Development of a Business Process Model Notations (BMPN) for a Cloud Manufacturing Architecture

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***Abstract*-Cloud manufacturing is a new paradigm that provides on-demand manufacturing services, by implementing the concept of sharing resources and capabilities from different provider's worldwide using internet of things and supporting technologies. Previous researchers have introduced different cloud manufacturing architectures which explained the logical flow and combination of cloud manufacturing resources. It is noticed that there is a gap between the middleware service layer and the application layer. These two layers need an additional layer between them that makes developers of applications understand and communicate effectively with the service layer and all lower layers. This paper analyzes elements and requirements for cloud manufacturing and proposes a new architecture that includes a business process modeling (BPM) layer to bridge this gap. Furthermore, a model was developed using business process model and notations (BPMN) tool to model, and virtualize process steps for the proposed BPM layer in the cloud manufacturing architecture. Automotive industry is used as a case study to clarify the developed BMPN workflow and investigate expected manufacturing issues.**

Keywords: *Business Process Model Notations (BPMN), Cloud Manufacturing Architecture, Cloud Manufacturing, Business Model Simulation.*

I. INTRODUCTION

Cloud manufacturing (CMfg) is a recent manufacturing model, which extended and orbited the concept of cloud computing for manufacturing. "*The aim is to transform manufacturing businesses to a new paradigm in that manufacturing capabilities and resources are componentized, integrated and optimized globally*" [1]. Cloud manufacturing is a service oriented model that gives the opportunity for small and medium enterprises to keep pace with industrial and business growth. It supplies all kinds of manufacturing services on demand from manufacturing customized products or parts to -on the shelf- mass production. In addition, it provides several levels of services in management and monitoring and control processes over the internet by using: internet of things (IoT) technologies, radio frequency identification (RFID), GPS and wired and wireless sensor network embedded system. All resources should be virtualized and integrated in the cloud manufacturing system.

The CMfg model was developed from existing advanced manufacturing models, typical examples are agile manufacturing (AM), networked manufacturing (NM), virtual manufacturing (VM), global manufacturing, application service provider (ASP), collaborative manufacturing network, lean manufacturing and digital manufacturing. All these models have made dramatic changes in the manufacturing field, aiming to save time , to respond quickly to market changes, to reduce manufacturing cost, obtaining high quality , and fulfilling customer requirements' by providing the best services and providing flexibility and higher knowledge [2].

The proposing of CMfg model brings the new information technologies innovation to manufacturing industries [3], increases the resource utilization for suppliers and reduce resources and energy consumption, reduces complexity and optimizes design and manufacturing and integrates lifecycle support with an instant access to manufacturing solutions to customers and accelerated time to market.

CMfg has many benefits from different perspectives by providing high quality services respectively to providers, consumers, businesses, and industry. For provider perspective, CMfg offers and shares manufacturing resources providers through its platform making it available whenever it in free status and that can increases provider's resources utilization. Also publish and share manufacturing businesses which leads to increase their corresponding incomes.

For consumer perspective, CMfg finds the best solution and use the most appropriate manufacturing resources offering a consulting by experts and Improve efficiency of their business and paying only for what they used without additional cost.

In addition, it gives the ability small companies to scale up or down responding to market need. From business perspective, CMfg gives more market opportunities for small and medium enterprises (SME's) to increase their market by offering various resources and capabilities to them as a service, could drive lower capital requirements make it easy and reliable to adopt for SME's [4]. From, industry perspective, CMfg concentrates on the supply for dynamic markets on demand. In addition, cloud manufacturing works as a green environment by using information technologies rather than papers [5].

II. ELEMENTS AND REQUIREMENTS OF CLOUD MANUFACTURING

There are primarily three elements in a CMfg system which are:
(1) The providers which own and provide the manufacturing resources and provide cloud manufacturing service.
(2) The operators which operate the CMfg platform to deliver services and functions to providers, consumers, and third parties.
(3) The consumers which use the manufacturing cloud services available in a CMfg service platform, consumers are usually small and medium enterprises [6].

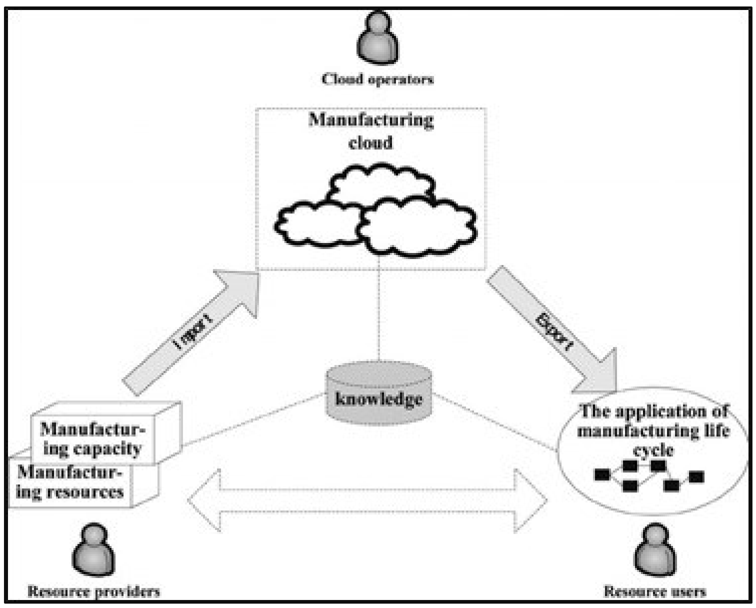

Fig. 1. Cloud manufacturing components [7]

To achieve the benefits of cloud manufacturing there must be some requirements. Eight requirements were suggested by D.Wu et al. [7]:

1. Provide social media to support communication, information and knowledge sharing in the networked manufacturing environment.
2. Provide cloud-based distributed file systems that allow users to have ubiquitous access to manufacturing- related data.
3. Have an open-source programming framework that can process and analyze big data stored in the cloud.
4. Provide a multi-tenancy environment where a single software instance can serve multiple tenants.
5. Collect real-time data from manufacturing resources (e.g., machines, robots, and assembly lines), store these data in the cloud, remotely monitor and control these manufacturing resources.
6. Provide Infrastructure as a service (IaaS), Platform as a service (PaaS), Hardware as a service (HaaS), and Software as a service (SaaS) applications to users.
7. Support an intelligent search engine to users to help answer queries.
8. Provide a quoting engine to generate instant quotes based on design and manufacturing specification.

II. CLOUD MANUFACTURING ARCHITECTURES

The proposing of CMfg models brings the new innovation to manufacturing industry. The existing related research on CMfg has focused on concepts and architectures. It is important to realize the interaction and collaborations between information resources and processing agents through service – orientation [8] .Service-Oriented Architecture (SOA) is an emerging technology aiming to enhance efficiency, interoperability, agility and productivity between IT (i.e., business agents) and device (i.e., shop floor agents) levels in the enterprise by positioning services as the building block. After reviewing previous architectures, most of them has explained the core layer that are required in the cloud manufacturing. TABLE I shows some examples of cloud manufacturing architectures as an extended version mentioned previously in [9].

III. THE PROPOSED CLOUD MANUFACTURING ARCHITECTURE

Different architectures have been proposed in the past for cloud manufacturing but there is a gap has not been covered in the previous architectures and this study try to explain how to bridge this gap by adding an additional layer called Business Process Modelling (BPM) layer located between the application layer and the middleware layer so it can helps the software developers to understand the process flow and also help to find a point of understanding between programmers and business analysts point. The objective of the proposed architecture is to enhance the communication between CMfg architecture layers by reducing the gap difference between each layer. The proposed architecture consist of eight layer as shown in figure 2.

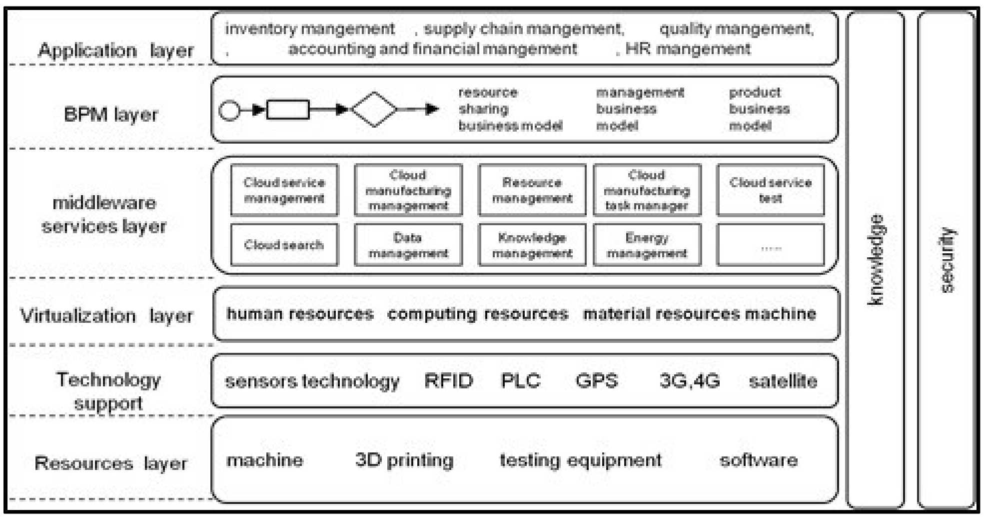

Fig. 2. Proposed Cloud Manufacturing Architecture

1. Resources layer*:* is the physical manufacturing resources and capabilities including machining manufacturing equipment, simulation equipment, testing equipment, servers, data, software, and knowledge in all the manufacturing process life cycle. People and knowledge are required to complete a manufacturing task, including design capability, simulation capability, and management capability. These physical manufacturing resources in tremendous number are distributed in a different location in the cloud and virtualized so it can be connected cloud manufacturing platform [10].

2. Technology support layer: is a collection of supporting technology and devices that detects events or changes in state, generally as an electrical or optical signal or wireless signals, it uses to identifying and tracking tags attached to objects, making it able to sense the physical resources and capabilities enabling them to connect to network ," it is possible to grasp real-time states of physical resources and the whole process of resource aggregation" [11]. Through IOT (Internet of Things), RFID (Radio-frequency identification), embedded cloud terminal technology data can be collected and sent to information center to analyze for feather use.

3. Virtualization layer: in this layer is a huge virtual manufacturing resources pool build so all physical resources can interconnection feedback control through the Internet, mainly in this layer analyzes manufacturing resources that have connected in cloud manufacturing. In to a virtual database (library), in this layer data is classified and sorted to support the virtual cloud manufacturing service. Manufacturing resources virtualization requires an accurate result from the physical or logical resources [2].

TABLE I. EXAMPLES OF CLOUD MANUFACTURING ARCHITECTURES

Architecture	Features	Description
1. Cloud manufacturing: a computing and service-oriented manufacturing model, F Tao, L Zhang, V C Venkatesh, Y Luo, and Y Cheng (2011)	Ten layers in three stages - Virtualization & encapsulation: Define resources as Manufacturing Cloud Services (MCSs); - Aggregation & invoking the MCSs into the cloud; - Reuse: Generation of new knowledge, resource, and abilities for future needs [9].	▪ Resource layer: provides the manufacturing resource and ability involved in the whole life cycle of manufacturing. ▪ Perception layer: is responsible for sensing the physical manufacturing resources and abilities. ▪ Resource virtualization layer: is responsible for the virtualization of manufacturing resources and abilities, and encapsulating them into the manufacturing cloud service. ▪ Cloud service layer: primarily provides two categories of service, the manufacturing cloud service (MCS) and the CMfg core service ▪ Application layer: based on the integration of the existing manufacturing system in an enterprise with CMfg. ▪ Portal layer: provides interaction interfaces for users accessing. ▪ Enterprise cooperation application layer: sup- ported by the MCSs and CMfg core services, different kinds of cooperation application. ▪ Knowledge layer: provides various knowledge needed in the other layers ▪ Cloud security layer: provides different security architecture for the CMfg system. ▪ Wider internet layer: provides the base communication environment to all resources, service, users, and operations in the CMfg system.
2. Cloud Based Design and Manufacture, Dazhong Wu, David W. Rosen, J.Lane Thames and Dirk Schaefer. (2012)	Four layers - Cloud consumer: Utilize cloud services. - Cloud provider: Provide cloud services. - Cloud broker: Manages the use, performance, and delivery of services. - Cloud carriers: Enables communication for the sharing of services [9].	▪ Cloud Based Design and Manufacturing CBDM Conceptual Reference Model Adapted from National Institute for Standards and Technology (NIST). It has Developed in 2011. ▪ Theoretical frameworks and prototypes that can guide the design of CBDM systems. ▪ Defines a set of actors, activities, and functions involved in the DMCloud.
3.Distributed Infrastructure with centralized interfacing system (DICIS) [12]	Three asset groups -human: consumer, producers, and managers. -communication: network and interface. - Process: physical and virtual resources [9].	Proposed called Distributed Infrastructure with Centralized Interfacing System (DICIS) model categorizes into three primary groups: ▪ Human Assets, Service consumers (i.e researchers/engineers look through a new design prototypes , service producers (i.e laboratory assistant or production manager to install a new set of devices) and service managers perform operations (i.e creating new user accounts, assigning user roles, scheduling projects). ▪ Communication Assets, communication network assuming that communications are via Internet Protocol (IP), network security for example firewall systems, human asset service communication interface (SCI) uses for example Web based protocols. ▪ Manufacturing Process Assets, hardware (physical): (i.e milling machines, laser cutters, 3D printers (3DP) and software (virtual): (i.e CATIA, Simulia, CAD) and they are bound to both the centralized interface (CI) and the distributed infrastructure (DI).
4.An interoperable solution for Cloud manufacturing (ICMS) [1]	Three layers -Smart Cloud manager (SCM): an agent –based mechanism that monitor and organizes allocation of services to consumers. -User Cloud (UCloud): User of the services. -Manufacturing Cloud (MCloud): A cloud of all physical and virtual manufacturing resources.[9]	The architecture explained fairly and in details by using diagraming and flowcharts also refers to concept ICMS and where has reported [13]. Mainly ICMS divided in to three layers: ▪ Smart Cloud Manager (SCM) is bullied by intelligent agents to execute complexity of manufacturing processes and consists of Enterprise Interface Agent (EIA), helping enterprises to search for qualified Service Providers.Customer Interface Agent (CIA), Broker Agent (BA) contact with the provider database and plans for the available Services Supervision Agent (SA) works with the Service Application Cloud (SACloud). ▪ User Cloud (UCloud), Customer user (CU) and Enterprise User (EU) ▪ Manufacturing Cloud (MCloud) a cloud which all of resources and capabilities of providers and storage in Storage Cloud (SCloud) based on database structure contained all information needed with quickly accessible way.

4. Middleware Service layer: provides core functions and services , including providing test management for provider; providing users management, cloud services management, data management for cloud services operators; providing cloud tasks management scheduling management services, etc. All these services provided Through fast- and high-performance computing for a quick response service request in the cloud [10].
5. BPM layer: analyzed process for improvement. BPM is typically performed by business analysts, who provide skills and knowledge in the modeling discipline; with they have specialized knowledge of the processes being modeled. The business objective is often to increase process speed or reduce cycle time; to increase quality; to reduce costs: such as labor, materials, scrap, or capital costs. In practice, a management decision to operate in business process modeling is often motivated by the need to document requirements for an information technology (IT) level. BPM (Business process model) helps enterprises to execute and continue to improve specially in manufacturing industry where collaborationis requires process planning procedure. The enterprise administrator customizes a service operation to provide flexibility to the user.
IBM defines BPM as a discipline combining software capabilities and business expertise to accelerate process improvement and facilitate business innovation. BPM allows an enterprise the agility and flexibility to define, observe and change business processes quickly and easily as business needs change. A layer of BPM narrows the gap between the business processes and the application programming which means that your business analysts can change and arrange the needed processes without performing any actual coding [14].
6. Application Layer: it is the top of the cloud manufacturing service platform, which provides different application interfaces between users and manufacturing cloud resources. Users can access the network from anywhere required for a service on demand through this layer that provide a special manufacturing application system according to specific demands for example: ERP system, supply chain management application, design, etc.
7. Knowledge layer: plays an important role important role in supporting cloud manufacturing system. Enterprises can make benefit use of knowledge resources on manufacturing network by sharing knowledge among enterprises in order to improve capability. By using cloud service technology for enterprises, information platform can be built. Knowledge is involved in every stage of both manufacturing processes and the whole life cycle of a cloud service [15].
8. Security layer: provides security and privacy, appalling strategies and applications and firewalls to insure the coverage of the whole manufacturing lifecycle.

IV. DESIGN OF A BUSINESS PROCESS MODEL AND NOTATIONS (BPMN)

Cloud manufacturing paradigm is realized by combining advanced IT technologies. In this context, this paper initially develops an architecture based on previous proposed architectures based on cloud computing theory and technology. In order to understand CMfg framework and to be implemented it must have a feasible and value generating business model, and that what has been proposed, this pattern displays the different business, transactions, and processes which occur between the different actors interacting in the service layer of the whole CMfg System prescribed.
BPMN is the new standard tool to model business process flows and web services, BPMN provides a notation to define the business process models so it become understandable by all business users, developed by the Business Process Management Initiative [16]. The first version of the standard was released in 2004. Recently, in March 2011 BPMN 2.0 was released [17]. BPMN has been designed to be understandable for all the business users that have to deal with process diagrams. The business analysts should be able to create the first sketches of the models, but the diagrams also have to be simple and easy to understand for technical developers who have to implement the business processes represented in the diagrams and employees who are involved in the processes. BPMN creates a standardized bridge for the gap between the business process design and process implementation [18].

To get a good model that represents cloud manufacturing model and be close to reality, it should include activities and processes that involved in the whole manufacturing lifecycle. The BPMN model proposed in this paper model was adapted from an earlier model (M. Jorick Lartigau) [19]. The model has been improved regarding the manufacturing side so it can be simulated. This model has been designed using BPMN 2.0 to communications and transactions, which place between three different actors interacting in the whole CMfg System. The three actors are the Resource Service Demander (RSD), the Resource Service Provider (RSP) and the CMfg platform. Figure 3 shows an abstract BMPN for cloud manufacturing which consists of four main blocks: order processing, planning and scheduling, designing product and manufacturing.

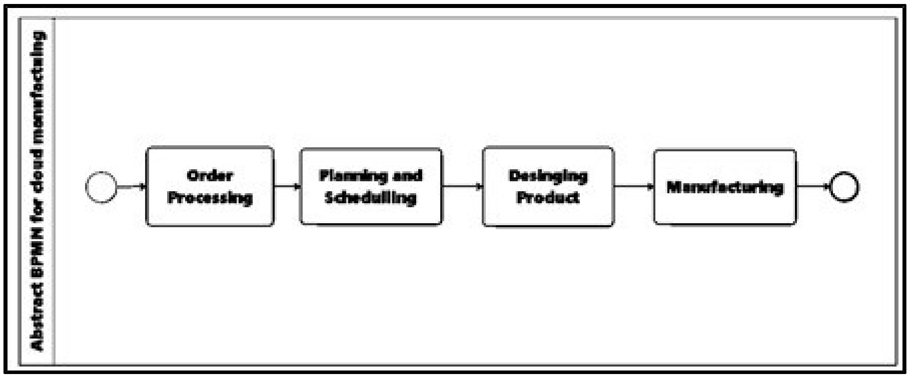

Fig. 3. Abstract BPMN

Figure 4 shows the order processing block. The BPMN has to include events and the expected things happen which can have a negative impact on the CMfg workflow, such as the rejection of a RSD's order or the unexpected modification of the RSPs planning, or failure in a machine .First a RSD's order through CMfg interface selecting all the required specifications and standards witch then the CMfg Platform receives it, the integrated CMfg Service checks whether it is feasible or checking the availability of the required resources and its capability and the deadline for providing the order. If the given order does not follow such conditions, the order is rejected and the RSD is informed about the cancellation of his order. The CMfg Platform itself may keep tracks of this order rejection. In the case where the order is accepted by offering alternative solution, a subcontractor will be signed between the RSD and the virtual RSP, through the CMfg Platform.

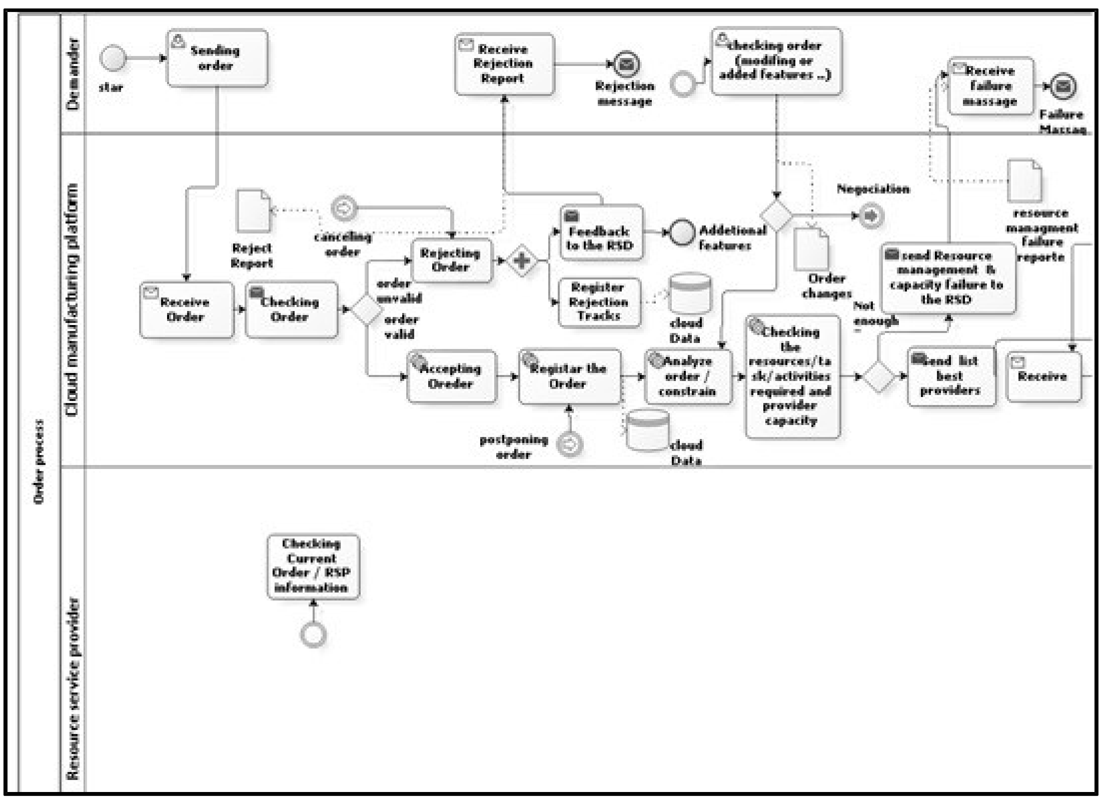

Fig. 4. Order Processing Block

The CMfg Platform firstly needs to ensure the availability of the manufacturing resources services that requested by the RSD, by offering the top providers to de selected by RSD, after selection are made, the negotiate with the RSPs starts, in order to define the delays to perform the tasks and activities involved in this process, and the sizes of the batches. The negotiation process involves request for proposal documents which allow each implied RSP to select the batches, targeting distinct tasks to perform, and input the time ranges of production availability. If the negotiation step fails, the CMfg Platform Informs the RSP, negotiates for a potential extension of the order deadlines.so the final contract can be signed.

Figure 5 shows the second block which is planning and scheduling block. Figure 6 shows the third block which is designing a product. With the addition of the possibility of obtaining designers with highest level of experience and efficiency with lowest cost and less at the time of the completion of the design so it can be sent to the RSD a 2D and 3D design file, so it can be printed by 3D printer as a prototype giving the opportunity for the RSD to physically visualize the prototype and can be tested if it's needed before move to the production stage, if the prototype model design didn't satisfy the RSD modification can be send back to the designer so the model can be edited until retching the desired design. Figure 7 shows the manufacturing block.

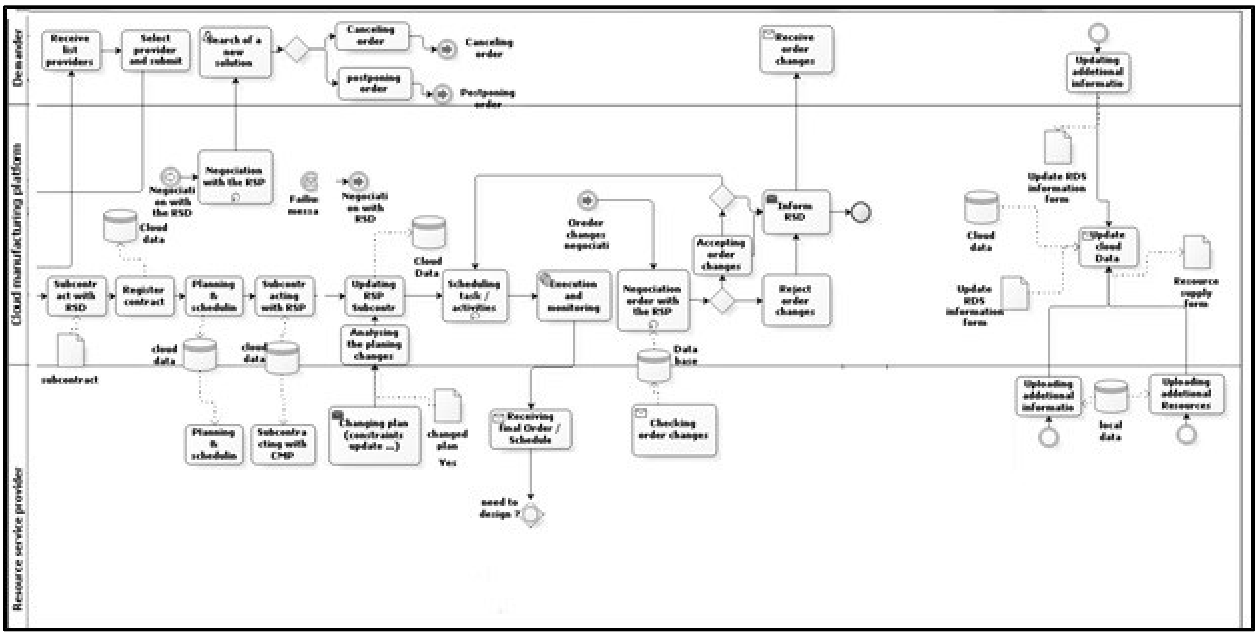

Fig. 5. Planning and Scheduling Block

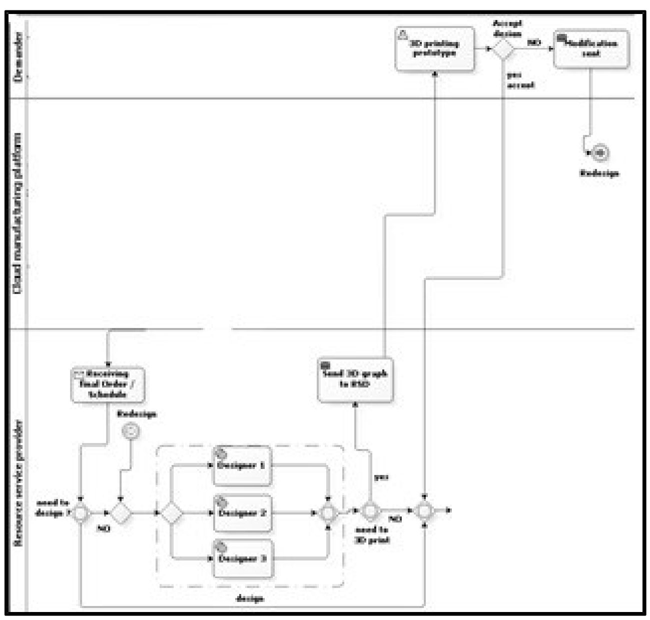

Fig. 6 Design Product Block

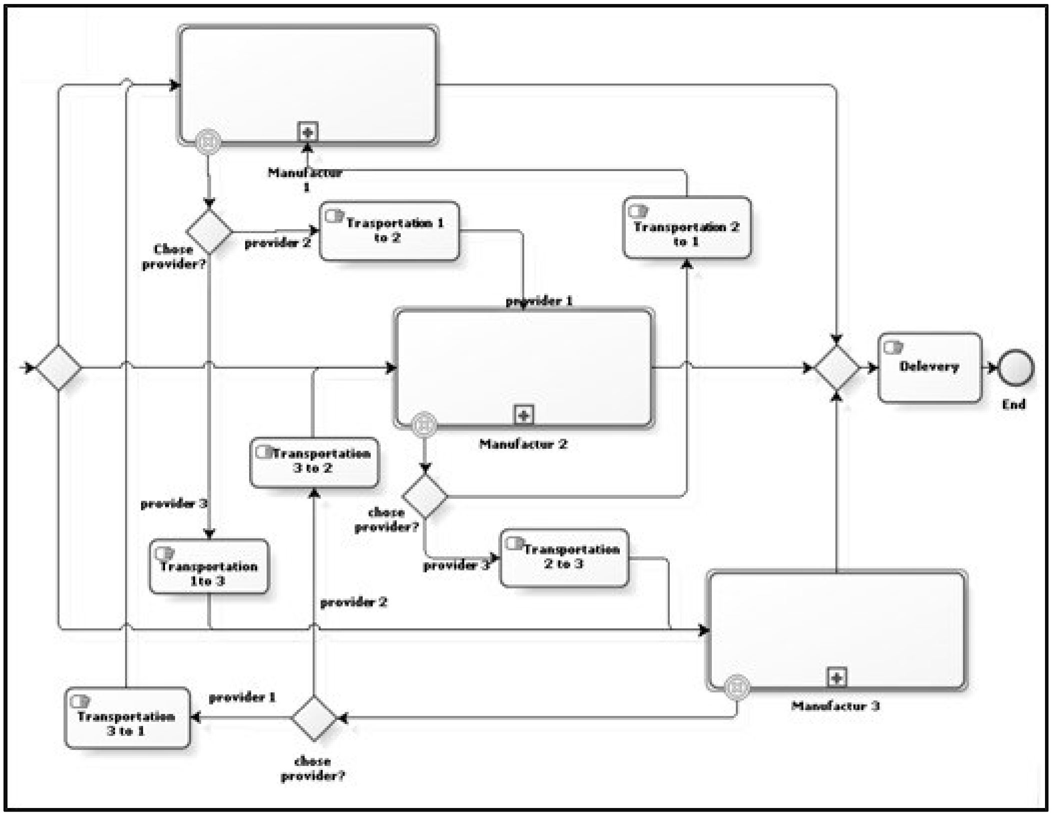

Fig. 7.Manufacturing Block

V. CASE STUDY

The proposed methodology is implemented in an automotive parts factory. Headlights are one of the major products in the factory where it passes through several different stages and have therefore been selected for investigation. This product is consists of eight parts and components as shown in figure 8 which are: 1. Front glass, 2. Rubber gasket, 3. Front housing, 4. Metal clips, 5. Reflector, 6. Plastic clips, 7. Rear housing, 8. Screw.

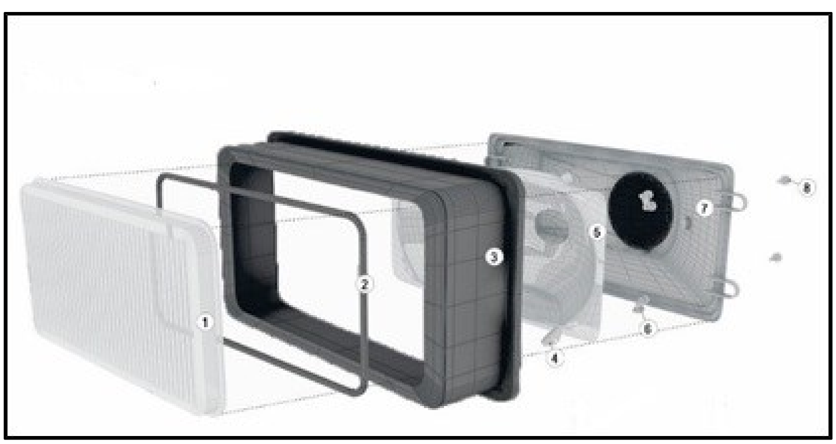

Fig. 8. Headlight

Figure 9 shows the sub process of manufacturer 1.The production process requires a number of processes (metal working, plastic injection, electrostatic painting, and glass production). Note that not all the parts are manufactured in the factory , some of them are purchased. Hence ,this study will be limited to operations details for parts produced in the factory. All the product manufacturing processes are presented as set of tasks and activities which include all the machining work and inspection until getting the three main parts (Rear gay housing, Frontal black cavity, Cavity) and then assembled so it can be finally applied to a functional test then packaging so it can be delivered to the customer.

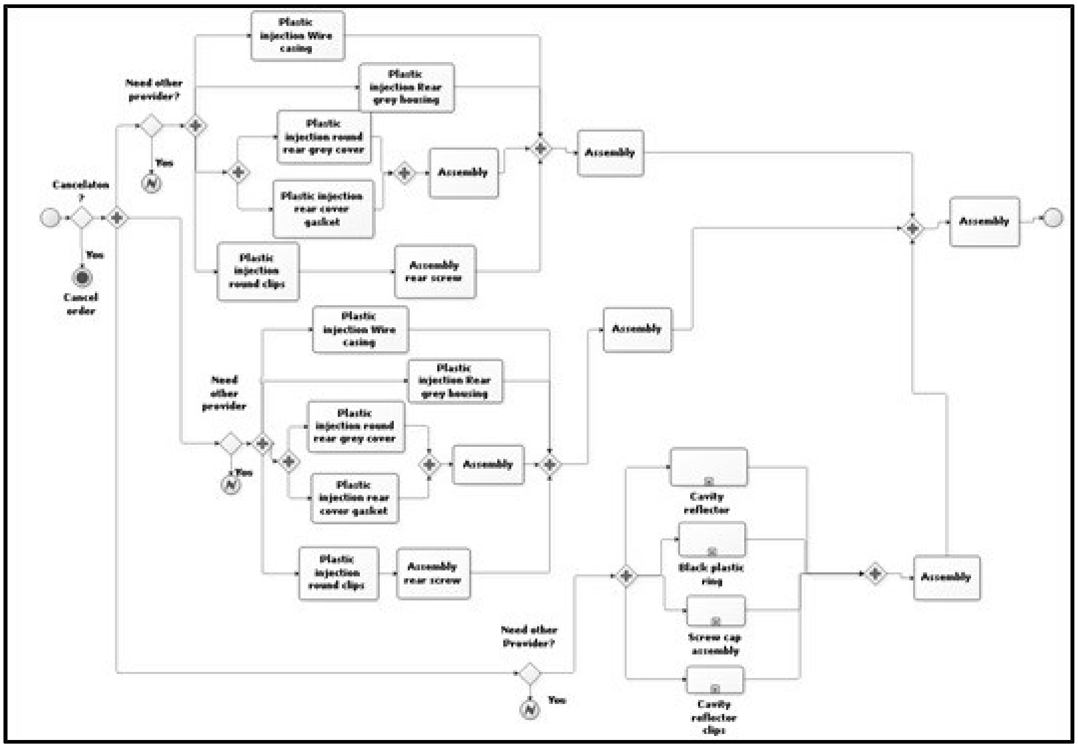

Fig. 9. BPMN for manufacturer 1

VI. CONCLUSIONS

This work investigated previous cloud manufacturing architectures and found a gap between two layers: the application layer and middleware service layer. It proposed a new architecture for cloud manufacturing using BPMN to perform a better communication between these two layers which in turns provide an effective integration between software developers and other actors. Furthermore, BMPN is a versatile graphical technique that helped in the development of the required cloud manufacturing model. This model will be simulated later under different scenarios to clearly understand the whole process of cloud manufacturing. A headlight product from an automotive spare parts factory was used as a case study to illustrate the developed model.

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