Management and Production Engineering Review
Volume 9 • Number 3 • September 2018 • pp. 90–99
DOI: 10.24425/119538

COLLABORATIVE MANUFACTURING BASED ON CLOUD, AND ON OTHER I4.0 ORIENTED PRINCIPLES AND TECHNOLOGIES: A SYSTEMATIC LITERATURE REVIEW AND REFLECTIONS

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Received: 12 July 2017
Accepted: 9 September 2018

Abstract
Recent rapid developments in information and network technology have profoundly influenced manufacturing research and its application. However, the product's functionality and complexity of the manufacturing environments are intensifying, and organizations need to sustain the advantage of huge competitiveness in the markets. Hence, collaborative manufacturing, along with computer-based distributed management, is essential to enable effective decisions and to increase the market.
A comprehensive literature review of recent and state-of-the-art papers is vital to draw a framework and to shed light on the future research avenues. In this review paper, the use of technology and management by means of collaborative and cloud manufacturing process and big data in networked manufacturing system have been discussed. A systematic review of research papers is done to draw conclusion and moreover, future research opportunities for collaborative manufacturing system were highlighted and discussed so that manufacturing enterprises can take maximum benefit.

Keywords
collaborative manufacturing, networked manufacturing, cloud manufacturing, I4.0, cyber physical systems, internet of things, and big data management.

Introduction

Recent global competition renders an adequate return on investment for innovative, complex and personalised products that achieve high quality, less associated process iterations, and more cost competitiveness through collaborative, integrated and networked manufacturing environments and management functions. In order to respond to today's intensely competitive environment and to obtain high product variety and customization, along with short product life cycles, by catering the needs of the above-mentioned requirements, a shift of the manufacturing and management paradigms from deterministic to a more rigorous, autonomous and dynamically adaptive control based on a flexible and agile manufacturing system seems inevitable. A befitting answer to this need is Collaborative Networked Manufacturing and Management based on Network based Manufacturing System (NMS). Liu [1] define networked manufacturing as a set of manufacturing activities ranging from market control, manufacturing technologies and manufacturing systems that can help enterprises to improve the business management and enhance their competitiveness in the market. Therefore, the study and analysis of networked manufacturing has become a necessity due to its advantages in current competitive atmosphere, as it meets a number of, often conflicting, objectives and goals, such as reducing the manufacturing cycle time, shorter lead times, better interoperability, and maintaining the production flexibility leading to many feasible process plans, and all these requirements can be fulfilled through collaboration based on appropriate supporting technologies for enabling integration, interoperability and digitalization, for reaching imperative main and common enterprise goals.

Cloud manufacturing, big data and collaborative manufacturing processes are used as tools or means through platforms to attain the objectives of improved efficiency, reduced lead time [2] and reduced total cost, along with maximum mutual profit precisely and easily in a networked manufacturing system [3, 4]. Although the monolithic approach of traditional manufacturing has its own advantage, it is not sufficient in the current dynamic manufacturing environment [5]. However, several problems related to the traditional manufacturing approach have been clearly stated [6]. To overcome these problems, researchers have realized that there is a need to integrate both the functions and the means to achieve better performance of the system. Subsequently, the need to integrate both of these issues activities have found the basis in the context of the networked and collaborative manufacturing environment. However, no conventional shop floor control system based on centralized or hierarchical control architecture can handle the required adaptive and autonomous control of manufacturing system. Therefore, the control architecture is gradually being shifted to the distributed, decentralized and autonomous control (DDAC) architecture. Since DDAC shop floor control system may have complete local autonomy, governing the reconfigurability, scalability as well as fault tolerance, it is suitable for a dynamically changing environment. To achieve the successful information and knowledge exchange between different facilities, there is a need for internet and communication technology IoT (internet of things) through which it can be possible to link all of them. Some of the key literature reviews for planning and scheduling and their integration, regarding the application of artificial intelligence based approaches, multi-agent based simulation, cloud manufacturing, internet of things, big data and digitalization will be further detailed in the following sections of this paper.

The main objective of this paper is to analyse, synthesise and present a comprehensive systematic literature review (SLR) of the role of collaborative and cloud manufacturing function process and big data management in networked manufacturing system. Thus the research questions (RQ) for this SLR are:

RQ1: What is the role of collaborative and cloud manufacturing function process and big data management for enhancing the system performance in networked manufacturing?

RQ2: What topics and issues related with collaborative and cloud manufacturing function process and big data management are considered when networked system manage their processes?

The aforementioned questions have been answered in a systematic way by analysing and reviewing research papers pertaining to considered keywords. In an initial analysis of the selected literature of 51 research papers an ontology/ framework was designed. The same framework will be used to elaborate on the findings of this review paper. The structure of the paper is as follows. The next section describes the research methodology applied in this paper, which follows a SLR five-step approach. Next, a section is dedicated to Collaborative Manufacturing. After, a resumed literature, along with main findings is provided, which includes subsections related to Cloud Manufacturing and computing, Interoperability, Internet of Things, Big Data Management, and Cyber Physical Systems. Finally, in the last section are provided some limitations and conclusions of the research carried out.

Research methodology

Owing to the limitations and a mainstream approach of traditional approaches, a better more systematic approach has been used for this literature review. Using a systematic literature review (SLR) approach it is possible to create a basic framework for a more in-depth analysis of the literature, adopting a replicable, scientific and transparent process. This systematic approach facilitates a more efficient and in-depth analysis by adopting a more transparent and convenient process. The following 5 step approach similar to the one used by Costa [7] is followed.

1) Question formulation,
2) Locating studies,
3) Study selection and evaluation,
4) Analyses and synthesis,
5) Reporting and using the results.

The steps are enumerated as follows:

Step 1: Concerns with the questions needed to be addressed by this review. The questions considered are, "How are the current advancements in technology influencing collaborative IPPS models?"", "How are the scenarios and issues specific to networked manufacturing addressed by these models and advancements?" and "What is the future scope and requirement of study and research in this particular context?"

Step 2: Deals with the selection of the sources of the literature to be reviewed. The bibliographical databases 'Scopus' and 'Web of Science' were majorly used for this review. The initial search strings using the two bibliographic databases resulted in the identification of 630 articles, i.e. 295 for Web of Science and 335 for Scopus. A small amount of literature was also obtained from secondary sources like Google search engine, science direct, among others.

In this study a set of six research questions (S1 to S6) was explored, based on the following and more or less closely and similar stings, which were combined through and/ or relations: "collaboration", "networked manufacturing", "cloud manufacturing", "Process planning and scheduling", "AI", "internet of things", "I4.0", "big data", and "cyber physical systems".

The next step (Step 3) involves the selection of study and evaluation. Some inclusion criteria have been used in order to narrow down the search results to more relevant studies to be considered for the review. Literature between the time limits of 2000 to 2017 was used for the review. The language considered for the review was further limited to English language and all type of articles and documents except books. The papers then were restricted to some specific research areas for the two bibliographic databases:

– Web of Science:
  a) International Relations;
  b) Business Economics;
  c) Engineering;
  d) Operations Research Management Science.
– Scopus:
  a) Business, Management and Accounting;
  b) Engineering;
  c) Decision Sciences.

These limitations reduced the number of articles and papers to 387.

In step 4, the matter in the filtered and finalized papers in Table 1 has been studied and analyzed.

Table 1
Summary of the systematic review articles selection and evaluation.

	S1	S2	S3	S4	S5	S6	Total
Bibliographic database analysis							
Web of Science	33	31	71	38	33	89	295
Scopus	29	43	58	58	48	99	335
Inclusion/exclusion criteria							
Scopus							
Date range (2000–2016)	29	43	58	58	48	99	335
Document type (All except books)	29	43	57	57	46	97	329
Subject area (Engineering, Computer Science and Decision sciences)	29	39	56	56	45	94	319
Language (English)	29	41	55	55	45	95	320
Web of Science							
Date range (2000–2016)	33	31	71	38	33	89	295
Document type (All except books)	33	31	71	37	33	87	292
Subject area (Engineering, Computer Science and Decision sciences)	33	31	70	37	32	87	290
Language (English)	33	31	71	38	33	89	295
Total							
After checking duplicates (in each search)	42	51	79	63	51	101	387
After checking duplicates (in all searches)	98						
Title and abstract analysis	76						
After detailed article analysis	51						

The key focus areas were determined and the key subject matter, issues and points were identified and represented in subjective and tabulated forms. The extraction of this data is done by multiple reviewers (the authors) and duplicate were checked using Mendeley and Endnote which resulted in a more accurate and comprehensive summarization with lesser discrepancies and critical analyses of the gaps in the reviewed literature. Further detailed analysis was done and 51 review papers (see Table 1) were chosen whose main contribution of findings will be discussed in this paper.

The current paper represents the formal presentation of the results to the academic community (step 5). The remaining content of the paper reports the findings of the present study in a thematic way for a better and clearer organization of the underlying subjects.

Collaborative Manufacturing

Collaborative Manufacturing has been defined by several authors and definitions have been evolving during the last years. One view by [8] consists on a new business paradigm where involved organizations combine their individual competencies and expertise to achieve overall network's goal and performance. According to this author this concept regarding Collaborative Manufacturing Function Process can be further divided into:

1. Collaborative forecasting model,
2. Collaborative design and product development,
3. Collaborative manufacturing model, and
4. Collaborative transportation/distribution.

Important points discussed in the research paper which are characteristics of the collaborative manufacturing process are as follows:

- Mapping the participants and its relationship.
- Information requirements: Information needed for interactions among them are based on the required information for each activity. It should be defined and be put in a holistic collaborative information structure.
- Communication protocols: In the holistic collaborative manufacturing network (CMN), communication among participants is very important. Protocol for helping participants communicate effectively and efficiently in the network is essential.
- Models for holistic collaborative manufacturing network: It is a research challenge for formulating a business collaboration model in the context of a comprehensive model of CMN.
- Integration and coordination: Integration should enable efficient operation management and control among heterogeneous business entities. The discussion on holistic integration and coordination should include activities, people, tools, data and information.
- Interoperability: The system should be adaptive and dynamic and enable participants to do an efficient work and control and to handle any kinds of interaction in the network.
- Planning and scheduling: In the context of holistic CMN, the design of project planning begins from very early in the production cycle until products are delivered to the end customer.
- Decision support system (DSS): Many of the information and decision processes such as production, managerial and economics are still controlled separately by various members participating in a collaborative model. DSS should enable participants to decide whether to join, leave or decide any issues related to their involvement in this collaborative network.
- Transportation and distribution management: The transportation issues should be discussed and cover a comprehensive aspect of logistic network.
- Performance measurement: The performance measurements should be conducted both, internally within a company and intra-companies in terms of cost, time and quality.
- Security and privacy: Issues of security and privacy in the holistic CMN are very important to be addressed where practical techniques and application should be developed to ensure the protection of participants and the network system.

For further contributing to define a suitable and general concept for collaborative manufacturing in the context of I4.0 we propose a set of main underlying levels as represented through Fig. 1.

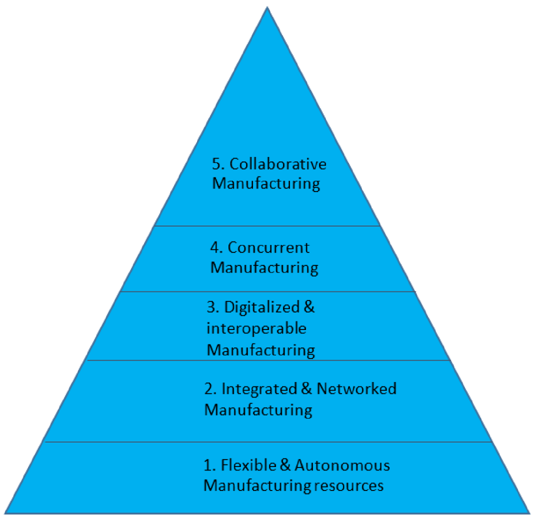

Fig. 1. Collaborative Manufacturing concept representation.

In this proposed collaborative manufacturing concept, at the basis, are found flexible and autonomous manufacturing resources (1). Next, appears the integrated and networked manufacturing level (2). Right after is positioned the digitalized and interoperable manufacturing level (3), followed by the concurrent manufacturing level (4), for finally reaching the fully collaborative manufacturing one (5).

Literature review and findings

Cloud Manufacturing

Guo [9] has mentioned that Cloud Manufacturing (CMfg) was first introduced in 2010 and it has been known as a type of service oriented platform. Liu [10] further clarified that Cloud manufacturing (CMfg) is an emerging business model for the manufacturing industry and its platform includes distributed and network manufacturing resources and services. Liu [11] asserts that the key technologies which help to attain such exemplary framework are connected simultaneously through centralized service and manufacturing management system to cater needs of customer, market and business. As discussed in [12], CMfg paradigm is a mixture of present manufacturing systems and growing technologies, such as big data, Internet-of-things (IOT), cloud computing and digitalization. CMfg and big data are being used to create intelligent and service platforms to improve Manufacturing Capacity, which is the main data throwing light on manufacturing levels and in turn is related to product quality. Based on the CMfg's idea, Fanghua [13] designed a new architecture of cloud manufacturing, which explains the course path and incorporation of CMfg resources, which includes the following layers: 1. physical layer, 2. resource oriented interface layer, 3. virtual resource layer, 4. the core service layer, 5. service-oriented interface layer and 6. application layer. These layers play a major role to keep the system working. Similar to this, Ji [14] has provided with 'modules' for manufacturing resources management system pertaining to Internet of Things which includes four modules: 1. Maintenance Module: managed by administrators and used in allotting supervisors, adding and removing different resources to further ensure the framework's information working. 2. Management Module: managed by the resource equipment's supervisors and its use is keep records of work history and its state and also for equipment's examination and repair. 3. Searching and Evaluating Module: Used to provide manufacturing resources and cater the 'searching and evaluating' requirement of members in the network. 4. Intelligent Searching Module: used for intelligent management of extractive, special and scarce equipment's. Therefore it can be seen that the internet of things will play a major role implementing such models and layers in CMfg. As an example of digitalization's research [15] presents a new telefacturing based distributed manufacturing environment based on user preference. Here an XML file of complex stored information was extracted using Ontology Software – Protégé 5.0, which is used for integration of process planning and scheduling considering a multi-job scenario. A priority and hierarchy model is created with Portege based Ontology Software which reduces the human efforts for further customization in any networked manufacturing system, being an example of digitalization used in CMfg. Another extension to this can be obtained from He [16] who defined Enterprise Digitalization as a novel model, which integrates information technology and modern manufacturing technologies employing Internet of things and big data to deal with product life-cycle and other facets of enterprise operation to attain integration and digitalization of product design, manufacturing, production control processes and manufacturing equipment. This statement can be analised in four ways: 1. The integration and digitalization of an entire product life-cycle, which is a basic platform of organization providing 'Computer Supported Cooperative Work'; 2. The integration and digitalization of functional systems including manufacturing system, designing system, and equipment system; 3. The integration and digitalization of organization's other business and cooperative system, and the underlying production equipment system; 4. The integration and digitalization of CAPP/CAD-CAM/CAE and SCM/CRM/ERP systems. Liu [17] has concluded that CMfg has merits in utilization rate, enterprise's utility and satisfaction rate related to Resource Sharing (RS) service over traditional networked manufacturing system. This paper also infers that there is a further need of work to be done in CMfg even though utility is enhanced in CMfg. Here CMfg enables the integration of all new emerging technologies. From the wider perspective of design and manufacturing, the internet based technology enables a great potential to develop virtual decision support systems to support the rapid development of mechanical products to meet global competition. Lee and Kim [18] described a model for remote analysis of CAD models for the exchange of geometric data. Later, they tried to apply the proposed concept in industrial environment; the results show its effectiveness. A group of researchers and developers [19] did put forward a

Tele-Manufacturing facility project to provide rapid prototyping services on the internet. Li [20] proposed a web-based system for the integration of product design and process planning using Cyber-Cut experiment based on Java-based programming. Zhang [21] presented an open collaborative design environment approach that can integrate 3D geometry of a product on the WWW with conventional CAD packages. With single internet interface, the semantic and syntactic content of the product model from different operating systems can be accessed to demonstrate the open architecture and interoperability.

Significant progress has been achieved in developing and applying web support systems for process and production planning and control. Cheng [22] explored the web-based simulation and production scheduling for production planning and monitoring problem. An IPPI (Integrated Production Processing Initiative) project has been initiated, in order to minimize the production costs, lead times, and inventories and maximize production and due date performance. IPPI aims to develop and validate a prototype process planning system by defining the product data into the STEP (Standard for the Exchange of Product model Data) files which are capable of generating intermediate product models when necessary. Researchers [23, 24] developed a Federated Intelligent Product Environment (FIPER) system funded by NIST to develop a new product design and analysis technology. A web-based distributed framework has been developed for design analysis and product lifecycle support with design tools/ methods such as Java Native Interface (JNI) and FIPER SDK toolkit. Xiao [25] developed the Web-DPR system for collaborative design and manufacturing based on Java Remote Method Invocation (RMI) mechanism and event base mechanism to coordinate the functional modules effectively. Mervyn [26] proposed a Web-based fixture design system in which XML format was designed to transfer the information and knowledge between functional modules in a distributed environment. Ivanov [27] developed a computer-aided fixture design system based on process-oriented approach, that in the automated mode ensure analysis of the workpiece, optimization of fixture configurations, and verification of the system "fixture – workpiece". The system is made according to the MDI-interface technology, a physical model of the proposed database is implemented with database management system MySQL.

Additionally, the computational approach for solving highly complicated multidisciplinary problems has been also successfully applied within the work [28].

Interoperability

Communication, integration and interoperability, along with digitalization, among manufacturing resources or units is a fundamental requisite for being able to reach fully collaboration.

Interoperability can be defined as a measure of the degree to which diverse systems, organizations, and/or individuals are able to work together to achieve a common goal. For computer systems, interoperability is typically defined in terms of syntactic interoperability and semantic interoperability. Syntactic interoperability relies on specified data formats, communication protocols, and the like to ensure communication and data exchange. The systems involved can process the exchanged information, but there is no guarantee that the interpretation is the same. Semantic interoperability, on the other hand, exists when two systems have the ability to automatically interpret exchanged information meaningfully and accurately in order to produce useful results via deference to a common information exchange reference model. The content of the information exchange requests are unambiguously defined: what is sent is the same as what is understood.

Internet of Things

The Internet of Things (IoT), which provides real-time based information and status of the machines, services and processes in manufacturing environment, is widely used as a part of digitalization and cloud manufacturing. IoT infrastructure senses the real-time state of service execution to increase the visibility of task progress [29]. IoT has its application in many areas but primarily it plays a vital role in determining the fluctuations in the orders in just-in-time manufacturing. The reasons for the fluctuations can be caused by expansion of productivity, breakdown of machines, new orders, cancelation of orders, etc. Ge [30] further segregates the functionality of the event driven dynamic service selection by IoT into: changes from marketplace and changes from service consumers. Another example given is that if any task is completed early the machine will go to select on the new task available in the Manufacturing Cloud. At the same time if the services are delayed the machine and service system has to adjust accordingly to meet the demand. Here, the IoT technologies, such as Radio-Frequency Identification (RFID) and Wireless Sensor Networks (WSNs), can increase the visibility of the real-time scenario and data from the shop floor or manufacturing facility. Finally a dynamic and efficient service selection, adjustments made in the selection due to delay, along with resource allocation can be carried out by the use of IoT.

Big Data Management

Big Data, one of the most popular expressions used nowadays, alludes to examination in view of expansive information accumulations. Headways in processing and memory execution, together with systems administration (not the slightest informal organizations) have made it conceivable to accumulate phenomenal measures of information [31, 32]. Cyber Physical Systems (CPS) and IoT empower to assist huge measures of information identified with physical frameworks to be made accessible for examination. Big Data is pertinent to non-specialized frameworks and IT frameworks, yet turn out to be much all the more fascinating frameworks when connected with regards to CPS because of the ramifications of physicality as far as capacities, specialized dangers and expenses.

Wang et al. trust that there has been some disarray between the terms underlying types of frameworks. Therefore, proper characterization is the best valuable cure that we can give to counter this disarray. As realised from the above insights about kind of frameworks, each one of the terms used depend unequivocally on networked software-intense frameworks, while underscoring distinctive parts of the relating frameworks. IoT predominantly alludes to innovation and data (from base up) while big data underlines information examination. CPS rather underscores co-operations among physical and digital parts, including people, though SoS (System of Systems), accentuation associations inside substantial scale developmental frameworks. The terms give alternate points of view and from the past exchange plainly there is no general incorporating term today. CPS however covers a bigger extension contrasted with IoT, and embedded systems, and will turn out to be progressively essential with regards to SoS and big data.

Wu et al. talked about Cloud Based Design and Manufacturing (CBDM) from a data and network point of view. CBDM utilizes the IoT (e.g., RFID), smart sensor, and remote gadgets to collect real-time design – and manufacturing-related data. The quintessence of IoT and implanted sensors is to catch occasions, to speak to physical items in a computerized frame, and lastly to interface machines with individuals. For example, IoT enables designers to approach information, for example, machine use, hardware conditions, and the rate of damaged items from any area. With the big data produced by the IoT-related gadgets, professionals may apply big data analytics for determining, proactive support, and automation. But such consistent associations cannot be given in web-and agent based outline and assembling frameworks in light of their restricted information securing and processing capacities.

Wu et al. likewise discussed a Programming model. From a programming model point of view, MapReduce, a parallel programming model, empowers CBDM frameworks to process substantial datasets with web and operator based manufacturing frameworks, based on: Data Acquisition System, Smart Phone, Camera, RFID Reader, Barcode Reader, Infrastructure-as-a-Service, Smart HMI Sensor, which should continue to be further explored to be properly managed. A standout among the most understood open source executions of the MapReduce model is Hadoop. Like other parallel programming models, Hadoop separates computationally broad assignments into little parts of work, and each work unit it is handled on a PC hub in a Hadoop group. The MapReduce structure is executed through two centre procedures named Map and Reduce. In particular, in a Map procedure, an ace hub gets an information task, isolates it into smaller sub-tasks, and disperses them to labourer hubs. The specialist hubs prepare the smaller sub-tasks, and send the appropriate response back to the ace hub. In a Reduce procedure, an ace hub gets the appropriate responses of all the sub-assignments and joins them to create the consequence of the first errand. Such a parallel programming model empowers CBDM to deal with enormous information created in complex manufacturing plans.

Cloud-based outline: from a necessities elicitation point of view, a cloud based design (CBD) framework permits configuration designers to conduct statistical research more successfully and effectively through web-based social networking. In particular, they can utilize business – targeted statistical surveying stages, for example, Hootsuite, and Salesforce.com to gather client criticism and reactions on existing and new components of automatons. For example, Hootsuite permits the plan group to gather enormous client input and surveys crosswise over the greater part of the significant informal communities, for example, Twitter, Facebook, Google in addition to and in addition social promoting locales, for example, Foursquare. So also, online networking based statistical surveying stages (e.g., social.com, radian 6, and amigo media) given by Salesforce permit the plan group to distinguish lead clients for outline development by making drawing in Facebook tabs as opposed to by performing study of expansive client populaces. In the wake of gathering this information from online networking, outline specialists can inspire plan prerequisites and client inclination utilizing cloud-based huge information investigation apparatuses, for example, Google BigQuery takes into account preparing these greatly expansive datasets utilizing the MapReduce system, a parallel and disseminated programming model. This information examination is created by Google BigQuery permit configuration specialists to determine the utilitarian necessities of the automaton all the more successfully and proficiently.

Cyber Physical Systems

During the previous decade, the rapid development of Information and Communication Technologies (ICT) has helped in the utilization of the Cyber-physical Systems (CPS) tools such as cutting edge sensors, information procurement framework, wireless communication devices, and appropriated processing arrangements [33]. Coordination with such advancements leads to utilization of effective and efficient resources in a concerned facility. CPS is an arrangement of teaming up computational elements which are in escalated association with the encompassing physical world and its on-going procedures, giving and utilizing, data-accessing and data-processing services available on the internet. CPS has gotten continually developing considerations of scientists from the scholarly world, industry, and government. In recent years, a precursor generation of CPS can be found in different application areas, such as aviation, automotive, civil framework, chemical processes, medicinal services, transportation, and manufacturing [34].

Findings

In traditional manufacturing, the machines associated with jobs are located and constrained in a single workshop or enterprise. However, for networked based manufacturing jobs and machines are distributed in different workshops or enterprises located globally at larger distances. Thus it can be inferred that for networked based manufacturing situation it is similar to one found in flexible manufacturing system, where many possible machines, operations are feasible but possibly not on the same shop floor.

Moreover, it can be said that in networked manufacturing, generation of optimal process plan for each job in the presence of several dynamic constraints, such as the present status of machines, tools, and fixtures, at a given manufacturing place, is posing a genuine challenge.

The following Table 2 presents a summarised comparison of main operations underlying traditional manufacturing and collaborative and networked manufacturing.

Table 2
Comparison of Networked Manufacturing over Traditional Manufacturing with various modes.

Operations	Traditional Manufacturing	Collaborative and Networked Manufacturing
Business range	Local/ confined to a shop floor	Globally distributed
Manufacturing and Management	Based on tradicional systems and centralized	Collaborative, decentralised and based on digitalization (IoT) and big data
Operational time	Shift base system with fixed time zone	Work around-the-clock without any interruptions
Organizational Structure	Function or product oriented	Process-or-project oriented based on flexible and autonomous resources
Production orientation	Make-to-stock	Make-to-order with customization
Relation between Enterprises	Competitive only	Competitive but collaborative
Manufacturing Functions	Linear	Integrated/ networked
Information Integration	Less response to change	Highly dynamic, agile and interoperable

Conclusion

In this paper, the literature review pertaining to analyse, synthesise and present a comprehensive systematic literature review (SLR) on the role of collaborative and cloud manufacturing process and big data in the context of networked manufacturing environment were discussed and presented. In this research, two books and nearly 51 journal publications were selected, reviewed and analyzed between the year 2000 to 2017 to find the future directions and opportunities for research in collaborative networked manufacturing environments. The SLR methodology is a useful tool to identify the gaps in the literature which leads to further establish the future opportunities to conduct the research. The developed methodology and conducted study can assist both academia and industry to develop new tools, techniques, and methodologies. The conducted research study may help enterprises to more easily realize what and how they can improve their existing distributed and networked manufacturing environments/ enterprises to be able to adapt to the exigent requisites of the forthcoming I4.0 era based on collaborative and cloud through networked manufacturing systems. Future research will focus on develop tools which could be used by manufacturing enterprises to maximization their benefits in I4.0 era.

This project is funded by Department of Science and Technology (DST-SERB), India under the grant Earlier career research. Moreover, this work has also been supported by COMPETE: POCI-01-0145-FEDER-007043 and FCT – Fundação para a Ciência e Tecnologia within the project scope: UID/CEC/00319/2013.

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