URBAN TRAFFIC CONGESTION REVISITED: A TRAVELER'S PERSPECTIVE

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Abstract
This study uses a traveler's perspective to solve urban traffic congestion in Karachi city (Pakistan) and applies multi-criteria decision-making techniques in finding the ideal solution. The novelty of the study is the incorporation of a traveler's perspective in finding a traffic congestion solution and the application of MCDM to the subject area. The results indicate that the current congestion solution policies adopted by the government through the construction of bus repaid transits system (BRT) and Karachi circular railways are cost-intensive, requires a longer time to complete, and also had higher operation costs, resulting in being a less effective solution for urban traffic congestion compared to the installation of tire killers, restricting the heavy traffic in city, restricted parking areas as these are easy, economical and quick to implement. These are also effective measures because the major congestion problem is not the lack of infrastructure but non-compliance with travelers' traffic rules.
Keywords: Traffic congestion, KCR, Metro bus, Karachi, TOPSIS, Pakistan;

1. INTRODUCTION

Traffic congestion is perhaps the major common problem faced by all megacities across the globe. Many countries have adopted solutions for solving the congestion problems that includes congestion toll tax (Albert & David, 2006), improving the public transportation system (Stopher, 2004), increased parking fee (Glazer & Niskanen, 1992). However, zero congestion is not possible nor desirable (Taylor, 2002).

Karachi is Pakistan's biggest and most populated city, with an area of 3,530 km^2 (GoS, 2018), with a population of 14.9 million (PBS, 2017). Karachi is the economic hub of Pakistan. It contributes about 25 percent in total revenues, between 28 – 30 percent to the GDP (GoS, 2018), and had two functional sea-ports of the country's total three sea-ports. Karachi is a favorite destination for employment, business, and earning opportunities across Pakistan. However, all this importance comes in the worst urban traffic congestion cost and, consequently, a degraded environment. Karachi had an operational steam-based

Theoretical and Empirical Researches in Urban Management
Volume 16 Issue 4 / November 2021

tram system in 1884 by the British rulers, which was, later on, converted to petrol engine trams in 1908 (Imran, 2009). Since then, Karachi's only significant public transportations investment was Karachi circular railways (KCR). KCR proposed and operationalized during the 1960s and worked fine for the first 15 years of operations, but then it was closed down due to a lack of investment in its infrastructure. It is also worth mentioning that during the same period, the government-procured around 1,200 buses to Karachi Road Transport Corporation and also encouraged the private sector to come forth and operate bus-based public transportation. The private sector gradually removed the government monopoly over public transportation in Karachi (Imran, 2009).

As of 2020, the British legacy of trams and later KCR are distant history. Karachi grew to about 15 million people, with approximately 3.7 million vehicles moving daily on roads (Ayub, 2015) and other 16,500 vehicles adding every month (Hussain, 2011) and having a public transportations system dominated by privately run buses that are in miserable conditions (due to humid Karachi weather) with lack of travel time reliability, comfort, safety or care for the environment. The travelers get additional challenges now and then in the form of strikes (Ali et al., 2020), political instability, terrorism, and the humid summer weather. These problems multiply with the rainy season. There is hardly any government-provided public transportation in Karachi, with traffic blockage and congestions being routine. The daily cost of congestion in Karachi city is equal to about US$ 690 million (Ali et al., 2014). Zubair et al. (2016) reported that 78 percent of the Karachi population is either under high or medium threat of noise and air pollution. Also, about 20 percent area of Karachi is either under high or medium threat of noise or air pollution

The government of Pakistan recently took some steps to improve Karachi's ever-worsening transportation conditions, such as constructing flyovers and bypasses, and recent announcements to construct Bus-based Rapid Transits Systems (BRT). However, to address the chronic problems of traffic congestion in Karachi, more need to be done. This particular study has two objectives. First, it aims to identify the solution for traffic congestion of the Karachi metropolitan city. Secondly, it aims to achieve its first objective by involving the ultimately affected (i.e., the travelers) from traffic congestions rather than applying a pure academician or bureaucratic approach to solving traffic congestion. The argument is that daily travelers suffer the most from congestion externality, so their feedback may be considered too while considering urban transportation congestion problems. The current study has an advantage over previous studies on congestions because it uses a daily traveler's perspective in solving the urban congestion problem while considering a megacity like Karachi. Furthermore, this study uses a multi-criteria decision (MCDM) methods to find the optimum solution to traffic congestion from a user perspective. MCDM has not been applied in congestion literature (as discussed in the next section). Thus, adding a new methodology for discussing and proposing a solution to urban traffic congestion contributes to urban congestion literature.

The rest of the paper is organized as follows: Section 2 is a literature review. Section 3 is the research methodology. Section 4 presents information on the survey and various alternatives considered in the study. Section 5 applied Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) technique and presents results and discussion. Section 6 concludes the paper.

2. LITERATURE REVIEW

The abundant scholarly literature on urban traffic congestion can be classified in several ways such as; by theoretical models that discuss congestion and its solutions (e.g., Hamad & Shinya, 2002; Verhoef & Rouwendal, 2004; Arnott et al., 2005; Arnott & Inci, 2006; Mougeot & Schwartz, 2018), congestion prices and road tolls (e.g., (Yan & Lam, 1996; Croci, 2016), Verhoef, 2002), the economics of traffic congestions (a good collection of scholarly work is that of Verhoef (2010), congestion of different modes of transportation (Brueckner, 2002; Zhanga & Zhang, 2006; Kidokoro, 2006; Beuthe et al., 2002).

Arnott et al., (2005) emphasized the microscopic models rather than a macroscopic model for alleviating urban traffic congestions. Accordingly, they suggested transportation policy to be more focused on downtown parking policies, encouragement of bicycle usage, work hours' changes, and a kind of toll tax on a vehicle entering urban areas to address urban traffic congestion. While Arnott et al., (2005) solutions seem plausible in the context of the USA but may not be workable for the developing countries where parking is not managed properly, the bicycle is not one of the popular modes of transportation, work hour flexibility is still not preferred option for the majority of organizations and congestion tax implementation could be a political suicide due to no public acceptability (e.g., Schade & Bernhard, 2003; Schaller, 2010; Eliasson, 2008, and Vonk et al., 2014). Similarly, Arnott & Inci (2006) modeled on-street parking and traffic congestions to study parking (downtown) 's economic perspective during business hours. After calibration, their theoretical model concluded that on-street parking fee raise is efficient (irrespective of on-street parking being optimal) to the point where cursing for parking is eliminated without parking becoming unsaturated. Mougeot & Schwartz (2018) proposed a model for reducing congestion when information about traffic with a car driver is asymmetric. Mougeot & Schwartz, (2018) is a theoretical study focused on traffic congestion reduction based on academic models. Studies like Arnott & Inci, (2006) and Mougeot & Schwartz, (2018) are useful insight for understanding the traffic congestion problems. However, the solution proposed on an ideal behavior model is of little usage outside of the academic research.

The research discussing the traffic congestion issues in urban centers can be classified into qualitative research based on interviews mostly and quantitative research based on surveys. In qualitative research, Raza (2016) conducted 23 interviews with different travelers about the Karachi city's traffic problems. His study concluded that existing mini-buses are getting replaced by the Qingqi rickshaws (a Chinese version

Theoretical and Empirical Researches in Urban Management
Volume 16 Issue 4 / November 2021

of a tuk-tuk) in Karachi city. Also, Qingqi is the preferred mode of transportation for all income groups travelers, but at the same time, it adds to traffic congestions. The growing population also encouraged the usage of motorcycles that, along with Qingqi, are the major troublemakers on the drivers' road. Because both motorcyclists and Qingqi drivers hardly follow traffic rules, and most of them are also underage. Another interesting work is that of Kumar & Barrett, (2008). They combined qualitative and quantitative indicators on urban transport from 14 cities of different African countries. They concluded that due to poor road conditions and lesser bus companies to cope with increasing transportation demand, motorcycles' commercial usage increased. The use of non-motorized vehicles is surprisingly low in African cities compare to Asian cities (Kumar & Barrett, 2008). Furthermore, traffic rules and regulations implementation are challenging in African cities. While Raza (2016) highlights urban transportation problems based on 23 interviews, their findings can not be generalized for a metropolitan city. Studies of such nature help insight into the problem but little convincing to solve a complex problem like urban traffic congestion. Kumar & Barrett, (2008) also do not provide a viable solution to urban traffic congestions from travelers' perspectives. However, it does discuss the policies to solve traffic congestions in these African cities.

Figueroa, (1996) studied road traffic congestion issues in five Latin American Cities, namely Buenos Aires, Lima, Mexico City, Sao Paulo, and Rio de Janeiro. Accordingly, the significant reasons for congestion in these cities are the high demand for public transportation and longer travel time in urban cities. Furthermore, all cities do suffer from traffic congestions and, as a result, had air pollution and a large number of accidents and had increased travel times. Figueroa, (1996) discussed congestion issues in Latin American major cities but did not incorporate the travel perspective. Pucher et al., (2007) compared urban transportation of China and India. Accordingly, both countries' urban areas are severely suffering from worsening transportation problems, including traffic congestion, lack of parking places, air, and noise pollution. Pucher et al., (2007) also assessed the government transportation policy in both countries. They suggested that the governments restrict motor vehicle usage in the congested city center, increase taxes, fees, and charges to incorporate high social and environmental costs vehicle travelers. The government should also focus on improving public transportation, encouraging cycling and walking, and environment improvement and producing environment-friendly vehicles. Similarly, Denga & Nelson (2013) concluded that the Bus Rapid Transit system that was adopted to ease the traffic problem in Beijing, China, is one of the critical measures for promoting sustainable mobility through some challenges to address.

Bertini (2006) did an unscientific online survey from transportation professionals and academics about the urban congestion definition, measurement, how reliable are the measurement of urban congestion and if there has been any change in congestion over the last two decades. Accordingly, respondent linked congestion definition and measurement mainly with travel time delays during peak periods. While the respondents hardly agree on the reliability of the congestion measurement, they do agree that the congestion got worsen more recently. Bertini (2006) defined the congestion, measurement of congestions and the reliability of congestions measurements per the transport professionals. However, it did not consider the traveler's perspective, nor did it discuss the solution to urban congestion.

The scholarly work that considers the travelers' perspective in solving or discussing urban traffic congestion is limited. For instance, Arain et al., (2017) is based on a travelers survey in Hyderabad (Pakistan) and reported that major reasons for congestion are lack of infrastructure, encroachment on roads, lack of implementation, and following traffic rules and regulations. Heraa (2013) did a qualitative study base on focus group discussion on the urban growth of Karachi city and its influence on transportation and the environment. Arain et al., (2017) is purely survey-based with no MCDM or other quantitative techniques applied to data, whereas Heraa (2013) uses a purely qualitative approach to discussing urbanization and transportation. Similarly, Baqueria et al., (2016) is based on a traveler survey and using a multinomial logistic regression model to quantify the influence of travel time and cost on the utility of travel on National Highway Karachi. Furthermore, Baqueria et al., (2016) estimated the cost of congestion equal to 3.67 US$ per hour and 0.97 US$ per hour for the car and other modes of transportation, respectively. Although Baqueria et al., (2016) is an economic perspective to traffic congestion of Karachi city using econometric models, it fails to identify and propose a solution to the problem.

This literature survey reveals that there is limited literature on travelers' perspectives on traffic congestions solutions. There is hardly any study that uses MCDM to find a solution to urban traffic congestion. We fill this literature gap with our current study. Accordingly, we will use the Multi-Criteria Decision Making technique TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) to find the best solution for Karachi city's traffic congestion.

3. RESEARCH METHODOLOGY

Multi-Criteria Decision Making (MCDM) techniques are popular in management sciences and have been in extensive use for various management or operations decisions. For instance, site selection for wind power plant (Ali et al., 2018b), selection of best energy project (Ali et al., 2018c), Airline service quality (Tsaur et al., 2002), portfolio optimization (Ehrgott et al., 2004), solid waste treatment options (Ali, et al., 2018a), production planning (Yousaf et al., 2017).

Theoretical and Empirical Researches in Urban Management
Volume 16 Issue 4 / November 2021

Theoretical and Empirical Researches in Urban Management
Volume 16 Issue 4 / November 2021

In MCDM, a variety of possible alternatives for achieving a target are analyzed simultaneously based on some specific criteria. Since a single alternative cannot entirely satisfy all criteria, the MCDM approach became useful for identifying the best suitable and feasible alternative while compromising the other less-suited ones. MCDM techniques consist of many sub-techniques among which the popular are analytic hierarchy process (AHP) (Saaty, 2008), analytic network process (ANP) (Saaty, 2013), Fuzzy VIKOR (Duckstein & Opricovic, 1980), Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) (Yoon, 1987).

TOPSIS being the MCDM approach's sub-technique, comes with the same objective, i.e., to select the most viable alternative among many. In the TOPSIS approach, the subjects (decision-makers) assign weights to each specific criteria for a particular alternative. These weights are subjective and can vary from place to place and from person to person. However, a study where the problem is under consideration is public. It is better to carefully assign these weights based on data gathered and the public's general opinion.

The application of the TOPSIS method is explained in the following steps. It starts with defining M1

$$\boldsymbol{M_1} = \begin{matrix} \boldsymbol{S_1} \\ \dots \\ \boldsymbol{S_m} \end{matrix} \begin{bmatrix} \boldsymbol{x_{11}} & \cdots & \boldsymbol{x_{1n}} \\ \vdots & \ddots & \vdots \\ \boldsymbol{x_{m1}} & \cdots & \boldsymbol{x_{mn}} \end{bmatrix} \quad (1)$$

Step 1: Where S1 …. Sm in the eq 1 is the subjects assigning weights to criteria C1 …. Cn. The same matrix is made for each alternative, M1 …. Mi, where i is the number of alternatives. Each column of the matrices formed is averaged to determine a single average weight for that criteria against the alternative i by using Equation 2.

$$\boldsymbol{w_{i1}} = \frac{\sum_{k=1}^{m} \boldsymbol{x_{k1}}}{\boldsymbol{m}} \quad (2)$$

Step 2: *These weights are then plugged into another matrix known as Decision Matrix (D) Equation 3 against each alternative and criteria.* $\boldsymbol{C_1}$ … $\boldsymbol{C_n}$

$$\boldsymbol{D} = \begin{matrix} \boldsymbol{A_1} \\ \dots \\ \boldsymbol{A_i} \end{matrix} \begin{bmatrix} \boldsymbol{w_{11}} & \cdots & \boldsymbol{w_{1n}} \\ \vdots & \ddots & \vdots \\ \boldsymbol{w_{i1}} & \cdots & \boldsymbol{w_{in}} \end{bmatrix} \quad (3)$$

A decision matrix is a matrix used to make decisions about selecting the most viable alternative objectively. The decision matrix obtained above is the final matrix that has to be analyzed to make this decision according to the following steps:

Step 3: Standardize the decision matrix using Equation 4.

$$Win(standard) = \frac{W_{in}}{\sqrt{\sum W_{in}^2}} \quad (4)$$

w_{in} in Equation (4) is the weight of that alternative concerning parameters. This weight is divided by the sum of the different weights of each alternative in that row.

Step 4: Determine the attribute weights for each criterion against each subject. Construct a weighted standardized decision matrix, which can be obtained by using Equation 5.

$$W_{in(weighted\ standard)} = W_{in(standard)} \times AW_n \quad (5)$$

AW_n are the attributes and $W_{in(standard)}$ are non-standardized weights. By taking the product of the above two, define weight; we get a weighted standardized matrix.

Step 5: After obtaining the weighted standardized matrix, Determine the ideal solution (most feasible) and the negative ideal solution (least feasible).

Step 6: Determine separation from an ideal solution, R_i^* and separation from a negative ideal solution, R_i' By using Equation 6 and 7.

$$W_{in}^* = (W_{in} - P_i^*)^2 \quad (6)$$

$$P^* or\ P' = \left(\sum_{n=1}^{n} W_{1n}\right)^{\frac{1}{2}} \quad (7)$$

Step 7: Determine relative closeness to the ideal solution by using Equation 8 and then rank the most feasible alternatives to the ones and last, which are least feasible.

$$Relative\ Closeness(RC) = \frac{P'}{P^* + P'} \quad (8)$$

Theoretical and Empirical Researches in Urban Management
Volume 16 Issue 4 / November 2021

4. DATA AND ALTERNATIVES

4.1 Survey

There is a wide range of MCDA techniques, each corresponding to a particular user based on the type of analysis, data to be collected, and the results required. As explained above, the allocation of weight is the primary step in applying the MCDM technique TOPSIS. In this study, weights were assigned based on the survey conducted in Karachi city. We designed a questionnaire to be filled online to record the opinions of the general public. This was mainly focused on the people residing in Karachi city. A total of 209 responses from Karachi city were collected through an online questionnaire.

The details of the obtained weights from the online survey suggested eight possible solutions for congestion issues listed in Table. Furthermore, secondary data from various sources (as discussed in detail in the following sub-sections) were also used for weight assignments.

4.2 Alternatives for Solution of Karachi Traffic Congestion (Travelers Perspective)

In total, there were eight alternatives considered for traffic congestion reduction as per the user perspective. The first alternative is developing a metro bus (Bus Rapid Transit System). The justification for this is that the number of vehicles is increasing on roads day by day (Hussain, 2011). The existing public transport is dominated by minibusses from the private sector and Qingqi rickshaws that lack travel time reliability, safety, comfort, and road traffic congestion and a major cause of air and noise pollution in the city.

4.2.1 Establishment of Bus Rapid Transit System (BRT)

The establishment of BRT may be an essential step to address all these issues. BRT is proposed in various corridors named Green-line, Orange-line (now named as Abdul Sattar Edhi line), Blue-line, Red-line, and Yellow-line. The total length of this network is about 109 km and will have around100 buses, initially. Work on various lines is already in progress.1 It is essential to mention that work on some segment of this proposed network is already in progress, and part of the network is expected to be functional soon. In the survey, about 70 percent of respondents weighted between 6 to 10 in favor of the BRT-based urban transportation system is the best solution. While only 30 percent weighted BRT between 1 to 5, as shown in Table 1.

[1] This network was announced by the Prime Minister of Pakistan, in July 2014, and work on it started in 2016.

4.2.2 Karachi Circular Railways (KCR)

China-Pakistan Economic Corridor (CPEC), an over 60 billion investment plan between China and Pakistan spread from 2015 to 2030 among other things (such as roads, railways, energy, special economic zones) also include the revival of Karachi circular railways (PC, 2018) at the cost of Rs. 207.5 billion (US$ 1.6 billion) (ET, 2017). Accordingly, it will be around 40 km long (circling major areas of Karachi city) with 24 stations and 162 locomotives to caters to about 0.55 million travelers every day. It is expected to be completed by 2020. It is expected that it will reduce the pollutions and noise levels in this region and control the congestion in Karachi city's major business locations.

In the survey, about 69 percent of respondents weight KCR between 6 and 10 as the best solution for Karachi traffic congestion, while only 31 percent weighted them between 1 to 5, as shown in Table 1.

TABLE 1 - TRAVELERS PREFERENCES FOR TRAFFIC CONGESTION SOLUTIONS ON SCALE OF 1 TO 10

Symbols	Alternatives	Travelers* Preferences on Scale 1 to 10									
		1	2	3	4	5	6	7	8	9	10
A1	Establishment of Bus Rapid Transit (BRT)	5.30** (11)***	2.40 (5)	4.80 (10)	4.80 (10)	12.90 (27)	12.40 (26)	15.30 (32)	16.70 (35)	9.60 (20)	15.80 (33)
A2	Karachi Circular Railway (KCR)	4.80 (10)	3.80 (8)	4.80 (10)	4.80 (10)	12.40 (26)	6.20 (13)	10.00 (21)	20.10 (42)	12.00 (25)	21.10 (44)
A3	Flyovers and underpasses	1.43 (3)	1.43 (3)	2.39 (5)	4.78 (10)	10.04 (21)	10.04 (21)	11.96 (25)	26.80 (56)	9.60 (20)	21.53 (45)
A4	Restricted parking areas on all roads	4.80 (10)	2.40 (5)	2.40 (5)	4.30 (9)	8.10 (17)	5.30 (11)	11.00 (23)	14.40 (30)	14.80 (31)	32.50 (68)
A5	Installing tire killers on roads (to discourage wrong-end drive)	4.80 (10)	3.34 (7)	3.34 (7)	5.74 (12)	9.60 (20)	7.20 (15)	14.35 (30)	12.44 (26)	12.91 (27)	26.31 (55)
A6	Strengthening the traffic police department	2.40 (5)	0.00 (0)	3.30 (7)	5.70 (12)	4.80 (10)	7.70 (16)	10.00 (21)	12.00 (25)	9.60 (20)	44.50 (93)
A7	Increasing the traffic signals and road signs	2.90 (6)	3.80 (8)	9.10 (19)	9.60 (20)	16.70 (35)	13.40 (28)	14.40 (30)	9.10 (19)	2.90 (6)	18.20 (38)
A8	Restricting the movement of heavy traffic	2.90 (6)	2.40 (5)	2.90 (6)	5.30 (11)	8.60 (18)	6.70 (14)	16.70 (35)	16.30 (34)	12.00 (25)	26.30 (55)

*Total survey sample was 209 respondents
**It is the Number of respondents in this category out of total respondents
*** It is the Percentage of respondents in this category out of total respondents

Theoretical and Empirical Researches in Urban Management
Volume 16 Issue 4 / November 2021

4.2.3. Flyovers and Underpasses

In several developing countries, the construction of flyovers and underpasses have been adopted to solve urban congestion problems (e.g., Kiunsi, 2013; Mahmud et al., 2012). Pakistani cities such as Lahore, Karachi, Rawalpindi, and Islamabad, also adopted this approach to ease congestion during the last two decades and only recently focused on bus-based urban transportation systems. The underlying rationale for this approach is that flyovers and underpasses facilitate and allow the free and uninterrupted traffic flow, in particular, at busy intersections of urban centers and thus ease congestion. This approach may be quite useful in densely populated areas where there are many road intersections and traffic signals.
This study's survey considered flyovers and underpasses as one policy solution for easing the congestion in Karachi City. Accordingly, about 78 percent of respondent gave this solution weights from 6 to 10 percent, while reaming 32 percent assigned weight between 1 to 5 as shown in Table 1.

4.2.4. Restricted Parking Areas on All Roads

Illegal parking refers to vehicles' parking alongside roads in restricted parking areas, or in front of walkways, hospitals that do block partially or fully traffic flow. In Pakistan, there are hardly designated vehicle parking areas in general and in Karachi, especially in business areas. Due to illegal parking, traffic congestion becomes worse. Therefore, one possible solution to overcome the urban traffic congestion problem is to build medium to large size parking areas in different areas of the city (particularly that of the shopping, financial district). This probably can control, to a large extent, traffic congestion. The survey conducted for this study reflects that about 72 percent of respondents gave 5 or above weight to construct restricted parking areas on all roads as a feasible solution to the traffic congestion (Table 1).

4.2.5. Installing Tire Killers on Roads

To smooth the outflow of traffic in the narrow street, Pakistan's common practice that crowded streets and ways are declared as one-way routes. However, many drivers do not follow these rules, and monitoring 24/7 encourages them to do so. Furthermore, there are dedicated one-way roads for each side of traffic in congested urban areas, but many drivers take risks and take so-called shortcuts and move against the one-way traffic and after some travel move back to its way. This is a risky driving behavior that may cause traffic accidents and become significant traffic blockages in many cities. Scholarly literature such as Nordfjærn et al. (2011) reports that risk-taking drive is typical in Sub-Saharan African countries compared to Norway and China drivers.
One solution to overcome one-way violations is to install tires killers, as it instantly kills typers, and drivers avoid taking a monetary loss and being caught for violation. The study's survey shows that about 73 percent of respondents weigh it between 6 to 10 as the most effective traffic congestion solution in Karachi city, whereas 27 percent of respondents weigh this solution between 1 to 5, as shown in Table 1.

4.2.6. Strengthening the Traffic Police Department

In Pakistan, the majority of traffic flow is controlled manually by the traffic police force. This, on the one hand, is good to accommodate a large number of population for jobs but on the other hand, becoming challenging to solve modern-day congestion and traffic issues efficiently. The drivers being risk-takers (Nordfjærn, et al., 2011), the proud of being lawbreakers and absences of proper reward and punishment system, and being run all by human force results in traffic violations, congestions, pollutions, and inefficiencies.

One possible solution to address this problem is to strengthen the traffic police department by increasing their budgetary allocations, pushing them to use more CCTV, and modern, safe city monitoring and control systems based on ICT and the latest technology. It will solve traffic congestion problems and address more important issues of Karachi city, such as traffic safety, law & order, and security. When respondents were asked about such improvements (strengthening the traffic police department for solving congestion problems) and were asked to weigh this solution on a 1 to 10 scale, about 84 percent of respondents weighted this solution between 6 and 10. In contrast, only 16 percent weighted between 1 to 5, as shown in Table 1.

4.2.7. Increasing the Traffic Signals and Road Signs

Traffic signals are vital tools for controlling and managing traffic flows. Similarly, road signs are important information for the drivers that help drivers make the right decisions at the right time and increase road safety. In Pakistan, traffic signals are old technology. The majority are static with the automatic time adjusted (rather than being controlled for traffic flows in different times), and road signboards are not adequate. Improvement of signals and modernization of it can improve traffic flow in urban centers. Increasing the number of road signboards can also help. The survey showed that about 58 percent of respondents think it's a critical solution and weighted it 6 or higher on a scale of 1 to 10 whereas 42 percent view it as of little importance and weigh it 5 or less on the same scale in Table 1.

4.2.8. Restricting the Movement of Heavy Traffic

The two available ports (out of a total of 3 ports) of Pakistan is located in Karachi city. The majority of shipments from Karachi city is directed via road to the rest of the country. Therefore, there is a considerable volume of heavy traffic in the city, particularly that of the oil tankers and container trucks. These oil tankers are hazardous (carrying flammable goods) and move slowly on roads, thus reducing traffic congestion. Besides that, due to a vast number of people from all over the country to the Karachi city, many private bus terminals have been established in various parts of the city. These private intercity buses are also adding to the already congested road networks.

The above-stated addition to road congestion can be reduced if heavy traffic to a particular part of the urban city is strongly restricted. When travelers were asked about it, about 78 percent of respondents agreed and weighted this solution either 6 or above on a scale of 10. In contrast, only 22 percent of respondents weighted it 5 or below on the same scale, as shown in Table 1.

5. RESULTS AND FINDINGS

This section applies TOPSIS and presents results and find. Besides, this section also includes a discussion on the results.

5.1 Application of TOPSIS

5.1.1. Alternatives versus Criteria (Traffic Congestion Solution Versus Constraints)

The above section describes and justifies eight alternatives that can be used to solve traffic congestion in Karachi, but the implementation of any of these is not automatic. These alternatives depend on one or more than one criterion (constraints), as shown in Table 2.

5.1.2. Area Classification, Congestion Timing, and Major Transportation Modes

Karachi is the business hub and had a home place for about 15 million people with areas that can be categorized as residential, shopping, business, or industries. To find a solution for traffic congestion, categorizing different areas in the city is required because different kinds of vehicles are used for different purposes.

TABLE 1 - CRITERION DECLARATION AND THEIR RATING SYSTEM.

Criteria	Definitions	Rating Scale
Capital Cost (CC)	The cost needed to implement a particular alternative and the feasibility to make amends in the budget to make room for this cost	10 (Very High) to 0 (Very Low)
Operating Cost (OC)	The cost required to run that particular alternative including maintenance	10 (Very High) to 0 (Very Low)
Completion Time (CT)	The time between the start and finish of that alternative	10 (Long Time) to 0 (Short Time)
Public Preference (PP)	The preference of the general public to use that particular alternative	10 (Highly Preferred) to 0 (Least Preferred)
Reduced Time Rating (RT)	Time ratio rating as compared to previous time	0 (Highly Preferred) to 10 (Low Preferred)

In this particular study, we use the local government township classification as a basis for classification. Accordingly, we identified different towns, the approximate number of travelers to this town, the traffic jam times, and their areas, respectively, as shown in Table 3. It is notable from Table 3 that the majority of traffic jam happens in morning and evening peak hours.

5.1.3. Attribute Weights and TOPSIS

The determination of attribute weights is the most critical part of the MCDM application. Because the results are sensitive to these weights, in this study, decision-making parameters are the areas (towns listed in Table 3) in which alternatives (various solutions of congestions) have to be applied. Criterion weights are an assignment to each alternative based on assessing the listed areas in Table 3. For example, areas that are hard hit by congestions will get a higher weight of *public preferences* (PP) because this area is most affected by congestion, contrary to areas with low traffic congestion, thus reducing *public preferences*. This process is applied. Accordingly, weights for every five criteria (capital cost, operating cost, completion time, public preferences, and reduced time rating) are assigned, as shown in the last five columns of Table 3. It may be noted that these values are assigned based on the areas, population traveling, expected delays due to daily traffic.

TABLE 3 SPECIFIC TOWNS AND THEIR RESPECTIVE AREAS AND ATTRIBUTES WEIGHTS

Town	**Daily people visiting (000)**	**Traffic Jam timings***	**Average transport used**	**Area (Km²)**	***Criteria***				
					CC	OC	CT	PP	RT
Baldia Town(S_1)	406	A D G	Heavy, Public**, motorcycle, car	19.25	6	8	7	10	6
Gulberg Town(S_2)	1,000	C E F	Car	11.1	6	6	7	8	8
Jamshed Town(S_3)	730	E C D	Car, motorcycle	16.9	8	6	9	9	9
Clifton (S_4)	660	D E	Car	4.65	4	5	3	3	5
New Karachi Town(S_5)	680	B C	motorcycle , Car, Public	14.6	5	4	5	8	8
North Nazimabad(S_6)	1000	E F	motorcycle , Public,	46.62	8	7	9	9	9
SITE (S_7)	467	D G	Heavy, Public	19	7	8	8	8	7
Bin Qasim Town(S_8)	315	E G	Heavy, Public	10	1	1	2	3	8
Gulshan Town(S_9)	650	C D	Car, motorcycle	53.59	9	7	10	8	9
Kemari Town(S_{10})	383	A C D G	Heavy, Car, Public	11	8	9	9	8	10
Saddar Town(S_{11})	1000	B C D	Public, Car, motorcycle	11.2	10	9	7	10	10
Lyari Town(S_{12})	1000	B E	Cars, motorcycle	5.89	7	7	5	8	5
Shah Faisal Town(S_{13})	335	A D E	Public, motorcycle	9.1	6	5	5	4	6
Korangi Town(S_{14})	660	A D G	Heavy, Car, motorcycle	55.26	6	3	4	7	8
Liaquatabad(S_{15})	5000	A B D E	Public, Car	7.4	7	7	8	10	4
Malir Town(S_{16})	981	A C E	Cars, motorcycle	2268	4	2	3	6	4
				Attribute Weights (AW_n)	*6.38*	*5.88*	*6.31*	*7.44*	*7.25*

* 6am-9am =A,9am-12pm=B, 12pm-3pm=C, 3pm -6pm=D, 6pm -9pm=E, 9pm -12am=F, 12am -6am=G
** public transportation includes, min-buses, buses and rickshaws

Theoretical and Empirical Researches in Urban Management
Volume 16 Issue 4 / November 2021

After weight assignments, for each alternative (out of 8 alternatives), a matrix is formed. The average weights of each matrix are plugged into the final decision matrix, which is further analyzed to determine the feasible best alternative among the 8 available alternatives. These 8 different alternative matrixes are compiled in one table and are shown in Table 4. It may be noted that weights assigned in these matrices follow the survey conducted to gather a general public opinion about each alternative. It is worth mentioning that the focus of the weighted matrix in Table 4 is on capital cost (CC), completion time (CT), operating cost (OC), and reduced time rating (RT). However, the general preferences are missing from it. Public preference is calculated from the survey results of Table 1.

The weighted average of all alternatives (as given in Table 4) is used to calculate the *decision matrix (D),* with general preferences being included from Table 1. *D* is standardized using the weighted average (shown in the last column of Table 4) and Equation (5). Accordingly, a weighted standardized decision matrix is created by multiplying each element of the standardized decision matrix with the corresponding value of attribute weight (as per Table 3) according to Equation (5) and is presented below in Table 5.

5.2 Results of TOPSIS

The outcome of the application of TOPSIS is the *positive ideal solution* and the *negative ideal solution*. Both solutions have specific characteristics according to the requirements. For instance, capitalized costs should be minimum for the *positive ideal solution* and maximum for the *negative ideal solution*. Similarly, operation costs must be minimum for the *positive ideal solution* and maximum for the *negative ideal solution*. These characteristics are summarized in Table 6.

Furthermore, the negative ideal solution and positive ideal solutions are separated using a weighted standardized decision matrix (Table 5) and an ideal solution base (Table 6). Equation (6) and the ideal positive solution are used to calculate the *positive ideal solution matrix.* The same process is repeated using the same equation with the negative ideal solution to calculate the *negative ideal solution matrix*. Equation (7) is used to calculate the separation from ideal positive solution P* using the ideal positive solution matrix. Using Equation (7), ideal negative solution P' is calculated from the ideal negative solution. Finally, Equation (8) is used to determine the relative closeness (RC) to the ideal solution and then rank the more feasible alternatives to the least feasible. The results of the final decision matrix are presented in Table 7. Alternative A5 (tire killers on wrong ways) is the best alternative, followed by A8 (restricting the moving of the heavy traffic) and A4 (restricted parking), respectively.

TABLE 4 - ALTERNATIVES, CRITERIA'S (C), ATTRIBUTES (A) AND AVERAGE WEIGHT CALCULATIONS

Alternatives	C / A	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	S_{10}	S_{11}	S_{12}	S_{13}	S_{14}	S_{15}	S_{16}	Weighted Average (win)
BRT (A1)	CC	9	7	9	6	7	9	5	2	9	8	10	6	6	4	9	4	6.88
	OC	8	6	7	4	3	6	2	1	7	6	7	4	6	3	8	1	4.94
	CT	9	8	8	6	7	10	6	4	9	10	9	7	8	5	10	4	7.5
	RT	1	1	2	1	3	0	2	1	1	3	1	3	0	3	0	1	1.43
KCR (A2)	CC	10	9	9	10	8	10	9	10	6	9	10	9	9	10	10	9	9.2
	OC	8	5	7	4	3	6	2	1	7	6	7	4	6	3	4	1	4.61
	CT	10	10	8	6	7	10	6	8	9	10	9	7	8	10	10	5	8.37
	RT	1	2	2	1	4	1	1	2	3	1	1	2	1	4	1	1	1.73
Flyovers and Underpasses (A3)	CC	3	4	4	6	6	6	5	3	5	6	5	6	6	4	3	4	4.78
	OC	4	3	1	4	3	2	2	1	3	4	1	4	2	3	2	1	2.49
	CT	9	8	8	6	9	5	6	4	9	7	9	7	8	5	6	4	6.88
	RT	4	3	5	0	6	5	5	4	4	4	3	2	6	4	4	5	4.07
Restricted Parking (A4)	CC	4	4	3	4	3	4	3	3	1	3	3	2	4	5	2	4	3.22
	OC	3	2	1	2	3	2	2	1	3	1	1	4	1	1	2	1	1.78
	CT	5	7	4	6	7	8	6	4	6	5	6	7	4	8	7	6	6.05
	RT	4	3	4	5	2	6	3	4	4	5	4	6	4	3	3	2	3.85
Tire Killers (A5)	CC	2	3	5	3	2	4	1	2	3	4	6	3	3	2	3	4	3.12
	OC	1	0	1	0	1	1	1	1	1	0	1	1	0	1	1	1	0.78
	CT	4	3	1	5	2	2	1	3	2	2	6	2	2	1	2	2	2.47
	RT	4	3	3	3	3	1	3	5	4	3	2	2	3	6	3	3	3.15
Strengthen Police (A6)	CC	4	6	5	3	5	6	2	4	4	3	5	5	4	3	5	8	4.51
	OC	7	8	5	6	3	9	6	4	8	6	4	4	5	4	6	5	5.63
	CT	4	2	1	6	7	4	6	4	3	3	4	7	8	5	2	4	4.36
	RT	5	8	7	3	7	5	7	3	5	7	5	7	5	6	7	5	5.71
Traffic Signals and Road Signs (A7)	CC	5	4	3	5	6	2	6	2	3	6	5	1	2	4	3	4	3.83
	OC	1	3	4	2	3	4	2	1	0	1	3	4	3	3	1	1	2.27
	CT	1	1	1	3	1	1	1	2	3	2	1	1	2	1	3	1	1.58
	RT	10	8	7	5	5	10	7	6	10	7	10	7	7	6	9	6	7.51
Restricting moment of heavy traffic (A8)	CC	5	4	3	5	6	2	6	2	3	6	5	1	2	4	3	4	3.83
	OC	1	3	4	2	3	4	2	1	0	1	3	4	3	3	1	1	2.27
	CT	1	1	1	3	1	1	1	2	3	2	1	1	2	1	3	1	1.58
	RT	10	8	7	5	5	10	7	6	10	7	10	7	7	6	9	6	7.51

Theoretical and Empirical Researches in Urban Management
Volume 16 Issue 4 / November 2021

TABLE 5 - WEIGHTED STANDARDIZED DECISION MATRIX

	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8
CC	2.99	4.01	2.04	1.40	1.33	1.97	1.46	0.38
OC	2.99	2.88	1.52	1.05	0.47	3.41	1.35	0.23
CT	3.02	3.40	3.02	2.46	0.75	1.76	0.63	0.32
PP	2.45	2.52	2.67	2.75	2.60	2.90	2.23	2.56
RT	0.72	0.87	2.10	1.59	1.45	3.62	3.84	4.27

TABLE 6 IDEAL SOLUTIONS BASE CHART

	CC	OC	CT	PP	RT
Positive Ideal Solution (P_i^*)	Min	Min	Min	Max	Min
Negative Ideal Solution (P_i')	Max	Max	Max	Min	Max

TABLE 7 - FINAL DECISION MATRIX RANKING THE ALTERNATIVES

	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8
P*	4.68	5.46	3.69	2.65	1.32	4.81	3.56	3.56
P'	1.17	0.6	2.79	3.67	4.79	2.70	4.29	5.73
P*+P'	5.85	6.06	6.48	6.32	6.11	7.51	7.85	9.29
RC	0.2	0.099	0.43	0.58	0.783	0.359	0.54	0.616
Rank	7	8	5	3	1	6	4	2

5.3 Discussion

The results indicate that incorporating public perceptions for the solution of traffic congestion in Karachi city, the solution that requires minimum capital cost, has minimum operation costs, requires minimum completion time, had maximum traveler's preferences and with reduced time rating, is the installation of tire killers. This finding is plausible given that Pakistan is a developing country and has short of resources to establish fancy solutions in the form of construction of *BRT* or *flyovers and underpasses*. It is a common observation that drivers hardly follow traffic rules in police absences on the spot. Thus, installing a tire killer may be a quick, economic, and easy fix to force the driver to obey the traffic rule and not create traffic jams on narrow streets or one way of the city, a major cause of traffic congestion in the city survey. The entry of heavy traffic, especially during peak hours to the city, is a big issue. To restrict their entry to the city is ranked the second-best solution for solving the traffic congestion problem as per travelers. Perhaps one better solution could be to construct pipelines from the port to the city's outskirts to reduce the following of the heavy oil tankers traffic in the city. A construction/designation of the separate route for heavy traffic can also be handy, given that it will also help reduce the containerized trucks. Also, a restriction may be placed on the construction and operation of private inter-city bus terminals across Karachi city. They should be forced to operate on the city's entry points only.

The third best solution is restricted parking areas. The government may need to look into its urban planning again. There must be a focus on the construction of parking floors in all new buildings (particularly that of the commercial and shopping areas). Parking plazas constructions must be encouraged and subsidized. This can reduce illegal parking significantly and, consequently, urban congestion.

In peak hours, the drivers are impatient, and at the intersection where there is no traffic signal, they take the risk of just going through it. This result mostly traffics accidents and creates traffic jams also. Installation of traffic signals can improve traffic flow a lot, especially if various traffic sign boards accompany it at appropriate places. This solution is ranked as fourth best by the travelers. It may be noted that a road intersection that does have signals. However, due to the massive flow of traffic, it is not sufficient (take too long to smoothen the traffic flow), the construction of flyovers and underpasses may be more effective. Perhaps that the reason they are ranked fifth just after the traffic signals and road signboards.

Traffic police are a vital stakeholder for all traffic-related issues. This study found that strengthening the police department is the sixth important solution to Karachi city's traffic congestion problems as for as the travelers are concerned. The use of modern technology, well-trained police with the department having financial resources to meet their need for extra staff, police patrol, training, and overtime expenses, can make a big difference.

It is interesting to see that BRT and KCR are currently under consideration, and some construction work is already. However, these solutions are the lowest-ranked solution for traffic congestion as per this study. The reason is simple; it is expensive, it needs huge capital cost, its completion time is longer, and its operations are expensive. The government is borrowing from China for these projects. These projects will be operating at a subsidy that will have financial sustainability in the future as KCR had in the past.

6. CONCLUSIONS

Karachi, a metropolitan city of Pakistan with a population of over 14 million, faces traffic congestion. The scholarly literature that discusses urban traffic congestion mainly focuses on theoretical models based on the ideal world while missing the traveler's perspective of a solution for the problem. This study includes the traveler perspective of traffic congestion and uses their feedback to identify the solution for traffic congestion. The study also brought methodological contribution by using MCDM and TOPSIS in traffic congestion studies, which is hardly being used in this research area.

The most interesting findings are that the current policy of BRT and KCR construction through borrowed money may not be the best solution to ease traffic congestion as per the travelers. Additionally, it may have financial sustainability in operations and maintenance. The results suggest that low-cost solutions such as the installation of tire killers that force the drivers to "behave" and not violate the single road violation are the best solution, followed by the restriction of heavy traffic (both passenger and freight) into the city and restriction of parking areas being a second and third-best solution to traffic congestion problems in Karachi city, respectively.

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