LOGISTICS 4.0 IN THE FUNCTION OF CIRCULAR ECONOMY IN THE AGRI-FOOD SECTOR

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Abstract: *By applying the solutions and technologies of Industry 4.0 in the field of logistics, the concept of Logistics 4.0 was developed. On the other hand Circular Economy (CE) is a model of production and consumption that ensures sustainable growth over time. The subject of this paper is to rank the main Logistics 4.0 based CE interest areas within the agri-food sector. The aim is to determine the areas which has the greatest potential for further development and should thus be in focus of the future planning. This is a multi-criteria decision making (MCDM) problem. For solving it a hybrid MCDM model combining the Analytical Hierarchy Proces (AHP) method for establishing the criteria weights, and the Comprehensive distance-Based RAnking (COBRA) method for the final ranking of the alternatives, is proposed. The results indicate that the most important CE interest areas are Reuse/Remanufacturing/Recycle, Supply Chain Management and Product Lifecycle Management.*

Keywords*: logistics, Industry 4.0, circular economy, agri-food, MCDM, AHP, COBRA.*

1. INTRODUCTION

In the broadest sense, logistics encompasses all systems and processes that enable the movement of material and non-material flows (Zečević, 2006). Processes that include the movement of these flows can be grouped from the aspect of direction and identified with the terms of forward logistics (flows from the place of origin to the place of consumption) and reverse logistics (flows from the place of consumption to the place of disposal, destruction, reuse, remanufacturing, recycling, etc.). However, both are covered by the term closed loop supply chain (CLSP) (Kumar & Kumar, 2013), which is often identified with the circular economy (CE) concept (Farooque et al., 2019).

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The main goals of the CE are the optimization of resources, reduction of raw materials consumption, and waste recovery by recycling or giving a product or some of its parts a second life. Therefore, CE is seen as a new production and consumption model that ensures sustainable growth over time. Hawing in mind the increasing importance of sustainability, it is clear why CE is becoming an important research topic, and especially the optimization of logistics processes that enable its efficient functioning. A significant contribution to the optimization of these processes is made by modern technologies developed within the paradigms known as Industry 4.0 (I4.0). The application of these technologies and their mutual networking for the realization of logistics activities has led to the creation of the concept of Logistics 4.0.

I4.0 represents a revolution that has initiated significant changes in all areas of human activity, including the agri-food sector as one of the primary, if not the most important economic sectors. Since it is fundamental to face the challenge of food security in the coming years, the agri-food sector cannot allow itself to lose the opportunities offered by modern trends brought by the concepts of CE and Logistics 4.0. Accordingly, the aim of this paper is to consider the possibilities of applying I4.0 technologies for the implementation of logistics activities in the CE interest areas within the agri-food sector and to rank these Logistics 4.0 based CE interest areas in order to identify those which have the greatest potential for further development and should thus be in the focus of future planning and development of strategies. Since this is a multi-criteria decision-making (MCDM) problem, a hybrid model which combines Analytical Hierarchy Process (AHP) method and the Comprehensive distance-Based RAnking (COBRA) method is proposed for solving it.

The paper is organized as follows. The next section deals with the establishment of the Logistics 4.0 based CE interest areas in the agri-food sector. The third section provides the methodology for prioritizing the CE interest areas, while the following section provides the obtained results. Final section provides main conclusions.

2. LOGISTICS 4.0 BASED CIRCULAR ECONOMY IN THE AGRI-FOOD SECTOR

Logistics 4.0 is defined as the application of the I4.0 technologies in logistics (Krstić et al., 2021). I4.0 technologies that found the widest application in logistics so far are Internet of Things (IoT), Autonomous Vehicles (AV), Automated Guided Vehicles (AGV), Artificial Intelligence (AI), Dig Data and Data Mining (BD&DM), Blockchain (BC), Cloud Computing (CC), Augmented Reality (AR), Additive Manufacturing (AM), Progressive Robotics (PR) and Electronic/Mobile Markeplace (EMM) (Krstić et al., 2021; 2022).

The CE is "*a model of production and consumption, which involves sharing, leasing, reusing, repairing, refurbishing and recycling existing materials and products as long as possible, thus extending the life cycle of products*" (EP, 2021). CE is mostly related to reverse logistics (e.g. Julianelli et al., 2020). However, if one carefully analyzes one of the main objectives of CE, which is to plan the product life cycle to minimize or avoid any waste in the first place (EMF, 2012), it is clear that CE encompasses the entire supply chain and that in addition to return logistics includes forward logistics. Rosa et al. (2020) identified supply chain management (SCM), circular business model (CBM), product lifecycle management (PLM), digital transformation (DT), resource efficiency (RE), smart services (SS), reuse (RU), remanufacturing (RM) and recycling (RC) as the main CE interest areas. CE is very much influenced by the new business paradigm brought by the development of I4.0

through the application of modern technologies in its main interest areas. Of course, this paradigm shift is present in all economic sectors, including the agri-food sector, which will be further investigated in the following.

2.1 Supply chain management

SCM as one of the broadest interest areas of CE provides most opportunities for the application of various I4.0 technologies for performing logistics activities. IoT is used in almost all phases of the agri-food supply chain and all logistics subsystems. It can be used for managing and processing orders, information between different participants in the chain, transport operations, vehicle fleet (locating, routing), warehousing operations, inventory levels, automatic packaging and labeling, smart packages that have the ability to monitor various parameters of goods, etc. AV could be applied as a replacement for retail facilities which would lead to a change in business and distribution models. AGV technology is widely used in various parts of the agri-food supply chain, primarily for the implementation of internal transport and transshipment processes in various nodes of the logistics network. AI-based systems in agri-food SCM contribute to maintaining the quality of agri-food products through testing and monitoring of food at each stage of the supply chain, enable sorting of products against a number of criteria in a short time, provide and improve hygiene standards by accelerating the sanitation of vehicles and equipment, enable the preparation of food and beverages according to the specific requirements of users, etc. The application of BD&DM technology facilitates SCM in the agri-food sector by supporting the management of various segments of the supply chain, such as order processing, transport, storage, inventories, packaging, available resources planning, last mile optimization, customer loyalty management, supply chain risk management, valorization of returns, etc. BC technology enables the creation of transparent, reliable, unchangeable and verifiable records that are the basis for the development of the agri-food traceability system. CC technology provides the flexibility needed to cope with the unpredictable variations in supply quality and quantity that characterize agri-food supply chains. CC enables more efficient application of various systems that are integral parts of SCM. AR technology can be used to improve the efficiency of agri-food product processing, product advertising, quality assessment, etc. AM technology supports personalized mechanisms for nutritional control and development of food products in accordance with the specific requirements of users. PR technology is used in agri-food supply chains in the stages of providing raw materials (for sowing crops, harvesting, etc.), in the production phase to perform various operations of processing, production, packaging, etc., as well as in the distribution stages to perform various storage operations (loading, unloading, sorting, etc.). EMM facilitates participants in the agri-food supply chains to procure, trade and cooperate with partners, diversify business opportunities, improve profitability and access the new markets that were previously inaccessible due to the geographical barriers.

2.2 Circular business model

In the agri-food sector, I4.0 technologies can be applied for the realization of numerous processes in the field of logistics. IoT can be applied to establish a flow control system based on Kanban management method to visualize the locations, times and quantities of goods and materials collection/delivery, which is especially important for the agri-food products that have a limited expiration date. IoT can also be used to collect large amounts of data, whose adequate structuring and analysis using BD&DM technologies can improve the overall circularity of the system. In addition, BD&DM can be used to establish strategic and tactical decision support systems, to plan agri-food logistics network by identifying locations for delivery and collection of agri-food products and ways to connect them, manage customer loyalty, as well as to assess innovative business models. AI can be applied to simulate the CE system with the aim of auditing cooperative agri-food networks, assessing the impact of changing business models, as well as to forecast the potential for redistribution of production. BC technology can enable better business cooperation between network participants by ensuring the security and confidentiality of data and information exchange, which is especially important for the logistics of agri-food sector whose flows are accompanied by a large number of documents. EMM has high potential in the agri-food sectors, especially in recent years in the circumstances of the COVID-19 pandemic. EMM enables the creation of new business models and logistics markets through supply expansion and services improvement.

2.3 Product lifecycle management

In the agri-food sector, various I4.0 technologies can support performance of forward and reverse logistics operations encompassed by the PLM as one of the interest areas of the CE. IoT can be applied for establishing a platform for animal/food product information sharing, track of raw materials and finished products, their surveillance during consumption in the consumers' households and undertaking the proactive corrective actions before the corruption of the products, e.g. food spoilage due to the inadequate storage, expiration, etc. AI in combination with other I4.0 technology can be applied to support various logistics-related operations in the agri-food sector. With the support of BD&DM technology for market analysis, identification of target users and their requirements, AI can be applied to agri-food product design, rapid concept development based on existing products, improving the quality of innovation and efficiency of product design, providing accurate, high quality and personalized services of sales, product deliveries, product returns and other related services, etc. In combination with AR technology, AI can be used for personalized and collaborative product design, especially packaging, that can have a crucial impact on the agri-food product attractiveness, testing and inspection, visualization and planning of warehousing operations, etc. BC technology can be applied for PLM in the agri-food sector to manage customer relationships and product data, quality, origin tracking, counterfeiting prevention, etc. CC facilitates the development of a PLM system that integrates various individual systems to control internal operations, as well as the creation of a cloud production system. AM strengthens PLM competencies by improving the performance of agri-food products, such as faster production, reduced product development costs, improved product quality, better material control, etc.

2.4 Digital transformation

Most of the technologies related to I4.0 have a significant impact on the DT in the agri-food sector through the implementation of various logistics activities. IoT enables digitalization of relations between participants in logistics chains through the establishment of systems for collecting, exchanging and managing information on various chain processes quickly and accurately in order to overcome problems arising from the great diversity of agri-food products and specific requirements for the logistics processes.

These systems have the ability to collect, monitor and analyze data in real time, thus creating databases that can be used in decision-making processes. CC technology enables wider and more efficient application of various systems, such as Enterprise Resource Planning (ERP), Electronic Data Interchange (EDI), telematics, etc., in the cloud. With the support of BD&DM technology, these systems support responsible business management, which enables the valorization of agri-food products, obtaining of timely warnings, anticipating the adverse situations, planning the actions to eliminate the consequences, etc. AI enables digitalization of monitoring the status of goods and means of transport, and with the support of AR technology facilitates the implementation of logistics activities, primarily those related to transport. EMMs are closely related to DT because they are the main drivers of digitalization of the market, which enables the realization of very fast electronic transactions, which is of particular importance in agri-food supply chains. As these electronic transactions are subject to abuse, the required level of security is provided by the BC technology, which enables the creation of digital contracts, digital bill of lading, etc. AM as a new production technology leads to the digitalization of food design and production processes thus enabling product characteristics to be adapted to individual requirements of consumers in relation to their health and physical activity. PR technology contributes to the digitalization of the process of storage/warehousing, sorting, internal transport and other activities which support the production process.

2.5 Resource efficiency

Logistics operations provide additional margins for achieving RE in the context of CE which by definition already implies resource saving and does not leave much room for further improvements. These improvements in the agri-food sector can be achieved by applying various I4.0 technologies. IoT can be used to develop a system that improves productivity based on the collection of data on the engagement of resources, both natural and other, in real time and making adequate decisions based on them. The system enables monitoring and identification of processes that are less efficient and suggests actions for their optimization. AVs, which often include electric drive, which automatically select and follow optimal routes and do not require the involvement of drivers, contribute to the reduction of natural resources, primarily fuel, but also other resources, primarily monetary, time and human. AI technology, supported by BD&DM technologies for data collection and analysis, can be used to identify potential places for resource rationalization, as well as resource savings through better planning of logistics operations, primarily transport and inventory, but also ordering and warehousing. Optimal planning of logistics operations reduces the consumption of energy and other resources through better allocation and capacity planning. BC technology provides savings in time and human resources through checking, controlling and ensuring the accuracy and reliability of information and data on transport documents, inventories status, customer requirements, providers and other participants in the chain. CC technology through sharing enables savings in the purchase and use of hardware and software resources used in all phases of the logistics chain, as well as the people needed to install and maintain them. Through the visualization of production and logistics operations, primarily transport, storage and transshipment, AR technology enables better preparation, planning and optimization of processes in the agri-food sector. AM enables the reduction of energy consumption, primarily fuel, due to the reduction of transport activities since the raw materials can be found closer to the place of production. Additionally supported by PR technology, AM also enables the reduction of manpower that has been replaced by machines, as well as costs and time of performing production and logistics processes, primarily transshipment and warehousing, but also AGV supported internal transport processes. EMM enables the allocation of resources, primarily monetary, time and human, which would initially be used for the implementation of traditional trade operations, to other activities, primarily logistics.

2.6 Smart services

In the agri-food sector, most I4.0 technologies are applied to the development of SS in all phases of the supply chain. IoT can be used for procurement of raw materials to provide crop performance assessment services. IoT can also be used to develop systems that identify shortages or expiration of certain agri-food products, and automatically initiate procurement and distribution or reverse logistics processes. Combined with CC and BC technologies, IoT enables the development of advanced product tracking services. CC in combination with EMM technology can be used to develop a smart online shopping platform that can provide essential information to both buyers and sellers that can ultimately lead to higher sales and higher profitability, improved marketing and pricing strategies, etc. Furthermore, EMM in combination with AR technology can be used to improve the experience of online retail shopping by providing potential customers not only to review the product to the smallest detail, but also to suggest modifications that can be implemented using AM technology (e.g. product or packaging customization, installation of various sensors, etc.). AV can be used for smart agriculture, for the processing like sowing, fertilizing and harvesting agricultural products, i.e. for the processes of providing raw materials in the supply chain. They can also be used in the phases of agri-food supply chains in charge of distributing and delivering products to the end users, as well as collecting and returning them in reverse logistics processes. AGV vehicles can replace the work of people in harsh environments that prevail in the nodes of agri-food supply chain networks that arise as a result of requirements for certain temperature regimes. In combination with PR and AI technologies, they can be used for automatic collection, sorting and packing of eggs, milking and feeding cows, automatic cleaning, reloading, transshipment, etc. In addition, BC technology enables reliable product traceability, which is especially important in the agri-food sector. BD&DM technology can be applied for forecasting, benchmarking and creating risk management models.

2.7 Reuse/Remanufacturing/Recycling

RU, RM and RC are the main processes that drive the return logistics activities. RU in the agri-food sector mostly refers to the redistribution of products in order to reduce the volume of surplus products generated. RM also referred to as the refurbishment or reconditioning, in the agri-food sector implies the return of the damaged or faulty packaged products, misshaped products, wrong weighted products, broken products, etc., with the aim of eliminating these shortcomings and re-producing the same products in accordance with the expected and designed characteristics. RC in the agri-food sector refers to the use of raw materials obtained from processing the returned or waste products to produce other products, such as animal food, biomasses for fertilization, energy sources (bio-fuels), etc. Almost all I4.0 technologies used in this interest area of CE are used in order to form a single waste and returnable management system consisting of four basic modules: collection, transport, redistribution, and processing. In the collection and redistribution modules, IoT technology can be used to communicate objects such as waste collection bins, vehicles and retail shops, which ensure efficient and fast waste collection, distribution, better utilization of vehicles, better route planning, etc. In this module, as well as in the transport module, there is a wide scope for application of the AV technology. With the support of BD&DM technologies, which collect, store and process large amounts of data, and AI technology, which allows automatic decision making, these vehicles reach their full potential and can completely independently perform processes of collection, distribution and transport. AGV technology can be used in the processing module to perform the internal transport process. Other technologies such as IoT, BD&DM, AI and PR are used in this module to implement the processes of sampling, classification, sorting, monitoring, as well as for data statistical analysis. AM technology through promoting in-situ recycling affects all three modules since it enables local sourcing, which simplifies collection processes, reduces transport distances and thus makes it cheaper, and combines processing with production activities. BC technology allows tracking of materials with unique codes or digital badges from the moment of collection to the moment of processing. With CC technology, the entire waste and return management system can function fully in the cloud, reducing the required hardware and software resources.

3. METHODOLOGY

To solve the MCDM problem in this paper, a hybrid model is defined that combines AHP (Saaty, 1980) and COBRA (Krstić et al., 2022) methods. The AHP method was used to obtain criteria weights, while the COBRA method was used to rank the alternatives. Application steps of the proposed hybrid MCDM model are described below.

First it is necessary to define the problem structure, i.e. the objective, alternatives and the criteria for their prioritization. Afterwards, it is necessary to define the evaluation scale for prioritization. This paper used the standardized nine-point Saaty scale in which 1 represents “Equal importance” and 9 represents “Extreme importance” (Saaty, 1980).

Application of the AHP method for obtaining the criteria weights begins with the establishment of pair wise comparison matrices:

$$P = \lfloor p_{ij} \rfloor_{oxo}, p_{ij} = 1, p_{ji} = 1/p_{ij}, p_{ij} \neq 0 \tag{1}$$

elements of which are p_{ij} *(i,j=1,2,...,o)* and denote the importance of element (criterion, sub-criterion) *i* in relation to element *j*. Afterwards, it is necessary to obtain the element weights based on the eigenvector. First, it is necessary to set up a matrix equation:

$$PW = \lambda_{\max} W \tag{2}$$

where *W* is the element weights matrix elements of which are w_i ($\sum_{i=1}^{o} w_i = 1$), and λ_{max} is the eigenvalue of the matrix *A*. In order to control the results of the method it is necessary to calculate the Consistency Ratio (*CR*) for each matrix and the overall inconsistency of the hierarchical structure. *CR* is calculated as (Saaty, 1980):

$$CR = CI / RI, \tag{3}$$

where *CI* denotes the Consistency Index and can be calculated as:

$$CI = \frac{\lambda_{\max} - o}{o-1} \tag{4}$$

RI denotes the Random Index, *CR* is used for checking the consistency of pair wise comparisons and must be less than 0.10. Only then it can be said that the comparisons are acceptable.

For ranking the alternatives using the COBRA method (Krstić et al., 2022) it is necessary to form the decision matrix *A* by evaluating the alternatives in relation to criteria using the Saaty scale.

$$A = \lfloor a_{ij} \rfloor_{mxo} \tag{5}$$

where a_{ii} is the preference value of alternative *j* (*j=1,...,m*) in relation to criterion *i* (*i=1,...,o*). Afterwards it is necessary to obtain the normalized the decision matrix:

$$\Delta = \left[\alpha_{ij}\right]_{m\times o},\ \alpha_{ij} = \frac{a_{ij}}{\max_j a_{ij}}, \tag{6}$$

as well as the weighted normalized decision matrix:

$$\Delta_w = \lfloor w_i \times \alpha_{ij} \rfloor_{m\times o}, \tag{7}$$

where w_i is the relative weight of criterion *i*.

For each criterion function it is necessary to determine the positive ideal (PIS_i), negative ideal (NIS_i) and average solution (AS_i) in the following way:

$$PIS_i = \max_j \left(w_i \times \alpha_{ij}\right), \forall i = 1,...,o \ for\ i \in B,\ PIS_i = \min_j \left(w_i \times \alpha_{ij}\right), \forall i = 1,...,o \ for\ i \in C \tag{8}$$

$$NIS_i = \min_j \left(w_i \times \alpha_{ij}\right), \forall i = 1,...,o \ for\ i \in B,\ NIS_i = \max_j \left(w_i \times \alpha_{ij}\right), \forall i = 1,...,o \ for\ i \in C, \tag{9}$$

$$AS_i = \frac{\sum_{j=1}^{m}\left(w_i \times \alpha_{ij}\right)}{o}, \forall i = 1,...,o \ for\ i \in B, C, \tag{10}$$

where *B* is the set of benefit and *C* the set of cost criteria.

For each alternative it is necessary to determine the distances from the positive ideal ($d(PIS_i)$) and negative ideal ($d(NIS_i)$) solutions, as well as the positive ($d(AS_i^+)$) and negative ($d(AS_i^-)$) distances from the average solution in the following way:

$$d(S_i) = dE(S_i) + \sigma \times dE(S_i) \times dT(S_i), \forall i = 1,...,o \tag{11}$$

where S_i represents any solution (PIS_i, NIS_i or AS_i), σ is the correction coefficient obtained in the following way:

$$\sigma = \max_j dE(S_i)_j - \min_j dE(S_i)_j \tag{12}$$

$dE(S_i)_j$ and $dT(S_i)_j$ denote the Euclidian and Taxicab distances, respectively, which are for the positive/negative ideal solution obtained as follows:

$$dE(PIS/NIS_i)_j = \sqrt{\sum_{i=1}^{o}\left(PIS/NIS_i - w_i \times \alpha_{ij}\right)^2}, \forall j = 1,...,m, \forall i = 1,...,o \tag{13}$$

$$dT(PIS / NIS_i)_j = \sum_{i=1}^{o} \left| PIS / NIS_i - w_i \times \alpha_{ij} \right|, \forall j = 1,...,m, \forall i = 1,...,o \qquad (14)$$

and for the positive/negative distance from the average solution obtained as follows:

$$dE(AS_i)_j^{+/-} = \sqrt{\sum_{i=1}^{o} \tau^{+/-} (AS_i - w_i \times \alpha_{ij})^2}, \forall j = 1,...,m, \forall i = 1,...,o \qquad (15)$$

$$dT(AS_i)_j^{+/-} = \sum_{i=1}^{o} \tau^{+/-} \left| NIS_i - w_i \times \alpha_{ij} \right|, \forall j = 1,...,m, \forall i = 1,...,o \qquad (16)$$

where

$$\tau^+ = \begin{cases} 1 \text{ if } AS_i < w_i \times \alpha_{ij} \\ 0 \text{ if } AS_i > w_i \times \alpha_{ij} \end{cases}, \tau^- = \begin{cases} 1 \text{ if } AS_i > w_i \times \alpha_{ij} \\ 0 \text{ if } AS_i < w_i \times \alpha_{ij} \end{cases} \qquad (17)$$

Final ranking of the alternatives is established according to the increasing values of the comprehensive distances (dC_i) obtained in the following way:

$$dC_j = \frac{d(PIS_i)_j - d(NIS_i)_j - d(AS_i)_j^+ + d(AS_i)_j^-}{4}, \forall j = 1,...,m \qquad (18)$$

4. PRIORITIZING CE INTEREST AREAS IN THE AGRI-FOOD SECTOR

Prioritizing the CE interest areas is the MCDM problem which is solved by applying the established model. The first step of the model implies the definition of the problem structure (objective, alternatives, criteria and sub-criteria). The objective is clear, to identify the CE interest areas that contribute most to the sustainability of the CE system in the agri-food sector. Alternatives are thus the CE interest areas explained in section 3. The only elements remaining for the establishment of the problem structure are the criteria and sub-criteria for the evaluation of the CE interest areas.

Since CE is a systematic approach to economic development designed to benefit businesses, society, and the environment, three main criteria are defined: ***Economic*** (Ec.), ***Social*** (So.) and ***Environmental*** (En.). Economic criterion further includes sub-criteria: ***Implementation costs*** (Ec.1), ***Operational costs*** (Ec.2), and ***Material value preservation*** (Ec.3); social criterion includes: ***Health*** (So.1), ***Safety*** (So.2), and ***Labor market*** (So.3); and Environmental criterion includes: ***Waste reduction*** (En.1), ***Emissions reduction*** (En.2), and ***Energy resource preservation*** (En.3).

The following steps of the proposed model imply the establishment of the criteria and sub-criteria weights using the AHP method. The pair wise comparisons of the criteria and sub-criteria are established and pair wise matrices are obtained according to the equation (1). By applying the equation (2) the criteria and sub-criteria weights are obtained. Pair wise matrices and the obtained weights are presented in Table 1. By applying the equations (3) and (4) the consistencies of the evaluations are checked and all values were less than 0.1, which means that all comparisons are acceptable.

Table 1. Pair wise comparison of criteria/sub-criteria and obtained weights

	Criteria			Sub-criteria											
	Ec.	So.	En.		Ec.1	Ec.2	Ec.3		So.1	So.2	So.3		En.1	En.2	En.3
Ec.	/	1.00	2.00	Ec.1	/	2.00	0.50	So.1	/	1.00	2.00	En.1	/	2.00	2.00
So.	1.00	/	1.00	Ec.2	0.50	/	0.33	So.2	1.00	/	1.00	En.2	0.50	/	1.00
En.	0.50	1.00	/	Ec.3	2.00	3.00	/	So.3	0.50	1.00	/	En.3	0.50	1.00	/
w	0.54	0.30	0.16		0.30	0.16	0.54		0.54	0.30	0.16		0.50	0.25	0.25

The final sub-criteria weights are obtained by multiplying the weights of sub-criteria with the weights of the corresponding criteria. The obtained sub-criteria weights are w(Ec.1)= 0.160, w(Ec.2)= 0.088, w(Ec.3)=0.292, w(So.1)=0.160, w(So.2)=0.088, w(So.3)= 0.048, w(En.1)= 0.082, w(En.2)= 0.041, w(En.3)= 0.041.

The next step was to evaluate the CE interest areas in relation to the established sets of sub-criteria and rank them using the COBRA method. Decision matrix is obtained according to the equation (5) (Table 2).

Table 2 Evaluations of the CE interest areas in relation to sub-criteria

	Ec.1	Ec.2	Ec.3	So.1	So.2	So.3	En.1	En.2	En.3
SCM	5	9	7	9	9	8	8	9	8
CBM	9	8	6	5	4	5	6	4	7
PLM	8	4	8	6	3	4	7	3	6
DT	6	3	4	3	7	7	4	6	4
RE	4	6	3	7	2	3	2	2	9
SS	3	5	5	4	6	9	3	7	5
RU/RM/RC	7	7	9	8	8	6	9	8	3

Decision matrix is then normalized using the equations (6) and (7), and weighted using the equation (8). For each criterion function PIS_i, NIS_i and AS_i are obtained using the equations (9), (10) and (11), respectively. By applying the equations (12) - (17) $d(PIS_i)$, $d(NIS_i)$), $d(AS_i^+)$ and $d(AS_i^-)$ distances are obtained for each alternative. By applying the equation (26) dC_i distances are obtained and by arranging them in the increasing order the final ranking of CE interest areas is established. Values based on which the ranking is established, as well as the ranking itself are presented in Table 3. It can be concluded from the results that the most important CE interest area is RU/RM/RC, followed by the SCM and PLM.

Table 3. Final ranking of the CE interest areas

	d(PIS)	d(NIS)	d(AS+)	d(AS-)	dC	Rank
SCM	-0.244	0.508	0.234	-0.209	-0.048	2
CBM	-0.044	0.123	0.029	-0.168	-0.015	4
PLM	-0.218	0.392	0.160	-0.103	-0.034	3
DT	0.441	-0.491	-0.278	0.247	0.056	6
RE	0.596	-0.518	-0.225	0.411	0.069	7
SS	0.355	-0.460	-0.258	0.148	0.047	5
RU/RM/RC	-0.887	0.447	0.338	-0.326	-0.079	1

5.CONCLUSION

The goal of this paper was to identify the CE interest areas which are most affected by the application of the I4.0 technologies for performing the logistics activities within the agri-food sector. After establishing the alternatives, they were evaluated in relation to the

defined set of criteria and ranked. For obtaining the criteria weights the AHP method is used, while the COBRA method is used for obtaining the final rank of the alternatives.
Results indicated that the RU/RM/RC, SCM and PLM are the interest areas that contribute most to the sustainability of the CE system in the agri-food sector and to which the greatest attention should be paid in the future plans and actions. One of the main contributions of this paper is the investigation of the wider application of I4.0 technologies for performing the logistics activities within the individual areas of the CE in the agri-food sector. Another one is the establishment of a framework for the evaluation and identification of the main interest areas which will be in focus of future plans, actions and development strategies aiming at achieving the sustainable CE in the agri-food sector. Future researches could investigate the applicability of the I4.0 based logistics activities in the main CE interest areas for some other sector. Since CE is a concept that influences multiple stakeholders, future researches could also investigate main CE interest areas priority in relation to the individual aims and goals of the various stakeholders, as well as the compromise priorities in relation to all of their goals.

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