

An Overview of Cloud Implementation in the Manufacturing Process Life Cycle

Noordiana Kassim, Yusri Yusof, Mahmod Abd Hakim Mohamad, Abdul Halim Omar, Rosfuzah Roslan, Ida Aryanie Bahrudin, Mohd Hatta Mohamed Ali

University Tun Hussein Onn Malaysia

Corresponding author: noordiana@uthm.edu.my

Abstract. The advancement of information and communication technology (ICT) has changed the structure and functions of various sectors and it has also started to play a significant role in modern manufacturing in terms of computerized machining and cloud manufacturing. It is important for industries to keep up with the current trend of ICT for them to be able survive and be competitive. Cloud manufacturing is an approach that wanted to realize a real-world manufacturing processes that will apply the basic concept from the field of Cloud computing to the manufacturing domain called Cloud-based manufacturing (CBM) or cloud manufacturing (CM). Cloud manufacturing has been recognized as a new paradigm for manufacturing businesses. In cloud manufacturing, manufacturing companies need to support flexible and scalable business processes in the shop floor as well as the software itself. This paper provides an insight or overview on the implementation of cloud manufacturing in the modern manufacturing processes and at the same times analyses the requirements needed regarding process enactment for Cloud manufacturing and at the same time proposing a STEP-NC concept that can function as a tool to support the cloud manufacturing concept.

1. Introduction

The rise of cloud computing is radically changing the way enterprises manage their information technology (IT) assets. Because of the changing market demand and the emergence of new technologies, manufacturing systems have undergone a number of major transitions [1], [2]. Cloud computing has proven to be a disruptive technology that leverages existing technologies such as utility computing, parallel computing, and virtualization. Some of its key characteristics include agility, scalability and elasticity, on-demand computing, and self-service provisioning [3], [4]. Cloud computing represents a combination of various IT technologies: hardware virtualization, distributed computing (grid computing, utility computing), internet technology (service oriented architecture, web services, Web 2.0, broad-band networks), system management (service level agreements, data center automation) and open source software [5], [6]. Cloud based solutions can be described as web-based applications that are stored on remote servers and accessed via internet by standard web browsers [6].

The cloud manufacturing concept was adapted from the cloud computing paradigm and was being introduced into the realm of computer-aided product development, cloud-based design and manufacturing (CBDM) and has been gaining significant momentum and attention from both academicians and industry practitioners. Cloud-based design and manufacturing (CBDM) refers to a service-oriented network for product development model in which service consumers are enabled and allowed to configure, select, and utilize customized product realization resources and services to their needs and demands ranging from CAE software to reconfigurable manufacturing systems [7].



Cloud manufacturing is a computing and service-oriented manufacturing model developed from existing advanced manufacturing models (e.g., application service providers, agile manufacturing, networked manufacturing, manufacturing grids) and enterprise information technologies under the support of cloud computing, the Internet of things (IoT), virtualization and service-oriented technologies, and advanced computing technologies [8].

The implementation of cloud computing in manufacturing can take two forms [9]. The first form is the mimicking of the cloud computing environment in manufacturing and the second form deals simply with the incorporation of cloud computing technologies into the manufacturing industry. Because of changing market demand and emerging technologies, manufacturing systems have undergone several major transitions [1], [10]. These transitions can be summarized as per shown in Figure 1 where it shows a brief evolution of manufacturing paradigms from the assembly line, to Toyota production systems (TPSs), to flexible manufacturing systems (FMSs), to reconfigurable manufacturing systems (RMSs), and lastly to Cloud Based Manufacturing (CBM). In the early days, manufacturing process just evolved around assembly lines, where at the times, manufacturers are more than satisfied with its performance where it helps in reducing labor costs as well as increase the production rate. The current trend of manufacturing has shown that the manufacturing businesses and concept has been transformed from solely focus on production and physical system oriented to a service oriented system through the emergence of cloud based manufacturing systems. In CBMS, manufacturers will be able to provide rapid elasticity to their service, where they can scale their resources as per needed, eliminating loss as well as reducing cost. At the same time, the manufacturing resources will be pooled at one place and it can enhance information sharing and machine utilization as well as improved reuse of resources.

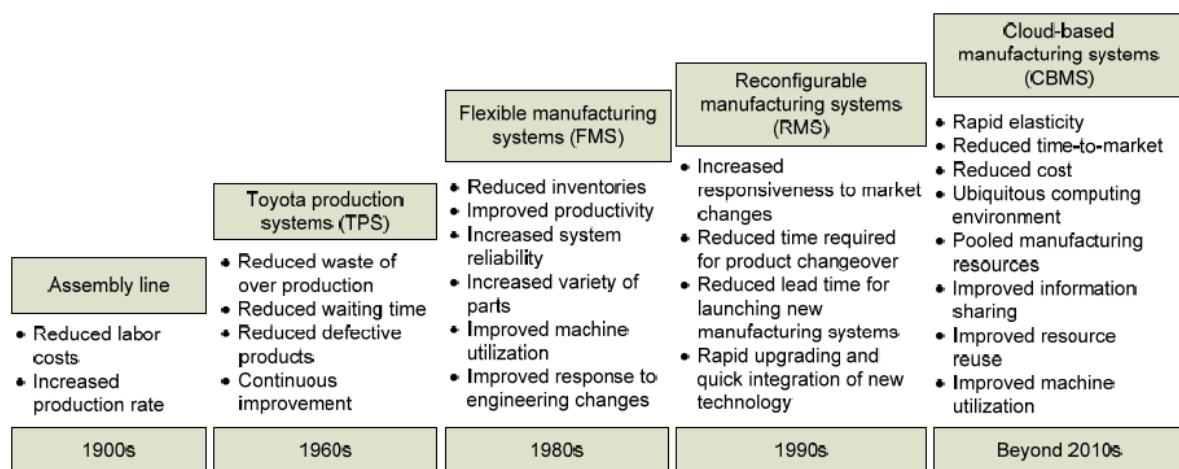


Figure 1 Evolution of Manufacturing Systems [11].

Not only the manufacturing systems concept has evolved over the years, the concept of computer aided design system also has gone through many positive evolutions as well, and it also has start utilizing the cloud concept. Manufacturing involves design, so design is also being considered as a key component in manufacturing business or services and design software has been offered as a service in this cloud technology.

In addition to the systematic design processes, product design also needs to be facilitated by computer-aided systems to assist designers in the creation, analysis, and optimization of a design. Design engineers have used Computer-Aided Design (CAD) systems to design products since the 1960s. Table 1 briefly summarizes key milestones of the evolution of computer-aided design from centralized standalone systems, to distributed web-based systems, and finally to Cloud Based Design (CBD) [7]. Starting from the early implementation of numerical control on product development up

until the 70s, manufacturing process setting configuration was centralized, where it was being controlled under a single activity or authority. It was based on a standalone system for local applications and does not utilized network capabilities. Starting from the early 80s, with the launch and popularities of IBM personal computers, manufacturing sector configuration has switched from centralized to distributed, where a network of geographically dispersed manufacturing facilities is coordinated using information technology.

Table 1 Evolution of Computer Aided Design System [7].

Time	Configuration	Characteristics
1960s	Centralized	Standalone system; operate on large and expensive computers; generate 2D drawings with a light pen on a CRT monitor.
1970s	Centralized	Standalone system; operate on affordable personal desktop computers; perform 3D solid modelling.
1980s	Distributed	Thin server and strong client; heavy weighted client mechanism; hard to be implemented on the internet.
1990s	Distributed	Strong server and thin client; light weighted client mechanisms; easy to be implemented on the internet.
Beyond 2010s	Distributed	Cloud computing based; virtualization; multi tenancy; social media; ubiquitous access; software as a server; pay per use.

So far, the basic approach to Cloud manufacturing has been defined, but there is a lack of software frameworks supporting it [12]. STEP-NC due to its intelligent structure [13], has been known as a standard that can keep detail manufacturing information in a tree structure that can be easily understand by anyone and not just the specific machine operator. STEP-NC would be able to best support the cloud manufacturing concept due to its richness of information, especially when the user or requester and the actual manufacturer are being separated under different entity, or in this scenario the people in process planning and the actual manufacturer. This would be the initial stage of the future work that would be done under this cloud manufacturing research project, where the STEP-NC machining concept [14][15] that utilises ISO 14649 [16] will be adapting the cloud manufacturing concept in the implementation of intelligent modern manufacturing.

2. Cloud-based Design Manufacturing (CBDM)

Cloud Based Manufacturing (CBM) is distinguished from web and agent-based manufacturing from the perspectives of computing architecture, data storage, operational process, information and communication, business model, and programming model [11]. It is a way of implementing the cloud base design on manufacturing.

Cloud-based design (CBD) and cloud-based manufacturing are the two fundamentals in understanding CBDM, and would need to be understand separately [17]–[19]. Cloud-Based Design (CBD) refers to a networked design model that leverages cloud computing, service-oriented

architecture (SOA), Web 2.0 (e.g., social network sites), and semantic web technologies to support cloud-based engineering design services in distributed and collaborative environments [19], [20]. Some of the important requirements of a CBD system include (1) it must be cloud computing-based; (2) it must be ubiquitously assessable from mobile devices; and (3) it must be able to manage complex information flow. Cloud-Based Manufacturing (CBM) refers to a networked manufacturing model that exploits on-demand access to a shared collection of diversified and distributed manufacturing resources to form temporary, reconfigurable production lines which enhance efficiency, reduce product lifecycle costs, and allow for optimal resource allocation in response to variable-demand customer generated tasking [21], [22].

3. Cloud Manufacturing Model

Many researchers have come out with their own cloud manufacturing model that could best describe the cloud process in manufacturing. Wu[22] has presented a dependable cloud manufacturing model that capture every factor, where it stated that in cloud manufacturing it will require an interaction between three main groups of people or sectors which are the users (consumers), application providers, and physical resource providers. The needs of users will be matched with the capabilities of resource providers through the application layer. This tri-group model as per shown in Figure 2, represents the simple supply-demand market that motivate the existence of cloud manufacturing.

3.1 Users

In the CM model [22], Users was can either be individuals or large OEMs (Original Equipment Manufacturer) or anyone or group that can generate engineering requirements to be used in a manufacturing setting. These engineering requirements, which describe the desired object and its final conditions, are provided to the cloud based application layer for interpretation [22].

3.2 Application Providers

When we talk about cloud manufacturing, it is well known that cloud computing will always come out first. The key thing in cloud computing concept is cloud computing services, basically offering things as a service, where users will only pay for the services that the use, with no hidden costs, and it will offer infrastructure, platform as well as software as a service to users and customers, or in some scenario manufacturers. These services are offered and managed by the application providers, usually, those who are engaging themselves in the ICT sectors and providing platform as a service, where users can purchase their services online without having to buy any software license. Some examples of the services would be like simulation package or 3D modelling.

The cloud based application layer that is provided by the application providers, will be responsible for managing all aspects of the CM environment and it will interpret user requirements into data that is required for production of a desired objects or products. For example, if a user desired product may require the development of a CNC tool path program and process planning to achieve a final desired plating condition – these would be created by the cloud based applications. The application layer will be managed and controlled by application providers, who offer their services as an intermediary between users and resource providers for a portion of the product profit [22].

3.3 Physical Resource Providers (PRPs)

Physical resource providers (PRPs) are those that own and operate the manufacturing equipment, but not just limited to machining technologies, finishing technologies, inspection technologies, pack-aging technologies, and testing resources. In addition to owning the physical resources, PRPs have the know-how and experience to utilize the machines effectively and efficiently. These PRPs are not limited by their geographic location; rather, PRPs join the CM network based upon their expertise alone. Ideally as a whole, the PRP network would represent every type of manufacturing capability available in the industrial sector, offering users instantaneous access to manufacturing capabilities provided through cloud services. The input to the PRP group is the manufacturing data created by the

cloud based applications, and the output is a finalized product in conformance with user requirements [22]. The physical resources involve will includes all the tangible and intangible resources and assets owned and used by a company such as land, manufacturing equipment and office equipment. Information and communication technology facilities and its equipment, computers, networks, servers and others, are included in the category of physical resources as well.

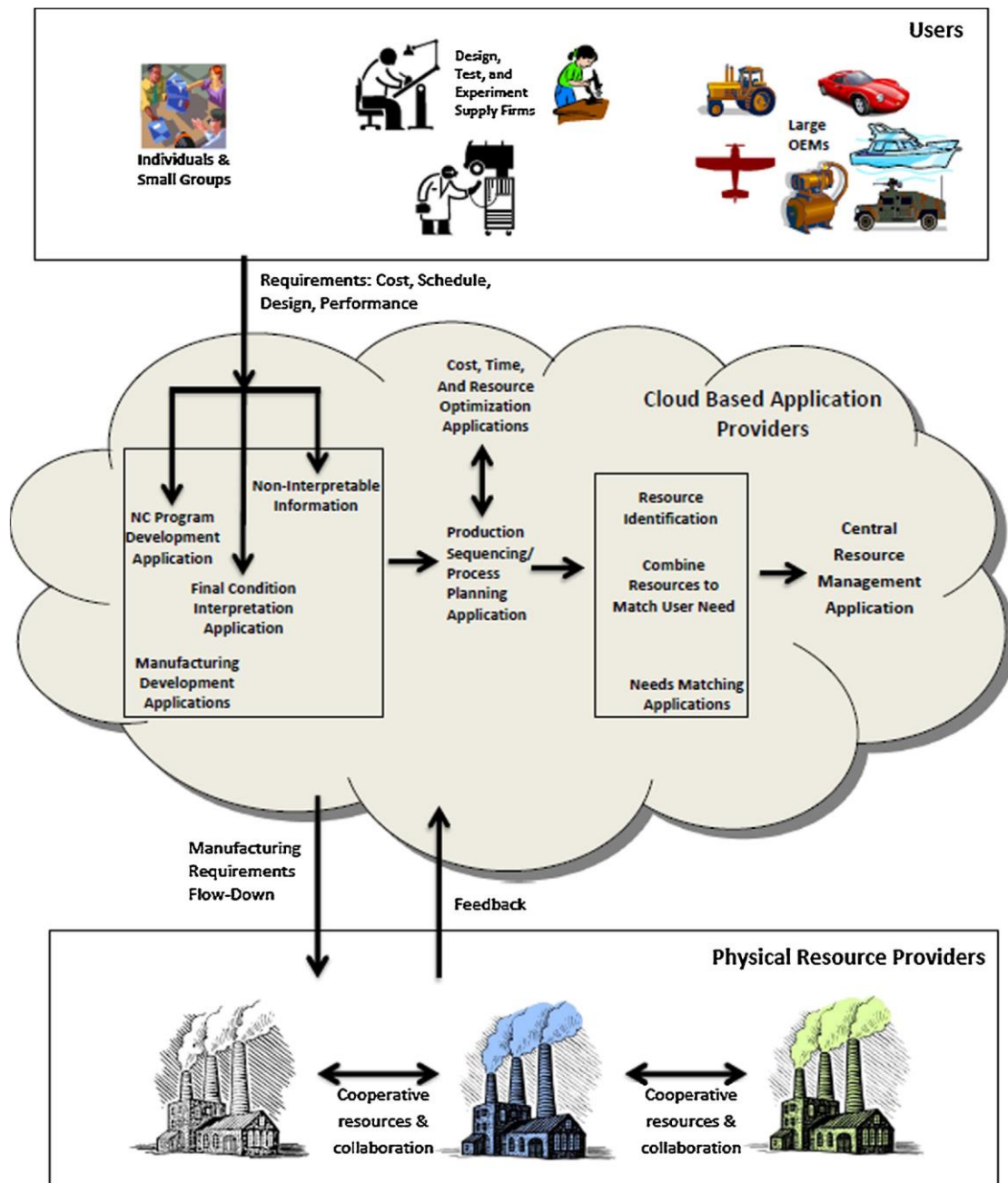


Figure 2 Strategic Vision for CM [22].

4. Advantages of Cloud Manufacturing

Manufacturing businesses nowadays are no longer about producing physical products and sell it to the end user or customers. Instead, it is more about sending the solutions to the customer together with the product. This could be done through cloud manufacturing, with its having competitive advantage in it the ITC field.

The main benefit for companies in choosing a cloud-based solution is that almost no local IT resource investment is required [6], [23]. In other words, users or manufacturers do not need to invest on high end computers or licenses or worrying about software upgrades or updates. Companies can utilize the flexibility of cloud resources dynamically to meet peak demand without investing in in-house resources [23]. Also, a cloud solution can handle the weaknesses of their current system regarding redundancy and high upgrade cost because Cloud is a virtualization of resources that maintains and manages itself [24].

In the CM environment, manufacturing supply chain relation-ships will be customer-centric, defined by enhanced efficiency, reduced cost, increased flexibility, and improved capabilities for the user. These benefits will be derived from the creation of flexible manufacturing sequences enabled by the pooling of resources from many different PRPs. Solutions will be customer, or even task, specific, as the cloud based application layer can be used to generate numerous options for the users based upon their specifications (the user would be allowed to specify key aspects of the desired job, such as cost, lead time, and quality, and different choices that fit within those ranges would be provided for consideration). The key goal of a CM environment is linking users, with needs, to resource providers who can fulfil those needs while meeting cost, schedule, and quality objectives of the user [22].

5. Applying Cloud Concept in STEP-NC.

The spread implementation of cloud concept in manufacturing has initiated a research proposal or framework that will be utilising the cloud concept in STEP-NC as per shown in Figure 3.

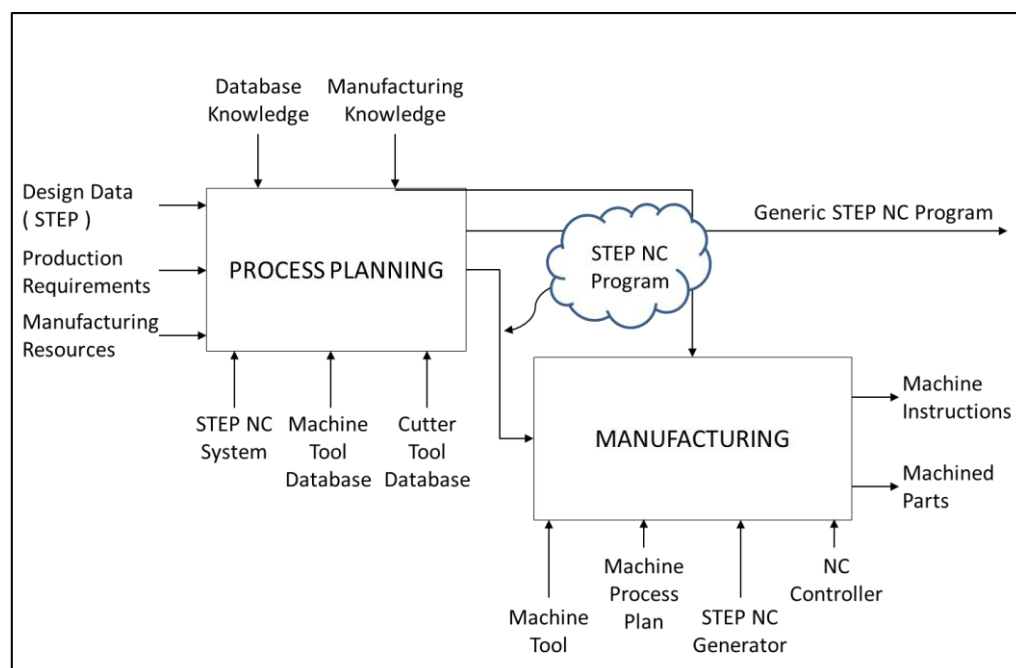


Figure 3 STEP-NC Process Planning and Manufacturing.

STEP-NC [25] has been known as a concept that are able support intelligent manufacturing due to its mass data collection capabilities in keeping all the data thought out the whole manufacturing process life cycle. As cloud concept are very much related and needed abundance of data, the richness of information in STEP-NC will be suitable to support this framework. These mass data like design, requirements, resources, machine tool and cutting tool will be made available in the STEP-NC file during the process planning stage. The process planning stage will represent the user in the cloud manufacturing concept. These planning data will be uploaded to the cloud environment to be translated to a data that can be machined by the physical resource providers which will be the manufacturer. More future research and papers will be done to further explore and explain this concept of STEP-NC in cloud environment.

6. Conclusion

The whole concept of manufacturing life cycle, from planning to design and finally to the machining of the product itself can be connected through the cloud concept, especially in modern manufacturing where product planners, designers and manufacturers does not need to be at the same specific location at the same time. It would be absolutely advantageous in reducing product lead time. Most of the concepts and model for cloud manufacturing was borrowed from the IT industry and manufacturing businesses has been adapting and applying the IT services concept to its domain. In this term, cloud manufacturing has been identified as a new way to run manufacturing businesses. It has been envisioned as the latest paradigm with high potentiality for next generation of manufacturing process life cycle, and many research studies have been conducted on CM. This paper aims at giving an overview in understanding the motivations and future of CM in fitting with the current advancement of information technology in manufacturing and later on how STEP-NC will be the best tool to support this concept. The framework that this research suggests in supporting cloud manufacturing is by applying it to the machining of product through the STEP-NC process or methods. By using information and communication technology as well as IoT technologies in cloud manufacturing, companies, process planners and manufacturers will be able to realize manufacturing processes that will satisfy customer demands for large series of production, mass customization, changing order situations, and short lead time in design. With the rapid changes and dependencies on information and technologies, it is safe to predict that information or knowledge based services would be the driven engine behind the future manufacturing businesses and manufacturing process life cycle.

References

- [1] S. J. Tolio, T., Ceglarek, D., ElMaraghy, H. A., Fischer, A., Hu and J. Laperrière, L., Newman, S.T., & Váncza, "SPECIES—Coevolution of products, processes and production systems.," *CIRP Ann. Manuf. Technol.*, vol. 59, no. 2, pp. 672–693, 2010.
- [2] Y. Hu, S. J., Ko, J., Weyand, L., ElMaraghy, H. A., Lien, T. K., Koren and & Shpitalni, "Assembly system design and operations for product variety.," *CIRP Ann. Technol.*, vol. 60, no. 2, pp. 715–733, 2011.
- [3] S. Foster, I., Zhao, Y., Raicu, I., & Lu, "Cloud Computing and Grid Computing 360-Degree Compared.," *Grid Comput. Environ. Work.*, 2008.
- [4] B. H. G. Putnika, A. Sluga, H. ElMaraghy, R. Tetid, Y. Korene, T. Toliof, "Scalability in manufacturing systems design and operation: State-of-the-art and future developments roadmap," *CIRP Ann. - Manuf. Technol.*, vol. 62, no. 2, pp. 751–774, 2013.
- [5] D. M. Manguic, "Enterprise 2.0 – is the market ready?," *J. Account. Manag. Inf. Syst.*, vol. 10, no. 4, pp. 516–534, 2011.
- [6] P. Helo, M. Suorsa, Y. Hao, and P. Anussornnitisarn, "Towards a Cloud-based Manufacturing Execution System for Distributed Manufacturing," *Comput. Ind.*, vol. 65, no. 4, pp. 646–656, 2014.
- [7] D. Wu, D. W. Rosen, L. Wang, and D. Schaefer, "Cloud-based design and manufacturing: A

- new paradigm in digital manufacturing and design innovation,” *CAD Comput. Aided Des.*, vol. 59, pp. 1–14, 2015.
- [8] J. X. Li BH, Zhang L, Wang SL, Tao F, Cao JW, “Cloud manufacturing: a new service-oriented networked manufacturing model,” *Comput. Integr. Manuf. Syst.*, vol. 16(1), pp. 1–7, 2010.
- [9] X. Xu, “From cloud computing to cloud manufacturing,” *Robot. Comput. Integr. Manuf.*, vol. 28, no. 1, pp. 75–86, 2012.
- [10] Y. Hu, S. J., Ko, J., Weyand, L., ElMaraghy, H. A., Lien, T. K., Koren and M. & Shpitalni, “Assembly system design and operations for product variety,” *CIRP Ann. Technol.*, vol. 60, no. 2, pp. 715–733, 2011.
- [11] D. Wu, D. W. Rosen, L. Wang, and D. Schaefer, “Cloud-based Manufacturing: Old Wine in New Bottles?,” *Procedia {CIRP}*, vol. 17, pp. 94–99, 2014.
- [12] S. Schulte, P. Hoenisch, C. Hochreiner, S. Dustdar, M. Klusch, and D. Schuller, “Towards Process Support for Cloud Manufacturing,” *2014 IEEE 18th Int. Enterp. Distrib. Object Comput. Conf.*, vol. 2014–Decem, no. December, pp. 142–149, 2014.
- [13] Y. Yusri, Z. T. Nurul Zakiah, and K. Noordiana, “Exploring the ISO14649 (STEP-NC) for Intelligent Manufacturing System,” *Eur. J. Sci. Res.*, vol. 36, no. 3, pp. 445–457, 2009.
- [14] N. Kassim, Y. Yusof, I. . Bahrudin, R. Mohd Hanifa, and M. H. Mohamed Nor, “Information Structure of STEP Converter of STEP-CNC Mapping System,” *Appl. Mech. Mater.*, vol. 773–774, pp. 38–42, 2014.
- [15] N. Kassim, Y. Yusof, M. Abd, H. Mohamad, M. N. Janon, and R. M. Hanifa, “Development of STEP-NC Based Machining System for Machining Process Information Flow.”
- [16] N. Kassim, Y. Yusof, and M. Z. Awang, “REVIEWING ISO 14649 THROUGH ISO10303,” *ARPJ. Eng. Appl. Sci.*, vol. 11, no. 10, pp. 6599–6603, 2016.
- [17] J.-C. S. Morad Mahdjoub, Davy Monticolo, Samuel Gomes, “A collaborative Design for Usability approach supported by Virtual Reality and a Multi-Agent System embedded in a PLM environment,” *Comput. Des.*, vol. 42, no. 5, pp. 402–413, 2010.
- [18] S. H. B. L.Q. Fan, A. Senthil Kumar, , B.N. Jagdish, “Development of a distributed collaborative design framework within peer-to-peer environment,” *Comput. Des.*, vol. 40, no. 9, pp. 891–904, 2008.
- [19] L. W. Fuh JY, “Advances in collaborative CAD: the-state-of-the art,” *Comput. Des.*, vol. 37, no. 5, pp. 571–581, 2005.
- [20] S. D. Wu D, Rosen DW, “Cloud-based design and manufacturing: status and promise,” in *Cloud-Based Design and Manufacturing (CBDM) A Service-Oriented Product Development Paradigm for the 21st Century*, D. Schaefer, Ed. London, UK:Springer, 2014, p. 282.
- [21] S. D. Wu D, Thames JL, Rosen DW, “Towards a cloud-based design and manufacturing paradigm: looking backward, looking forward,” in *Proceedings of the ASME 2012 international design engineering technical conference & computers and information in engineering conference (IDETC/CIE12)*, 2012.
- [22] D. Wu, M. J. Greer, D. W. Rosen, and D. Schaefer, “Cloud manufacturing: Strategic vision and state-of-the-art,” *J. Manuf. Syst.*, vol. 32, no. 4, pp. 564–579, 2013.
- [23] J. V. D. M. T. Wood, P. Shenoy, A. Gerber, K.K. Ramakrishnan, “The case for enterprise-ready virtual private clouds,” in *HotCloud’09 Proceedings of the 2009 Conference on Hot Topics in Cloud Computing*, 2009.
- [24] H. C. K. Zhang, B. Ma, P. Dong, B. Tang, “Research on producer service innovation in home-textile industrial cluster based on cloud computing platform,” in *nformatics, IEEE International Conference on Service Operations and Logistics and (SOLI)*, 2010, pp. 155–160.
- [25] N. Kassim, Y. Yusof, and M. Z. Awang, “The Development of New STEP-NC Code Generator (Milling STEP Coder),” *Appl. Mech. Mater.*, vol. 465–466, pp. 667–671, 2014.

