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A Multi-Agent System based on MCDM Approach for Multi-Modal Transportation Problem Resolution

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Abstract: In the past few years, using an advanced transportation information system (ATIS) has become essential for effective urban mobility management. These systems play an important role in the transport sector and aim to manage travelers' movements better. Users of these systems can plan their trips according to their own needs and define their preferences. However, the expression of preferences over itinerary criteria is crucial for the performance of urban mobility and has a considerable effect on the success of transport management. After all, satisfying the traveler and facilitating his travel is the first sign of effective urban mobility management. To resolve such problems, a multi-agent system should use a multi-criteria decision-making methodology (MCDM) method to find the optimal itinerary that meets the user's needs. The article presents the application of the MCDM as a multi-agent system for multimodal transportation. The system should offer an itinerary that meets the user's needs. The user could define an order of preference on the different criteria so the system will know how to calculate his itinerary. The proposed criteria are travel time, cost, number of modes changes, and safety. These criteria will simplify the evaluation of the several solutions proposed by the system in terms of utility and efficiency to meet the user's needs in terms of travel. The system contains six agents: Personnel Travel Agent *PTA*, Information Agent *IA*, Directory Selecting Agent *DSA*, Sorting Agent *SA*, Calculating Agent *CA*, Decision-Making Agent *DMA*. Therefore, The *DMA* agent is responsible for this process of finding the optimal itinerary.

Keywords: Multi-Agent System, multi-criteria decision making, multimodal transportation, transportation simulation, TOPSIS.

农场实地考察对学生实践管理咖啡行业废物的影响

摘要：在过去几年中，使用先进的交通信息系统已成为有效城市交通管理的必要条件。这些系统在交通领域发挥着重要作用，旨在更好地管理旅客的出行。这些系统的用户可以根据自己的需要计划他们的旅行并定义他们的偏好。然而，表达对行程标准的偏好对于城市交通的表现至关重要，并且对交通管理的成功有相当大的影响。毕竟，让旅行者满意并为他的旅行提供便利是有效城市交通管理的第一个标志。为解决此类问题，多智能体系统应采用多准则决策方法论的方法来寻找满足用户需求的最优行程。本文介绍了多标准决策作为多式联运多代理系统的应用。系统应提供满足用户需求的行程。用户可以根据不同的标准定义优先顺序，以便系统知道如何计算他的行程。提议的标准是旅行时间、成本、模式变化的数量和安全性。这些标准将简化对系统在效用和效率方面提出的几种解决方案的评估，以满足用户在旅行方面的需求。系统包含六个代理：人事旅游代理、信息代理、目录选择代理、分拣代理、计算代理、决策代理。因此，决策代理负责寻找最佳行程的这个过程。

关键词：多代理系统、多标准决策、多式联运、运输模拟、通过与理想解相似的偏好排序技术。

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1. Introduction

Efficient management of urban mobility plays an important role in the transport sector. However, this sector faces many problems. These urban transport problems arise at different levels and are subject to some changes. One of the biggest challenges facing this sector is identifying multimodal itineraries. The choice of itineraries in the context of multimodal transport is an important element [1]. It is undeniable that the problems of choosing itineraries for urban transport are characterized by great complexity. The complexity of this choice lies in the fact that it is based on real decisions, data, and criteria [2]. Indeed, this choice of itineraries should meet several criteria and consider many aspects such as traffic conditions, climate, timetables etc.

Nowadays, there are new approaches in software engineering, which allow better control of mobility in big cities like multi-agent systems. This technology could be used to manage the movements of travelers better. Users of these systems can plan their trips according to their own needs and define their preferences. A multi-agent system can use the multi-criteria decision-making methodology (MCDM) to solve such problems, which is increasingly applied to the resolution of complex and multidimensional decision-making problems.

The use of an MCDM method will facilitate identifying the optimal itinerary that meets the user's needs. Indeed, there are many classifications of MCDM methods. Thus, depending on the decision-making problem to be solved, the method can be distinguished according to choice, classification, and sorting. This article proposes a technique of order of preference by similarity with the ideal solution (TOPSIS) to effectively prioritize multimodal itineraries and improve the performance of the multimodal transport system by choosing the optimal itinerary among the different possibilities that meet the criteria of the 'user.

In the literature, TOPSIS has been used to solve many multi-criteria problems identified in public transport. This methodology makes it possible to consider several contradictory objectives and to conduct the evaluation process globally. Indeed, it facilitates the classification of possible itineraries alternatives. Moreover, most previous studies concerning the problems of choice of itineraries adapt mathematical models such as stochastic programming or whole programming to maximize the quality of service [3]. However, this research rarely concerns criteria that cannot be expressed in real data, such as travel time, cost, and the number of mode changes, safety, and traffic conditions. This article fills this gap by using the TOPSIS approach that deals with both qualitative and quantitative criteria to assess the reasoning behind the choice of the itinerary and define the optimal alternatives of the itineraries.

The rest of this paper is organized as follows. In the next section, a literature review is conducted on the multi-criteria decision-making model (MCDM), including TOPSIS Methodology. The proposed TOPSIS technique is described in section 3. Section 4 presents the application of the TOPSIS methodology in the multimodal transport system. Section 5 covers the conclusion, limitations, and further study.

2. Related Works

Multi-criteria decision-making methods (MCDM) are approaches to structuring information and evaluating solutions to problems with multiple and conflicting objectives [4], [5]. In the literature, many authors have applied MCDM methods to assess and select transport itineraries. MCDM is widely used in selection problems in many industrial applications [6] whose decision-makers cannot accurately assess decision problems because it is impossible to obtain precise data on assessments of decisions. Several studies have implemented the MCDM for evaluation purposes in the field of public transport systems. Yeh [7] used MCDM to assess the performance of bus companies. Zak [8] proposed two possible applications of the MCDM methodology in public transport systems. We can divide MCDM problems into two main groups where the decision parameters could be evaluated with fuzzy and sharp variables. There are many different alternative methods for MCDM problems, which can be used when the decision parameters are sharp or fuzzy.

Among the methods most used in the literature are the Analytical hierarchy process (AHP), analytical network process (ANP), decision-making trial and evaluation laboratory (DEMATEL), elimination and choice translating reality (ELECTRE), and technique for order preference by similarity to ideal solution (TOPSIS). These methods are applied to the data to provide us with more visibility on the decisions. MCDM refers to decision-making in the presence of multiple, generally contradictory criteria. MCDM models are known to evaluate a finite set of alternatives against several criteria. Since there are too many techniques involved, Hwang and Yoon [9] have provided a taxonomy for classifying techniques: types of information, main characteristics of information, and a large class of methods. The alternatives represent the different choices of action available to the decision-maker. Usually, the set of alternatives is assumed to be finished, ranging from several to hundreds. They are supposed to be selected, prioritized, and ultimately classified. In most MCDM applications, the main objective is to obtain the preferred global values of the alternatives at an acceptable scale. Keyvan-Ekbatani and Vaziri [10] assert that the evaluation of urban public transport services is intrinsically an MCDM situation due to the presence of conflicting evaluation factors. Some works have evoked several MCDM methods and have tried to compare the results of each method on urban transport data as in the work of Keyvan-Ekbatania and Oded Catsa [11].

For example, AHP is a MADM technique commonly used in many areas of research. The applications of AHP were dominant in manufacturing, followed by environmental management and agriculture, the energy and energy industry, the transport industry, construction, and Health care [12], [13]. On the other hand, TOPSIS is a technique well known for classical MCDM. Many researchers have used it to solve the problem of fuzzy MCDM [14], [15], [16], [17]. Because the weighting of attributes in TOPSIS has a strong subjectivity and decision-makers can directly assign a weighting to attributes without considering the consistency of the weighting value [18], [19]. In addition, the TOPSIS method can be used for complex decision problems. Therefore, we proposed integrating TOPSIS to reach the global objective and classify the alternative itineraries [5].

The TOPSIS and TOPSIS fuzzy methods are used for many MCDM models [20], [21], [22]. TOPSIS fuzzy as an extension of the classic TOPSIS method is preferable when the alternative evaluation values/criteria are linguistic [23]. There are so many applications where the fuzzy TOPSIS method is deployed [24], [25], [26]. Hwang and Yoon [27] proposed TOPSIS, which was the most widely used MCDM approach. The main idea of TOPSIS is that the best or chosen alternative must be very close to the positive ideal solution and far from the negative ideal solution. Therefore, this solution minimizes the cost criteria and maximizes the profit criteria. The problem to be solved for Wang and Chan [28] has a hierarchy. They treated the difference between conventional TOPSIS and hierarchical TOPSIS. The first can lead to a bad decision, while the second considers the hierarchical structure in the decision problem.

An agent is a computer system in its environment and capable of acting autonomously in this environment to achieve its design objectives. It is generally used to achieve their design goals. An agent is a component that can exhibit reasoning behavior under proactive (goal-oriented) and reactive (event-driven) stimuli. Generally, more than one agent is used in industrial problems [29]. When several software agents are adapted together collaboratively or competitively, these systems are called multi-agent systems [23]. Multi-agent systems are generally used when the problem areas are particularly complex. In our context, we use this technology to understand the problem of urban mobility better. This multi-agent system aims to associate user requests with information linked to the different transport operators. The system allows choosing the modes of transport to combine and offering itineraries that meet itinerary requests. Thus, the traveler will no longer have to consult several transport sites to plan his trip [30], [31] because he can express his preferences between different modes of transport and define a decreasing order of priority with several criteria such as time, number matching, cost, and safety. The article presents the application of the MCDM in a multi-agent system for multimodal transportation. The system provides an itinerary that meets user's needs. The user could define an order of preference on the different criteria so the system will know how to calculate his itinerary.

The related work mentioned above gives an idea of the multi-criteria methods used in the transport field for decision making and travel planning. However, this work only offers methods to meet travel needs with fixed alternatives and does not consider user preferences.

To the authors' knowledge, none of the existing work has combined a multi-criteria method with agents in the context of urban mobility to take on the tasks of a multimodal transport system and facilitate decision-making. However, the main contribution of this article focuses on the decision-making part and the identification of the optimal itinerary that meets the passenger's needs.

3. Description of the Applied MCDM Method: TOPSIS

In this section, first, we will start by explaining the decision matrix in MCDM methods. Next, we will see the methodology for calculating the weights for each evaluation criterion. That will be followed by a detailed explanation of the TOPSIS method "Technical Order Preference by Similarity to Ideal Solution," which will be applied to determine the classification of alternatives in this work. Each MCDM method has three main stages:

- Determine the relevant criteria and alternatives
- Calculate the relative importance, i.e., the weights of the criteria
- Classify the alternatives.

An MCDM problem could be represented using a decision matrix. A problem with m alternatives and n evaluation criteria can be described by a matrix of elements m × n. Each element, such as Xij has either a unique numerical value or a single note, representing the performance of the alternative Ai when it is evaluated according to the decision criterion Cj.

$$D = \begin{matrix} A_1 \\ \vdots \\ A_m \end{matrix} \begin{pmatrix} C_1 & \cdots & C_n \\ X_{11} & \cdots & X_{1n} \\ \vdots & \ddots & \vdots \\ X_{m1} & \cdots & X_{mn} \end{pmatrix} \quad (1)$$

with i= 1,2,3,…,m and j= 1,2,3,…,n

Most MCDM methods require relative importance or weight of each criterion corresponding to their impact on the decision problem. Keyvan-Ekbatani and Vaziri [10] converted the ranking order of the evaluation criteria (i.e., specified by respondents in the questionnaire survey) to numerical scores to analyze the data statistically. A procedure has been proposed assuming that each respondent must distribute 100 points among the criteria selected according to their importance. A linear scale was used to distribute the scores among the criteria chosen. Suppose that we have 100 points and that we have to distribute them on the different criteria according to their degree of importance. We have two cases that arise: the first if we have only one single criterion, and in this case, we will give all the 100 points for this criterion. Still, otherwise, we have several criteria is. In this case, the scores of the criteria can be calculated as follows:

$$S_{jl} = \frac{100\,(N_l + 1 - K_{jl})}{\sum_{k=1}^{Nl} k} \quad (2)$$

$$S_j = \frac{\sum_{l=1}^{N} S_{jl}}{FS_j} \quad (3)$$

where N is the number of participants, Nl is the number of factors selected by respondent l, Kjl is the rank of criterion j by participant l, and Sjl is the factor j by respondent l. If a factor has not been chosen, the score will be assumed zero. In equation (3), Sj is the average score of factor j, and FSj is the frequency of selecting criterion j. To calculate the weight of each criterion, use the following equation:

$$W_j = \frac{N_j . S_j}{\sum_{j=1}^{n} N_j . S_j} \quad (4)$$

$$\sum_{j=1}^{n} W_j = 1 \quad (5)$$

where Wj is the weight of the criterion Cj, and Nj is the frequency for which Cj has been selected.

TOPSIS is based on a simple concept that consists of saying that the ideal alternative is the one that has the best level for all the criteria. In contrast, the least desired alternative is the one that has the worst score for all the criteria [32]. Hwang and Yoon [9] proposed the TOPSIS method to facilitate the order of preference from similarities to find the ideal solution or the best alternative to an MCDM problem. This method is based on the compromise principle solution, which indicates that the best alternative should have the shortest Euclidean distance from the positive ideal solution (PIS) and the Euclidean distance farthest from the negative ideal solution (NIS). The TOPSIS method is used to evaluate and select alternatives for MCDM problems with a finite number of alternatives [33]. The following procedure is performed to evaluate the performance of the alternatives after having given the decision matrix corresponding to the problem with m alternatives and N criteria:

• Normalize the elements of the decision matrix using the following formula:

$$R_{ij} = \frac{X_{ij}}{\sqrt{\sum_{i=1}^{m} X_{ij}^2}} \quad (6)$$

• Determine the weighted normalized vector:

$$V_{ij} = W_j . R_{ij} \quad (7)$$

• Calculate the solutions PIS (A +) and NIS (A-) from the following set of equations:

$$A^+ = \{(\max V_{ij} \mid j \in J), (\min V_{ij} \mid j \in J')\} = \{V_1^+, V_2^+, \ldots, V_n^+\} \qquad J + J' = n$$
$$A^- = \{(\min V_{ij} \mid j \in J), (\max V_{ij} \mid j \in J')\} = \{V_1^-, V_2^-, \ldots, V_n^-\} \quad (8)$$

This step aims to determine the wrong and the best alternative. With $A +$ allows us to find the best positive solution, and $A-$ allows us to find the best negative solution. J represents the most optimal value of the index j and is associated with the criteria positively impacting. As for J, it represents the worst value of the index j and is associated with the criteria having a negative impact.

• Calculate the distances $Si +$ and $Si -$ of each alternative I from $A +$ and $A-$ using the following formulas:

$$S_i^+ = \sqrt{\sum_{j=1}^{n} (V_{ij} + V_j^+)^2} \quad (9)$$

$$S_i^- = \sqrt{\sum_{j=1}^{n} (V_{ij} + V_j^-)^2} \quad (10)$$

• Obtain the similarity index relative to the positive ideal solution $A +$:

$$C_i^+ = \frac{S_i^-}{(S_i^+ + S_i^-)} \quad (11)$$

with $C_i^+ = 1$ only if the alternative i has the best solution and $C_i^+ = 0$ if the alternative i has the worst solution.

• Classify the alternatives according to C_i^+ : the more the value of the index C_i^+ is higher, the more the performance is better.

In the following section, we will present our multimodal information system and detail its architecture. Thus, we will focus on the part concerning the calculation of the suggested itineraries and the choice of the final itinerary that satisfies the user's preferences.

4. Application of TOPSIS Method in the Multimodal Transportation System

Urban public transport is one of the most important elements in creating a sustainable urban environment. Attractive, accessible, and reliable public transport systems can provide the basis for economically efficient and environmentally sustainable urban development. The development of urban public transport services directly influences users, especially when it comes to travel needs. A passenger should have visibility on the path to take on a multimodal trip. Therefore, the path he will take should meet his needs. This work aims to provide an effective decision-making tool to facilitate passengers' trips while combining several modes of transport during their journeys and satisfying their preferences about the different criteria presented: travel time, several mode changes, cost, and safety. The decision support tool we are setting up is a multimodal information system agent-based. Indeed, it is a question of developing a multimodal information system based on the notion of agents linked to multimodal databases to provide optimal or approximate solutions based on the preferences expressed by users. Hence, the central problem of our work is that of finding itineraries in a multimodal transport network. This multimodality characteristic leads to the consideration of several constraints, in particular traffic conditions, passenger preferences, and safety. Thus, the need to measure and evaluate the itineraries proposed by the system. Multi-criteria analysis is commonly used in evaluating these performances to take into account multiple aspects and perspectives. The MCDM provides multi-criteria modeling for decision-making. It is generally used to obtain choice alternatives satisfying several constraints. Consequently, we place ourselves in a multi-criteria modeling framework for decision-making to evaluate the different alternative itineraries proposed by the multimodal information system. To cope with this situation, decision-making requires an intelligent and efficient modeling methodology to support the main tasks of urban mobility. Consequently, the multi-agent system used breaks down complex problems into small sub-problems easy to manage and solve by the individual agent in cooperation.

4.1. Organization of the Multi-agent Information System

This paper is an extended work of our previous contribution in multimodal information systems based on multi-agent architecture, in which different layers were detailed [30], [31]. This architecture consists of six layers which are the HMI layer, the selection layer, the decision-making layer, the information layer, the semantic layer, and the physical layer [34], [35], [36] (Fig. 1). In this paper, we focus on the decision-making layer. The Decision-making layer is composed of three agents:

The SA "Sorting Agent" examines the different itineraries proposed by the DSA "Directory Selecting Agent" and decides how to treat them according to the users' preferences.

The DMA "Decision Making Agent" is based on the method TOPSIS "Technique for order of preference by similarity to ideal solution" as an MCDM methodology to facilitate decision-making and choose the itinerary that will satisfy the user's preferences.

The CA "Calculating Agent" takes up the itineraries proposed by *the DSA "Directory Selecting Agent"* to calculate each itinerary's necessary parameters. These parameters are calculated based on user preferences (travel time, number of mode changes, cost, and safety).

We suggest designing an agent-based information system capable of finding the source of information necessary to meet the diverse demands of users. This system should be able to produce optimized multimodal information in real-time and calculate the requested itinerary. It should access the database of the various transport operators and integrate the results generated by the various agents that compose it. Figure 1 shows the detailed design of the proposed multi-agent system architecture.

Thus, the main tasks of the decision-making layer are analyzing the criteria and calculating the final itinerary that meets the needs of the user.

4.2. TOPSIS Approach Application

To deal with this situation and produce an optimized multimodal itinerary that will satisfy the user's preferences, we used MCDM to offer multi-criteria modeling for decision-making. MCDM is generally used to obtain choice alternatives that satisfy several constraints. The method we are going to adopt for our problem is that of TOPSIS: *"Technical Order Preference by Similarity to Ideal Solution"* which is a multi-criteria analysis method. TOPSIS is a compensatory aggregation method that compares a set of alternatives by identifying the weights, normalizing the scores for each criterion, and calculating the Euclidean distance between each alternative and the ideal solution that has the best score in each criterion.

This method is applied to simulation data. These data relate to several itineraries between different departure and arrival points. The purpose behind this simulation is to classify the different itineraries that the system will offer. The results provided to us will help support planning decisions for multimodal trips in urban areas. In other words, the itinerary that most meets the criteria expressed by the user will be the final itinerary that will be taken.

Unlike other works in the literature, the alternatives will not be fixed. Indeed, they vary according to the point of departure and arrival. With each new itinerary request, we have new alternatives that will be evaluated.

The criteria for these alternatives fall into two types of criteria and are as follows:

- *Negative criteria to minimize*: Travel time, cost, number of modes changes.
- *Positive criteria to maximize*: Safety

This simulation case was applied to the transport network of the Greater City of Casablanca. The figure below highlights all the bus and tramway lines in the city of Casablanca that we used in our simulation. We used Google Map, which allowed us to extract all the data relating to the various tram stations and bus stops without forgetting the lines and the associated travel time. After extracting the data using Google Map, we created this map using the Google MyMaps tool, which allowed us to trace all the trips corresponding to each line and each mode of transport. The public transport network of this city consists mainly of Buses and Tramways.

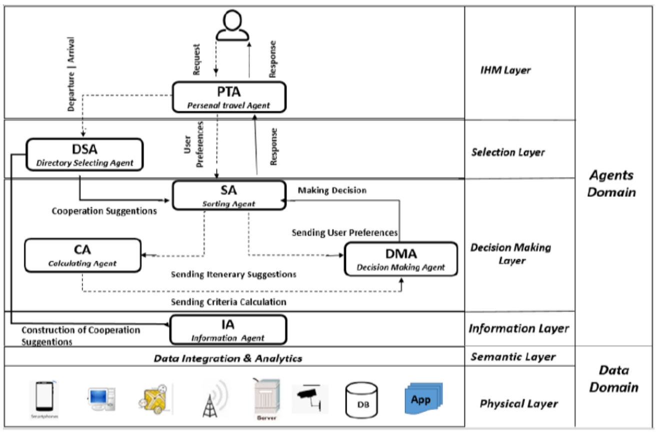

Fig. 1 Multi-agent system architecture overview

Fig. 2 Casablanca transport network data map

The notion of time in a journey can be very important for a passenger when traveling. A passenger who seeks to minimize only the time of his journey in a multimodal context may find himself at the end with a path that contains several mode changes but which at the same time allows him to arrive at his destination more quickly. On the other hand, some passengers are no longer acceptable to take a path containing several mode changes simultaneously. Hence, they prefer to choose an itinerary with a minimum number of modes changes. Consequently, an itinerary carried out without mode change, or even by a minimum number of modes changes, could result in a very long journey. For other passengers, what matters most during a trip is safety. While some only focus on the cost of traveling. A user can choose the criteria he wants or even combine several according to his order of preference. There is no rule to apply in this context, hence the need to have a multi-criteria method that will facilitate decision-making and present the user the itinerary that suits him. The example that we present of the following allows concretizing this situation.

Each criterion should have a weighting or coefficient that reflects its importance in the final choice of the alternative. In our simulation, the user sets these weights by defining preferences for the criteria that interest him the most. Two cases arise from this situation. Either the user is interested in only one criterion, and in this case, the weighting will be 1 for the latter. Otherwise, it is the order of the criteria that will fix the value of the weights.

Our study begins by choosing a scale for measuring the values of the criteria and giving the associated decision matrix, and then we will apply the different steps of the TOPSIS method and give the results of this part.

Table 1 Measurement scale

Numerical Value	Linguistic value
1	Poor
2	Fair
3	Good
4	Very Good
5	Excellent

This measurement scale in table 1 will help the user to define the order of preference for the criteria that interests him and will be used to define the weight of each criterion. To calculate the weight of each criterion, the method of direct determination of weights or simple cardinal evaluation is applied. In this method, each criterion is evaluated according to a predefined measurement scale; in our case, this scale is from 1 to 5. To normalize the evaluations, we divide by the sum. The formula below is applied, where w_i is the weight of criterion i and v_i is the numerical value assigned to it.

$$w_i = \frac{v_i}{\sum v_i} \qquad (12)$$

Based on these weights, the system could determine the data matrix made up of the cited criteria and the suggested alternatives for the requested itinerary. Indeed, the system assigns to each of the criteria the weight that has been calculated. For positive criteria, the higher the score, the more positive the criterion. On the other hand, the higher the score, the more negative the criterion for negative criteria. The weights are defined so that their sum is equal to 1. The score that was assigned for each criterion is presented in table 2 below and the weight calculated By the CA agent:

Table 2 Weight calculation

Criterion	Linguistic value	Score	Weight
Safety	Good	3	0,2
Travel Time	Excellent	5	0,4
Number Of Modes Changes	Fair	2	0,1
Cost	Very Good	4	0,3

Table 3 Itineraries suggested by DSA for the simulation

	Departure	Arrival	Mode	Line	Time
Itinerary 1	Mandarona	Place Marechal	Bus	Line 22	28 Min
	Place Marechal	Nation Unies	Walking		2 Min
	Nation Unies	Sidi Moumen	Tramway	L3	38 Min
Itinerary 2	Mandarona	Station Mekka-Panoramique	Walking		38 Min
	Station Mekka-Panoramique	Sidi Moumen	Tramway	L3	58 Min
Itinerary 3	Mandarona	Omaria - Bus 44	Walking		20 Min
	Omaria - Bus 44	Bernoussi- Bus	Bus	Line	45

		Station 65		44	Min
	Bernoussi- Bus Station 65	Res Saada	Bus	Line 65	20 Min
	Res Saada	Sidi Moumen	Walking		9 Min
Itinerary 4	Mandarona	Place Marechal	Bus	Line 22	28 Min
	Place Marechal	Hay Masjid- Bus Station 47	Walking		1 Min
	Hay Masjid- Bus Station 47	Res Saada	Bus	Line 47	50 Min
	Res Saada	Sidi Moumen	Walking		9 Min
Itinerary 5	Mandarona	Marjane Drissia	Bus	Line 22	20 Min
	Marjane Drissia	Hay Korea- Bus Station 47	Walking		5 Min
	Hay Korea- Bus Station 47	Res Saada	Bus	Line 47	38 Min
	Res Saada	Sidi Moumen	Walking		9 Min

Table 4 Parameters calculation generated by the CA for each itinerary

	Itinerary 1	**Itinerary 2**	**Itinerary 3**	**Itinerary 4**	**Itinerary 5**
Total Time	68 min	96 min	94 min	88 min	72 min
Cost	15 MAD	8 MAD	10 MAD	10 MAD	10 MAD
Number of Mode Changes	2	0	2	0	2
Safety	5	4	4	5	5

Then, the CA agent builds the corresponding decision Matrix for the given itinerary and sends it to the DMA agent.

Table 5 Decision matrix built by CA

Alternatives	**Travel Time**	**Cost**	**Number of Modes Changes**	**Safety**
Itinerary 1	5	2	2	5
Itinerary 2	2	4	4	4
Itinerary 3	1	3	2	1
Itinerary 4	3	3	4	4
Itinerary 5	4	3	2	2

The DMA agent then applies the different steps of the TOPSIS method that we defined previously.

Below the results table provided by DMA Agent, with S as the proximity coefficient to the ideal solution. The DMA agent also arranges the alternatives in order.

Table 6 Calculation of the proximity coefficient of the ideal solution and ranking of the alternatives in order

Alternative	S^*	**Order of Alternatives**	**Distribution of the coefficients**
Itinerary 1	0,5851	1	37%
Itinerary 2	0,55323	4	12%
Itinerary 3	0,31622	5	7%
Itinerary 4	0,52227	3	20%
Itinerary 5	0,54937	2	23%

Thus, for the given request, the optimal itinerary that perfectly satisfies the user's preferences is the itinerary that has the highest percentage rate. The ranking of the different alternatives provided by the TOPSIS method based on weights and scores has shown that the first suggested itinerary is the most suitable to meet the user's preferences with 37%. Itinerary five meets more or less the needs of the user with a percentage of 23%. In the third order, we find itinerary four. This latter is less suitable for the user with a percentage of 20%. In the fourth and fifth positions, there are itineraries two and three, respectively. These latter are present with a percentage of 12% and 7%, which is not suitable for the user. Indeed, these are the last alternatives to adopt since they do not meet many criteria. In a case, it turns out that the percentage of adaptation for two or more itineraries are equal, the system will propose both of them to the user. Therefore, the latter will have the choice of taking the itinerary that suits him. The results presented the result from the simulation that we made. It should be noted that the alternatives, scores, and weights vary according to the user's request.

Below the figure 2 represents the map tracing the optimal multimodal itinerary to take.

Fig. 3 Optimal multimodal route map

5. Conclusion

The interest of our work for a scientific community interested in Smart City Applications lies first in the implementation of a multi-agent information system in the context of multimodal transport for the resolution of routing problems. Second, it resides in the fact that this system includes an MCDM approach for decision-making [37], [38]. Thus, the passenger has visibility on the path to take on a multimodal trip that meets their needs. This approach was carried out using a TOPSIS method. This article presents a simulation of this method in the case of the city of Casablanca. We set as criteria: travel time, cost, number of mode changes, and safety. Overall, this is a complementary step towards an increasingly complete environment in which the main objective is to provide an intelligent information system to manage urban mobility effectively. The next step is to set up a procedure for user data collection; the main objective of this procedure is to improve the system's performance by data learning.

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