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| RESEARCH ARTICLE

Enhancing Production Strategies Using Service-Oriented Architecture and Enterprise Service Bus in Manufacturing Companies

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| ABSTRACT
To counter economic constraints, the demand for abundance customization and globalization for cost decrease has significantly increased, and the consequence of production systems has moved towards lean manufacturing strategies. Implementing a lean Plan in a company will lead to reorganizing the logical production chain to prevent waste. The proper flow and circulation of information in a group play a crucial role in achieving a lean strategy. Now, a company's information system comprises various software and designed systems. Enterprise Resource Planning, Product Lifecycle Management, Supply Chain Management (SCM), and other software are each designed to achieve objectives from business aspects. Product diversity is essential for all companies, it creates abundance and diversity and increases the magnitude of data. This lack of cohesion can generate significant issues in internal communications within a company. This research introduces a method that utilizes Service-Oriented Architecture (SOA) and Enterprise Service Bus (ESB), featuring modules for Intelligent Routing, Monitoring and Governance, Mediation, and Dynamic Choreography. Considering the case study and evaluation conducted for the proposed architecture, the results of this research provide agility to adapt to company strategies and business needs and support the interaction between compatible systems as part of work during production and intra-company collaboration.

| KEYWORDS
Mass Customization, Lean Manufacturing, Service-Oriented Architecture (SOA), Enterprise Service Bus (ESB), Supply Chain Management (SCM)

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1- Introduction

The current manufacturing sector faces challenges of increased dynamism and globalization of the market environment (Agarwal et al., 2022). The survival of any organization, whether manufacturing or service-oriented, depends on its capabilities and the continuous improvement of its processes. Therefore, added value to processes is necessary to achieve this excellence. In this context, the lean manufacturing system offers various strategies to improve performance and compete in emerging markets. Lean manufacturing images have evolved from the Japanese industry, mainly from Toyota. Although deemed a process for waste deduction, in practice, it maximizes product significance by minimizing waste. (Alabi et al., 2022). In other words, the lean manufacturing system represents a new thought and approach to managing industrial organizations. It conducts process management and precise resource identification through principles, techniques, and methods derived from it, following the complete and comprehensive elimination of waste and the rise of productivity in all activities, both inside and outside the organization. To develop lean manufacturing, one must find 1- processes, 2- information, 3- resources, and 4- company production plans. However, the demand for the logical development of products/services requires not only the expansion of the production process chain plus throughout their life cycle (delivery, services, etc.). It leads to developing collaborative strategies

(Andries & Vander Weyden., 2021). By concentrating on its core business and leveraging the experiences of others, the company can share costs, shorten development time, and maintain better control over product quality.

The key for a company to provide a comprehensive view of its processes, functions, resources, and production status is the deployment of an information system (Awwad., 2023). An information system must be accustomed to responding to fluctuations and uncertainties, help create agility to speed up new processes, facilitate cooperation with suppliers and customers, and ease the interaction between business systems. A company's information system includes multiple software and designed systems such as ERP.[1], PLM[2], SCM[3], and other software aimed at achieving goals in one part of the business. The lack of data cohesion in information systems leads to redundancy, heterogeneity, and an increase in the volume of information. To address these challenges, integrating data systems is essential, so we need to seek a solution.

Beinir and his colleagues proposed an architecture that emphasizes two key processes—control and display—within a service-oriented framework, supporting various levels of interoperability. They employ service-oriented architecture to enhance agility and urbanization, decreasing redundancy (Bîgu & Săveanu, 2022). This urbanization architecture organizes the information system into distinct levels, separating activities from the information system and the technical infrastructure. Implementing such an architecture necessitates redefining process synchronization procedures to adapt processes to the specific constraints of the target organization. However, achieving this integration of different workflows and overall optimization through the organization of resource activities can be challenging.

Srinivasan and his colleagues combined service-oriented architecture research, multi-agent systems, and supply chain management systems. In the supply chain management system, different parts of the factory are considered agents, and the interaction of these agents in supply chain management results in the creation of services. This method reduces the execution time of programs and costs, which is a primary concern for the management of any industry (Closs et al., 2011). The integration provided in this research only covers supply chain management, which is part of the production system, resulting in a lack of support for the interaction of compatible systems and proper intra-company collaboration.

Ullman and his colleagues proposed a method for implementing a flexible industrial product-service system based on service-oriented architecture. This article uses service-oriented architecture in the implementation phase, turning functions into services (Dolgui et al., 2018). The proposed plan is not aligned with lean manufacturing and does not cover semantic interoperability, resulting in redundancy and an increase in the volume of information.

In his research, Trombolidis presented an implementation of the IEC 61499 standard of service-oriented architecture in distributed automation. FBs are considered service providers and provide an interface for events and input/output data **(**Ghadge et al., 2022)**.** Using this technology to integrate device software architectures' flexibility it supplies results in significant complexity and performance overhead.

Zhang states that integrating telecommunications and IT services is a significant challenge in supporting the evolution of next-generation services from heterogeneous networks. He considers adopting a hybrid environment for implementing IT/telecommunications services essential for service integration. He mentions that ensuring work cohesion and quality of service is a key issue in a hybrid environment. This article uses a service-oriented architecture and a **s**ervice bus routing framework to adopt a hybrid framework for service deployment. The proposed enterprise service bus design supports two request/response and publish/subscribe messaging approaches. It illustrates **w**ays to enhance service availability and reliability for the two interaction patterns. Additionally, it offers dynamic adaptability to ensure continuity of operations in the event of a node failure and load balancing for unpredictable load fluctuations to enhance service availability in integration **(**Hsu et al., 2022)**.** In other words, the main focus of this design is on decoupling systems from each other, enabling them to communicate in a consistent and manageable way, thereby providing agility and scalability.

Sharaghi and his colleague consider maintenance management systems one of the vital business units in companies, playing a key role in reducing machinery and equipment breakdowns (Islam et al., 2024). Therefore, they state that the new era of information technology has led to the execution of information systems for expansion in maintenance management. This research examines the recent management trends of information systems in various maintenance applications. In this article, services are the main elements of maintenance systems from a service-oriented perspective. The use of service-oriented architecture and maintenance strategy in industries shows that the trend of integrating information systems and maintenance management is rapidly growing **(**Ivanov., 2022). This research indicates that recent trends in maintenance systems show a tendency for greater flexibility in integration with other business events in different methods, which results in waste prevention and cost reduction.

[1] Enterprise Resource Planning
[2] Product Lifecycle Management
[3] Supply Chain Management

A moderately complex supply chain begins with a dynamic system approach alongside a model with four levels centered around the manufacturer and a custom system. This design aims to model the supply chain network and obtain accurate responses to its behavior by integrating the information flow system. The analysis of the model's behavior in the base model and various scenarios over a year using simulations indicates that an integrated information system can maintain a significant degree of customer satisfaction by reducing safety stock (Ivanov., 2021).

The proposed design only covers the supply chain, which can be part of the production system, accomplishes not cover semantic interoperability, resulting in a lack of support for the interaction of compatible systems and proper intra-company collaboration. Naeimi Seddigh and his colleagues proposed a coordination example in a competitive supply chain utilizing a game approach course with cooperation and non-cooperation scenarios, where the seller-buyer supply chain has a wholesale price mechanism. Due to this mechanism, the vendor and customer have conflicting objectives. The proposed models consider the relationships between the buyer and seller in both cooperative and non-cooperative game scenarios. In the non-cooperative game, the customer and seller have equal power and decide simultaneously. Due to the conflict in objectives, the purchaser's and vendor's models are inefficient. Therefore, a cooperative game is proposed for the buyer and seller to ensure that both achieve higher profits than the non-cooperative scenario (Li et al., 2021**)**. This model does not include lean manufacturing principles. In lean manufacturing, the interaction between the company and the supplier is hierarchical and based on the supplier's experience and history of cooperation with the factory. Practically, the supplier and the company reduce the cost of each part of the production process through value engineering techniques, ultimately determining the price based on market capacity and reasonable profit for both parties. Another difference is the factory inventory level, which reaches zero with the execution of the Kaizen system (i.e., at each stage, only the number of parts used in the next stage are manufactured). Finally, in lean manufacturing, the highest focus is on customer needs and market share.

Bafandeh Mayavan and his colleagues focused on the progression of component-based software and the quantitative measurement of software component reusability. Component-based development highlights the structure and configuration of software designs using reusable parts. When the development process is too costly to build all parts of a software system from scratch, this can significantly reduce production costs with the help of pre-fabricated components that ensure timely delivery, flexibility, quality, efficient maintenance, and scalability **(**Li, C., & Liu., 2013)**.**

On the other hand, in recent years, with the expansion of organizational functions and technological advancements in networks and distributed systems, service-oriented architecture has gained significant importance in the progress of software systems centering on increasing interoperability and system integration. The goal of this architecture is to achieve loose coupling in the communication between software components, resulting in increased flexibility, agility, and interoperability in both internal and external company collaborations.

Roesler and his colleagues analyzed the utilization of lean manufacturing methods to determine their impact on production flexibility and efficiency in the CIP—simulation environment. The research focused on three lean manufacturing methods: production leveling, flexible production systems, and customer demand management. It also addressed three lean manufacturing factors: equipment, personnel, and internal logistics. The simulation model of all three lean manufacturing approaches is analyzed simultaneously. For all sub-scenarios, the average output rate increased by 25% to better respond to customer demand. Increasing production flexibility using a combination of lean manufacturing methods demonstrates that it can be achieved (Agarwal et al., 2022). This research examines manufacturing flexibility in internal supply chain (Hasan et al., 2024) management and does not regard industrial information software or its integration. Therefore, the proposed plan does not provide agility to adapt to company strategies and business needs and does not support the interaction between compatible systems as part of work during production and intra-company collaboration.

Implementing a lean strategy in a company will lead to waste prevention and thus reduce company costs, a topic less addressed in previous research. However, in the proposed plan, lean manufacturing is considered one of the main pillars of work. The diversity of information systems in a company leads to both similarities and differences, increasing the importance of communication. This lack of cohesion can generate significant troubles in internal company communications. Previous studies have examined the combination of two or three software systems. However, the proposed design considers the integration of other industrial information software.

Therefore, the proposed plan addresses the combination of information systems (SCM, ERP, MES, PLM, CRM, etc.) in industrial environments. Leaving an enterprise service gateway and agility is achieved through a service-oriented architecture. The integration of these systems will focus on business processes at the process control levels by the system and at the company's management levels. Consequently, the system must include exact current data on business processes, precise reports, responses on activities performed in the company, and a detailed guide.

This section uses ISA-S95 and the company ontology to assess the level of agility and integrity of the work.

"This paper is organized as follows:"

- Part 1: Presents the technical and semantic interoperability.
- Part 2: Explains the structure of the suggested architecture.
- Part 3: Provides a case study of the research.
- Part 4: Evaluate the proposed architecture using the ISA-S95 ontology and the company ontology.
- Part 5: Provides conclusions and recommendations for future studies in this field.

2- Technical and Semantic Interoperability

This article does not include organizational interoperability. Regarding technical interoperability, the service-oriented architecture pattern coordinates components to perform an assignment, operation, or procedure. Service-oriented architecture facilitates the integration of knowledge from various system components and ensures alignment between IT and business, including systems like Enterprise Resource Planning, Customer Relationship Management, Supply Chain Management, and other software (Xiang et al., 2024).

Semantic interoperability ensures understanding at the business level among information system components. It involves the interpretation of exchanges between different company applications and between the company and its partners through a common vocabulary. Business ontology defines organized knowledge about company activities, such as processes, organizations, and strategies. Implementing a lean plan in an organization includes core activities carrying out value and outsourcing secondary activities. Business ontologies are compared (Table 1: Comparison of business ontologies).

The comparison shows that the ISA-S95 standard integrates organizational resources, production planning, and product definition.

Its standard lacks customer management and marketing. Therefore, in the continuation of the work, the standard business ontology will be used by adding business concepts to the EO ontology.

Table (1). Comparison of business ontologies

	Business area covered	Specific business	Industrial information system connection	Intra-company	Intercompany
EO	Related concepts include: Activity and processes - Organization - Strategy - Marketing	It considers models of processes and activities across the company's business.	It is limited to organization, strategy, and marketing and without a definition of production.	It cannot deal with this issue alone.	Ability to communicate with partners through integrated models
TOVE	A set of constraints: - Operations-Resources - Organization - Objectives - Products - Services - Events - External Environment.	It includes actions, services, and even product definitions and links multiple transactions jointly.	The model considers the organization's resources, goals, etc. (but not the industrial information system).	It is related to the business model and the limitations of the relevant obligations.	It seems that the external environment of the company and the business processes or exchanges between partners within the framework of inter-company cooperation are not specified.
PSL	-Trade between industrial processes -	It includes the meaning of industrial	Management information is not considered and	The information provides limited models. The	It defines industrial processes but

	Knowledge transfer between devices -Sets of activities/processes -Objects -Moments (How to measure the variable)	activities and processes and focuses solely on the manufacturing industry.	does not establish a connection between management and production.	company considers this model a general discussion.	does not model business processes and collaboration.
ISA-S95	Including: Product definition -Production definition (instructions) Production results -Production capacity	Defines the business activities and processes connected to producing a product or service according to customer specifications.	This set is a strong model regarding integration with the company's comprehensive industrial information system.	It provides a model of the production process but not all of the company's business processes, such as customer management and marketing.	Well-defined production processes consider sharing, resource allocation, and customer needs. It can also examine the collaborative processes of the model, which remain limited.

3- Proposed Architectural Structure

The company has developed its information system to run in a stable environment with limited variability. This design method begins with a thorough set of requirements, which leads to a cumbersome system. Collecting data for a comprehensive view proves challenging due to the system's complexity and lack of agility, impacting the organization's overall effectiveness. Furthermore, the continuous evolution of business and information system management techniques is complex, and the lack of agility of the information system generally impacts the company. Each company integrates various business applications without unifying them to track the value chain. Implementing a lean strategy in the company will prevent waste and consequently reduce company costs.

Previous research has less addressed this topic. However, in the proposed plan, lean manufacturing is considered one of the main pillars of the work. The diversity of information systems within a company causes redundancy, heterogeneity, and an increase in the volume of information, leading to significant problems in internal company communications. Previous research has examined a combination of two or three software systems, but the proposed plan considers the integration of other industrial information software systems.

Since 2000, many new and innovative methods for creating web applications have emerged. Recently, with the expansion of e-commerce in organizations and the need for fast and large-scale solutions, these methods are moving toward enterprise environments. Organizations prefer to create new applications by combining existing resources and software rather than developing software from scratch. These new applications are called composite applications or Mashups. What makes Mashups unique and gaining industry attention is the ability to **create** and deploy quickly. Mashups achieve this by leveraging existing software assets and avoiding a large codebase size. They also offer low-cost applications and greater alignment between IT and business, promising a future for business software.

The proposed scheme is to create data mashups based on syntactic processing. Also, data semantics is one of the various components of an information system. It is allowed by the semantic mediator module, which allows the "format" of data content to be rooted in the core ontology of this research. This semantic layer provides four main modules by adding the definition of EO ontology to ISA-S95 ontology, which supports the integration of mediation and business functions:

1. Semantic Mediator Module
2. Dynamic Choreography Module
3. Intelligent Routing Module
4. Monitoring and Governance Module

3-1- Semantic Mediator Module

The semantic mediator module is at the heart of the lean enterprise service bus, enabling interoperability between the blocks of existing information systems. This layer facilitates communication between the company's business components, leading to the integration of product definition, production definition, production results, and production capacity. The industrial semantic layer allows mediation between the company's business components, leading to the merging of product definition, production definition, production results, and production capacity. As shown in Figure 2, the semantic mediator module filters, sorts, and integrates data streams from business software and handles the data formatting process through syntactic transfer. This module can also work with product meta-models, definitions, capacity, and production performance to extract relevant data, transform "business" data, and combine them to create content aligned with business needs. This information defines the production process to identify workshop constraints concerning resource allocation and the active state of services.

3-2 Intelligent Routing Module

The intelligent routing module utilizes the results from the semantic analysis of the semantic mediator module. It manages resource allocation in line with the lean production system by using the product definition and production capacity meta-model and calculates their availability in real-time (Figure 3). The business process created by the intelligent routing module includes a schema of resources, routing rules, and work priority rules. Interaction between different resources is also conducted based on these principles. Messages are exchanged between industrial services and resources using a relationship with the existing information system scheduler.

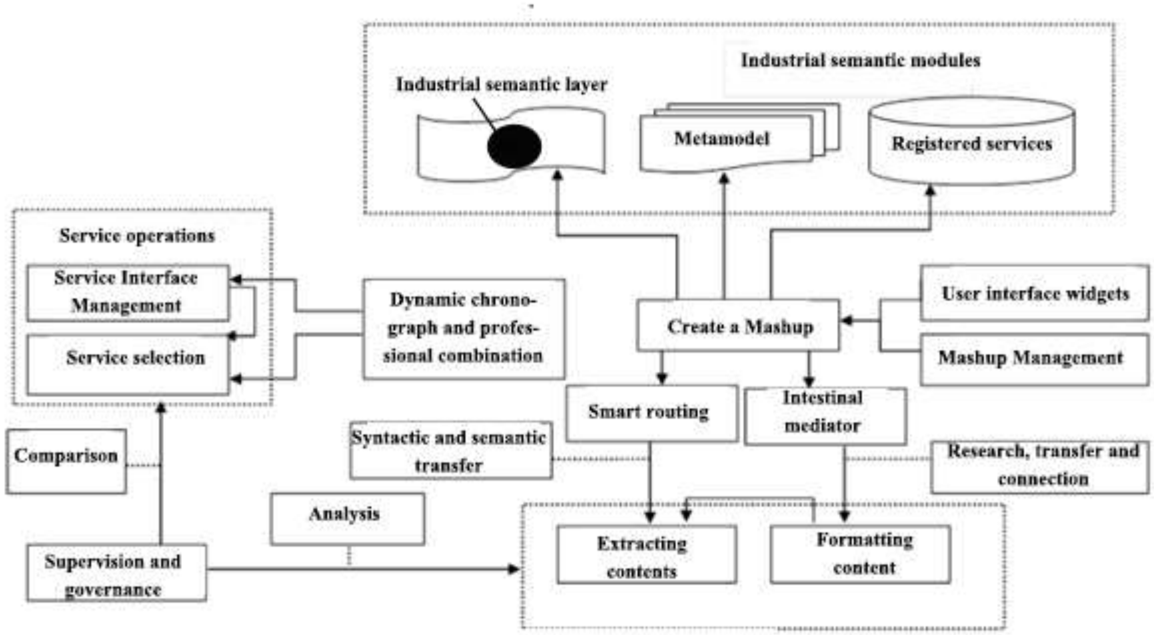

Fig (1) .Proposed Mashup Architecture

3-3 Monitoring and Governance Module

The monitoring and governance module analyzes data streams from the intelligent routing module and compares them with service flows from the dynamic choreography module (Figure 4). It manages products and services. Service indicators in the "Service Level Agreement" include key performance indicators (overall company activity performance) and key quality indicators (Yeh & Kashef., 2020). Quality indicators demonstrate the quality of features provided by a service, evaluated using the following parameters (Yu & Buyya., 2005): responsiveness to customer needs, service availability, adherence to schedules, integration of the industrial information system with the company's overall information system, etc. It intends to arrange the monitoring and governance module (performance, production, and product quality) through lean manufacturing principles. It retrieves indicators related to the resource status output, compares them with stored indicators, and reports any anomalies. In such cases, the intelligent routing module redefines resource allocation to ensure the process continues uninterrupted.

3-4 Dynamic Choreography Module

The challenge of service-oriented architecture is to provide services to its customers and respond to the needs of an application (or user) with the available services. This principle is named "service composition," allowing the interaction and coordination of multiple services to achieve a goal (Zhang et al., 2020). Service composition falls into two categories: static and dynamic. A service composition is named static when it uses pre-selected components or services defined by prior flow management. Conversely, a composition is named dynamic when services are selected and formed according to the needs formulated by the user.

In dynamic choreography design, the Mashup service is developed in terms of functionality (Figure 5). The definition of meta-models for data production and flow from mediation and routing modules allows the choreography module to provide an overall view of the workshop and define workflows and output tools for a production system. It utilizes the combination and arrangement of services to achieve a specific goal in lean manufacturing.

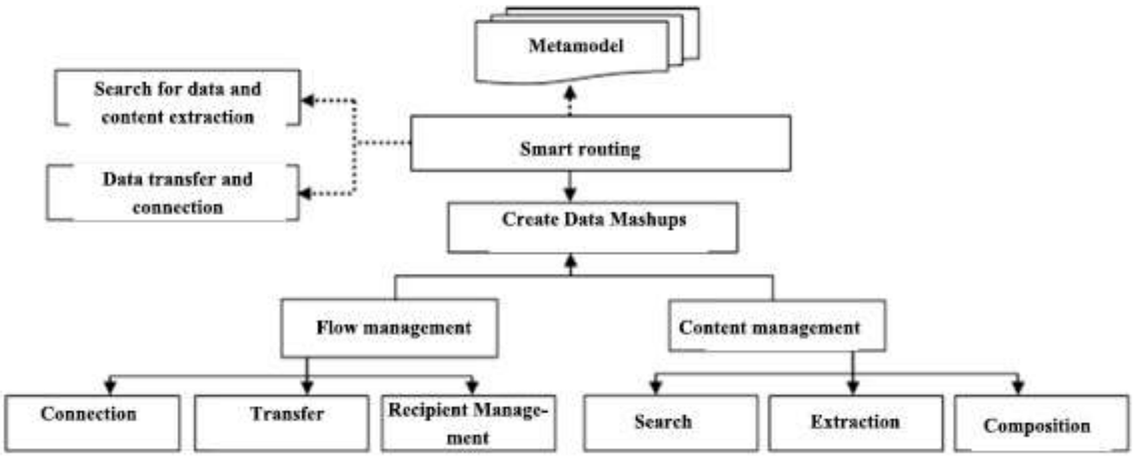

Fig (2). Creating a Data Mashup with the Semantic Mediation Module

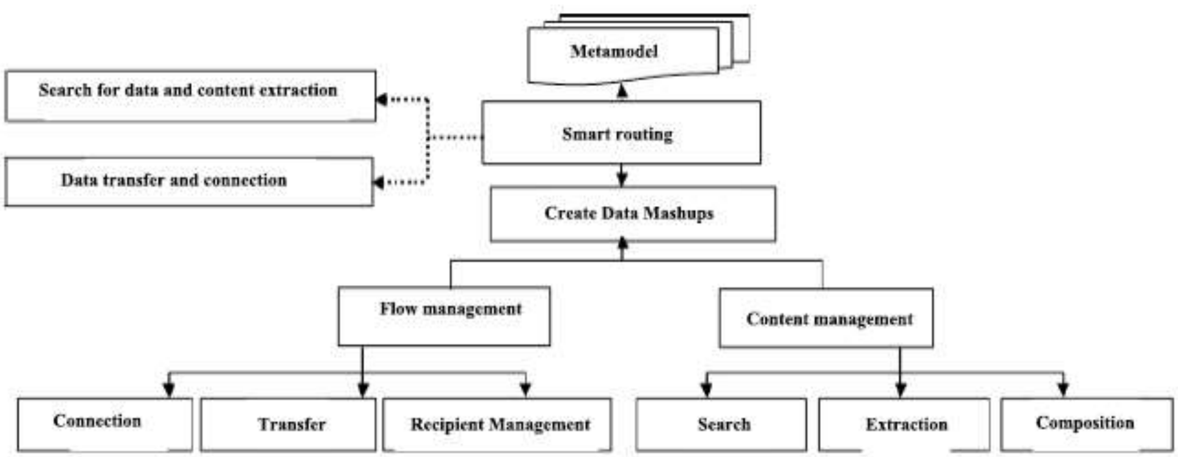

Fig (3) . Creating a Data Mashup from the Smart Routing Module

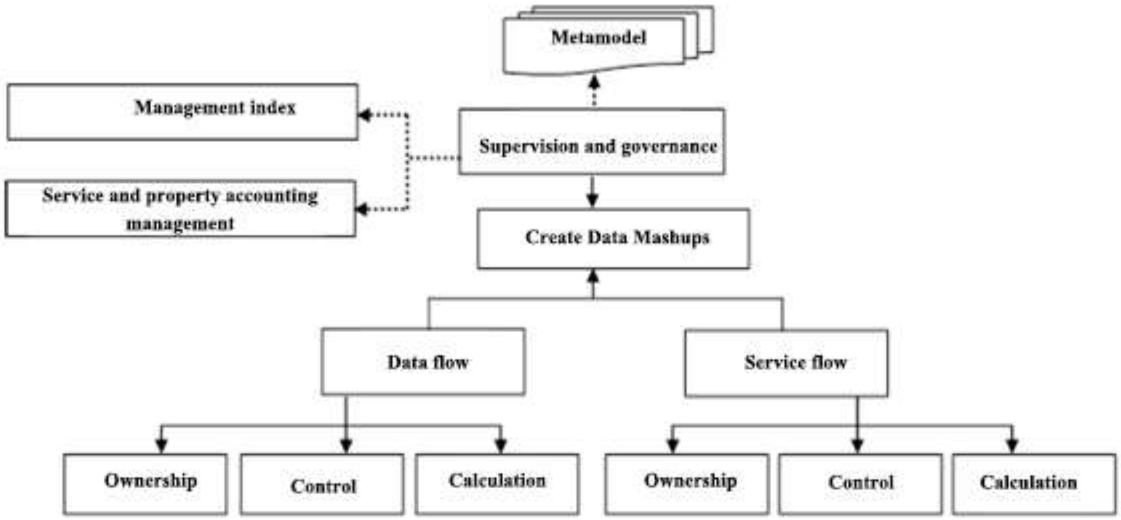

Fig (4). Creating a Data and Service Mashup for the Monitoring and Governance Module

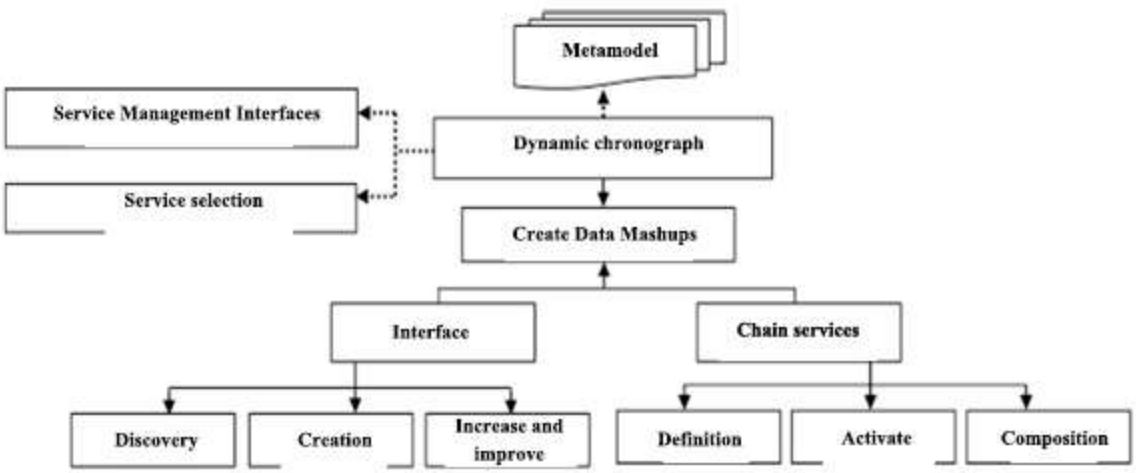

Fig (5). Creating a Data and Service Mashup for the Dynamic Chronography Module

4. Case Study

The current investigation is a simulation schedule for the manufacturing and wrapping of a tile and ceramic company positioned in Yazd Industrial City. Each production system, as shown in Figure 6, consists of:

The central conveyor belt and six devices create a loop.

Machinery

Simulating storage operations

Retrieval

Assembly

Disassembly

Quality control alongside the supervision of programmable logic controllers that monitor the entry and exit of the equipped machines. Logic controllers can be programmed to manage magnetic adhesives, sensors, motor units, and manufacturing equipment. Machines 4 and 6 are operated by Adept One and RX90 robots, respectively.

Given that the company in question currently has information redundancy and lacks the necessary agility in the data flow, this research aims to address these weaknesses by integrating various elements of the information system. The proposed design emphasizes defining a unified plan that consolidates industrial constraints, such as product definition, company resources, physical processes, plus more.

In this simulation, the raw materials include empty pallets and various colored pieces with geometric shapes, with the finished product being a combination of these three components. Each pallet has a magnetic label that describes the output product and the production schedule. The programmable logic controller from Device 1 sets the magnetic strip on the empty pallet as the final product designated for sale.

The movement of the empty pallet from Device 1 to Device 4 occurs via a conveyor belt for placing the pieces onto the empty pallet. The programmable logic controller from Device 4 reads the load label to define the product for machine loading. Based on the product definition, Device 4 assembles the pieces of different colors and shapes in a specific order. After this stage, the final product, consisting of a pallet composed of three sections, is controlled by Device 5. If the product quality is approved:

1- It is maintained in machine (2).

2- Otherwise, the finished product is maintained in the machine (3).

4- It is transferred to machine (6), where its components are separated and modified.

The data flow and service model related to the pallet manufacturing process (data flows plus services in purple and orange rectangular shapes) are shown in Figure 7.

figure 7 shows the production process and the workshop control system created from a data mashup. For services, the formation of a Mashup service results from a combination of selected procedures. Dynamic choreography ensures the real-time selection of business services as a clever routing process, providing the necessary information flow for the operation of a service through dynamic mediation to interpret the required content.

Device 7 is the workshop control station, responsible for managing the total system and the six machines in the workshop. It oversees operational states, stoppages, execution timing synchronization, and the security of all equipment. Additionally, it manages the loading of machining programs for the machinery and equipment across the entire workshop and interacts with the following systems:

- Enterprise Resource Planning [4]:

"Facilitates cohesive information from different business processes."

- Production Execution System:

"A system for managing and controlling production processes that links planning and control systems."

Therefore, Device 7 connects the physical production system (i.e., all workshop machinery) with the management of the production execution system, the supervisory control system, data acquisition, and enterprise resource planning. The production plan retrieves information related to (product definition, quantity, and production schedule). It passes the information to the production execution system through the Lean Enterprise Service Gateway middleware module. The production execution system retrieves data related to production planning, product definition, equipment performance, production rules, and operational instructions concerning supervisory control and data acquisition. This response is sent back to the production execution system about operations, data equipment, and manufacturing processes.

4.1. Semantic Mediation Module

The middleware module extracts information about products and resources in the functional characteristics of industrial services involved in production. This information defines the production process to identify shop floor constraints related to resource allocation (data used by the intelligent routing module) and the active status of services (used by the dynamic dance module). In the case study, this module extracts the following from the enterprise resource planning system:

- Production plan
- Production instructions
- Production capacity
- Resource Capacity

[4] ERP

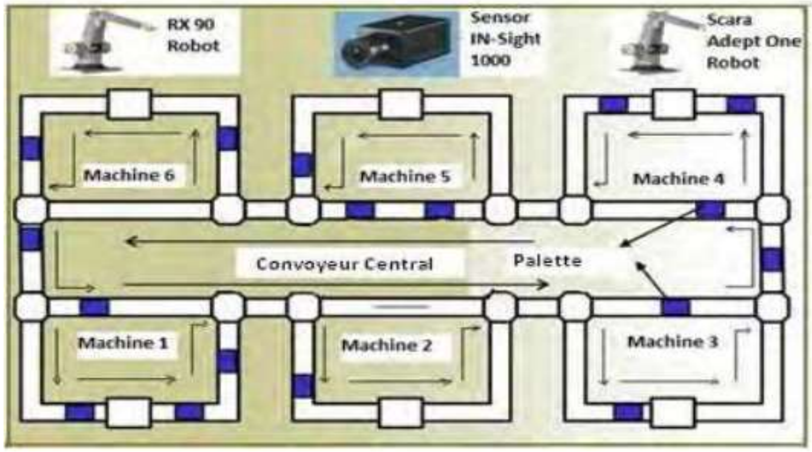

Fig (6). Structure of the simulated company platform

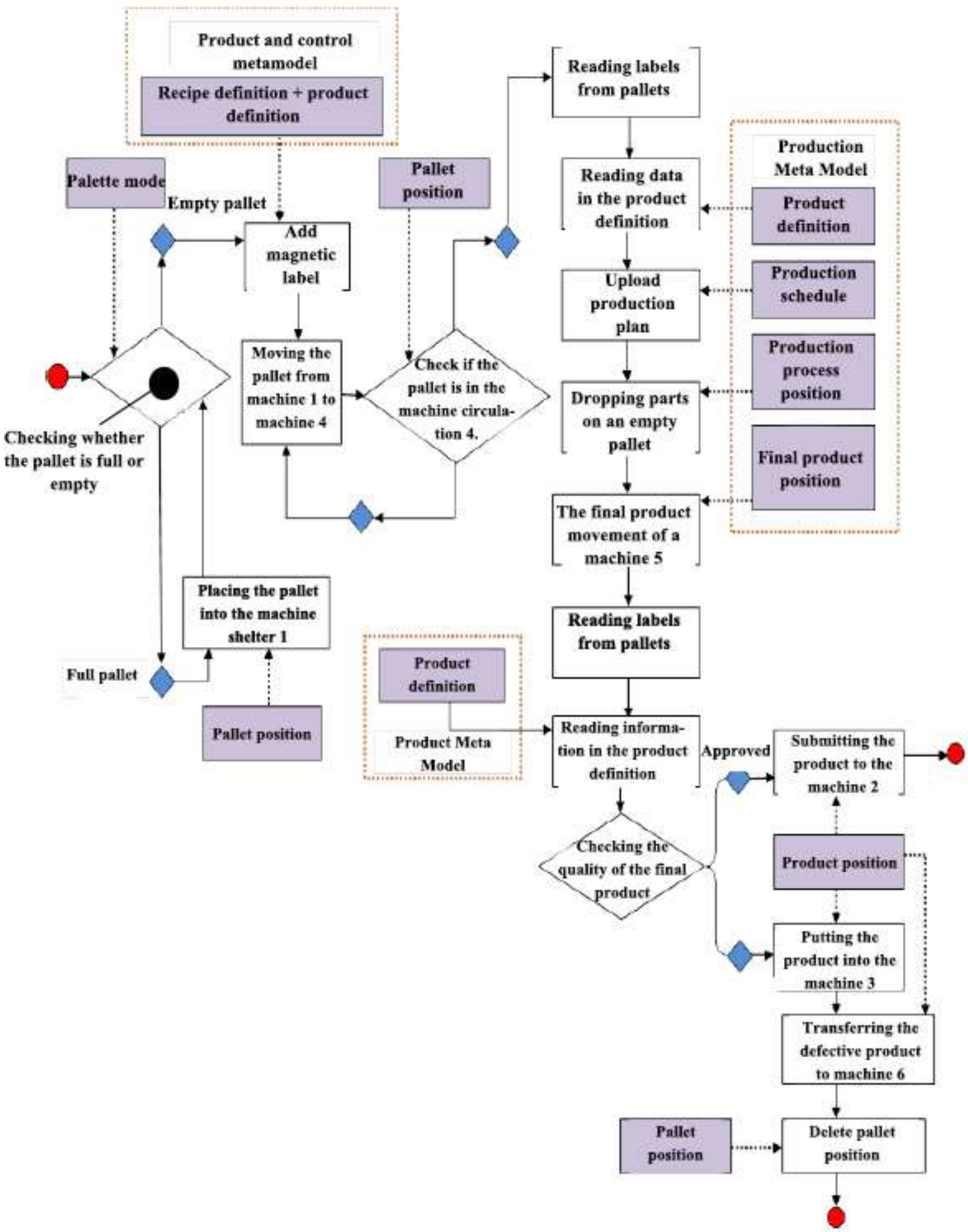

Fig (7). Factory workflow for a pallet

4-2 -Intelligent Routing Module

In the case study, the intelligent routing module considers the production plan defined by the Enterprise Resource Planning (ERP) system to describe and adjust the production schedule based on machinery loading. In job definition:

A set of production plans is implemented from ERP to define routing rules.

Routing rules:

1- To connect to the production execution system
2- For the data collection monitoring system.
The list of routing rules for production conditions (in this example, producing 15 units of "colored pallets") is as follows:

- Raw materials must be available.
- Machine 1 must be available.
- Machine 4 must be available to transfer pallets from Machine 1.
- The final product must consist of a colored pallet and various shapes.
- The processing time for Machine 4 for the product is 15 minutes.

4-3-Monitoring and Governance Module

Production indicators are managed by monitoring the process of product quality, device performance (performance time, quality level, etc.), resource status, response time, etc. The indicators are related to an ontological axis that includes an ontology domain. This ontology domain consists of a service ontology (technology-related aspects of managing service indicators) and a business ontology (business-related aspects of managing production indicators), along with the definition of the calculation process (a set of primary processes).
Built by the Dynamic Chronography module of service and property calculations. The monitoring and governance module has three main functions: obtaining inputs/outputs from the intelligent routing and dynamic choreography modules, "matching" defined performance indicators with the core ontology, and "switching" between indicators and production services.
The supervisory control system and data collection identify anomalies by enhancing the dedicated process with product quality indicators and signals connected to executing the entire production model and product definition process.
The calculation process and activity results are transferred to the monitoring process to redefine the composition of processes regarding anomalies and to the dynamic choreography module for revisions.
In the case study, the monitoring and governance module supervises the production process, quality control of the final product, raw materials, production execution, and order fulfillment, considering time constraints.

4-4 Choreography Module

In the case study, the dynamic choreography module manages the production and monitoring processes, coordinating services and the production process while overseeing the receipt of a customer order in light of a pull production strategy. The dynamic choreography consists of the production process utilizing the following services:

- Loading empty pallets
- Defining labels
- Moving pallets
- Reading labels
- Retrieving product information
- Loading the production schedule for machinery
- Loading empty pallets
- Controlling the final product

Each service collects quality metrics from sensors on the device through a monitoring process. Then, the choreography module registers subprocesses based on the results provided by the monitoring process (Machine 3 for separating parts or Machine 2 for delivery). It is designed with data from other proposed modules in this hybrid service and uses new services according to data flow logic and business needs.
Design is implemented in an environment with an extensive supply chain for quality control in production and a framework for intra-company collaboration in the patient analysis of this analysis. This research demonstrates the middleware between different business sectors. Additionally, the workshop facilitated the execution of directing and choreography.
The alignment of information systems in industrial companies provides good semantic interoperability among the implemented software components. In this study, the proposed service bus supported the lean strategy by avoiding waste concerning the company's information system, demonstrating that employing mashups leads to the reconstruction of data and service flows.

5. Evaluation of the proposed architecture

The concepts of the ISA-S95 ontology's metamodel classes include production planning, production capacity, product performance, production definition, and maintenance. This project discusses the construction of a product ontology through the ISA-S95 definition. It includes all resources in the various product production stages, dependencies between process parts, work definition representing operational stages, and product production rules.
The middleware module uses the terminology (ISA-S95), including its information and operational models, to publish information about product production, process definitions, and production results (Figure 8). A logical grouping of resources,

equipment, and materials created to begin production. The job definition also specifies the operational steps of production and controls the flow of resources and raw materials (Figure 9).

Job definition provided by the intelligent routing module. This management serves as an interface between production management and workshop management, defining resources that include capacity related to the resource job requirements for executing the production process (see Figure 10). The section response contains information connected to display data and the actual capacity of resources, crude materials, and the product section (about the fabrication of one or more products). Figure 11 describes resources using the ISA-S95 ontology. An ISA-S trigger using the lean manufacturing ontology (production cycle) will define the dynamic choreography module. By selecting a service trigger, the dynamic choreography sends messages to the various monitoring software used on the shop floor. Finally, the dynamic chronography module starts the observation process when a service runs.

The EO ontology is a rich ontology that includes a wide range of rules and regulations related to company descriptions. It also facilitates the exchange of information and knowledge among users, different systems, and tasks, providing an organization summary (Zkik et al., 2024). It includes several main sections on activities, specific processes, organization, strategy, and marketing. Marketing unites concepts related to sales and the market, where potential sales roles (such as salesperson, sales representative, current customers, potential customers, product features, minimum price, selling price, etc.) are displayed.

In the case study of this research, order quantities, for example:

Between 100 and 300 product packages can be offered to sales representatives for promotions at a 5% discount, quantities between 301 and 500 product packages at a 10% discount, etc.

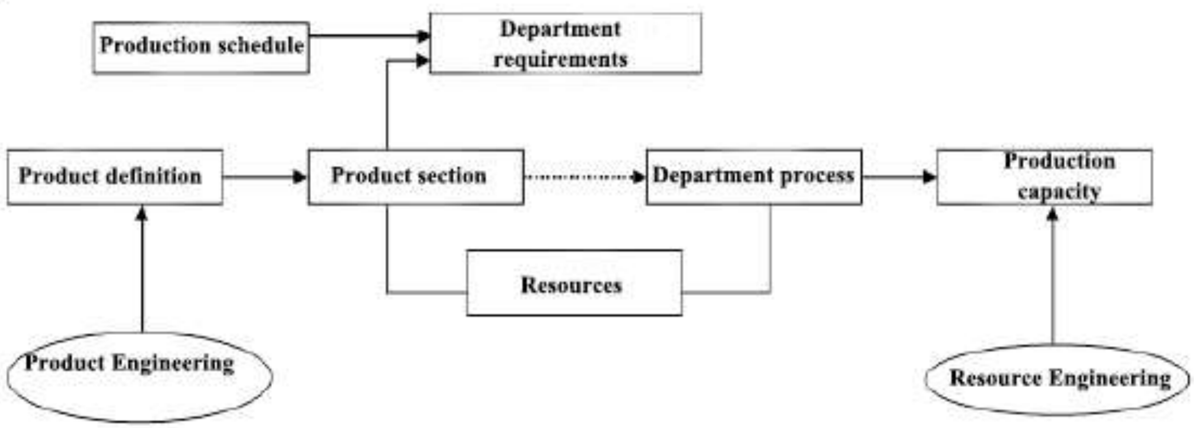

Fig (8). ISA and production cycles

Fig (9). Definition of work

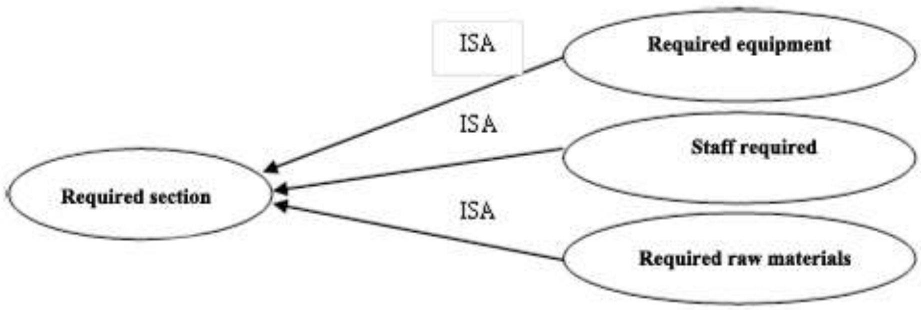

Fig (10). Description of requirements

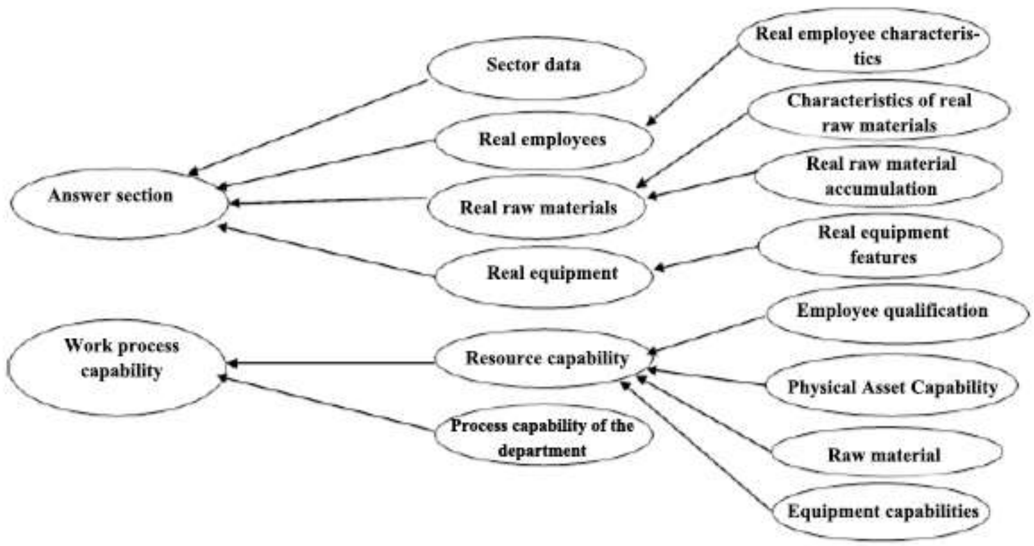

Fig (11). Definition of ontology resources based on ISA-S95

6- Conclusion and future work

A lean strategy suggests economic constraints on new organizational forms, including collaboration between large corporations and strategic companies. The strategy necessitates effective process management, careful resource assessment, and the removal of unused resources, all grounded in the customer-defined value framework**.** Organizing production according to the value chain necessitates the development of a logical flow in response to customer requests.

Custom product manufacturing within a very short time frame requires a strong and interoperable production tool. Therefore, information sharing is prioritized over physical flow to ensure the most cost-effective mode. Currently, the complexity of the company's information system and the multiplicity of independently designed software and systems do not align with the integrated perspective of lean production.

This paper presents an industrial service-oriented architecture and proposes a middleware to support industrial services and enterprise coordination across multiple business information systems. This middleware is developed by adding a semantic layer to the traditional industrial service bus. This layer is formed by integrating the company ontology with the standard ISA-S95 ontology, providing business-related aspects, including the semantic middleware module, dynamic choreography module, intelligent routing module, and monitoring and governance module.

Integrating various middleware components and the enterprise service bus in the current design has led to a comprehensive solution. However, further research is needed to explore the feasibility of integrating this with other existing tools to offer a practical solution.

The proposed design offers an ontology based on the standard ISA-S95 ontology, considering key concepts. The conceptual framework is reinforced with other ontological models to recommend maintaining and ensuring the overall quality of the company model. The referenced can significantly contribute to defining an autonomous intelligent industrial information system.

- Creating an autonomous component platform for industrial information systems: Industrial autonomous components are defined as intelligent services, which are lean enterprise service gateways that depend on the operations of each user entity. Intelligent services exchange information with external resources to determine how to utilize these resources and when to offer their services to others. Therefore, the definition of business rules, in addition to the ontology, can also give a behavior model for intelligent services.

- Integrating the opportunities offered by mobile applications to improve flow management: The development of the Internet has given rise to mobile technologies, which are a real challenge for industrial organizations, to the extent that this technology can help predict some of the results. Utilizing this technology in industrial service architecture involves creating each real and virtual space within a specific framework that enhances the integration of business-related information.

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