Construction of Vehicle Theft Index by Using TOPSIS Method with Entropy Based Criteria Weights

Mohd. Firdaus Abd Khabir[#1], Maznah Mat Kasim[*2], Malina Zulkifli[#3]
[#]*Universiti Utara Malaysia (corresponding author)*
[*]*Universiti Utara Malaysia*
[#]*Universiti Utara Malaysia*
[1]mohd.firdaus18@yahoo.com, [2]maznah@uum.edu.my, [3]malina@uum.edu.my

***Abstract* --- Property theft especially vehicle theft is a major contribution of entire crime. Estimating the level of crime by depending solely on the total of vehicle theft cases recorded is insufficient in order to observe the direction of the problem itself. The aim of this paper is to construct a vehicle theft index based on multi-criteria decision method to analyse vehicle theft pattern in particular and property theft in general for 82 areas in peninsular Malaysia. As vehicle theft is the major part of property crime, it is influenced by other criteria such as unemployment, level of education, immigrant and drug which should be considered in the vehicle theft index construction. Hence, this study takes into account the diversity of intrinsic of information in the criteria by measuring the entropy or the degree of diverseness of the data as proxies of the relative importance of the criteria. Then a Technique for Order Preference by Similarity to the Ideal Solution (TOPSIS) was used to construct the vehicle theft index of 82 areas in peninsular Malaysia. The finding shows the top three areas in descending order are Kuala Lumpur, Petaling and Johor Bahru. The vehicle theft index constructed in this study can illustrate the actual direction of theft problem in Malaysia and the index construction process can be applied in other countries as well.**

***Keywords* ---** *Entropy, Index, TOPSIS, Weight, Vehicle theft.*

1. Introduction

There was a twofold increase in the number of vehicle thefts in Malaysia between 2000 to 2009, that is, from 20 145 cases to 40 287 cases[1]. Even though the record had shown a declining at certain points of years, the total number of cases is still high.

This scenario is mostly contributed by property crime, even though the public has given more attention towards violence crime. Notably, vehicle theft has contributed almost half of the total number of property crime reported [2]–[4]. This probably due to opportunity for victims to make insurance claims which resulting the obvious increase compare to other property crime category.

It is a common practice for a victim of vehicle thefts to file a police report to the nearest police station which usually located in any of the 82 districts of states of Peninsular Malaysia. Logically the degree of occurrence of vehicle theft will vary according to the locations. Ref. [5] reported that urban area has higher degree of occurrence of vehicle theft than the rural area. Perhaps the difference degree of occurrence of vehicle theft might be influenced by activities related to drug that encourage criminals to steal.

Furthermore, these criteria certainly have different degree of contributions towards the occurrence of the theft. The weights or the degree of importance should be appraised to distinguish the role among the criteria related to vehicle theft. Obviously the determination of weight of criteria should be completed at the earlier since it is important and able to regulate the direction of an analysis [6].

However, generating the objective weight of criteria based on the raw information only without considering the aspect of uncertainty of the intrinsic information is insufficient. Therefore the quality of diverseness of the information should be considered. Hence, the aim of this paper is to construct a vehicle theft index constructed by TOPSIS method by employing the objective weights of the criteria that are generated through entropy technique. Entropy is basically synonymous to 'uncertainty', and it is measured by considering the quality of diverseness of intrinsic value of information contained in the criteria.

This paper is organized in 6 sections, section 1 is the introduction, followed by a brief explanation regarding vehicle theft in section 2, multi-criteria decision methods in section 3, the methodology is explained in section 4, and the results and conclusions are presented in section 5 and 6 respectively.

2. Vehicle theft

Vehicle theft is defined as an attempt or an activity of taking vehicles permanently from the authentic owner illegally. Federal Bureau Investigation (F.B.I) define vehicle as a self-propelled vehicle for land surface movement excluding farm equipment and construction equipment [7].

Two leading types of theft criminal have been categorized by researchers. A 'joyrider' is a type of thief who commits the vehicle theft only for self-satisfaction without any specific purpose [8]. Meanwhile a 'jockey' is classified as a thief of business orientation type [9]. Commonly, the individuals who involve in this crime are young males [10], who typically have a week education background [11] and unemployed [12].

Even though there is no significant evidence between drugs and immigrants toward vehicle theft, the existing of both drug addiction problem [13] and immigrants [14] might

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influence the direction of property crime. Therefore, the two elements might possibly influence vehicle theft since vehicle theft is a major component of property crime [3].

In constructing the vehicle theft index for Peninsular Malaysia, this paper has successfully utilized the data from Insurance Service Malaysia and the Royal Malaysia Police from 2001 to 2003 as the latest record of vehicle theft is classified and unavailable. Besides, the other data were supplied by Malaysia National Drug Agency and Department of Statistics Malaysia in order to illustrate the proposed methods.

3. Multi-criteria decision making method

[15] stated that multi-criteria decision making (MCDM) as a discipline has evolved since the 1970s which facilitates decision makers to have better, and systematic ways to analyze multi-criteria problems which leads to have reliable results. The MCDM is also known as models, methods and techniques that provide effective solutions for complex real world problems with a variety of conflicting criteria [16]. [17] reported that MCDM is capable to solve problems which involved conflicting criteria in order to evaluate, prioritize, organize or choose an alternative. Typically in order to solve problems through MCDM, the identified criteria and alternative are formatted as decision matrix to ease the mathematical concept representation and calculation. Let a matrix X of size $m \times n$ represents n alternatives evaluated on the basis of m criteria, and x_{ij} is an element of performance valuation of alternative i, A_i, $i = 1, \dots, m$ against criterion j, C_j $j = 1, \dots, n$ as illustrated in Table 1 [18].

Table 1. Decision matrix

	C_{11}	…	C_{1j}	C_{1n}
A_1	X_{11}	…	X_{1j}	X_1
A_i	X_{i1}	…	X_{ij}	X_i
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
A_n	X_{m1}	…	…	X_{mn}

3.1 Objective weight

Weight is a crucial aspect in MCDM modelling since the weights represent the degree of importance among the criteria [6]. Basically, there are two types of weights which are objective and subjective weights. The objective weights are mainly determined based on intrinsic information such as entropy, mean weight, Criteria Importance Through Inter criteria Correlation (CRITIC) [19], standard deviation, and statistical variance [20].

The objective weight usually originates from set of data of the problem without any interventions or preferences of experts or decision makers [21]. The advantage of objective weight is the weight constructed would be from based on reliable data which are provided by established sources such as Royal Police Malaysia. Moreover the objective weights allow aspects of efficiency, benefit and cost to be considered in the quantitative assessments. On the contrary subjective weights represent the degree of importance of criteria which derived from decision maker's or expert's judgments, views, and opinions. One popular subjective weighting method is Analytical Hierarchy Process [22]. However, Analytical Hierarchy Proses is inappropriate when involving a large number of alternative because the pair wise comparisons made by decision makers would be inconsistent.

3.2 Entropy

Entropy concept was first introduced by [23] in formulating a measurement of uncertainty of information based on probability theory. Then, entropy measurement was implemented by [24] as objective weighting method by stating that the criteria weight is a reflection of the average intrinsic information which is generated by a given set of data. Some successful applications of entropy method are water quality assessment [25], supplier selection [26] and product evaluation [27].

However to the best of authors' knowledge, no further entropy concept is applied in vehicle theft problem. Hence, this paper applies measures of entropy of the criteria in determination of objective criteria weights in vehicle theft problem. Some approaches of measuring entropy of criteria are fuzzy entropy, probabilistic entropy and inequality entropy [28]. This paper utilized entropy approach by [29] since the paper is dealing with of benefit and cost criteria. In order to visualize comparable criterion the step begins by normalizing each criterion by the formula as shown in (1) for benefit criterion and (2) for cost criterion respectively.

$$z_{ij} = x_{ij} - \check{x}_j / \hat{x}_j - \check{x}_j \quad (1)$$

$$z_{ij} = \hat{x}_j - x_{ij} / \hat{x}_j - \check{x}_j \quad (2)$$

Where $\hat{x}$ is maximum value and $\check{x}$ is a minimum value of jth criterion.

The entropy values E_j is given as in as follows.

$$En_j = -k \sum_{j=i}^{n} f_{ij} \ln f_{ij}\,, \quad (3)$$

$$i = 1,2, \dots n$$

Where

a. the z_{ij} value is in [0 1] and n is the number of area.

b. $f_{ij} = \frac{z_{ij}}{\sum_{j=i}^{n} z_{ij}}$,$k = \frac{1}{\ln n}$ and if $f_{ij} = 0$ then $\ln f_{ij} = 0$

Therefore, the objective weight for *j*th criterion is

$$w_j = 1 - En_j / m - En_j \quad (4)$$

where m is number of criteria (evaluating object), while $0 \leq w_j \leq 1$ and $\sum_{i=1}^{m} 1$.

3.3 TOPSIS

One of the most commonly utilized method in MCDM invented by [30] is Technique for Order Preference by

Similarity to Ideal Solution or well known as TOPSIS [31]. The idea of TOPSIS is to choose the best alternative which satisfies simultaneously the shortest distance from the best ideal solution and the farthest distance from non-ideal solution [16]. Therefore, in this paper the best ideal solution would be safest area in peninsular Malaysia and vice versa for non-ideal solution. TOPSIS is utilized by the following steps.

Step 1: Decision matrix in Table 1 is normalized by using the following formula.

$$r_{ij} = x_{ij} / \sqrt{\sum_{i=1}^{J} x_{ij}^2} \quad (5)$$

$i = 1,2, \dots m$ and $j = 1,2, \dots n$

Step 2: The weighted normalized matrix is constructed through (6)

$$v_{ij} = w_i \times r_{ij} \quad (6)$$

Where $i = 1,2, \dots m$, $j = 1,2, \dots n$ and $\sum_{j=1}^{n} w_{ij} = 1$

Step 3: Determination of ideal solution

$$A^* = \{ v_1^*, v_2^*, \dots, v_n^* \} \quad (7)$$

where $v_j^* = max_i \, v_{ij}, i = 1,2, \dots, m$ and $j = 1,2, \dots n$

and non-ideal solution

$$A^- = \{ v_1^-, v_2^-, \dots, v_n^- \} \quad (8)$$

where $v_j^- = min_i \; v_{ij}, i = 1,2, \dots, m$ and $j = 1,2, \dots n$

Step 4: Calculation of separation of each alternative A_i from A^+ is shown as

$$S_i^+ = \sqrt[2]{\sum_{j=1}^{n} \left(v_j^* - v_{ij}\right)^2} \; i = 1,2, \dots, m \quad (9)$$

and calculation of separation of each alternative A_i from A^- is

$$S_i^- = \sqrt[2]{\sum_{j=1}^{n} \left(v_j^- - v_{ij}\right)^2} \; i = 1,2, \dots m \quad (10)$$

The relative closeness to the ideal solution is given as

$$C_i^* = S_i^- / (S_i^- + S_i^+) \;, 0 \le C_i^* \le 1 \quad (11)$$

4. Methodology

Firstly, the decision matrix as shown in table 2 is constructed. The matrix consists of a list of 82 areas in peninsular Malaysia as a set of alternatives with the following criteria; the number of stolen vehicles, unemployment, immigrant, and drug which are as considered as cost criteria. Education would be the only benefit criterion considered which is divided into three criteria (primary level, secondary level and tertiary level). Next the weight of each criterion is determined through the entropy method started by the normalization of benefit criterion by (1) while (2) is for cost criterion. The values of entropy for each criterion generated by (3) and finally the objective weight of criterion is calculated by using (4).

Table 1. Decision matrix for 82 areas against criteria

	Education					
	Vehicle theft	Unemployment	Secondary level	Tertiary level	Immigrant	Drug
$Area_1$	X_{11}	…	X_{1j}	…	…	X_{1n}
$Area_i$	X_{i1}	…	X_{ij}	…	…	X_{in}
.	.	.	.	.	.	.
.	.	.	.	.	.	.
.	.	.	.	.	.	.
$Area_{82}$	X_{m1}	…	…	…	…	X_{mn}

Then, the TOPSIS method is employed. Since the entropy method used is to determine the objective weights of the criteria is considering benefit and cost aspects simultaneously. Therefore, the criterion of education is considered as benefit aspect while the cost aspect are listed as; vehicle theft, unemployment, immigrant and drug. Based on the formula (1) which is a benefit aspect the value produced by this equation would shows the highest value while the formula (2) which is a cost aspect would shows the lowest value.

Consequently, the end result of this paper would shows the most positive area or the safest area should be ranked at the first position, and it is followed by the second safest area until to the most risky area at the last position. In order to overcome the problem, equation (11) has to undergo some modification by replacing S_i^- by S_i^* as the numerator which finally would rank the alternatives (areas) from the most risky area at the top of the ranking, while the safest area would be at the last position.

5. Result and discussion

Table 3 shows the weights of 6 criteria that are used to construct the Vehicle Theft Index. The tertiary level in education has the highest weight followed secondary level with value 0.5147 and 0.3473 respectively. Next, the weight of drug criterion is 0.0710 while unemployment, immigrant and stolen vehicle are 0.0347, 0.0168 and 0.0155 respectively.

Table 2. The weight of criteria

	Education					
	Vehicle theft	Unemployment	Secondary level	Tertiary level	Immigrant	Drug
weight	0.016	0.035	0.35	0.51	0.017	0.071

The weight of criteria in Table 3 is used in TOPSIS to produce the score for the selected 82 areas in Peninsular Malaysia. Table 4 shows the top three areas of vehicle theft in Peninsular Malaysia which are Kuala Lumpur at the first place followed by Petaling Jaya and Johor Bahru among the 82 area.

Table 3. The top three of unsafe area in peninsular of Malaysia

	Area	Score
1.	Kuala Lumpur	0.9845
2.	Petaling Jaya	0.5097
3.	Johor Bahru	0.0614

6. Conclusion

Hence this paper has successfully illustrated the application of MCDM methods to provide a guideline and recommendation for respective authority to notice and aware towards the direction of vehicle theft and the momentum of potential factors (cost criteria) which might stimulate the problem to occur.

Based on the result in Table 3 clearly that education factors should be enhanced by government to ensuring that all of Malaysian youths are educated in order to encourage them to be good civilians by government through since the awareness among the citizen is an important aspect in order to manage the direction of vehicle theft activity. Through proper education process, it is believable the opportunity to restrain other problems that might be an influence the occurrence of vehicle theft such as activities related to drug and unemployment. Moreover by reducing and controlling the vehicle theft problem could reduce the statistical record of property theft in general since the vehicle theft problem has highest report frequency in property theft category [4].

Next, TOPSIS method has successfully considered the distance between safest area (ideal solution) and the most risky area (non-ideal solution) simultaneously. In fact the quality of criteria weight constructed through entropy is much reliable since aspect of diverseness among intrinsic information has taken into account. As a result, the MCDM methods has shown some prestigious quality to become a new technique in order to construct a Malaysia vehicle theft index in future.

However, this paper can be improved by considering other rational criteria such as the age and the type of criminal such as joyrider or jockey, the level of urbanization, the vehicle's model/age and perhaps the quality and the quantity of data. Subjective method or combinative method can be considered in term to reflect the degree of importance of criteria of vehicle theft.

Finally, as a conclusion the vehicle theft should be measured not merely on the total of recorded case by authority. Obviously other criteria such as unemployment, drug and level of education of respective area should be considered.

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