Smart Manufacturing and Supply Chain Management

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***Abstract*—In the fourth industrial revolution, smart manufacturing will be characterized by adaptability, resource efficiency and ergonomics as well as the integration of customers and business partners in business and value processes. Business model, operations management, workforce and manufacturing process all face substantial transformations to reasoning the manufacturing process. This paper explores the impacts of smart manufacturing on supply chain management, and develops several propositions to improve supply chain performance under the context of smart manufacturing.**

Keywords—smart manufacturing; supply chain

I. Introduction

Smart manufacturing has been regarded as one of the essentials in the fourth industrial revolution. Driven by the Internet and the fast development and application of other information technologies, the future manufacturing will be characterized by adaptability, resource efficiency and ergonomics as well as the integration of customers and business partners in business and value processes. Smart Manufacturing envisions the enterprise that integrates the intelligence of the customer, its partners and the public. It responds as a coordinated, performance-oriented enterprise, minimizing energy and material usage while maximizing environmental sustainability, health and safety and economic competitiveness [1].

Many countries have started to actively play leading roles in shaping the fourth industrial revolution. For example, German industry initiated the "Industry 4.0" forward-looking project since 2012 [2]. The "Industry 4.0" project takes into account important aspects of location from a technological, industrial and social perspective. Germany already plays a leading role in the field of software-intensive embedded systems, particularly in the car industry and engineering. The focus regarding the topic of "Smart Factories" is on intelligent production systems and processes and the realization of distributed and networked production sites.

In the United States, an initiative known as the Smart Manufacturing Leadership Coalition (SMLC) is also working on the future of manufacturing [3]. SMLC is a non-profit organization of manufacturing practitioners, suppliers, and technology companies; manufacturing consortia; universities; government agencies and laboratories. The aim of this coalition is to enable stakeholders in the manufacturing industry to form collaborative R & D, implementation and advocacy groups for development of the approaches, standards, platforms and shared infrastructure that facilitate the broad adoption of manufacturing intelligence.

In china, with the fast and steady development and the deepening of China's economic restructuring, the demand of smart manufacturing to realize transformation and upgrading will gradually appear [4]. China has been working on an innovative industrial model called "Smart Factory 1.0." Some automation companies, research institutes, and system integrators are working to define this innovative industrial model for China's manufacturing, to meet the demands of China's industrial reform. Unlike the "Industry 4.0" project, the "Smart Factory 1.0" is more focused on the practical implementation of existing leading technologies as needed by industries in China, rather than focusing on the most advanced technology.

Many of current researches and reports are focused on the issues related with technologies and standards, this paper will mainly focus on the supply chain related issues of smart manufacturing, and aims to develop several propositions to ensure the expected performance outcomes from smart manufacturing.

II. Transformations of Smart Manufacturing

Manufacturing experienced huge changes with the broadly use of advanced information technologies. Under the context of smart manufacturing, there are many transformations need to be took care to guarantee the success of smart manufacturing.

A. Transforming the Factory from Cost Center to Profit Center

Smart manufacturing transforms traditional factories from cost centers into profit centers that progressive businesses will strategically invest in to increase sales [5]. Traditional factories are regarded as cost centers, and managers are always trying to heavily cutting costs through economic of scale, which is producing large volume to reduce the unit cost. Lean production is popular to factories for controlling their production cost and then offering low price products to market, which is believed to attract the customers a lot. In other ways, many factories choose to relocate their manufacturing facilities in low labor cost countries, and even directly outsource to third party to control the production cost.

With smart manufacturing, the adoption of new technologies will facilitate the transformation of traditional factories from cost centers to profit centers. ICT-based solutions applied across the manufacturing process chain help to make manufacturing efficient. Both elements in combination allow for a more personalized, diversified and mass-produced product portfolio and flexible reaction to market changes. Progressive businesses have already begun gathering information and manufacturing intelligence by investing in highly automated and IT-driven production. This manufacturing intelligence enables the factory floor to become a profitable innovation center.

B. Transforming the Operational Focus from Process to Data

Traditionally, the operational focus is process, most of the investments in a factory will be put into improving the efficiency and effectiveness of the processes in order to increase the productivity. In terms of smart manufacturing, real-time data and information are the key to the future manufacturing supply chain [6].

To smart manufacturing, modern information and communication technologies like RFID, sensor, Internet of Things, Cyber-Physical Systems, Big Data or Cloud Computing will help predict the possibility to increase productivity, quality and flexibility within the manufacturing industry and thus to understand advantages within the competition. In order to provide useful insight to the factory management and gain correct content, data has to be processed with advanced tools (analytics and algorithms) to generate meaningful information. Considering the presence of visible and invisible issues in an industrial factory, the information generation algorithm has to capable of detecting and addressing invisible issues such as machine degradation, component wear, and others in the factory floor [7].

C. Transforming the Management Focus from Labor to Knowledge

Traditionally, labor is one of the key cost factor, that’s why many manufacturers reallocate their manufacturing facilities to less developed regions and countries to make the benefits of low labor cost. Once the situation changed, they will find new places to reallocate themselves again to maintain the cost advantage.

With smart manufacturing, automation processes are designed and controlled by engineers, so a highly skilled workforce becomes a pre-condition for the success of these innovation processes. We could regard smart manufacturing is a combination of knowledge and intelligence. In this scenario, labor cost is not the first priority anymore. Knowledge, skills, and even experiences are much more important to the success of smart manufacturing. The manufacturing process will not be labor-intensive anymore, but knowledge-intensive one.

III. RESEARCH PROPOSITIONS

In order to reach a success of smart manufacturing, industries and factories should respond to not only the technological issues, but also the supply chain related issues. This paper proposed the following propositions to respond the transformations of smart manufacturing.

Proposition 1: Smart manufacturing should emphasize the total performance of the whole supply chain, not just the individual manufacturing factory.

With the widely use of Internet and other modern communication technologies, all the stakeholders in the supply chain are inter-connected as a virtual unit responding to customer’s demand. IT-enabled smart factories represents a context-sensitive manufacturing environment that can handle turbulences in real-time production using decentralized information and communication structures for an optimum management of production processes [8]. A supply network with smart factories can better respond to national interests and strategic imperatives and can revitalize the industrial sector by facilitating global competitiveness and exports, providing sustainable jobs, radically improving performance, and facilitating manufacturing innovation [1, 9].

Under the context of smart manufacturing, a systematic thinking logic should be built to emphasize that individual optimization is not good enough to make sure all stakeholders in the system are happy. Total optimization should be the performance measurement to ensure the success of the smart manufacturing and the satisfaction from end consumers. In this sense, an entire “smart” supply chain should be built, including smart supply, smart distribution, smart warehouse, smart transportation, and even smart network.

On the other hand, efficiency is still one of the top key performance objectives, but a comprehensive supply chain performance framework should be designed to cover comprehensive performance objectives including profit, cost, quality, reliability, productivity, agility, asset utilization, and energy and material for sustainability. Meanwhile, system performance assurance methods and tools should be developed to control and monitor performance in the smart manufacturing systems. In other words, real time based optimization through entire supply chain will be very valuable to improve the performance of the whole supply chain.

Proposition 2: Smart manufacturing is data driven, the data covers not only factory operations but also supply chain operations in a whole.

Due to broadly use of the Internet and modern communication technologies, achieving real-time data capture and collection become possible comparing two decades ago. Endowed with total visibility, smart automation is quite essential for responsive manufacturing and efficient supply-chains [10]. While smart tag agents manage visibility for agile process flow and supply-chain management, smart resource agents improve responsiveness in shop floors and across supply chains.

On the other hand, those technologies also facilitate the close relationship among all stakeholders in the supply chain [11], which in turn enhance the real-time information sharing and visibility along the whole supply chain. However, these benefits actually will also lead to a challenge of huge data to process and analyze, and also build an infrastructure that will enable the sharing of knowledge and information in a manufacturing environment, regardless of time and place [12, 13, 14]. Since all information is available when it is needed, where it is needed, and in the form it is most useful [1,2] to drive optimal actions and responses, smart manufacturing can be regarded as data driven, knowledge enabled, and model rich with visibility across the enterprise (internal and external) such that all operating actions are determined and executed proactively by applying the best information and a wide range of performance metrics [15].

Data analytics and associated methods and tools should be built to enable and assess diagnostics and prognostics for smart manufacturing systems in real time [16, 17]. For instance, apps, and toolkits are required to assemble customized SM applications on a common, standards based workflow architecture and deploy on infrastructure that is accessible by small, medium, and large companies [15]. Furthermore, with smart manufacturing, machines are connected as a collaborative community. Such evolution requires the utilization of advance- prediction tools, so that data can be systematically processed into information to explain uncertainties, and thereby make more "informed" decisions [18, 19].

The new technical idea is to develop open protocols, analytical models, implementation frameworks and standards to enable the application of data analytics to turn data into insights and actions. For example, a virtual factory is proposed as a digital-manufacturing-based manufacturing system that predicts, solves (improves) and manages (controls) problems with overall production tasks by linking them to the actual sites, in a virtual environment [20]. It also proposed a strategic plan and a systematic design for the efficient implementation and application of the virtual factory to real manufacturing companies. In addition, an efficient and systematic means of introducing the virtual factory is presented via diagnosis, analysis and establishment of the strategy, implementation plan and system design case with an electronic parts manufacturing company.

Proposition 3: Smart manufacturing is knowledge enabled, the manufacturing network design should take knowledge and skills into consideration, not just the labor cost.

To achieve smart manufacturing, many countries and firms are still facing lots of challenges including talent, core technologies and supporting industries. Today's dilemma of the manufacturing system is to realize stable processes while manufacturing's environment is affected by global competition, high degree of complexity and autonomy, short delivery times and high product variety [21]. Both the technology and organizational issues could become the barriers to the implementation of smart manufacturing [22].

Firms are highly recommended to deploy resources accordingly, in particular human resources. For one thing, comprehensive assessments of the labor costs (especially the skillful labor) should be conducted to understand its impacts on the efficiency and performance of smart manufacturing. For another, appropriate manufacturing strategy should be developed to achieve the best balance between the adoption of the modern and advanced manufacturing technology and the allocation of the human resources [23].

From the perspective of supply chain, high knowledge or skilled labor are normally located in a limited regions and countries, an optimized supply chain network should be designed to make sure it can bring in skilled labor from other regions, at lower cost. In fact, industrial production of the new smart manufacturing era will need high flexible in production volume and customization, which demands extensive integration between customers, companies, and suppliers, and above all sustainable [24, 25]. For this, ICT will allow to create a virtual manufacturing network consisting independent stakeholders from different geographical location [26, 27, 28].

IV. CONCLUSIONS

Nowadays we live in a smart world, consisting of smart devices, smart home, smart, and even small city. This paper puts emphasize on smart manufacturing and smart factory. Smart manufacturing considered as a new trend of modern manufacturing helps to meet objectives associated with the productivity, quality, cost and competiveness. It is characterized by decentralized, distributed, networked compositions of autonomous systems.

The paper discussed the transformations of factory focus, operational focus, and management focus, and developed several propositions to pursue the success of the smart manufacturing. Due to the limitation of the research propositions developed based on broad literature review, further case study will be desired to further verify and test the research propositions, and build up the knowledge base for smart manufacturing. Meanwhile, comparative case studies will be very valuable to understand the development of smart manufacturing in different country backgrounds.

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