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Digital Transformation of the Supply Chain Network

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ABSTRACT
The article analyzes the implementation of digital technologies in supply chain management systems. The principles and tasks for digitization of supply chains are described. The digital technologies and their implementation, used for the improvement of efficiency in supply chain management, are described. An approach is proposed used to perform digital transformation in supply chains for various logistics processes and systems. The required conditions for digitalization of logistics processes are formulated. Positive and negative issues during the introduction of digital technologies in logistics processes are covered. Examples of digital logistics systems, tested in practice, are given.
Keywords: *information system; supply chains; digital logistics; blockchain; digital technologies; digital transformation; digitalization problems*

1. INTRODUCTION

Despite all the efforts that companies are making to improve efficiency in supply chain management, relatively few have unlocked the full potential of digital technology. Most of the technologies, implemented by companies at the burst of digital innovation have made it possible to simplify routine activities, extend functions of specific systems, automate certain processes and improve analytical methods. While these technologies are valuable and have resulted in efficiency enhancement, they do not perform the complex functions that are transforming supply chain management. It took some time for technological innovation to evolve and combine in new approaches. Now that new digital solutions are available, companies can considerably improve supply chain performance.

Information technology of the 20th century is now well studied, resulting in the transition to a new era of digital logistics. Digital technologies not only accompany and facilitate material processes, but change the use of human resources, and, as a consequence, restructuring of their material, financial and information flows, described in "Digital logistics" by Afanasenko I.D., Borisova V.V. [8].

The digital environment has its own infrastructure. At this, the information and telecommunications facilities enhance, unmanned vehicles with 100% robotic control appear.

Also, the Internet is entering a new era of rapid increase in speed, costs are cut down due to logistic synchronization and timely exchange of information between service providers and trading partners [9,1].

2. METHODOLOGY OF THE STUDY

In supply chain management, large volumes of information shall be stored and analyzed. Considering that the amount of information is constantly growing, modern tools for data analysis and processing become a must. These tools include various information systems that automate accounting, planning and control processes, taking optimal decisions, etc. [11]

Supply Chain Management (SCM) is a concept , providing an integrated approach to the management and planning of information flows of business entities regarding products, raw materials, materials and services. In logistics processes, aimed at satisfaction of end users, information is generated and transformed. At the same time, the company has to get the maximum possible profit from its activities. This approach has been developed over time and has been applied in supply chain management. The supply chain is a collection of warehouses, forwarders, manufacturers, distributors, trade enterprises, cooperating and interacting in material, financial and information flows, as well as flows of services from sources of raw materials to the end consumer. The supply chain is a set of material processes and corresponding information flows between the chain participants. [11]

For many companies, SCM is a key concept in business process management. First of all, such companies include large-scale networks of divisions and branches with material flows between them, as well as the exchange of related information flows.. These companies include logistics service providers, large industrial enterprises, trade and distribution networks, and transport companies. The above-mentioned companies can be combined into a single system or a common supply chain. At the same time, common business principles of these companies will result in even greater efficiency of the common supply chain management [13].

Supply chain management is the planning and management of all activities (within the supply chain), including sourcing and purchasing management, product transformation (processing), and management of all types of logistics activities.

It is recommended to form the network structure of the supply chain based on the following parameters:

1) Network boundaries and structural dimensions;
2) Supply chain participants;
3) Types of interaction between supply chain participants.

Thus, the supply chain network structure is a combination of three closely interacting elements. The construction of the supply chain network structure includes identifying supply chain participants and business processes for their interaction, their integration level, their position in relation to the focus company, as well as network structural dimensions and its boundaries.

At the same time, solving the problem of configuration selection and construction of the logistics network structure is a fundamental direction for supply chains optimization, described in A.G. Samoilova's work. [15]

The authors' studies have demonstrated that the model of the supply chains network structure shall be constructed based on optimization principles of the following parameters:

- Deviation in volume and time of the actual execution of the order from the planned one;
- Amount of stock;
- The human factor impact on processes in supply chains.

Modern data storage and processing technologies are entering the supply chain management software arena as more companies take advantage of the benefits they offer over traditional data storage and processing methods. The term "cloud computing" refers to general software and information access, provided to users over the Internet. Instead of information storage on their physical servers or computer hard drives, users rely on servers, serviced by cloud software providers. From the user's point of view, all information is stored and easily accessed online in a 24/7 format and from various types of devices such as desktops, laptops, tablets, and smartphones. Instead of using their own physical servers or hard drives to store software and information, more and more logistics professionals get to these software services, hosted and available online.

Real-time data processing technologies make planning and management more flexible and precise. With the introduction of modern systems, artificial intelligence can replace investments. For example, a computer system that can provide efficient scheduling of inventory requirements will reduce the need to take inventory of reserve resources. Available and flexible computing means provides supply chain participants to simulate possible problems and solve them in the future. [10,8]

The implementation of digital technologies in logistics systems are analyzed by many scientists. This problem was studied in their works by Afanasenko D.A., Basansky M.V., Borisova V.V., Gorsky D.V., Krasnoperova M.V., Kokurin D.I., Kupriyanovskaya Yu.V., Kupriyanovskiy V P., Larin O. N., Lysenko M.V., Lysenko Yu.V., Matveev V.V., Nemanova A.N., Rozhko O.N., Sergeev V.I., etc.

Gorsky D.V. in his work "Conceptual fundamentals of supply chain management in e-commerce" indicates the relevance and need for the development of information systems in supply chain management, as it is a resource for reduction of logistics costs for goods distribution, provided by e-commerce without the attraction of commercial intermediaries and personnel in their traditional form. The introduction of information technology brings control in supply chains to a new level, generates relevant data for operational decisions, it becomes possible to optimize production based on monitoring demand information [14].

Basansky M. V. in the article [16] notes the need for the introduction of modern information systems for procurement at enterprises. He remarks that procurement standardization and centralization at the enterprise provide new opportunities for management in logistics and supply chains, but at the same time much information that needs to be processed quickly, is impossible without information systems.

Krasnoperova M.V., Matveev V.V. in the study "Analysis of modern trends in the development of logistics infrastructure ..." express the opinion that for the buyer, as the product end user, the trend of Internet introduction into logistics allows transparent transportation process. Firstly, the buyer will be able to trace the product starting point - whether the product is counterfeit or fake. Secondly, when the logistics company installs temperature change sensors, the recipient can check whether product transportation conditions have been violated. For example, for transportation of iron ore concentrate, freezing during winter transportation and leaving a part of the cargo on the railway carriage sides, information about delivery temperature and method can become essential for decision taking in a logistics company. [17]

Also, during introduction of digital technologies, qualifications of specialists, involved in the management of modern information systems, is of paramount importance. Levkin G.G., Nikiforov O.A. in "Information support of the company's logistics system processes" note that the qualification level of its employees, operating modern information systems, is important. One of the main conditions for effective operations at the enterprise is availability of highly qualified specialists, therefore, along with material flows, labor flows are included in logistics system [18].

Improvement of supply chain efficiency is not just the purchase and installation of a new information system, hardware, or software

. As supply chain management is a complex management concept, most measures to improve efficiency in supply chains shall include changes in the way people exchange information between specialists and contractors, consider problems and opportunities, make effective decisions and take necessary actions.

An integrated approach and development of a unified information environment in transport digitalization are described in the study by Bubnova G.V., Levin B.A.: "Digital transport, as an infrastructure basis, is designed to ensure the development of a unified IT environment for interconnected systems, complexes, and technologies to provide traffic and manage a single technological process, integrating all transport types and participants at transportation market." [3]

In the study "Development of a single information space for digital logistics using databases of intelligent transport systems" Rozhko O. N. describes digital technologies for

managing information flows in logistics, noting that traditionally information flow management in logistics is performed by various integrated hardware and software systems known as digital management systems. The modern digital management toolkit for a single information space is formed on the basis of:

– Storage Area Network (SAN) architecture concepts to exchange data, supported by client file systems, attached to storage servers;

– Cloud Computing cloud technologies, providing clients with secure servers for information storage and processing;

– Block Chain technologies with data storage distributed on users' devices, the chain is available to all SCM participants and protected by cryptographic mechanisms, the complete history of data changes is stored. [19]

SAN is a dedicated high-speed network, providing block-level data access for storage. SAN networks are typically made up of interconnected hosts, switches, storage elements, and storage devices using various technologies, topologies and protocols. SAN represents storage devices to the host so that the storage appears to be locally attached. This simplified storage representation to the host is achieved using various virtualization types.[23].

3. RESULTS OF THE STUDY

The study of modern methods for digital logistics modeling makes it possible to assume that it is recommended not only to introduce information automation of logistics processes, but generate a new digital process, being a new model, the most automated and robotic infrastructure to manage the actions of technology and people, set tasks and control their implementation and results. Also, according to the authors, during the digitalization of logistics processes, the main task shall be performed - to reduce logistics costs and resulting decrease in the cost of goods for the end consumer. Therefore, when digital methods are introduced, it is important not to perform meaningless automation of everything in a row, where the resources spent on automation exceed the economic benefit of their implementation. There are also security problems, discussed by Natalya Kasperskaya at the digital technologies forum - each modern technology has a remote control, creating the risk of a one-time restriction for users of this technology [12]. It is important to consider personal information security, as storage and analysis of personal data of people are involved.

The right approach to digitizing supply chains shall integrate advanced technology with updating or replacing current processes. The authors believe that the following approach to transformation can be taken as a basis:

Modeling of supply chain network structure

Assessment of the supply chain current state

Transformation algorithm development.

To model supply chains, it is recommended to use simulation methods, to construct a model, corresponding to the real world, accurately reflecting the environment and current processes in supply chains. [7]

The assessment shall consider whether operations and technologies are sufficiently integrated, and whether the company has an innovative strategy and organizational structure that promotes innovation and continuous improvement.

The transformation algorithm shall have a specific time frame, account for feasible and possible introduction of digital technologies.

The work "Digital transformation of procurement logistics" recommends the following technologies for implementation: cognitive computing and artificial intelligence, intelligent content extraction, predictive and in-depth analytics, visualization, joint portals, crowdsourcing, 3D printing, robotization, blockchain, sensing devices, cyber tracking, virtual reality and three-dimensional spatial analytics. [2]

Certainly, blockchain technology is effective for introducing into logistics system processes, as noted by the authors [4], [5], [6].

The distinguishing feature of digital technology is that it can integrate better collaboration practices into company processes and prevent the company from going back to its old, less efficient operation methods.

Once the supply chain model has been constructed at the first stage, it is necessary to check whether it reflects the following processes, important for digitization:

– Operational decision making. The introduction of artificial intelligence concept can provide guidance to supply chain participants on action algorithms.

– End-to-end interaction between chain participants. Digital technologies can improve the quality of customer service by providing supply chain participants with real-time control of processes and transparency to customers.

– Automation of operations. Implementation of automated operations frees up time for specialists to concentrate on more important tasks.

– Innovations. A digital supply chain can ensure a company with unique competitive advantages, strengthen its business model, and expand into new market segments.

To plan for the second phase of transformation, a comprehensive assessment of business and technical capabilities, it is recommended to put the following questions to identify gaps and capabilities in five cross categories:

– Data. Is all the data for our purpose collected and generated? Is this information stored, how easy is it to access?

– Analytics. Are there analytic capabilities to extract useful information from a dataset?

– Software and hardware. Do software and hardware systems support the analytics and technology capabilities required by the company requires?

– Innovations. Are digital experts involved? Do our culture and organizational model promote experimentation, innovation, and continuous improvement?

– Processes. Are all processes clear and well defined for every supply chain participant? [1]

The last planning step is to develop an action plan and activities for a certain period of time, probably, for several

years in advance. It is necessary to identify operational improvements and evaluate the results of new technologies introduction based on the existing resources of the company to develop new capabilities, described in its strategy. It is important to identify the problems underlying the decline in current performance.

The authors also propose, taking into account the sequence of processes in the supply chain network model and directed from link to link of material and information flows, to represent this model in the form of a directed graph.

According to the authors, existing Ford-Bellman and Dijkstra algorithms for problem solution on directed graphs, digital implementations of these algorithms, make it possible to construct an information system based on an economic and mathematical model, open the way for solving specific applied problems. To solve optimization problems for modeling, using a directed graph, the authors propose to use the following mathematical tool.

A graph is a set of a non-empty set of vertices and edges (sets of pairs of vertices). Two vertices on a graph are adjacent if they are connected by a common edge. A weighted (or labeled) directed graph is a pair of $W = (G, \varphi)$, where $G = (V, E)$ is an ordinary directed graph,and $\varphi: E \to \mathcal{R}$ is weight function (or labeling function) with valuesin some idempotent semiring $\mathcal{R} = (R, +, \cdot, \mathbf{0}, \mathbf{1})$, and also $(\forall e \in E)(\varphi(e) \neq \mathbf{0})$.

Let us assume the vertices of a directed graph are numbered. Then the weighted directed graph can be given by matrix A, its element a_{ij} is equal to $\varphi((i,j))$ of weight function on arc (i,j), if from vertex$i$ leads the arc to vertex j, or zero of the semiring otherwise. This matrix is called the arc label matrix. Calculation of iteration A^* of matrix A gives a solution to all the problems formulated above, if for each problem the corresponding semiring is selected.

We will call the problem of computing matrix A^* for a directed graph a problem of the path in weighted directed graphs. The cost of passing from vertex v_i in vertex v_j (or between the i-th and j-th vertices) is a sum in semiring $\mathcal{R}$ labels of all paths form vertex v_i to vertex v_j. The sum of the cost of passing is an infinite sum of a closed semiring, i.e. the exact supremum of the corresponding sequence of labels, since the set of all paths in the general case is infinite. We also determine the cost of passing from one vertex to another along a set of paths. If the cost of passing between a pair of vertices along any set of paths is equal to 0, then it means that there is no path belonging to the given set of paths leading from the first vertex of the analyzed pair to the second vertex. In a directed graph, the path $v_1 \to v_4 \to v_1$ has rank 4, path $v_4 \to v_1 \to v_2$ has rank 1, path $v_4 \to v_1 \to v_3 \to v_2$ has rank 3. Paths $v_4 \to v_3 \to v_2$, $v_4 \to v_1 \to v_3 \to v_2$ and $v_4 \to v_2 \to v_2 \to v_3 \to v_2$ also have a rank

By matrix $C^{(k)}$ we denote costs of passing between different pairs of vertices along all paths of rank not exceeding k. Its element $c_{ij}^{(k)}$ contains the cost of passing from vertex v_i to vertex v_j on all paths of ranks $1, \ldots, k-1, k$.

Let us derive the formula to calculate the element $c_{ij}^{(k)}$ of matrix $C^{(k)}$. Along the path of rank, not exceeding k, from vertex v_i to vertex v_j it can pass in the following ways:

1) from vertex v_i to vertex v_i along a path of rank not exceeding $k-1$, that is, bypassing the vertex v_k

2) first, from v_i to v_k along the path of rank, not exceeding $k-1$, then "spinning" a certain number of times (and perhaps never) along some contour or any closed path from v_k in v_k of the rank, not exceeding $k-1$, and finally, passing from vertex v_k to vertex v_j along the path of rank, not exceeding $k-1$.

According to the first method, the cost of passing from vertex v_i in v_j on all rank paths will be $c_{ij}^{(k-1)}$.

According to the second method, the cost of passing from vertex v_i in v_k on all rank paths, not exceeding $k-1$, will be $c_{ik}^{(k-1)}$. Cost of passing from v_k in v_k on all closed rank paths, not exceeding $k-1$, will be $(c_{kk}^{(k-1)})^*$.

Cost of passing from vertex v_k in vertex v_j on the rank path, not exceeding $k-1$, is equal to $c_{kj}^{(k-1)}$. The cost of passing on the rank path, not exceeding k, for the indicated passing route, it will be

$c_{ik}^{(k-1)} (c_{kk}^{(k-1)})^* c_{kj}^{(k-1)}$. v_i in v_j on the rank path, not exceeding k,

leads to the following formula to calculate the matrix element $C^{(k)}$:

$$c_{ij}^{(k)} = c_{ij}^{(k-1)} + c_{ik}^{(k-1)} (c_{kk}^{(k-1)})^* c_{kj}^{(k-1)}.$$

Let us assume that a_{ij} are elements of the matrix of arc labels of the directed graph. Since each path of rank 0 between non-coinciding vertices consists of one arc, and each vertex is reachable from itself along a path of zero length labeled 1 or along a loop labeled a_{ii}, then matrix elements $C^{(0)}$ have the form

$$c_{ij}^{(0)} = \begin{cases} a_{ij}, & \text{if } i \neq j; \\ \mathbf{1} + a_{ii}, & \text{if } i = j. \end{cases}$$

Then the cost matrix $C = A^*$ can be determined by sequential computing of matrices $C^{(k)}$, $k = \overline{0, n}$ by above formulas. These calculations form the Floyd–Warshall–Kleene algorithm to determine the cost of passing between pairs of vertices.

4. DISCUSSION OF RESULTS

The value of the introduction result of certain technologies is easy to determine, but it is more difficult to assess complexity of making changes, project "pitfalls", assess company's resources and willingness to bring these changes to their logical conclusion. It should also be noted that current technologies are constantly being improved - what is impractical today, may become relevant in a year, or vice versa.

The study of modern Internet technologies, software, modeling and information support in supply chain network structures in the works of authors [10], [11] proves that digital logistics shall be based on a new generation of

logistics applications of web technologies, ensuring collaboration and optimization using a central information logistic path, providing transparency for all logistic process participants.

Let us consider, for example, the digitalization of taxi companies through online applications. It is not just ordering a taxi or interaction between participants being automated, but a new real process is generated without participation of a taxi company: this business area "dies out", people become unemployed, only the digital platform remains: the service customer - the service provider. Thus, introduction of thousands of taxis without Google drivers is "killing" an entire segment of taxi drivers. Only the service customer, the digital platform and the robot car are used.

Designing real processes of international transportation in GTC-GROUP logistics company, the authors built the sequence and participants of these operations. Let us analyze examples of this sequence before and after introduction of digital technologies. Before introduction: The customer of the transportation service (this is the end customer, consumer); Logistics company; Container owner; Railway carrier; Railway agent; Sea line; Agent in a port on a foreign territory; Agent in a port on the RF territory; Service providers in ports and customs terminals; Customs broker-declarant; Customs post, customs inspector; A company that provides the export of a container after customs clearance.

A digital process may have the following sequence: Customer-consumer of the service; Electronic platform for transportation and document management, organizing operations of service providers in ports and customs terminals, carriers and owners of rolling stock and containers; Electronic system of customs declaration.

Certainly, this process "kills" the whole industry of logistics companies, being an integral part of the logistics services market, they provide numerous outsourcing services - agency services in ports and terminals, provide interaction of the customer and the final carrier. Logistics companies analyze and process information, assess risks, optimize routes in terms of time and cost. All participants in logistics processes handle large amounts of information, however, there is no central information highway, functioning online. With the digital transformation of this logistics process, most specialists will be left unemployed, they will have to get trained for a new occupation. But some of them will be working for a new digital process that can set tasks, manage their time, calculate and automatically pay salaries.

5. CONCLUSION

Advances in digital technology allow organizations, with relatively small investments, to improve efficiency in supply chain management, providing a competitive advantage at the market. However, the attractiveness of these technologies result in a situation where some companies began to hastily implement everything in a row, without having a verified system of tasks to be solved by the introduction of a certain technology. Finally, it can transform a digitalization project to a standstill. It may be concluded that digital transformation of supply chains shall be performed according to a well-considered action plan, performed analysis and strict adherence to the list of scheduled activities.

The companies that are aware of change and invest in a timely manner in the development of new digital logistics technologies will get huge benefits. Those who do not pay due attention to the current trend and in doubts, in oncoming years may lag behind the market leaders without any chance to overcome the gap.

However, during digitalization, it is necessary to consider green logistics principles to preserve the ecosystem on the planet, security issues of data storage and transmission of companies and individuals, the possibility of alternative (manual) process control in case the information system failure.

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