Implementation of Agile Manufacturing in the Shipbuilding Industry: Challenge and Recommendation

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Abstract

Agile manufacturing (AM) is the result of manufacturing strategy evolution in the manufacturing industry, which continues to develop and respond to the challenges of rapid global market changes. The manufacturing industry sectors in many countries, such as the chemical industry, pump manufacturing, steel industry, electronics industry, and automotive industry, have implemented agile manufacturing and positively impacted operational and business performance. Nevertheless, the shipbuilding industry, which differs from a typical manufacturing industry with specific characteristics such as market volatility, customized job orders, and customer-driven, has partially implemented the AM concept at the functional level. However, increasing the company's performance depends on its ability to find and manage the vital factors of agile manufacturing. Therefore, 13 related scientific articles were reviewed in this study, and their proposed factors were comparatively analyzed. The result shows that numbers of vital factors have significant influences in creating an effective implementation of AM in the shipbuilding business. The vital factors of AM are classified into seven groups: technologies, organizational culture, empowerment, manufacturing system, supplier relationship, customer focus, and core competence. These vital factors are considered appropriate for developing an agile manufacturing model in the shipbuilding industry, including the correlation of the vital factors to the operational performance, which is a challenge for further research.

Keywords
agile manufacturing, shipbuilding industry, customized job orders, vital factors of agile manufacturing, operational performance

1. Introduction
Global business competition and market disruption have become a global challenge for all industrial sectors, including the shipbuilding industry. The shipbuilding industry has unique characteristics: capital-intensive, labor-intensive, technology-intensive, and customized job orders (Mandal 2017). In addition, the market for new shipbuilding is always volatile due to strongly influenced by several factors, including economic growth, seaborne trade, oil prices, global steel production output, exploration, and utilization of natural resources, as well as the use of the sea for recreational activities (Hossain and Zakaria 2017; Bruce 2021). Hence, the global shipbuilding market from 2010 to 2019 was very volatile, with a significant decline from 129.9 million DWT in 2010 to 73.2 million DWT in 2019 (BRS Group 2020). Furthermore, even the Covid-19 pandemic, which began in early 2020, has decreased new shipbuilding orders at global shipyards by 41 percent compared to 2019 (VesselsValue 2020).

Considering the characteristics of the shipbuilding industry and market that are constantly fluctuating, customized job orders, and customer-driven, the shipbuilding industry needs to implement agile manufacturing (AM) as an alternative strategy that has become a solution for the manufacturing industry to rapid market changes. AM is defined as the ability to explore the main factors of competitiveness (speed, flexibility, innovation, quality, and profitability) by integrating resources and transforming knowledge into products and services according to customer desires in a rapidly changing market competition environment (Yusuf et al. 1999). Moreover, AM implementation in the manufacturing industry has a significant positive impact on operational performance (Vasquez-Bustelo et al. 2007; Inman et al. 2011; Khalfallah et al. 2020) and increases business performance (Vasquez-Bustelo et al. 2007; Nabbas et al. 2018; Kumar et al. 2019). Therefore, shipyards will be able to adapt to provide a fast and effective response to the competitive environment and speedy market change by implementing AM.

The success of AM implementation in the manufacturing industry is mainly determined by its ability to find and control vital factors of AM. However, from some literature, there are some differences in AM vital factors that scientists have identified, and these variations seem to depend on the industry's environmental aspects. Therefore, this paper aims to identify appropriate vital factors of AM that significantly influence the effectiveness of AM implementation in the shipbuilding industry at the business level and give recommendations for further research.

2. Literature Review

AM is the result of the evolution of the manufacturing strategy paradigm in the manufacturing industry, which continues to develop and respond to the challenges of rapid global market changes (Goldman et al., 1991). AM was born as a solution to the problems of unpredictable and dynamic demand with a higher level of mass customization of the product (Sanchez and Nagi, 2001). AM focuses on organizational operations with project characteristics and jobbing processes because the advantages of mass customization can be achieved by the economies of scope principle (the existing process can be used to obtain greater variety at low cost and time). In contrast to the operational types of batches, flowline, and continuous organizations, where the superiority of the mass production concept is achieved by the economies of scale principle (low cost is obtained from high volume and low variety) (Harrison, 1997).

The AM concept was first introduced at the Iacocca Institute of the University of Lehigh by Goldman et al. (1991) in a report entitled '21st Century Manufacturing Enterprise Strategy'. Further research on the framework and implementation of AM has been done widely by scholars in many industrial sectors in several countries, including the chemical industry, pump manufacturing, steel industry, electronics industry, and automotive industry in England, the United States of America, India, Finland, and Iran (Kumar et al. 2020b).

Some researchers have evolved the AM framework; Gunasekaran (1998) found four enablers of AM, namely: value-based pricing strategies, investments in people and information, organizational changes, and cooperation, with four main criteria: strategies, technologies, systems, and people, which is each consist of several sub-criteria with a total of 11 sub-criteria (Gunasekaran 1999). On the other hand, Yusuf et al. (1999) developed the AM model with four core concepts: core competence management, capability for re-configuration, knowledge-driven enterprise, and virtual enterprises. Dubey and Gunaskaran (2015) developed the AM framework with six criteria: technologies, empowerment, customer focus, supplier relationships, flexible manufacturing systems, and organizational culture. Each criterion has sub-criteria and a total of 29 sub-criteria. Kumar et al. (2019) conclude that AM framework is built of seven pillars and supported by one foundation with seven elements performance indicator roof. Seven pillars (human resources, organizational culture, suppliers, customers, innovation, concurrent engineering, information technology), one foundation (leadership support), and seven elements of performance indicators (customer, financial, business, operational, employee, supplier).

Zhang and Sharifi (2000) developed the AM implementation model consisting of three blocks: agility drivers, agility capabilities, and agility providers. Agility capabilities consist of responsiveness, competency, flexibility, and speed. Achieving agility is done through an assessment to find out the gap and then develop a strategy formulation. Vazquez-Bustelo et al. (2007) described AM implementation model by the relationship between drivers, enablers, and outcomes. AM enablers consist of five strategic areas: human resources, technologies, value chain integration, concurrent engineering, and knowledge management. AM is affected by market turbulence as a driver, AM produces manufacturing advantages (cost, flexibility, quality, delivery, service, environment) and impacts competitive advantage or business performance. Meanwhile, Ramesh and Devadasan (2007) generated AM implementation procedure with 20 criteria based on a literature study on ten papers from 2001 to 2003.

The AM implementation in the manufacturing industry positively impacts company performance. Inman et al. (2011) found that many manufacturing companies adopt lean manufacturing (LM) practices, such as JIT and TQM to reduce costs and improve quality. However, many competing companies also apply the same thing, so many companies lose in the competition. Therefore, many companies are starting to adopt AM practices to improve their ability to respond quickly to customer requests so that many companies are becoming more agile. Based on research on the relationship between the elements of LM (JIT-production and JIT-purchasing) associated with AM and its impact on firm performance, it shows that: (1) a higher level of adoption of JIT-purchasing strategy will affect the higher level of AM firm; (2) higher AM level will have a positive impact on the company's financial performance; (3) higher AM level will have a positive impact on the company's marketing performance; (4) higher AM level will have a positive impact on the company's operating performance.

Khalfallah et al. (2020) conducted a study to determine: (1) the natural relationship between LM and AM practices; (2) the relationship between LM practices (direct/indirect) with organizational performance; (3) the relationship between LM elements is interconnected; and (4) the relationship between AM and organizational performance. Their research on LM practices includes Total Quality Management (TQM), JIT-Production, JIT-Purchasing, and Total Productive/Preventive Maintenance (TPM), while organizational performance is operating performance and financial performance. The research was conducted by distributing questionnaires to 900 manufacturing companies in Tunisia with direct interviews and internet-based surveys of related managers. Where many as 205 questionnaires (22.8%) were filled out and accepted, the data were processed using SEM statistical tools and resulted in the conclusion that (1) LM practice has a direct relationship with AM except for JIT-Production; (2) AM has a positive impact on operating performance; (3) LM practices do not directly contribute to operating performance, but this relationship is significant if through AM; (4) the results are not significant on several variables on financial performance, raising the question that the research conducted is not appropriate to describe the impact of AM, TQM, JIT-Production, JIT-Procurement and TPM variables on financial performance.

Kumar et al. (2020a) noted that several medium-scale (annual turnover > Rs75 crores but Rs250 crores) and large (annual turnover > Rs250 scorer) manufacturing companies in India have successfully implemented or are in the stage of implementing AM. For this reason, the research is intended to determine the impact of AM practices on business in the manufacturing industry in India. Their study used the questionnaire method, and questionnaires were distributed to 500 respondents/companies, with 154 questionnaires (30.8%) returned as responses. Based on the analysis of the existing data, the research results obtained: (1) there is a positive relationship between business performance on AM enabler variable, the relationship between business performance and AM enabler has a value of $r = 0.335 – 0.706$. The highest correlation (0.706) is the relationship between the human resource issues variable and business-related achievements. While the lowest correlation (0.335) is the relationship between the innovation variable and financial performance; (2) AM enablers have a significant impact on business performance; (3) the period for AM implementation has a substantial effect on the success of AM implementation; and (4) the implementation of AM has a high success rate.

In the field of the shipbuilding industry, Moura and Botter (2012) presented an idea for implementing AM with reference to agility capabilities (Zhang & Sharifi, 2000) and four main criteria of AM (Gunasekaran, 1999). As a result, the implementation of AM in shipyards requires tight integration between design, planning, and manufacturing functions. Also, it requires accurate and complete information on all aspects of products, production processes, and operations. Further, Jagush et al. (2020) investigated the implementation of agile production in the pre-fabrication stage of a new shipbuilding project at a shipyard in Germany using three of the four enablers Gunasekaran (1999), namely strategy, technology, and system. The enablers of AM implementation at the pre-fabrication stage at shipyards are a digital representation for the proactive preparation, databased product adjustments, rapid response capability through real-time communication, and optimizing profitability by avoiding scrap.

Many previous studies have evolved the AM model and its implementation in the manufacturing industries, which positively correlated with operational and business performance. Nevertheless, the AM vital factors vary depending on the industry characteristic and business environment of its sector. The AM vital factors of the manufacturing industry, such as the chemicals, pumps, steel, electronics, and automotive, have developed and matured. However, there is no specific development of AM model for the shipbuilding industry at the business level. Therefore, identifying AM vital factors in the shipbuilding industry based on its uniqueness and business characteristics is needed to develop the AM model appropriate for the shipbuilding industry.

3. Methods

This present study has executed by comparative analysis method to identify vital factors of agile manufacturing in the shipbuilding industry. We began the study with the literature review on agile manufacturing articles from 1991 to 2020, but only those articles are shortlisted those proposed vital factors of agile manufacturing. Therefore, the study focused on 13 scientific articles depicted in Table 1.

Table 1. Scientific Articles those Proposed Vital Factors of Agile Manufacturing

No	Authors (Year)	Journal Name	Publisher
1	Gunasekaran (1998)	International Journal of Production Research	Taylor & Francis
2	Gunasekaran (1999)	International Journal Production Economics	Elsevier
3	Yusuf et al. (1999)	International Journal Production Economics	Elsevier
4	Zhang and Sharifi (2000)	International Journal of Operations & Production Management	Emerald
5	Vazquez-Bustelo et al. (2007)	International Journal of Operations & Production Management	Emerald
6	Ramesh and Devadasan (2007)	International Journal of Operations & Production Management	Emerald
7	Raj and Vinodh (2014)	Journal of Engineering Design & Technology	Emerald
8	Dubey and Gunasekaran (2015)	International Journal Advance Manufacturing Technology	Springer
9	Sindhwani and Malhotra (2016)	International Journal Process Management & Benchmarking	Inderscience
10	Sindhwani and Malhotra (2017)	Benchmarking: An International Journal	Emerald
11	Goswami and Kumar (2018)	Measuring Business Excellence	Emerald
12	Nejatian et al. (2018)	Benchmarking: An International Journal	Emerald
13	Kumar, Singh and Jain (2020b)	International Journal of Quality & Reliability Management	Emerald

The next step is collecting all vital factors identified by 13 scientific papers. All factors are analyzed by qualitative comparative; hence, any vital factors repeated in more than one article or have similar meanings are grouped together. The factor's weight is calculated from the occurrence of the variable divided by 13. Then, from comparative analysis, the factors with a weight of 0.23 or more are proposed as vital factors of agile manufacturing in this study.

4. Data Collection

The vital factors of agile manufacturing proposed by 13 scientific articles were collected and found 345 vital factors of agile manufacturing. The vital factors that repeated and similar meanings were grouped together. The present study shows 183 factors of agile manufacturing as the result of the first step of comparative analysis. However, due to space constraints, only the summary of the comparative analysis is shown in Table 2.

Table 2. Summary of Comparative Analysis of AM Vital Factors

Frequency of Vital Factors	Weight (Frequency/13)	Number of Vital Factors
1	0.08	114
2	0.15	34
3	0.23	17
4	0.31	9
5	0.38	4
6	0.46	2
7	0.54	3
Total		183

5. Results and Discussion

In the result of a comparative analysis of the existing factors from 13 scientific articles, the weight factors of 0.23 or more are identified as vital factors of agile manufacturing, as shown in Table 3.

Table 3. Final Result of Comparative Analysis of AM Vital Factors

Group	Vital Factors	Articles													Freq	Weight
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**		
Technologies	Integrated information technology		1			1	1	1		1	1	1		1	8	0.62
	Enterprise resource planning (ERP)								1	1		1		1	4	0.31
	Automated-guided vehicle systems						1	1	1					1	4	0.31
	Advanced design technologies					1				1				1	3	0.23
	Advanced manufacturing technologies					1				1				1	3	0.23
	Electronic commerce	1							1					1	3	0.23
Organizational culture	Organizational structure						1	1			1	1			4	0.31
	Cooperation (internal and external)				1				1					1	3	0.23
	Top management support		1							1	1				3	0.23
	Nature of management						1	1				1			3	0.23
Empowerment	Delegation of authority			1			1	1	1			1	1	1	7	0.54
	Manpower utilization						1	1	1	1	1	1		1	7	0.54
	Team working			1		1		1	1				1	1	6	0.46
	Training and education		1	1		1							1	1	5	0.38
	Status of productivity						1	1				1			3	0.23
Manufacturing system	Concurrent engineering	1	1	1				1		1			1	1	7	0.54
	Cost-effectiveness				1		1	1				1			4	0.31
	System integration and database management		1			1		1							3	0.23
	Volume flexibility				1				1			1			3	0.23
	Design improvement						1	1				1			3	0.23

Group	Vital Factors	Articles													Freq	Weight
		1	2	3	4	5	6	7	8	9	10	11	12	13		
	Production planning and control system		1			1	1								3	0.23
	Production methodology						1	1				1			3	0.23
Supplier relationship	Close relationship with suppliers	1		1		1		1	1				1	1	7	0.54
	Outsourcing						1	1				1		1	4	0.31
Customer focus	Product quality			1	1		1	1	1			1			6	0.46
	Customer response adoption						1	1	1			1	1	1	6	0.46
	Customer satisfaction			1					1				1	1	4	0.31
	Product life cycle management			1			1	1			1				4	0.31
	Long term and trust-based relationship with customers			1		1							1	1	4	0.31
	customer-driven innovation			1									1	1	3	0.23
Core Competence	Multi-skilled and flexible people			1	1					1	1		1	1	6	0.46
	Knowledge management		1		1	1		1				1			5	0.38
	New product development			1	1			1					1	1	5	0.38
	Virtual enterprise formation tools	1	1					1		1	1				5	0.38
	Change in business and technical processes						1	1				1			3	0.23

The vital factors of agile manufacturing, which are a result of comparative analysis, are classified into seven groups as follows:

a. Technologies

The company uses software, hardware, and systems that can quickly respond to the market. Integrated information technology is required to integrate design, manufacturing, and administration, and also a means to share information effectively and efficiently. Integrated information technology drives the company to become agile by implementing an integrated customer/supplier information system and an integrated manufacturing information system (Vazquez-Bustelo et al., 2007). The tasks not to be supported by paperwork are removed and integrated by IT (Ramesh and Devadasan, 2007). Besides that, enterprise resource planning (ERP) has been adopted by shipbuilding companies widely. The use of automated-guided vehicle systems, advanced design technologies using computer-aided design (CAD) tools, and advanced manufacturing technologies, including robotics and CNC machines, have impacted to speed up the production process. In addition, electronic commerce is growing in the digital transformation era, which could influence shipbuilding agility for the future.

b. Organizational Culture

The organizational culture that creates a competitive performance environment empowers human resources and involves every personnel in innovation programs to grow company performance. Organizational structure can be executed to achieve organizational agility by cutting down organizational layers and building cross-functional teams and their management (Ramesh and Devadasan, 2007). The factors of organization culture, organization structure, and management are internal strategic factors of shipbuilding competitiveness (Ma'ruf et al., 2006). Besides organizational structure, the nature of management is also a management responsibility enabler of agile manufacturing (Raj and Vinodh, 2014). Cooperation (internal and external) and top management support are an organizational culture that is embedded in all agile companies.

c. Empowerment

The management takes policy for strengthening HR to increase productivity and minimize waste, including training and assignments in different activities to create HR capabilities in adaptation, innovation, collaboration, and speed of response to make appropriate and effective decisions (Dubey and Gunasekaran, 2015). Furthermore, to empower the people, the management needs to implement essential policies such as delegation of authority to avoid the long process of making decisions and manpower utilization to reduce the cost and increase productivity. Therefore, the delegation of authority, manpower utilization, team working, training/education, and productivity status could be considered vital for agile manufacturing.

d. Manufacturing System

The manufacturing system can produce products with different advantages from similar products by using the latest technology and having outputs that benefit the company. Key variables such as concurrent engineering, cost-effectiveness, system integration and database management, volume flexibility, design improvement, production planning and control system, and production methodology could be vital factors for implementing agile manufacturing. Specifically related to production methodologies, on the way to the 21st century, new ship production technology has been developed by optimizing the use of the latest technology, known as modular construction production technology. Modular construction is the engineering of production technology by building several modules as parts of the ship, which are then assembled into one complete ship (Abdullah, 2011). In addition, engineering and database management are internal strategic factors in the shipbuilding industry for sustainable competitiveness (Ma'ruf et al., 2006).

e. Supplier Relationship

The role of cooperation with suppliers is seen as a strategic partner, including supplier accountability in terms of meeting the needs of raw materials, materials, and equipment needed by the company following the required quality and quantity, as well as sharing risks in the event of product failure. Close relationship with suppliers is vital in achieving material Just in Time (JIT) to support on-time delivery of products. Furthermore, the relationship with suppliers to obtain suitable quality materials and reasonable price is an external strategic factor in building the shipbuilding industry's global competitiveness (Ma'ruf et al., 2006). However, the shipbuilding industry with labor-intensive characteristics needs outsourcing to supply labor from the vendors.

f. Customer Focus

The company's policy is to maintain customer satisfaction through efforts to meet customer needs and even exceed customer expectations by offering products or services in the shortest possible time and at reasonable prices. Increasing customer expectations led to the pursuit of quality by manufacturers through the implementation of a quality concept such as total quality management (TQM), statistical process control (SPC), and quality function deployment (QFD) to respond voice of customer (Yusuf et al., 1999). Product quality, customer response adoption, and customer satisfaction are essential matters that need to be organized well, including product life cycle management, long-term and trust-based relationship with customers, and customer-driven innovation. These vital factors of agile manufacturing related to customer focus will impact the increasing operational performance.

g. Core Competence

The company must build core skills and knowledge of human resources and organizations so that they have the core ability to access a broader market through collaboration and provide value to customers in products through the change in business and technical processes that are difficult to imitate by competitors (Yusuf et al., 1999). These vital factors are not found in Gunasekaran (1999) or Dubey and Gunasekaran (2015), especially variable of the developed business practice difficult to copy, as one of the company's competitive advantages. Besides that, virtual enterprise tools could be used to fulfill owner requirements for complex new products developed through a global network and work collaboratively with other companies.

Many benefits are obtained from AM implementation, such as improved quality of products, competitive cost of products, and better delivery speed (Kumar et al., 2020b). These benefits are related to the indicators of shipyard operational performance, that are the quality of the products should be met to customer requirements, the realization of costs that do not exceed the budget, and delivery of products must be on time according to the contract. Therefore, achieving these indicators will make shipyards more competitive in today's disruption era.

6. Conclusion and Recommendation

AM becomes a challenge for the shipbuilding industry as an alternative solution to resolve the problem of a fluctuating market environment. As a result of the comparative analysis of AM factors proposed in 13 scientific articles, several factors were considered appropriate vital factors in creating an effective implementation of AM in the shipbuilding industry at the business level. The practical implementation of agile manufacturing positively impacted the operational performance of shipyards. These vital factors are classified into seven groups: technologies, organizational culture, empowerment, manufacturing system, supplier relationship, customer focus, and core competence. Furthermore, the correlation between the vital factors will help the shipyard formulate a strategy to improve operational performance and increase shipyards' competitiveness amid increasingly disruptive global competition. This study provides appropriate vital factors of agile manufacturing for the shipbuilding industry at the business level distinct from previous research at the functional level. In further research, the agile manufacturing model in the shipbuilding industry may be developed using these vital factors, including the correlation of vital factors and the operational performance of the shipyard.

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