

Agile Manufacturing System: Benefits, Challenges, and Critical Success Factors

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Abstract—Identified as a manufacturing system that enables a production company to attain flexibility and also respond to the changing demands of the customers by manufacturing diverse innovative products at reduced cost and lead time, Agile Manufacturing System was given a broad definition by the paper, which observed that the manufacturing technique applies agility at every stage of manufacturing; from design stage through planning and production stages. Apart from reduction in volumes, time-to-market, quantities, lead and cycle times, as well as increase in throughput, market share, product mix, new product development, changeover, flexible machines and equipment, and enhanced flexible and responsive processes, the other benefits of agile manufacturing highlighted by the paper include saleable product design, IT based organization, high quality products, cooperation between supply chain, empowered employees, among others. After discussing some of the challenges of the manufacturing system, the paper explained that addressing all dimensions of organization, people, technology, management and accounting practices within the manufacturing system will mitigate most of the enumerated challenges. Before discussing the other critical success factors of the manufacturing approach, the paper noted that the first factor that is responsible for its successful implementation in a manufacturing company is the management involvement and commitment. The paper later concluded by noting that manufacturing companies need to plan and carefully implement the concept of agile manufacturing, while understanding that the concept is a journey and not an objective that has a foreseen end.

Keywords—*agile manufacturing, automation, flexibility, lean production system, technology, quality, innovation*

1. Introduction

To remain competitive in the ever-dynamic 21st century enterprise, manufacturing companies are repositioning themselves by embracing production strategies that will ensure timely production of high quality products that will guarantee customer satisfaction. According to Okpala, Anozie, and

Mgbemena (2020), the need to adopt a unique production technique that will address the numerous challenges of manufacturing firms, and also reposition them for world-class manufacturing will not only reduce their losses, but will also increase their throughput and profitability.

One of such manufacturing strategies is Agile Manufacturing System (AMS). Manivelmuralidaran (2015), observed that the concept of agility refers to a business model which makes an organization immune to damage caused by unpredictable events and changing circumstances, which is achieved by the organization being able to react and adapt rapidly. However, Srivastava et al. (2011), explained that agile manufacturing is a “business strategy aimed at providing an enterprise with the capabilities for success in the current changing environment that demands flexible solution.” They noted that it evolved because of the limitations of earlier paradigms, therefore tools of other manufacturing paradigms can also be used for the manufacturing technique.

In the advancement of manufacturing methodology, agile manufacturing is considered as the next step after lean production system, as it does not only lead to the manufacturing of high quality products at less the time, but also efficient in promptly responding to modifications in the demands of the customer.

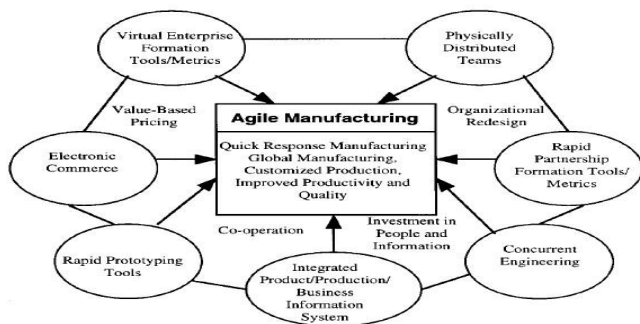
Agile manufacturing is a term applied to an organization that has created the processes, tools, and training to enable it to respond quickly to customer needs and market changes while still controlling costs and quality. At the mention of Agile manufacturing, maximum flexibility comes to mind, as it refers to fast thinking methods and clever approaches to timely response to consumer needs, despite unforeseen occurrences in market situation. AMS is mainly focused on achieving efficiency by delivering high quality products at a minimal cost, as well as an innovative tailored solution to the consumers’ needs.

Agile manufacturing can also be defined as the capability to survive and prosper in a competitive environment of continuous and unpredictable change, by reacting quickly and effectively to changing market, driven by customer designed products and services. The key emphasis of AMS is to completely and

explicitly understand the customer requirements and translating them into value quicker and cheaper than other competing enterprises. Gupta and Mittal (1996), explained that AMS is “a business concept that integrates organization, people and technology into a meaningful unit by deploying advanced information technologies and flexible and nimble organizational structures to support highly skilled, knowledgeable and motivated people.”

Ribo (2019), stated that an “enabling factor in becoming an agile manufacturer has been the development of manufacturing support technology that allows the marketers, the designers and the production personnel to share a common database of parts and products, to share data on production capacities and problems — particularly where small initial problems may have larger downstream effects.” He emphasized that AMS “is a general proposition of manufacturing that the cost of correcting quality issues increases as the problem moves downstream, so that it is cheaper to correct quality problems at the earliest possible point in the process.”

As shown in Figure 1, AMS which incorporates value-based pricing, co-operation among the various departments, organizational re-design, and investment in staff and information, also entail quick response manufacturing, global manufacturing, customized production, and enhanced productivity, and quality of manufactured products.



Agile manufacturing template. Source: Ribo (2019)

In Agile manufacturing system, agility is applied at every stage of manufacturing; from design stage through planning and production stages. At the design stage, the feedback from customer are reviewed and considered for innovations. Tools such as Computer Aided Design (CAD) and other fast, articulate engineering tools can be employed. In a similar manner for the planning stage, tools such as Scheduling, Materials requirement planning (MRP), Gantt Charts and the likes are used. Lastly for the production stage, the main functionality is process modelling, monitoring, diagnosis, control, inspection and assembly. Artificial Neural Networks and Fuzzy Logic Systems techniques are frequently applied to the production functionality for improving the learning ability and adaptability of systems (Wang, 2001).

Also, Kidd (1994), noted that agility in agile manufacturing is achieved by integrating three basic

resources in a coordinated and independent system. He listed the resources as (i) an innovative management organization and structure, (ii) a worker base consisting of highly trained, motivated and empowered people and (iii) advanced, flexible and intelligent technologies.

Although AMS is inspired by Lean Production System (LPS), and also seems to be similar with it, it is however a different manufacturing approach. According to Khan and Dalu (2015), LPS is a response to competitive pressures with limited resources, and is a collection of operational techniques focused on productive use of resources. While AMS, on the other hand, is a response to complexity brought about by constant change, and is an overall strategy focused on thriving in an unpredictable environment.

2. Benefits of AMS

According to Gunasekaran et al. (2018), “as a means of remaining competitive, agile manufacturing stresses excellence on a wide range of competitive objectives rather than cost or quality alone.” They noted that most importantly, AMS emphasizes being first to market with leading-edge customized products, delivered at the cost of mass production, and that such products should surpass customer expectations and be able to derail competitors’ plans to the extent that the products become change agents.

Agile manufacturing typically builds on what is good in lean manufacturing, by adding individual power and opportunities created by new technologies, as well as integrating design and manufacturing as one entity in developing ways to interact with customers and suppliers on product demand and inventory stock. Often described as the integration between Lean and Flexible manufacturing systems, AMS emphasizes on excellence on a broad range of competitive aims instead of just quality or cost.

Manivelmuralidaran (2015), pointed out that the benefits of agile manufacturing are “short time-to-market, fast new product development, short/fast order processing, low volumes, low quantities, high product mix, configurable components, fast supplier deliveries, short lead times, short cycle times, highly flexible and responsive processes, highly flexible machines and equipment, use of advanced cad/cam, quick changeover, as well as empowered employees.”

The benefits of AMS also include the following:

Saleable Product Design - one of the key steps of agile manufacturing involves having a communication link with consumers to enable access to feedback information, which is in turn worked into the product to create a better product that will ensure customer satisfaction. Hence, in an organization that practices agile manufacturing, the products are more saleable as it involves the customers’ opinion during production.

IT Based Organization - due to the high demand of agile manufacturing in terms of technology, the system usually has a sophisticated technology which helps it to stay efficient and on time. With this feature, quick decisions which keep production flowing are made.

High Quality Products - Agile manufacturing is an ideal approach for manufacturers that have competing products. In such companies, little variations in product delivery or quality can have a big impact on sales as well as reputation. To avert this great menace, it's necessary to manufacture high quality products at the best possible cost. AMS therefore helps to meet customer's needs without compromising quality.

Cooperation Within Supply Chain - Manufacturers who adopt AMS usually have very strong relationships with their suppliers, together with multiple cooperative teams which work within the company to deliver products effectively. Such manufacturers can also adapt their facilities rapidly and negotiate new contracts with their suppliers quickly, in response to changing market forces. This means that producers can ramp up production quickly to meet higher demand, or slowdown production if required. In addition, they can rapidly re-design their products if issues emerge. This enables the entire supply chain to be able to align with consumers' demand.

Market Share Advantage: AMS is very useful in industries that are highly competitive and conditions can change quickly. If the method of manufacturing employed in an organization within such companies are not able to adapt fast to changes, they will likely be left behind and of course lose their competitive advantage and market share. Agile manufacturing is applied as a way of keeping up with the competitors, and in some cases stay ahead of the competition through constant innovation and designing of new products.

3. Challenges of AMS Implementation

Despite the identified benefits of AMS implementation, many manufacturing companies that adopted the manufacturing technique are still finding it difficult to excel due to their inability to overcome the challenges of the manufacturing system. According to Moradlou and Mehrdad (2015), the major challenge of AMS implementation is company's dependability on the key employees, which can be considered as a bottleneck in different stage of the production when an employee is absent due to illness or vacation purposes. They explained that "one way to overcome such a barrier is to continuously change the employee's role and responsibilities to give them the chance for learning all the processes required in the production, and be familiarized with the agile techniques."

One of the most important challenges identified by Manivelmuralidaran (2015), is the interdisciplinary design requirement for agile manufacturing systems in

the new knowledge intensive era. This entails much more than just applying the knowledge domains of psychology as well as other organizational sciences, but in exploring other areas between these disciplines by managers and system designers as well as integrators of agile manufacturing system design. More so, where these disciplines overlap could also give new insights, new knowledge and new solutions to its development.

Manufacturing policies which fail to adopt extended value chain and new strategies, hinder the successful implementation of AMS measures, as well as rigidity in strategies and policy decision for action. As today's manufacturing systems require smaller lot sizes, shorter delivery times to market and power manufacturing costs, the lack of organizational structure which promote non-hierarchical management style is also a challenge, as work environment needs to stimulate and support individual cooperation as well as teamwork. Also, the inadequacy and need for computer based technologies for information integration and knowledge sharing is also a great concern.

Sustainable competitiveness is often times difficult due to performance measures of cost, speed, quality, flexibility, dependability and innovation which are no longer sufficient in an agile manufacturing system. Of equal challenge is the dependence of agile manufacturing to highly skilled and motivated workforce, which are scarce from a wider skill base set of future workforce, spanning all age, gender and social status.

Other challenges of successful agile manufacturing system implementation include but not limited to the following:

Employee Resistance: This is a people-factor challenge. The employees in an organization are often the ones to directly apply the new tools and methods as set out by agile manufacturing. If these persons have doubts or inabilities in the implementation of the process, they tend to resist it. This resistance could be as a result of various reasons such as not having trust in the employer, fear of losing their jobs after the new method is implemented, or even lack of satisfaction on remuneration from the job. It is therefore very important to have a good employer-employee relationship for effective and successful implementation of agile manufacturing.

Understanding the Method: AMS is a dynamic process and quite not suitable for some processes requiring complex decision-making system or formal planning. The implementation of agile manufacturing requires a lot of experience and skill by the implementation team. The inability to have a well trained and experienced team will make understanding the process quite difficult. Therefore, it is paramount to fully understand the process and what it entails for an effective and successful implementation.

Philosophy/Cultural Challenges: Adopting agile manufacturing practice requires complete shift from existing methods. This is often difficult for managers and employees to embrace, as any organizational culture that is in contrast with the AMS culture will make it difficult for the new system to be adopted. Miller (2013), pointed out that it has been observed from literature that agile manufacturing thrives better in a low management control environment, as opposed to a high management control environment for traditional methods of project management.

Implementation Time: The agile manufacturing process due to its complex nature requires a considerable amount of time from the start to the completion of the involved processes. Often times, management could be under pressure and achieving success within the stipulated time may not be feasible. This could lead to lack of interest by the owners of the business, and might also lead to frustration on the part of the employees who are implementing the new manufacturing strategy. Experience has shown that patience is required for a successful outcome of AMS.

Managerial Challenges: The successful implementation of agile manufacturing involves certain expectation from management and leadership of an organization. Some of these expectations may not always be met by management. This is a major challenge to the successful implementation of the manufacturing technique.

These expectations include: (a) **Effective communication:** The management, employees and implementers of the new method require effective communication and sometimes face to face conversation which is the best form of communication. Close cooperation is expected amongst the entire team involved in the project. (b) **Commitment to the new task:** It is equally important that management show commitment to the demands and expectation of developers and clients to ensure overall success of the project. If this is not done, the project might fall off track. Maintaining an effective feedback system with developers will aid in ensuring the right areas are being focused on if any setbacks occur. (c) **Proper Documentation:** having a detailed documentation is essential to avoid official misunderstandings and misrepresentation of information.

Addressing all dimensions of organization, people, technology, management and accounting practices within the manufacturing system will mitigate most of these challenges enumerated. This will also, ensure the rapid growth, development and eventual introduction of agile manufacturing system within the productive sector of the nation's economy.

4. Critical Success Factors of AMS Implementation

Due to the complexity and comprehensive nature of agile manufacturing system, successful and effective implementation cannot be achieved on a platter. From the knowledge obtained from local

organizations, and the review of literature, the following has been identified as the critical success factors of the manufacturing technique.

Management Involvement/Commitment: The first factor that is responsible for the successful implementation of agile manufacturing system in a manufacturing company is the management involvement and commitment. In an organization, every decision-making stem from the management cadre, as the decision to adopt the new method down to its planning and execution all emanate from them. Hence, to achieve success, the management need to have an in-depth knowledge of the process, and equally believe in the expected outcome, while also exercising some patience due to the time it usually takes to make the switch from traditional manufacturing methods. Every other factor of success depends solely on this major factor, as the careful consideration and application of the steps needed to achieve success emanates from the top management down to the technicians.

Hence, the attitude of the management will influence that of the entire staff, as it is their duty to enforce long term commitment in the development team. They also need to ensure that there is joint understanding of the entire process by all the units of the organization, as well as corporation amongst them, bearing in mind that AMS requires planning and performance within every stage of the manufacturing process in order to achieve overall effectiveness.

Expertise/Skilled Team: experienced and skilled workforce is very vital to successful AMS implementation. In the absence of adequate number of skilled workforce, a firm should incorporate and invest in intensive trainings of its workforce to ensure optimal output. According to Okpala and Egwuagu (2016), to overcome the challenge of unskilled workers, their knowledge and skills should be enhanced through the organization of workshops and trainings. They noted that "the trainings which must be broad based should be suitably designed to address all specific topics, rudiments, approaches, and procedures."

Communication: Effective communication increases the success in terms of development and implementation of the manufacturing strategy. With close communication, problems are identified while solutions are proffered timely. Liu and Zhia (2017), posited that where by various methods of communication are useful in ensuring effectual and timely communication in AMS, face-to face communication has been identified to be highly effective.

Team Collaboration: The close collaboration of teams promotes the process of development and implementation of agile manufacturing. This can also inspire team enthusiasm and in turn help in achieving success with the completion of the project in good time. If the team treats collaboration negatively, the switch to the new method of manufacturing cannot be

achieved as planned. This is because the close collaboration of teams enables them to work toward same goal, and achieve agility in the various processes involved in the cycle of production and delivery of goods and services to the consumers.

Automation of manufacturing Process: An agile system is expected to respond promptly to unforeseen situations in business, and equally remain profitable in the face of market instabilities. This response to the prevailing situation is said to be agile since it is expected to be smart and timely. To achieve this agility successfully, the need for manufacturing automation can never be over-emphasized, as it entails deploying of automated human processes, information and communication technologies, which helps to integrate data across the business processes. Three kinds of automation in manufacturing has been identified:

i. Intelligent automation – Waters (1996), noted that the intelligent automation is computer controlled, with closed-loop feedback systems and in-built diagnostic capability which operate as integrated but independent networks of Computer Numerically Controlled (CNC) machines, feeders, controllers, actuators and sensors connected by conveyors. Supported by advanced network communications and distributed computer systems, they can be programmed to conduct a wide range of machining and assembly tasks. Intelligence and mobility are crucial for speedy customization and replication of the core modules of intelligent products at little or no extra cost.

ii. Flexible automation - Although valuable time is spent to retool and change over, flexible automation has an advantage of being adaptable and able to perform a wider range of operations.

iii. Mass automation - In mass automation, machines had been in-built to perform specific operations and cannot be altered, retooled, or re-programmed to perform other operations.

Production Methods: The method of production employed in a manufacturing firm can make or mar the success of AMS implementation. The application of robust design in manufacturing companies has yielded great benefits to the manufacturers. According to Okpala and Ihueze (2019), robust design entails the reduction of variation in a process through the robust design of experiments, with overall objective to produce high quality products at low cost to the manufacturer. Also, Nwankwo and Ihueze (2020), noted that over the years, this method has proved to be reliable in modelling of a product or process, as it focuses on eliminating the noise factors in a system at the design stage, thereby reducing cost of failure and or maintenance for the system. With Robust methods, waste is eliminated and optimum quality is guaranteed to be within the acceptable standards.

Technological Know-how: For success in the implementation of agile manufacturing system, companies and organizations need to adopt new

technologies to enhance their competitive advantage. Gunasekaran et.al. (2018), explained that intelligent synthesis of tools and methods are important for satisfying consumer's need from all fronts.

Staff Empowerment: Every employee in an organization has a role to play in the way value is created and added to the consumer. Employee empowerment refers mainly to training, teaming, and involvement of the employees in decision making. When a market is unstable, agile measures are mostly required to keep the organization going profitably, hence the need for employees' empowerment to ensure success in the implementation of the manufacturing technique.

5. Conclusion

The successful implementation of agile manufacturing system which enhances a company's ability to achieve diverse customers' demand at both reduced cost and lead time, also enables it to beat the competitors and excel in a market of continuous change. Although there are numerous benefits of agile manufacturing system, the benefits cannot be realized overnight due to the numerous associated challenges which must be effectively tackled.

In recent times, companies and organizations are moving towards agile manufacturing. However, it has been observed that often times, this transition is not planned, as it just happens as a result of innovation and moving with trend. This tends to lack strategic direction. Therefore manufacturing companies need to plan and carefully implement the concept of AMS, while understanding that the concept is a journey and not an objective that has a foreseen end.

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