they use those resources.

The other benefit of cloud manufacturing is shortened time to market. A company which receive high demand but its facilities incapable of doing so, then this company must find other companies which have similar facilities. Traditionally, an industry catalogue or normal online search engine will be used as a reference to discover dedicated companies. However, this way is time-consuming, and it is difficult to find the exact machines or equipment needed. Cloud manufacturing platform will eliminate this process and directly provide options on lower facility level such as machines and equipment. It can search available resources on its system. To illustrate the cloud manufacturing process, Figure 2 shows how cloud manufacturing principle work. In general, a customer or cloud user has the design of a product in CAD file. By submitting this CAD file into cloud manufacturing platform, which in this case illustrated as Google search, the system will pop up different machines that can process their product can be found. For simplicity, this process is similar to Google search engine when searching for a specific sentence. In cloud manufacturing, a typical search engine is developed. So, by inserting a CAD file into a cloud manufacturing platform, a cloud user can find a number of machines that capable to process the product as required on CAD file. Then, this cloud user can select the best machine based on machine specification, price per hour, geographical location, availability status (scheduling), etc.

Figure 2: Cloud manufacturing process illustration

There are different topics to realize this concept, such as manufacturing resource virtualization, service selection, service composition, scheduling, pricing strategies, and so on. Despite the limited implementation of cloud manufacturing concept, the development of cloud manufacturing implementation for the Indonesian SMMEs will be a good example for other countries. The complexity of the system, the technology enablers, and industrial awareness are some of the challenges. Other factors influence this implementation also include the typical manufacturing companies, geographical conditions, government policy, etc. Based on the conditions of the Indonesian SMMEs, we propose Industry 4.0 implementation for small and medium manufacturing enterprises for Indonesia context, which focuses on cloud manufacturing technologies.

3.2 Business Process

Figure 3 below shows the cloud manufacturing participants and business process. Ideally, machines and equipment are connected to the internet and available to be accessed for real-time monitoring and responsiveness. Data are gathered through intelligent devices (sensors, cameras, RFIDs, smartphones, wearable) and stored in the cloud. The cloud can be accessed privately for internal purposes or open to public for data sharing with other business partners. Big data analytic helps smart factories to analyse the data and to derive useful information for certain decision-making purposes.

In cloud manufacturing, there are three main participants, i.e. service providers, a cloud operator, and cloud users/consumers, either individual entity or business organization.

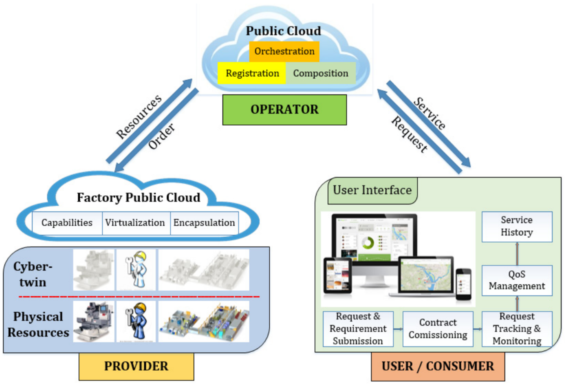

Figure 3: Cloud manufacturing business process

First, companies which have manufacturing resources will participate as service providers. Machines, equipment and other devices on physical resources are virtualized. In advanced version, these virtual machines produce data. To keep internal data safe and secure, data are saved in the factory private cloud. Only data related to resources for sharing are uploaded via factory public cloud. Service providers virtualize resources and provide manufacturing resources information database to be uploaded to the cloud. This database consists of physical manufacturing resources, such as machine tools, cutting tools, materials, etc., and their manufacturing capabilities. Then, those data are virtualized and connected to the internet for ubiquitous access. IoT sensing provides real-time resource monitoring showing availability status of each resource.

Second, the cloud operator. Cloud operator is responsible for taking control of the whole service activities, such as service registration, orchestration, and composition. The main role of the cloud operator is to find matching user requests with suitable resources. Then, offer the list of matching resources for users to select based on their requirements. The operator also manages to provide the best service to users and providers. In addition, the operator also concerns with cybersecurity issue in a cloud environment to protect intellectual property (IP) of the requests (products) and other private data. Dealing with faulty in some extent also need operator attention.

Third, cloud users or cloud consumers. Users submit their request, such as product data, and select the best resources from the list of matching resources provided by the operator. They will be given access to track and monitor the request status in real-time based. Any feedback for both operator and provider are submitted to measure the quality of service.

The overall processes is developed based on a knowledge-based system to determine manufacturing related decision making as well as to optimize the systems. All data and events, in the overall processes are captured to building the basis of this knowledge. Rules then created to drive the systems.

4 IMPLEMENTATION STRATEGY

This research focuses on finding the way for cloud manufacturing implementation in the Indonesian context. Therefore, some characteristic of SMMEs and typical government organization is described first. Then, step by step implementation procedure is proposed. Following that, an initial development process in our laboratory is also presented.

4.1 Business Process

Indonesia as a developing country has a large number of SMMEs. Therefore, the government through the Ministry of Industry pay attention more to this industrial sector. Based on our investigation, we define three supporting conditions for the adoption and implementation of cloud manufacturing concept in Indonesia. First, the establishment of industrial clusters or industrial zones in many cities. Those industrial clusters are developed mainly based on similar products. For example, central for foundry industry which located in Klaten, furniture industries in Jepara, leather industries in Sidoarjo, and so on. These industrial clusters simplify the collaboration format that needs to be established as the beginning step.

Second, support from local government. Indonesia has local representatives for the ministry of industries, called “Dinas UMKM” or “Dinas IKM” that focus on developing local SMMEs. They have data and information regarding the type of industries, the size of the industries, etc. in their local area. The local government also has a good relationship and communication with the industries. Within this good circumstances, the local government can play the role as cloud operator which facilitate the industries to provide their manufacturing resource capabilities information.

Third, the new infrastructure development such as highway and transportation systems. Since cloud manufacturing concept is overlooked geographical location, which means the manufacturing resources can be located anywhere as well as cloud users also can have access from anywhere, the role of transport systems must be influenced. This new huge improvement on the infrastructure facilities enables the cloud manufacturing implementation in Indonesia.

4.2 Step-by-Step Implementation

To implement the cloud manufacturing concept, we define nine steps based on the cloud manufacturing service management proposed by Tao et al. (2015).

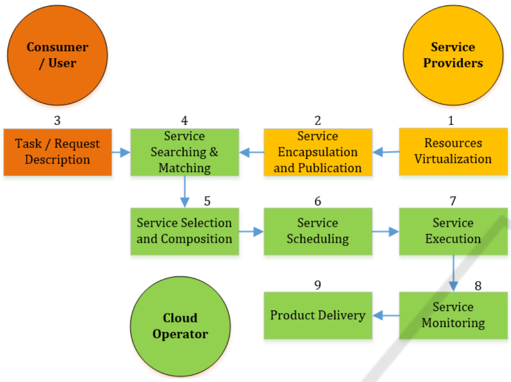

Figure 4: Cloud manufacturing implementation procedure

The implementation procedure is divided into nine steps as below:

1. Resource description and virtualization. Manufacturing resources such as machines and equipment are virtualized using cloud computing technologies and agent-based technologies. Beside those hard manufacturing resources, soft manufacturing resources such as a person (smart talents), software, and other computational resources also can be offered as s service.
2. Service encapsulation and publication. Resource capabilities are translated into service modelling language (using ontology modelling) and published on public cloud pool.
3. Task/request description. Tasks and other specific requirements are represented as product data in semantic description language.
4. Service searching and matching. Similarity algorithms are commonly used for service discovery to search and match user tasks with suitable cloud services.
5. Service selection and composition. Knowledge-based systems or other approach and methodology can be used for optimal selection and service composition.
6. Service scheduling. Selected resources are scheduled using scheduling algorithms based on resources real-time availability
7. Service execution. Production processes are executed based on the scheduling.
8. Service monitoring. Users can access the real-time status of their request.
9. Product delivery. Finished tasks/requests are delivered to users.

4.3 Application Development

We have initiated this work in our lab, the Laboratory of Robotics and Automation Laboratory, University of Trunojoyo Madura. We have 2 CNC milling machines, 2 CNC turning machines, and one robot welding, also one robot assembly. The initial project currently performed is how to virtualize the CNC and robots in the machine (computer) readable format. Ontology modelling is the best option so far to virtualize the manufacturing resources. Figure 5 shows CNC milling machine characteristics that need to be virtualized.

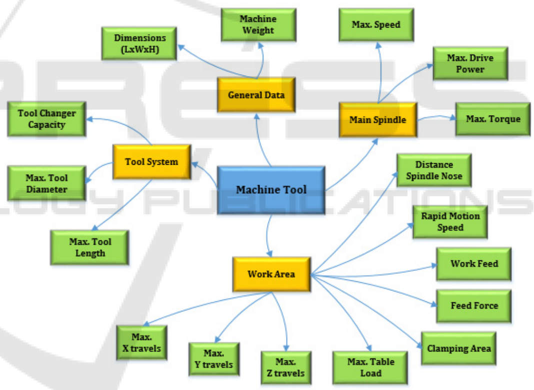

Figure 5: CNC milling data and characteristics

In compliance with cloud manufacturing environment, these characteristics are required to be transformed into ontology modelling (Talhi et al., 2019). Figure 6 shows an example of the development of machine tools ontology using Protégé software.

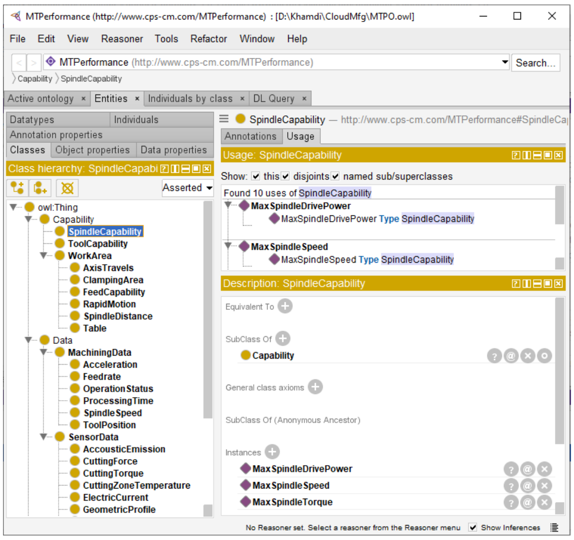

Figure 6: CNC Milling ontology

5 CONCLUSION

This research proposed a strategy for cloud manufacturing implementation in the Indonesian context to strengthen SMMEs global competitiveness by building close collaboration among SMMEs. The concept of cloud manufacturing is described and the suitability with the Indonesian context is discussed. As a result, three supporting conditions are defined and nine implement strategies for the cloud manufacturing adoption are developed. However, following the step by step procedure proposed, the real implementation of this project is still in the initial stage. Therefore, for future research, the efforts will be focused on the next steps as presented in this paper. Furthermore, by utilizing cyber-physical systems (CPS) and big data analytics, the opportunity to gather data from machines and process the data for prediction process purpose and process simulation needs to be investigates. So that, the cloud users will be able to simulate the overall process before placing a request on the cloud manufacturing platform. In addition, cybersecurity issues also will be our concern.

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