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MULTICRITERIA METHODOLOGY TO MODE OF TRANSPORT CHOOSING - THE PORTUGUESE CASE

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ABSTRACT

In this work we used a methodology based on a multicriteria model, which aims to provide a systematic approach to the whole decision process, able to allow the selection, within a provided set of alternatives, the most advantageous. For this, the principal criteria were identified, using questionnaires and interviews, and these were the basis for the evaluation of each alternative within the two methods that have been tested (MMASSITTI and AHP).
Having identified the criteria, they were tested and how each should be measured was identified. They were then introduced in two different models to support decision making so as to realize what is the best alternative.
Once the quantitative criteria were treated, a qualitative scale was applied to companies with which they usually work, knowing their level of service, presenting a budget with all expenses including shipping (with equal loads) and time transport, in order to understand what mode of transport, regardless of the criteria, presents a better solution, and thus achieved the applicability of the test multicriteria model on a real case.

Finally the option selected by the models was evaluated in order to understand whether different models feature the same results.

Keywords: Freight transport, intermodal, support decision making; multicrieria

1. Introduction

The freight transport sector is critical to the development of the economy and the welfare of society. The main objective consists in providing mobility which can be considered as one of the essential requirements for the exercise of an economic activity and allows the development of economies of scale across the European Union [1,2,3].

The transport sector generates 10% of the wealth of the European Union in relation to gross domestic product (GDP) and employs more than ten million people [4].
Taking in particular account the neeed to mitigate the significant negative impact that transport has on the environment and the need for transport companies to use alternative modes of transport (e.g. rail), the EU has been imposing through policies and regulations along the last decade towards the adoption of new policies so as to promote competitiveness and intermodality [5,6).
Decision making can be typically described as "choosing between different alternatives." But this view is simplistic because decision making is a comprehensive process, not just a simple act of choosing between different alternatives.
The decision making process is divided into a set of eight steps which begins with identifying the problem and the decision criteria. Then it is necessary to develop, analyze and select an alternative that can solve the problem. Then it is important to implement the alternative and, finally evaluate the effectiveness of the decision.
The objective of this study was to evaluate the transport sector regarding the modal use and respective motivation for their choice, including: geographic location, infrastructure limitations, existing legislation, environmental impact and sustainability. Therefore the decision process in selecting alternative transportation with a focus on intermodal perspective is a problem of multicriteria framework, for which companies do not use specific models.
The efficiency of decision making in the evaluation and selection of the modal or intermodal transport consists in choosing, as much as possible, which one provides better results, both in terms of minimal logistics costs, response time and quality in customer service [7,8,9,10].
This paper is organized as follows: section 1 introduces the subject studied, in section 2 a short characterization of the Portuguese freight situation is made. In section 3, a review is carried out within the framework of the TM and models to use, focusing on multi-criteria models.

2 Portuguese freight situation

The three main markets for Portuguese exports continue to be Spain, Germany and France which represent 51.4% of total exports; a situation that is also found in imports, according to information provided by the national statistical institute [11].
Currently, in Portugal and the rest of Europe, the road transport still remains the main mode of transport used because it presents numerous advantages when compared to other remaining modes, namely, the flexibility of routes, reduced door -to-door delivery times, the frequency of service and high reliability. [12, 13].
Rail transport has a key role in the implementation of intermodality. However, to make it happen, the sector will have to suffer a greater restructuring, regarding both the modernization of infrastructure, and the management of the business [5, 14].
The gauge (distance between rails) is one of the most relevant challenges the Portuguese railroad faces today. The Iberian Peninsula has a different gauge from the one used in the rest of continental Europe, which has been detrimental for Portugal

and Spain, especially when the merchandise's destination lies beyond the Pyrenees, because of the need to change wagons at the border[15].
Portugal's commitment to the Kyoto Protocol makes it urgent to adopt measures to reduce pollutant emissions, without jeopardizing the country's economic development, otherwise the invoice in emissions trading will be unacceptable to the country in the medium term.
So that the objectives of the Marco Polo II program are achieved, with regard to intermodality is necessary to:

- Sustain growth rates in the transport sector, allowing, in this way, to keep mobility in the sector by 2050.
- Creating an efficient basic network to ensure the development of intermodality in long-haul transport of goods.
- Reduce GHG emissions in 60% until 2050 by developing an efficient and competitive transportation system.
- Develop and implement propulsion systems for propulsion use of sustainable fuels.
- Optimize the operation of the intermodal logistics chain, promoting the integration of transport modes that use energy more efficiently.

The Strategies necessary for the European Union to achieve some of the objectives proposed involve:

- Development of a Single European Transport Area - Elimination of the few remaining barriers between different modes of transport.
- Creation of a European Strategic Research, Innovation and Development organization in the transport sector.
- Development of a European network of mobility, with a common vision and with sufficient economic resources [16].

Taking into consideration the current logistics infrastructure in Europe, the Portuguese logistics situation can be considered deficient, both in qualitative and quantitative terms, due to the strong modal and territorial unbalance.
This situation is essentially due to the fact that the major load points (airports, ports, logistics and railway stations) have difficulties in handling goods because they do not have a second line which allows the development of complementary functions which in turn would allow them to share common services with various companies and thus reduce logistics costs.
With the development and improvement of the Portuguese logistic system, it would be possible to obtain:
1 – Environmental and energetic gains;
2 - Bigger and better modal balance;
3 - Higher utilization and profitability of all rail and port capacity;
4 - Greater market competitiveness;
5 - Rationalization of logistics activities to attract new market players;
6 – The promotion of intermodality, through the enhancement of infra-structures and the development of rail transport;
7 - An overall contribution to the development of the entire national economy [17].

In order to achieve the objectives of this study - to identify the key factors and criteria and their respective weightings, which currently preside over the choice of mode and respective transport agents by the shipping companies operating in Portugal - different research methodologies were used to evaluate qualitative variables and process them in different quantitative resources.
At this point theories, methods and types of multicriteria applications will be identified, as well as different multicriteria applications already developed by different European countries.

3 Problematic decision support

3.1 Process to support decision making

Currently, practically at every moment, humans beings need to take different decision which, depending on the context, are simple sometimes and more complex at other times. These decisions involve different levels of responsibility; they may affect only the decision maker, those around him or even the organization as a whole. This need not always explicit, and often poses problems which are specific to each situation [18].
The most complex problems, for which, due to various alternatives, there are more than one objective and multiple criteria, with conflicting goals, can be solved using multi-criteria models.
Multi-criteria decision making assists and supports, through a varied set of methods and criteria, the selection of alternative solutions, where different criteria from distinct areas and sometimes contradictory criteria (minimizing costs or maximizing profits) have to be considered [8,9,10,19].
In general, these decisions have at least some of the following characteristics [20]:

- criteria for solving the problem are at least two and conflict with each other;
- criteria and alternative solutions are not clearly defined and the consequences of choosing a particular alternative, with regard to at least one criterion, are not clearly understood;
- criteria and alternatives should and can be interlinked in such a way that a criterion appears to partially reflect other criteria, while the efficacy of an alternative choice depends on a choice being selected or not, in case those alternatives aren't mutually exclusive.

The decision should seek the option that present the best performance, the best evaluation, the lowest cost, the best quality or even the closest match between the expectations of the decision maker. [8,9,10].

3.1.1 Multicriteria models

Within the multicriteria model there is a set of different models that have been developed and are the most used by a high number of authors in solving

transportation problems. Some of these models are: AHP (direct rating, paiwise, individual or group) (21,22); ELECTRE 1, 2, 3… pro suite (23,24,25,26); Topsis suite [26,27); PROMETHEE suite [28,29,30,31,32]; MMASSITTI [33]; TODIM [34;35].

The choice of model is related to the simplicity of use and perception by the DM, as well as the methodological foundations.

The AHP has been used to solve problems in this context as it solves decision making problems with a high number of criteria more easily. Its main advantage is that it decomposes the problem hierarchically, establishing a hierarchy of criteria and converting all subjective evaluations of different amounts of a set of scores or weights in a generalized way [36, 37]. It has also been used in combination with others, where the AHP structures the problem and another model aggregates valuations and sensitivity analysis.

The AHP model is intended to reduce complex decisions within a given set of simple comparisons between a set of elements belonging to the hierarchy decision.

This method consists of the following steps:

- Structuring decisions in a hierarchy;
- Setting the decision maker's preferences, comparing pairwise the elements from one level of the hierarchy in relation to the next higher level;
- Determining the weight vector for each of the different matrices;
- determining the consistency of preferences depending on the value of the reason for consistency;
- Marking the relative importance of each alternatives in relation to the main objective. [37,38]

The other model used in this study was MMASSITI. This model's methodology proposes a new and different approach to the process of structuring the problem and respective data collection, presenting the different decision makers with a conceptual model which forms a work base and incorporates different decision makers' knowledge, thus facilitating the comprehension of the problem, the collection as well as the systematization of information. The methodology, because of its simplicity, helps understanding problem solving and using methodology, leading decision makers through the various stages of solving a multi-criteria problem.

This method consists in eight distinct steps, namely:

- Setting criteria;
- Validating and describing each criteria;
- Setting reference levels ('neutral' and 'best');
- Assigning weights to the alternatives;
- Setting a continuous scale containing seven levels;
- Setting "neutral" and "best" level for each alternative;
- Evaluating different alternatives;
- Analysing sensitivity.

Considering that a transport system is composed of entities providing different services and features which ensure the independence of the criteria, two different levels of the model were considered:

- Adjustment of the transport system to the requirements of the decision maker;

• Information related to the technical and functional aspects of transportation systems in analysis [33].

3.1.2 Problem Formulation

The alternatives considered here are for containerized transport, including modes: road (there are a large number of carriers in this area in Portugal), short sea shipping (SSS); rail and intermodal.
The SSS is increasingly an option for loads that are transported to third countries, since the geographical area chosen is the north of Portugal, where most ports are located, two of them are relevant Leixões and Aveiro and still relatively close to the Spanish port of Vigo.
The rail corresponds to approximately 5% share of transport, with options for specific loads and Iberian market as the rest of Europe requires the gauge change.
Thus, Portuguese intermodal transport is greatly reduced by the limitations mentioned above.
To choose the alternatives in a particular multi-criteria model, it is important to understand the criteria used for the selection of the mode of transport.
The criteria should be relevant and incorporate the basic properties for multicriteria modelling, being independent, having minimum size operability and not redundant.
To this end, a selection of information from a sample of companies was defined methodologically so as to identify which multi-criteria model would support the evaluation and selection of transport alternatives.

The survey was sent to a set of such stakeholder, according to the following distribution (number of entities)

- Freight forwarder 30;
- 20 Logistics operators;
- 134 Importing companies;
- 129 Exporting companies.

From the information gathered we found that the relevance of the criteria was:

- Criterion 1 - Compliance with deadlines - 23%
- Criterion 2 - Rate of Transport - 20%
- Criterion 3 - Time Transport - 20%
- Criterion 4 - Service Level - 15%
- Criterion 5 - Adaptation to the quantity shipped - 13%
- Criterion 6 - Risk of loss or damage - 5%
- Criterion 7 – Transport electronic monitoring - 2%
- Criterion 8 - Shipping price- 2%
- Criterion 9 - Environmental impact - 2%

3.1.3 Operationalization of the criteria

- Compliance with deadlines

This decision criterion can be easily quantified by the DM using the carrier history or quantitatively by determining the number of orders delivered within the stipulated time over the total of orders during this period.

- Time transport

The criterion time is combined with the distance and speed of the vehicle used, which makes the time of freight vary considerably. The load consolidation depends on the distance traveled, the urgency of the cargo, the characteristics of the goods transported, the existence of storage capacity or not (many companies with continued flows try to keep the stock in transit so as not to have to pay for storage) the existence of more loads along the entire route the average time spent on the route from source to destination, considering transport door-to-door to the end customer. Therefore, this criterion is measured quantitatively, i.e., time from the origin (To) to the destination (Td) including the consolidation (C) and deconsolidation (D) of goods taking into account the number of kilometers that the mode of transport has to travel is quantified.

- Rate of Transport

This criterion consists of a sum of costs associated with transporting of goods, cost of cargo transport (where the carrier includes the cost per kilometer and cost per ton transported, the cost of tolls, indirect costs associated with transportation such as insurance and taxes) and the cost of unloading the goods at the final customer's premises or a particular logistics platform.

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- Level of service

The service level criterion can be determined quantitatively or qualitatively. The qualitative approach can be based on company history or portfolio and qualifying elements such as certifications they may have. The quantitative analysis can be determined by dividing the number of orders fulfilled by the total of orders, multiplied by 100 (%).

4 Application of the model

4.1 Application of the model to the multicriteria problem

Having identified the criterion considered the most important by the companies surveyed in the choice of a particular mode of transport,from the ones considered in the model, it was decided to collect data and apply the model on two tools that implement multicriteria models – AHP and MMASSITI.

The model was applied to the choice of a shipping company to transport goods from the industrial district of Arrifana, in Santa Maria da Feira, to the city of Birmingham in the UK, by a decision maker of a company which needed the service. As this transport can be accomplished by resorting to shipping or road, the decision maker asked for quotations for the two modes of transportation, corresponding to a total of five alternatives, ie, n = 5

The alternatives considered by the decider were companies that perform this task usually, namely:

- Alternative A
- Alternative B
- Alternative C
- Alternative D
- Alternative E

Only alternative A presented a quotation for freight transportation by shipping. The remaining companies presented quotations for road transportation.

4.1.1 Application of the AHP Model

Having introduced all the data in the model and having compared all the alternatives within each of the different criterion, the best alternative within the weights that were assigned to each of the different criteria in analysis was identified.

The concluding was that the most advantageous alternative for the company under study to transport their goods is alternative B, and then alternative A.

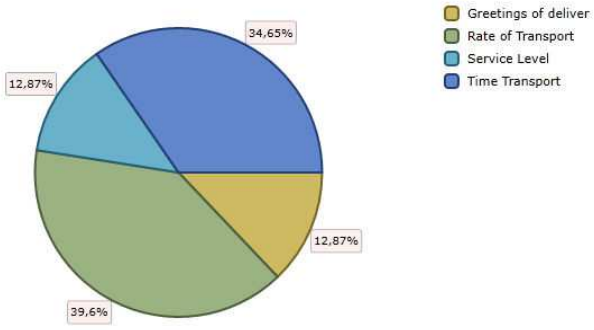

Figure 1. Weight assigned to the different criteria

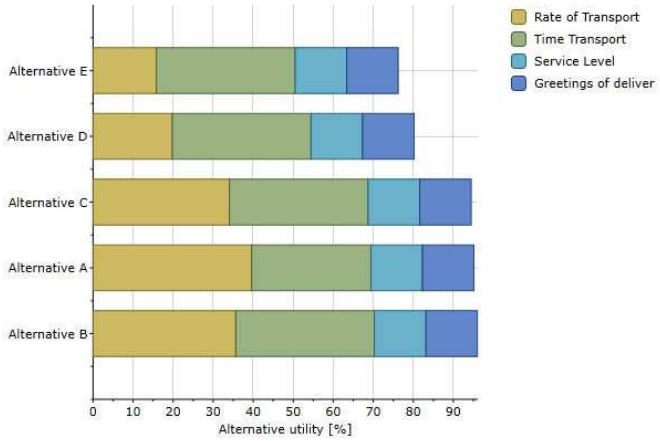

Figure 2. AHP model results

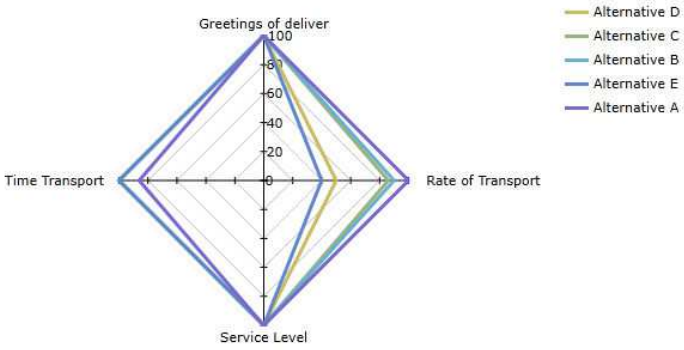

Figure. 3. Result of the different alternatives

Because the results presented were very similar, a sensitivity analysis was necessary. The sensitivity analysis, proved that, despite varying the weights assigned to each criterion or assigning equal weights, the order remains the same, i.e,. Alternative B remains the alternative which provides a better result, followed by alternative A.

4.1.2 Application of MMASSITI model

The method used is a multicriteria methodology used in this study in order to facilitate the selection of one of the alternatives presented, according to a set of previously defined criteria by the companies surveyed. The selection was performed using a continuous scale with seven semantic references that would allow assigning a value to each criterion, according to the alternative currently being evaluated.

After having entered all the data in the model and assigned weights and values to each of the different alternatives within each criterion under analysis, the conclusion was that the two transportation alternatives selected as those that presented a better service were alternative B and A.
Since the overall value of alternatives B, A and C were very close, we performed a sensitivity and robustness analysis by varying the weight of the criteria.
These analyses proved that, regardless of the weight assigned to each of the different criteria or whatever the changes made, the order remains the same. Therefore, alternative B is the company with best results.

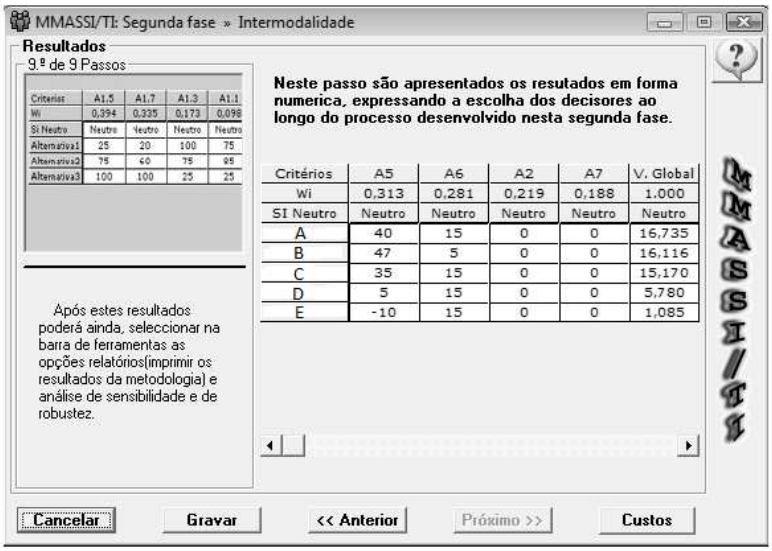

Figure 4. MMASSITI model results

4.2 Comparison of methods applied

The model was applied in two methods which, despite their differences, allowed the researchers to reach of same conclusions. The MMASSITI, a multicriteria methodology created for the purpose of selecting systems and information technologies, but has been applied to the selection of transportation modes in this study, has proven fit for application to any multi-criteria problem (which consists of a set of criteria and alternatives).
The AHP is a methodology widely used by decision makers in issues related to transportation. In this case, it was used in order to understand whether the two models, although totally different, would reach the same results, see table 1.

Table 1. Comparison results

	AHP model results					MMASSATTI model results				
	Rate of Transport	Time transport	Compliance with deadlines	Level of service	Total AHP	Rate of Transport	Time transport	Compliance with deadlines	Level of service	Total MMASSATTI
Weight	**0,4**	**0,35**	**0,13**	**0,13**		0,313	0,281	0,219	0,188	
Alt. B	0,26	0,22	0,2	0,2	**0,88**	40	15	0	0	**16,735**
Alt. A	0,33	0,11	0,2	0,2	0,84	47	5	0	0	16,116
Alt. C	0,21	0,22	0,2	0,2	0,83	35	15	0	0	15,17
Alt. D	0,12	0,22	0,2	0,2	0,74	5	15	0	0	5,78
Alt. E	0,08	0,22	0,2	0,2	0,7	-10	15	0	0	1,085

From the analysis of the results of the two methods, it is possible to conclude that the most advantageous alternative for the company under study is the same, i.e.. Alternative B followed by alternative A.
Another conclusion is that if only criteria rate and transport were under study, the most advantageous transportation company for the decision maker would probably not be alternative B but alternative A, since this was the carrier that submitted a lower quote.

The fact that there was another criterion that the decider considered quite as importantly, i.e. the transportation time / time to transit, allowed the validation the road option, as road transportation has slightly lower transit time (approximately 2 days). Because the company planned to deliver the goods as soon as possible to customers to meet their needs, faster shipping was selected, as price difference was just slightly higher. The other two criteria considered in the model (timeliness of delivery and service level) were undervalued by the decision maker, this was due to fact that they had worked with the different alternatives and knew their level of service, so they were always assigned the same value since all alternatives met these two criteria equally.

5 Conclusions and suggestions for further work

The transport sector is responsible for one of the most serious environmental problem in Europe, since the intensity of transportation is increasing.
To meet the main objective of this study, which is to understand the criteria used by logistics companies to choose the mode of transportation and the reason that leads or may lead to increased use of intermodal solutions, we conducted a survey.
The survey also identified the criteria that lead to the choice of a mode of transportation, namely the timeliness of delivery, transport fee, shipping time and service level. The remaining criteria - environmental impact, rate of storage, risk of loss or pallets and others - were not considered.
After having identifyed the criteria companies surveyed considered the most important in choosing a particular mode of transport, it was decided to collect data and apply these criteria in two existing models in order to be able to validate the criteria and understand its importance, and how to apply them. The models were applied to the choice, by a decision maker, of a suitable shipping company to

transport the goods from the industrial district of Arrifana, in Santa Maria da Feira, to the city of Birmingham in the UK. Because this transport can be done either by road or by resorting to shipping, both modes of transport were included, corresponding to a total of five alternatives.

After having identified the alternatives, the decider assigned the respective weights to each of the different criteria, depending on their relative importance, and weights assigned to each criterion depended on the decision maker, the company, the type of product to be transported. What the analysis of the results of the two models showed is that the first, most viable alternatives are the same (in the same order), which reinforces the confidence in the suggested choices and strongly suggests that the criteria used in the two models are probably the most suitable.

If the decision maker had considered solely the cost of the transportation, the shipping company would have been selected, as they presented a lower cost. However, a set of factors influenced this decision indirectly; ranging from reliance on ports docks (dependent on dockworkers' strikes, for example) to government interference, among others. It was thus possible to conclude that, when the cost of road and maritime transport are close, decision makers usually choose road transportation, dismissing concerns with environmental issues.

There is another important factor the decision maker considered which is the time of transit / transportation. This factor is subjected to conditions such as the type of charge, the company, the characteristics of the goods, the fact that many companies that have continued flows try to keep stocks in transit so as not to pay storage fees, the existence of more cargo along the route and the average time spent on the route from source to destination, considering door-to-door delivery. This criterion made the decision maker assign a higher value to the road option instead of to the sea, because shipping had a slightly higher cycle time (2 days).

The criteria level of service, which is directly related to the availability of the product, the product cycle, compliance with deadlines, the frequency of delivery, the flexibility of the delivery system and information system available, among others, was considered a qualifying element because it was assumed that all companies considered complied with these requirements.

The criteria fulfillment of delivery times was also considered an eligible element, since all companies usually met the deadlines.

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