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Sustainable Delivery Model Selection using AROMAN Approach

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ABSTRACT

The development of electronic commerce has resulted in an increase in the number of shipments in their transfer systems. Delivery companies strive to respond to emerging situations, meet customer needs, and achieve profit through the optimization of their operations. The imperative is to establish a delivery system that is in line with the principles of sustainable development. This paper defines the task of choosing a sustainable model for shipment delivery and proposes the AROMAN method for its resolution. The applicability of the proposed method is demonstrated by solving the defined task in the territory of the city of Belgrade.

1. Introduction

The development of e-commerce and other business models, whose core activities depend on the transfer of shipments between sender and recipient locations, has led to the generation of a large number of shipments in postal and other delivery systems. The challenges faced by delivery companies in optimizing business activities are further complicated by regulations that focus on improving the sustainability of systems.

In the last decade, significant technological development has contributed to the evolution of postal companies. In addition to information systems and numerous software solutions that enable efficient business activities, substantial progress has occurred in the technological equipment and mechanization used in various phases of transportation. Furthermore, the development of the automotive industry and cargo transport has allowed for the renewal of fleets in companies.

In line with European Union regulations, emphasis has been placed on radically reducing harmful gas emissions. In the European Union (EU), transport accounts for about 30% of total CO_2 emissions, with over 70% coming from road transport. The EU has set a long-term goal to reduce emissions from transport by 60% by 2050 compared to 1990 levels. This has accelerated the process of implementing

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hybrid and electric propulsion in transportation vehicles, as well as other alternative fuels. Today, there is a trend of electrification in the fleets of postal companies.

In the process of shipping, the last phase - shipment delivery - stands out due to its characteristics, especially in terms of the complexity of organizing business activities and the numerous constraints and requirements for fast and efficient transfer. Additionally, delivery represents the most expensive phase in the shipment transfer process. Therefore, optimizing business activities in this phase is of great importance, as confirmed by a large number of studies addressing these tasks.

In this paper, within a case study, the task of choosing a suitable model for delivering shipments in part of the territory of Belgrade was addressed. By applying the proposed AROMAN method in collaboration with experts, the alternatives or delivery models were ranked.

2. Literature Review

In this section, a literature review in the field of shipment delivery is presented. The authors of this paper have explored databases of scientific papers published in the last five years. Given the widespread popularity in the field of delivery, scientists and postal operators worldwide are making significant efforts to ensure that the end user, a crucial factor, is satisfied. The result is the publication of a large number of papers in this field in recent years [1, 2]. The authors address various issues, such as sustainable delivery [3], the choice of cargo bicycle distribution concepts [4], the selection of electric vehicles for delivery [5], sustainable modes of delivery in urban logistics [6], innovative solutions, concepts, challenges, and practices in the delivery phase [7], consequences and obstacles in the delivery phase [8], challenges and solutions for driverless delivery [9], factors influencing the acceptance of green delivery by e-shoppers [10], measuring customer satisfaction in the e-commerce delivery phase [11], and the potential of drone delivery [12]. For better clarity, the research results are also presented in Table 1.

Table 1
Literature review in the field of shipment delivery

References	Tasks
Švadlenka et al. [3]	Sustainable delivery
Bošković et al. [4]	Choice of cargo bike distribution concept
Bošković et al. [5]	Choosing an electric vehicle for delivery
Yilmaz et al. [6]	Sustainable delivery modes in urban logistics
Mohammad et al. [7]	Innovative solutions, concepts, challenges, and practices in the delivery phase
Balaska et al. [9]	Challenges and solutions for driverless delivery
Kader et al. [10]	Factors influencing the acceptance of green delivery by e-commerce customers
Vrhovac et al. [11]	Measuring customer satisfaction in the e-commerce delivery phase
Eskandaripour & Boldsaikhan [12]	The potential of drone delivery

In this paper, the authors have chosen to apply a novel multicriteria approach to solving the problem of selecting a sustainable delivery model, recently developed by Bošković et al. [5]. Considering the method's relatively recent development, it has been applied to address several types of problems to date: an Intuitionistic Fuzzy model for assessing the performance of Eco Ports [13], an interval decision-making method of type-2 fuzzy AROMAN for enhancing the sustainability of postal networks in rural areas [14], a decision-making model for selecting professional drivers [15], and the evaluation of sustainable human resource management in manufacturing companies [16]. The results are presented in Table 2.

Table 2
Overview of the applications of the AROMAN method in the literature

References	Tasks
Bošković et al. [5]	Choosing an electric vehicle for delivery
Yalçın et al. [13]	Model for assessing the performance of eco ports
Nikolić et al. [14]	Improving the sustainability of the postal network in rural areas
Čubranić-Dobrodolac et al. [15]	Selection of professional drivers
Rani et al. [16]	Assessment of Sustainable HRM in manufacturing companies
This paper	Sustainable delivery model – choice of delivery mode

3. The AROMAN Method

The AROMAN method is one of the newer multicriteria analysis methods developed by Bošković et al. [5]. This method combines normalized data from normalization in two steps and obtains an average aggregated matrix from normalized data. The AROMAN method can be described in the following steps:

Step 1 – *Determination of the initial decision matrix with input data.*

Before initiating the decision-making process, it is necessary to define the initial decision matrix with input data. Depending on the problem, input data is typically pre-collected in terms of alternatives and criteria. Therefore, let us assume that we have a decision matrix X_{mxn} with input data $x_{11}, \dots, x_{2j}, \dots, x_{mn}$:

$$X = \begin{bmatrix} x_{11} & \cdots & x_{1j} & \cdots & x_{1n} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ x_{21} & \cdots & x_{2j} & \cdots & x_{2n} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ x_{m1} & \cdots & x_{mj} & \cdots & x_{mn} \end{bmatrix}; \; i = 1, 2, \dots, m, j = 1, 2, \dots, n. \tag{1}$$

Step 2 – *Normalization of input data.*

After defining the decision matrix with input data, the second step is the normalization of input data. This means that the input data should be structured within the intervals between 0 and 1. There are two types of normalization (Eq. (2) and Eq. (3)):

Step 2.1. *Linear normalization:*

$$t_{ij} = \frac{x_{ij} - \min_i x_{ij}}{\max_i x_{ij} - \min_i x_{ij}}; \; i = 1, 2, \dots, m, j = 1, 2, \dots, n. \tag{2}$$

Step 2.2. *Vector normalization:*

$$t_{ij}^{*} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}}; \; i = 1, 2, \dots, m, j = 1, 2, \dots, n. \tag{3}$$

Step 2.3. *Average aggregated normalization:*

Aggregated average normalization is performed using Eq. (4):

$$t_{ij}^{norm} = \frac{\beta t_{ij} + (1-\beta) t_{ij}^{*}}{2}; \; i = 1, 2, \dots, m; j = 1, 2, \dots, n. \tag{4}$$

where t_{ij}^{norm} denotes the aggregated average normalization, β is the weighting factor that varies in the range from 0 to 1. In our case, we considered β = 0.5.

Step 3 – *Determination of the weighted average normalized decision matrix.*

The weighted average normalized matrix is calculated based on Eq. (5):

$$\widehat{t_{ij}} = W_{ij} \cdot t_{ij}^{norm}; i = 1, 2, \dots, m, j = 1, 2, \dots, n. \tag{5}$$

Step 4 – *Summation of weighted normalized values according to the criterion type.*

This can be calculated using Eq. (6) and Eq. (7):

$$L_i = \sum_{j=1}^{n} \hat{t}_{ij}^{(min)}; i = 1, 2, \dots, m, j = 1, 2, \dots, n, \tag{6}$$

$$A_i = \sum_{j=1}^{n} \hat{t}_{ij}^{(max)}; i = 1, 2, \dots, m, j = 1, 2, \dots, n. \tag{7}$$

Step 5 – *Raising the obtained sum of values L_i and A_i to the parameter λ.*

This step is calculated using Eq. (8) and Eq. (9):

$$L_i^{\wedge} = L_i^{\lambda} = (\sum_{j=1}^{n} \hat{t}_{ij}^{(\mathrm{min})})^{\lambda}; i = 1, 2, \dots, m, j = 1, 2, \dots, n, \tag{8}$$

$$A_i^{\wedge} = A_i^{1-\lambda} = (\sum_{j=1}^{n} \hat{t}_{ij}^{(max)})^{1-\lambda}; i = 1, 2, \dots, m, j = 1, 2, \dots, n. \tag{9}$$

where λ represents the power of the criterion type coefficient. Since we have included both types of criteria, we considered the parameter λ=0.5.

Step 6 – *Calculating the difference between the values $L_i^{\wedge}$ and $A_i^{\wedge}$ and applying Eq. (10) for final ranking (R_i)*:

$$R_i = e^{(A_i - L_i)}; i = 1, 2, \dots, m. \tag{10}$$

where R_i denotes the final rank of alternatives.

4. Case Study

As part of the case study, a portion of the territory of Belgrade was analyzed (Figure 1), which is a suitable representation of the entire city due to its topography, population density, and developed transportation network. The primary goal was to define a ranking for a selected set of delivery alternatives based on the specified criteria. The AROMAN multicriteria analysis method was applied in collaboration with experts in the postal traffic domain. Criteria and delivery alternatives were first defined. Subsequently, the assessment of criteria and alternatives in relation to the given criteria was carried out.

In collaboration with experts, the following criteria were established:

i. *Investment and operation costs* (K_1) – Encompassing all costs related to establishing a system, including education, technology acquisition, and resources that will ensure the smooth functioning of a specific delivery method. Additionally, it involves costs incurred during the delivery process.

ii. *Energy efficiency* (K_2) – Relates to energy consumption during the delivery process. The significance of energy efficiency is reflected not only in costs but also in the reduction of harmful gas emissions. One of the main goals of socially responsible companies is to reduce the negative impact on the environment and promote environmentally responsible business practices.
iii. *Noise level* (K_3) – Noise in the context of parcel delivery has a significant impact on the environment and the quality of life of residents, especially in urban areas. Delivery activities involve the use of various types of vehicles that generate a significant noise level. There is a trend towards developing quieter and environmentally friendly delivery models.
iv. *Public space occupation* (K_4) – Involves the use of public spaces during the delivery process. One of the most prevalent examples is the parking of vehicles used for delivery. Depending on the delivery model, this can be a significant constraint, especially in urban environments.
v. *Delivery speed* (K_5) – Relates to the time it takes to complete a delivery, with a tendency for it to be as short as possible. This parameter is crucial in the era of e-commerce expansion, where next-day delivery becomes the standard. Customers are increasingly demanding, expecting their shipments to be delivered as quickly as possible.
vi. *Delivery capacity* (K_6) – Depending on the delivery model, the capacity, i.e., the number of shipments that can be delivered within a specific time interval, varies. There are models where individual deliveries can be realized in a very short time interval. However, due to the limited cargo space of the transport vehicle, a longer waiting period occurs for the next delivery (until the transport vehicle returns to the center, where loading for the next delivery takes place).
vii. *Health and safety at work* (K_7) – It plays a crucial role in parcel delivery systems, where workers often operate under deadline pressure, extensive routes, and strenuous physical demands. Depending on the delivery model, workers are exposed to various risks, as are other individuals who may be in close proximity to business activities.
viii. Mobility (adaptability to different conditions) (K_8) – Depending on the delivery model, the use of a specific means of transportation varies, and consequently, the ability to respond to different unforeseen circumstances. A common example from practice is traffic congestion, where the delivery process is expected to continue with an alternative route in a short time interval.
ix. *Complexity of delivery execution* (K_9) – Parcel delivery can be a very complex process due to numerous factors influencing the success of the entire process. These factors include the choice of the delivery model, traffic dynamics, various delivery routes, types of shipments, and client needs.
x. *Adaptation to weather conditions* (K_{10}) – Involves the independence of the delivery model from weather conditions; i.e. the ability of a particular delivery model to adapt to changes in weather conditions.

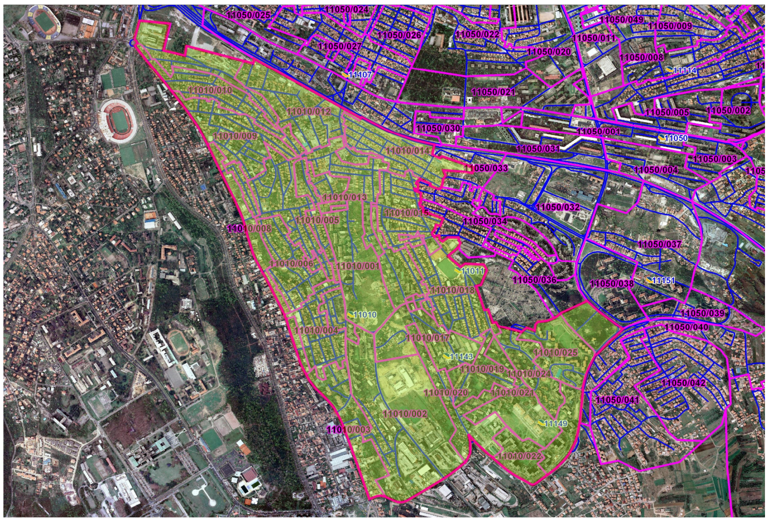

Fig. 1. Analyzed Territory

In addition to the mentioned criteria, for the multicriteria decision-making task, the following seven alternative delivery models have been identified, with the assumption that each alternative is subject to regulatory conditions for operation:

i. *Walking mail carrier* (A_1) – Involves the original form of traditional parcel delivery performed by a mail carrier who does not use any means of transportation. This approach is still present in many urban and rural areas.
ii. *Electric cargo bicycle* (A_2) – Parcel delivery using electric cargo bicycles is an innovative and environmentally friendly model. Cargo bicycles are equipped with electric propulsion and cargo space, enabling drivers to cover longer distances and transport a larger number of parcels.
iii. *Electric scooter* (A_3) – Parcel delivery by e-scooter is becoming increasingly popular in urban environments. Currently, they are mainly used for food delivery but are becoming more prevalent for delivering other types of parcels.
iv. *Electric mobile parcel locker* (A_4) – Unlike fixed parcel lockers, these move along a defined route in accordance with demands. Users have the option to track the location of the mobile parcel locker through an application, allowing them to plan the use of the service. Mobile electric parcel lockers represent a step forward in sustainable delivery.
v. *Electric car* (A_5) – Involves the traditional concept of parcel delivery by a courier who, in this case, uses an electric car for carrying out delivery activities.
vi. *Autonomous delivery robot* (A_6) – Represents a technologically innovative delivery model involving a robot that moves without a driver. The robot's movement is facilitated by an appropriate system of sensors and a navigation system. Upon reaching the delivery location, after authentication, the user is granted access to the cargo space and the parcel.
vii. *Drone* (A_7) – Relies on the use of unmanned aerial vehicles for parcel delivery. This concept has numerous advantages, such as fast delivery and the ability to reach difficult-to-access locations. However, there are also certain limitations, including regulations, safety, and delivery capacity.

5. Results and Discussion

After applying the AROMAN method, the final ranking of alternatives was obtained. The results are presented in Tables 3–8. The first step is the formation of the input data matrix, which was created based on consultations with experts in the postal traffic field. Three experts provided importance ratings on a scale from 1 to 10 for each alternative based on the identified criteria. Additionally, the experts assessed the importance of each criterion, considering that not all criteria are equally important to decision-makers. The input data matrix is presented in Table 3.

Table 3
Initial matrix of input data

	K_1	K_2	K_3	K_4	K_5	K_6	K_7	K_8	K_9	K_{10}
A_1	5	10	1	1	1	2	2	4	2	5
A_2	3	9	2	3	7	7	4	7	3	4
A_3	4	7	3	2	6	2	1	6	3	3
A_4	2	3	5	8	4	10	6	4	6	9
A_5	1	4	4	7	5	9	6	4	4	9
A_6	8	7	2	5	2	5	7	3	9	5
A_7	7	7	6	2	8	1	7	10	10	4
W_i	0.11554	0.09960	0.09960	0.06375	0.09562	0.10359	0.11952	0.11155	0.09163	0.09960

Following the formation of the initial decision-making matrix, the next step is the normalization of input data. In other words, this is the process of reducing data to a range from zero to one with the aim of obtaining the same data structure. In the AROMAN method, a combination of two types of normalization, linear and vector normalization, is used. Afterward, the normalized data is created through the aggregation of linear and vector normalization following the steps of the AROMAN method. The normalized data is respectively presented in Tables 4–6.

Table 4
Linear normalization

	K_1	K_2	K_3	K_4	K_5	K_6	K_7	K_8	K_9	K_{10}
A_1	0.5714	1.0000	0.0000	0.0000	0.0000	0.1111	0.1667	0.1429	0.0000	0.3333
A_2	0.2857	0.8571	0.2000	0.2857	0.8571	0.6667	0.5000	0.5714	0.1250	0.1667
A_3	0.4286	0.5714	0.4000	0.1429	0.7143	0.1111	0.0000	0.4286	0.1250	0.0000
A_4	0.1429	0.0000	0.8000	1.0000	0.4286	1.0000	0.8333	0.1429	0.5000	1.0000
A_5	0.0000	0.1429	0.6000	0.8571	0.5714	0.8889	0.8333	0.1429	0.2500	1.0000
A_6	1.0000	0.5714	0.2000	0.5714	0.1429	0.4444	1.0000	0.0000	0.8750	0.3333
A_7	0.8571	0.5714	1.0000	0.1429	1.0000	0.0000	1.0000	1.0000	1.0000	0.1667

Table 5
Vector normalization

	K_1	K_2	K_3	K_4	K_5	K_6	K_7	K_8	K_9	K_{10}
A_1	0.3730	0.6047	0.0000	0.0000	0.0000	0.0709	0.0870	0.1140	0.0000	0.2209
A_2	0.1865	0.5183	0.1336	0.1933	0.5145	0.4253	0.2611	0.4558	0.0861	0.1104
A_3	0.2798	0.3455	0.2673	0.0967	0.4287	0.0709	0.0000	0.3419	0.0861	0.0000
A_4	0.0933	0.0000	0.5345	0.6767	0.2572	0.6380	0.4352	0.1140	0.3443	0.6626
A_5	0.0000	0.0864	0.4009	0.5800	0.3430	0.5671	0.4352	0.1140	0.1721	0.6626
A_6	0.6528	0.3455	0.1336	0.3867	0.0857	0.2836	0.5222	0.0000	0.6025	0.2209
A_7	0.5595	0.3455	0.6682	0.0967	0.6002	0.0000	0.5222	0.7977	0.6885	0.1104

Table 6
Aggregated normalization

	K_1	K_2	K_3	K_4	K_5	K_6	K_7	K_8	K_9	K_{10}
A_1	0.2361	0.4012	0.0000	0.0000	0.0000	0.0455	0.0634	0.0642	0.0000	0.1385
A_2	0.1181	0.3439	0.0834	0.1198	0.3429	0.2730	0.1903	0.2568	0.0528	0.0693
A_3	0.1771	0.2292	0.1668	0.0599	0.2858	0.0455	0.0000	0.1926	0.0528	0.0000
A_4	0.0590	0.0000	0.3336	0.4192	0.1715	0.4095	0.3171	0.0642	0.2111	0.4156
A_5	0.0000	0.0573	0.2502	0.3593	0.2286	0.3640	0.3171	0.0642	0.1055	0.4156
A_6	0.4132	0.2292	0.0834	0.2395	0.0572	0.1820	0.3806	0.0000	0.3694	0.1385
A_7	0.3542	0.2292	0.4170	0.0599	0.4001	0.0000	0.3806	0.4494	0.4221	0.0693

The next step is the formation of the weighted aggregated decision matrix. Afterward, the sums of all criteria by rows are determined, depending on the type of criteria. In other words, as suggested by the AROMAN method, criteria of the minimum type are summed separately from criteria of the maximum type. The result of this step is presented in Table 7.

Table 7
Weighted aggregated normalization matrix with sums by criterion type

	K_1	K_2	K_3	K_4	K_5	K_6	K_7	K_8	K_9	K_{10}	L_i	A_i
A_1	0.0273	0.0400	0.0000	0.0000	0.0000	0.0047	0.0076	0.0072	0.0000	0.0138	0.0273	0.0732
A_2	0.0136	0.0342	0.0083	0.0076	0.0328	0.0283	0.0227	0.0286	0.0048	0.0069	0.0344	0.1536
A_3	0.0205	0.0228	0.0166	0.0038	0.0273	0.0047	0.0000	0.0215	0.0048	0.0000	0.0457	0.0764
A_4	0.0068	0.0000	0.0332	0.0267	0.0164	0.0424	0.0379	0.0072	0.0193	0.0414	0.0861	0.1453
A_5	0.0000	0.0057	0.0249	0.0229	0.0219	0.0377	0.0379	0.0072	0.0097	0.0414	0.0575	0.1517
A_6	0.0477	0.0228	0.0083	0.0153	0.0055	0.0189	0.0455	0.0000	0.0338	0.0138	0.1052	0.1064
A_7	0.0409	0.0228	0.0415	0.0038	0.0383	0.0000	0.0455	0.0501	0.0387	0.0069	0.1250	0.1636
Min/Max	Min	Max	Min	Min	Max	Max	Max	Max	Min	Max	–	–

After this step, the values $\hat{L_i}$ and $\hat{A_i}$ are determined, along with the final ranking of alternatives. The results are presented in Table 8.

Table 8
Weighted aggregated normalization matrix with sums by criterion type

Alternatives	$\hat{L_i}$	$\hat{A_i}$	$e^{(A_i - L_i)}$	Rankings
A_1	0.1652	0.2706	1.1112	3
A_2	0.1855	0.3919	1.2293	1
A_3	0.2138	0.2763	1.0645	5
A_4	0.2934	0.3812	1.0917	4
A_5	0.2398	0.3895	1.1615	2
A_6	0.3243	0.3262	1.0020	7
A_7	0.3535	0.4045	1.0523	6

As seen in Table 8, the best alternative for the given case study is A_2 - electric cargo bicycle. The overall ranking of alternatives is presented in the following descending order: $A_2 > A_5 > A_1 > A_4 > A_3 > A_7 > A_6$.

4. Conclusions

Sustainable business practices are imperative for every company in any industry. It is based on responsible actions in all three dimensions of sustainability – environmental, social, and economic. By following this concept, companies can achieve significant success in the market. The paper analyzes sustainable delivery models, considering defined criteria, with the aim of selecting the most suitable model for a part of the territory of Belgrade.

Through collaboration with experts and the application of multicriteria analysis, 10 key criteria and seven different delivery alternatives were identified. The research results indicate that the most suitable model for sustainable delivery in the observed territory is the one that involves the use of electric cargo bicycles. This decision was made based on the model's ability to meet all the specified criteria, including sustainability, economic benefits, and practicality.

The obtained results confirm the importance of using alternative delivery models, especially in urban environments where congestion and harmful gas emissions are increasingly problematic. Shipment delivery systems will continue to shape themselves in the future with a focus on speed, efficiency, and sustainability, while modern technological solutions will play a significant role in meeting customer needs and enhancing the delivery experience.

Conflicts of Interest

The authors declare no conflicts of interest.

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