A COMBINED AHP-TOPSIS MODEL FOR THE EVALUATION AND SELECTION OF TRUCK DRIVERS

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ABSTRACT

Accidents involving heavy trucks result in severe human and material damage. This severity is mainly due to the weight and difficulty controlling the truck. Human error is often the cause of road accidents, hence the interest in carefully choosing the appropriate driver to deliver an order. In fact, the drivers likely to deliver an order must be evaluated according to a set of criteria to choose the one with the least risk of causing an accident. In solving selection problems, multi-criteria decision support methods are often used in most domains. In this paper, we address the problem of decision-making in the transportation domain and, more precisely, the driver selection problem. We propose a model based on two multi-criteria decision support methods, AHP (Analytic Hierarchy Process) and TOPSIS (Technique for Order Preference by Similarity to Ideal Solution), to select the driver who has the most negligible probability of causing an accident. A driver's choice is justified by ranking all the candidate drivers according to a range of criteria using the combined AHP-TOPSIS model. The AHP method determines and calculates the relative weights of the decision criteria, while the TOPSIS method is used to obtain the final ranking of alternatives. The prioritization of the evaluation criteria was done based on brainstorming with experts in the field, which allowed us to provide a decision support tool for carriers to evaluate their drivers before assigning them to different routes. The results indicate that the use of medicinal products containing Gemfibrozil and Glibenclamide and the driver's affliction with diabetes are the main criteria in the driver selection process.

Keywords: *AHP, TOPSIS, Truck Driver Selection, Decision Making, Multi Criteria Decision Method.*

1. INTRODUCTION

Road accidents are constantly increasing around the world. Every year thousands of people are killed and injured in this road war [1]. Traffic accidents are considered the leading cause of death [2]. According to the Global Status Report on Road Safety for 2018, the annual number of deaths due to road crashes recorded worldwide exceeds 1.3 million people [3]. These accidents are both a social problem and an economic drag on the country's development [4], causing significant economic losses for victims, their families, and the country as a whole ranging from 1% to 3% of gross domestic product for developing countries [5].

Accidents involving heavy vehicles are a serious social problem [6]. In addition, due to the weight of heavy vehicles, the severity of traffic accidents involving this type of vehicle is higher. It results in many fatalities and injuries [7]. The causes of traffic accidents are wide-ranging [8]; however, it is estimated that more than 90% of fatal traffic accidents are due to driver error and other human factors [9].

Drivers, therefore, have an essential role in reducing the number of road accidents, and it is necessary to select the appropriate driver to deliver an order carefully. With this in mind, we propose a model to assist carriers in selecting and ranking drivers who can deliver an order. This choice takes into professional and personal consideration, and personality criteria of the drivers to choose the one who has the slightest chance of causing an accident, and this is by combining the TOPSIS and AHP methods. A brief review of the literature will be presented in the following section.

2. LITERATURE REVIEW

Multi-criteria decision support considers a set of criteria to address different decision problems, which will better model decision-makers preferences [10]. Decision makers commonly use multiple criteria decision-making (MCDM) methods to solve selection problems in most domains. Through a robust and rational decision-making process, an evaluation model is constructed by considering all the criteria of the problem, which will result in an evaluation of all the alternatives and will propose an optimal solution to the problem that best achieves the anticipated objectives (Stewart 1992). The adoption of multi-criteria analysis is widespread for solving different types of problems, especially in the transportation domain, where there is a gradual increase in the use of these methods in decision-making [11].

Among the most widely used decision-making techniques are AHP (including fuzzy AHP), followed by TOPSIS and VIKOR [12]. The use of AHP and TOPSIS methods spans several axes in the transportation domain:

Ul Islam et al [13] were able to assess supply chain challenges and problems among retailers during the COVID-19 outbreak using the hybrid AHP-TOPSIS MCDM technique.

The application of fuzzy AHP and TOPSIS allowed Shen et al [14] to optimize the selection of intermodal transportation between Chongqing, China and Yangon, Myanmar, via sea and land by applying fuzzy AHP and TOPSIS. It has reduced transportation costs and strengthened the collaboration between the two countries. It also assists policymakers in adopting the necessary improvements for the optimal efficiency of intermodal transport chains.

The selection of the best bus chassis among the alternatives was addressed by James et al [15], based on a hybrid methodology of AHP and TOPSIS. A solution was developed that will help bus fleet owners to choose the suitable chassis that meets their requirements most optimally.

In the area of autonomous vehicles, Bakioglu and Atahan based on MCDM techniques and proposed a hybrid approach involving, (AHP), (TOPSIS) and (VIKOR), with Pythagorean fuzzy sets to prioritize the risks of automated vehicles [16].

Regarding the study of road accidents, the AHP method was used by Fernandez et al [17] to prioritize the factors of road accidents; thus, they surveyed a sample of drivers, which allowed them to determine the weight of importance of the factors of road accidents. The research focused on five criteria causing road accidents: lack of knowledge of traffic signs, poor driving behavior, physical and emotional state of drivers, lack of adequate driver training and driver distraction. The research results indicated that lack of knowledge of traffic signs is the most critical factor contributing to road accidents. At the same time, poor driving behavior is considered the least important factor.

To identify the most important causes of accidents, Xi et al [18] used the hierarchical analysis process (AHP) to order the factors that cause accidents according to their relative importance. Then, to determine the degree of accident or level of influence, the Apriori algorithm is used, which specifies the type and severity of accidents caused by a variety of factors. The factors studied were grouped into four categories: driver, vehicle, road and environment. The study concluded that driver-related factors are crucial in the occurrence of accidents, while vehicle-related factors are the least influential. The results also showed that environmental factors and accident type are strongly correlated.

Ngoc and My Thanh combined the AHP method and the Customer Satisfaction Index (CSI) to prioritize and assign weights to adopted road safety measures [19]. The CSI method was used to collect the opinions of road users to identify traffic problems, while the AHP method was used to prioritize the selected measures.

Ma, Lou, and Wang proposed a new approach to analyze the factors that lead to driving errors in accidents based on the improved AHP method [20]. The study analyzed the relationship between road accidents and drivers' errors of perception, judgment, and operational errors. They were able to conclude that the main factor contributing to traffic accidents is drivers' low perception and judgment ability. These factors are not necessarily related to the road or the environment; only one can cause road accidents.

Our search of the literature revealed research applying MCDM methods in the field of transportation that focused on the study of road accidents and aimed to classify their contributing

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factors through AHP and TOPSIS. In these works, we did not find a study that details the criteria related to the driver, as most studies do not deal with these factors in their entirety and are only interested in some criteria. Hence the originality of the work we are developing.

In our case, we combine the AHP and TOPSIS methods to classify the drivers likely to deliver an order. The interest that led us to focus on drivers is due to the critical role of the human factor in accidents. Driver-related factors cause 87.2% of large truck accidents, 10.1% are due to vehicle-related factors, and 2.3% are related to environmental factors, according to the Federal Motor Carrier Safety Administration's March 2006 report on the causes of large truck accidents in the U.S. Congress [21]. However, driver selection is a multi-criteria decision influenced by various factors that the decision-maker must consider.

3. PRESENTATION OF THE PROPOSED SOLUTION

Our solution is to propose a coherent and optimal decision support model helping carriers choose the best driver to deliver an order while minimizing the risk of an accident. An assessment of the potential drivers is necessary, and the ultimate decision is made after a rating based on a set of criteria. These criteria measure the impact of the driver's choice on the probability of an accident.

Thanks to a literature review, we could distinguish the evaluation criteria of the factors related to the drivers and having an impact on the occurrence of an accident, which allowed us to solve this multi-criteria decision support problem.

In our model, we combined the AHP and TOPSIS methods. The AHP method allowed us to determine and calculate the relative weights for all the decision criteria. Then we used the TOPSIS method to obtain the final ranking of the alternatives.

To develop our model, we followed the following methodology:

The first step is to build the hierarchical architecture of our AHP model. The meetings and brainstorming sessions we had with experts in the field and our research in the literature allowed us to identify the predictors related to the driver and which contribute to the occurrence of accidents.

The second step is to construct the pairwise comparison matrix. Based on the opinions of domain experts on carrier preferences concerning the identified criteria, we were able to derive the pairwise evaluation of the criteria in terms of relative importance.

Next, we divided each element of the matrix by the sum of its corresponding column, and finally, we averaged each row of the matrix to obtain the weight of each criterion.

To select the best driver, we used the TOPSIS method. To do this, we constructed the decision matrix, which includes the scores for each alternative concerning the identified criteria. Since these scores are expressed in different dimensions, it is essential to normalize the matrix. We obtain the weighted decision matrix by multiplying the matrix entries by the weights associated with the criteria. Then, the ranking of the alternatives is obtained after calculating the positive and negative ideal solutions. Figure 1 illustrates the algorithmic process of the proposed solution.

4. IDENTIFICATION OF THE CRITERIA AND CONSTRUCTION OF THE HIERARCHICAL ARCHITECTURE OF OUR MODEL

4.1. Presentation of the AHP method

The Analytic Hierarchy Process, also known as (AHP), was developed by Saaty [22]. It is considered a multi-criteria analysis technique that can be used to address complex decision problems. It consists of three parts: the goal or problem to be solved, all potential solutions or alternatives, and the criteria by which these alternatives will be evaluated [23]. As such, it offers several advantages, including managing complexity, identifying critical elements related to a problem, and addressing both quantitative and qualitative criteria [24]. It is made possible through a hierarchical tree, which prioritizes all criteria and alternatives.

Four steps comprise the multi-criteria decision-making methodology used in the reasoning process [25]:

First, we identify the criteria and the alternatives to be evaluated. Then, a tree-like hierarchy is established that considers all the specified decision criteria.

The alternatives and criteria are compared in pairs using a judgement matrix that allows the relative importance of each criteria and alternative to be specified. This comparison is made via the scale proposed by Saaty [26], which is described in Table 1.

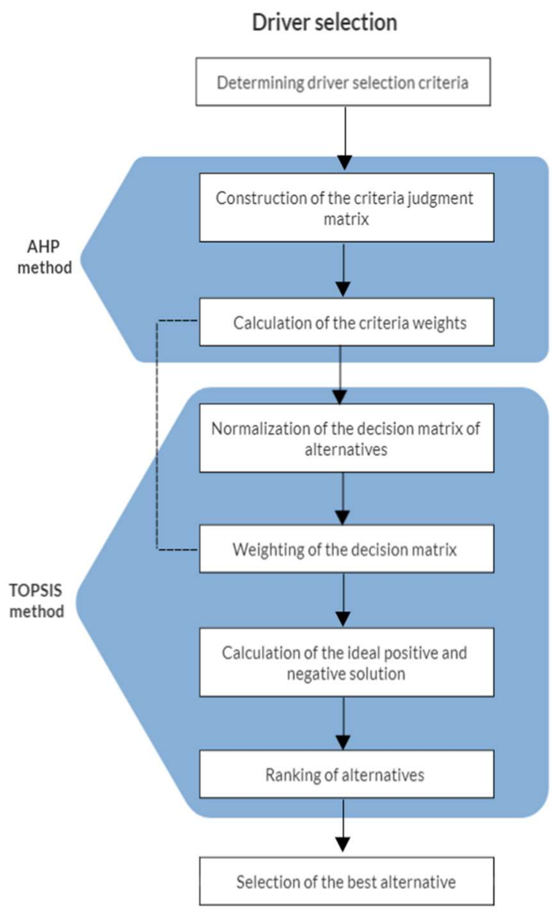

Figure 1:The algorithmic process of the proposed solution

The judgement matrices of the criteria and alternatives thus developed will make it possible to estimate the weights of the decision elements through the calculation of the weighted rankings of each alternative by combining the scores of the alternative and the criteria.

4.2. Building the AHP architecture

Identifying accident predictors is a crucial preliminary step in the driver selection process. In this sense, we based ourselves on the literature and on meetings and brainstormings that we carried out with experts in the field to identify the predictive factors relating to the driver that contribute to the occurrence of accidents. The study focused on nine main criteria, and the results were used to construct judgment matrices. Figure 2 shows the Hierarchical Structure of our model.

Table 1: Saaty scale for pairwise comparisons

Numerical value	Description
1	Equal importance
3	Slight importance of one over another
5	Moderate importance of one over another
7	Very strong importance
9	Extreme importance of one over another
2,4,6,8	Intermediate values between two adjacent values

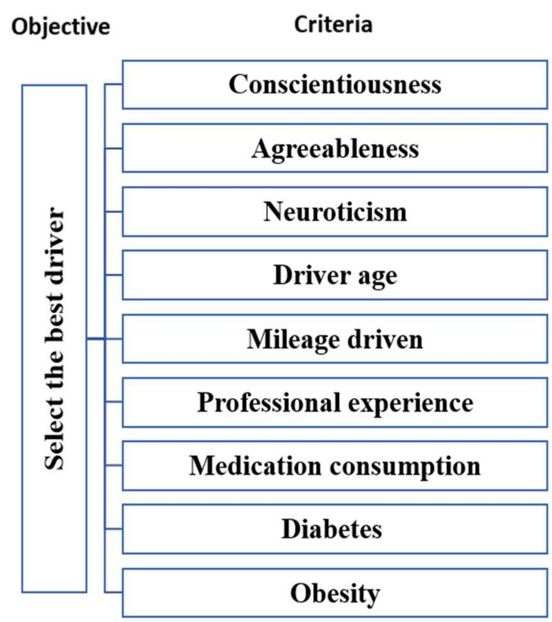

Figure 2: The hierarchical structure of our model

Thus, we built the hierarchical architecture of our AHP model based on a set of criteria to be considered when choosing a driver:

- ✓ Neuroticism (or emotional stability): Neuroticism is a personality trait characterized by negative emotionality. This negative emotionality includes depression, worry, schizophrenia, and anxiety [27]. Results show that people without anxiety, anger, or guilt tendencies are less likely to be involved in accidents [9].

- ✓ Agreeableness (empathy): Agreeableness is a personality trait marked by a sympathetic, friendly, and harmonious relationship with others [28, 41]. Generally, people who have empathic tendencies are usually the least likely to have accidents [9].
- ✓ Conscientiousness (caution): Conscientiousness is a personality trait distinguished by a tendency to be thorough, cautious, and vigilant [42, 29]. Various studies have addressed the link between personality factors and crash involvement; according to [9], the risk of crashing is often minimal for more self-controlled people.
- ✓ Diabetes: The risk of accidents in people with diabetes is significant, as people with diabetes have high or low blood sugar levels, which is enhanced using medical drugs as well as their side effects; the subjects have a poorer vision and suffer from decreased consciousness [30].
- ✓ Obesity: Obesity is a significant threat to road safety [40], Stoohs et al [31] presented preliminary evidence that obese drivers have twice the crash rate of non-obese drivers due to significant daytime sleepiness. However, the degree of obesity appears to impact older drivers' driving safety [32].
- ✓ Medication consumption: The consumption of drugs influences the occurrence of accidents [43]; in fact, the event of accidents in people who consumed Gemfibrozil (helps reduce cholesterol and triglycerides in the blood) and Glibenclamide (treat type 2 diabetes) was higher. Because these drugs had more side effects like vision problems, dizziness, and headaches, leading to more accidents [30].
- ✓ Driver age: Drivers aged 18-24 have the highest fatal crash involvement rates of any age group [33]. According to Sullman, Meadows, and Pajo [34], young truck drivers are about 50% more likely than middle-aged drivers to be charged with an offense in a crash. They show that young truck drivers drive more miles yearly and at higher speeds than older drivers. Additionally, they claim that drivers under 30 are nearly 50% more likely than drivers over 30 to be charged with a collision offense.
- ✓ Work experience: studies assessing the relationship between the length of work experience as a truck driver and reports of crash involvement have shown that more extended work experience was inversely associated with reports of crash involvement and near misses [7].
- ✓ Mileage driven (per week): It turns out that fatigue, such as that caused by long-distance driving, is another crucial factor in the safety of older drivers. Certainly, older drivers have certain occupational advantages, such as a greater tolerance for difficult work situations, such as long waiting times and vehicle type [32].

Table 2 presents the above criteria that are classified by nature (favorable and unfavorable). The higher the value of a favorable criterion, the lower the accident probability. On the other hand, the higher the value of an unfavorable criterion, the higher the likelihood of an accident.

Table 2 Driver Evaluation Criteria

	Criteria	Code	Nature
Personality trait	Neuroticism	Neu	Unfavorable
	Agreeableness	Agr	Favorable
	Conscientiousness	Cons	Favorable
Personal information	Diabetes	Dia	Unfavorable
	Obesity	Obe	Unfavorable
	Medication consumption	MC	Unfavorable
	Driver age	Ag	Favorable
Professional information	Work experience	EP	Favorable
	Mileage driven	MD	Unfavorable

4.3. Evaluation of the criteria

After establishing the problem's hierarchical structure, we build the judgment matrix for the criteria chosen in the prior stage. We created and distributed a questionnaire to experts in the field on the study of the preference of carriers in relation to the identified criteria, the results obtained were used to feed the matrix of judgments. Table 3 shows the pairwise comparison matrix.

Table 3: Criteria pairwise comparison matrix

	Neu	Agr	Cons	Dia	Obe	MC	Ag	EP	MD
Neu	1	6	4	1/3	5	1/3	2	3	1/2
Agr	1/6	1	1/3	1/5	1/2	1/5	1/5	1/3	1/6
Cons	1/4	3	1	1/3	2	1/5	1/3	1/2	1/5
Dia	3	5	3	1	4	1/2	4	5	2
Obe	1/5	2	1/2	1/4	1	1/6	1/4	1/3	1/6
MC	3	5	5	2	6	1	3	3	2
Ag	1/2	5	3	1/4	4	1/3	1	2	1/3
EP	1/3	3	2	1/5	3	1/3	1/2	1	1/4
MD	2	6	5	1/2	6	1/2	3	4	1

Calculating the consistency ratio CR allows verifying the consistency of the comparisons in the judgment matrix. It consists of a comparison between the Consistency Index (CI) and the Random Consistency Index (RI) using the formula:

$$CR = \frac{CI}{RI} \quad (1)$$

With CI (the Coherence Index) is defined by:

$$CI = \frac{\lambda_{max} - n}{n-1} \quad (2)$$

Table 4 determines a Random consistency index RI based on the number of criteria addressed by the hierarchy in question. The RI corresponding to the number of criteria in our matrix equals 1,45 [35].

Table 4: RI Index Table

	3	4	5	6	7	8	9	10
RI	0,58	0,90	1,12	1,24	1,32	1,41	1,45	1,49

The computation of the consistency associated with our judgment matrix gives:

$$\mathrm{CI} = \frac{\lambda\mathrm{max} - \mathrm{n}}{n-1} = \frac{\lambda\mathrm{max} - 9}{9-1} = 0{,}082$$

And so: $\mathrm{CR} = \frac{0{,}082}{1{,}45} = 0{,}057$

The comparisons in the judgment matrix are consistent since the CR value is less than 0,1. Table 5 summarizes the priorities and the ranking of the criteria obtained.

Table 5 : Priorities and ranking of criteria

Criteria	Priority	Rank
Neuroticism (Neu)	0,125	4
Agreeableness (Agr)	0,024	9
Conscientiousness (Cons)	0,044	7
Diabetes (Dia)	0,206	2
Obesity (Obe)	0,030	8
Medication consumption (MC)	0,244	1
Driver age (Ag)	0,088	5
Work experience (EP)	0,059	6
Mileage driven (MD)	0,180	3

The most important criteria is " Medication consumption ", with a priority of 24.4%.

5. EVALUATION OF ALTERNATIVES (DRIVERS)

5.1. Presentation of the TOPSIS method

Decision makers can evaluate and categorize the corresponding alternatives to a decision problem using the TOPSIS method. The idea behind this approach is that the ideal alternative should be as close as possible to the ideal positive solution and as far away as possible from the ideal negative option [36]. The following steps should be followed in order to use the TOPSIS method [37] :

- ✓ Construction of the decision matrix: it is essential to establish the decision matrix, which includes a qualitative assessment of the performance of the alternatives against the criteria.
- ✓ Normalization of the decision matrix: the elements of the decision matrix can be expressed in different dimensions, so it is necessary to transform them into dimensionless elements. The decision matrix is normalized by equation (3):

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{n} x_{ij}^2}} \quad (3)$$

n is the number of alternatives, and x_{ij} is an element of the decision matrix.

- ✓ Determining the weighted normalized matrix: this involves multiplying the normalized decision matrix with the vector of criteria weights, as shown in the following equation (4):

$$rp_{ij} = r_{ij} * p_j \tag{4}$$

p_j is the weight of criterion j and r_{ij} an element of the normalized decision matrix.

- ✓ Determine the positive optimal solution A^+ and the negative optimal solution A^-: A^+ and A^- are calculated (here in the case where criteria j is to be maximized) from the weighted normalized matrix, using the following equations:

$$A_j^+ = max\{rp_{ij}\}, avec\ 1 \leq i \leq n \tag{5}$$

$$A_j^- = min\{rp_{ij}\}, avec\ 1 \leq i \leq n \tag{6}$$

- ✓ Calculate the separation of an alternative i from the positive ideal solution $S_i^+$and the negative ideal solution S_i^-: $S_i^+$and S_i^- are calculated from the following equations:

$$S_i^+ = \sqrt{\sum_{j=1}^{m}(rp_{ij} - A_j^+)^2} \tag{7}$$

$$S_i^- = \sqrt{\sum_{j=1}^{m}(rp_{ij} - A_j^-)^2} \tag{8}$$

The separation of each alternative from the ideal solution S_i^* is calculated by :

$$S_i^* = \frac{S_i^-}{S_i^- + S_i^+} \tag{9}$$

- ✓ Rank the alternatives using the calculated S_i^* value for each alternative.

5.2. Classification of drivers using the TOPSIS method

Here we use the TOPSIS method to evaluate, according to the previously identified criteria, three drivers, D1, D2 and D3, likely to deliver a given good. For the non-numerical criteria, we will adopt the representation shown in Table 6.

Table 6: Representation adopted for non-numerical criteria

Criteria	Representation
Neuroticism, Agreeableness, Conscientiousness	Score out of 10
Diabetes	1 for diabetic drivers 0 for non-diabetic drivers
Medication consumption	A number indicating the number of drugs taken by the driver containing Gemfibrozil and Glibenclamide
Obesity	Body mass index (BMI)

Studying the variation of each alternative from the positive and negative ideal solution allowed us to rank the drivers and then determine the best one. Table 7 presents the data of the different drivers according to the criteria identified in our case study.

After identifying the evaluation matrix of the alternatives, the TOPSIS method allows us to determine the normalized and weighted matrix of the different alternatives by applying equations (eq 3) and (eq 4). The positive and negative ideal solutions are then determined using equations (eq 7) and (eq 8). Table 8 shows the variation of the alternatives from the positive and negative ideal solution.

Table 7 Evaluation of alternatives according to the criteria

	Neu	Agr	Cons	Dia	Obe	MC	Ag	EP	MD
D1	8	5	5	1	22	1	40	13	3000
D2	7	5	6	0	27	2	50	10	2500
D3	7	6	7	0	24	1	37	9	2200

Table 8 Variations of the alternatives from the ideal solutions

Alternatives	Variation from the positive ideal solution (E^+)	Variation from the negative ideal solution (E^-)
D1	167,29	0,52
D2	56,70	110,60
D3	1,37	167,29

The ranking of the three drivers is presented in Table 9. The driver who satisfies the most selection criteria is D2, which justifies that he is the best choice provided by our approach, followed by driver D1 and D3.

Table 9: Final driver ranking

Alternatives	Separation / ideal solution	Separation / ideal solution (%)	Ranking
D1	0,0031	0,31%	3
D2	0,6611	66,11%	2
D3	0,9919	99,19%	1

6. DISCUSSION

The use of MCDM improves the organization of the amount of information considered essential in most cases and allows for better decision-making in transportation-related problems. By combining the AHP and TOPSIS methods, we proposed an approach that provides carriers with a decision support tool that allows them to evaluate their drivers before assigning them to different routes.

We used a multi-criteria analysis method to select the ideal driver to deliver an order. This analysis was based on evaluation criteria identified through a literature review of driver-related predictors of accident occurrence. These criteria were then prioritized and weighted using the AHP method, and finally, all the alternatives were evaluated and ranked using the TOPSIS method.

Considering the weights obtained and classifying the factors related to the drivers according to their weight, we can see that the consumption of medication has a higher weight and importance in this method. The second variable of this method is the presence of certain diseases in the drivers, mainly diabetes. It was also found that "Agreeableness" is the lowest priority factor.

The developed approach simultaneously takes into consideration qualitative and quantitative attributes of drivers and offers a scientific, logical and coherent model for driver selection. The main advantage of this model is that it prevents carriers from making any mistakes when deciding on the most appropriate driver to deliver a given order. Moreover, the developed model can be applied to other sets of criteria, we can even add new criteria to have a more specific result.

7. CONCLUSION

Truck accidents often result in lengthy road blockages and disrupt the supply chain by causing costly operational delays. In addition, the weight and size of larger and heavier vehicles limit manoeuvring and lead to more severe consequences than car accidents [21].

In this paper, we explored the vital driver-related predictors contributing to the occurrence of truck accidents to develop a model to help carriers select the best driver to deliver an order. Nevertheless, the weighting of these criteria is subjective because it is based on the preference of the decision-maker over the alternatives or criteria and depends on his unique knowledge and individual viewpoints. However, the objective weighting approaches rely on performance data and mathematical formulas to determine weights [38]. On the other hand, the combined methods use a parameter to control the degree of consideration of expert opinion and objective evaluation. This parameter's value depends on the experts' availability and confidence level [39].

As a potential perspective to work presented, we can perform a comparative study between a TOPSIS-AHP model and a model based on objective methods or combined methods.

Similarly, a sensitivity analysis of the coefficients of the pairwise comparison matrix is a very promising avenue of research. Small changes in these factors will reveal their impact on driver ranking and the subjective impact of the coefficients assigned in pairwise comparisons.

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