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DEVELOP FRAMEWORK FOR CLOUD MANUFACTURING SYSTEM

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Abstract: In a modern competitive production environment, manufacturing organizations today face challenges including (dealing with a large amount of data, collaborative use of it, flexibility of production processes.). It is also usually the production departments, suppliers, and distributors are distributed in different locations in the world, including manufacturing resources and capabilities are also in different locations. A way must be found to convert distributed manufacturing resources into services and manage them centrally. Cloud manufacturing enables the flexible sharing of a variety of distributed manufacturing resources and capabilities, and holds the key to the mission essential to implementing Manufacturing as a Service (MaaS).
Keywords: Cloud Manufacturing, A Proposed Framework for Cloud Manufacturing System.

Introduction:

With the emergence of the concept of the fourth industry (I4.0) and the increasing spread of the Internet, the manufacturing industry has moved to a new level of communication in digital transformation. I4.0 provides interesting technologies in the manufacturing industry such as the Internet of Things (IoT), cloud computing (CC), virtualization (VS), cyber-physical systems (CPS), and artificial intelligence (AI). These technologies provided a comprehensive environment for communication and the independent exchange of information through networked sensors and software. This improved the production flow centrally and increased the ability of different organizations to collaborate and integrate (Scholten, 2017:2). One of the most prominent concepts that emerged in (I4.0) was the concept of cloud manufacturing (CM) as a promising manufacturing model that allows collaboration and sharing of manufacturing resources and capabilities and perfect control between different units.

In 2009, Professors Li Bohu and Lin Zhang at the 15th China Science and Technology Planning Symposium first proposed the term cloud manufacturing (Wan et al., 2020:2). Later Li and colleagues published the first paper titled "Cloud Manufacturing: A New Service-Oriented Grid Manufacturing Paradigm". His achievements have been recognized by the international academic community (Ren et al., 2013:1).

Third: The concept of Cloud Manufacturing:

Since Li Bohu and Lin Zhang introduced cloud manufacturing in 2009, many active research initiatives have emerged with academic and industry-level participants in international projects of various sizes and scopes (Adamson et al., 2015:19). And due to the existence of different areas that interpret (CM), there are different views on giving a single concept to it, as each research group focuses on certain aspects. Perhaps perspectives related to information technology make it possible to analyze more issues and together contribute to building a concept of CM (Fiore, 2019:46). Table (1) shows some of the concepts put forward by researchers for cloud manufacturing.

Table (1) Some concepts (Cloud Manufacturing)

Seq.	source	conceptual
1	(Li et al., 2010:5)	A new network manufacturing paradigm that uses the network and service platform to organize cloud manufacturing resources and capabilities, according to user needs, and provide users with diversified manufacturing services on demand.
2	(Wu et al., 2013:3)	A manufacturing model that can enhance knowledge and resource sharing and rapid product development at low cost through a social network and negotiation platform between service providers and consumers.
3	(Yadekar et al., 2016:3)	A manufacturing model that provides manufacturing resources and capabilities and a knowledge base for cooperation between different users (suppliers, manufacturers, consumers), to achieve their goals using the latest information technologies and advanced communication networks.
4	(Fiore, 2019:31)	The complete model and architecture that provides manufacturing services, by which the service user's demand for a manufacturing service can be matched and the manufacturing resource provider's offer of available manufacturing resources.
5	(Zhang and Liu, 2022:6)	A manufacturing model that transforms manufacturing resources and capabilities into services via virtualization to create secure, reliable, high-quality, on-demand cloud services for the entire manufacturing lifecycle, and manage and operate them unified in the cloud to support intelligent, global, and efficient collaboration and collaboration.

Source: Prepared by the researcher based on the literature referred to.

In light of the foregoing, the concept of (CM) can be given as (a manufacturing model that transforms manufacturing resources and capabilities into secure, reliable, and high-quality cloud services that can be provided on demand for the entire manufacturing life cycle through a cloud service platform, centrally managed and operated to support smart, effective, and global sharing and collaboration between cloud providers, operators and users).

Fourth: The Operating Principle of the Cloud Manufacturing System:

The idea of (CM) is mainly based on (centralized resources and decentralized services). In the sense that the manufacturing resources distributed in different geographical locations are centralized through large servers, forming a physical service center, and the (service provider) provides manufacturing services (to users) distributed in different geographical locations, and a third party (service operator) operates and manages the manufacturing services (Li et al., 2010: 2).

Each pointed out (Tao et al., 2011:673), (Huang et al., 2013:1264), (Zhang et al., 2014:172), (Adamson et al., 2015:2), (Zhang and Liu, 2022:8), to the operating principle of the (CM) system, as shown in Figure (1)

The operating principle of the (CM) system shows that there are four basic pillars for operating the system (manufacturing resources and capabilities, manufacturing cloud, manufacturing life cycle applications, knowledge), and they are linked through the work of three participating categories in the (CM) system, as shown below:

Resource Provider: Provides (encapsulated and virtualized) manufacturing resources and capabilities in the form of manufacturing services using virtualization and service-oriented technologies (Zhang and Liu, 2022:7). The manufacturing services are then linked to the manufacturing cloud using Internet of Things (IOT) technology (Huang et al., 2013:1264).

Cloud Operator: Responsible for realizing the effective management and operation of the CM platform in an intelligent and standardized manner, and provides secure, reliable, high-quality, low-cost and on-demand manufacturing services, supported by cloud computing technology (Zhang et al., 2014:172).

Resource user: Manufacturing services can be shared by users for simple and complex tasks all over the world, throughout the entire manufacturing lifecycle, covering a wide range of cloud services (market and customer requirements analysis, resource planning, product design, simulation, chain control supply, manufacturing, management, maintenance, ...) up to end-of-life services (Adamson et al., 2015:2). using different types of cloud applications (Zhang et al., 2014:172).

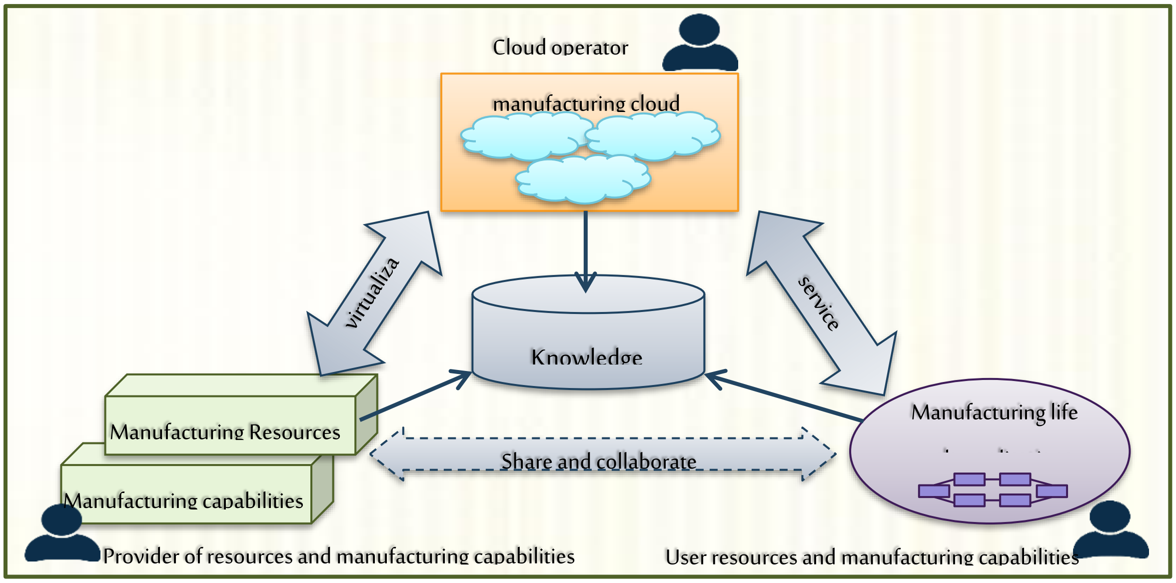

Figure (1) Principle of Operation of the CM System

Source: Prepared by the researcher based on the literature referred to.

Knowledge also plays an essential role in supporting the operation process, as it supports access to virtualization and cloud services packaging for manufacturing resources and capabilities (Zhang and Liu, 2022:8), and achieves integration across the entire manufacturing life cycle, and the most important role is achieving effective management, smart matching, scheduling, and smart search cloud collaboration, etc. (Zhang et al., 2014:173).

Fifth: Research Contributions in Describing the Cloud Manufacturing System:

Much effort has been made in the literature to describe and discuss CM system architecture and application industry. As the researchers presented many (engineering, models, programs, frameworks, applications) to describe the (CM) system. The structures of the proposed systems differed between (5-12) layers. As shown in table (2) below:

Table (2) Proposals to describe the (CM) system

ت	layer Source	1	2	3	4	5	6	7	8	9	10	11	12
1	(F. Tao et al. 2011:1971)	resources	perception	Virtualization	cloud service	application	entrance	Corporate collaboration application	Knowledge	Cloud security	Internet		

2	(Huang et al. 2013)	manufacturing resources	integrated operating environment	Basic support	Continuous service	the engine	the tool	service component	service model	business model	transaction	Enterprise service	User
3	(Adamson et al., 2015:7)	Material resources	perception	virtualization	cloud service	application	user interface	Security	Knowledge	Connection			
4	(Mourad, 2018:40)	Material resources	virtual resource	Basic service	application interface	application							
5	(Haghsefat and Liu, 2021:3)	Basic technology support	Material resources	virtual resource	service	Tools	application interface	Access	User				

Source: Prepared by the researcher based on the literature referred to.

Sixth: The proposed framework for the cloud manufacturing system:

This is study presented a framework as a proposal for the CM system, as shown in the figure (2) below:

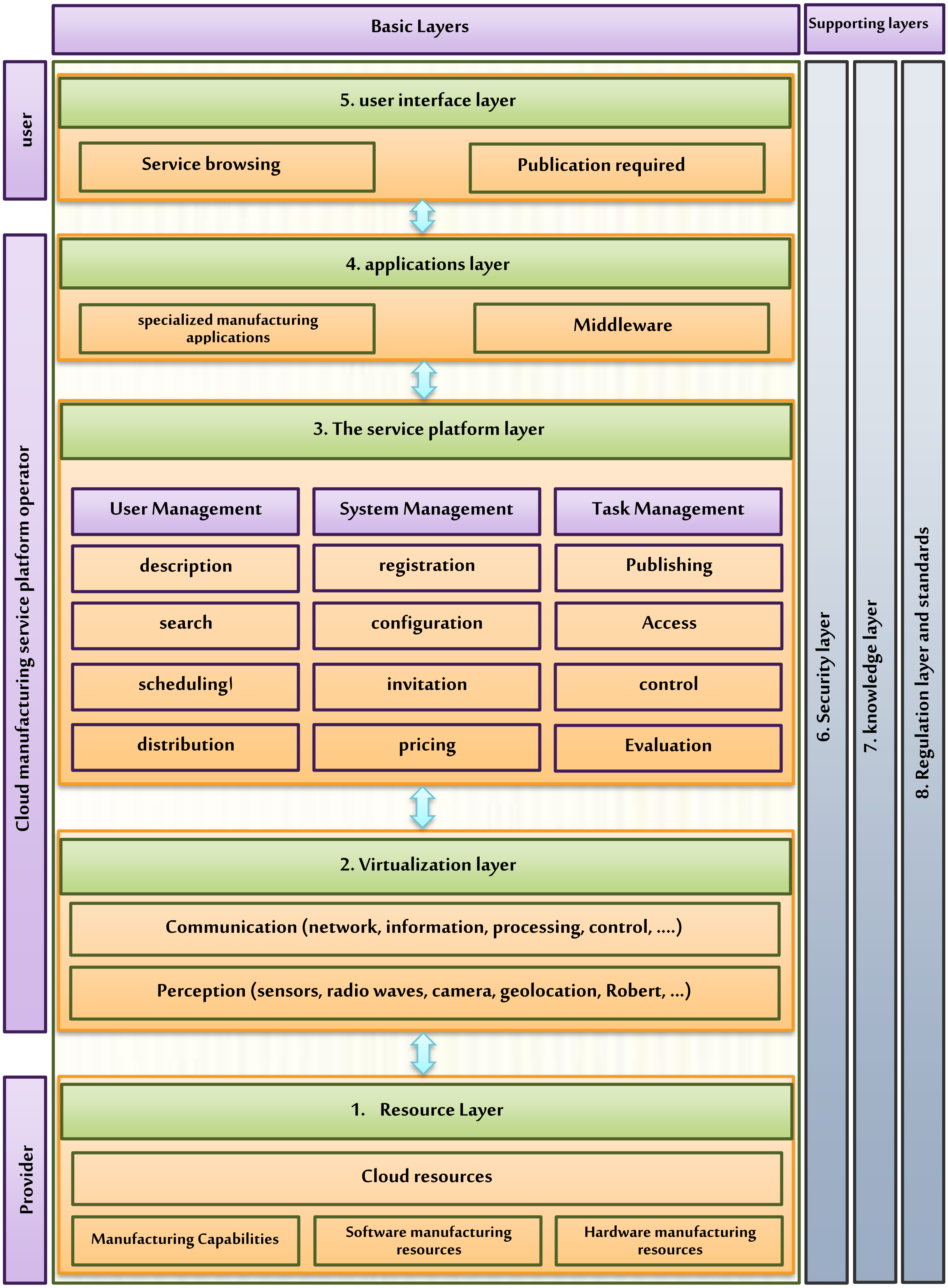

Figure (2) The proposed framework for the (CM) system
Source: Prepared by the researcher.
Seventh: Cloud Manufacturing System Requirements:

From the proposed CM framework, the basic requirements for the implementation of the CM system are evident. It consists of basic and supporting layers, as shown below:

Basic layers: It includes five layers:

1. Resource Layer: In CM all manufacturing resources and capabilities required for the entire manufacturing life cycle are virtualized, with the help of cloud resources. As explained below (Wang, 2012:59) (Wang and Xu, 2013:7):

a. Hardware manufacturing resources: It includes material manufacturing requirements, as follows:

Equipment and machinery: the tools needed to complete the manufacturing task such as (machines, cutters, testing equipment, ...).

Control devices: devices used to control equipment or materials in the production, testing and monitoring process, such as (breakers, valves, relays, automatic control units, ...).

Materials: inputs and outputs from the production system, such as (raw materials, product in progress, finished product, energy, water, lubricants, spare materials, ...).

Storage: various physical storage means such as (tanks, warehouses, cylinders, ...)

Transportation: the means used to transfer manufacturing inputs/outputs from one location to another, such as (pipes, cars, railways, ...)

Software manufacturing resources: These include intangible manufacturing requirements, as follows :

Knowledge: Information and knowledge necessary to complete manufacturing tasks, such as (engineering knowledge, product models, standards, evaluation procedures, ...).

Skill: the ability to perform a specific manufacturing task and accomplish it with high efficiency.

Individuals: the human resources involved in the manufacturing process, such as (designers, managers, technicians, programmers, ...).

Experience: the possibility of high performance, quality and evaluation in their work.....

Business Network: business relationships inside and outside the organization.

c. Manufacturing Capabilities: It is the professional competitiveness, and it includes the following:

Design ability: Design knowledge of the manufacturing domain, organization experience, and previous experience with previous design activities.

Production capacity: depends on the speed and quality of creating outputs (product, service), to fulfill production orders.

The ability to experiment: the ability to run experimentally and obtain scientific results and discover daily problems and address them.

Ability to manage: It includes (planning, organizing, staffing, leadership, follow-up), and depends on the ability of operational business and organizational activities.

Communication: the ability to exchange data (transfer, speed, storage, conversion).

d. Cloud resources: These include cloud computing devices that support the manufacturing process, as follows:

Computers: This includes all computers connected to the system.

Network equipment: including servers, towers, cables....

Data Warehouses: includes data storage space and central processing unit ....

2. Virtualization layer: Virtualization is a technology that hides the physical characteristics of manufacturing resources from users, and aims to virtualize manufacturing resources and capabilities and include them in the cloud service (F. Tao et al., 2011:1972) (Adamson et al., 2015:7) , and include the following:

Perception: Responsible for sensing manufacturing capabilities and resources and enabling them to interact and relate on a large scale to the network and convert them into data that can be processed. It includes different types of devices such as (sensors, radio frequency identification, robots, cameras, geolocation, ...).

Communication: Responsible for communication with the service platform, including (local and/or global network, information, processing, control, ...).

Cloud manufacturing service platform layer: It is called the cloud manufacturing platform. This layer deals with two classes of service. The first is the manufacturing cloud service resulting from the service packaging of manufacturing resources and capabilities. The second / basic service provided by the system: It is the main services provided by the cloud service to the three categories (provider, operator, user) (Adamson et al., 2015: 7). It aims to (achieve the digital engineering integration of the CAX series for the entire manufacturing life cycle, achieve horizontal integration through the integration of many information technology systems, processes, resources, capabilities and information flows within the organization and between organizations, achieve vertical integration between manufacturing systems between departments and hierarchical levels of the organization). (Pereira and Romero, 2017: 1210). These include (F. Tao et al., 2011:1972) (Adamson et al., 2015:7):

Task Management: Responsible for managing the various manufacturing tasks and the access of resource and capabilities providers to cloud services, such as (Publishing, access, control, evaluation, ...).

System Management: Responsible for managing the cloud services platform, such as (registration, configuration, invitation, pricing,...).

User Management: Responsible for managing user access to cloud services, such as (description, search, scheduling, distribution, ...).

Application layer: Provides specific software applications that enable users of the system to access the cloud service on demand (Zhang et al., 2014:174). These applications support the acquisition of cloud services across multiple stages of the manufacturing life cycle (Ren et al., 2014:8).

Specialized manufacturing applications: It includes applications throughout the manufacturing life cycle, such as applications (design, analysis, simulation, operations planning, ...), that achieve cooperation in the business operations of the organization (Guo, 2016:286).

Middleware: Semantic structures and models (graphics, symbols, schema,...) to represent virtual resources and services and standardize data, such as (SCADAD, CORBA, RPC, ...). It allows integration of manufacturing resources and capabilities across organizations and supply chains (He and Xu, 2015:246).

5. User interface layer: This layer provides support for end users to access the cloud platform, using various peripheral equipment (such as personal computer, tablet computer, smart phone,...). This contributes to the possibility of accessing cloud services from everywhere (Ren et al., 2014:16), including:

Publication required: includes the type of cloud used for user access to cloud services, which is cloud (public, private, hybrid, combined).

Service browsing: It includes various application interfaces to interact with users and their access to cloud services.

Supporting layers: It includes three layers:

6. Security Layer: This layer supports system security from physical to virtual security and includes (Kresimir and Zeljko, 2010:5) (Yadekar, 2016:98):

Breach / loss / leakage of data: related to saving data from breach, deletion or change of records without backup by external / internal users to the cloud through (passwords, hosting malicious data, loss or destruction of encryption keys, entry of unauthorized parties access to sensitive data,...)

Data control: associated with preserving data from losing control over physical assets by protecting database sites from exposure (damage, destruction, burning, theft, ...)

Data privacy: It is related to regulating contracts, regulations, and laws to preserve data privacy between the beneficiary of the cloud and the cloud providers where the database is located.

Secure cloud service interfaces: linked to the security of the cloud interfaces provided by the system to the user from (anonymous access, reusable passwords, content transfer, inappropriate licenses,...)

Application Security: relates to the ability to protect software applications from IP intrusions and cloning.

Security and development of cloud interfaces: It is related to the ability to protect applications that originate from certain development toolchains such as (JAVA, ASP.NET,), which may be insecure due to lack of knowledge of the security measures used in applications.

Data transmission security: relates to the extent of errors in transmission and message processing between cloud service interfaces.

Security of remote access to cloud services: It relates to the security of remote access to cloud services without affecting the encryption / decryption mechanism in the cloud.

Intellectual property protection: relates to the ability of the cloud to prevent hacking/phishing attempts from competition.

Secure encryption levels: relates to the ability of the cloud to determine the appropriate type of encryption for each type of data.

The knowledge layer: focuses on system performance and its ability to dynamically adapt to changes and provide cloud services with minimal human intervention. It includes (Xu, 2012:77), (Yadekar, 2016:99):

Scalability: relates to the ability of the system to provide additional resources or services.

Bandwidth capacity: related to the system's ability to collect real-time data from manufacturing resources and capabilities to servers, in addition to manufacturing data generated during the production process, which requires wide network bandwidth.

Availability of the cloud service: It is related to the ability to provide a continuous network and not to fail the system or the system's inability to access cloud services when the network connection is interrupted.

System Integration: It relates to the system's ability to reach all its stakeholders.

Data standardization: relates to the interoperability of the system to deal with different formats for design and standardization of data.

Response time: It is related to the system's ability to be highly flexible in responding to requests faced by cloud services interfaces.

Fault tolerance: relates to the system's ability to continue operating in the event of failure of some of its components.

Flexibility to change design or manufacture: relates to the system's ability to change the design/manufacturing request of the cloud provider.

Disaster recovery: It is related to the system's ability to recover cloud services after the occurrence of natural disasters, hardware theft, and electronic accidents.

The strength of the provider of the cloud: relates to the ability of the system to transfer data and programs away from the provider of the cloud system.

8. Organization and standards layer: Focuses on the effective management of the system through cooperation, participation and communication between (providers, operators, users) of the cloud, using standards and agreements that clarify the responsibilities and duties of each party of the system. These include (Xu, 2012:78), (Adamson et al., 2015:11), and (Yadekar, 2016:100):

Authentication mechanism: related to providing secure authentication methods to access cloud services (contracts, partnership).

Administrative organization: related to providing administrative procedures that determine who can perform data-related operations (creation, access, disclosure, transfer, destruction) through the cloud system.

Permissions control: related to providing licenses to share manufacturing resources and users' access of different levels to different resources in the cloud system.

User Limits: related to the extent to which you can control the amount of resources/data that a user of cloud services can access.

Quality control and assurance: related to providing tools to monitor and document the quality of the cloud service to control and ensure its quality.

Training: related to the possibility of training employees on cloud services whenever new programs are introduced.

Standards: related to providing standards for the interoperability of cloud services (cloud operators) and system infrastructure (resource providers) and understanding the responsibilities of each party.

Change in cost: related to the ability to deal flexibly with changing the cost of updating or changing the cloud system in the future.

System quality: related to providing standards to ensure the performance of the cloud system, network availability and security for each of (manufacturing resources or services, cloud service request) that change over time.

Communication: related to providing the cloud system connection with other departments such as planning, marketing, finance...

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