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THE TRANSITION TO INDUSTRY 4.0 IN ONE OF THE TURKISH LOGISTICS COMPANY

Elifcan GÖÇMEN[1] Rızvan EROL[2]
[1,2] Çukurova Üniversitesi, Endüstri Mühendisliği Bölümü, Adana

ABSTRACT

Fourth Industry Revolution (Industry 4.0) is a new era for all sectors and a transition to smart facilities. In this paper, Industry 4.0 approach at a logistics company is examined in transportation, warehousing, loading/unloading and information service units. The purpose of this approach is to evaluate Industry 4.0 principles in these service units. In this study, a literature survey focusing on these issues is presented and the key principles to design the logistics companies in this field are determined. The fuzzy method is used to prioritize criteria, which are important for transition to Industry 4.0 such as autonomous transportation, autonomous inventory management, 3D warehouse, global resource planning, real time routing and provides to understand the transition requirements. Additionally, current applications, opportunities and suggestions for the logistics company are presented.

Keywords: Fourth Industry Revolution, Logistics, Smart Facility, Fuzzy approach.

TÜRK LOJİSTİK FİRMALARINDAN BİRİNDE ENDÜSTRİ 4.0'A GEÇİŞ

ÖZET

Dördüncü Sanayi Devrimi (Endüstri 4.0) tüm sektörler için yeni bir çağdır ve akıllı tesislere geçiştir. Bu çalışmada, bir lojistik firmasında Endüstri 4.0 yaklaşımı; taşımacılık, depolama, yükleme/boşaltma ve bilgi hizmetleri birimlerinde incelenmiştir. Bu yaklaşımın amacı, Endüstri 4.0' ın ilkelerini bu hizmet birimlerinde değerlendirmektir. Çalışmada, bu konulara odaklanan bir literatür çalışması sunulmuştur ve bu alanda lojistik firmalarını tasarlamak için gerekli temel ilkelere karar verilmiştir. Endüstri 4.0'a geçiş için önemli olan otonom taşıma, otonom stok yönetimi, 3D depolar, küresel kaynak planlama ve gerçek zamanlı rotalama gibi kriterlerin önceliklendirilmesi için bir bulanık yöntem kullanılmıştır ve yöntem, geçiş için gereklilikleri anlamaya yardımcı olmaktadır. Ayrıca, mevcut uygulamalar, fırsatlar ve öneriler, lojistik firması için sunulmuştur.

Anahtar Kelimeler: Dördüncü Sanayi Devrimi, Lojistik, Akıllı Tesis, Bulanık yaklaşım.

1. INTRODUCTION

The arrival of the fourth industrial revolution, the rapid increase in the world trade and increasing competition have led to the redefinition of the logistics concept. The logistics sector where the transportation of goods, warehousing, loading/unloading, and information services are carried is one of the most important sectors Industry 4.0 approach can be implemented. Vehicles used in the transportation units are more appropriate for an autonomous system. By this way, robot technologies are alternative to the warehousing and loading/unloading units. The application of the key design principles correctly in these service units is important for the entire company.

Industry 4.0 may be summarized as automation trends, Internet of Things (IoT), and transition of the organizations to the smart facilities in which machines communicate with each other. The main aim is to create a smart facility that can operate a long period. Right investment and appropriate training are needed to have good results in terms of logistics costs and time saving.

There are publications about the concept of Industry 4.0 [1-7]. Some of these studies include Cyber Physical Systems (CPS) [8-10]. In the literature, cyber physical systems are studied as device management, human computer integration, security and privacy [11]. Device management by CPS is used for home automation [12]. A CPS study is presented to protect the information, physical security of IoT [13].Human computer integration is provided for blind handwriting. Students can imitate their teacher's drawing with this system [14]. Smart factory and production are also presented in other studies [15-18]. Smart product [19-21] and smart cities [22], [23] are also examined about Industry 4.0. Smart products are responsible to ensure information for both of the previous and further processes. They also control their operations and maintenance by algorithms [24]. Smart cities are evaluated as an advanced city that ensures quality of life (QoL), competitiveness, resource availability for present and next generations [25]. Smart cities use information communication technology and other technologies to increase efficiency of city operations [26].

There has been very little research reported on Logistics 4.0 in the literature. The effects of Industry 4.0 are discussed on logistics management [27]. They present the implications in two processes: Physical Supply Chain and Digital Value Chain. Physical supply chain applications include the autonomous logistics like autonomous vehicles, advanced handlings like picking robots, order processing by block chain technology. Digital value chain applications are collecting data by machine and sensor providing for the cloud. Industry 4.0 solutions for logistics processes are presented. Internet of Things (IoT), Big Data, and Industry 4.0 are considered as the most important solutions [28].

The objectives of this paper are to propose a framework of Logistics 4.0 and explain real applications in the logistics company which draw inspiration from some principles of the Logistics 4.0. This work is the first of considering the Logistics 4.0 criteria by the fuzzy approach. A summary about Logistics 4.0 is presented in Section 2. Section 3 presents potential applications of Industry 4.0 in the logistics company. Opportunities and suggestions are given in Section 4. Finally, final remarks are given in Section 5.

2. LOGISTICS 4.0

The application of Industry 4.0 on logistics sector can be referred to as "Logistics 4.0". The main topics of interest are Cyber-Physical Systems (CPS), Internet of Things (IoT), Big Data and Data Mining (DM) and Internet of Services (IoS). CPS is related to the integration of digital and physical world by using sensors. IoT provides interaction with other systems and users. DM has to be managed carefully because of the volume of the data and speed of computation. IoS is provided by different/multiple providers and it includes business models, users, and services. Smart services and products are important components of Logistics 4.0. Smart products have capabilities of communicating, controlling the processes, and real time capturing. Smart services provide measuring, pricing, and information services. The most important step is identifying the company thoroughly. The processes and the environment of the company are identified in the first step. RFID (Radio Frequency Identification) labels are used for determination of logistics objects. These labels provide load information and loads with identity numbers are presented. The RFID technology also ensures transparency, low costs, and efficient processes. Finding the location where loads are defined is also considered.

Although new technologies are used for determining the location, RFID systems which is the most common technology is used for closed location systems. Hybrid approaches such as the combination of GPS (Global Positioning System) and RFID are also available. In practice, it is seen that RFID technology is used indoors and GPS is used for outdoors.

The Internet of Things can control every load in real time. They control the dynamic supply chain and share information concurrently by analysing each procedure and data at the same time. It can optimize supply chain management and it enables the efficient use of resources. The ability ensures that the entire supply chain is visible so that supply chain transparency can be improved. Additionally, the supply chain is managed in real time and it turns the supply chain into highly agile and completely integrated process [29].

IoS is the term used to designate the concept of providing services over the internet so that they can be turned into value-added services by various suppliers. IoS is based on service providers, service infrastructure, and business models that are provided by the services. The services created are accessible to the customers. For example, individual services create virtual production technologies and features by combining different capabilities to perform a complex task by observing time or financial constraints [30].

2.1. Background of Logistics 4.0

Evaluation of Logistics 4.0 has passed three stages until now. These can be listed as Logistics 1.0, Logistics 2.0, Logistics 3.0, and finally Logistics 4.0. Manual trolley and warehouse processes, transportation modes with steam engine are used in the era of Logistics 1.0. Logistics 2.0 opens the doors to global resource planning, vendor management, automatic warehouse processes, and centralized transport modes. Logistics 3.0 introduces the computing system to manufacturing.

Autonomous inventory management, autonomous forklift, and warehouse processes are integrated into the logistics system in this era. The Internet of Things (IoT) and services have led to the fourth industrial revolution and usage of the smart factory, smart products, and services are common in this period.

3. INDUSTRY 4.0 POTENTIALS FOR THE LOGISTICS COMPANY

Logistics sector has been built on digital technology in the "Industry 4.0" era. Challenges in the logistics will be seen in vehicles communication, transportation operations, and automated warehouses. Logistics sector is ready for these revolutions. Smart plants can be organized with warehouses, shelves, production processes. Smart machines can be adjusted by feeding information on stock levels, disruptions, and damaged goods. Resource Planning, Warehouse Management Systems, Transportation Management Systems, Intelligent Transportation Systems and Information Security are also provided as technological applications [31]. A real-time tracking of material flows, improved transport handling systems, risk management are other applications for the logistics sector [27].

The company's research and development (R&D) operations focus on the Logistics 4.0 by digitalization and visualization, process integration through the internet and mobile applications, creating a network among objects, efforts aimed at cloud computing and communications technologies, simulation and robotic systems as shown in Figure 1. The company's current technologies which show the potential transition to the Logistics 4.0 are listed below.

- **POD (Proof Of Delivery)**

The person receiving the delivery should send signature via PDA delivery.

- **EDI (Electronic Data Interchange)**

System ensures both data interchange with Transportation Management System (TMS) and data transfer with Transportation Management System (TMS).

- **IOD (Information of Delivery)**

Navigation devices in the trailers ensure real-time notifications such as load, unloading arrivals.

- **In Trailer Monitoring System**

Taking video or photo recording can be directed automatically by any movements and monitoring is provided on real time inside the vehicle.

- **Sensor Trailer Locking System**

The system controls the door not to unlock without approval and gives coordinate notifications when the door is unlocked.

- **Geo-Fencing**

The system defines a specific route for the vehicles. System gives alarms when the vehicles have not arrived at the set location on time.

- **Warehouse Management System-WMS**

In-house developed software provides to meet customer expectations, and ensures to produce solutions and improvements in a larger spectrum. The system can be interfaced with other software.

- **Material Flow Control Systems-MFS**

MFS ensures to manage, control and optimize flow of materials and information within the automated warehousing solutions system.

- **Portal Applications**

The applications provide a transparent system in which both the customer and the staff view the same information in real time.

- **Automated Storage and Retrieval Systems (ASRS)**

ASRS is a system stocks up loads to their destinations and unload from shelves.

- **Automation Systems for Garments on Hanger**

Automation systems ensure that the garments on hanger are carried, stored, sorted according to orders and brought to dispatch area without human touch.

The systems provide to carry, storage, sorting of the garments on hanger autonomously.

- **Vertical Lift Systems**

Vertical lift systems use the trays stored in automated lift systems. Products are picked up and carried to the operator.

- **Pick to Light Systems**

This system requires order picking and gives the staff information and product quantities on a led screen.

- **Automated Sorter Systems**

Sorting the products used in order preparation and returns handling are resource intensive step. The company serves automated solutions for the most labour-intensive processes.

- **Product Pick by Voice**

Receiving commands by a headphone and sending feedback by a microphone are ensured through this system. This system lets the staff to free their hands and eyes. Order picking process, especially in the consumer goods requires this system.

- **RF Handheld Terminal**

The staff takes orders from the system related with the warehouse and gives the results to the system related with work through RF Handheld terminal in which physical entities are also controlled simultaneously.

The company's R&D Centre is the scene of research on areas such as Vehicle Route Planning, Distribution Network Design, Pricing, Ergonomics, Process Analysis, Quality Management, Capacity Planning, Plant Investment and Investment Planning with a view to improving basic service types of Transportation, Warehouse Management and Customs Clearance.

As a consequence of "Logistics 4.0", the company's R&D Centre is conducting research and development focused on digitalization and visualization, process integration with internet and mobile applications, inter-object networks, cloud computing and communications technologies, simulation, and robotic systems. The centre is developing a new, advanced Transportation Management System (TMS), in which all stakeholders interact, is being developed, and storage technologies equipped with automation technologies are designed to enhance human-machine interaction. Additionally, the establishment of a new and modern data warehouse environment that will enable large-scale data analysis is among the on-going projects for the future.

Figure 1. An industry 4.0 network [32].

Image processing projects have gained attraction and projects have started within the scope of "Industrial Based Integrated Image Verification in Dynamic Structure and Analysis System Development". Technologies for monitoring vehicles with satellite tracking systems have been planned and vehicles in communication with other vehicles by sensors about traffic and road situation information are used in this system. Intelligent systems are considered in which route updates can be applied autonomously. Storage technologies equipped with automation technologies that are widely used in existing operations are being carried out with the development of face recognition technologies, voice or light guidance systems to increase human-machine interaction. It is aimed to make the storage technologies, automated routing storage devices, intelligent shelf and storage units, and automation components that can determine their own roads in relation to the Industry 4.0 concept.

4. APPLICATION OF FUZZY APPROACH

Fuzzy approach uses linguistic values. The inputs are represented by these linguistic values. The inputs in this study are fuzzied using membership functions. Fuzzy if-then rules are developed. A fuzzy approach is applied and coded using the Fuzzy Logic Designer Tool in Matlab. Autonomous transportation, autonomous inventory management, 3D warehouse, global resource planning, real time routing are used as inputs, and the transition to Industry 4.0 is the output. The fuzzy design developed in this study is shown in Figure 2. Mamdani min max method is used. Fuzzy logic designer includes “and” “or” methods, “implication”, “aggregation”, “defuzzification” sections. In our design, min- max methods, min implication, max aggregation, centroid defuzzification are selected. For each input, values between (0-3) ranges are determined.

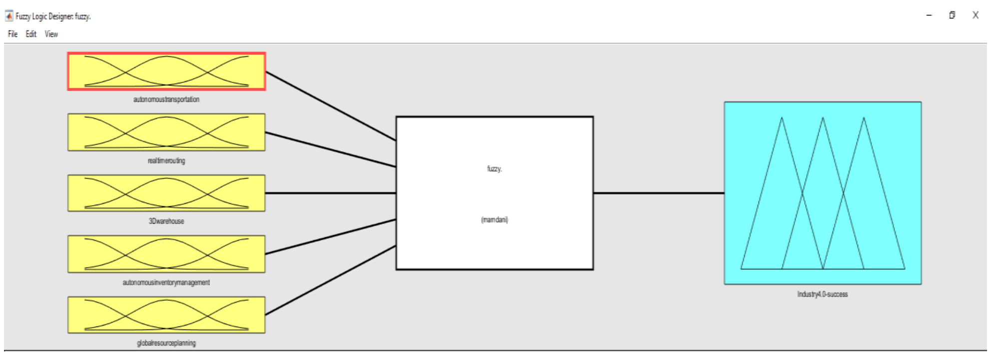

Figure 2. Design of Fuzzy FMEA

The triangular membership function is used and the membership function for inputs is given in Figure 3 and consists of low, medium, high. Fuzzy numbers are low (0, 0, 1.5), Medium (0, 1.5, 3) High (1.5, 3, 3). The figure means that the importance of each input is scored by fuzzy numbers. For example, if the importance of autonomous transportation is low, this input takes numeric value between 0-1.5.

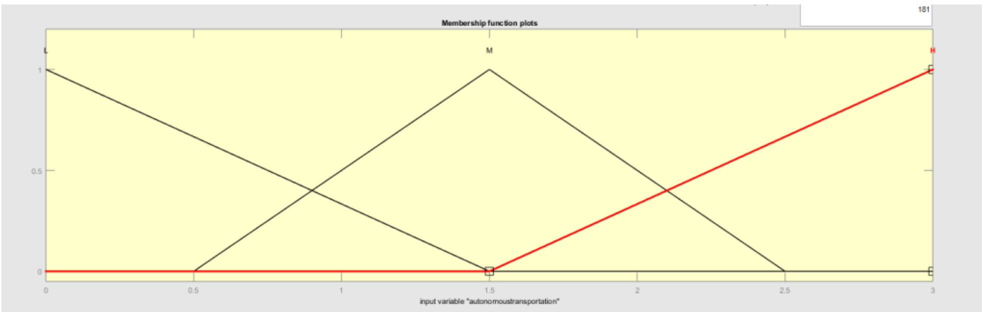

Figure 3. Membership function plots of input variables

The triangular membership function is used and the membership function for output is given in Figure 4 and consists of low, medium, high. Fuzzy numbers are low (0, 0, 50), Medium (25, 50, 75) High (50, 100, 100). The figure means that the success percentage of output is scored by fuzzy numbers. For example, if the success of output is low, this output takes numeric value between 0-50.

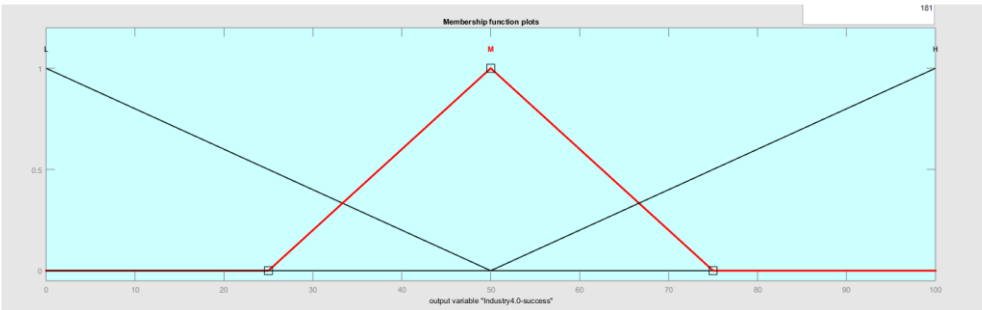

Figure 4. Membership function plots of output variable

100 decision rules are developed for the logistic firm. The most important parameter is autonomous transportation for the firm and so, the rules are formed with high value. Some rules are here:

-If autonomous transportation is low, real time routing is low, 3D warehouse is low, autonomous inventory management is low, global resource planning is low, then Industry 4.0 success is low.

- If autonomous transportation is high, real time routing is high, 3D warehouse is high, autonomous inventory management is high, global resource planning is high, then Industry 4.0 success is high.

- If autonomous transportation is low, real time routing is low, 3D warehouse is medium, autonomous inventory management is medium, global resource planning is medium then Industry 4.0 success is medium.

- If autonomous transportation is low, real time routing is low, 3D warehouse is high, autonomous inventory management is high, global resource planning is high, then Industry 4.0 success is medium.

- If autonomous transportation is low, real time routing is low, 3D warehouse is low, autonomous inventory management is medium, global resource planning is medium, then Industry 4.0 success is medium.

-If autonomous transportation is high, real time routing is high, 3D warehouse is medium, autonomous inventory management is medium, global resource planning is medium, then Industry 4.0 success is high.

Decision rules are tried with different input values and successes of output are evaluated. When autonomous transportation, real time routing and autonomous inventory management values are increased, success percentage also increases. Two examples are shown in Figure 5-6.

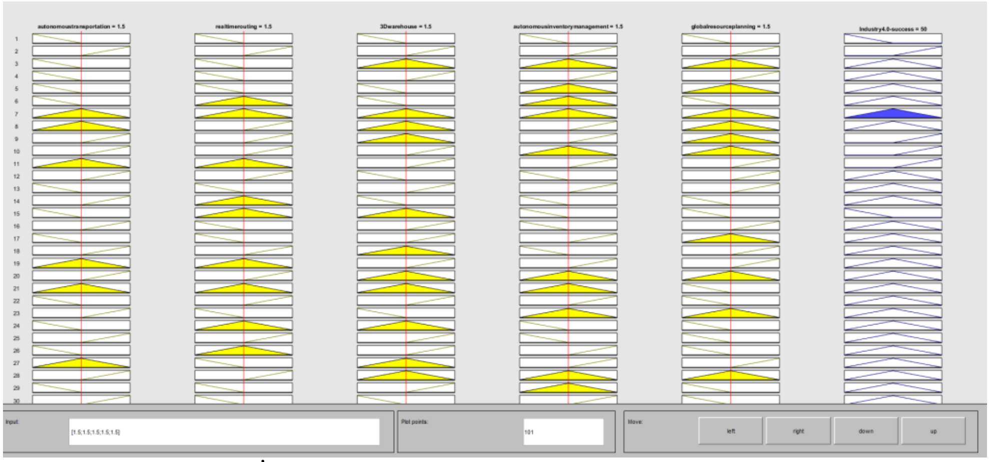

Figure 5. İnput and output values according to the decision rules

All inputs are given with medium values in Figure 5. The inputs take 1.5 value (importance is medium) and the output is 50 percentage successes.

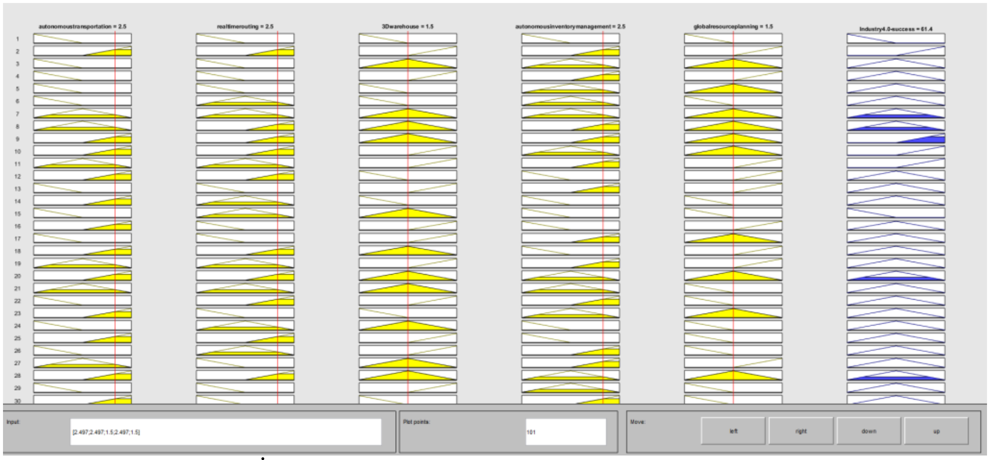

Figure 6. İnput and output values according to the decision rules

Autonomous transportation, real time routing and autonomous inventory management values are higher than others; and the transition success increases (61.4 percentages). Figure 6 shows that these values are important of the transition to the Industry 4.0.

5. OPPORTUNITIES AND SUGGESTIONS

The transition to Logistics 4.0 requires several stages. Some opportunities are listed below:

- Current situation in the context of technological developments is evaluated and gaps are determined.
- The logistics company's digitalization level is determined and the strategy of transition to smart factory is decided.
- Application steps of transition are given and some examples carried out to show the application's advantages.
- After small applications, potential customers and other network parts are determined and developments of applications are updated.

New trends and suggestions can be integrated into these processes as shown in Figure 7. Some of them are given below:

- Time of flight cameras for depth imaging and vision cameras for geometric dimensions can be used.

- Block chain technology can be used by open data sharing and control on supply chain management. A system can be developed to follow the block chain technology.
- Cruise control technology used in truck platooning ensures to drive by a certain speed, safe distance. The system has braking, accelerating, and automated steering.
- By 3D printing, logistics companies can open 3D warehouses in airport or marine ports to respond quickly.
- Electronic market platforms provide collaboration between actors in a chain.
- Smart factory puts the people to the centre of digital processes. People will be influential to design, setting, and control of Logistics 4.0 technologies.
- Multi agent systems that provide autonomous transportation should be used.

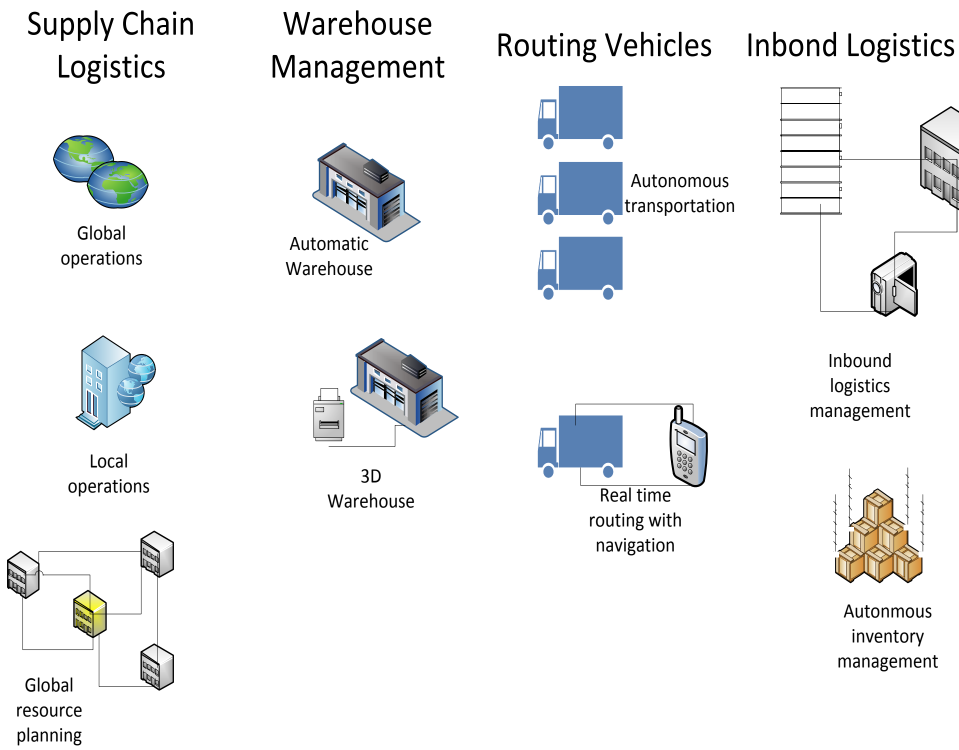

Figure 7. Main components for Logistics 4.0

5.1. Outputs and success criteria

- By starting R&D activities that are necessary for a superior and digital system than the current processes, a smart factory mentioned about Industry 4.0 principles will be introduced as a basic output.
- Research carried out during the R&D process, the applicability of autonomous technology and its application on a working system are important outputs.
- When the smart applications are completed, it is an important requirement to put the results within measurable definitions.
- Some criteria can be evaluated in terms of market success as well as the technical competence criteria mentioned above. At the end of the year, applications have been evaluated to meet the technical criteria and compared to the other logistics companies. New innovations in the R&D process should be supported to get the best position in the sector.

6. CONCLUSION

6.1. Findings

This study includes Industry 4.0 applications in Logistics Company. The company provides information to transportation, warehousing, and distribution service units. On these units, Transportation Management System, Industrial Based Integrated Image Verification in Dynamic Structure and Analysis System Development, Satellite Tracking Systems, Storage Technologies Equipped with Automation Technologies have been planned. The company's R&D operations include digitalization and visualization, internet and mobile applications, cloud computing, communication technologies, simulation, and robotic systems. The company must give priority to the autonomous transportation, inventory management and real time routing firstly.

6.2. Limitations

The study aims to evaluate Logistics 4.0 technologies and apply these technologies on the logistics company. The investigation is especially focused on transportation, warehousing, and distribution service units. There are a lot of service units to investigate their transitions to Logistics 4.0. While the study handles the potentials and suggestions, security, risks, laws for cyber physical systems are not considered.

6.3. Future research suggestions

Academic and practical studies about Logistics 4.0 received much attention, recently. There is not a precise definition of Logistics 4.0 principles and technologies. The future studies should focus on better understanding of the Logistics 4.0 key points. Although transportation and warehousing systems are generally considered, financial analysis, risk analysis for these systems should also be presented besides technological improvements. In this paper, Industry 4.0 approach on Logistics Company is presented as a general framework. It is planned to make future research that examine the operations of the facilities in operational, tactical, and strategical levels.

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