DIGITALIZATION OF SUPPLY CHAINS

Michał Adamczak, Aleksander Niemczyk,
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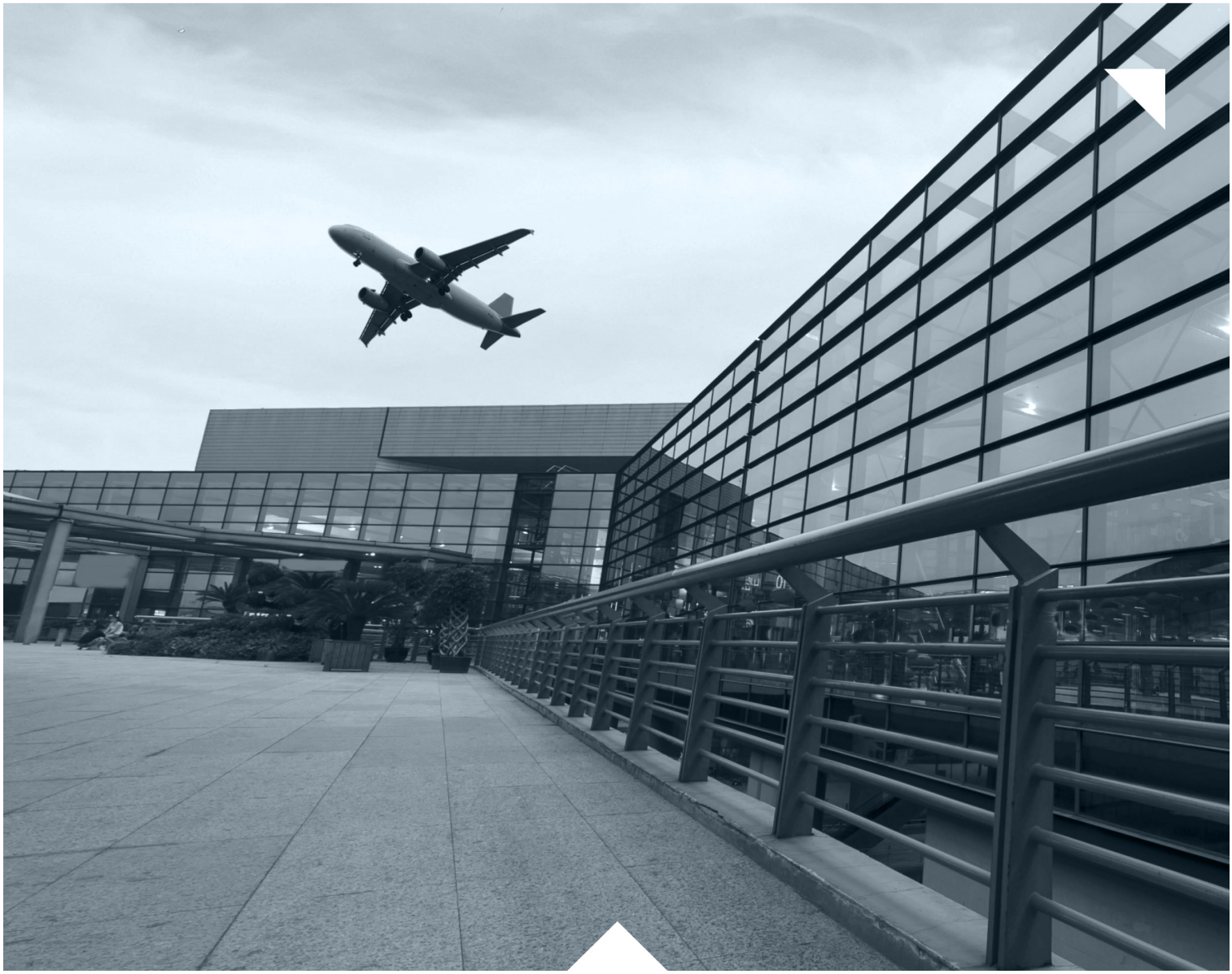

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CONTENT

Preface

The main topic of this monograph is the digitization of supply chains and the requirements places on the competence of logisticians. Digitization can now be called the strongest trend perceived in the development of supply chains. The rapid development of digitization is supported by factors that can be divided into two groups: technological and organizational. The technological factors include: the dynamic development of ICT, the availability of broadband internet (4G as well as the developing 5G network), cheaper electronic components (i.e. sensors). Organizational factors include first of all: accelerating the flow of information and access to it, but also reducing the number of mistakes, shortening process time, reducing control costs, and the ability to create new products and services.

In the monograph, the authors of individual chapters raise the most important issues in the field of digitization of supply chains. They present the implementation of elements of the Industry 4.0 concept in supply chains, the developing concept of Logistics 4.0 and how to determine the level of maturity of the implementation of these tools in enterprises. The monograph also presents the concept of Physical Internet aimed at a revolution in building transport networks and the Internet of Things that allows ongoing monitoring of processes.

Process management is a very important field for implementing digital solutions. The process approach as one of the current paradigms allows the wide application of modern solutions in order to constantly improve the processes implemented in the organization. This aspect is included in this monograph too. The authors draw attention to an important issue which is process awareness in organization. Process awareness is the beginning of implementing changes in the organization aimed at digitalization of processes. The combination of process approach and digitization of the supply chain is the text on the concept of communication integration for automated production processes regarding Logistics 4.0. Implementation of these issues would not be possible without tool support, in particular ERP systems and supporting tools such as spreadsheets and dedicated applications.

The summary of this part of the monograph is a chapter on technologies used in supply chains consist of international companies.

The competences of logistics industry employees are just as important as the digitization of supply chains itself. Digitizing supply chains would be meaningless without employees who

can analyze data, transform it into information, and make accurate business decisions based on this information. That is why it is necessary to shape new competence models of logistics specialists. These models must be adapted to the requirements of the changing supply chains of their environment and the technologies used in them. In the face of such rapidly changing technologies, shaping competences becomes a challenge. Training logisticians due to its interdisciplinarity is a long-term process. It is therefore necessary to shape competences that respond not only to current needs but for the future too. Thanks to this, it will be possible to prepare employees for effective work. The authors in this monograph present concepts of logistics competence in the conditions of a changing economic and technological environment. They pay particular attention to transversal competences and dual-mode education combining university studies with internships in logistics companies. The monograph also contains a text about the assessment of the level of maturity of competences and plans for their further development.

We encourage you to read and contact the authors of individual chapters. One of the goals of the monograph is to present the results of the authors' work, which will enable establishing cooperation, building new scientific teams and conducting research relevant to the development of the logistics field.

Special thanks to Piotr Cyplik and Szymon Strojny, reviewers of the monograph.

Michał Adamczak, Aleksander Niemczyk, Adam Koliński, Adrianna Toboła
Editors

I. SUPPLY CHAINS IN 4TH INDUSTRIAL REVOLUTION

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SUPPLY CHAIN IN INDUSTRY 4.0

ABSTRACT

Background: The changes taking place in enterprises under the influence of the Industry 4.0 concept place new requirements not only for enterprises but also for supply chains. We can assume that as time passes, more and more enterprises will undergo changes consisting in adapting their operation to the requirements of this concept. However, these changes will not occur at the same pace in all enterprises nor will they have a uniform character. Therefore, there will be a problem of cooperation in supply chains of enterprises with various levels of advancement in the implementation of the industry 4.0 concept.

Methods: The aim of this article is to identify and present possible ways to solve this problem. In the considered conditions, the importance of coordinating the activities of individual partners in the supply chains is growing. The effectiveness of coordination will depend on communication between partners.

Results: The article presents two possible scenarios of improving communication in supply chains. The first of these is to leave the problem of improving communication at the level of individual enterprises. Observing the current operations of supply chains, it can be concluded that two scenarios are possible within this scenario: creating common data sets and using agent technologies. The second possible scenario is the attempt to create a central communication mechanism at the level of the chain and in the field of communication between the chain and the environment. The analysis will examine the advantages and disadvantages of individual scenarios and current results as part of their implementation.

Keywords: Supply Chain, Industry 4.0, Communication in the Supply Chain

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INTRODUCTION

The formulating of the problem considered in this article, should be started by defining the terms used in its title. Definitions of supply chains appearing in the literature can be divided into two groups. A characteristic of the first of these is treating the supply chain as a process, i.e. a series of events in the movement of goods, which increase the value of the goods moved. The above-mentioned definition can be considered characteristic for such an approach [Fertsch 2016]. For the purposes of this article, the definition quoted above will be obligatory.

The second group of definitions focuses on the institutional aspects of the supply chain. It treats the supply chain as an organization. This approach will not be considered in this article.

A broad review and discussion of various definitions of the supply chain can be found in [Ciesielski and Długosz 2010] and [Witkowski 2010].

The concept of Industry 4.0 (fourth generation industry) is difficult to define According to the available sources, it can be assumed that Industry 4.0 is the name of a modern trend in automation, information exchange and manufacturing technology. It includes cybernetic - physical systems, the Internet of Things, information processing in the cloud and intelligent data processing (cognitive computing) Production in Industry 4.0 takes place in so-called "smart factories". In the modular structure of these factories, cybernetic and physical systems implement and monitor physical processes, create a virtual copy of them, and make decentralized decisions. These systems communicate via the Internet of Things and collaborate with each other and with people in real time.

The key concept in the above-cited definition is the cybernetic-physical system. It is defined as a mechanism (physical system) controlled or monitored by software communicating with it and between itself via the Internet. In cybernetic-physical systems, physical components and software are closely related. Each of these elements operate in different physical locations and at different times and interacts with each other in different ways that change with the context.

With regard to production systems in the conditions of industry 4.0, certain conditions (principles) of their functioning have been formulated.

They are:

- interoperability - the ability of machines, devices, sensors and people to connect and communicate via the Internet.

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- information transparency - the ability of information systems to create a virtual copy of reality and enrich the virtual copy of the factory with data from sensors. This requires aggregation of raw data from sensors to the level of information, full-fledged contextual data.
- technical support - first of all, the ability of IT systems to support people in collecting and visualizing information relevant to making decisions as quickly as the situation requires. Secondly, the ability of the production system to support and replace people in some jobs.
- decentralization of decisions - the ability of systems to make decisions about their own actions and carry out their tasks as autonomously as possible.

Changes that take place in enterprises under the influence of the Industry 4.0 concept set new requirements not only for enterprises but also for supply chains. We can assume that over time, more and more enterprises will undergo changes consisting in adapting their activities to the requirements of this concept. However, these changes will not occur at the same pace in all enterprises, nor will they be uniform. Therefore, there will be a problem of cooperation in supply chains of enterprises with various levels of advancement in implementing the concept of industry 4.0.

The purpose of this article is to identify and present possible ways to solve this problem. In the conditions under consideration, the importance of coordinating the activities of individual partners in supply chains is growing. The effectiveness of coordination will depend on communication between partners.

STRUCTURE OF THE SUPPLY CHAIN IN THE CONDITIONS OF INDUSTRY 4.0

The supply chain process is not a simple or homogeneous process. We can distinguish in it a number of partial processes (streams) that form it:
- stream of physical movement of goods (products) or services,
- information flow process controlling the movement of goods or services,
- commercial information flow process. This information is the basis for making decisions by enterprises or natural persons performing activities of physical movement of goods or services. This information is used by chain participants to calculate the profitability of their activities.
- promotional information flow process. This information is the basis for making decisions by customers - recipients of goods or services offered by the chain. Based on them, customers decide to purchase a specific good or service.

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- money flow process - making payments for delivered products or services.

Three out of five partial processes (streams) forming the supply chain are related to the flow of information. Nowadays, information systems are widely used to handle the flow of information. They are complex computer programs or sets of cooperating programs designed to perform specific functions. Two factors - the development of computing power of computers and emerging new management concepts have created different ways in which management support information systems perform their tasks. However, the operation of the two factors mentioned above did not lead to the formation of one standard of the IT system supporting management. The operation of IT systems used in practice is based on various concepts. The most advanced of them are ERP systems - Enterprise Resource Planning. When characterizing the current state of the concept (the ERP standard - the use of this name is not entirely correct, because the ERP system standard has never been officially adopted, but due to its dissemination, it actually plays the role of the current standard of the IT management support system) its following features should be emphasized [Ginters 2002]:

- its origins date back to the '70s of the last century,
- a well-known and described standard, verified many times,
- has a number of drawbacks (most often 15-20 defects of the ERP standard are mentioned in the literature),
- difficult to implement - requires adaptation of the company's operation to the principles of software operation,
- very effective, primarily in the sphere of accelerating capital rotation and reducing inventories.

The problem considered in this article is an attempt to create a architecture model of the supply chain information system in the conditions of Industry 4.0.

ELEMENTS OF THE SUPPLY CHAIN IN THE CONDITIONS OF INDUSTRY 4.0

The elements forming the supply chain in the conditions of industry 4.0 can be divided into four groups (layers):

- physical layer - it is made up of production and auxiliary machines and devices that implement and support physical processes - production processes. The term "support" used above should be understood in a narrow sense - as the implementation of physical processes ensuring continuity and proper course of the basic process, which is the change of work objects

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(materials) in terms of shape, size, appearance, physical or chemical composition or properties. Other processes are so-called auxiliary and service processes - transport and storage in the production process, production quality control, replacement of tools and workshop aids, maintaining cleanliness in the production process.

- IT layer - devices (computers) and software controlling elements of the physical layer and creating a virtual copy of physical reality and supporting people in collecting and visualizing information relevant for making decisions. The task of this layer is also to make some decisions in accordance with the principle of decentralization.
- social layer - people working in the production system, cooperating with its various layers.
- communication layer - Internet ensuring information flow between individual layers and their elements.

After characterizing the individual layers of the supply chain under the conditions of Industry 4.0, let's deal with the general principles of their functioning.

The physical layer will consist of cybernetic and physical systems. Their operation, according to the views prevailing in the literature on the subject, will be based on embedded system technology [Noergaard 2005]. These are special purpose computer systems that are an integral part of the equipment they support. Each embedded system is based on a microprocessor (or microcontroller) programmed to perform a limited number of tasks or even only to one [Lee and all 2011].

The IT layer according to the literature will cover five levels [Lee and all 2014]

- the level of data collection devices - It consists of data collection devices - sensors (sensors) installed on machines and devices whose task is to capture signals from the surrounding environment, recognize and register them and the network amplifying the signals and sending them over long distances, to subject them to further processing using digital techniques and computers as well as remembering it.
- level transforming data into information - this level consists of a set of programs collecting and processing data collected by the layer of data collecting devices. These programs can be placed on one central computer, on several computers or in a "cloud". The tasks of this level are:
- diagnosing the condition of machines, devices and work environment,

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- prediction of machinery and equipment failures and environmental hazards and their potential impact on system operation,
- analysis of collected data in terms of searching for their temporal, spatial and causal relationships for the needs of system and environmental diagnostics.

Some tasks at this level can also be implemented by embedded systems, which are elements of the physical layer. The division of tasks in the field of transforming data into information between the elements of the physical and IT layers is not clearly defined. It is difficult to indicate the criteria for this division. It seems that the main criterion should be to maximize the reliability of the entire system.

- information analyzing level - consists of a set of programs collecting and processing information collected by the layer transforming data into information. The tasks of this level are:
- modeling the behavior of machines, devices, changes in the availability of resources over time,
- analysis of distributions (statistics) of events, activities, system states over time to forecast their frequency and duration,
- grouping of collected information in terms of their similarity for the purposes of analysis using techniques for analyzing large sets of information.

- the level recognizing (diagnosing) the operation of the system - consists of a set of programs collecting and processing information collected by the information analyzing layer. It also organizes communication in the system by controlling the flow of data and information between individual layers. The tasks of this level are:
- preparation of information and data visualization for the needs of computer-human communication,
- simulation and integration of information to forecast resource demand,
- organization of cooperation in the scope of joint (human-human and computer-human arrangement) situation assessment and joint decision-making.

Analyzing the tasks of the level analyzing (diagnosing) the system's operation, we encounter a very interesting issue. It's a decision making problem. One may wonder whether the decisions will be permanently assigned to specific decision-makers (regardless of whether it is a human or a computer) or whether the obligation to make decisions will be dynamically allocated depending on the analysis of the situation.

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- the level configuring (organizing, planning) the operation of the system - consists of a set of programs that process information collected by the level analyzing the operation of the system. He also works with people at the highest level of system management. The tasks of this level are:

- planning the system's operation under normal operating conditions as well as in conditions of system interference and changes in the system environment,
- proposing changes in the operation of the system adapting it to changes in the environment,
- anticipating changes in the structure and operation of the system that improve the flexibility of its operation.

RELATIONSHIPS BETWEEN ELEMENTS OF THE SUPPLY CHAIN IN THE CONDITIONS OF INDUSTRY 4.0

In the supply chain operating in the conditions of Industry 4.0, direct production machines and devices and production employees creating cybernetic-physical systems can be located in various manufacturing facilities (manufacturing facility) and be assigned to perform specific tasks on an ongoing basis. In this situation, the production plant, which in the traditional approach is a system of resources intentionally accumulated on a common area for the production of a specific assortment, becomes the sum of cybernetic and physical systems located in many locations that perform selected operations in physical processes in the basic process, which is the change of work objects (materials) in shape, size, appearance, physical or chemical composition or properties. It must be supplemented with a set of purposely selected auxiliary machines and devices (which are also cybernetic and physical systems), implementing auxiliary and service processes - transport and storage in the production process, production quality control, replacement of tools and workshop aids, maintaining cleanliness in the production process.

The issue of the criterion for selecting elements of this set becomes a crucial issue. They can have the nature of a technological criterion - in apparatus processes, where the basic requirement is to maintain the continuity of the process or a specific phase thereof, continuous processes and the machines and devices operating them as well as employees will be gathered in one production location. Since production processes are usually determined by production volume in continuous processes, these will be large production plants. In this case, the

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cybernetic and physical systems making up the production system will not always be created on the basis of a single machine or device. An intermediate level may appear for installations implementing a certain phase of technology (e.g. fuel supply phase in a conventional power plant). In the conditions of continuous production processes, it may also be that the most economical solution will be creating a cybernetic-physical system at the level of the entire manufacturing facility (manufacturing facility). Other criteria for structuring the physical layer under continuous production processes may be the reliability or operational safety of the entire production facility.

Under discrete production processes (job shop production, batch production, cellular production), the main criterion for configuring the supply chain will certainly remain the minimization of production costs. The supply chain will be the sum of cybernetic and physical systems located in different locations that perform selected operations in physical processes in the basic process. It must be supplemented with a set of purposely selected auxiliary machines and devices (which are also cybernetic and physical systems) that implement auxiliary and service processes.

In the case of a supply chain built from cybernetic and physical systems, the effectiveness of its operation will depend on the degree of centralization of system organization.

- Under strictly centralized systems, where all decisions will be concentrated in one place of the system, transformation of the logistics system into a cybernetic-physical system will not introduce significant changes in its operation.

- Under mixed-system systems, in which the decision-making powers will be dispersed at various places in the supply chain and its subsystems, a difficult to diagnose situation will arise where the extent of the cybernetic-physical system's interference in the operation of the supply chain and impact on the effectiveness of its operation as a whole and its subsystems will be hard to predict at the design stage.

- In the conditions of fully decentralized chains, consisting of cooperating independent cybernetic-physical systems with their indefinite or unclear hierarchy, it seems likely to expand the structure of the supply chain information layer by an additional level - the level of optimization.

This level will consist of a set of programs that process information collected by the configuration layers (organizing, planning) the operation of individual independent elements.

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Operation of this level, as has been shown earlier, cannot be based on the ERP model because this model does not provide optimal solutions.

The tasks of this level will be optimal planning of the entire supply chain:

- optimal planning of the operation of each independent element in terms of restrictions resulting from the optimal operation of the whole,
- proposing changes in the structure and operation of the supply chain in advance that will improve its flexibility
- programming changes in the operation of the supply chain as a whole.

OPTIMIZATION LEVEL OPERATION

The basic element of the level under consideration in accordance with [Dagli 1994] will be a world model containing the knowledge about the environment in which the supply chain operates. The concept of such a model is presented below:

parameters:

Rj - demand in j- period [value]

Co- initial price [value]

Mij - investment in marketing of i - supply chain in j - period [value]

R & Dij - R&D investment of i - supply chain in j - period [value]

Qij - investment in quality of i - supply chain in j – period [value]

Rij - value of resources of i - supply chain in j - period [value]

Cj - medium price in j - period,

IDCj - indicator of price dinamics in j - period,

Kj - indicator of economic situation in j - period,

RDj - indicator of technology development in j - period,

Sij - sales of i - supply chain in j – period [value]

Cij - price for unit of sales of i - supply chain in j - period [value]

RWij - "value" of i - supply chain in j - period [value]

Uij - share in market of i - supply chain in j - period [value].

equations:

$R11 = \sum Si1\ C0$ [1]

$R1j = \sum Sij\text{-}1\ Csj\text{-}1\ IDCj\text{-}1$ [2]

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$$Csj = \sum Cij / n \quad j = 1, ..., n \qquad [3]$$

$$RWij = \sum Rij \qquad [4]$$

$$IDCj = Csj / Csj\text{-}1, \; IDC1 = Cs1 / C0 \qquad [5]$$

$$Rj = R1j \; Kj \; RDj \; [1+ f \; (Mj + R \; \& \; Dj + Qj)] \qquad [6]$$

$$Uij = Rj \times f \; (Mj + R \; \& \; Dj + Qj + RWij + Uij\text{-}1) \qquad [7]$$

$$Sij = Uij / Cij \qquad [8]$$

SUMMARY

The article presents the current progress of work on creating a model architecture of the supply chain information system in the conditions of Industry 4.0. The next steps will be software and testing of the world model as well as developing the concept of an IT system for communicating the optimization level with the remaining levels of the information layer. The final result will be the development of procedures for the optimization level in the supply chain information system architecture.

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