Factory of the Future Requirements in Relation to Manufacturing Technology in Automobile Industry for Economic Enhancement

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Abstract
This paper reviewed approximately recent reported researches on requirements, challenges and current innovations in Manufacturing Technology System (MTS) in the area of the Factory of the Future (FoF) application for the economic enhancement of the automobile industry. These MTS researches are categorized to addressing: manufacturing technology aspects, introduction of computers to enhance automation using Computerized Numerical Control (CNC), Adaptive Control (AC), Industrial Robots, Computer Integrated Manufacturing Systems (CIMSs), and also Computer-Aided Design/Engineering/ Manufacturing (CAD/CAE/CAM), Theories and Models of Manufacturing Systems framework. The paper elaborated on 4th Industrial Revolution also, known as vision of Industry 4.0 which is for Cyber-Physical Production Systems in which sensor-laden "smart products" tell machines how they should be processed. This vision brings about situation of processes govern themselves in a decentralized, modular system, with smart embedded devices working together wirelessly either directly or via either the Internet 'Cloud', that is, the Internet of Things (IoT) to revolutionize manufacturing. This paper also elaborated revolutionize manufacturing system in the form of Flexible Manufacturing Systems (FMS),Computer Integrated Manufacturing (CIM), Integrated Manufacturing Production System (IMPS) – Lean Production,Adaptive Control/Manufacturing,Smart Manufacturing and Artificial Intelligence Application in manufacturing. This paper did achieve solutions embellishment on requirements, challenges and innovations on the areas of FoF requirements for automobile components manufacturing using intelligent manufacturing system, completely ICT-based production systems with high quality manufacturing technologies and intelligent capabilities aimed at high output with accurate performance.

Keywords: Factory of the Future, Manufacturing Technology, Industry 4.0, Smart Manufacturing, Cyber-Physical Systems.

Introduction

Technology has made such great strides in recent years that its practitioners must recommit themselves anew to learning and ardently seek to expand their interest areas in order to be sensibly up to date. According to the European Commission's (EC) vision for the way forward, a new model of production systems should address transformable, networked and learning factories, depending on several drivers such as high-performance, extreme customisation, environmental-friendliness, superior efficiency of resources, eminent human potential and significant knowledge creation (EC 2016). The EC coined this domain as Factories of the Future (FoF), and more recently others have coined this evolution in the manufacturing environment as Industry 4.0 – The Fourth Industrial (R)evolution (BCG 2015). According to Richard, David and Antonio (2017), FoF embrace information and communication technology (ICT)-based production systems with high-quality manufacturing technologies and intelligent capabilities aimed to optimise their performance with a high degree of autonomy and adaptability for a balanced combination of high throughput with accurate production. The relevance of FoF is acknowledged bythe funding agencies, as stated by Filos (2016) that following a positive assessment of the Public–Private Partnerships (PPPs) in the seventh

Framework Programme, the EC decided to continue and even increase its stake in manufacturing Research, Development and Innovation (R + D + I) in the new HORIZON 2020 programme by continuing the FoF initiative with a funding envelope of €1.15 billion and also with a new initiative that addresses Sustainable Process Industry through Resource and Energy Efficiency (SPIRE) with a funding envelope of €900 million until the year 2020.The paper analyses conceptual, theoretical, empirical and technological contributions from several leading authors in the area. Also, the paper considers five interwoven dimensions:manufacturing system in the form of Flexible manufacturing systems (FMS), Computer Integrated Manufacturing (CIM), Integrated Manufacturing Production System (IMPS) – Lean Production,Adaptive Control/Manufacturing,Smart Manufacturing and Artificial Intelligence application in manufacturing.

Statement of the Problem

There are limited resources for research on thestate-of-the-art and a knowledge transfer medium to the manufacturing industry on leading technological innovations towards the envisaged Factory of the Future (FoF) requirements for project developments to reach the desired output within global accepted limits.

Objectives

The main objective of this paper is as a reference source for research on thestate-of-the-art and a knowledge transfer medium to the factory on leading technological innovations towards the Factory of the Future(FoF) requirements in the manufacturing technology of automobile industry for economic enhancement. Analysis of novel contributions from researchers and practitioners who are exploring the identified major challenges and anticipated leading innovations of the FoF in a global perspective, putting focus on novel strategies, methods and tools in a scientific-based standpoint for manufacturing.

Specifically, since this historic developments in intelligent manufacturing, rapid progress has continued to be made in automating most aspects of manufacturingwhich included the introduction of computers to enhance automation using computerized numerical control (CNC), adaptive control (AC), industrial robots, computer integrated manufacturing systems (CIMSs), and also computer-aided design, engineering, and manufacturing (CAD/CAE/CAM). Factory workers are to fit in to the demands of the factory of the future.

Theories and Models

The following theories and models supported the work:

TheOstrom (2005) stresses the necessity of distinguishing between levels of specificity of academic work that are often confused, stressing special importance to the clear consideration of frameworks, theories and models. Also, the author stressed that the development and use of a general framework helps to identify the elements and relationships among these elements that one needs to consider for analysis. Frameworks organise diagnostic and prescriptive research and inquiry(Richard, David and Antonio, 2016). Hence, they provide the most general list of variables that should be used to analyse all types of manufacturing systems research and development. Manufacturing systems frameworks will provide a meta-theoretical language that is necessary when developing theories for manufacturing systems and that can be used to compare theories (Richard, David and Antonio, 2016). Thus, manufacturing systems theories will focus on a framework and make specific assumptions that are necessary for an analyst to diagnose a phenomenon, explain its processes and predict outcomes. Several theories are usually compatible with any framework.

Models make precise assumptions about a limited set of parameters and variables (Ostrom 2005). Logic, mathematics, game theory, architectures, experimentation and simulation, and othermeans are used to explore the consequences of these assumptions systematically on a limited set of outcomes (Richard, David and Antonio, 2016). Multiple models are compatible with most theories and thus, the contributions by Moghaddam and Nof (2016), Marcelino-Jesus et al. (2016) and Ilie-Zudor et al. (2016) attempt to organise the manufacturing systems body-of-knowledge by creating frameworks and models for the FoF (no theory has been put forward). Moghaddam and Nof (2016) provide a framework of the Collaborative Factory of the Future (CFoF). Richard, David and Antonio (2016) reviewed a set of examples of 'e-Factories' and they abstracted a task-resource model as the basis for the Task Administration Protocol (TAP), which stress that all trends described by holons, IT/shop-floor subsystems, sensors, RFIDs, knowledge bases, humans, robots, manufacturing enterprises can be regarded as resources (physical and/or cyber) that accomplish a set of defined, desired and allocated tasks (designated as 'e-Activities'). The objectives of such Complex Collaborative e-Systems will not be materialised without effective and dynamic identification of requirements, assignment, parallelisation and synchronisation of tasks, resources and information, and systematic detection and prevention of errors and conflicts (Richard, David and Antonio, 2016). The outcome of such engineering processes will be a fault-tolerant system with fewer failures, capable of handling dynamic changes in its configuration, complexity and emergence with higher or lower scalability as needed (Richard, David and Antonio, 2016). Moghaddam and Nof (2016) state that what they designate as CFoF designs are challenged to provide promising solutions and address the emerging performance criteria (named as: 'e-Criteria'), such as agility, dependability, integrality, resilience, robustness and scalability, and that these emerging e-Criteria combine with security, information assurance, collaboration incentives and multi-/cross-cultural factors and sustainability.(Richard, David and Antonio, 2016) foresee future manufacturing systems as 'systems of systems', which will require effective interaction between dynamic and complex systems to realise the goals at system-wide and local levels. Service-oriented manufacturing (SOA-Mfg.) will need to advance in order to address the premise of cloud manufacturing that is integration/distribution of distributed/ integrated resources, and according to (Richard, David and Antonio, 2016), in the context of the CFoF, such advancement will follow through optimal real-time, intelligent and autonomous execution of e-Activities and e-Transactions, conflict prevention and resolution, and emergence handling.

Marcelino-Jesus et al. (2016) presents a framework targeted at entrepreneurs to help them in the evaluation and validation of new manufacturing technologies development. From the various phases of a project lifecycle, in which the proposed methodology is handled, it is the Technology Assessment (TA) phase that the research work of Richard, David and Antonio (2016)focused on. Based on an evaluation of frameworks to analyse the most appropriate to be used in the project viability methodology, Richard, David and Antonio (2016) chosen DECIDE, because of its generic but well-structured approach, and mainly due to its openness in aggregating in its process different mechanisms. Marcelino-Jesus et al. (2016) developed a project pilot evaluation for textile SMEs that included four different mechanisms: (1) GQM – Goal-Question-Metric – approach to define evaluation metrics assuring the addressing of all the objectives; (2) the software quality evaluation methodology, which was defined by Richard, David and Antonio, (2016) based on standards such as ISO/IEC-25040, to technically evaluate the project results; (3) the qualitative evaluation mechanism for the business evaluation of the project outputs; and finally, (4) the performance indicators mechanism to evaluate the work conducted in the project assuring its completeness. Grounded on two application scenarios, Ilie-Zudor et al. (2016) research work focused on developing a set of models that enable examining the relationship of decision levels, performance measures and modelling, and decision support approaches for manufacturing and logistics application fields for strategic, tactical and operational decisions.

In the proposed Virtual Factory Framework (VFF), strategic to tactical decision support service offers 'best practice' solution templates to manufacturing challenges formalised in an adequate way, thereby few restrictions are made regarding the branch of industry or any other distinctive features, a high degree of abstraction is required to be able to cover a reasonably large variety of cases (Richard, David and Antonio, 2016). In the case of the VFF, a set of generic and manufacturing-related features were selected as an organising principle of the underlying knowledge base, and theIntermediate Knowledge Representations (IKRs) CaseBasedReasoning (CBR) service was deployed for retrieval and maintenance of the discrete cases (Richard, David and Antonio, 2016). While the suggestion of a best practice can be machine-aided, the need for human attention at adaptation makes the entire procedure at best semiautomatic; in turn, the latter can go hand-in-hand with the revision of stored knowledge based on actual experience, which is an important step in the maintenance of a knowledge corpus for CBR.

Ilie-Zudor et al. (2016) also present the ADVANCE model focus on operational and tactical decision support in logistics networks, with two main objectives: (1) improving process transparency by an adequate layout of dataflows, processing functionalities and user interfaces that deliver the right data at the right time and in the right form to the given user; and (2) employing model building and prediction to 'patch up' missing information that would be needed for making the proper decisions.The global policy agenda that has been urging higher education institutions to prepare students for the job market since approximately the mid-1990s, stressing neoliberal (Letts, 2019). The neoliberal interpretation claims that contemporary working life is constantly changing and cannot guarantee secure employment, and emphasizes that people themselves most deal with this uncertainty by becoming and staying employable (Björck, 2021). According to Björck (2021), employable means being able to constantly adapt to changes in the world of work, and what happens when this idea of graduate employability enters the discourse of the standard model of higher education called work-integrated learning. Educators in the Universities should endeavor to train students in the use of modern automobile diagnostic tools for better learning outcome required in the world of work (Ezeama, Obe, Aniago & Ede, 2017).

Methodology

In this work, literature review was done on processes of manufacturing technology, manufacturing systems used in the industries or factories in the use of automation interface with the computer to achieve production. Describing methods used to actualize the purpose of the study on emerging manufacturing design and control patternprocesses of manufacturing technology in FoFs. Reiterating on Service-oriented manufacturing (SOA-Mfg.) as an emerging manufacturing design and control pattern that enables interaction and collaboration between different layers like 'cloud manufacturing' to support the notion of 'manufacturing-as-a-service' that is integration/distribution of distributed/ integrated resources, and in the context of the CFoF, such advancement will follow through optimal real-time, intelligent and autonomous execution of e-Activities and e-Transactions, conflict prevention and resolution, and emergence handling. Marcelino-Jesus et al. (2016) presents a framework targeted at entrepreneurs to help them in the evaluation and validation of new manufacturing technologies development. Based on an evaluation of frameworks to analyse the most appropriate to be used in the project viability methodology,Richard, David and Antonio (2016) chose DECIDE, because of its generic but well-structured approach, and mainly due to its openness in aggregating in its process different mechanisms. These different mechanisms areto assure that the project developments reach the desired output accordingly to the identified requirements constitute the methodology of this study focused on to explain the processes involved. Below are manufacturing systems involved in the area of FoF aspects of productions and mechanisms:

The 4th. Industrial Revolution

Industry 4.0 is interpretable as the true automation wherein human judgment is replaced by the capability of a machine to measure and compare results with a desired value. It is the coalescence of A1 to A3 levels of automation, putting us at the dawn of Industry 4.0, an age where "smart devices" really are smart enough to assume major control over our machines of manufacturing and distribution.The vision of Industry 4.0 is for "cyber-physical production systems" in which sensor-laden "smart products" tell machines how they should be processed. Processes would now govern themselves in a decentralized, modular system, with smart embedded devices working together wirelessly either directly or via either the Internet 'Cloud', that is, the Internet of Things (IoT) to once again revolutionize manufacturing.

Cyber-physical systems Internet of Things (IoT)

The cyber-physical systems Internet of Things (IoT) has attracted attention of stakeholders in industrial landscape and it is currently one of the most expected emerging technologies. Thedevelopment of IoT platforms is driven by the need to facilitate machine-to-machine connectivity, which is emerging at unprecedented rate. Brynjolfsson and Mcafee (2014) predict that machine-to-machine connections will rise from 2 billion in 2012 to 12 billion in 2020. Hobbs, Manyika, and Woetzel (2015) value IoT market to 19 trillion USD. CPS is similar to the IoT, sharing the same type of architecture, though CPSs present a higher combination and coordination between physical and computational elements. This is reflected in the works of Ghimire et al. (2016) and Delgado-Gomes, Oliveira-Lima, and Martins (2016). Ghimire et al. (2016) validate their reference architecture through theimplementation into a scenario of project management in the construction industry, where project supervisors have a deeper insight of the situation of the project. Delgado-Gomes, Oliveira-Lima, and Martins (2016) propose a CPS-based Infrastructure to collect and monitor energy data in real time for manufacturing and production systems, along with a Manufacturing Energy Management System (MEMS).

Cloud Computing, shown figuratively in Figure 1 below means storing and accessing data and programs over the Internet, while with the Internet of Things (IoT), devices connect over the internet, letting them talk to us, communicate with other applications, and with each other. Decentralized intelligent as machine-to-machine communication hits the shop floor. Presently, Industry 4.0 is more of a vision than a reality, but it is one with potentially far-reaching consequences, and the concept continues to evolve as people think of innovative ways to implement it.

Figure 1 : Cloud computing

Manufacturing Systems

The innovation that is currently going into the implementation of Industry 4.0 has involved some new areas of knowledge in manufacturing systems and manufacturing technology(Ertel, 2011). The manufacturing system is designed to accept inputs in order to produce goods of various ramifications for the consumer. Manufacturing technology, on the other hand provides the productive tools that power a growing, stable economy, and raises thestandard of living (Youssef, El-Hofy, and Ahmed,2012). Some of the key innovative strategies, as opined by Youssef, El-Hofy, and Ahmed (2012), even if in themselves still visionary, are discussed in what follows:

Flexible Manufacturing Systems

Flexible manufacturing systems (FMS) introduce automation into small batch production. It consists of a highly automated manufacturing system that utilizes of a collection of production devices, logically organized under a host computer and physically connected by a central transport system. It has developed to provide some of the advantages of the economics of mass production to small batch manufacturing. The basic elementsaccording to Youssef, El-Hofy, and Ahmed, (2012)of FMS include:

1. Workstations
2. Automated handling and transportation of materials and parts
3. Control systems.

The main advantage of FMS is the flexibility in terms of the little effort and short time required to manufacture a new product. Its major features and characteristics include, the immerging of costs and quality benefits for most engineering sectors requiring batch production, extensive use of industrial robots, see Figure 2 for material handling, inspection activities and assembly operations, and software that integrates CNC and the handling systems.

Figure 2: Example of Industrial Robots

Computer Integrated Manufacturing (CIM)

The concept of Computer Integrated Manufacturing (CIM) was developed during the 1990s as a combination of software and hardware for product design, production planning and control, and production management in an integrated manner (Ertel, 2011). It is essentially more a methodology and a goal rather than an assemblage of equipment and computers. The main tasks involved in CIM as opined by Youssef, El-Hofy, and Ahmed, (2012) can be separated into four unique blocks as in diagram below:

1. Product design, for which an interactive computer-aided design (CAD) system allows drawing, analysis, and design to be performed. The computer graphics are useful to get the data out of the designer's mind ready for interaction.
2. Manufacturing planning, where the computer-aided process planning (CAPP) helps to establish optimum manufacturing routines and processing steps, sequences, and schedules.
3. Manufacturing execution, in which computer aided manufacturing (CAM) identifies manufacturing problems and opportunities. Intelligence in the form of microprocessors is used to control machines and materials handling and collect data controlling the current shop floor.
4. Computer-aided inspection (CAI) and Computer aided reporting (CAR) so as to provide a feedback control loop.

CIM Technology according to Ertel, (2011) offers the following advantages:

1. High rates of production with high precision
2. High flexibility of producing diverse components in the same setup
3. Easy and quick manipulation of software
4. Uninterrupted production with little supervision
5. Economical production even in the case of moderate batch sizes
6. Drastic reduction in lead times
7. Drastic changes in product design
8. Integration and fine tuning of all major factory functions

Integrated Manufacturing Production System (IMPS) – Lean Production

As has been said in the foregoing, CIM, in principle is the conceptual definition of the methodology and goal for high level production efficiency rather than the physical assemblage of equipment, plant and computers. What is called lean production appears to be more important to the future rather than CIM (Youssef, El-Hofy, and Ahmed, 2012). Total employee and union participation are absolutely necessary in IMPS.

Adaptive Control/Manufacturing

Adaptive control (AC) machine tools are a logical extension of CNC systems of the A4 level of automation. Accordingly, the part programmer sets the processing parameters on the basis of the existing knowledge of the work piece material and various data on the particular manufacturing process (Youssef, El-Hofy, and Ahmed, 2012). In manufacturing, the three fundamental AC system variants include, adaptive control with optimization (ACO), in which an economic index of performance is used to optimize the process, adaptive control with constraints (ACC), in which the process is controlled using online measurements to maintain a particular process constraint, and geometric adaptive control (GAC), in which the process is controlled using on-line measurements to maintain desired dimensional accuracy or surface finish (EcnMag, 2016).

Smart Manufacturing and Artificial Intelligence

Artificial intelligence (AI) is the basictool for smart manufacturing (SM). AI is an area of computer science concerning systems that exhibit some characteristics which are usually associated with intelligence in human behavior, such as learning, reasoning, problem solving, and understanding of the language. Its goal is to simulate such human endeavors on the computer and represent a technique for solving problems in a better way than is available with conventional computer programs (CCP). A CCP typically relies on algorithmic solutions, in which a finite number of explicit steps produce the solution of a specific problem. These algorithms work fine for scientific or engineering calculations that are numeric in nature to produce satisfactory answers. AI application in manufacturing according to Ertel, (2011 generally, encompasses expert systems, natural language, machine vision, artificial neural networks, and fuzzy logic.

Factory of the Future (FoF)

The trend towards the fully automated factory seems only a short distance away.Wiesner and Thoben (2016) and Angulo et al (2016) provide new insights on how FoF should address the servitisation challenge. Wiesner and Thoben (2016) address the requirements for models, methods and tools to support servitisation through collaboration of manufacturing enterprises andservice providers. A novel approach to elicit these requirements is proposed and aims to fulfil them by establishing Manufacturing Service Ecosystems (MSEs), and developing models, methods and tools to realise products and services in Virtual Manufacturing Ecosystems (VMEs). Richard, David and Antonio (2017) stated approach which covers the challenges of servitisation, namely, service innovation, ecosystem governance and support of the transition by guidelines, techniques and ICT tools in three different domains: (a) physical resource-related, (b) organisational/human-related and (c) IT-related. The distributed architecture of the system developed spans three levels: (a) single enterprise, (b) manufacturing ecosystem and (c) future Internet of Services. Wiesner and Thoben (2016) refer that the level of the single enterprise (manufacturers, suppliers, customers, service providers and service consumers) includes knowledge models and ontologies, service descriptions of tangible and intangible assets, access services to private data vaults and legacy systems. For the level of the manufacturing service ecosystem (VFs and virtual enterprises, supply chains and global value networks), it includes the assets owned by the ecosystem itself, as well as the experiences gained by the VFs and virtual enterprises from time to time (created, operated and dissolved) in the ecosystem to respond to collaboration business opportunities.

The level of the future Internet of Services (including Cloud Computing, Platform as a Service, Software as a Service Utility) is where basic platform services, utility services and value-added services will be provided globally to all the enterprises under a flexible and dynamic composition. Based on the requirements, analysis, supporting models, methods and tools could be specified for servitisation and collaboration, leading to the development of an Innovation Reference Framework, a Feedback Management Service and a Virtual Marketplace. For the MSE in general, an Innovation Ecosystem Platform (IEP) provides a platform to manage in terms of level of activity, interactions, roles and flow of information between its members. The need for support in the organisational, functional and governance dimensions led to a Methodology for Management and Governance of MSEs that supports the setup of a VME for a specific collaborative business opportunity. The Virtualisation Method for Tangible/ Intangible Assets supports the composition of the right assets for a desired product–service combination. The destination seems to be the factory of the future (FOF) wherein the integration of the new techniques involving CNC, FMS, Robots, CAD, CAM, CAPP and GT will bring about FoF reality.

Results

In this review, the study revealed five broad categories: manufacturing systems frameworks, theories and models; the pervasiveness of Cyber- physical Systems (CPSs); the critical role of semantic technologies and interoperability; the Virtual Organization (VO) of manufacturing systems; and the servitisation of manufacturing systems.

Conclusion

This paper presented a set of models which examine the relationship of decision levels, performance measures, modelling, and decision support approaches for manufacturing and logistics application fields for strategic, tactical and operational decisions. In our review, which also discussed how evolving technologies in the 'IoT' in project management, through Collaborative FoFs. In somepapers, authors presented how a 'CPSbased infrastructure' collects and monitors energy data in real time for manufacturing and production systems for improving energy consumption awareness and analysis to identify where to take actions in the manufacturing process in order to reduce the energy consumption. These categories of research by some authors, suggested that because of challenges and leading innovations in intelligent manufacturing for the FoF, indicate need for ongoing research.

Recommendation

The Factory of the Future (FoF)requirements must embrace ICT-based production systems with highquality manufacturing technologies and intelligent capabilities aimed to optimise their performance with a high degree of autonomy and adaptability for a balanced combination of high output with accurate production. As expected, FoF should adopt full implementation of the sustainable manufacturing concept as theoretically/holistically justified with simulated models and frameworks.There were diversity of focus considering the objective of the study on the application of the required tools for FoF involving various aspects of manufacturing technology which in turn, can be engineered and augmented through operators in order to address FoFadopting Collaborative FoFs requirements. Thus, further work needs to do on manufacturing technology development to support the implementation of concepts, resulting in an integrated framework, theories and models for the implementation of leading innovations in intelligent manufacturing for the FoF. It is recommended that all manufacturing technology systems be computer controlled, while the role of humans will be in the continuous development of FOF systems, overall process supervision, maintenance, security, and the like.

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