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Article

Application of AHP and DEMATEL methods in choosing and analysing the measures for the distribution of goods in Szczecin region

Kinga Kijewska [1,*], Witold Torbacki [1], Stanisław Iwan [1,*]

[1] Maritime University of Szczecin, Faculty of Economics and Engineering of Transport, 11 Pobożnego Str., 70-507 Szczecin, Poland; k.kijewska@am.szczecin.pl (K.K.); w.torbacki@am.szczecin.pl (W.T); s.iwan@am.szczecin.pl (S.I.)

* Correspondence: s.iwan@am.szczecin.pl

Abstract: Urban areas are centres of business and innovation. Freight transport is indispensable for the proper functioning of any modern urban society. Urban areas can't function without an appropriate freight transport system, due to the need to replenish stocks of food and other goods in retail shops. The complexity of the decisions concerning implementation of measures to improve the movement of goods in the city requires tools designed to support this process. The purpose of this article is to introduce the possibility of applying the Analytic Hierarchy Process (AHP) as well as the Decision Making Trial and Evaluation Laboratory Method (DEMATEL) in choosing a set of measures and in analysing in the field of distribution logistics, which will help to solve the delivery problems and streamline the cargo flows in Szczecin, in the context of sustainable development.

Keywords: urban freight transport; city logistics; decision making process; multi-actor decision support; Multi-Criteria Decision Analysis; MCDA; Analytic Hierarchy Process; AHP; Decision Making Trial and Evaluation Laboratory Method; DEMATEL

1. Introduction

Efficient functioning of transportation systems in cities depends on a proper implementation of measures that enable effective management of the processes taking place in the subsystems, as well as on their correlation with the whole urban system. The complexity of the structural interdependencies and its considerable heterogeneity imply a need to focus on efficient methods helping to choose appropriate measures that take into account the expectations of different stakeholders engaged in urban freight transport systems functioning (e.g. transport system users, local or regional administration, business entities, logistics operators, etc.).

A city, being a system of economic entities which are its users, operates and develops as a result of a variety of activities performed by each of these entities. Individual entities fulfil specific functions, striving to achieve their objectives. However, objectives of individual entities are generally diverse, which often leads to a conflict of interest. This is particularly important with respect to the freight transport subsystem, and it results from its specificity. Lack of consensus between the expectations of different groups of stakeholders can cause many problems and risks relating to social, economic and environmental issues. Therefore, appropriate management and implementation of appropriate measures play an important role in the functioning of urban freight transport.

In recent years, many international projects and activities were focused on the problems of proper implementation of measures in urban freight transport, like for example BestUFS [1], TRAILBLAZER [2], SUGAR [3], C-LIEGE [4], STRAIGHTSOL [5], COFRET [6], GRASS [7] or the new NOVELOG project that is currently underway [8]. These projects developed some different methodological approaches and some methods which could be helpful in the decision making

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process. This paper is focused on the example of applying the multi-criteria decision analysis (MCDA) to support the choice of measures to be implemented in the UFT system, including the points of view of different stakeholders.

Diverse expectations of stakeholders and complexity of the system affect the structure of the decision making process in the UFT area. The approach where different and usually conflicting objectives of various stakeholder groups are considered is called the multi-actor multi-criteria analysis (MAMCA) [9]. The major difference of this methodology compared to the typical multi-criteria decision analysis is the introduction of different stakeholder groups at a very early stage of the decision making process [10].

The major objective of this paper is to introduce the Analytic Hierarchy Process (AHP) as well as the Decision Making Trial and Evaluation Laboratory Method (DEMATEL) as an efficient analysis and decision-making methods for the purposes of choosing UFT measures in the context of sustainable development. The presented approach was successfully applied in the Szczecin Municipality (Poland) during the implementation of a sustainable UFT system in the city area. Based on the results, the most appropriate solutions were chosen.

The approach presented in this paper could support decision-makers in cities. A critically important part of the multi-criteria decision process is a proper analysis of the correlations between the criteria. The results of the comparative analysis of the criteria introduced in this paper could help to simplify the decision process.

2. Decision making process in urban freight transport systems as the multi-criteria decision analysis (MCDA)

Being a complex system, the city is an important area for human functioning. Ensuring an effective system for the movement of both people and goods to a large extent determines the quality of life in the city and its competitiveness in relation to other cities. A growing number of users (residents, visitors or companies operating in it) leads to an increase in the demand for transport of goods - raw materials, semi-finished products, finished products as well as industrial and municipal waste. The largest part of this transport is generated by industrial, commercial and service entities. The distribution initiated by these companies increases the logistics flows in a limited area. Urban areas are important centres of economic activity and innovation. Transportation of goods is essential for the proper functioning of a modern urban society. No urban area can function without an adequate freight transport system, due to the need for replenishment of food and other goods in retail stores, delivery of documents, parcels and other accessories necessary for everyday functioning of offices.

2.1. Urban freight transport as a city sub-system

The city can be defined as a dynamically changing open system [11]. It includes two key subsystems: physical (consisting of buildings connected by streets, roads and infrastructure), and human (which consists of traffic, interactions and activities of its residents) [12].

The purpose of any urban system is to serve its residents and visitors. Its implementation, however, depends on proper cooperation between urban subsystems, in line with the principle of synergy. Bearing in mind that relationships between elements are constantly changing the system as a whole and include many interrelated and interdependent elements, we can say that the logistics and transport functions performed by the city form a logistics subsystem, which may include transport of material goods and media transmission, transport and storage of municipal waste, collective and individual transport, storage of goods in the industrial and commercial districts and trade chains of the city, and control of the flow of goods and persons [13].

It should be emphasized that differentiation between the city's subsystems depends on the adopted interpretation. In the above example, the adopted criterion includes logistic functions performed by the individual subsystems. From the spatial perspective, a logistics system of the city can be divided into: logistics subsystem of the city centre, logistics subsystem of suburban areas or logistics subsystem of industrial areas, logistics subsystem of residential zones, and others depending on the urban structure, delimitation of individual areas, the nature and specifics of the city and so on. With regard to the implementation of the transport processes, two major subsystems should be emphasized: passenger transport subsystem, and freight transport subsystem.

Locating urban freight transport in the city logistic system requires to extract it from the goods transport subsystem, while stressing its strong correlation with goods and persons flow control subsystem. It can be assumed that it is a set of the following components (Fig. 1) [11]:

- transportation;
- storage and selling points, goods processing and types of movements executed;
- handling and types and requisites of handling along the physical flows;
- location and management of the basic infrastructure for the physical flows processing, including warehouse activities of inbound and outbound goods;
- logistics information systems activities.

The system complexity is determined by four key elements [14]: purpose and function, size and configuration, structure (including the composition and layout), and type of growth (dynamics). By emphasizing components included in the urban freight transport system, it can be described as follows:

$$S_{UFT} = (U, G_{m,n}, V, P, W, I_{m,n}, Z_{m,v}, R_{p,q}, R'_{e,p}) \quad (1)$$

where:

S_{UFT} – urban freight transport system;

U – set of stakeholders (the system users), being $U = \{U_R, U_S, U_C, U_A, U_M\}$, where:

- U_R – residents,
- U_S – shippers,
- U_C – freight carriers,
- U_A – administration;
- U_M – manufacturers;

$G_{m,n}$ – volume of the demand for goods, declared by *m-th* purchaser from *n-th* supplier, where $m, n \in U$;

V – set of transport means (delivery vehicles);

P – storage and selling points, goods processing and types of movements executed;

W – location and management of the basic infrastructure for the physical flows processing;

$I_{m,n}$ – information between stakeholder m and n, where $m, n \in U$;

$Z_{m,v}$ – transport tasks carried out by supplier m, by transport means v;

$R_{p,q}$ – set of relations within the system, where $p, q \in \{U, G_{m,n}, V, P, W, I_{m,n}, O_{m,v}\}$

$R'_{e,p}$ – set of relations with element e of environment E, where $e \in E$ and $p \in \{U, G_{m,n}, V, P, W, I_{m,n}, O_{m,v}\}$.

This formula highlights the complexity of the structure of urban freight transport and the relationships that exist therein. This is the basis for the analysis of management processes in the system studied.

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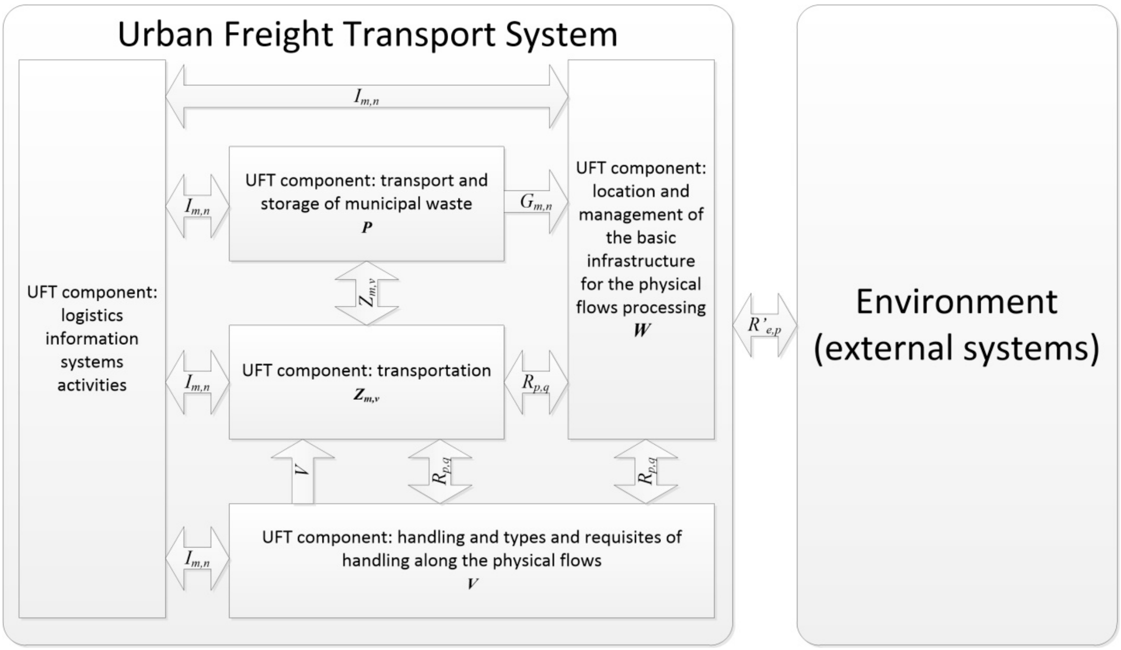

Figure 1. The structure and inter-relations of UFT system. Source: own study.

Freight transport in the cities depends on sites in which economic activity takes place, goods that require transportation to and from the sites, vehicles that provide transportation services, and city infrastructure [15]. These elements interact in four functional aspects of the city: accessibility, land use, transport and traffic. The transport system capacity is determined by the interaction between the above mentioned elements that should be taken into account in comprehensive planning, organizing and controlling of the movement of goods in the city. This subsystem primarily affects the health of residents, noise and environmental pollution, safety and the occurrence of congestion [16]. Delivery vehicles compete with public passenger and individual transport for limited road infrastructure (nodal and linear infrastructure). This leads to transport congestion as a result of which freight transport is perceived negatively by the locals.

2.2. Different expectations of UFT stakeholder groups/ Influence of stakeholders on urban freight transport management process

When analysing the issue of UFT measures implementation, the first of the factors determining the efficiency of this process that should be emphasized is the need to ensure consensus between the expectations of different groups of stakeholders. In addition, it is necessary to identify the key groups that directly influence management processes.

Classification of urban freight transport stakeholders primarily must involve extracting the individuals, institutions and organizations representing the private sector (chambers of commerce, wholesalers, retailers, manufacturers, logistics providers, as well as residents and users of cities, shop owners, developers, etc.) as well as institutions and organizations of the public sector (in particular local government and authorities - local, regional and national authorities, road authorities, police, etc.). In general, these stakeholders can be divided into five basic groups, which determine functioning of the system to a various degree and in different contexts [17,18]:

- shippers – this is a group that includes both senders and recipients of goods, usually retailers, wholesalers and manufacturers;
- freight carriers – this group includes external professional transport operators, logistics service providers, courier services, private providers, urban managers of supply centres and dispatchers;

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- residents – this group includes both city residents as well as other city users, like commuters and visitors, people who come to the city to do shopping, and any other road traffic participants such as store owners, developers, associations and organizations of citizens and consumers;
- city administrators – this group can be divided into administrators of urban system for goods distribution, like regional authorities, municipalities, municipal managers of supply centres and other administrators, providing inputs to the system, like planners, policy makers, infrastructure managers and supporting institutions, such as chambers of commerce, associations of cities, etc.;
- truck & vehicle manufacturers as well as manufacturers of non-conventional delivering technologies.

These groups can perform four basic roles in the urban freight transport system [18]:

- want it –these are the transport market participants, who want the system to limit the problems associated with the movement of vehicles and its impact on the environment; to provide information services on routes, provide facilities for freight operators and to create better living conditions for the residents and users of the city; this group includes mainly local authorities, residents, groups and associations representing the interests of the city, but also retailers, shop owners or developers;
- make it – mostly suppliers of equipment and software for the creation of a system, vehicle manufacturers, system integrators, providers of innovative solutions for loading and unloading or loading units, city developers, etc.;
- use it – this class of users includes two categories: primary and secondary; primary users use the results of the system, e.g. retailers, carriers, freight forwarders, drivers; secondary users control the system and introduce, inter alia, a substantial portion of the input data e.g. traffic control operators, freight dispatchers, distribution centre managers;
- rule it – usually local authorities responsible for issuing the regulations (e.g. in the field of environmental zoning, traffic restrictions, time windows, using dedicated lanes, parking spaces, or infrastructure).

The factor which has a direct impact on the heterogeneity of urban freight transport is a diversity of needs (goals) and expectations of stakeholders representing these groups. In general, these goals relate primarily to the profit growth for shippers and contractors, and the well-being factor for city residents (safety, quality of life, freedom of movement around the city). From the perspective of public administration, what is of crucial importance is to enhance the economic efficiency of cities and to reduce the negative impact of transport on the urban environment.

From the perspective of efficient management of a freight transport system, three main categories of stakeholders should be noted, who have a direct influence on decisions made within this system. These are:

- local authorities, which make decisions regulating and conditioning the transport processes in the city,
- transport system monitoring and security entities, which supervise the organization and functioning of transport within the city and react in emergencies in order to reduce the negative impact of any events occurring in the urban space on the functioning of the entire transport system;
- shippers and freight carriers, who are directly responsible for rendering their services and making key decisions affecting their performance and effectiveness.

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3. Methodological background

The basis of the analysis introduced in this paper is the multi-criteria decision analysis (MCDA). This approach is well known in the area of transport. In recent years, it was many a time applied for the purposes of analyses of e.g. support for material flow management in a whole supply chain [19], location of logistics centres [20], evaluation of transport policies to reduce climate change impacts [21].

Due to the facts emphasized in the previous section, urban freight transport lends itself to application of MCDA. Some interesting examples are presented in [22-24]. The purchase and distribution of goods in the city meets difficulties resulting from the infrastructure overload, the external costs and disputes between the stakeholders. Urban distribution of goods is organized by private entities (manufacturers, carriers, retailers, end-consumers), working or living in the urban space that is managed by a public authority. The public sector plays an important role in the planning of infrastructure, initiating implementation of new solutions, undertaking activities to acquire knowledge of problems that exist or may arise in the supply of goods in the city. The complexity of decisions taken on implementation of measures to improve the flow of goods in the city requires tools to streamline the decision-making process, keeping in mind the need to balance the goals represented by the various stakeholders. An interesting approach is the multi actor multi-criteria analysis (MAMCA) proposed by C. Macharis [9]. This approach is based on engagement of all UFT stakeholder groups in the multi-criteria decision analysis. The analysis is performed in 7 steps [10]:

1. define alternatives,
2. stakeholder analysis,
3. define criteria and weights,
4. criteria, indicators and measurement methods,
5. overall analysis and ranking,
6. results,
7. implementation.

Examples of applying this approach are introduced in [25-29].

The most important aspect for MCDA efficiency is to choose the proper analytical method. There are many of them, e.g. ELECTRE (ELimination and Choice Expressing REality) I, II, III and IV, PROMETHEE I and II, MAPPACC, PRAGMA, ANP (Analytic Network Process), AHP (Analytic Hierarchy Process) and the Decision Making Trial and Evaluation Laboratory Method (DEMATEL). These methods are focused on many attributes of problems, like the analysis of chosen methods introduced in [30] and [31]. Also, the analysis of applying more than 40 MCDA methods to solve the MCDA problems was discussed in [32, 33]. A comparison of the chosen methods is presented in Table 1. Due to the specificity of the problems discussed in this paper and according to guidelines presented in [34] and [35], the single-criterion-preference-aggregation was taken into account.

Table 1. Comparison of selected MCDA methods. Source: own study based on [32,33].

Method name	Preference relations	Compensation effect	Preferential information
AHP	Indifference, Preference	Partial	Cardinal, Deterministic, Non-deterministic
ANP	Indifference, Preference	Partial	Cardinal, Deterministic, Non-deterministic
COMET	Indifference, Preference	Total	Ordinal, Cardinal, Deterministic, Non-deterministic, Fuzzy
DEMATEL	Indifference, Preference	Partial	Cardinal, Deterministic, Non-deterministic, Fuzzy
EVAMIX	Indifference, Preference	Partial	Ordinal, Cardinal, Deterministic

Method name	Preference relations	Compensation effect	Preferential information
MACBETH	Indifference, Preference	Partial	Ordinal, Cardinal, Deterministic, Non-deterministic
MAUT	Indifference, Preference	Partial	Cardinal, Non-deterministic
MAVT	Indifference, Preference	Partial	Cardinal, Deterministic
Maximin	Indifference, Preference	No	Ordinal, Cardinal, Deterministic
Maximin fuzzy method	Indifference, Preference, Weak preference	No	Ordinal, Cardinal, Deterministic, Non-deterministic, Fuzzy
Simple Additive Weighting (SAW)	Indifference, Preference	Total	Cardinal, Deterministic
SMART	Indifference, Preference	Partial	Cardinal, Deterministic
TOPSIS	Indifference, Preference	Total	Cardinal, Deterministic
UTA	Indifference, Preference	Partial	Ordinal, Deterministic

The analysis presented in this paper is based on the Analytic Hierarchy Process (AHP) and the Decision Making Trial and Evaluation Laboratory Method (DEMATEL).

The DEMATEL methodology is often used in the case of numerical support of decision process [36-41]. In this paper, the DEMATEL is applied to evaluate the parameters used to create the system of monitoring of urban freight, which allows effective analysis of relations between the indicators. In effect, as a result of the implementation of the chain of methods and measures, which contain the determination of parameters, the creation of the perspectives and the performance of analysis with the use of AHP and DEMATEL technologies, the Szczecin Municipality obtains a powerful support mechanism in their strategic decision-making processes. It is also worthwhile to mention that approach of using both methods is increasingly used for various selected problems in logistics [42-45] as well as in other fields [46-49].

3.1. AHP method

The AHP method developed by T. L. Saaty belongs to a group of methods that apply the multi-functional model of hierarchical analysis [50,51]. It is applied especially to support multilevel decisions involving many criteria (this refers mainly to problems such as selection of projects, suppliers or technology) [52-55]. Since its formulation in the mid-seventies, the AHP method has been successfully applied to solve various social problems. For the first time it was applied in the US Department of Defence when fighting against terrorism. Then it was applied, among others, to determine the policy of exploitation of resources, energy policy or forecasting the results of presidential elections in the United States [52]. AHP is easy to use, scalable, its hierarchical structure can be easily adjusted to fit multidimensional problems and could be used with regard to performance-type problems, resource management, corporate policy and strategy, public policy, political strategy, and planning [31].

The decision criterion determines the allocation of all possible decision, quantitative or qualitative assessment of the benefits resulting from taking a particular decision. It should therefore enable assessing the preferences in connection with its choice. In the case of the multi-criteria model, each decision alternative is evaluated with respect to each criterion. Application of AHP provides a set of alternatives ordered according to their suitability in terms of various criteria. It should be emphasized that to a greater or lesser extent each of them depends on the same set of criteria. The decision-making process based on this method is carried out in the following steps:

- developing a hierarchical model,

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- creating a matrix of pairwise comparison of individual criteria,
- determining the CR (Consistency Ratio) and the possible adjustment of assessments,
- ranking decision alternatives.

The hierarchical model includes a graphical representation of the hierarchy of goals and the criteria affecting their implementation (Fig. 2). It is a tree structure consisting of three level categories: goal, criterion and alternative. The main goal may consist of intermediate goals, as well as criteria may depend on sub-criteria.

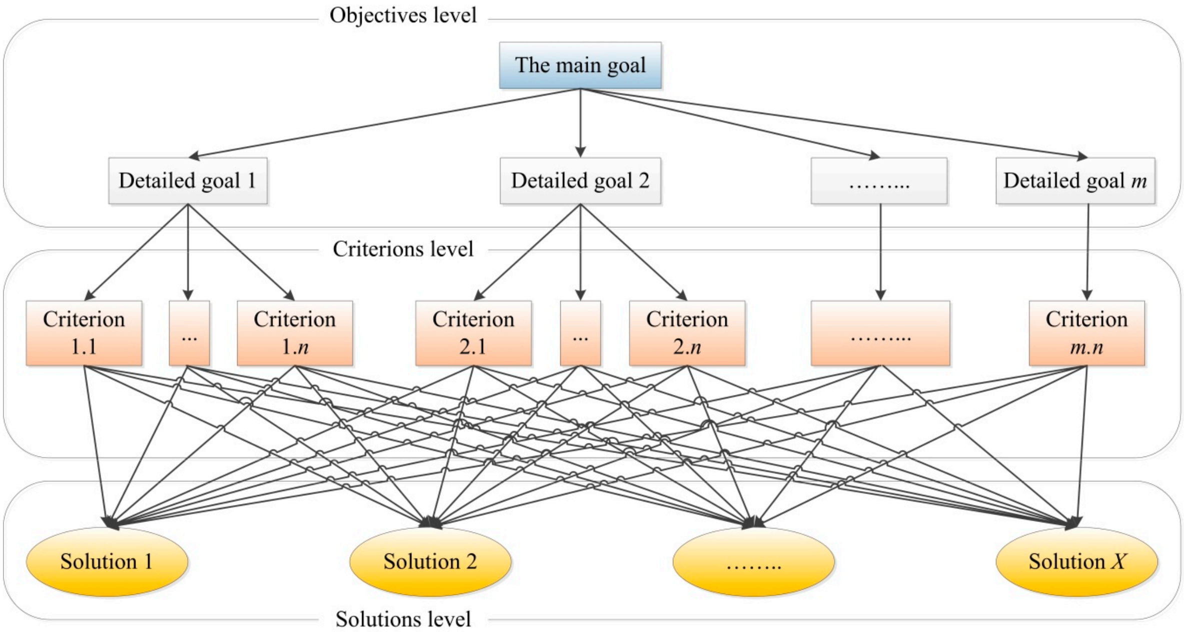

Figure 2. An example of the hierarchical model structure. Source: own study.

Alternative or criterion comparisons are conducted with the use of a pairwise comparison matrix. Each matrix ought to be reciprocal and positive. The proportion means that every matrix element fulfils the characteristics defined by the formula (2):

$$a_{ji} = \frac{1}{a_{ij}} \quad (2)$$

The interpretation of the formula (2) is as follows: if an element $a_{i,j}$ contains a value a, then an element a_{ji} should contain a reverse value, i.e. 1/a. Moreover, elements on the main diagonal $a_{i,i}$ should include unitary values [56]. When specifying the positivity of matrices one needs to point out that it should contain the Saaty's ratio scale, i.e. from the range of 1 to 9 and their opposite values, where 1 indicates equality of compared alternatives or criteria and 9 indicates an extreme advantage of an alternative or criterion i over j [57]. Therefore, each matrix is completed with one of 17 values: 1/9, 1/8, ..., 1/2, 1, 2, ..., 8, 9 [58]. The meanings of individual values of the Saaty's ratio scale are presented in Table 2.

For every pairwise comparison matrix a preference vector $w=[w_1, w_2 \ldots w_n]^T$ is defined, which demonstrates the force of alternatives or criteria compared in matrices. Components of the vector are included in the pairwise comparison matrix, which is presented in the formula (3) [50].

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$$\begin{array}{c} \\ A_1 \\ A_2 \\ \vdots \\ A_n \end{array} \begin{array}{c} \begin{array}{cccc} A_1 & A_2 & \cdots & A_n \end{array} \\ \begin{pmatrix} \frac{w_1}{w_1} & \frac{w_1}{w_2} & \cdots & \frac{w_1}{w_n} \\ \frac{w_2}{w_1} & \frac{w_2}{w_2} & \cdots & \frac{w_2}{w_n} \\ \vdots & \vdots & \ddots & \vdots \\ \frac{w_n}{w_1} & \frac{w_n}{w_2} & \cdots & \frac{w_n}{w_n} \end{pmatrix} \end{array} \quad (3)$$

The advantage of the AHP method over non-linguistic methods is the possibility of selecting criteria that do not meet the measurability condition, which means that there is no need for direct measurement of the value of the particular criterion. For subsequent evaluation it is sufficient to demonstrate how one of the criteria exceeds the other in achieving the goal.

3.2. DEMATEL method

Below, the main stages of DEMATEL [59-60] methodology are described. At the start, a list of parameters, which will undergo the analysis, must be made. Indicators in the form of analytical formulas are preferred to descriptive forms. The analytical form of an indicator allows direct use of data collected from various sources. In the next step, with the use of any method, the level of mutual influence of all criteria pairs must be determined and the initial direct influence matrix ***D*** must be created. It is assumed that each of the criteria may directly influence other criteria, but it can not influence itself. In practice, based on expert suggestions, expert systems or numerical methods, a cluster of partial direct influence matrices is derived. Matrices aggregation, in effect, provides a direct influence matrix ***D***. The direct influence matrix ***D*** is derived according to the following formula:

$$\boldsymbol{D} = \begin{bmatrix} d_{11} & \cdots & d_{1j} & \cdots & d_{1n} \\ \vdots & & \vdots & & \vdots \\ d_{i1} & \cdots & d_{ij} & \cdots & d_{in} \\ \vdots & & \vdots & & \vdots \\ d_{n1} & \cdots & d_{nj} & \cdots & d_{nn} \end{bmatrix}, \quad (4)$$

In the next step a normalized direct influence matrix ***N*** is determined, in which, all parameters assume a value within range [0,1].

$$\boldsymbol{N} = S\boldsymbol{D}, \quad (5)$$

where

$$S = \min(1/\max\sum\nolimits_{i=1,n} d_{ij}, 1/\max\sum\nolimits_{j=1,n} d_{ij}), \quad (6)$$

In the next step a matrix of total relations ***E*** is derived:

$$\boldsymbol{E} = \lim\nolimits_{k\to\infty}(\boldsymbol{N} + \boldsymbol{N}^2 + \cdots + \boldsymbol{N}^k) = \boldsymbol{N}(\boldsymbol{I} - \boldsymbol{N})^{-1}, \quad (7)$$

where ***I*** is the identity matrix. In $\boldsymbol{E} = [e_{ij}]$ matrix, sums of individual rows are calculated (r_i) – which mirror the sum of indirect and direct *i* influences criteria on other criteria (equation 8) and sums of all (c_j) columns – which show the sum of direct and indirect influences the *j* criterion receives from other criteria (equation 9).

$$\boldsymbol{r} = (r_i)_{n\times 1} = (\sum\nolimits_{i=1,n} e_{ij})_{n\times 1}, \quad (8)$$

and

$$\boldsymbol{c} = (c_j)_{1\times n} = (\sum\nolimits_{j=1,n} e_{ij})_{1\times n}, \quad (9)$$

Next a $r_i - c_i$ – relation indicator is determined, which is also called a net influence and a $r_i + c_i$ – position indicator, which is also called an overall influence. If $i=j$ then the value $r_i + c_i$ indicates the sum of criteria values, which both, influence the other criteria, and are under the influence of other criteria. Value $r_i - c_i > 0$ means, that the *i* criterion, influences other criteria, and influences the entire system as well. Value $r_i - c_i < 0$ means, that other criteria influence the *i* criterion, hence the *i* criterion, is not a source of influence on remaining criteria in the system. Taking into consideration above position and relation indicators a casual diagram can be created in a $(r_i + c_i, r_i - c_i)$ layout. When analyzing the values of $r_i + c_i$ and $r_i - c_i$ indicators, the DEMATEL technique identifies the degree of interdependence of criteria on one hand, and on the other hand it determines these criteria which influence other criteria, as well as criteria, which depend more on other criteria, and which are the recipients of influence of other criteria.

4. Multi actor multi criteria analysis for implementation of sustainable urban freight transport measures in Szczecin, based on the AHP and DEMATEL methods

4.1. Selection of decision alternatives

As a starting point for the analysis in the later part of the paper, the categories of solutions developed under the C-LIEGE project were applied. The analysis of good practices based on a review of 97 implementations in selected European countries resulted in the selection of 17 categories of solutions. The selection was made based on the knowledge and experience of experts from 11 European countries, involved in the project. The analysis was focused on soft solutions, both push and pull types.

After taking into account the specifics of Szczecin, 16 solutions were chosen for further analysis (Tab. 2). Implementation of a low emission zone was eliminated due to the polycentric character of the city. Other actions were subject to the multi-criteria AHP analysis, which allowed making a choice of solutions that can be implemented in Szczecin in order to improve the efficiency of the urban freight transport.

Table 2. Selection of measures to be analysed. Source: own study.

Category	Name of the measure	Description
Administrative measures (*A*)	Implementation of loading/unloading and transit restrictions (*A1*)	Access restrictions for loading/unloading operation as well as for moving/circulating related to (a) the type of transport means, and most commonly to vehicle emissions, weights and sizes; (b) access time within specified areas; (c) preferred truck routes and designated lanes; (d) loading and unloading zones; (e) based on licences.
	Incentives in terms of loading/ unloading and transit (*A2*)	Giving incentives to freight companies to implement environmentally friendly operations. Such behaviour would be encouraged by - for example - giving these companies: i) additional access 'time windows' for loading and unloading (e.g. possible night deliveries) in restricted areas, ii) additional freight loading/unloading slots, iii) ad-hoc routes for freight distribution.
	Dedicated parking spaces for loading/ unloading (*A3*)	From an environmental, business and traffic flow/security point of view it is best for freight vehicles to avoid double lane stops and to reduce waiting times for getting into a loading/unloading parking space.
Financial measures (*F*)	Mobility credit schemes/ congestion charging (*F1*)	Limiting the access of freight vehicles to an urban area by making freight operators 'pay' for each access with mobility credits that were initially distributed by the public administration (or money payments for entries in excess of the

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Category	Name of the measure	Description
		assigned credits). Access control equipment in freight vehicles records every entry to the zone and permits the implementation of a mixed pricing / enforcement scheme for different users
	Financing systems for vehicle purchase (*F2*)	Attractive, publicly subsidised financing (e.g. leasing) models that stimulate freight operators to use more environmentally friendly freight vehicles.
Technical/ organisational measures (*T*)	Information on freight routes (*T1*)	Channelling trucks that drive into cities of the urban agglomeration through designated truck routes, e.g. by setting up special road signs or providing special maps with designated routes and lorry-relevant road information.
	Intelligent route guidance in freight transport (*T2*)	Integrating designated lorry routes and lorry-relevant information in navigation software. On this basis, data received from freight vehicles in traffic with regard to their current locations, loaded cargo and destination plans can be connected with real-time road traffic data.
	Integrated logistical tools (*T3*)	Web-based logistics tools linking and coordinating producers, recipients and freight operators in order to optimise logistics flows.
	Alternative delivery systems (*T4*)	Implementation of van-sharing, cycle-logistics, night-delivery service, packstations/ parcel lockers etc.
Promotional/ awareness/ information (*P*)	Promotional campaigns for sustainable transport (*P1*)	Awareness-raising campaigns to promote responsible, eco-efficient logistics among freight recipients and distribution firms.
	Eco-driving trainings (*P2*)	Training for drivers on responsible and eco-efficient driving behaviour.
	Freight Operators Recognition Scheme (FORS) (*P3*)	Public authorities (or freight partnerships) awarding noticeable signs to logistic firms which employ eco-friendly vehicles and/or other similar measures. This shall contribute to a better image and an increased importance of the topic of eco-friendly logistics.
Urban planning and governance measures (*U*)	Local (freight) transport plan, Local Freight Development Plan (LFDP) (*U1*)	Strategic freight transport plans (formal or informal), which are based on a systematic analysis of freight traffic and local stakeholders and include goals and planned measures for the medium or long term.
	Distribution plan-scheme (*U2*)	Distribution schemes/ plans are a set of actions intervening on an administrative level aiming for efficient and sustainable urban freight transport by addressing freight operators and retailers to (re)organise their freight delivery processes.
	Freight transport Quality Partnership (*U3*)	Freight Quality Partnerships (FQPs) are means for urban authorities, businesses, freight operators, environmental groups, the local community and other interested stakeholders to work together to address specific freight transport problems. Typically, partners exchange information, experiences and initiate transport projects.
	Special conditions of urban planning (*U4*)	Integrating sustainable transport conditions into the land use and urban planning process, e.g. by making special, freight traffic related, contractual arrangements (including enforcement powers) a precondition for a new business or a large complex to receive a building permit.

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4.2. Stakeholders engagement

The stakeholders engagement was provided via the Freight Quality Partnership for the Szczecin Metropolitan Area, which was established during the C-LIEGE project implementation. The functioning of this structure is the basis of activities carried out under the next projects GRASS (GReen And Sustainable freight transport Systems in cities) [7] and NOVELOG (New cooperative business models and guidance for sustainable city logistics) [8], which is the direct continuation of C-LIEGE. The Freight Quality Partnership is a kind of agreement between the city authorities, representatives of businesses, logistics operators, transport companies, organizations dealing with the environmental protection, local communities and other stakeholders. It determines how to work together to solve specific problems related to the freight transport [61]. The main task of FQP is ensuring sustainable growth of freight transport in cities while meeting expectations of various stakeholder groups and reconciling them with a city's or region's overarching strategic goals. It’s achieved by integrating the cooperation between municipalities, transport operators, entrepreneurs, environmental organisations and other interested parties, which forms the basis for developing a collection of best practices for freight transport to make it more ecological, economical, safe and efficient [62].

A FQP is established most often by: local authorities, freight transport industry, local businesses, local communities, environmental organisations and other interested parties. Its aim is to develop a possibly full and consensual understanding of freight transport issues and problems, to promote constructive solutions which reconcile the need for access to goods/services with the local environmental and social concerns and thus optimally serving the needs of local businesses and communities. Judging from the experience gained by the cities that have implemented FQPs, its proper functioning is dependent mainly on keeping its members interested, acquiring financial resources, and attracting new stakeholders [63].

The FQP in Szczecin engaged the stakeholders from several key groups: delivery companies and distributors, local and regional authorities, local businesses, local communities, environmental organizations, and universities. As part of the functioning of the Freight Quality Partnership in Szczecin, the partners first and foremost exchange information and experience, and also initiate projects regarding transport issues in their broad sense. Working meetings are usually held in the form of the so-called “round tables”, at which the individual stakeholders present their problems and try to work out consensus solutions, to ensure meeting their expectations (based on the achieved compromise).

4.3. Identification of the criteria and weights

The starting point for the development of the hierarchical model was to determine the main goal, which was “the selection of solutions to improve the distribution of goods while maintaining the principles of sustainable development and an indication of their possible adaptation in Szczecin, taking into account the local conditions”. For the goal formulated in such a way it is possible to specify the following set of elementary consequences, resulting from the implementation of specific solutions:

- consequences for residents, such as a change in habits, increase in security, reduction of environmental pollution caused by the commercial vehicles traffic;
- consequences for entities engaged in economic activities in the surveyed area (e.g. shops and HoReCa sector entities), such as: the need to adapt to changes in delivery hours, the cost of implementing some solutions;
- consequences for the city, including improving the image and functionality of the city;
- consequences for the environment, e.g. improving the environment quality by reducing the traffic of commercial vehicles, noise reduction.

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Based on the above-mentioned factors, the three main criteria to assess the planned actions were determined [63]:

- scope of change - understood as the scope necessary to carry out interventions in the current structure of the city, both in terms of changes in infrastructure and organization;
- implementation possibility - understood as the possibility to overcome difficulties in implementing the solutions; this criterion was divided into four sub-criteria taking into account the division of implementation difficulties according to the following categories:
  - administrative decisions - the impact of official decisions, legislative circumstances, strategies, policies, etc. on the implementation of the solutions;
  - cooperation - the importance of the degree of cooperation between stakeholders aimed at successful implementation; this factor determines the extent to which this cooperation determines achievement of intended results;
  - time - determines the extent to which the success of the implementation is determined by time, within the meaning of the time required for its effective implementation (usually large, complex projects require to take into account a much broader time horizon);
  - funds - it determines the extent to which financial resources determine the success of the project, or in other words, what is its sensitivity to the available funds;
- positive impact on the environment - this criterion is the basis for actions taken in the development of sustainable transport and EU requirements; it is understood as an impact on the reduction of pollution and noise levels.

Figure 3 shows the hierarchical structure of criteria constructed for the purpose of this paper.

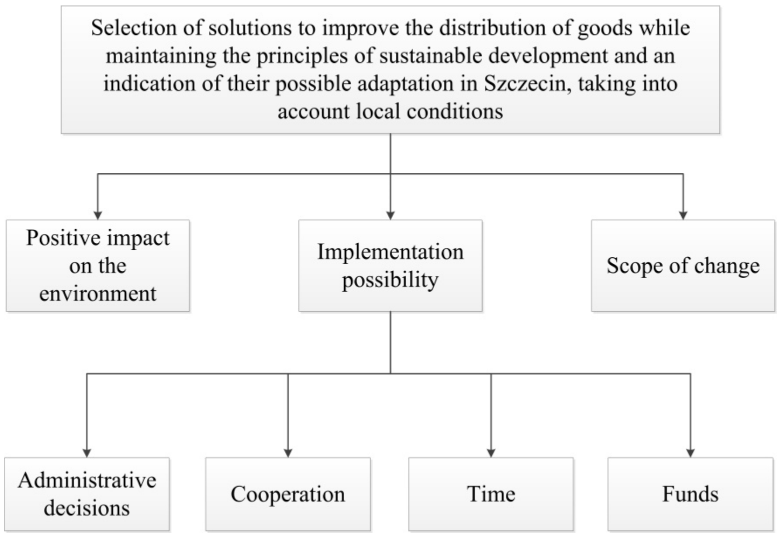

Figure 3. Hierarchical structure of criterions. Source: own study.

For the criteria developed above, based on the evaluation made by the experts involved in activities carried out under the FQP Szczecin, the pairwise comparison matrix was determined (Tab. 2). The pairwise comparison was based on the judgments of the experts involved in the analysis. Each pair of the criteria was analysed in the context of their importance – which one is more important in relation to the other one. Results were summarized in the pairwise comparison matrix. According to that, the results presented in Table 3 should be interpreted as: "Impact on environment" is twice as important as "Implementation possibility" and three times as important as "Scope of change", "Implementation possibility" is three times as important as "Scope of change".

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Table 3. Pairwise comparison matrix for main criteria. Source: own study.

Criteria	Impact on environment	Implementation possibility	Scope of change
Impact on environment	1	2	3
Implementation possibility	1/2	1	3
Scope of change	1/3	1/3	1

The next step is to determine the hierarchy of criteria. For this purpose, it is necessary to determine the vector of priorities. According to the assumptions developed by Saaty, the first step of the process is to square the matrix of criteria comparisons [50]. Then the priority distribution vector is determined by summing up the rows of the matrix and making their normalization to one unit. For a square matrix A of m size, this vector is calculated as:

$$p_i = \sum_{j=1}^{m} A_{i,j}, \quad i \in m, \tag{4}$$

$$pn_i = \frac{p_i}{\sum_{i}^{m} p_i}, \tag{5}$$

where:

p_i – the priority value in the priority vector for the *i*-th criterion,
$A_{i,j}$ – element of the A matrix lying in the *i*-th row and *j*-th column,
pn_i – normalized priority in the matrix vector for the *i*-th criterion

With the use of an iterative process, this procedure is repeated until the value of the normalized priority vector for matrix A does not differ from the values for the normalized priority vector for matrix A calculated in the previous iteration, assuming a limit to the accuracy of four decimal places. Table 4 contains the priority distribution vector.

Table 4. Normalized priority distribution vector for the main criteria. Source: own study.

	Priority distribution
Impact on environment	0.5278
Implementation possibility	0.3325
Scope of change	0.1397

A similar procedure was applied to prepare the matrix for pairwise comparisons of sub-criteria. Normalized sub-criteria priority distribution vector is shown in Table 5.

Table 5. Normalized priority distribution vector for sub-criteria. Source: own study.

	Priority distribution
Time	0.0829
Funds	0.4801
Cooperation	0.2185
Administrative decisions	0.2185

Illustrative priority distribution of the main criteria and sub-criteria is shown in Figure 4a and 4b.

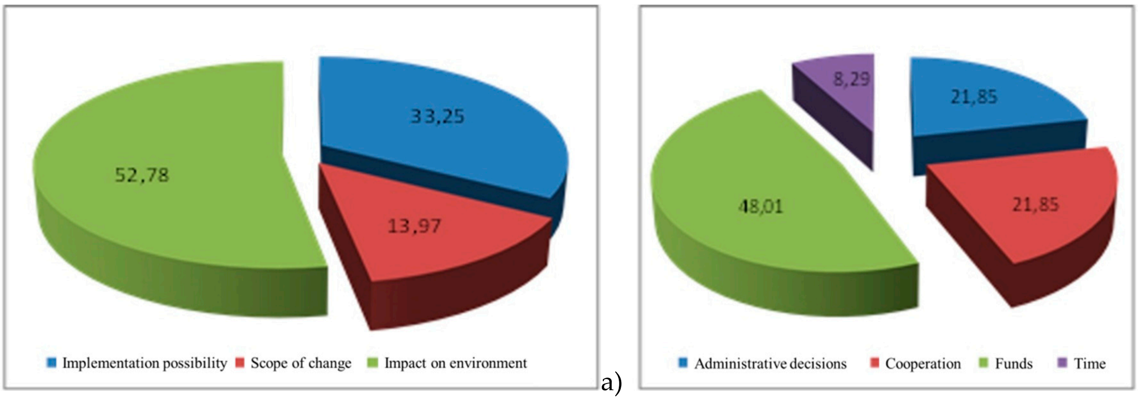

Figure 4. Priority distribution for: a) main criteria, b) sub-criteria. Source: own study.

The most important criteria ranked as follows: environmental criteria (52.78%), implementation possibility (33.25%) and scope of changes 13.97%. The most important sub-criterion turned out to be funds (45.1%); followed by administrative decisions and cooperation which obtained 21.85% each, and the least significant was time (8.79%).

At this stage, priorities for the criteria indicate their rank in relation to the original criterion. In the next step, it is necessary to define global priorities for each of the sub-criteria, which will show their impact on the main goal and will form the basis for further analysis. This is done by multiplying the sub-criterion by original criterion priority value. Following the calculations, the final hierarchical structure of the criteria and sub-criteria and their priorities took the form presented in Figure 5.

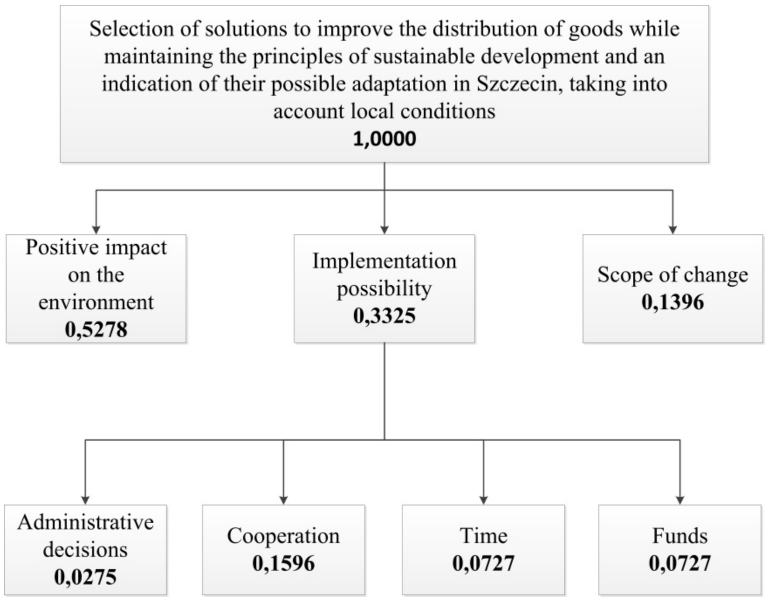

Figure 5. Hierarchical structure of criteria. Source: own study.

4.4. Measurement of the indicators

Decision alternatives were evaluated using the expert method. The external experts and representatives of stakeholders involved in the FQP in Szczecin were asked to complete a questionnaire in which each of the above mentioned criteria for the analysed solutions was assigned a value ranging from 1 (least favourable for a given criterion) to 3 (the most favourable for a given criterion). In the case of the "scope of change" criterion, the values relate to the degree necessary to make changes in the infrastructure or to make additional investments. In the case of implementation

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possibility this means significant difficulties in implementation (value 1) or high implementation potential and ease of carrying out the processes (value 3). However, with regard to the impact on the environment, this means a relatively smaller or larger scope of the impact.

Averaged results of the expert research were (Tab. 6) the basis for further analysis using priority vectors for the criteria presented above.

Table 6. Expert evaluation results for the analysed solutions (average values). Source: own study.

Solution category (decision alternatives)	**Scope of change**	**Implementation possibility**				**Positive impact on environment**
		administrative decisions	cooperation	time	funds	
Implementation of loading/unloading and transit restrictions (*A1*)	2.50	1.57	2.14	2.14	2.14	2.14
Incentives in terms of loading/unloading and transit (*A2*)	**2.71**	2.14	2.07	2.14	1.93	1.86
Dedicated parking spaces for loading/unloading (*A3*)	1.86	2.29	1.71	2.00	1.79	1.93
Mobility credit schemes/congestion charging) (*F1*)	2.64	2.07	2.21	**2.43**	2.29	2.00
Financing systems for vehicle purchase (*F2*)	1.86	1.43	1.71	1.64	1.36	**2.64**
Information on freight routes (*T1*)	1.57	2.07	1.93	2.21	2.00	2.00
Intelligent route guidance in freight transport (*T2*)	1.50	2.21	1.64	1.86	1.71	2.29
Integrated logistical tools (*T3*)	1.71	2.14	2.07	2.00	1.79	2.00
Alternative delivery systems (*T4*)	2.00	2.36	2.29	2.14	2.14	2.43
Promotional campaigns for sustainable transport (*P1*)	2.21	2.29	2.21	2.29	2.21	2.21
Eco-driving trainings (*P2*)	2.36	**2.79**	**2.64**	**2.43**	**2.64**	2.43
Freight Operators Recognition Scheme (FORS) (*P3*)	2.14	1.71	2.29	2.14	2.07	2.07
Local freight transport plans (*U1*)	2.14	1.50	1.57	1.64	2.14	1.93
Distribution plans (*U2*)	1.79	1.86	1.43	1.86	2.21	2.00
Freight Transport Quality Partnership (*U3*)	1.93	1.79	1.43	1.93	2.29	2.36
Special conditions of urban planning (*U4*)	1.64	1.43	1.79	1.43	1.57	2.57

In order to evaluate the solutions it was necessary to normalize the results. Table 6 summarizes the normalized values for results of the expert research shown in Table 7.

Table 7. Normalized values for expert evaluation results. Source: own study.

Solution category (decision alternatives)	**Scope of change**	**Implementation possibility**				**Positive impact on environment**
		administrative decisions	cooperation	time	funds	
Implementation of loading/unloading and transit restrictions (*A1*)	0.0768	0.0496	0.0687	0.0663	0.0663	0.0614

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Incentives in terms of loading/unloading and transit (*A2*)	**0.0833**	0.0676	0.0665	0.0663	0.0598	0.0534
Dedicated parking spaces for loading/unloading (*A3*)	0.0570	0.0724	0.0549	0.0620	0.0555	0.0554
Mobility credit schemes/congestion charging) (*F1*)	0.0811	0.0654	0.0710	**0.0753**	0.0709	0.0574
Financing systems for vehicle purchase (*F2*)	0.0570	0.0452	0.0549	0.0508	0.0421	**0.0757**
Information on freight routes (*T1*)	0.0482	0.0654	0.0620	0.0685	0.0620	0.0574
Intelligent route guidance in freight transport (*T2*)	0.0461	0.0698	0.0527	0.0576	0.0530	0.0657
Integrated logistical tools (*T3*)	0.0526	0.0676	0.0665	0.0620	0.0555	0.0574
Alternative delivery systems (*T4*)	0.0614	0.0746	0.0736	0.0663	0.0663	0.0697
Promotional campaigns for sustainable transport (*P1*)	0.0680	0.0724	0.0710	0.0709	0.0685	0.0634
Eco-driving trainings (*P2*)	0.0724	**0.0882**	**0.0848**	**0.0753**	**0.0818**	0.0697
Freight Operators Recognition Scheme (FORS) (*P3*)	0.0658	0.0540	0.0736	0.0663	0.0641	0.0594
Local freight transport plans (*U1*)	0.0658	0.0474	0.0504	0.0508	0.0663	0.0554
Distribution plans (*U2*)	0.0548	0.0588	0.0459	0.0576	0.0685	0.0574
Freight Transport Quality Partnership (*U3*)	0.0592	0.0566	0.0459	0.0598	0.0709	0.0677
Special conditions of urban planning (*U4*)	0.0504	0.0452	0.0575	0.0443	0.0486	0.0737

4.5. The final evaluation and ranking of alternatives

The table showing the ranking of the analysed solutions according to the established guidelines and in relation to all the decision-making criteria was obtained by multiplying the value of the normalized results of the expert research by global priorities for each criteria and sub-criteria. The calculation results are shown in Table 8.

Table 8. Table of the decision alternatives evaluation for the analysed solutions. Source: own study.

Solution category (decision alternatives)	**Criteria**							
	Scope of change	**Implementation possibility**					**Positive impact on environment**	***Total for the criteria***
		administrative decisions	cooperation	time	funds	**Total for the criterion**		
Eco driving training (*P2*)	0.0101	**0.0064**	**0.0062**	**0.0021**	**0.0131**	**0.0277**	0.0368	***0.0746***
Alternative delivery systems (*T4*)	0.0086	0.0054	0.0053	0.0018	0.0106	0.0232	0.0368	*0.0685*
Promotional campaigns for sustainable transport (*P1*)	0.0095	0.0053	0.0052	0.0020	0.0109	0.0233	0.0335	*0.0663*
Mobility credit schemes/congestion charging (*F1*)	0.0113	0.0048	0.0052	**0.0021**	0.0113	0.0233	0.0303	*0.0649*
Freight Transport Quality Partnership (*U3*)	0.0083	0.0041	0.0033	0.0016	0.0113	0.0204	0.0357	*0.0644*

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Implementation of loading/unloading and transit restrictions (*A1*)	0.0107	0.0036	0.0050	0.0018	0.0106	0.0210	0.0324	*0.0641*
Financing systems for vehicle purchase (*F2*)	0.0080	0.0033	0.0040	0.0014	0.0067	0.0154	**0.0400**	*0.0633*
Special conditions of urban planning (*U4*)	0.0070	0.0033	0.0042	0.0012	0.0078	0.0164	0.0389	*0.0624*
Freight Operators Recognition Scheme (*P3*)	0.0092	0.0039	0.0053	0.0018	0.0102	0.0213	0.0313	*0.0619*
Incentives in terms of loading/unloading and transit (*A2*)	**0.0116**	0.0049	0.0048	0.0018	0.0095	0.0211	0.0282	*0.0609*
Intelligent route guidance in freight transport (*T2*)	0.0064	0.0051	0.0038	0.0016	0.0085	0.0189	0.0347	*0.0601*
Distribution plans (*U2*)	0.0077	0.0043	0.0033	0.0016	0.0109	0.0201	0.0303	*0.0581*
Information on freight routes (*T1*)	0.0067	0.0048	0.0045	0.0019	0.0099	0.0210	0.0303	*0.0581*
Integrated logistical tools (*T3*)	0.0073	0.0049	0.0048	0.0017	0.0089	0.0203	0.0303	*0.0579*
Local freight transport plans (*U1*)	0.0092	0.0034	0.0037	0.0014	0.0106	0.0191	0.0292	*0.0575*
Dedicated parking spaces for loading/unloading (*A3*)	0.0080	0.0053	0.0040	0.0017	0.0089	0.0198	0.0292	*0.0570*
Total for alternatives	*0.1396*	*0.0727*	*0.0727*	*0.0276*	*0.1596*	*0.3325*	*0.5278*	*1.0000*

4.6. The implementation of DEMATEL method to assess the urban freight transport parameters

At the beginning of DEMATEL creation, for categories as well as measures presented in Table 9, the values of mutual interaction on each other of pairs of all criterion have been set. A scale of 0-5 has been adopted, where 0 means no influence, and 5 means extremely high influence. Based on the equation (4) and expert methods a matrix of direct influence ***D*** has been created (Table 9).

Table 9. The initial direct influence matrix ***D***.

D	*A1*	*A2*	*A3*	*F1*	*F2*	*T1*	*T2*	*T3*	*T4*	*P1*	*P2*	*P3*	*U1*	*U2*	*U3*	*U4*
A1	0.00	3.69	3.5	3.65	3.26	2.85	2.62	2.82	2.58	4.23	4.02	4.45	4.58	4.62	4.29	4.34
A2	3.45	0.00	3.36	3.71	3.45	2.13	2.14	2.53	2.72	4.14	4.03	4.01	4.37	4.31	4.02	3.83
A3	3.23	3.46	0.00	3.45	3.56	1.65	1.78	1.43	1.65	4.04	4.23	4.34	3.56	3.65	3.52	3.84
F1	4.23	4.67	4.27	0.00	4.67	4.82	4.69	4.84	4.67	4.83	4.39	4.62	4.73	4.82	4.59	4.81
F2	4.35	4.73	4.12	4.56	0.00	4.62	4.84	4.67	4.04	4.69	4.74	4.59	4.83	4.69	4.82	4.79
T1	1.36	1.54	1.36	3.54	3.46	0.00	4.21	3.76	3.82	1.67	2.53	2.54	4.18	3.54	3.23	3.51
T2	1.43	1.23	1.75	2.95	2.57	2.51	0.00	2.91	3.23	2.54	2.74	1.72	2.54	2.86	3.53	2.32
T3	2.43	2.41	2.16	2.94	3.43	3.41	3.32	0.00	3.54	1.94	2.18	1.54	2.31	2.11	2.75	3.04
T4	1.31	1.67	1.87	2.95	2.92	3.04	2.87	2.72	0.00	2.43	1.65	2.72	2.11	2.98	3.35	3.59
P1	2.56	2.76	2.15	4.56	4.67	4.11	4.23	4.34	4.26	0.00	4.61	4.45	4.03	4.02	4.12	3.56
P2	2.45	2.34	2.45	4.86	4.43	4.62	4.34	4.12	4.69	4.51	0.00	4.48	3.65	3.23	3.54	3.76
P3	2.24	2.58	2.67	4.69	4.66	4.45	4.32	4.64	4.11	4.23	4.42	0.00	3.11	3.56	3.34	3.32
U1	3.45	3.62	3.72	4.45	4.76	4.12	3.87	3.93	3.85	2.56	2.19	2.64	0.00	3.23	3.54	3.02
U2	3.53	3.24	3.75	4.34	4.23	4.34	3.51	3.45	3.63	2.63	2.65	3.12	3.21	0.00	2.61	2.76
U3	3.43	3.65	3.54	4.27	4.28	4.62	3.56	3.95	4.21	2.89	2.57	3.32	3.57	3.26	0.00	2.49
U4	3.62	3.75	3.06	4.25	4.61	4.42	4.24	4.15	4.27	3.53	2.65	2.76	3.05	3.42	3.41	0.00

According to the equation (5) the normalized direct influence matrix ***N*** has been calculated (Tab. 10).

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Table 10. The normalized direct influence matrix ***N*** (all values are multiplied by 10).

N	*A1*	*A2*	*A3*	*F1*	*F2*	*T1*	*T2*	*T3*	*T4*	*P1*	*P2*	*P3*	*U1*	*U2*	*U3*	*U4*
A1	0.0	0.53	0.50	0.52	0.47	0.41	0.38	0.40	0.37	0.61	0.58	0.64	0.66	0.66	0.62	0.62
A2	0.50	0.0	0.48	0.53	0.50	0.31	0.31	0.36	0.39	0.59	0.58	0.58	0.63	0.62	0.58	0.55
A3	0.46	0.50	0.0	0.50	0.51	0.24	0.26	0.21	0.24	0.58	0.61	0.62	0.51	0.52	0.51	0.55
F1	0.61	0.67	0.61	0.0	0.67	0.69	0.67	0.69	0.67	0.69	0.63	0.66	0.68	0.69	0.66	0.69
F2	0.62	0.68	0.59	0.65	0.0	0.66	0.69	0.67	0.58	0.67	0.68	0.66	0.69	0.67	0.69	0.69
T1	0.20	0.22	0.20	0.51	0.50	0.0	0.60	0.54	0.55	0.24	0.36	0.36	0.60	0.51	0.46	0.50
T2	0.21	0.18	0.25	0.42	0.37	0.36	0.0	0.42	0.46	0.36	0.39	0.25	0.36	0.41	0.51	0.33
T3	0.35	0.35	0.31	0.42	0.49	0.49	0.48	0.0	0.51	0.28	0.31	0.22	0.33	0.30	0.39	0.44
T4	0.19	0.24	0.27	0.42	0.42	0.44	0.41	0.39	0.0	0.35	0.24	0.39	0.30	0.43	0.48	0.52
P1	0.37	0.40	0.31	0.65	0.67	0.59	0.61	0.62	0.61	0.0	0.66	0.64	0.58	0.58	0.59	0.51
P2	0.35	0.34	0.35	0.70	0.64	0.66	0.62	0.59	0.67	0.65	0.0	0.64	0.52	0.46	0.51	0.54
P3	0.32	0.37	0.38	0.67	0.67	0.64	0.62	0.67	0.59	0.61	0.63	0.0	0.45	0.51	0.48	0.48
U1	0.50	0.52	0.53	0.64	0.68	0.59	0.56	0.56	0.55	0.37	0.31	0.38	0.0	0.46	0.51	0.43
U2	0.51	0.47	0.54	0.62	0.61	0.62	0.50	0.50	0.52	0.38	0.38	0.45	0.46	0.0	0.37	0.40
U3	0.49	0.52	0.51	0.61	0.61	0.66	0.51	0.57	0.60	0.41	0.37	0.48	0.51	0.47	0.0	0.36
U4	0.38	0.54	0.44	0.61	0.66	0.63	0.61	0.60	0.61	0.51	0.38	0.40	0.44	0.49	0.49	0.0

Next, based on equation (7) the matrix of total relations ***E*** has been determined (Table 11).

Table 11. The matrix of total relations ***E*** (all values are multiplied by 10).

E	*A1*	*A2*	*A3*	*F1*	*F2*	*T1*	*T2*	*T3*	*T4*	*P1*	*P2*	*P3*	*U1*	*U2*	*U3*	*U4*
A1	1.26	1.86	1.79	2.24	2.19	2.06	1.99	2.01	2.01	2.07	2.01	2.11	2.20	2.22	2.19	2.15
A2	1.67	1.29	1.70	2.16	2.12	1.88	1.84	1.89	1.94	1.99	1.94	1.98	2.10	2.10	2.07	2.00
A3	1.55	1.67	1.15	2.00	2.02	1.70	1.68	1.63	1.68	1.87	1.87	1.92	1.88	1.90	1.89	1.89
F1	2.10	2.27	2.17	2.12	2.75	2.67	2.62	2.63	2.64	2.47	2.37	2.46	2.57	2.60	2.58	2.55
F2	2.11	2.27	2.14	2.72	2.11	2.64	2.63	2.59	2.55	2.44	2.41	2.44	2.57	2.57	2.60	2.54
T1	1.18	1.28	1.22	1.84	1.83	1.31	1.86	1.79	1.82	1.40	1.48	1.52	1.80	1.73	1.70	1.70
T2	1.04	1.07	1.11	1.56	1.51	1.46	1.09	1.48	1.54	1.36	1.34	1.24	1.40	1.45	1.55	1.36
T3	1.22	1.29	1.22	1.63	1.69	1.64	1.61	1.14	1.65	1.32	1.33	1.28	1.44	1.42	1.52	1.52
T4	1.05	1.16	1.16	1.60	1.60	1.57	1.52	1.50	1.14	1.36	1.23	1.40	1.38	1.51	1.56	1.56
P1	1.66	1.78	1.65	2.42	2.43	2.29	2.28	2.28	2.30	1.55	2.13	2.16	2.19	2.20	2.23	2.11
P2	1.61	1.70	1.66	2.43	2.37	2.33	2.26	2.22	2.32	2.13	1.48	2.13	2.11	2.07	2.13	2.10
P3	1.56	1.70	1.67	2.37	2.36	2.27	2.23	2.26	2.21	2.06	2.06	1.50	2.01	2.08	2.07	2.02
U1	1.66	1.77	1.74	2.23	2.27	2.12	2.06	2.06	2.07	1.76	1.68	1.78	1.50	1.95	2.01	1.89
U2	1.63	1.67	1.70	2.17	2.15	2.09	1.96	1.94	1.99	1.73	1.70	1.80	1.89	1.46	1.83	1.81
U3	1.66	1.78	1.72	2.23	2.22	2.20	2.03	2.07	2.13	1.82	1.74	1.88	2.00	1.97	1.53	1.84
U4	1.57	1.80	1.67	2.24	2.28	2.19	2.14	2.12	2.16	1.91	1.76	1.82	1.94	2.00	2.01	1.50

The matrix of total relations ***E*** can be viewed as a E_C submatrix based on five categories from Table 2 and E_M submatrix based on measures. Table 12 presents E_C and E_M matrices and respective position and relations indicators.

Table 12. The E_C and E_M submatrices and position and relations indicators

E_C	r_i	c_i	r_i+c_i	r_i-c_i	E_M	r_i	c_i	r_i+c_i	r_i-c_i
					A1	3.236	2.454	5.689	0.782
A	0.955	0.825	1.781	0.13	*A2*	3.067	2.635	5.702	0.431
					A3	2.831	2.545	5.376	0.285
F	1.222	1.082	2.305	0.14	*F1*	3.955	3.395	7.351	0.560
					F2	3.933	3.389	7.322	0.543
					T1	2.546	3.240	5.786	-0.694
T	0.722	1.034	1.755	-0.312	*T2*	2.149	3.178	5.327	-1.029
					T3	2.292	3.159	5.451	-0.867
					T4	2.230	3.213	5.443	-0.984

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P	1.035	0.945	1.98	0.09	*P1*	3.364	2.921	6.285	0.442
					P2	3.304	2.852	6.156	0.452
					P3	3.242	2.943	6.185	0.299
U	0.961	1.009	1.969	-0.048	*U1*	3.054	3.097	6.151	-0.043
					U2	2.951	3.123	6.073	-0.172
					U3	3.083	3.148	6.231	-0.065
					U4	3.111	3.053	6.164	0.058

Next, based on Tab. 12, a causal diagram can be created in ($r_i + c_i$, $r_i - c_i$) layout for five categories which allowed making a choice of solutions that should be implemented in Szczecin in order to improve the efficiency of the urban freight transport (Fig. 6).

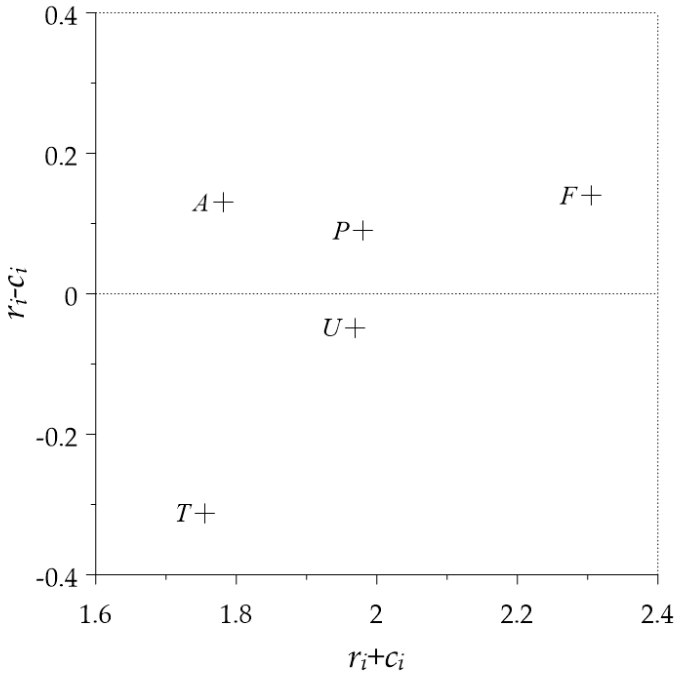

Figure 6. Casual diagram for five categories of the urban freight transport in Szczecin.

In Fig. 7 diagram for sixteen measures of the urban freight transport in Szczecin has been presented.

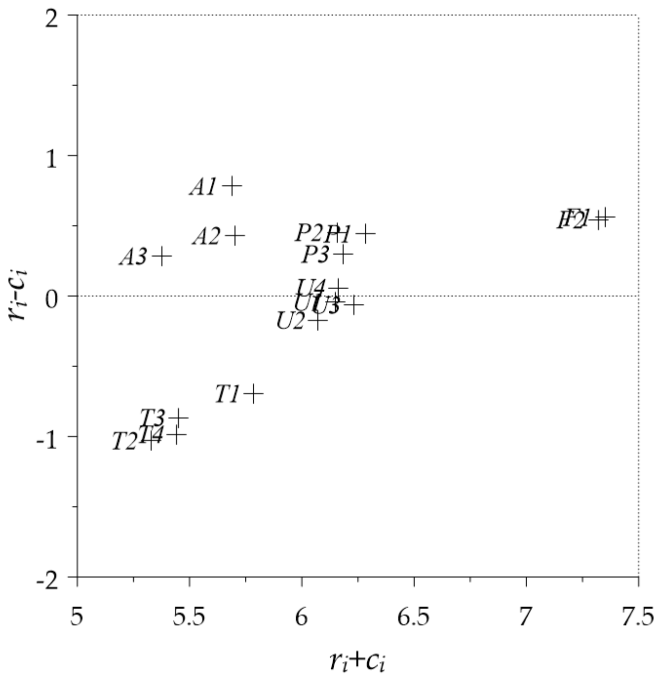

Figure 7. Casual diagram for sixteen measures of the urban freight transport in Szczecin

In figure 6 the *F* – Finance perspective has the highest $r_i + c_i$ position indicator value which means, that it is related in the strongest way with other perspectives, taking a central place in the web of mutual relations. The lowest value of this indicator is attained by the *T* - Technical perspective. Moreover, in figure 7, the highest indicator value of position is assigned to *F1* criteria – Mobility credit schemes, thereby taking the central position in the web of mutual relations with other criteria. The lowest position indicator value is attained by *T2* criteria – Intelligent route guidance in freight transport.

In turn, the r_i - c_i relation indicator allows to set a level of influence of analyzed parameter on other parameters. Is is simultaneously assumed, that it allows to reflect the parameter's priority among other analyzed relations. In fig. 6, the *F* - Financial perspective has the greatest, positive value of r_i - c_i relation indicator which means, that this perspective has a dominating, casual influence on other perspectives and simultaneously it is the most important among all perspectives. In turn *T* - Technical perspective, having the highest negative value of the relation indicator, is in to the highest degree recipient of the influence extended by other perspectives. In figure 7, the *A1* – Implementation of loading, with the highest positive value of relation indicator, extends the strongest influence on other criteria and is the most important criteria for asses the urban freight transport. On the other hand, the Intelligent route guidance in freight transport – *T2* criteria, with the highest negative value of r_i - c_i is among criteria the largest recipient of influences from other parameters and it has the lowest priority in the group of 16 criteria for assessment of the urban freight transport in Szczecin.

4.7. The results of the analysis

In this analysis, taking into account the total value for all criteria, the ranking was topped by the alternative "eco-driving trainings". This solution achieved the best result with respect to the implementation criterion and very good results for the other two criteria. The runner-up alternative in the ranking proved to be "alternative delivery systems". This was mainly due to the impact on the environment and high implementation possibility of this solution. Another solution, which turned out to be the most advantageous from the point of view of all the adopted criteria, was "promotional campaigns for sustainable transport". It is worth noting that all these actions are voluntary ('pull' type) actions and are not based on any restrictions imposed on carriers, suppliers or customers. It is also important that the expert research participants were convinced of the importance of sustainable transport awareness and the need to promote knowledge in this regard. Undoubtedly, only in this

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case it is possible to actually reduce the negative impact of freight transport on the urban environment.

The AHP results are often considered in a short period time. On the other hand, the DEMATEL method evaluates both the importance of criteria and shows the causal relations of factors. Analysing the causal diagrams might improve the effects of decisions for the long period. Finally, the main advantage of using AHP and DEMATEL methods simultaneously is that the decision process can be continuously improved from both short period and long period perspective.

4.8. The policy implication and utilization of the results

The results presented above should be the basis of an implementation plan for sustainable UFT development. This approach could help to prepare a UFT policy for a city in accordance with different objectives and taking into account points of view of various stakeholder groups. It was applied in the sustainable UFT measures implementation planning for the Szczecin Municipality.

The AHP results correlate with the general conclusions of the C-LIEGE project and the approach adopted in the project, based largely on the popularization of knowledge in this field and providing mechanisms for cooperation and exchange between multiple stakeholders (including the Freight Quality Partnership or the role of an urban logistics manager).

According to the results of the analysis, three major measures were implemented in Szczecin:

- publication of Eco-driving guide, made available for free on the Szczecin municipality web-site, and including this approach in the activities of "SOS Foundation – Responsible Driving Schools" (related to the measure "eco-driving trainings");
- analysis of utilization of InPost parcel lockers in Szczecin area and, in the next step, in other areas of Poland; this analysis helped to optimize the parcel lockers system to reflect the users' points of view and in terms of reducing the number of trips to pick up the parcels (related to the measure "alternative delivery systems");
- web-based promotion of the sustainable UFT system in Szczecin and the Szczecin Metropolitan Area, meetings with stakeholders, organization of "The Sustainable Transport Day" at the Maritime University of Szczecin, media-based activities (related to the measure "promotional campaigns for sustainable transport").

The direct continuation of the activities started under the C-LIEGE project was the next international project - GRASS.

The example of Szczecin shows that AHP is a very efficient, simple and valuable method of multi-actor-multi-criteria decision making. It is a good background for a process of planning implementation of measures in the area of urban freight transport systems. It is significantly important in view of diverse expectations of different UFT stakeholder groups.

5. Conclusions

The proper implementation of measures is the most important factor of sustainable urban freight transport development. In view of the very high complexity of this system as well as diverse and often conflicting expectations of UFT stakeholders, the decision making process in this area becomes very much complicated. Due to that, utilization of the MCDA methods, and particularly the MAMCA approach, is a very good way to find solutions that are optimal from all perspectives.

In this paper, the authors introduced the practical example of applying the MCDA method, as well as some aspects of the MAMCA method, in implementing sustainable urban freight transport measures in Szczecin.

The analysis was based on the Analytic Hierarchy Process (AHP) as well as the Decision Making Trial and Evaluation Laboratory Method (DEMATEL), which are well-known approaches to multi-criteria problem solving.

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In the article, the analysis of a set of criteria dedicated for the assessment of transport system is presented. After determining, in each of the five perspectives, the most important criteria, a set of 16 factors is obtained. Next, with the use of DEMATEL methodology, the matrix of interdependent influences is determined for all criteria pairs. Finally, the matrix of total relations $\boldsymbol{E}$ is created and indicators of position and relation are determined for 5 perspectives, as well as for 16 parameters. Following, both five perspectives as well as criteria within these perspectives, have been determined, having the highest and least overall and net influence.

The results of the analysis were prepared under the Freight Quality Partnership, established in Szczecin during the C-LIEGE project and continued under the GRASS project. Theses results of analysis can be useful to Szczecin Municipality in both the evaluation of current operations, as well as in setting future strategies for more efficient urban freight transport system which will be able to meet the expectations of sustainable development of the city transport.

It needs to be emphasised that the principal strategic document adopted by the Szczecin Municipality, named "The Strategy for Szczecin Development 2025" [64], covers the areas of the city development policy (in the social, economic and spatial aspects) which, if supported under the current budget conditions, will contribute to the most effective social and economic development of the city. A Local Freight Development Plan has been developed since 2016. It will be a strategic plan focused on freight transport functioning, covering the goals and measures to be taken in the mid- and long-term time horizon. Additionally, it will be based on systematic surveying the needs of local stakeholders, who, as the research has shown so far, aptly recognise many urban delivery problems. It is also important that the selection of measures, achieved during the analysis, is not closed and there is openness towards other ideas and projects that may be devised by a vast range of the city development stakeholders (both internal and external in relation to the local self-government, including inhabitants, entrepreneurs, investors, institutions, organisations etc.).

The authors are focused on utilization of other MCDA methods to prepare even more valuable results and to include different factors in the analysis, which affect the urban freight transport system in Szczecin. Nowadays, the analysis includes not only the Szczecin city centre, but also the area of other parts of the Szczecin Metropolitan Area.

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Abbreviations

The following abbreviations are used in this paper:
AHP: Analytic Hierarchical Process
DEMATEL: Decision Making Trial and Evaluation Laboratory Method
FQP: Freight Quality Partnership
LFDP: Local Freight Development Plan
MAMCA: Multi Actor Multi Criteria Analysis
MCDA: Multi Criteria Decision Analysis
UFT: Urban Freight Transport

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