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Sustainability Aspects of Logistics and Operation Fulfilment in Cloud Manufacturing Systems

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ABSTRACT

The manufacturing business models have been recently revolutionized due to emerging technologies and theories like Cloud manufacturing and service-oriented paradigms. However, the requirements of the current globalized economy for environmental and sustainability aspects have been neglected. This paper aims to consider sustainability as a key element in emerging paradigms like Cloud manufacturing and propose a model to minimize the negative environmental impacts in terms of considering energy, natural resources, and CO2 emissions. Moreover, it tries to concentrate on aspects like quality, environment, logistics, and service to create a measurement for companies to transform from product-oriented manufacturing to service-oriented manufacturing. Considering the recent studies on Cloud manufacturing systems and their contributions toward environmental aspects, an evaluation model has been proposed for sustainable Cloud manufacturing systems with a focus on global logistics. The role of different stakeholders inside Cloud manufacturing business models in respect of the evaluation model is discussed.

Keywords: Sustainability, Cloud manufacturing, Manufacturing system, Environmental sustainability

INTRODUCTION

Several factors have contributed to this rapid change in modern manufacturing, including extreme global competition, economic globalization, resource globalization, and the rapid development of advanced manufacturing, information, computer, and management technologies (Zhang et al., 2014). As the manufacturing industry develops, a form of service-oriented manufacturing-Cloud manufacturing is emerging. Cloud manufacturing is a modern and smart way to acquire low-cost, high-quality manufacturing services. Cloud manufacturing as a modern and smart manufacturing model, how to achieve sustainability became a more and more important question. This paper tries to develop an evaluation system to evaluate the readiness of businesses to transform to Cloud manufacturing with a special sustainability focus (Valilai and Sodachi, 2020; Sadeghi Aghili et al., 2021).

LITERATURE REVIEW

Sustainability

Sustainable development stems from the 1987 (Visser and Brundtland, 2013), also known as "Our Common Future", which explained sustainable development as "meeting present needs without compromising the future needs of future generations". This is an explanation that is even now extensively cited in the literature (Stubbs and Cocklin, 2008). Sustainability has been approached from points of view like improving the financial performance of enterprises, environmental aspects like CO2 emissions, and also the societal effects of enterprise business model operations (Sodachi, Sahraei and Valilai, 2020; Lobo, Wicaksono and Valilai, 2022). Sustainable manufacturing encompasses the three fundamental components of manufacturing products, processes, and systems to empower long value creation and productivity expansion. To improve manufacturing sustainability, each of these components must independently enhance environmental, economic, and societal benefits (Jawahir, Badurdeen and Rouch, 2013). The 6R (Reduce, Reuse, Recycle, Redesign, Recover, and Remanufacture) method was introduced, assisted by three new Rs beyond the 3Rs included in green manufacturing. Reducing contributes to the elimination of energy, materials, and other assets, along with reducing emissions and waste management, in the 6R method (Jawahir and Jr, 2007). The reuse of end-of-life products or elements in the following life cycles is termed reusing. Recycling is the process of converting waste materials into novel materials. Recover entails the gathering of products at the end of their useful life for reuse in subsequent lifecycle products, whereas Redesign places emphasis on the utilization of recovered materials, components, and resources in the redesign of next-generation product lines. Remanufacturing concentrates on reprocessing previously used goods in order to restore them to a like-new situation by reusing as many components as possible (Enyoghasi and Badurdeen, 2021). To implement the 6Rs and allow closed-loop material flow, their effects on products, processes, and systems must be taken into account at the same time (Jawahir and Bradley, 2016).

Service-Oriented Manufacturing

Services and products differ mainly in terms of the form of their input and output, delivery, and consumption (Kianto and Andreeva, 2014). The strategy of Service-Oriented Manufacturing (SOM) is a newer type of manufacturing that integrates servitization into the traditional manufacturing industry (Zhen, 2012). The degree of service orientation is calculated as the share of service value added in manufacturing exports. The service input comes either from within the country or from abroad, which is quantified by domestic or foreign servitization, respectively (Delaram *et al.*, 2021; Rezapour Niari, Eshgi and Fatahi Valilai, 2021).

The cloud platform for manufacturing services for small and medium enterprises is a networked manufacturing platform. It is based on the research of the service platform ASP, which has been merged with the Cloud manufacturing service model, the characteristics of small and medium-sized enterprises, and the comprehensive implementation of cloud computing, cloud security, and the Internet of Things (Aghamohammadzadeh and Fatahi Valilai, 2020). It is a newer platform for networked production services initiated by technologies such as the Internet. It can effectually develop network-based sharing of production resources and cooperation among small and medium-sized enterprises (Radmanesh, Haji and Fatahi Valilai, 2021). Manufacturing services are part of modern services. However, by providing modern manufacturing services, production can be improved. The proportion of medium-sized services, the logical allocation and use of resources, the reduction of energy consumption, and environmentally friendly production. Based on the development of manufacturing enterprises, given that product manufacturing is highly competitive in terms of cost, technology, function, and quality, it is indispensable to transform into service-oriented manufacturing. To obtain the goal of providing differentiated products, the value created in the production procedure of the product is far less than the value created in the service phase.

Technology in Sustainable Manufacturing

Sustainable manufacturing has benefited greatly from technological improvements and from the other side, the contribution of big data analytics, artificial intelligence, machine learning, blockchain, and other technological innovations in applying sustainable manufacturing has been explored in greater depth (Menon et al., 2022). To keep up with the changing in today's fiercely competitive world, these many industries demonstrate a positive trend forward into automating systems and utilizing technology such as the Internet of Things, cyber-physical systems, and so forth (Ivascu, 2020). Cyber-physical systems and the Internet of Things enable transparency in production by tracking resource consumption in real time, offering production planning with a stable platform for better responsiveness (Chen, Despeisse and Johansson, 2020). Because of the rapidly increasing need for data analytics in sustainable manufacturing, (Jamwal, Anbesh; Agrawal, Rajeev; Sharma, Monica; Kumar, Anil; Kumar, Vikas; Garza-Reyes, 2021) concentrated on comprehending the wider scope of machine learning algorithms in sustainable manufacturing. Producers can benefit from machine learning by enhancing employee safety, effectiveness, and quality of products. Machine learning has achieved successfully manufacturing-oriented prerequisites which include the ability to handle large data sets and complicated problems, the ability to adapt in dynamic habitats at lower costs, lowering the complexity of outcomes, continuing to work with restricted and accessible data, and mapping the connection among procedures. In (Uhlmann *et al.*, 2016), researchers have selected Microsystems technology as the primary method. With its supply chain management and production space research, microelectronics is playing an increasingly important role in Industry 4.0 and cyber-physical systems. There is also a focus on reprogrammable industrial equipment and wireless sensor network new tech. Intelligent modules are created using modular construction. Adaptive components and timely machine upgrades have also been considered as potential methods. In the production line, sustainability is progressively going to be a big desired property. The sustainability metrics are taken into account alongside other standard assembling measurement methods such as time, adaptability, and quality.

Literature Gap Analysis

Table 1 illustrates the literature review of related studies to Cloud manufacturing and focus on analyzing sustainability and logistics effects, industry 4.0. The studied literature papers are investigated for their business model structure and also sustainability mechanism. The results show the Cloud manufacturing-related performance assessment model and the issue of transition from a product/process oriented to a service-oriented business model

Table 1. Literature review gap analysis.

Research Studies	Sustainability and Logistics effects	Industry 4.0. assessment model	Business model transition from product/process-oriented to service-oriented
(Pacchini et al., 2019)		Readiness to implement Industry 4.0	
(Yao, Ying and Ying, 2019)		Readiness evaluation in manufacturing	
(Strandhagen et al., 2017)	Logistics and sustainable business model		
(Li et al., 2014)		Trust evaluation	Cloud manufacturing service platform
(Siderska and Jadaan, 2018)			Service-oriented technologies
(Zhou, Zhang and Fang, 2020)	Logistics service scheduling	Manufacturing provider selection in Cloud manufacturing	
(Wu, Jia and Cheng, 2020)	Sustainability	Optimal selection	Cloud manufacturing service composition
(Fisher et al., 2018)	Sustainable process manufacturing route		
(Tao et al., 2015)			Manufacturing service management
(Huang et al., 2013)			Service platform for small and medium sized enterprises
This Paper	Logistics on sustainable Manufacturing	Readiness of Migration to Cloud manufacturing	The transition from product-based to service-based business model

are not considered from a sustainability perspective. All these subjects are commonly approached separately.

BUSINESS MODEL OF CLOUD MANUFACTURING

Initial Theory Description

Recent studies on Cloud manufacturing have focused on optimizing resource allocation for quality of service (QoS), considering cost, and time. They have rarely brought the perspective of sustainability into the discussion, even though sustainability is indispensable in the Cloud manufacturing environment.

In order to achieve beneficial management, convenient users, and reliable transactions of resources and tasks, a framework for a trust evaluation system in Cloud manufacturing has been established and a trust evaluation model for the Cloud manufacturing service platform focused on the field of mechanical manufacturing has been proposed using the study reference model in (Li et al., 2014) and is illustrated in Table 2.

- Time Control
- Economic Efficiency
- Processing Quality
- Service Attitude
- Business Scale
- Logistics Effectiveness

Trust Level Scope Definitions

Based on research conducted in (Li et al., 2014), trust-level linguistic explanations and the scope of values in the discourse domain are interpreted. Based on the characteristics of the Cloud manufacturing service platform and existing requisites, a hierarchical and figural model as illustrated in Table 3 for reputation assessment was defined using the study in (Feng and Huang, 2018).

Logistics is one of the main elements in a company's transition from product-oriented manufacturing to service-oriented manufacturing. Logistics service runs through all links of the service-oriented production network. The cooperation of various formistics actors forms an organic whole and

Table 2. Trust evaluation.

Trust Level	Linguistic definitions	Scope of values on discourse domain
A	Fully trustworthy	(0.9,1]
B	Very trustworthy	(0.8,0.9]
C	Largely trustworthy	(0.6,0.8]
D	Medium trustworthy	[0.4,0.6]
E	Basic trustworthy	[0.2,0.4)
F	Little trustworthy	[0.1,0.2)
G	Untrustworthy	[0,0.1)

Table 3. Individual evaluation model.

Evaluation Object	Service Instance	Service Product	Service Owner
Individual Evaluation Model	Rapidity Reliability Quality Economic efficiency	Description relevance Technology capability Quality assurance	Third-party verification Technology competence Business credibility

coordinates the fulfilment of logistics service tasks. Based on the characteristics of the service-oriented production model, the need for logistics service capabilities will increase to better serve different enterprises and customers. Despite the importance of logistics in service-oriented manufacturing, there are few works that address the requirements of logistics in service-oriented manufacturing and the function of logistics in the success of the transition to service-oriented manufacturing. Moreover, for criteria of performance evaluations, the paper proposes Table 4 in which all operational aspects of Cloud manufacturing systems for fulfilment of manufacturing services and the required logistics beside quality of service and environmental aspects are considered.

Platform & Service-Provider-to-Customer

The Cloud manufacturing service provider and operator are the same. In the classic top down B2C model, Cloud manufacturing service providers provide platform operation services. Customers are required to publish Cloud manufacturing requirements on the platform. And platform providers will directly provide manufacturing services.

Scope of application: in this scenario, many Cloud manufacturing service providers are also customers. This business model is suitable for the connection between large enterprises with abundant manufacturing resources and manufacturing capabilities.

Platform & Service Provider-to-Customer & Service Provider

The Cloud manufacturing service provider and the operator are the same. Different from the first model, on the platform, Cloud manufacturing service providers can be seen as individuals who provide manufacturing services. The main feature of this business model is that platform operators not only provide manufacturing services but also allow third-party manufacturing resource providers to use the platform.

Scope of application: this type of business model is suitable for collaborative manufacturing between different companies (especially small batch customization), that is: multiuser collaboration to complete a certain stage of manufacturing/multi-user collaboration to complete certain cross-phase manufacturing (such as the design of military products in the full life cycle) cross-enterprise collaboration.

Table 4. Proposed evaluation system.

Aspect	Criteria	Functional Description of metric
Service	Attitude of the customer service employees	An indicator that measures the friendliness of the employees.
	Level of the technology	An indicator that measures the technology customer service applies
	Time to respond	An indicator that measures the timeliness of customer service
	After-sales customer service	An indicator that measures the service level of after sales customer service
Logistics	Costs of transportation and logistics	
	Earliness/tardiness	
	Service level of logistics	
	Loss during transportation	
Environment	Energy consumption	An indicator that measures organizational energy use.
	CO2 emission	An indicator that measures organizational impacts on air quality, relative to standards for what such impacts ought to be to ensure human well-being
	Water emission	An indicator that measures organizational water use relative to an allocated share of locally available renewable supplies.
	Solid waste assimilation	An indicator that measures organizational emissions of solid wastes relative to an allocated share of the earth's assimilative capacity to safely absorb them (e.g., landfill capacities)
	Weight of hazardous waste	An indicator that measures organizational impacts of hazardous waste, relative to standards for what such impacts ought to be to ensure human well-being
Quality	If the product fits the description	
	Price-performance ratio	
	Quality of the product	

Platform & Service Provider-to-Service provider

Operators and customers are merged into one role. Customers play the role of resource publishing and management. Customers can explore and use manufacturing resources through the cloud platform. Scope of application: this model is suitable for building product supply management systems for large enterprises (e.g., container Xchange).

Service & Customer-to-Customer & Servicer

The characteristics of this type of model are that the cloud platform is operated and maintained by a third-party operator, customers, service operators, and platform operators are independent of each other, and all parties carry out supply and demand docking activities around the platform (e.g., Alibaba, eBay).

CONCLUSION

To help product-oriented companies to evaluate their readiness to transform to service-oriented manufacturing like Cloud manufacturing, this paper developed an evaluation system that has four main aspects, including service, quality, logistics, and environment. This evaluation system not only can help them to evaluate their readiness but also can help them to find out the aspects that they can improve and work on to reach the goal of being service-oriented. Moreover, this paper demonstrated the four popular business models of Cloud manufacturing. And how these models can be applied in which line of business and the example companies. The development of Cloud manufacturing can play a positive role currently to help businesses and their customers to combat the negative effect brought by COVID-19. It can activate many idle manufacturing resources and optimize global manufacturing resource allocation.

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