Review article

Digitalization of Production & Supply chain systems from XaaS to a Web 3 paradigm

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Abstract

The paradigm of Cloud production and manufacturing system can be considered as one of the most dominant enablers of Industry 4.0 paradigm. The emphasize of this paradigm for realization of service-oriented production and manufacturing systems has established new perspectives for manufacturing business models toward globalized and distributed orientations. This paper has reviewed research studies conducted through 2014-2022 regarding the elaboration of Cloud production and manufacturing system concepts. Considering the proposed roadmap of the research, four main themes have been considered for clustering the research studies. First theme, the research studies which have contributed to platforms and architectures for globalized service-oriented production and manufacturing systems. Second theme, the research studies which elaborated the idea of Cloud production and manufacturing systems by encompassing the transportation and logistics as service paradigm. The third theme, the research studies that contributed to development of operations research models for Cloud service network management and planning. Last theme, the research studies that extended and contributed the application of Blockchain and emerging Web 3 technologies in Cloud manufacturing networks. The studies emphasize the potential and capabilities of Web 3 for establishment of new business models in this network. The convergence of the themes in this research concentrates on more realization of service-oriented production and supply networks. The globalized interaction frameworks which operate with autonomous structures capable of resembling the preferences of Cloud stakeholders. From point view of sustainability pillars high research potentials can be of investigated. Moreover, the paper proposes the future studies with motivation of more globalized, sustainable, and autonomous Cloud networks in form of tokenization paradigm.

Keywords Cloud production and manufacturing systems, service-oriented network, Globalized supply network, Blockchain, Web 3.

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List of Abbreviations

3PL	Third-Party Logistics
AD	Axiomatic Design
AS/RS	Automated Store and Retrieval system
BWE	Bullwhip Effect
CAD	Computer Aided Design
CAM	Computer Aided Manufacturing
CIM	Computer Integrated Manufacturing
CNN	Convolutional Neural Network
DA	Data Analytics
DApps	Decentralized Application
DICOM	Digital Imaging and Communications in Medicine
DT	Digital Twins
EDI	Electronic Data Interchange
ERP	Enterprise Resource Planning
FEM	Finite Element Method
IF-VIKOR	Intuitionistic Fuzzy VIKOR
IoT	Internet of Things
IT	Information Technology
ISO	International Organization for Standardization
MCOCS	Multi Criteria Optimization and Compromise Solution
MES	Manufacturing Execution System
MDP	Markov Decision Process
ML	Machine Learning
MOM	Manufacturing Operation Planning & Management
OPC	Operation Process Chart
OR	Operations Research
PACS	Picture Archiving and Communication System
PLM	Product Lifecycle Management
PoW	Proof of Work
PoS	proof of Stake
PSO	Particle Swarm Optimization
QoS	Quality of Service
RMS	Reconfigurable Manufacturing Systems
SCM	Supply Chain Management
SD	System Dynamics
SME	Small and Medium Enterprises
SOM	Service Oriented Manufacturing
SPFL	Single Product Flow Line
TOPSIS	Technique for Order of Preference by Similarity to Ideal Solution
VIKOR	VIekriterijumsko KOmpromisno Rangiranje (MCOCS)
VRP	Vehicle Routing Problem
XaaS	Everything as a Service

1. Introduction

Cloud manufacturing as a service oriented manufacturing paradigm has been introduced around one decade ago[1–3]. This paradigm introduced a XaaS (Everything as a Service) idea for production and manufacturing systems[4, 5]. This trend proposed new insights for transformation of manufacturing and production systems from "Product Oriented"[6–8] and "Process Oriented"[9, 10] to service oriented business models. Through the last decades, there were various research orientations for the realization of Cloud manufacturing paradigm specially from point view of Industry 4.0 paradigm[11, 12]. This paper has investigated the research studies conducted by the author and categorized them into research focus themes and has analyzed the effects of themes for improving the Industry 4.0 paradigm. Moreover, discussing the latest research studies, it has elaborated the trends of the research studies for transformation of production and manufacturing business models from "Service Oriented" paradigm to "Tokenization Oriented" models.

The paper has organized the published research studies conducted from 2014 to 2022 in terms of the themes they have covered and investigated their contributions for realization of Industry 4.0 through Cloud manufacturing paradigm. Also, the requirements and trends of digital transformation for developing the Tokenization oriented model for production and manufacturing systems and the supply chains has been investigated. The main objectives which have been targeted can be categorized as:

- The transformational aspects of production and manufacturing systems and their supply chains in Cloud production and manufacturing systems and its alignment with Industry 4.0 paradigm.
- The research study aspects for new operations management models fulfilling the transformational aspects in Cloud manufacturing.
- The role of digital transformation technologies in shaping new business models for production and logistics business models.
- Special focus on Web 3 capabilities for enabling the new business models for production and manufacturing systems and their new models for decentralized production and supply chain organization.

2. Literature review

The paper will study 44 publications conducted by the author between 2014 and 2022. These studies have been publications in alignment with Cloud production and manufacturing paradigm and have targeted different aspects of this paradigm. In First section, a quantitative analysis for the publications would be introduced. In the second step, the paper proposes research themes for analyzing the research publications in clusters for better research explanation. The publications would be then discussed within themes for their contribution and alignment.

2.1. The quantitative analysis of the publications

For the qualitative analysis of the publications, the research studies are categorized based on their focus of research, the type of publications and publishers and their publication year between years 2014 to 2022.

2.1.1. Publication year

The total number of the publications is 44 which are distributed through years 2014-2022 s illustrated in Figure 1.

Figure 1. Publications distribution through years

From point view of types of publication, as shown in Figure 2, majority of publications are among journal publications.
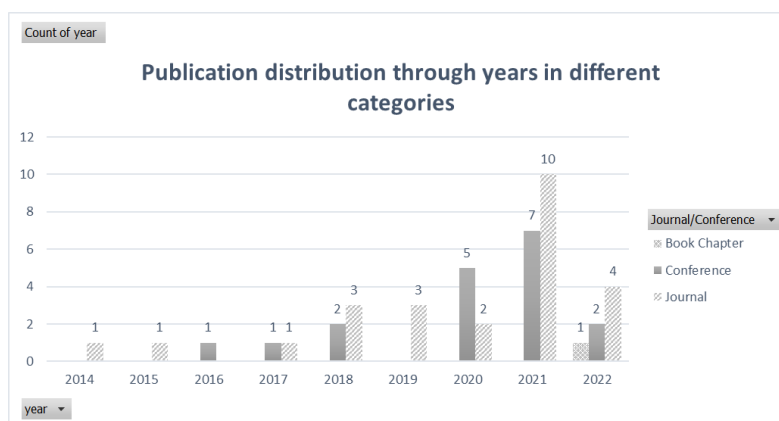
Figure 2. Publication category distribution through years

2.1.2. Journal publishers and titles

The publishers of the journals are distributed as shown in Figure 3, while Elsevier and Taylor & Francis are among the top referred journals.
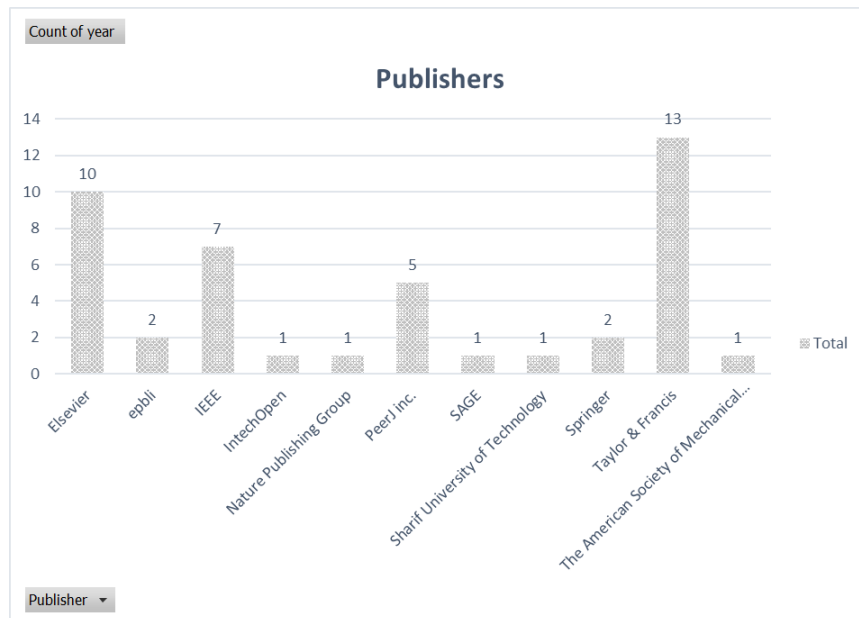
Figure 3. Contribution research publishers

Figure 4 Shows that the "International journal of production research", "IEEE Xplorer" and "PeerJ computer Science" are among dominant journal titles for research studies.

Figure 4. Journal titles for publications

2.1.3. Author contribution

The author has been in the corresponding author role of 41 published research studies among which his role in 33 papers has been defined as the last author. The author has been the first author in one of the publications. Figure 5 shows the distribution of the author number in which the majority is with three author participation.
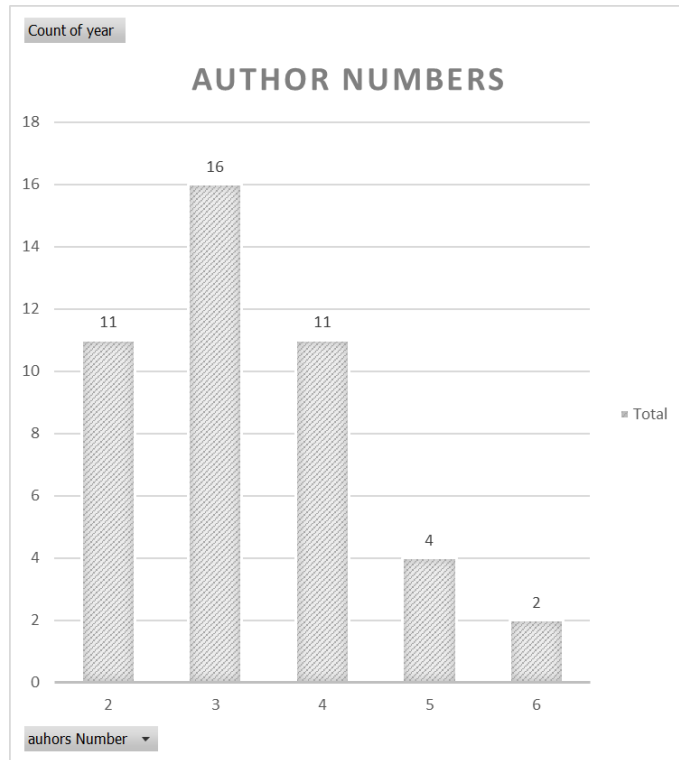
Figure 5. Number of the authors in publications

2.2. Research study analysis and discussions

In this section, the paper investigates and discusses the published research studies from quantitative perspectives. For integrity of discussions, the paper has proposed the following themes for categorizations of the contributions and their research orientations:

- Cloud manufacturing and XaaS paradigm realization. This theme considers all the publications which have proposed architectures and frameworks for realization of service oriented models in manufacturing and production systems. The main contributions in this theme focus on the required Information Technology (IT) features in terms of computational and communicational technologies to enhance the information exchange through different layers of production and manufacturing functionalities. This includes Manufacturing Execution System (MES) level and Manufacturing Operation Planning & Management (MOM) levels and the related process and data integrity. Also, the innovative technologies introduced in Industry 4.0 paradigm like 3D printing and their roles in realization of service-oriented production and manufacturing systems are investigated.

- Cloud Manufacturing & Transportation integration models. Considering the first theme which emphasizes on the realization of Service oriented manufacturing systems, the necessity of considering logistics and transportation in manufacturing operation service models would be inevitable. This is due to the nature of Cloud manufacturing which enables globally distributed manufacturing facilities which accomplish the fabrication operations through their available services. In this theme, the contributions are focused on facilitation of transportation and logistics services and their integration in terms of mutual production and manufacturing service and transportation service matching which will promote the service-oriented paradigm to a wider area including the Supply Chain Management (SCM) interaction level. Considering the global service matching paradigm and engagement of distributed fabrication enterprises in this paradigm, the issue of interoperability from point view of data and information exchange besides the process integration has been considered as well.

- Cloud Manufacturing & Operations Research Service models. This theme focuses on Operations Research (OR) perspective of Cloud manufacturing. Considering the two early mentioned themes, after the models and architectures for realization of service-oriented production and manufacturing systems are proposed, the contributions target the operations management perspectives of the models. The main target is the facilitation of practical aspects of service definition, composition, and matching. In this theme, the conventional production planning and transportation planning models are extended to fulfill the requirements of service-oriented production and manufacturing systems.

- Cloud Manufacturing Paradigm & Web 3 paradigm. This theme has been considered through the last three years of research contributions and is mostly focused on the application of Web 3 (also called Blockchain technology) in service-oriented paradigm of production and manufacturing systems. The main motivations of contributions in this theme will solve the problems of service-oriented production and manufacturing operation planning and management from a global perspective. As discussed in research studies in the third theme, the operations research aspects of the Cloud manufacturing systems are NP-hard[13] which introduces challenges for time wise solution providing. On the other hand, considering the global collaboration among different firms together, the centralized operations management paradigm would not be an efficient solution. The contributions in this theme will elaborate the capabilities of technologies in Web 3 and Blockchain for efficient realization of Cloud production networks.

The quantitative analysis of the research contribution in proposed four themes are shown in Figure 6. As illustrated, the first theme has been considered through all years of the research. The service-oriented production and manufacturing models

are highly important, and the research contributions have tried to enable new and competitive advantages aligned with industry 4.0 paradigm. In the last four years, the operations research theme and transportation were considered in parallel with the first theme to elaborate the practical aspects of the research framework and architecture in the first theme for a supply chain alignment. The last theme has been encouraged due to the trends for Web 3 technologies in the last three years. It is important to mention that overlap among the themes is inevitable and the focus of the contributions was the main criteria for categorization of the research studies.
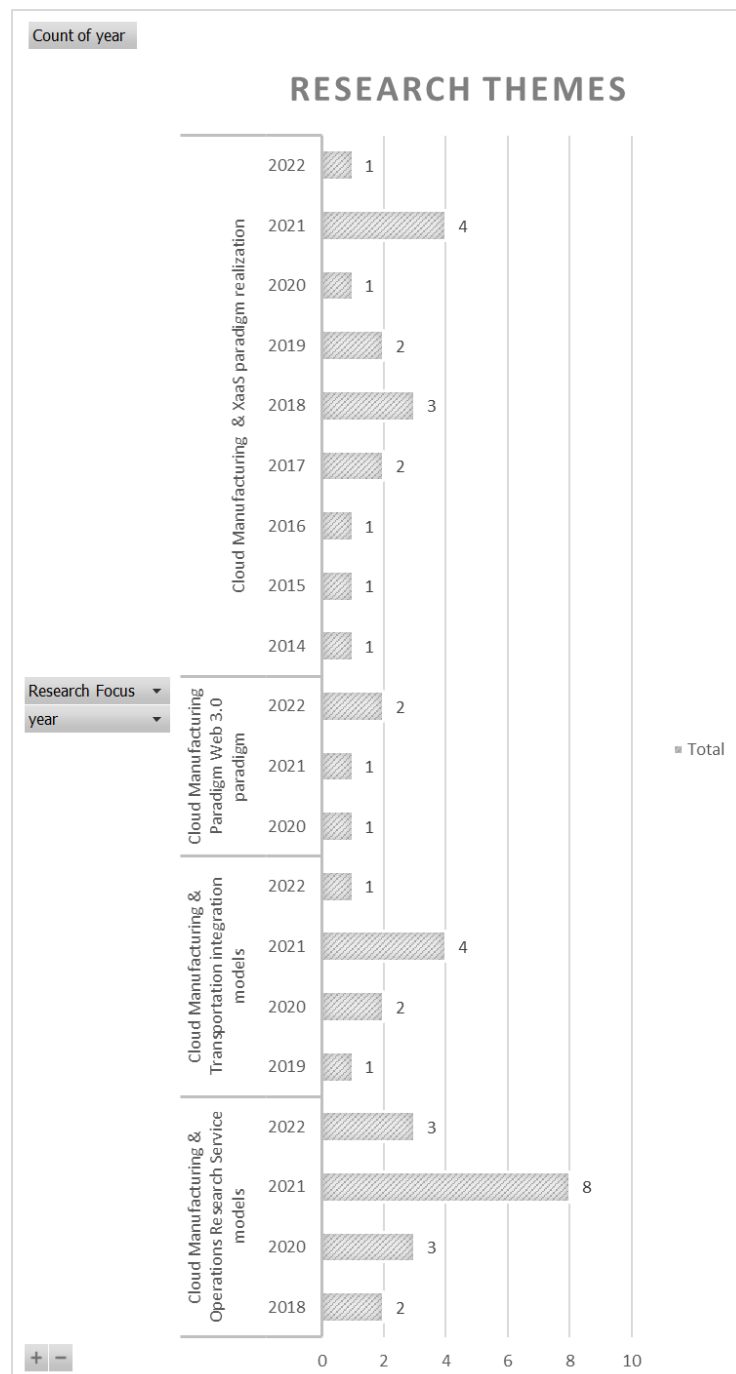
Figure 6. Research themes and their distribution through years

2.2.1. Cloud manufacturing and XaaS paradigm realization

As mentioned earlier, this theme contributes to the research studies which have proposed frameworks and architectures to enable the service-oriented production and manufacturing paradigm. Using the Industry 4.0 paradigm and its related emerging technologies, it was mainly intended to elaborate the functional frameworks in which the realization of the service-oriented production and manufacturing systems would be possible. These architectures are contributed to enable the interoperability and integrity of data and information among collaborating firms in production and supply chain networks. Also, the issue of application of emerging technologies and their applications from a global perspective has been focused.

Depicting additive manufacturing from a global perspective; using Cloud manufacturing paradigm for integration and collaboration[14]

This paper has considered the globalization as one of the requirements of Cloud manufacturing and considered the additive manufacturing potentials and its application trends in Industry 4.0 paradigm besides its characteristics for fulfilling the quick design to manufacturing were investigated. The research has discussed the requirements and necessities of additive manufacturing with respect to a Cloud manufacturing and globalized production systems. Two major requirements were demonstrated as the integration of manufacturing operations and enabling collaboration through the distributed manufacturing service providers. A framework for enabling additive manufacturing in the global paradigm was introduced. The framework applied the Cloud manufacturing paradigm for considering the 3D printing services through the network for communication of Computer Aided Design (CAD) and Computer Aided Manufacturing (CAM) data among distributed firms. The integration of processes for transition of data from design to fabrication phase over the globe has been discussed and a framework was proposed by the study.

Cloud-Based Global Supply Chain: A Conceptual Model and Multilayer Architecture[15]

Considering the service-oriented nature of Cloud manufacturing, the distribution of required production operations with various production service providers would be inevitable. This study discussed the required insights for managing the supply chain interaction for Cloud manufacturing systems. Considering the cloud manufacturing paradigm as an advanced form of networked manufacturing, its relationship with existing manufacturing systems and emerging technologies like virtual manufacturing, manufacturing grid and Internet of Things (IOT) was investigated. The study proposed a prospective conceptual model called cloud-based global supply chain (CBGSC). This model addressed challenges related to supply chain processes on a global scale. CBGSC was designed to extend the conventional three tier customer manufacturer supplier supply chain model into a new five tier customer cloud provider of manufacturing applications (CPMA), manufacturer cloud provider of supplying

applications (CPSA) supplier mode. The new tiers act as intermediators for improving the variety of markets of conventional supply chain parties.

Development of a Novel Solution to Enable Integration and Interoperability for Cloud Manufacturing[16]

The service-oriented nature of Cloud manufacturing necessitates the interaction of diverse operation service providers over the globe together. In this study the challenges regarding the integrity of manufacturing operation data and also the requirements regarding the seamless data exchange among them have been investigated. This is one of the essential gaps for enabling the complete realization of Cloud Manufacturing solutions. To resolve the integration and interoperability requirements, the application of EDI X12 (Electronic Data Interchange) standards for fulfilling the integrated and standard data format was considered. The application of the proposed model for Supply Chain process Management among service providers has been discussed and illustrated through case study scenarios.

A Novel Solution for Manufacturing Interoperability Fulfillment using Interoperability Service Providers[17]

Considering the past research studies for enabling the interoperability an integration of service accomplishment among the service providers, this research proposed a novel idea in which the integration and interoperability could also be assumed as services. This idea aligned with the XaaS paradigm was trying to improve the interaction in terms of available services which manufacturing operation service providers could acquire from cloud platforms. Due to wide global distributions of manufacturing service providers, the seamless data exchange inside the service-oriented architectures should be enhanced. So, applying a service-oriented approach of the cloud manufacturing was proposed by Information Technology related service provider firms. The firms can fulfill the data integrity requirements in manufacturing clouds with their interoperability services. The manufacturing cloud members acquired these services for facilitation of data communication with their collaborators. The research focused on mechanisms regarding service integration functions and also service mapping functions for data integration.

Configuration design in scalable reconfigurable manufacturing systems (RMS); a case of single-product flow line (SPFL)[18]

To enable the service-oriented production and manufacturing systems, conventional product or process centric management of such systems should be changed. This requires the transformation of operation definition in such production systems into a service-oriented style. The concept of reconfigurable manufacturing systems (RMS) concept was focused in this study for enabling this transformation. The paper considered the RMS configuration design as a basis for service definition. As the demand of a single product can vary throughout its production life cycle, the system

configuration can change accordingly to fulfill the demand in RMS. The idea was used to develop a method for defining the proper configuration design and the required reconfigurations according to demand rate changes. The concept of module and enabling the reconfigurability of production operation enables the flexibility and agility of manufacturing systems for different production scenarios. This can be an enabler for service-oriented manufacturing operation definition. This flexibility will enable the service providers to fulfill the required manufacturing operation based on the possibility of different service composition scenarios which are provided in the Cloud ecosystem.

Process-oriented perspective in structure dynamics: A novel way to enhance ERP systems[19]

One of the important aspects of production and manufacturing systems is related to the operation planning and management. This concept is fulfilled with the Enterprise Resource Planning (ERP) solutions. In this research, the issue of fulfilling the Cloud manufacturing and its service-oriented paradigm was investigated in relation with ERP systems. Considering that Cloud manufacturing necessities the flexibility of production operation management in form available services, a system dynamic approach was introduced to deal with dynamic perspective of operation management. This enables the sustainability of system mechanisms to adapt with time through dynamic changes. To handle the dynamic behavior of the Cloud systems, a process-oriented architectural for analyzing the manufacturing organization structure was considered through the supply chain which would be capable of analyzing the structure dynamic behaviors. Also, the critical role of ERP systems for operation data acquisition and analysis was investigated.

An architectural view to computer integrated manufacturing systems based on Axiomatic Design Theory[20]

Considering the service-oriented paradigm, the application of Computer Integrated Manufacturing (CIM) solutions will face with challenges. Enabling the possibility of interacting with globally distributed manufacturing CIM solutions and also the wide range of processes through the manufacturing supply chain from service-oriented perspective introduce the complexity of integration of the solutions. To enable the manufacturing systems to benefit from the capabilities of CIM solutions an architectural view as the basis for designing and development of cloud manufacturing systems was adopted. The proposed architecture was a layered architecture covering five perspectives of a CIM Cloud manufacturing system. Physical, Functional, Managerial, Informational, and Control aspects of Cloud manufacturing systems were analyzed and were mapped to the layers of the proposed architecture. The study applied the Axiomatic Design theory to make sure the complexity of five layers functionalities is feasible from point view implementation. Also, integrity of data and information exchanged inside the architecture were fulfilled using (International

Organization for Standardization) ISO standards aligned with the globalized manufacturing industry.

Configuration design of scalable reconfigurable manufacturing systems for part family[21]

As in previous research studies, the issue of service orientation for Cloud based production and manufacturing operations was focused, this study has been initiated in terms of more realistic assumptions for encompassing of variety of product varieties in manufacturing systems. As the modularity of manufacturing systems can facilitate the realization of service-oriented manufacturing systems, considering the variety of product and defining a framework for handling the configuration for flexibility of production system was focused. This research proposed the possibility of agile response of production and manufacturing systems for changes in manufacturing operation capabilities and capacities which would be a necessity for Service oriented paradigm. A mathematical model also was proposed for fulfilling of configuration design for a scalable reconfigurable manufacturing operation. The capabilities of the research contribution were compatible with conditions in which analysis for total system design costs for flexibility of service fulfilment or possibility of offering the unused capacity as services were encountered.

An architectural solution for virtual computer integrated manufacturing systems using ISO standards[22]

To continue the issue of integrity of data regarding production and manufacturing operations, this research focused on the capabilities of ISO standards for data integrity in Cloud ecosystems. This is a key element for fulfilling the manufacturing ecosystems which can interact with other service providers in a globalized context. So, defining the integration issue from CIM point of view, a Virtual CIM (VCIM) was introduced in this research as an effective solution to extend the traditional CIM solutions. The research investigated recent research studies in VCIM/CIM with focus on the necessities of globalized Cloud manufacturing systems. An effective solution for data integrity with a feasible implementation approach was proposed. Like former conducted research studies, to fulfill the complexities in designing the integrated model, the study exploited Axiomatic Design (AD) Theory for validation of the proposed integration framework. The implementation aspects of the framework using based ISO standards were analyzed and validated in case studies.

A novel digital dentistry platform based on cloud manufacturing paradigm[23]

While the main aspects of Cloud based production and manufacturing systems were elaborated through research and studies, there have been opportunities to propose new business models with the application of the service oriented and Industry 4.0 based production and manufacturing systems. From one point of view, the service-oriented

perspectives of production and manufacturing systems enabled the offer of services for fabrications of prosthetics or oral scanning services for CAD files and from other perspectives technologies like 3D printing and their capabilities for rapid and agile fabrication of customized products. The research proposed the digital dentistry paradigm and elaborated the digital dental workflow in terms of phases including scan, design, production planning and fabrication. In each phase the application of a variety of software solutions and digital technologies were investigated. The service-oriented approach in terms of intensive collaboration of dentists, dental laboratories, imaging, and production centers were discussed. The facilitation of interoperability among digital components was also considered and the application of Digital Imaging and Communications in Medicine (DICOM) standard for integration of data was suggested. Moreover, the application Picture Archiving and Communication System (PACS) concept for fulfilling the design, implant planning, process planning, and production workstations was considered. This study can be considered as one of the transformation production business models which benefits from the service-oriented production network.

Inspiration of Industry 4.0 to Enable a Proactive Sustainability Assessment Model through the Supply Chain[24]

Considering the elaboration of global production and manufacturing systems, a challenge in context of sustainability assessment framework was addressed in this research. The main motivation was concentrated on the improvement of sustainability assessment for compatibility with Industry 4.0 and service-oriented paradigm. The implementation of sustainability assessment concepts and for supply chains which includes the composition of distributed service providers over the globe is an important challenge for future production business models. While most of Industry 4.0 technologies enhance the short-term decision-making processes for production systems, the long term and dynamic consequences of the decisions should be integrated at the senior level and long-term decision making for sustainability perspectives. Moreover, by realization of Industry 4.0 paradigm and the application of Data Analytics (DA) tools for managing the dynamic changing environment, this integration would be more challenging. The research focused on dynamic behavior of data analytics results and how it would affect pillars of firm, environment, and society. An analytical Markov Decision Process (MDP) decision model to address the sustainability concerns was proposed. This enables an adaptive and proactive sustainability assessment model integrated with data and information in Industry 4.0 context. The model could be applied for supporting the robust decision-making structure for sustainability. The paper has elaborated on the capabilities of MDP as a statistical tool for treating the dynamic of data analysis in the Industry 4.0 context while fulfilling sustainability assessment through resilience structure. A case study has been designed to investigate the details of framework capabilities for supporting decision making in senior levels of the firm.

A novel framework for storage assignment optimization inspired by finite element method[25]

Elaborating the perspectives of service-oriented production and manufacturing systems, the concept of inventory and storage management would be an essential topic. The service-oriented paradigm requires high agility for transfer of various materials and final products while fulfilling the services. So, this study focused on the novel operation management models for Inventory management. The study investigated the requirements for fundamental and structural changes in inventory management of the production and manufacturing systems to fulfill the industry 4.0. The study proposed a new definition of storage assignment and layout problem for fulfilling storage mechanism agility for Automated Store and Retrieval system (AS/RS) in service-oriented paradigm. The study proposed a new model called SAO/FEM (storage assignment optimization technique) which was inspired by algorithms of stress distribution analogy and total potential energy theory. This model was developed to handle storage assignment optimization. The capabilities of the model for enabling agility in inventory level and fulfilling the requirement of agile and rapid material handling in Cloud production systems were discussed in different case studies.

Allocation and scheduling of digital dentistry services in a dental Cloud manufacturing system[26]

As in earlier mentioned research study, the concept of digital dentistry was proposed in terms of applying Cloud based and service-oriented production and manufacturing system, in this research the ideas were elaborated toward the development of Cloud base ecosystem for complete dental Cloud production ecosystem. The study focused on characteristics of dental products from point view of highly being customized and personalized based on the patient's characteristics and the required manufacturing process flexibility and agility for fulfilling requirements like quality, delivery time and cost. Also, considering the variety of software and hardware solutions like scanners, design software and production devices, the collaborative and interoperable paradigm was investigated in digital dentistry ecosystem. The study proposed a Cloud dental production system enabling the collaborative workflow of medical manufacturing processes. Moreover, a new mathematical model was developed for allocation and scheduling the services in the cloud dental platform for responding to the NP-hard challenges of the service planning and scheduling.

An autonomous framework for interpretation of 3D objects geometric data using 2D images for application in additive manufacturing[27]

Considering the service-oriented paradigm in production and manufacturing systems and widespread application of 3D printing, this research focused on the 3D printing services. The main idea focused on the concept of using 3D printing service providers distributed over the globe for fulfilling the fabrication process. However, to enable the

3D printing service selection, design file regarding the product CAD files should be interpreted for fabrication cost and lead time estimation. The paper focused on the application of artificial intelligence for CAD file interpretation. The paper has proposed additive manufacturing, artificial intelligence, and cloud manufacturing as three pillars in industry 4.0. The Study also proposed a framework for creation of an autonomous platform for Cloud-based service composition for 3D printing services. The proposed framework interprets shapes, or their informative two-dimensional pictures, automatically by decomposing them into simpler shapes by using Convolutional Neural Network (CNN) as decomposition and recognition tools respectively are proposed. This enables the possibility of benefiting from 3D printing services without the requirement of human intervention in early stage of 3D printing service acquisitions which highly improve the spread of Cloud production networks.

A Distinctive Real-time Information for Industries and New Business Opportunity Analysis Offered by SAP© and Anylogic© Simulation[28]

Elaborating the service-oriented production and manufacturing paradigm, the collaboration of different disciplines engaged in operation planning and development would be inevitable. This research focus on the concept of Digital Twins (DT) in Industry 4.0. This is essential as the service providers and their real-time data communication within Clouds would require a DT environment which would be used for prediction and planning of manufacturing operation execution. So, to handle the dynamics of behavior of different service providers in the Cloud, a solution for integrating two prominent simulation software packages for operational planning was considered known as SAP© and Anylogic© for real-time data interaction. SAP© was focused from point view of utilizing real-time data analysis from MES level and then communicating it with AnyLogic© for evaluation of alternative scenarios for operation planning.

The Requirements of Product Lifecycle Management (PLM) frameworks for integration and synergic collaboration with Omnichannel strategy[29]

In the latest research in this category, the issue of transforming the Product Lifecycle management (PLM) frameworks has been focused. Considering the service-oriented production and manufacturing systems, no longer the product or process-oriented disciplines for product development would be effective solutions. This requires the integration of data obtained from production service fulfilment and realization of the trends of applied services for product development in the context of Industry 4.0. The study focused on sales related support services which are used in Omnichannel context and can be useful for extracting the customer experience. The integration of the processes related to product promotion and digital marketing in Omnichannel due to lack of process integration would be a great challenge. The study has investigated the capabilities of the Omnichannel strategy for enhancing the functionalities of PLM. By analyzing the characteristics of mutual integration of PLM and Omnichannel, the

application of knowledge extracted from Omnichannel in PLM disciplines has been investigated.

XaaS realization conclusion and discussions

The analysis of the research studies in section 2.2.1 demonstrates the different aspects of improving the production and manufacturing systems for service-oriented paradigm adoption. Table 1 shows the overall characteristics of these studies. The studies are aligned with the motivations in Industry 4.0 in terms of benefiting from digital transformation technologies. The most important aspects in this theme can be interpreted as the fulfilment of challenges which were affecting the process and data integration and interoperability for globally distributed production and manufacturing service providers. The studies in this area shall be continued with a special focus for enabling the integration of knowledge models among the service providers. The proposal of service providers for facilitation of interoperable frameworks would of other interesting further research topics in this theme.

Table 1. Cloud manufacturing and XaaS paradigm realization theme research studies

Research theme	Focus of study	Targeted research gaps	Contribution
3D printing and Cloud manufacturing[14]	3D printing and additive	Interoperability and integration of CAD/CAM data for 3D printing	Proposal of framework for service-oriented 3D printing in XaaS paradigm
Cloud based Supply chain Conceptual model[15]	Cloud based supply chains	Supply chain processes in Cloud manufacturing from a global perspective	Proposal of tiers for enabling of variety of supply chain parties' collaboration
Interoperability and integration in Cloud manufacturing[16]	Data exchange in Cloud manufacturing	Seamless data communication for service composition	Application of EDI X12 (Electronic Data Interchange) standards
Interoperability service providers[17]	Data exchange in Cloud manufacturing	Facilitation of the data exchange among service providers	Mechanisms for integration and interoperability as Services
Production operation definition as services[18]	Reconfigurable manufacturing system	Enabling the production operation definition compatible with service-oriented paradigm	Modularity of manufacturing operation and reconfiguration model
ERP systems and the dynamic of manufacturing operation[19]	ERP and Cloud Manufacturing	The dynamic of operation planning for global manufacturing	System Dynamics approach for manufacturing enterprise dynamic operation analysis

Research theme	Focus of study	Targeted research gaps	Contribution
Complexity of service-oriented realization in manufacturing systems	Computer Integrated solutions for Cloud manufacturing systems	Complexity of manufacturing operation integrity in service-oriented context	Using Axiomatic Design theory to enable the feasible CIM solutions for Cloud manufacturing systems
Production operation definition as services[21]	Reconfigurable manufacturing systems	Enabling the production operation definition compatible with service-oriented paradigm	Modularity of manufacturing operation and reconfiguration model with possibility of production variety
ISO standards for Cloud manufacturing data integration[22]	Integration of data and operation in Cloud manufacturing	Integrated data models for global production and manufacturing systems	Proposing the application of ISO Standards for fulfillment of production and manufacturing operation in a global context
Application of Cloud manufacturing for novel business models[23]	Digital Dentistry	Application of Industry 4.0 paradigm in digital dentistry	Proposal of a workflow model including service oriented digital manufacturing services for scanning and fabrication
Sustainability and service-oriented manufacturing[24]	Elaborating the sustainability in Cloud based production systems	Sustainability assessment in a globalized context	The pillars of globalized sustainability assessment
Cloud based Production operation management[25]	Storage and inventory management	The agility of storage systems for service-oriented paradigm	A storage assignment for agile inventory assignment
Elaboration of Cloud manufacturing for digital dentistry[26]	Digital Dentistry	The allocation of resources for efficient patient treatment	A dental Cloud manufacturing ecosystem
3D printing and Cloud manufacturing[27]	3D printing through service-oriented paradigm	Autonomous frameworks for CAD data interpretation	3D data autonomous interpreter as a service in Cloud
Data communication	Data integration	Lack of integrity among software	A simulation model for integrating data

Research theme	Focus of study	Targeted research gaps	Contribution
for operation exchange in Cloud manufacturing[28]	among software solutions	solution in service-oriented production systems	communication among SAP© and Anylogic© software solutions
Product lifecycle management in service-oriented production system[29]	PLM and its fulfillment in service-oriented context	PLM traditional product or process-oriented structure	Transformation of conventional PLM models for service-oriented production systems

2.2.2. Cloud Manufacturing & Transportation integration models

The realization of Cloud based production and manufacturing systems insists on consideration of whole production and manufacturing processes as available services distributed over the globe. Although the composition of the services for fulfilling the requirements of production operation provides great opportunities for different business models, the distribution of operation service providers requires the consideration of transportation and logistics among the operation service providers. This theme encompasses all the research studies which contributed to form of transportation and logistics models and integrating them into service-oriented Cloud production and manufacturing systems. Special focus also has been devoted for the integrity of process and information from supply chain management perspectives. This includes considerations for the raw material procurement and the inbound logistic operations as well as distribution and dispatching operation for last middle delivery of produced products to the end consumers and their effects on the management and planning of fabrication services.

A novel model for optimization of logistics and manufacturing operation service composition in Cloud manufacturing system focusing on cloud-entropy[30]

This study developed the idea of integration of transportation and manufacturing operations in terms of available services over the globe. So, besides the availability of services for fulfilling the manufacturing operations, the transportations services can be adoptable from the Clouds to facilitate the material handling among the fabrication service providers. The study considers this transformation as one of the main factors for globalization and geographically distributed suppliers across the globe. By analysis of the Cloud manufacturing integration with its supplier network, the idea of logistics planning and manufacturing service composition is developed. So, the production tasks and logistics operations are considered as available services. The study considered an operations planning model for selection of optimal set of manufacturing and logistics service with consideration of lower operation and logistics costs for production. To handle the complexity of transportation services with corresponding manufacturing

operations, the whole network of services was analyzed with a perspective of Cloud entropy of logistics and operation suppliers.

Public sustainable transportation planning with service level efficiency: Hamburg case study[31]

Considering the aspects of transportation as service and the required service evaluation mechanisms, this study contributed to service level evaluation models for public transportation services. The public transportation service network was targeted for this study and assignment of public transportation services with evaluation criteria for cost and environmental aspects were targeted. Using the operation planning models for resource assignment problem and proposing the multi-objective planning paradigm a public transportation service assignment was proposed. The model could analyze the tradeoffs for improving the service fulfilment in terms of financial metrics and controlling the environmental metrics for emissions. The study used the real data of Hamburg public transportation for investigation of model capabilities.

A novel mathematical model for a cloud-based drone enabled vehicle routing problem considering multi-echelon supply chain[32]

The idea of mutual Cloud manufacturing and transportation services highlights the role of effective transportation service management for realization of service-oriented production and manufacturing systems. This is due to the requirements of physical material handling among operation service provides throughout the globe and the effects of corresponding logistics costs. In this study, one the recent technologies for enhancing the logistics cost and service level known as Drone technology was focused. The study investigated the product delivery systems and the motivations of Cloud production systems for reducing cost and waiting time of last-mile delivery. The paper proposes the potential of drone technologies to deal with the cost efficiency of transportation services and has developed a novel operation planning model for routing and assignment of drone services based on their assigned routing among nodes in a multi-echelon supply chain. The drone logistics services were assumed to be available through the Cloud solution by third-party logistics companies (3PL) and warehouses owners.

Dynamic mutual manufacturing and transportation routing service selection for cloud manufacturing with multi-period service-demand matching[11]

To elaborate the realization of mutual transportation and manufacturing operation service management, this research study focused on the dynamic characteristics of service providers in the Cloud. The main idea was the possibility of participation of manufacturing firms and logistics service providers together in Cloud ecosystems aligned with XaaS paradigm. The research study focused on efficient service composition both for including mutual operation and transportation services and their

effects on each other in Cloud manufacturing paradigm. The challenges were investigated to be the service composition complexity due to large size and complicated dynamic characteristics for continually received service requests. The study proposed a model for fulfilling the Quality of Service (QoS) requirements for service composition. The study also considered NP-hard characteristics besides the dynamicity of the allocation problem in the Cloud composition problem and contributed for the practical aspects of solving the model time-efficient approach. The results demonstrated the capabilities of the model for service composition with dynamic behavior of manufacturing and logistics service composition for possibility of including arrival of new services and demands into the Cloud.

Alternative Process Routing and Consolidated Production-Distribution Planning with a Destination Oriented Strategy in Cloud manufacturing[33]

To progress the mutual transportation and manufacturing service orientation, this study extended the ideas in terms of using the operations services with a strategy to produce the final product near to final customer delivery location. So, the operation services can be selected with orientations for geographical locations near to their targeted delivery locations. This enables the paradigm of Cloud manufacturing to overcome the crises for transportation more efficiently for using distributed manufacturing resources while using the opportunities to decrease the logistics and production costs. The study proposed a structure model for decomposing ordered tasks to several subtasks and then considering them as services which should be allocated to distributed manufacturing resources. Form the implementation aspects, the paper also developed an operational planning model for evaluation of Cloud manufacturing performance. The proposed decomposition models for services created the alternative process routing concept. So, the decomposition of operation tasks to several manufacturing plans enabled the flexibility of Cloud system for proper service assignment which was offered as consolidated production-distribution toward destination nodes strategy.

Sustainable Public Transportation using Markov Chains: Case study Hamburg Public Transportation[34]

This study was extending the former research study[31] in terms of realization of transportation services in public service sectors. The main idea was the proposal of efficient public transportation systems with high service levels by enhanced prediction of public transportation service providers' arrival time to stations. The study considered the dynamic behavior of transportation services and proposed models for prediction by considering the buses' operation parameters and variables with stochastic characteristics using a Markov Chains. Also, for fulfillment of both customer-oriented service evaluation metrics and also environmental aspects, a model for service assignment based on multi-objective planning structure was considered. For validation of the proposed framework, the real data of Hamburg public transportation

was considered. The findings illustrated the possibility of effective strategic planning for public service assignment while protecting the environmental aspects in terms of minimizing environmental emissions.

Extending the Last Mile Delivery Routing Problem for Enhancing Sustainability by Drones Using a Sentiment Analysis Approach[35]

The idea of engaging the customers in enhancing the sustainability perspectives of transportation services in Cloud production and manufacturing system was considered in this research. In this research, the idea of using drones as an effective approach for facilitating the transportation services was enhanced with the power social media platform. The motivation was to involve the customers in improving the sustainable perspectives of transportation service planning. The study focused on last mile delivery as one of the important stages of Cloud supply chains for the final stage of delivering products to the end customers. The research investigated the biggest challenges for improving the sustainability perspective and reducing pollution of transportation services. An idea was proposed for fulfilling the transportation service planning in form of vehicle routing problem with drones. The idea relied on a sentiment analysis approach for revealing the alignment of customer sentiments on environmental protection and including them for flexibility of transportation service planning. The study has proposed the potential of data analytics and machine learning potential for customer engagement in improving the sustainability of the Cloud supply chains.

Drone routing problem model for last-mile delivery using the public transportation capacity as moving charging stations[36]

The idea of considering drone technology for transportation service fulfillment in Cloud production and manufacturing system was pursued in this research. The study investigated at the first stage the cost efficiency of transportation services via drone technology. Also, the application of drones as a promising technology was studied in terms of its merits for improving both environmental and economic criteria. The study considered the drone transportation services in a last mile delivery model and the possibility of using the public transportation system for available charging services. To fulfill the practical aspects, an operation planning model based on vehicle routing problem was also extended to cover the problem scope. The study applied a real-world case inspired based on Bremen 2025 transportation strategic paradigm. The analysis of results explained the important effects for sequencing of customers visits and availability of public transport stations on the framework performance. The study considered two important aspects of service-oriented models. The first aspects referred to the drone transportation services for product delivery and second aspects pointed out the high potential energy saving for drone-enabled transportation services by using the public transportation network service for charging.

Service oriented transportation and manufacturing conclusion and discussions

The analysis of the research studies in section 2.2.2 demonstrates the aspects of transportation and logistics service evolvement in Cloud production and manufacturing systems. The studies emphasized the importance of service-oriented transportation for XaaS production systems. Table 2 shows the overall characteristics of these studies in terms of transportation service fulfillment. While the first theme of research studies was more focusing on shopfloor aspects of material processing Cloud ecosystems, the second theme has concentrated on the efficient models of transportation in global manufacturing. As illustrated in Table 2, the studies have tried to open new paradigms of Industry 4.0 technologies like drone technologies and social media data analytics. This theme of research studies is an essential key factor for successful Cloud based production systems which benefit from distributed services over the globe and keep their performance criteria in terms of transportation costs and challenges. The studies in this area shall be continued with a special focus for enabling more efficient transportation service composition models and alignment with sustainability perspectives of transportation paradigm. It is worth mentioning that as stated earlier, the overlap of the research studies in the second theme with other themes is inevitable as for practical aspects operations research models were also developed. However, the focus of these research studies was mostly toward the service-oriented frameworks for transportation aligned with second theme focus.

Table 2. Cloud Manufacturing & Transportation integration model theme research studies

Research theme	Focus of study	Targeted research gaps	Contribution
Logistics and transportation in XaaS paradigm[30]	Transportation operation planning for Cloud manufacturing	Mutual transportation and manufacturing service operation planning	Using an entropy based mechanisms for effective mutual transportation and manufacturing services
Public transportation fulfilment in service-oriented paradigm[31]	Transportation operation planning	Prediction of transportation requirements and adaptive planning	Extending the VRP models for public transportation services
Drone planning for transportation services in service oriented manufacturing systems[32]	Transportation service effective business models	The potential of using Drone technology as transportation service in service-oriented manufacturing network.	Proposal of a drone enabled transportation model
Transportation and manufacturing service management	Mutual service composition models for fulfilling both manufacturing and logistics	Fulfillment of dynamic characteristics of operation and transportation service providers	The dynamic mutual service assignment framework with capability

Research theme	Focus of study	Targeted research gaps	Contribution
Mutual transportation and manufacturing service management[33]	Flexibility of service management and efficiency	Alternative routing for more compatibility of operations and logistics services	Shared transportation services for operation service fulfillment with alternative routing
Public transportation fulfilment in service-oriented paradigm[34]	Transportation operation planning	Consideration of sustainability paradigm in transportation service planning	A Markov chain model
Logistics and transportation in XaaS paradigm[35]	Transportation service effective business models	Customer engagement through social media for effective transportation planning	Extending the capabilities of traditional transportation planning models by machine learning techniques
Drone planning for transportation services[36]	Transportation service planning	The charging capacity limitations for drone application	Integrating the public transportation as mobile charging stations for drone transportation service planning

2.2.3. Cloud Manufacturing & Operations Research Service models

The third theme of the research studies would focus on operations research aspects of XaaS production and manufacturing systems. The main pillars of contributions are related to mathematical models for encompassing more realistic Cloud based ecosystems operational models. The main challenges for Cloud production and manufacturing systems are due to global perspective of the model which with the NP-hard nature of these problems which necessitate the effective solving approaches for practical aspects. So, the studies in this theme are contributing to both mathematical model structure and the solving approaches.

A Mathematical Model for Task Scheduling in Cloud Manufacturing Systems focusing on Global Logistics[37]

This study focused on the mathematical models for service scheduling problem of single or multiple tasks in Cloud manufacturing. The structure of mathematical model fulfils the logistic aspects. The possibility of using shared logistics services for cluster of operations services is enabled. The objective function considers the operation and transportation costs. The dependencies among the operation service fulfilment and also the sequences of the operation service fulfillment were also embedded thought the

model structure. The model was developed to maintain the linear structure for efficient solving and was solved in small sample cases with deterministic approach.

Mutual manufacturing service selection and routing problem considering customer clustering in Cloud manufacturing[38]

This study focused on the mathematical models for operation and transportation service assignment problem using the operation process chart (OPC) of product for efficient transportation service assignment in Cloud manufacturing. The structure of mathematical model fulfils the clustering of customer for product delivery for shared logistic aspects. The possibility of using shared logistics services for cluster of operations services is considered. The objective function considers the profit in terms of sales profits and the operation and transportation costs. The dependencies among the operation service fulfilment and also the sequences of the operation service fulfillment were also embedded thought the model structure. The model was developed with linear structure for efficient solving time and was solved in large scale sample cases with genetic metaheuristic algorithm. This study has contributed to the service composition models with customer orientation service composition which highly decrease the transportation costs for global manufacturing. The study considers single-product supply network in Cloud manufacturing. The service selection model benefits from the layered structure of transportation and production services with clustered.

Flexible flow line scheduling considering machine eligibility in a digital dental laboratory[39]

This study developed a mathematical model for the research studies in the first theme related to digital dentistry paradigm. The main idea was to develop a service assignment and scheduling model for digital dentistry required task organization in form of a flow line problem. The model was designed to set for the minimization of lead time of prosthetic delivery to patients. The resulting model included constraints for assessment of orders in digital dentistry environment and optimization of production planning and scheduling. The study also developed a metaheuristic algorithm based on Particle swarm optimization (PSO) to respond to NP-hard challenges of the model. The model objective function considered makespan and total completion time objectives which targets the lead time of prosthetics production and enhance the patient treatment service level in digital dentistry.

Manufacturing Cloud Service Composition Based on the Non-cooperative and Cooperative Game Theory[40]

This study considers the Cloud production and manufacturing systems from a new perspective. This perspective emphasizes the consideration of utilities from different stakeholders' point of view like service providers and demanders. So, the mathematical modeling approach should be able to include all the benefits from different parties in service matching problem. This is an important perspective for Cloud based supply

chains consisting of various firms collaborating. The study considers a new model for manufacturing Cloud service by defining the stakeholders like service providers and demanders and their corresponding utility aspects. Also, a profit function and a mathematical model for service composition based on game theory approach are structured. The study investigates the non-cooperative and cooperative games for analyzing the interaction of stakeholders in Cloud ecosystems. This can be interpreted as a public Cloud markets. The results demonstrate that the cooperation game is more profitable than the non-cooperative game based on the formal cooperation among the Cloud service providers. Analysis also shows the level of Quality of Service (QoS) in the cooperative game is greater than the game type of non-cooperative which can be beneficial for designing the market strategies for Cloud based ecosystems.

Equilibrial service composition model in Cloud manufacturing (ESCM) based on Non-cooperative and cooperative game theory for healthcare service equipping[41]

Considering the concept of public Cloud markets and including the utilities of all stakeholders in modeling of service composition, this study has investigated the solution approach in game theory models. Focusing on the importance of efficient service composition in manufacturing Clouds and the interaction of service providers with distributed geographical locations, the application of game theory for mathematical modeling was investigated. From point view of solution providing a named Equilibrial service composition model was proposed which considers the service providers and consumers mutual benefits. The structure of the model elaborates the payoff function based on a profit function of stakeholders. The study developed a service composition model based on a non-cooperative game approach. The Nash equilibrium was proposed as the QoS value of service composition with the payoff value for the players. Also, the model was analyzed from point view of cooperative game approach in which the players participate in coalitions to develop the composite services based on formal cooperation. The results showed the players' payoff and the QoS value are better in the cooperative game than in the non-cooperative game.

An Analysis of the BWE-Associated Costs: The issue of Demand Forecasting Accuracy[42]

This study concentrated on modeling the demand forecasting for more effective service composition in Cloud supply chains. The study suggests the importance of the bullwhip effect (BWE) and its impact on increasing the total cost of a supply chains affecting the preferences of whole network stakeholders. The study explores the role of demand forecasting accuracy on the amount of the BWE related costs and proposes a simulation model on a two-echelon supply chain to investigate the association between forecasting accuracy and the BWE related costs. Ideas about the replenishment policies were suggested to determine order values that mitigate the BWE costs in comparison to the classic policies. The result of this study plays an

important role in determining the parameters of service composition models. To increase the robustness of the solutions provided by the service composition models and insure the effects of fluctuations through the supply chain service providers.

A Matching Mechanism for Public Cloud Manufacturing Platforms using Intuitionistic Fuzzy VIKOR and Deferred Acceptance Algorithm[43]

To pursue research studies on public Clouds, this study focuses on service matching mechanisms in Cloud Manufacturing platforms based on the Intuitionistic Fuzzy Sets Theory, VIKOR method, and Deferred Acceptance algorithm. As the study focused on solution approach for game theory approach, the main intentions were to check and analysis the capabilities of game theory solving solutions for market design strategy. The results stated that VIKOR method provides a rational, scientific, and systematic approach to enable service providers and demanders for assessing the attributes of other parties and developing the preference lists. From point view of stable pairs of manufacturing service matching partners, the use of Deferred Acceptance (DA) algorithm was investigated. The study contributed to public Cloud market design strategies and organization of service matching parties.

Topology Analysis of Manufacturing Service Supply–Demand Hyper-Network considering QoS Properties in the Cloud Manufacturing System[44]

Cloud Manufacturing and its capabilities to enable a network of transportation and manufacturing services over the globe can enable a resilient network production strategy. However, the evaluation criteria to assess the network capabilities was not approached in the literature. By the beginning of year 2020 and the spread of COVID-19 pandemic, this study was initiated to both help the idea of networked manufacturing of medical equipment and also has proposed evaluation models for network Cloud ecosystems. So, the study started the idea of Cloud manufacturing concept as the integrated distributed resources and its capacities in a shared economy paradigm. The operational perspective of this network has been analyzed from the point view of a service-demand matching problem. The study evaluated the service-demand matching problem from a structural perspective for its capabilities of resiliency paradigm. The resulting framework was named as Cloud hyper-network-based model which proposed a mathematical model for evaluation of QoS properties. This enabled the participation of Small and Medium Enterprises (SMEs) with their available capacities as services in the Cloud manufacturing network. The model was enriched to evaluate the service-demand matching problem from its complex assessment perspectives by using the topological characteristics aspect. The model enabled the strategic decision makers in Cloud networks for robust and resilient service-demand matching strategies. The research used the mode for real case study about the COVID-19 ventilator manufacturing systems.

A Utility-based Matching Mechanism for Stable and Optimal Resource Allocation in Cloud Manufacturing Platforms using Deferred Acceptance Algorithm[45]

The public Cloud manufacturing ecosystem and the strategies for Cloud Manufacturing configuration require the analysis of interaction among stakeholders in this ecosystem. This study pursued research and investigation for public Cloud markets form point view of provisioning of manufacturing resources and capabilities as services for global networks. The study focused on resource allocation in Cloud services and interaction of service providers and demanders. The paper analyzed the impact of the allocation on the stakeholders' utilities and modeling the behavior of the manufacturing providers and consumers based on their preference attributes. The special focus has been set on matching algorithms and the effects of resource availability. The paper continued the game theory approach in former research studies[43] and suggested the optimal matching algorithms for consumer as proposer in terms of Deferred Acceptance for public platforms when the resources are greater than or equal to the demand, and for provider as proposer Deferred Acceptance algorithm when the resources are less than the demand in the same platform. Moreover, for the private platform, analysis of optimal algorithms consumer-oriented Kuhn-Munkres was proposed when the resources are more than or equal to the demands and provider-oriented Kuhn-Munkres when the resources are less than the demand. The study established strategic pillars for establishments of service demand matching for public and private Cloud ecosystems.

Stable Allocation of Services in Public Cloud Manufacturing Platforms: A Game Theory View[46]

This study is aligned with perspective of former research[45] and focuses on the stability of provided matching in public Cloud ecosystems. This is an important issue, as the nature of Cloud production ecosystems necessitates the service-oriented approach which can be dynamic in terms of allocated services in this network. The study investigated the on-demand service approach of Cloud ecosystems. Especially from point view of public Clouds, the service allocation problem should be treated as a matching game among the manufacturing providers and consumers which would be a complex form of games. The study has analyzed the stakeholders in this game as the players in form of manufacturing resources owners and also service receivers or demanders. The study focuses on matching game model for public Cloud manufacturing platforms and discusses the stability of solution in the game based on Deferred Acceptance algorithm. The provided case study for automotive spare parts manufacturing in Iran was used to investigate the stability of proposed approach and interaction of stakeholders in the ecosystem.

Developing Game Models for Service Composition to Improve Customization in the Equilibrium State Based on Cloud Manufacturing System[47]

The public Cloud ecosystems and the service composition models were focused in this study. The service composition modeling by focusing on selection of appropriate Quality of Service (QoS) strategies were focused. The study has investigated the importance of diversity of manufacturing Cloud service providers and the interactions with consumers in determining the end value of QoS. This is an interesting topic for Cloud manufacturing ecosystems as it would provide the motivations for engaging both service providers and demanders aligned with Industry 4.0 paradigm. The mathematical models in this research fulfill the service composition based on the Stackelberg and the non-cooperative game structures. The interactions of service providers and demanders as game players and their strategies are analyzed the results stated that the consumers will have better benefits in the Stackelberg game than the non-cooperative game with the same results for service providers. This emphasizes the importance of collaboration of public Cloud stakeholders in these ecosystems for synergic service fulfillment.

Enabling Robust Service Composition in Cloud Manufacturing with Sustainability Considerations[12]

This study extends the concept of service composition models with sustainability aspects. The study tries to investigate the sustainability assessment and its evaluation approach and proposes a model for performance evaluation of Cloud manufacturing systems in the service composition model. Considering the various uncertainties which affect the cost efficiency of Cloud networks, the paper also included the robustness in modeling besides sustainability perspectives of Cloud network. This has initiated the idea of multi objective model and has been enriched by investigation of technologies that complement Cloud manufacturing for stabling the production and supply network. The study also has discussed the solution approach in terms of both robustness of network and sustainability of operation. The sustainability assessment of the Cloud ecosystems is an important and challenging issue due to the nature of service-oriented collaborations focusing more on short term financial benefits rather than long term sustainability perspectives.

Framework Development for Sustainable Manufacturing Cloud Service Composition System (SMCS) Based on Axiomatic Design[48]

This study tries to consolidate the public Cloud manufacturing paradigm and sustainability perspectives together. The main focus is to achieve a sustainable Cloud network with three dimensions of sustainability. So, the study considers the game participants in the form of service providers and demanders and share the sustainability perspectives in their preferences. To shape the model perspectives, the study uses the Axiomatic Design (AD) theory and tries to provide the best solutions

in the Cloud network for achieving beneficial manufacturing services based on all perspectives of sustainability in the Cloud manufacturing. The proposed model includes the sustainability of services in service composition model in the design game structure in form of its equilibrium state. The study has analyzed the sustainable aspects besides the financial gains of manufacturing service providers and designed an equation for the payoff function in the game structure.

Adaptive Capacity Management in Cloud Manufacturing Hyper-Network Platform: Case of COVID-19 Equipment Production[49]

COVID-19 provided an enormous opportunity for evaluation of Cloud production and manufacturing system for resilient structure. Theis study continued the earlier research[44] for application of Cloud Manufacturing in form of hyper-network-based service-demand matching architecture. The study established the idea of service-oriented manufacturing (SOM) paradigm which emphasizes on dynamic, scalable, and virtualized working ecosystem. The study elaborated the concept of quality of service (QoS) evaluation in Cloud network systems to produce customized products in a stable and reliable network. The study proposed adaptive strategies for using the available resources and capacities as services over the network to enhance the Cloud system stability and reliability against the disaster. The study evaluated the capabilities of the proposed idea for COVID-19 disruption in ventilator production processes in Iran as a case study. The results establish new ideas for engaging small and medium enterprises (SMEs) in transportation and production network by an adaptive strategy.

Multi-phase Matching Mechanism for Stable and Optimal Resource Allocation in Cloud Manufacturing Platforms using IF-VIKOR Method and Deferred Acceptance Algorithm[50]

This study continued the public Cloud manufacturing market design studies with focus on service provider and demander interaction and preferences. The study believes that public Cloud platforms will be of important digital transformation trends for next generation manufacturing networks. The study considers public platforms as an environment for manufacturers and demanders interaction and contract establishment. The study focuses on optimal model of service demand matching with a multi-phase matching mechanism which insures the stable and optimal resource allocation in public platforms. The extension of evaluations for demanders and providers with an intuitionistic fuzzy VIKOR method for measurement of quality, time, and sustainability. By clustering the demanders, the study then proposed an allocation model based on the Deferred Acceptance (DA) algorithm to the service providers. A case study of the Iranian automotive industry was considered for perspectives of the grading method impact, clustering analysis impact, and the platform mode impact. The results of the study will open a new horizon for motivating the manufacturing service providers for participation in Cloud platform and enable strategies for governing and orchestrating the Cloud production networks.

Development of Public Cloud Manufacturing Markets: A Mechanism Design Approach[51]

The convergence of the former research for public Cloud networks has resulted in this study for an effective market mechanisms design approach. The study has considered the online manufacturing markets as the emerging Cloud manufacturing and production ecosystems and proposed the mechanism for organizing the interactions of service providers and demanders. The effective matching among service providers and consumers is known as an important success factor of public Cloud markets. The proposed allocation has used the VIKOR method for developing preference of providers and consumers besides Intuitionistic Fuzzy Sets to remove complexities and uncertainties. The matching mechanism has benefited from Deferred Acceptance (DA) algorithm. The study analyzed the performance of the mechanism under influence of the service providers and their service availability besides demanders of services.

Cloud Manufacturing & Operations Research Service model conclusion and discussions

The analysis of the research studies in section 2.2.3 illustrates the mathematical models for service-oriented production and manufacturing system operation management and planning. While in two former themes, the elaboration of architectural framework for realization of Cloud manufacturing and transportation systems were focused, in this theme the operational aspects of service definition, allocation scheduling and matching was investigated as illustrated in Table 3. Table 3 emphasizes the importance of service planning in Cloud ecosystems. While one part of the research studies was concentrating on private Clouds and tried to offer competitive advances for better operation management in comparison with conventional production and manufacturing systems, the second part has proposed the concept of public Cloud networks. The possibility of matching the services and demands and the design of effective strategies for service providers and demanders would be fundamental of public Cloud service-oriented production and manufacturing networks.

Table 3. Cloud Manufacturing & Operations Research Service model theme research studies

Research theme	Contribution	Mathematical model structure	Solving approach
Service scheduling model[37]	Task service decomposition with transportation services	Mixed integer model, QoS for total cost and transportation cost, Multi objective modeling approach	Linear optimization with small size case study
Service assignment model[38]	Mutual operation and transportation service planning	Mixed integer model, QoS for total profit including sales and cost	Linear optimization with genetic metaheuristic algorithm

Research theme	Contribution	Mathematical model structure	Solving approach
	using OPC structure for customer clusters	of operation and transportation.	
Service scheduling model[39]	Task service scheduling for digital dentistry	Mixed integer model, QoS for with lead time of product delivery and total cost with a flow line scheduling orientation	Linear Optimization with PSO metaheuristic algorithm
Service assignment model[40]	Public Clouds and game theory approach	Non-cooperative and cooperative game theory model	Analytical investigation of non-cooperative and cooperative game for small case studies
Service assignment model[41]	Public Clouds and game theory approach with solution focus	Non-cooperative and cooperative game theory model	Equilibrium point proposal for non-cooperative and cooperative game for real case sample data
Service management and demand accuracy[42]	Demand forecasting for robust parameter modeling	Simulated model for a two-echelon supply chain model	Design of experiments, Analysis of Variance (ANOVA) to test the adequacy and significance of model
Service matching model[43]	Public Clouds and game theory approach with solution focus	Game theory approach, modeling the game stakeholders and the structure of interactions	Intuitionistic Fuzzy Sets Theory, VIKOR method, and Deferred Acceptance algorithm were analyzed
Service matching network analysis model[44]	Cloud manufacturing and resilience paradigm	Graph theory and topological analysis for disaster management	Topological analysis of Cloud supply network and evaluation of network resiliency with real case study for COVID-19 ventilator manufacturing
Service matching model[45]	Public Clouds and game theory approach with solution focus	Game theory approach, modeling the game stakeholders and the structure of interactions	Matching algorithms, Deferred Acceptance algorithm for demander oriented and Provider-oriented Kuhn-Munkres algorithms
Service matching model[46]	Public Clouds and game theory approach with stability of solution	Game theory approach, modeling the game stakeholders and the structure of interactions	Matching algorithms, stability of solution of Deferred Acceptance algorithms for service matching
Service composition model[47]	Public Clouds and game theory models	Game theory approach, game modeling	Service composition with Stackelberg game structure

Research theme	Contribution	Mathematical model structure	Solving approach
	for service composition		
Service composition model[12]	Cloud eco-systems with sustainable Service composition approach	Multi Objective modeling, QoS for lead time and resource utilization	Linear optimization with small size case study
Service composition model[48]	Cloud manufacturing and sustainability paradigm	Game theory and payoff function design	Matching algorithm with equilibrium state with small case study sample
Service matching network analysis model[49]	Cloud manufacturing and resilience paradigm	Graph theory and topological analysis for disaster management	Topological analysis of Cloud supply network for providing adaptive capacities with real case study for COVID-19 ventilator manufacturing
Service matching model[50]	Public Clouds and game theory approach with solution focus	Game theory approach, modeling the game stakeholders and the structure of interactions	Matching algorithms, Intuitionistic fuzzy TOPSIS-DA and intuitionistic fuzzy VIKOR-DA compared
Service matching model[51]	Public Clouds and game theory for market design	Game theory approach, modeling the game stakeholders and the structure of interactions	Matching algorithms, VIKOR method to develop preference lists, Intuitionistic Fuzzy Sets to remove complexities, Deferred Acceptance (DA) algorithm for matching mechanism

2.2.4. Cloud Manufacturing Paradigm & Web 3 paradigm

The fourth theme of the research studies would focus on one of the disruptive technologies of recent year known as Web 3 or Blockchain technology. The main motivation behind this theme can be interpreted due to the globalized characteristics of Cloud production and manufacturing networks. While the globalized network of service providers and demanders encompass various individual and firms to collaborate, most of the research studies of former themes considers centralized and inhouse architecture and framework besides operation research models. Moreover, the globalized structure of Cloud networks results in large scale problem size in terms of operations research which would be a great challenge as operations research models of Cloud networks are NP-hard and will face with great problems for proper and optimal policy making in agile and dynamic context. So, the idea of decentralized mechanisms for both frameworks and architectures fulfilling the interactions in Cloud ecosystems and also operations research models for optimal and effective service has been strongly focused on application of decentralized technologies. Over the last four years, this theme of studies has been established with a special focus on Blockchain and Web 3

technologies. The capabilities of these technologies for enabling decentralized network and enabling seamless interaction among stakeholders can be highly used for fulfilling the former research themes in terms of globalized scale.

A novel cloud manufacturing service composition platform enabled by Blockchain technology[13]

This study established the first application of Blockchain technology among the research in this theme. In this study the inefficiency of service matching models for Cloud production systems were discussed. Considering the requirements of globalized collaboration of stakeholders in this ecosystem, supporting large pools of service providers and Service demanders are inevitable. The study introduced the dynamic behavior of parameters in Cloud networks and challenged the centralized mechanism of service matching problem. A novel platform entitled Blockchain-based service composition model (Block-SC) was based on the Blockchain technology. The proposed model had the capabilities for dividing the original service matching problem into multiple sub-problems each of which contains a small fraction of the service/task pool. The workflow of Blockchain based architecture in terms of Service providers and demanders and introduced solvers was introduced and rewarding mechanisms for encouraging the optimality of solutions in the platform was described. The capabilities of the proposed platform were remarkable for providing an effective mechanism for collaboration of service matching in the service-oriented paradigm and also the optimality of service composition problem.

Blockchain based Cloud Manufacturing Platforms; A novel idea for service composition in XaaS paradigm[52]

The capabilities of Blockchain solution for globalized scale of Cloud network was found to be so promising and the research studies continued for developing and extending the framework of Blockchain technology. The study has elaborated the service-oriented architecture for service composition and allocation to demanders with its dynamic behavior. While criticizing the centralized global optimization models, a distributed deployment of the globalized service matching was proposed. The study mapped the required component in Blockchain platform to the service matching model in terms of service matchings as transactions in the Blockchain and the feasibility of provided solution in terms of consensus mechanism. The concept of Proof of Work (PoW) was also elaborated in terms of the endeavor for proposing the proper service matching. The resulted service matching structure highly increased the response time and improve the overall optimality of supply-demand matching. Although the Blockchain solution was considered as a nonglobal optimization technique, by using the reward mechanisms, the proposed solution was in between 15.14% to 34.8% better for reduction in costs and 20% to 68.4% better solving time. This study encouraged the Blockchain capabilities for enabling effective service processing mechanisms in globalized Cloud manufacturing networks.

SRP: a Sustainable Dynamic Ridesharing Platform Utilizing Blockchain Technology[53]

This study continued the application of Blockchain based solutions in Cloud network of service providers by elaborating the transportation service matching. The study considered the concept of ridesharing and interpreted it in the form of a transportation service network matching ecosystem. The study also targeted the sustainability perspective in terms of carbon-dioxide (CO2) emissions control. Criticizing the ridesharing services matching performance and also the concerns regarding the security of stakeholders in the platform, a sustainable ridesharing platform was proposed. The proposed platform elaborated the Blockchain's capabilities such as consensus mechanism in form of Proof of Stake (PoS); smart contracts; and solvers roles for best possible service matching scenarios and encryption mechanism for data access security. The reward function encouraged the solvers for service matchings which fulfilled the sustainability perspective with priority. The study encouraged the role of matching services in the ecosystem as a new form of obtainable service besides service providers and demanders.

Enhancement of Crowd Logistics Model in an eCommerce Scenario Using Blockchain-Based Decentralized Application[54]

The studies elaborated more on the application of the Blockchain for Cloud transportation service matching. This study considered the globalized characteristics of transportation services and the challenges for optimal matching. With the investigation of Cloud supply chains, the concept of crowd logistics was analyzed. The service-oriented characteristics of crowd logistics nominates it as one of the promising technologies for supply networks. The study has investigated crowd logistics and the challenges like user trust, data safety and security, security of the financial transactions for transportation service demanders and providers. The study proposed an e-commerce crowd logistics conceptual model based on Blockchain technology while elaborating its capabilities and the interaction model of the stakeholders in this ecosystem. Components of this Blockchain based model like the smart contract mechanisms for managing the financial interaction of transportation service demanders and providers and the related claim management structure and the Decentralized Application (DApps) for enabling the flexibility of the crowd logistics system were discussed. This study encouraged the idea of developing a new role in service-oriented Clouds for service organization and matching which resembles the tokenization model in shared economy perspectives.

Cloud Manufacturing Paradigm & Web 3 paradigm conclusion and discussions

The analysis of the studies in section 2.2.4 shows the promising future research studies for Blockchain application in Cloud production and manufacturing networks. As shown in Table 4, most of the challenges expressed in former themes have been

approached and effective solutions have been provided. The challenges regarding the globalized and large-scale model of interactions in Cloud ecosystems can be efficiently treated by Blockchain based models. The main challenge would be the mapping of the Cloud production and manufacturing networks to Blockchain architectures. The consensus mechanisms and reward function definition which help the effective processing of distributed interactions in the Cloud networks are of the most important issues in this research theme. The research theme proposes the establishment of complementary and supportive services in Cloud ecosystems in form of tokenized services which facilitate the organization and management of services and highly increase the performance of Cloud networks.

Table 4. Cloud Manufacturing Paradigm & Web 3 paradigm theme research studies

Research theme	Contribution	Competitive advantage vs conventional research studies	Blockchain Capabilities
Service matching model[13]	Blockchain based operation service matching	Gaining higher performance for optimality of matching services	Consensus mechanism, PoW, Reward Function
Service matching model[52]	Blockchain based logistics and operation service matching	Gaining higher performance for optimality of matching services	Consensus mechanism, PoW, Reward Function
Service matching model [53]	Blockchain based transportation service matching	Sustainability perspectives besides the optimal transportation service matching	Consensus mechanism, PoS, Reward Function
Service matching model [54]	Blockchain based transportation service matching	Financial contract and claim perspectives for transportation service matching	Consensus mechanism, DApps, Reward Function

3. Conclusions and discussions for future research

The paradigm of Cloud production and manufacturing systems can be considered as one of the most dominant enablers of Industry 4.0 paradigm. The emphasize of this paradigm for realization of service-oriented production and manufacturing systems has established new perspectives for manufacturing business models toward globalized and distributed orientations. Using other emerging technologies in Industry 4.0 like Digital Twins (DT), Internet of Things (IoT) and Data Analytics (DA) has empowered more this paradigm in terms of global interactions of processes, data and knowledge in the Cloud ecosystems.

This paper has reviewed the research studies conducted between 2014-2022 regarding the elaboration of Cloud production and manufacturing system concepts. Considering the roadmap of the research, four main themes have been proposed for clustering the research studies:

- The research studies have contributed to platforms and architectures for globalized service-oriented production and manufacturing systems. The Cloud ecosystems require mechanisms which facilitate the data and information exchange among the stakeholders. The production processes and product lifecycle management disciplines require transformation and alignment to benefit from the Cloud production paradigm. The conducted research studies in this theme contributed for integration and interoperability of stakeholders and processes to enable the fulfillment of services. This research theme requires to be continued with a focus on knowledge interoperability in autonomous form for future research plans.

- The research studies which elaborated the idea of Cloud production and manufacturing systems by encompassing the Transportation and logistics as service paradigm. The globalized and distributed nature of service-oriented production systems require seamless material flow in form of transportation services. The main contributions of the research studies in this theme can be interpreted as mutual and synergic production and transportation service alignment. These contributions fulfill the cost efficiency and sustainability aspects of Cloud logistics distributed over the global with effective and efficient material flow. This research theme requires to be more elaborated to encompass whole supply chain process integration in the form of as a service structure. Especially focus for share economy of transportation services and focus on sustainability perspectives will highlight the future studies in this theme.

- The research studies that contributed to development of Operations Research (OR) models for Cloud service network management and planning. Considering the earlier themes, effective planning, assignment, and scheduling of the services are key essential competitive advantages for service-oriented networks. The challenges for encompassing the Cloud manufacturing

stakeholders' preferences and constraints like operation service providers and product customers and utilities and preferences into mathematical models have been approached by the studies in this theme. The research studies have contributed to the proposal of mathematical modeling approaches which consider multi objective modeling to enable the dynamic treatment of model elements. Moreover, considering the globalized and large-scale size of these mathematical models, effective solution proving approaches have been proposed which insure near to optimal solutions in reasonable time expected in dynamic Cloud networks. The concept of public Cloud networks and the market design have been also approached and the interaction of stakeholders have been also extended in this theme. The studies in this theme shall be continued with a perspective of sustainable Cloud supply networks and effective mathematical models which can provide near to optimum solutions with agility and encompass the tradeoff of stakeholders' preferences through model components.

- The research studies that extended and contributed to the application of Blockchain and emerging Web 3 technologies in Cloud manufacturing networks. These research studies have accomplished the early steps for improving the effectiveness of the third theme and are continued with the perspective of share economy and tokenization models in service-oriented networks. The studies emphasize the potential and capabilities of Web 3 for establishment of new business models in this network. These services can be imagined through a token model structure which supports the more efficient service and demand matching. The role of smart contracts for increasing the autonomous level of Cloud manufacturing and supply network would be one of the important future research directions.

The convergence of the themes in this research concentrates on more realization of service-oriented production and supply networks. The globalized interaction frameworks which operate with autonomous structures that resemble the preferences of their stakeholders in this ecosystem. From the point view of sustainability pillars, high research potential can be of refereed. The successful case studies for fulfilment of COVID-19 equipment emphasize the capabilities of service-oriented production network for resiliency and flexibility. The potential of service-oriented network manufacturing for Small and Medium Enterprises (SMEs) has been found to be great, which can be a unique opportunity for globalized production networks. Finally, future studies with motivation of more globalized, sustainable, and autonomous Cloud networks in form of tokenization paradigm is highly recommended.

4. Acknowledgement

5. Index list

6. Publication list

[1] Fatahi Valilai, O. & Houshmand, M. Depicting additive manufacturing from a global perspective; using Cloud manufacturing paradigm for integration and collaboration. Proc. Inst. Mech. Eng. Part B J. Eng. Manuf. 229, 2216–2237 (2014).

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