ISSN Online: 3006-4708
ISSN Print: 3006-4694

SOCIAL SCIENCE REVIEW ARCHIVES
https://policyjournalofms.com

A Review of Change from Industrial-Aged Systems to Information-Based Systems

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DOI: https://doi.org/10.70670/sra.v3i4.1253

Abstract
New industrial technology marked the commencement of the fourth industrial age. On the other hand, it is tough to update an industry's obsolete technical level. Retrofitting is a common method for incorporating new technology into older equipment in a timely and cost-effective manner. In recent years, academics and business leaders have embraced Industry 4.0, often known as the Fourth Industrial Revolution. Manufacturing processes, efficiency, data management, customer interactions, and market competitiveness are all components of Industry 4.0. This study seeks to build new manufacturing paradigms. The usage of data defines an industry 4.0 production typology. This research provides access to an ever-growing repository of knowledge about Industry 4.0. Research into Smart Factories has unearthed a plethora of unknown knowledge.

Keywords: Industry 4.0, Model-driven engineering, Modular components, Product life-cycle management, Production Framework.

Introduction
A handful of the world's most prominent industrial corporations have already begun testing cybernetic manufacturing. Since its inception in 2011, governments of industrialized nations throughout the world have shown substantial support for Industry 4.0 (Aoun and Alain 2021). Domestic products, automobiles, machinery, and equipment production of new cyber-production solutions need colossal expenditures; thus, upgrading a business will take decades (Zhang, C., & Shao 2020). Despite the fact that its patterns and ramifications may be seen in both macro and micro market sectors, the media and literature continue to shape public views of Industry 4.0. As a result of their strategic importance to so many market participants, anticipated technological developments have altered the competitive landscape and the manner in which firms meet consumer needs, impacting every link in their value chain and the method by which they are connected. In modern companies, consumer expectations and needs are always evolving (A. Sigov and L. Ratkin 2022). The Fourth Industrial Revolution (also known as Industry 4.0) is being adopted because globalization and rising labor costs have diminished the contribution of Western European nations to global industrial production (F. Yang and S. Gu 2021). German scientists have designed a new industry model to aid their country in regaining its position as an industrialization leader and halting the worrying trend of companies leaving Europe, which has led to a further decline in European industrialization. To be considered a member of "Industry 4.0," one must recognize that it entails

several technologies and mental adjustments. The Internet of Things, cloud manufacturing, intelligent factories, cyber-physical systems, and social product development are merely some of the components of Industry 4.0 (M. R. Kabir and S. Ray 2023) (X. Ye, S. H. Hong 2021). It helps to acquire goods in the same order as before. This project's development and implementation must be guided by a distinct set of goals (which may change). Numerous variables contribute to its ebb and flow. Customers and revenue will gain from this action (V. Sima and I. G. Gheorghe 2020). Modern firms must leverage digitally backed manufacturing technologies such as Big Data Analytics, Data Mining, and Information Communication Technology (ICT) systems that enable machine-to-machine and human system-to-machine communication in a virtual environment across the supply chain to compete on the global market (H. Tran-Dang and D.-S. Kim 2021). Industry 4.0 connects products, their environments, and their business partners via digital value chains. As a result of the convergence of Internet technologies and intelligent things, industrial production seems to have shifted dramatically (machines and goods). Modular and efficient manufacturing processes will be the norm in the future. The PLM (Product Life Cycle Management) chain employs intelligent mechatronic products to design new products, virtual documentation, print 3D models, laboratory tests, produce a product in a virtual production environment and testing, etc. (V. B. Jain and J. G. Satish 2023). By connecting a rising number of enterprises to society, technology has given us tremendous power over production and commodity management for the first time in human history. Utilizing cutting-edge IT across the board, Industry 4.0 enables the production of not just individual products but also whole value chains (X. Zhang and D. P. van Donk 2011). Thanks to contemporary information and communication technologies, it is feasible to alter production to meet client demands while maintaining cheap pricing, excellent quality, and high productivity (ICT). Because of artificial intelligence, additive manufacturing, and other technologies, traditional business processes and market structures are being disrupted at an unprecedented rate (M. Li, D. Yin, H. Qiu 2021) (M. Mandapuram and S. S. Gutlapalli 2020).

Industry 4.0 refers to the development of complex commercial networks interconnected by Internet-communicating intelligent resources, such as the Internet of Things (IoT), Big Data, and Cloud Computing (L. Georgios and S. Kerstin 2019). To thrive in today's market, organizations must develop Cyber Industry Networks (CINs) and collaborate with other businesses that deploy cyber-physical systems (S. Saniuk, A. Saniuk 2021). Thanks to improvements in ICT networks, a totally interconnected supply chain of suppliers, manufacturers, and consumers may now function in open virtual networks. To integrate all subsystems, production, and supply chain processes, as well as system resources, an ICT-based solution will be implemented. ICT integration will result in the creation of Cyber-Physical Systems (CPS), which are open social engineering systems (N. Tvenge and K. Martinsen 2018). In order for CPS systems to be successful, network-wide data collection, evaluation, and physical process modification are required. Industry 4.0 considers all enterprises to have an intelligent module that can be networked throughout the supply chain (L. D. Xu and E. L. Xu 2018). Firms are now more likely to thrive or fail based on their ability to recruit and retain top talent, as well as their willingness to adopt new technologies such as cloud computing, big data, and the Internet of Things. Industry 4.0 has gotten much too little attention and research despite its significance. Academics are beginning to acknowledge the necessity for greater research.

In this paper, we provide detailed knowledge about Industry 4.0 and its production typology. This study searches to shape new manufacturing models. The rest of the paper is organized as follows Section II gives a literature review related to this paper, Section III describes the proposed methodology, and Section IV presents the findings of the paper. Finally, Section V concludes the paper.

Literature Review

Under the corporate world, the fourth industrial revolution is now in progress. Because of these revolutions, industrial equipment has experienced significant changes. The first industrial revolution machines depended significantly on steam power. On assembly lines, electromechanical gadgets pushed the Second Industrial Revolution forward. During the third industrial revolution, machinery was automated and interconnected with computers (A. N. Matheri and M. Belaid 2023). In conclusion, the fourth industrial revolution will use Cyber-physical production systems (CPPS) and IoT networks to connect devices. The productivity of the industry has increased as a consequence of technical advances, especially automation technologies.

As a result of demographic trends, geopolitical unpredictability, and increasing product and process complexity, manufacturers confront significant obstacles today. CPPS is an ardent advocate of vital skills and certifications, as well as technological progress. Industrial equipment, both automated and non-automated, as well as the Internet of Things and cloud computing, all contribute to the optimization of production processes. CPPS may consist of a variety of essential technologies. The retrofitting of industrial equipment needs a combination of communication and technology. In the automated sector, several industrial networks are available, such as Profibus (L. A. Rodríguezand C. J. Vadillo 2019). The advent of Industrial 4.0 has increased the importance of communication in industrial processes. Consequently, it is crucial that all retrofitted industrial equipment has access to the integration of industrial networks and Industry 4.0. The Open Platform Communications - Unified Architecture (OPC-UA) standard is used by customers, developers, and the majority of manufacturers in the automation industry for secure and dependable data transfer (Aoun and Alain 2021). Communication that is independent of platform and vendor, data security, standardization, and decentralized intelligence are only a few of the industrial growth ideas that OPCUA promotes. Consequently, OPC-UA offers a message standard for industrial process control current interchange that is enabled by Industry 4.0 technologies such as the Internet of Things and the cloud.SDNs (Software-Defined Networks) are another crucial way of communication to be aware of (SDN). In this new computer network paradigm, network architecture and applications are separated from control and data planning. Silva et al (Silva and Luis 2019) assert that SDN networks may be used in Industry 4.0 due to their dynamism, flexibility, and capacity to distribute network resources. With these features, the retrofit ability of many networks may be increased.

A System of Information is Utilized to Examine the Product Development Process

In the product realization process, both product development and the manufacturing system are incorporated. This procedure continues throughout the product's lifetime. There are currently several procedures involved in the manufacturing of a final product, and these processes are not confined to the confines of a single company. Collaboration inside an organization is known as "Building an Extended Enterprise" (Ansari and S. Erol 2018). As demonstrated in Fig. 1, an Extended Enterprise must focus on c.f. since the competition requires shorter lead times, better performance, and higher Quality.

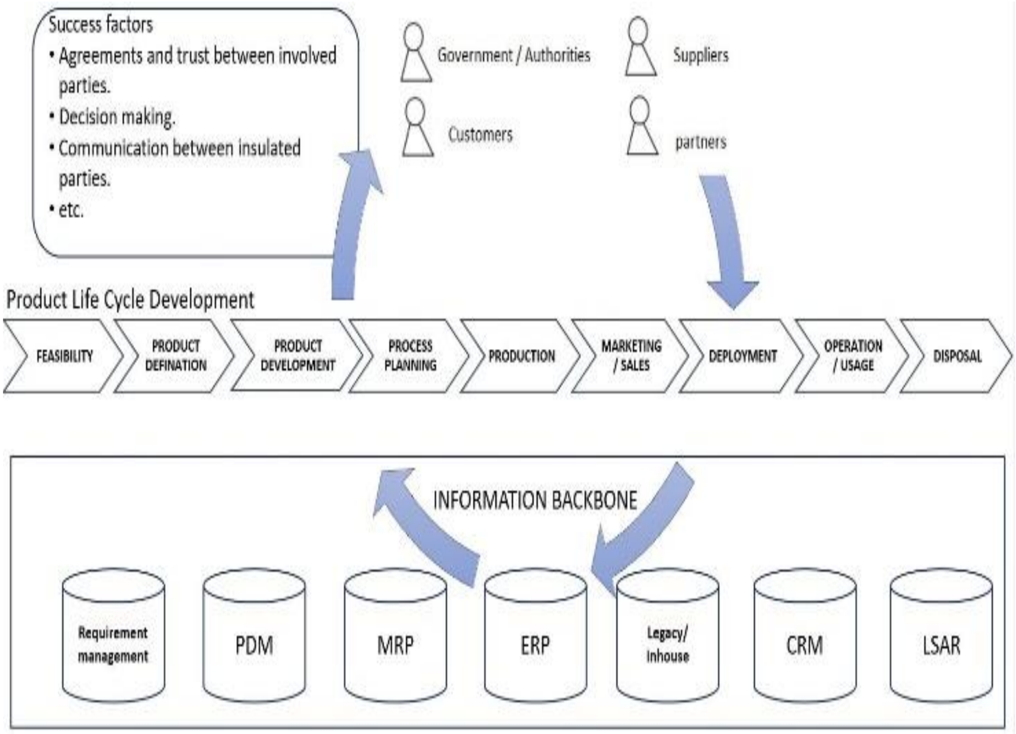

Figure 1: The industrial product realization process (E. B. Magrab, S. K. Gupta 2009)

Original equipment manufacturer (OEM) through the end user. The Virtual Enterprise surpasses the Extended Enterprise by establishing a dynamically adaptable organizational structure by integrating information, knowledge, and competence supply networks with logistical supply chains. When we say "supply chain," we're talking about a sequence of interrelated procedures that begin at the retailer and end with the manufacturer. A "value network" is included in the present strategy. All parties engaged in the product's life cycle must communicate in both directions. Long process chains do not prevent value network suppliers from doing business with whomever they choose.

In product data and information management writing, "Extended Enterprise" and "Virtual Enterprise" are often used interchangeably. It defines Extending Enterprise as a material supply network that is vertically integrated and operates across the product life cycle (V. Sima, I. G. Gheorghe 2020). A genuine virtual company, as shown in Fig. 2, combines material and data supply networks with human knowledge across the whole product manufacturing life cycle.

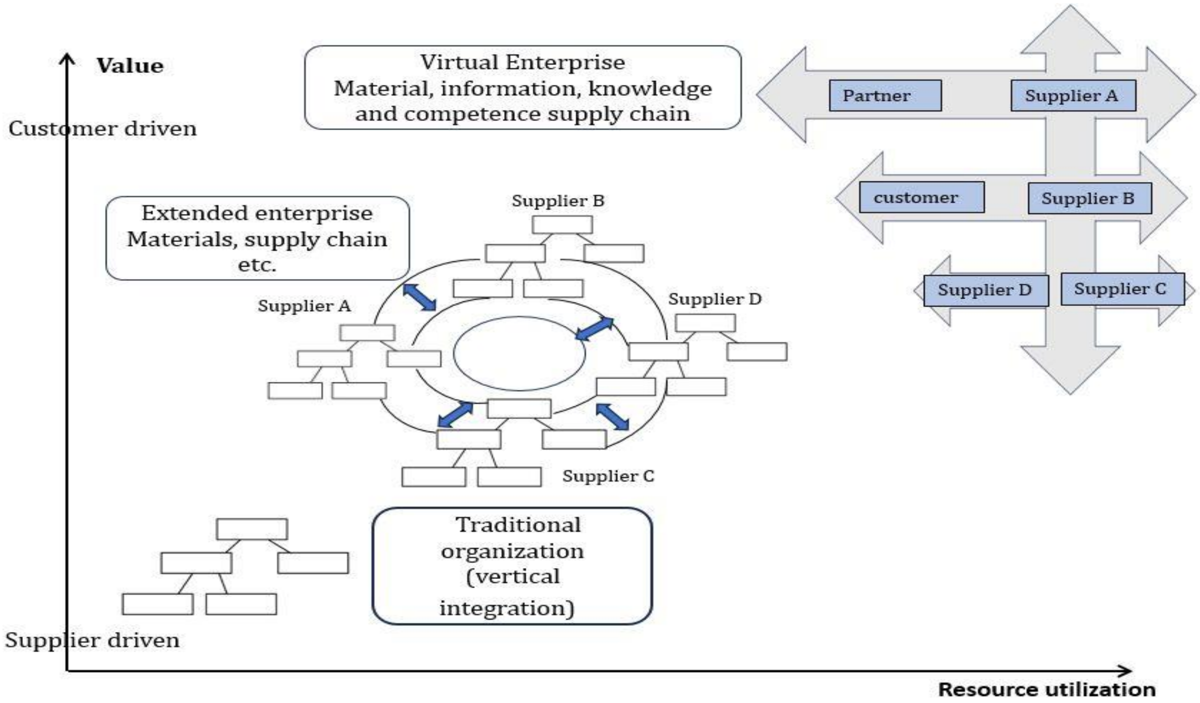

Figure 2: the development of supply chain organization

Effective and profitable supply chain management in Extended Enterprises and Virtual Enterprises depends significantly on information management (Campos and Jaime 2016). It is vital to have accurate and readily available product information across its full lifespan, as well as a set of business systems to coordinate resources, logistics, and operations, for a successful supply chain integration. EDI and other current electronic business technologies may also be used for supplier. The information supply chain requires information interchange capabilities that enable the collection of pertinent data. During the life cycle of a collaboration, information is generated and consumed in several ways, and each of these techniques has its own viewpoint and representation.

Material Requirement Planning and Enterprise Resource Planning

By automating departments such as finance and human resources, ERP software assists businesses with order processing and production scheduling. ERP (enterprise resource planning) systems integrate accounting, sales, production, human resources, and logistics. All enterprise resource planning (ERP) system internal apps may share a single database and set of analytical tools. The basic objective of an ERP system is to simplify and synchronize the flow of information across an organization's core business processes. The extensive and intricate scope of the ERP system installation involves the reengineering and modification of corporate business processes to satisfy the ERP system's needs. Material Requirement Planning (MRP I) software, which once emphasized production planning, has grown to include economic and administrative responsibilities as well as personal administration. Material management, delivery forecasts, and suitable lot sizes were incorporated in the first adoption of MRP in the 1970s. MRP I did not add aspects like as "capacity," "capital," or even well-known technological improvements and their associated costs. From Manufacturing Resource Planning (MRP) I through MRP II, several concepts have evolved, including "master scheduling," "rough cut capacity planning," "detailed capacity planning," and "shop floor management." The establishment of a feedback loop between actual production results and planning activities, allowing for process improvement, was crucial to the success of MRP II. Engineering firms that outsource production must use PDM systems while manufacturing firms must implement MRP systems. This indicates that ERP and PDM are fundamentally distinct in terms of functionality and viewpoint on the data being managed. The 30th count Important to note is that, unlike the Time-to-Customer view, the Time-to-Market view displays product configurations that may be utilized in the Time-to-Customer view. Product data management (PDM) is responsible for keeping track of all design-phase-generated information. At various stages over the product's lifespan, additional users reuse this information (Hasanah and Nur 2024). The data is constantly current due to ERP's function in monitoring and improving an organization's internal processes.

Product Life-Cycle Management (Plm) Systems

PDM vendors refer to their systems as "Product Life-cycle Management" (PLM) when they include capabilities such as early design phases and product person support. Steve Shoaf of IBM describes PLM as follows. PLM assists in design engineering, production planning, service, and maintenance, in addition to conceptual design. It connects smoothly with other processes, including component supplier management, supply chain management, and enterprise resource planning (ERP). Steve Shoaf's broad comment on PLM reveals that a system-oriented approach obscures the complexities of information management.

It is not feasible to characterize the objective of PLM by comparing it to existing system paradigms, since a manufacturing-focused company may integrate PDM capabilities into its ERP system. To effectively characterize PLM, we must differentiate between systems, business processes, and information management. A product lifecycle management (PLM) system is one that combines people, processes, systems, and information to facilitate the collaborative generation, management, distribution, and use of product definition information throughout the extended organization in real-time, according to CIM data. Fig. 4 shows the transformation from MRP to ERP.

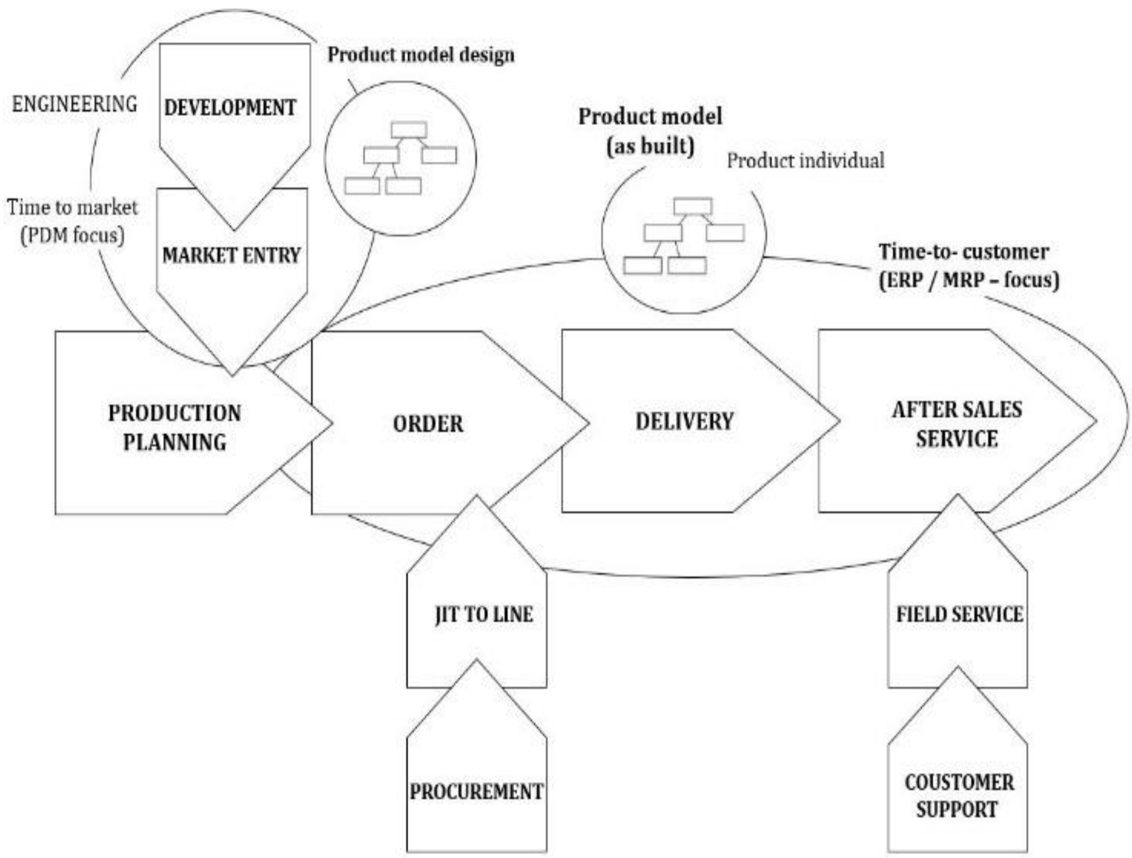

Figure 3: The transformation from MRP to ERP, as well as the overlap between PDM and ERP (Kroenke, D., & Leitheiser 2018)

Methodology

The concepts are founded on model-driven development, product data technology standards, software engineering standards, and component-based development. In contrast, engineering science research methodology employs a quantitative approach. Instead of merely analyzing and developing theories to explain the world as it currently exists, Gunnar Sohlenius proposes using an engineering science perspective to develop theories that propose what the real world could look like, thereby suggesting new ways to develop new digital information systems. In addition to generating new ideas, researchers utilize qualitative approaches to study the surrounding environment (Aoun, A.and Ilinca 2021). To conduct action research for the qualitative portion of the study, participating researchers modified real-world use cases and their environments. The following stages are utilized to organize and describe this research using an engineering scientific approach:

Analytical Approach

This approach is used to research the issue area and provide a list of problem statements and study needs. As its name implies, qualitative research methodology is a method that focuses only on analysis.

Imaginative Approach

In this stage, you synthesize a response to the difficulties you encountered during the process. In the language of science, this is a quantitative investigation. Although the theory presented here is grounded in natural sciences, it also seeks to advocate new practical approaches to the development of computer-based information systems.

Creative Approach

This procedure implements or materializes the developed solution. The outcomes section comprises components of the research that were conducted in line with the research.

Synthesize the Results

This approach aims to verify and confirm the results. This section gives the investigation's concluding results and a foundation for further study.

The process of establishing or modifying information models called information modeling (or process). Depending on its scope and discipline, an information model may be defined in a number of ways, but one frequent definition is that it is an abstraction of real-world concepts. In this study, information models are described as models (of information). In general, a model is a set of assumptions pertaining to the researched system. There are two types of statements: truthful statements and false statements (Campos and Jaime 2016). Therefore, any information models devoid of misleading expressions are considered valid. If all of its statements are true, the information model accurately depicts the analyzed system. As a system description, an information model may also be used (F. Ansari and S. Erol 2018). This indicates that a system is deemed valid if every assertion in the information model is true. In order to be effectively positioned, an information model must also possess a scope and a viewpoint.

The study focuses on two key applications of information models. As an implementation-independent domain-specific representation, Product Data Technology employs information models as one of its disciplines. In this work, the Product Data Technology viewpoint on information models is conceptualized. The third topic, the design and implementation of information systems, is anticipated to impact information models in the actual world. Unlike physical information models, conceptual information models do not rely on the storage and programming language bindings of

digital information systems. Contextual information model refers to the data representation, data storage, and retrieval mechanisms of a system. The Universe of Discourse contains information modeling concepts (UoD).
The tangible information model includes both the physical storage of the information base and the way users interact with the information system by updating the information base. In addition, a specification is a component of physical information modeling. Therefore, if the computer system in issue (or a component thereof) meets the standards, it will be deemed legal. To establish the validity of a conceptual information model, all statements about the system under investigation must be validated. For a computer-based information system to be legitimate in the Universe of Discourse, its implementation and materialization must be model-driven, since conceptual information models lead to a variety of real information models. As indicated in Table I, information models are a set of models that individually contribute to the understanding of real-world concepts and the design and comprehension of information systems.

Table 1: An Information Model Is Made Up Of Several Type of Models

Type	DESCRIPTION
Conceptual information model	The conceptual information model captures the Universe of Discourse, sets the scope, defines the information base, and sets the closed set.
Concrete information model	Concrete information models represent the design and implementation of an information system that stores and accesses the information base, ensuring efficient storage and access to the database.
Data model	It helps in the creation of a physical model that designates the layout of an information base, a logical data model describes semantic relations between entities, while a physical data model describes storage layout.
Activity model	An activity model is a crucial tool for understanding the function of an information system and its relationships in business processes. It structures activities, their information flows, input, output, controlling mechanisms, and resources required. Often designed before a conceptual information model, an activity model serves as a representation of which activities a conceptual information model supports.
Workflow model/process model	A workflow/process model outlines activities, relationships, and dyna a process, considering temporal aspects like start, termination, trigge guarding conditions.

Information Systems That Are Constructed Using Modular Components.
Component-based development was used in this dissertation to govern and regulate the growth of the digital information system. An engineering information system must be conceived with a modular approach in mind from a technical and functional perspective. In a modular design, it is feasible to separate the functionality given by components from the mechanism through which they provide it. In software architecture, the division of a system into modules is an essential concept. In

the computer industry, "Component Based Architecture," "Component Based Development," and "Component Based Software Engineering" allude to the modularity of this approach (CBSE).

The interface of a component may be built and consumed by other components employing contemporary technologies such as Microsoft COM, regardless of the programming language used to construct the component (F. Yang and S. Gu 2021). Modern technologies such as Microsoft COM enable the design and consumption of a component's interface regardless of the utilized programming language. It is not essential to recompile software systems that employ an updated or upgraded component (Kroenke and Leitheiser 2018). A component's interface describes the data structures and methods that may be used. Interfaces may be constructed using a number of approaches, including OMG IDL, Microsoft IDL(MIDL), and mechanisms incorporated within the programming language such as C++ for traditional programming libraries.

Models Are Used In the Development Of Digital Information Systems

Information modeling has been used to create computer programs for decades. To keep coding and design separate, information modeling has mostly been used to provide software system design layouts. When UML was introduced, the focus was on the design of software systems via information modeling and the execution of the established design models. Information modeling's function in software development has shifted from documentation of software system architecture to automated code generation, which is mostly utilized to produce stubs. Lastly, information models that may be utilized to run and simulate code while it is being built and compiled in another environment are being created. Fig. 4's source code was generated automatically as a result of optimization for certain compilers. This indicates that the design model cannot be connected to the generated code or any other created models. To codify forward engineering, one way is to use templates that explicitly define how a model may be altered when it is used to generate another model.

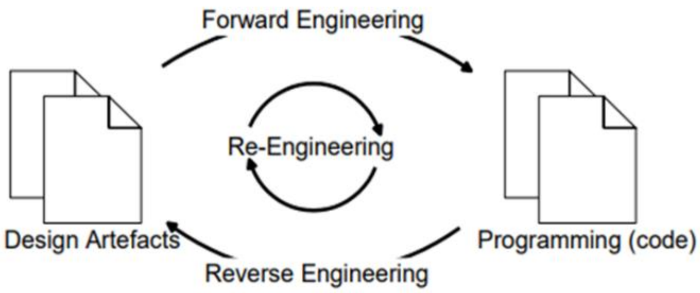

Figure 4: FORWARD, REVERSE AND REENGINEERING PROCESS

Important to a model-driven development paradigm is the ability to experiment with the model before implementing it in order to understand its behavior. This enables concurrent engineering, which has consequences for both disciplines. Model Driven Architecture (MDA) is dependent on the capacity to experiment with the information model; hence, an action semantic language has been designed to facilitate this. Table II represents model-driven concepts with its explanation.

Table 2: Model Driven Concept with its Explanation

Model driven concepts	EXPLANATION
Model execution	Simulations of information models can be achieved using Action semantic language in modelling environments. These simulations focus on the design of the software system, specifically the conceptual model. These models specify the static structure of information needed for capture and populated by the software system. By creating populations and instantiating the conceptual model, it can be analysed and compared to real-world objects.
Template mapping	Generating new models for abstraction layers requires specifying a mapping process that allows parameterization and customization of pockets. This allows for the creation of extensions of mapping profiles based on template reuse and can integrate into existing model-driven development frameworks.
Re-engineering	Model-driven development requires synchronization of information models in forward and reverse engineering cycles to avoid inconsistent environments in the model-driven development environment.
Reverse engineering	Generated information models can be updated for forward engineering by making changes to the model, ensuring accurate and reliable forward engineering.
Forward engineering	An information model can be used to generate another, such as transforming a conceptual information model into a concrete information model. Examples include static structures for database content, exchange file syntax, and object-oriented software applications like Java or C++.

Object orientation has been crucial to software development because it enables the incorporation of a conceptual information model into the design and development of a software system, hence facilitating model-driven development. Storage systems, data exchange techniques, and web-based clients using HTML and scripting technologies are all non-object-oriented software system components. Typically, non-object-oriented building blocks may be represented in an object-oriented information model using certain UML profiles; for instance, relational database layouts can be object-oriented.

Findings

Each of the selected papers provides a distinct contribution to the discipline. In hindsight, the research group is comprised of four major topics. Among the topics covered are integrated (standard) models, information sharing, and collaborative process sharing. Most engineering IT systems provide front-end (client) applications for CAD systems that define product requirements, such as geometry and component characterization. A back-end system is one of the most prevalent systems for storing and maintaining product description data (server). Throughout the development of these front-end and back-end systems, the IT architecture components are emphasized. CORBA (Common Object Request Broker Architecture), SOA (Service Oriented Architecture), and SaaS are examples of architecture.

A Standard-Based Integrated Design and Production Framework

To complete tasks more quickly, it is necessary to have more concurrent workers and a more effective data interchange. Shorter lead times and the requirement to interact efficiently and simultaneously with enterprises outside the company's boundaries make it more difficult to govern information flow in the extended business. In a heterogeneous environment (heterogeneous business processes, systems, and information), data may be consumed and manipulated independently of the system or process that originated it, even if current IT technologies and software systems are capable of distributed computing. These systems include product data management (PDM), factory simulation (CAR), computer-aided robotics (CAR), CAD, CAE, and MRP. When it comes to providing valuable data, each of these platforms takes a different approach. The ISO 10303 STEP standards are examined in depth for the objectives of this research. Fig. 6 represents the building layout.

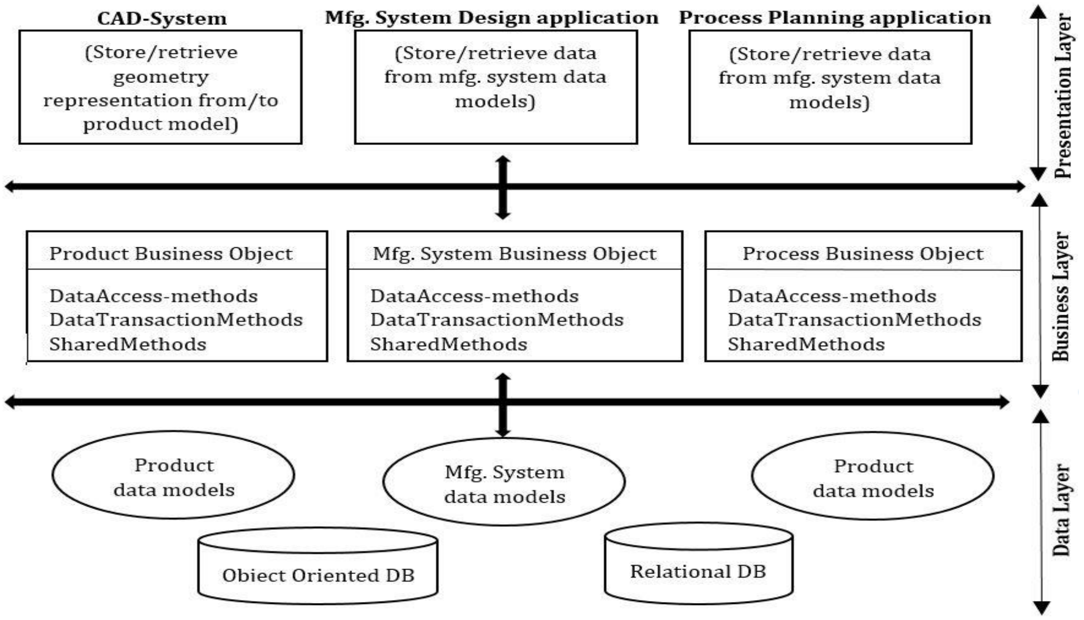

Figure 6: THE DIAGRAM OF BUILDING'S LAYOUT (V. Sima, I. G. Gheorghe 2020)

The MDM toolkit and Process Modeler's graphical user interfaces were developed using the ISO 10303-214 application protocol. The scope of the application is the design of production systems. In this phase of the research, graphical user interfaces provide functionality that interacts directly with the information concepts established in the standard. MDM and Process Modeler were used to investigate the duplication of a manufacturing process. The development of simulated processes using MDM toolbox data and process models as shown in fig. 6.

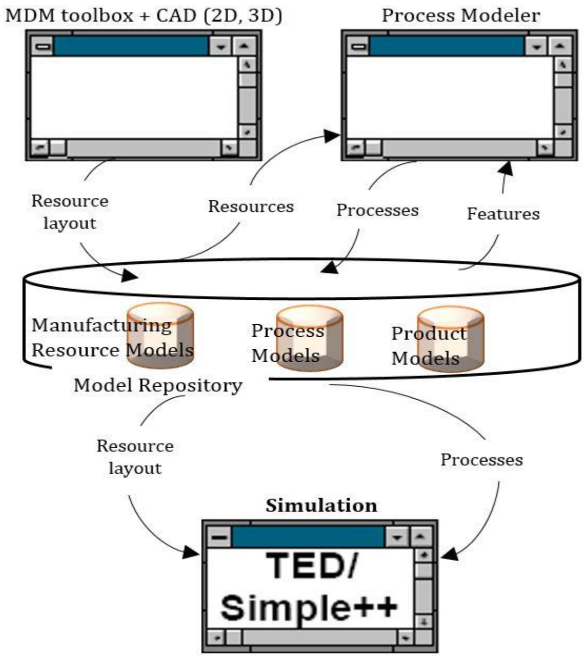

Figure 7:The MDM toolkit is used in combination with a process planning and simulation program

The logical flow of the collaborative engineering change management process is shown in Fig. 7 utilizing the VDA4965 ECM reference procedures in the Collaboration Hub architecture. Messages are recognized via the usage of the VDA4965 ECM reference process set. In contrast, the OMG PLM Services standard focuses on the content.

It is feasible to execute private processes inside a shared data repository while concurrently having access to relevant, referenced data. This option increases productivity by dictating when and how the private process connects with the common repository (V. Sima, I. G. Gheorghe 2020). Even if the private process is independent of other participants, it may decide to act independently on changes to the shared information repository.

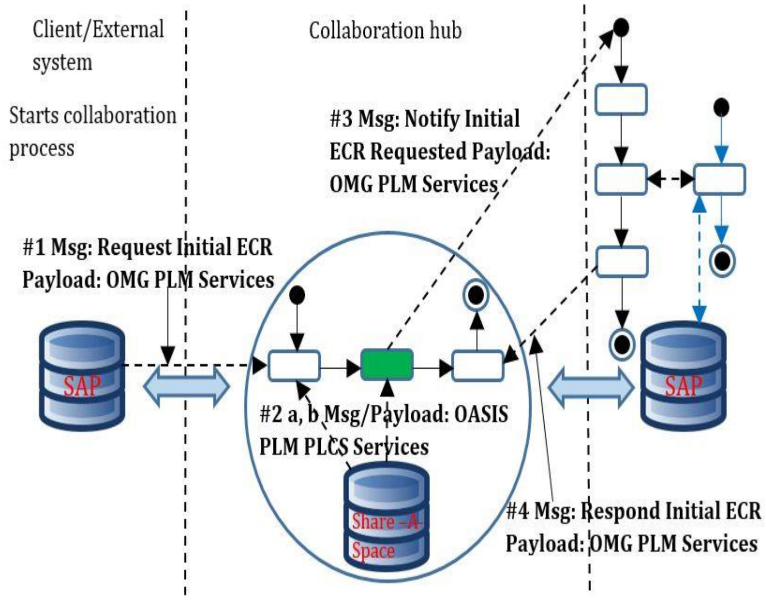

Figure 8: Architecture for Collaboration Hubs

References

Aoun, Alain, et al. "A review of Industry 4.0 characteristics and challenges, with potential improvements using blockchain technology." *Computers & Industrial Engineering* 162 (2021): 107746.

Zhang, C., & Shao, X. (2020). Research on intelligent analysis of port logistics information based on dynamic data mining. Journal of Coastal Research, 115(SI), 93–95

A. Sigov, L. Ratkin, L. A. Ivanov, and L. D. Xu, "Emerging enabling technologies for industry 4.0 and beyond," *Information Systems Frontiers,* pp. 1-11, 2022

F. Yang and S. Gu, "Industry 4.0, a revolution that requires technology and national strategies," *Complex & Intelligent Systems*, vol. 7, pp. 1311-1325, 2021

M. R. Kabir and S. Ray, "Virtual Prototyping for Modern Internet-of-Things Applications: A Survey," *IEEE Access*, vol. 11, pp. 31384-31398, 2023.

X. Ye, S. H. Hong, W. S. Song, Y. C. Kim, and X. Zhang, "An industry 4.0 asset administration shell-enabled digital solution for robot-based manufacturing systems," *Ieee Access*, vol. 9, pp. 154448-154459, 2021.

V. Sima, I. G. Gheorghe, J. Subić, and D. Nancu, "Influences of the industry 4.0 revolution on the human capital development and consumer behavior: A systematic review," *Sustainability*, vol. 12, no. 10, p. 4035, 2020.

H. Tran-Dang and D.-S. Kim, "The physical internet in the era of digital transformation: perspectives and open issues," *IEEE Access*, vol. 9, pp. 164613-164631, 2021.

V. B. Jain, J. G. Satish, V. Vinayak, N. Kulkarni, and B. Kotturshettar, "Enterprise resource planning solution for industry 4.0," in *AIP Conference Proceedings*, 2023, vol. 2548, no. 1: AIP Publishing.

X. Zhang, D. P. van Donk, and T. van Der Vaart, "Does ICT influence supply chain management and performance? A review of survey-based research," *International Journal of Operations & Production Management*, vol. 31, no. 11, pp. 1215-1247, 2011M. Li, D. Yin, H. Qiu, and B. Bai, "A systematic review of AI technology-based service encounters: Implications for hospitality and tourism operations," *International Journal of Hospitality Management,* vol. 95, p. 102930, 2021.

M. Mandapuram, S. S. Gutlapalli, M. Reddy, and A. Bodepudi, "Application of artificial intelligence (AI) technologies to accelerate market segmentation," Global Disclosure of Economics and Business, vol. 9, no. 2, pp. 141-150, 2020.

L. Georgios, S. Kerstin, and A. Theofylaktos, "Internet of things in the context of industry 4.0: An overview," 2019.

S. Saniuk, A. Saniuk, and D. Cagáňová, "Cyber Industry Networks as an environment of the Industry 4.0 implementation," *Wireless Networks,* vol. 27, pp. 1649-1655, 2021.

N. Tvenge and K. Martinsen, "Integration of digital learning in industry 4.0," *Procedia manufacturing,* vol. 23, pp. 261-266, 2018.

L. D. Xu, E. L. Xu, and L. Li, "Industry 4.0: state of the art and future trends," *International journal of production research,* vol. 56, no. 8, pp. 2941-2962, 2018.

A. N. Matheri, M. Belaid, C. Njenga, and J. C. Ngila, "Water and wastewater digital surveillance for monitoring and early detection of the COVID-19 hotspot: industry 4.0," International Journal of Environmental Science and Technology, vol. 20, no. 1, pp. 1095-1112, 2023.

L. A. Rodríguez, C. J. Vadillo, J. R. Gómez, and I. Torres, "Education+ Industry 4.0: Developing a web platform for the management and inference of information based on machine learning for a hydrogen production Biorefinery," in *Computational Collective Intelligence: 11th International Conference, ICCCI 2019, Hendaye, France, September 4–6, 2019, Proceedings, Part II 11*, 2019: Springer, pp. 603-613.

Silva, Luis, et al. "On the adequacy of SDN and TSN for Industry 4.0." *2019 IEEE 22nd International Symposium on Real-Time Distributed Computing (ISORC)*. IEEE, 2019.

F. Ansari, S. Erol, and W. Sihn, "Rethinking human-machine learning in industry 4.0: how does the paradigm shift treat the role of human learning?," *Procedia manufacturing,* vol. 23, pp. 117-122, 2018.

E. B. Magrab, S. K. Gupta, F. P. McCluskey, and P. Sandborn, Integrated product and process design and development: the product realization process. CRC Press, 2009.

Campos, Jaime. "Managing the information systems in the industrial domain." *Cogent Business & Management* 3.1 (2016): 1180967.

Hasanah, Nur, Dhanar Intan Surya Saputra, and Dewi LaeIa Hiiyatin. "ERP-based management information system for MSMEs in Indonesia: A systematic literature review." *RIGGS: Journal of Artificial Intelligence and Digital Business* 2.2 (2024): 36-42.

J. Sandberg, J. Holmström, and K. Lyytinen, "Digitization and phase transitions in platform organizing logics: Evidence from the process automation industry," Management Information Systems Quarterly, vol. 44, no. 1, pp. 129-153, 2020.

Kroenke, D., & Leitheiser, J. M. (2018). The evolution of information systems: From industrial age to the digital age (6th ed.). Cengage Learning. https://www.researchgate.net/publication/263849621_On_the_Evolution_of_Information_Systems

T. M. Choi, S. Kumar, X. Yue, and H. L. Chan, "Disruptive technologies and operations management in the Industry 4.0 era and beyond," *Production and Operations Management,* vol. 31, no. 1, pp. 9-31, 2022.

K. Bakon, T. Holczinger, Z. Süle, S. Jaskó, and J. Abonyi, "Scheduling under uncertainty for Industry 4.0 and 5.0," *IEEE Access,* vol. 10, pp. 74977-75017, 2022.

Xu, Xun, et al. "Industry 4.0 and Industry 5.0—Inception, conception and perception." *Journal of manufacturing systems* 61 (2021): 530-535.

Ahmad, Tanveer, et al. "Energetics Systems and artificial intelligence: Applications of industry 4.0." *Energy Reports* 8 (2022): 334-361.

Collins, L. M., and L. M. Smith. "Smart agri-systems for the pig industry." *animal* 16 (2022): 100518.

Golovianko, Mariia, et al. "Industry 4.0 vs. Industry 5.0: Co-existence, transition, or a hybrid." *Procedia Computer Science* 217 (2023): 102-113.