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MODE-ROUTE CHOICE DECISIONS: A CASE STUDY OF CPEC INVESTMENT IN PAKISTAN RAILWAYS

Summary. This study proposes the use of multi-criteria decision models (MCDM) for transportation mode-route choice decisions. This method is beneficial when trips' microdata are unavailable. Route-mode choice decisions were investigated for three public transportation modes (buses, railways, and airlines) in the post-China Pakistan Economic Corridor (CPEC) investment in Pakistan Railways (PR) for a link between Peshawar and Karachi. TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) was used for the mode choice decisions and a hybrid model of AHP (Analytical Hierarchy Approach) – TOPSIS was used for the route choice decision ML-1 link of PR. This study concludes that rails were the best mode of transportation in post-CPEC investment. Furthermore, route 3, linking Karachi to Peshawar via Lodhran, Multan, and Miniawali, is the best route connection among the four considered routes.
Keywords: Route-Mode Choice, AHP-TOPSIS, Hybrid-CDM

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1. INTRODUCTION

Transportation mode-route choice decisions are essential for travellers. In public transportation, these choices have become increasingly important for public transport service providers. Because public transport service operators have to ensure uninterrupted public transportation to cater to travellers' demands. The three most common long-distance modes of transportation are buses, railways, and airlines. Public sector intervention in investment, infrastructure development, policies, and regulations influences travellers' mode choice within these three main public transportation choices. Accordingly, service providers respond to the route choice of each mode of transportation and government regulations. For instance, massive investment in the railways can make it more attractive, resulting in people switching from buses and airlines to railways, thus posing an extra challenge for the policymaker in addressing the additional demand.

Nowadays, the Pakistan Railways (PR) is one of the major public sector enterprises that rely heavily on government subsidies to meet its operational and other losses. PR lost its market share of freight and passenger transportation to its competitors (namely, military-run National logistic cell (for freight), buses, and airlines (for passenger transportation). Other reasons for PR's fall are a lack of government interest in railway investment, more discriminatory policies for developing road transportation, and corruption. In 2017, PR lost Rs. 80 billion (0.69 billion US$) and aggregate to overall losses during the 2013-2017 period equalled Rs. 1.58 trillion (13.5 billion US$) (Abbas, 2018)). These losses were paid by the Pakistani government, which had chronic difficulties in meeting its budget deficits.

In March 2013, China started working on its *Belt and Road initiative* (BRI) (PRC, 2015). In the same year, under BRI, China and Pakistan signed a Memorandum of Understanding for an economic corridor (named China-Pakistan Economic Corridor (CPEC)). CPEC aims to establish various connectivity links (including roads and railways) between both countries. The current agreed-upon volume of investment in Pakistan under CPEC is about US$ 62 billion, expected to be made in infrastructure development by 2030. For China, this provides the quickest and most economical alternative route to the Arabian Sea via the Pakistani port, Gwadar, and offers a strategic advantage for a presence in the region close to important sea trade routes. It is an opportunity for Pakistan to upgrade its deteriorating and financially troubled railways, among other gains. Until March 2018, there were three major railway infrastructure projects under CPEC that were either under consideration or ongoing for PR (PC, 2018). Construction of dry port at Havelian (the last functional railway link close to the Chinese border), capacity building of PR, and up-gradation and improvement of ML-1 link of PR.

The work on ML-1 under CPEC consists of two phases that include the up-gradation and the doubling of rail tracks for the entire route, respectively. The up-gradation consists of constructing new train stations and repairing and upgrading the bridges and tunnels on ML-1. Further, the up-gradation includes protection fencing on both sides of the track, introducing modern technologies, and auto block signalling. This intervention will increase the speed up to 160 km/hour. Expectantly, this will significantly increase the revenues of PR.

This research had multiple objectives. First, it aimed to analyze the influence of CPEC investment in PR and its impact on railway travel compared to its competitors, mainly buses and airlines. Second, it attempts to suggest the best route for policymakers for the ML-1 rail link (across various Pakistani cities) to be considered in a post-CPEC investment. The study's contribution is combining route-mode choice decisions in the post-CPEC investment intervention in PR, the first of its kind, to discuss these considerable investments in railways. The significant contribution is applying MCDM techniques in route-mode choice decisions and developing a hybrid model based on TOPSIS (*Technique for Order of Preference by Similarity to Ideal Solution*) and AHP (*Analytical Hierarchy Approach*).

The rest of the paper is organized thus: Section 2 investigates the relevant literature. PR and its connection with CPEC are discussed in Section 3. Furthermore, Section 3 states the competitiveness of PR with available buses and airline services in Pakistan. Section 4 describes the research methods applied in this study, along with some literature on these methods. While Section 5 contains the presentation and discussion of the results. This section is divided into sub-sections presenting the mode and route choice decisions. Finally, Section 6 concludes the paper.

2. LITERATURE REVIEW

Transportation mode choice and route choice decisions are important decisions for travel. Transportation mode choice decisions depend on many factors, including income and ownership of vehicles (Dissanayake and Morikaw, 2010), level of service such as safety (Larsen et al., 2013), comfort (Johanssonab et al., 2006), reliability (Bhat and Sardesai, 2006) and even important life events (Scheiner and Holz-Rau, 2013). Similarly, transportation route choice is also an important decision for travellers (Prato, 2009).

Mode and route choice for transportation are extensively researched subjects in developed countries due to the easy availability of *revealed preferences (RP)* travel surveys (travel surveys based on original travel choices and behaviour). However, studies from developing countries are few, and even those available (for example, Dissanayake and Morikawa, 2002; Srinivasan et al., 2007) are not quite detailed compared to travel surveys obtained from research from developed countries.

The econometric and statistical techniques applied in these studies vary and are based on data and research objectives. However, discrete choice models (such as binary choice models, multinomial logit or probit, and nested logit) are the most frequently used techniques (for example, Srinivasan et al., 2007; Bhat and Sardesai, 2006; Dissanayake and Mosrikaw, 2010; Larsen et al., 2013; van Amen and Helbich, 2017; Sun et al., 2017; Aziz et al., 2017). Discrete choice models gained popularity following the seminal scholarly contribution of Daniel McFadden (McFadden, 1974), later by (Ben-Akiva and Lerman, 1985), and recently (Hensher et al., 2007) and (Train, 2009). Similarly, Prato (2009) presents an overview of route-mode choice-based studies based on a user perspective.

Discrete choice models are extensively used models for transportation mode and route choice decisions and other applications. These models are mostly employed for modelling *RP* data. *PR* based studies provide real-world choices for various modes of transportation as they are more reliable, and have findings that are easily validated and applied. However, at the same time, it comes with higher time and monetary costs with the constraint of adding only available modes of transportation (Hensher et al., 2007). Therefore, if a new mode of transportation becomes available (or will be available soon), PR data cannot study such a choice as it was not available at the time of the survey (when people made choices for their transportation modes).

Hensher et al. (2007) discussed the process of using discrete choice models for the *stated preferences* (SP) choices. In *SP data*, people indicate their transportation mode choices among all available alternatives without taking the trips. *SP data* provides an additional benefit of including a non-existent choice in decision making, which was not possible in *PR data*. In a developing country like Pakistan, where travel surveys are non-existent, and no prior studies are available on transportation mode choices, SP-based studies seem more useful.

Route choice decisions also had extensive use of discrete choice models. However, more recently, the use of MCDM is becoming increasingly popular due to its relative ease of application and less extensive use of data. For example, Hamurcu et al. (2016) used AHP-TOPSIS for the best route based on several criteria such as construction costs, aesthetic and visual impacts, access to employment, and education. Ivona et al., (2017) proposed a method for railway route selection using three MCDM techniques: Weighted Sum-Model, AHP, and VIKOR. Their results confirm the validity and usefulness of MCDM application in route choice decisions for railways.

This study focuses on both mode and route choice decisions for travellers in Pakistan. However, we contribute to the existing literature by employing multi-criteria decision-making techniques. We used a hybrid model based on the TOPSIS technique (Technique for Order of Preference by Similarity to Ideal Solution) and AHP (Analytical Hierarchy Process) instead of the traditional discrete choice models for transportation mode and route choice decisions. Furthermore, in this study, route choice decisions are considered from the public transport operator's perspective to optimize the route subject to several criteria. A *stated preference survey* (Hensher et al., 2007) was conducted online on Pakistan's residents about their travel time preferences for railways (post-CPEC investment in ML-1), roads, and bus. The novelty of this study is the use of the multi-criteria decision analysis rather than the more popular techniques of discrete choice, namely TOPSIS for mode choice (railways versus other modes of transportation, particularly buses and airlines) and AHP for route choice decision and applying it in the context of PR in the post-CPEC investment scenario.

3. PAKISTAN RAILWAYS: BACKGROUND AND COMPETITIVENESS

3.1. Railways background

The first rail link (Karachi-Kotri), having a length of 105 miles of existing PR, was opened in 1861 by the British (Pakistan Railways, 2018). Afterwards, various extensions were opened under British rule, and later after 1947, through the Pakistan government, the total railway track length was extended to the current operational 7,791 kilometres (MoF, 2018). It is worth mentioning that major extensions and development took place in the pre-1947 period under the British rulers. For a few decades, in the post-1947 period, public infrastructure investment policies favoured railways; however, it gradually became more biased toward road transportation. Rail tracks and infrastructure were initially designed for a maximum speed of 110 km/hour. However, this speed has been significantly reduced in recent times. Currently, the main railway link for PR is the ML-1 that links Karachi (a port city in the South) to Peshawar (a city in North-West and close to the Afghanistan border), crossing through the populous Punjab province, connecting all major cities. ML-1 is shown as a bold line in Figure 1.

3.2. Bus, railways and airline competitiveness: mode choice and route choice decisions

During the last few decades, Pakistan Railways, compared to other transportation modes, have become less competitive. For example, in the year 2018, rail travel on the ML-1 took about 33.5 hours (at the cost of Rs. 1,490≈12.88 US$) with 59 stops, covering 1687 kilometres (Pakistan Railways, 2018). This 33.5-hours trip between Peshawar-Karachi is announced time by PR (this makes it about 50.35 km/hour), but delays and unreliability in travel time is a big issue. For instance, the day on which this rate and travel time are obtained from the Pakistan railway's official website. The train on the same route on taking this information from the website was 1 hour and 20 minutes late. At the same time, the one-way bus trip will take 11 hours (at the cost of Rs. 4,050 ≈35 US$). The same Peshawar-Karachi one-way airline trip cost Rs. Rs. 10,100≈ 87.32 US$ and takes 1.5 hours. All information about *trip timings* and *costs* were obtained from the Daewoo express bus websites, railways (Pakistan Railways), and airlines (Pakistan International Airlines), respectively, on March 26-29, 2018.

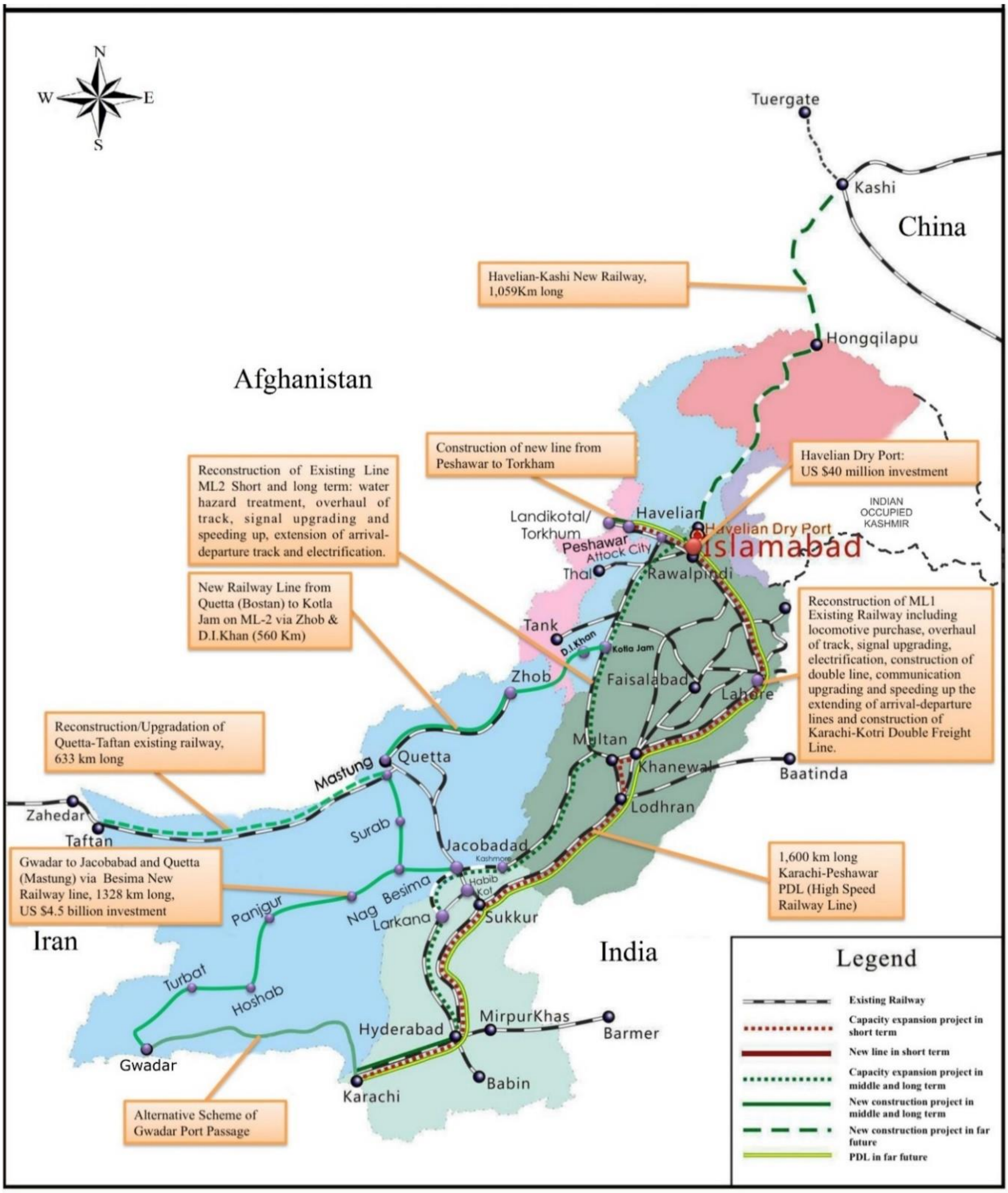


Fig. 1. Pakistan railway map (CPEC projects are also shown on the map)
Source: (PC, 2018)

Similarly, the route choice for these three modes of transportation is different. For the airline, it is a direct flight from Peshawar to Karachi. However, the bus travels via the Indus highway (a direct road link between Peshawar to Karachi going diagonally across Pakistan), passing through major cities. The bus stops on this route are Kohat, D. I. Khan, D. G. Khan, Rajanpur, Kashmore, Hyderabad, and Karachi, to mention the major few. The train even includes more train stations, and it goes diagonally, connecting all the major cities on the ML-1 route while travelling between the two cities.

The above facts show that the airline while being the fastest mode, is an expensive travel mode. While bus being with decent travel time, had a medium range of fares. Although railways are economical; however, the time their frequent delays take makes them less competitive compared to buses and airlines. Therefore, CPEC is an opportunity for PR to get a massive investment in its up-gradation that will not only reduce the travel time but will also make it more reliable. Thus, it will increase the competitiveness of PR compared to buses and airlines. Subsequently, one of the objectives of this research is to study which mode of transportation will be preferred for travel in post-CPEC investment in PR (an option not available yet) while comparing the three modes of transportation between Peshawar and Karachi.

4. RESEARCH METHODOLOGY

As earlier stated, this study employs two MCDM techniques by combining TOPSIS and AHP into a hybrid model. This particular section describes these two models and their processes in brief.

4.1. Technique for order of preference by similarity to ideal solution (TOPSIS)

Hwang and Yoon introduced TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) in 1981. It is a simple MCDM method that ranks the alternatives. TOPSIS selects an alternative with the *shortest distance* from the *positive ideal* solution but the *largest distance* from the *negative ideal* solution. Furthermore, the *positive ideal* solution shows the high value of benefit criteria and the low value of cost criteria. The *negative ideal* solution shows the low value of benefit criteria and the high value of cost criteria.

The TOPSIS method is highly used in several applications including supply chain management and logistics (Boran, 2009). TOPSIS is similarly used in airlines' service quality (Tsaur, 2002) and railways' route choice decisions (Kosijer et al., 2012). Hamurcu et al. (2016) used AHP and TOPSIS for Ankara's Monorail route. Using AHP and TOPSIS, the study made route selection based on construction costs, total travel time, integration, and accessibility. In this study, TOPSIS is applied to compare various modes of public transportation (train, air, and bus) in the post-CPEC investment in the ML-1 rail track of PR.

Application of TOPSIS

Steps involved in the application of TOPSIS are as follows:

Step 1: First, each criterion (weights) is assigned according to their relative importance based on which alternatives are checked for selection, such as speed and travel cost. The decision-makers assign these weights. In this study, the decision-makers are public people. The rating scale is as follows (Table 1).

Tab. 1.

TOPSIS (1 to 10 Rating)

Attributes	Linguist Values	Scale
Positive attributes	Very good	10
	Very low	1
Negative Attributes	Very good	1
	Very low	10

Step 2: A decision matrix is formed. In this matrix attribute, weights are given to criteria by experts or decision-makers. In this study, these weights are obtained from AHP performed for each criterion, and the rating value in AHP comes from the survey. It should be noted that a_{xy} are the attribute weights obtained earlier from AHP.

Step 3: The decision matrix is then standardized. In this step, each column is divided by the root of the sum of the square of all the numbers of the columns to obtain a standardized matrix.

$$(r_{xy})_{m\times n} = \frac{a_{\mathrm{xy}}}{\sqrt{\sum_{x=1}^{m} a^2{}_{xy}}} \qquad x=1, 2 \ldots m \qquad y=1, 2 \ldots.n \tag{4}$$

Step 4: A weighted standardized decision matrix is formed by multiplying each rating of the standardized decision matrix with each criterion's attribute weight. The decision-makers give weights to each criterion relative to each alternative. The attribute weights (w_{xy}) are obtained by taking all the alternative weights of one criterion. The weighing scale is discussed in step 1. The weighted normal values 'z_{xy}' can be calculated by the given equation.

$$h_{xy} = w_{xy} \times r_{xy} \tag{5}$$

Where

x=1, 2….m y=1, 2….n

Step 5: Ideal solution and negative ideal solutions are identified in this step. The ideal solution (B+) is a set of maximum values for each criterion, selected from a weighted standardized decision matrix. For the *negative ideal* solution *(B-),* a group of minimum values for each criterion are selected.

$$v^+_y = (\max \{h_{xy}\} \mid x=y) \qquad x=1, 2\ldots\ldots\ldots..m \tag{6}$$

$B+ = \{v_1+v_2+\ldots\ldots\ldots\ldots..v_n\}$ ideal solution

$$v^-_y = (\min \{h_{xy}\} \mid x=y) \qquad x=1, 2\ldots\ldots\ldots..m \tag{7}$$

$B- = \{v_1+v_2+\ldots\ldots\ldots\ldots..v_n\}$ Negative ideal solution

Step 6: The separation of obtained solution from an *ideal solution* and *negative ideal* solution is checked in this step. The separation from an *ideal solution* and a *negative ideal* solution is obtained by subtracting the ideal solution or negative ideal solution from each element of a row of weighted standardized decision matrix and then square it, sum it and take the square root of the sum.

$$S_i^+ = \sqrt{\sum_{x=1}^{m} (h_{xy} - v_y^+)^2} \tag{8}$$

Similarly, distance from negative ideal solution is calculated using the following equation

$$S_i^- = \sqrt{\sum_{x=1}^{m} (h_{xy} - v_y^-)^2} \tag{9}$$

Step 7: This is the last step in which the closeness of the solution is obtained. For this, the ranking score must be calculated.

$$A = \frac{S_i^+}{S_i^+ + S_i^-} \tag{10}$$

A is the ranking score

Check the *A* value for each alternative. If the *A* value of any alternative is near 1, it is considered ideal, and the one closer to zero is regarded as a *negative ideal* solution. Option having an '*A*' value nearer to 1 is the best selection (Karahalios, 2017).

4.2. Analytical Hierarchy Process (AHP)

Analytical Hierarchy Process is a multi-criteria decision-making technique used for analyzing complex decisions. It is based on the pairwise comparison. Several studies have applied the AHP technique for choice decisions in the existing literature.

The AHP technique is more prevalent in operations research and has been applied in studies for mode and carrier selection choice for the supply chain. Meixell and Norbis (2008) present an overview of such scholarly studies. However, themes related to the environment, energy, security, supply chain integration, international growth, and the ICT have been under-represented in the transportation choice literature (Meixell and Norbis, 2008).

4.3. Process of AHP

The general stepwise application of AHP is detailed in Saaty (2008). A brief description of the application of AHP in this study context is explained below.

Step 1. List all the concerned alternatives in the table. In this case, we are considering three options, namely, bus, train, and airlines.

Step 2. Make the pairwise comparison matrix. The alternatives are listed horizontally and vertically. Rate the importance of one choice to the other. The rating number indicates the importance of horizontal choice with the vertical one. The rating is done on a 1 to 9 scale (Table 2).

Tab. 2.

AHP 1-9 Rating

Rating Scale	Rating Values
Equally preferred	1
Moderately preferred	3
Strongly preferred	5
Very strongly preferred	7
Extremely preferred	9
Intermediate importance	2,4,6,8

In a comparison of *x* and *y* alternatives, if *x* is 3 compared to y, then y is 1/3 compared to *x*. The value of 1 is assigned when the comparison of alternatives is made with itself. The generalized matrix is:

$$D = \begin{bmatrix} 1 & a_{12} \cdots & a_{1n} \\ a_{21} & 1 & \vdots \\ \vdots & & \\ a_{n1} & \cdots & 1 \end{bmatrix} \tag{11}$$

${a_{12}}/{a_{21}}$ or generally can be written as $a_{21} = {1}/{a_{yx}}$

Step 3: The matrix is normalized. The normalization of the matrix is done so that all the numbers in a column are added, and then each number in that column is divided by the resultant sum. The sum of these modified numbers in that column is 1.

Step 4: In this step, the priority vector is constructed. The priority vector is made by taking the average of all the modified numbers from the normalized matrix in each row. This results in a column matrix, and its sum is also 1.

Step 5: Multiply each column with its propriety vector number and then sum all the numbers row-wise.

Step 6: In this step, the consistency of the matrix is checked. A column vector is made from step 5. Divide this column vector by the priority vector. The action results in one more column vector. From this vector, we get the λ_{max} value. λ_{max} is the average of the vector entities.

Then the consistency index is calculated using the following formula.

$$CI = \frac{(\lambda_{max} - n)}{n - 1} \tag{12}$$

From the consistency index, then the consistency ratio is calculated.

$$CR = \frac{CI}{RI} \tag{13}$$

The RI values depend on the number of alternatives been compared. The RI values are given in Table 3.

Tab. 3.

AHP Random Indices

N	1	2	3	4	5	6	7	8
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41

If the consistency ratio is less than 0.1, then the alternatives are within the acceptable range (Jayant, 2014). The priority vector is shifted for TOPSIS. This priority vector is for only one criterion

The whole process of the AHP is similarly repeated for each criterion.

5. ESTIMATION AND RESULTS

The estimation process is applied in two phases. In the first phase, TOPSIS is used based on the survey (details about the survey are given below), and the best mode of transportation between Karachi and Peshawar is obtained among buses, trains, and airlines. In the second phase, weight for various selection criteria (such as fair, track length, and the number of train stations) is obtained through the AHP technique. These weights are then used in the TOPSIS model (thus having a hybrid model) to select the best route between the two cities.

There was an online survey from September-December 2017 for about 100 respondents. The survey was for selecting the best alternative mode of transportation (bus, rail, and airline). The respondents were asked to indicate their preferences for a particular mode of transportation on a scale of 1-10 (1 for minimum and 10 for maximum) based on specific criteria such as *speed*, *travel cost*, the *population* of the cities through which the alternative travel, *number of stops* (number of stations), *environmental pollution*, *safety and security*, and finally, *benefits to the public* of each alternative. This information was used to obtain the weight for these criteria and then applied in TOPSIS (explained in Section 5.1) for the mode choice decision.

The route choice decision is made as follows: Once we select the best mode of transportation, we optimize their route choice based on several criteria (such as track length and number of stations); thus, a hybrid model (AHP-TOPSIS) is used in which information from the AHP is feeder in TOPSIS to select the best rail route to connect the two cities (Section 5.2)

5.1. Mode choice decisions: TOPSIS model

In TOPSIS, there are two weights; the attribute weights assigned to each attribute or criteria based on their importance and the weights assigned to each alternative for each criterion. The survey respondents recorded their opinion on the significance of each attribute. The survey questionnaire recorded the importance of each attribute on a *1 – 10* scale. *One* referred to the highest for the negative attributes like *travel cost* and *environmental pollution*. Whereas, One for the positive attributes referred to the lowest score. Afterwards, the weighted mean average for each attribute was calculated and then used as criteria weights.

The results indicated that *speed* and *safety/security* had been assigned the maximum weight of *8*. This is obvious given that timely arrival is the most preferred attribute for any traveller (mostly for long distances), and safety/security concern is also understandable being that Pakistan has, in recent times, faced terrorist attacks on travellers. The other notable higher weight criteria were benefits to the public (weight 7), environmental pollution (weight 6), and travel cost (weight 5), respectively. These weights have been directly used in TOPSIS.

5.2. Application of TOPSIS

There are three modes of transportation, and each mode of transportation is checked for five different criteria, as shown in Figure 2. The survey questionnaire asked the public about the preference they would give to each alternative concerning each criterion on a scale of 1-10. The survey results indicate that aeroplanes have the highest rank on the speed criteria, the train (with improved speed after CPEC investment) was ranked second highest, followed by the bus being the last. On the other hand, *travel costs* being a negative criterion ranked airlines the worst. However, improved train services in the post-CPEC intervention as second, while bus travel was the best; for environmental pollution, travel by train was ranked the best, followed by airline and bus being the worst. Similarly, the aeroplane was selected as the best for safety and security, followed by the bus being second and the train being the worst. Finally, for *benefits to the public*, train (improved after CPEC investment in PR) was considered the best followed by the bus and airline, respectively. These values were used in the TOPSIS decision matrix; the final matrix showing each alternative's ranking is presented in Table 4.

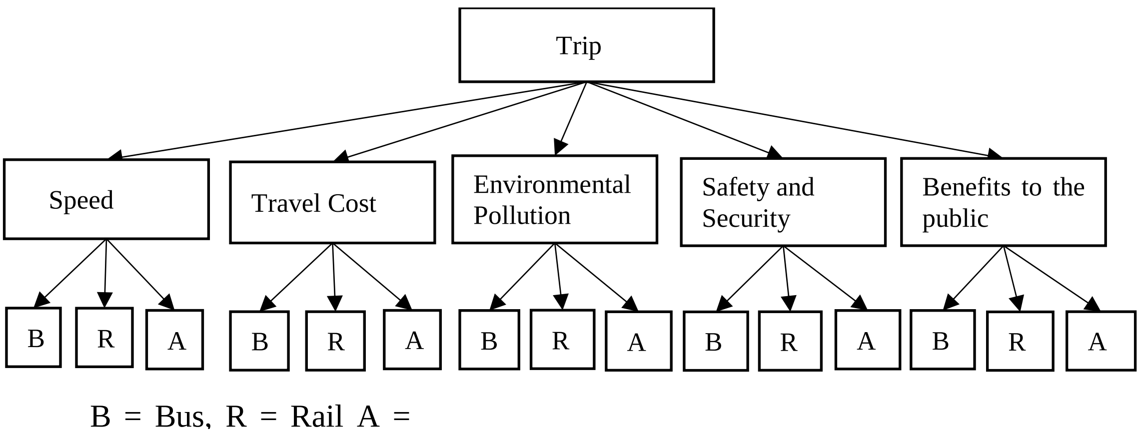


Fig. 2. Transportation mode choice and different criteria

Tab. 4.

Final ranking matrix

Criteria/Alternative	Aeroplane	Bus	Train (post-CPEC)
Si* (Positive)	1.870	1.401	2.736
Si' (Negative)	2.831	2.167	2.007
Si*+Si'	4.701	3.569	4.743
Si'/(Si*+Si')	0.398	0.393	0.477

The ranking results in Table 4 show that the train in the post-CPEC investment intervention is ranked as the best alternative among airlines and buses for the long-distance Peshawer-Karachi route travels.

These findings from TOPSIS are plausible. The train (in the post-CPEC investment era) will provide a high-speed journey at a *low cost*. Trains are relatively *safe/secure* because of fewer terrorist attacks on railways in the past. Furthermore, the *environmental pollution* caused by trains is less compared to buses. Furthermore, the *population* that would benefit from the train (in the post-CPEC investment era) is larger than the people that could benefit from the other modes of transportation as trains travel through all populated cities.

5.3. Route choice decisions: hybrid model

The selection of a short route for public transport operators is of equal importance. It saves time, fuel costs, increases trip travel time reliability and reduces the trip's total travel cost. We now consider four alternative routes (Table 5) for railways to pick the best route linking Peshawer-Karachi (ML-1 route) based on the hybrid model (AHP-TOPSIS). Table 5 also presents various criteria for each route.

We used Google Maps to calculate each route's length of track and the number of bridges. Figure 3 presents the various route options. The population benefitting from each route was obtained from the Census of Pakistan 2017 (PBS, 2017). For each path's security factor, recent terrorist attacks have been recorded for different cities on each route, and corresponding values have been assigned to each route. The recent terrorist attacks on the railway lines on each route were taken from the South Asia Terrorism Portal (SATP, 2018). It is clear from the table that route 2 (proposed route by CPEC) with a distance of 1,687 km is longer than that of routes 1 and 3; consequently, route 1 gets the highest weight based on distance followed by route 3, then route 2 and route 4, respectively. The same procedure is replicated for weighting other criteria in Table 5.

To refine these weights, the AHP technique is used with values entered according to each route's performance concerning each criterion, and a consistency ratio was calculated. The weights are readjusted for each case where the consistency ratio was greater than 0.1. After solving the AHP for each criterion, these values were entered into the TOPSIS decision matrix. Then an *educated guess* was made to assign weights to each alternative in AHP. This guess was based on the cost/unit associated with each attribute. Next, through AHP, these values were refined to get more accurate values for the criteria weights by calculating the consistency ratio. These consistency ratios are presented in Table 6.

It is clear that security is assigned with the highest weight (safety is the most important factor), followed by several bridges (due to high costs) and the population (people who benefit from the service), respectively. These weights are then used in TOPSIS to select the best route. The final decision matrix after TOPSIS has been applied is presented in Table 7.

As indicated in Table 7, route 3 is the best alternative. Route 3 is selected because its length is the second lowest compared to other alternative routes. Besides, route 3 has the highest value for security factors. In addition, the population being benefited is comparable to other alternative routes.

Tab. 5.

Route choice and selection criteria

		Track length (km)	Number of bridges	Number of terrorist attacks on route	Population (millions)
Alterna.	Route 1	1,450	21	23	21.82
	Route 2	1,687	16	27	38.01
	Route 3	1,540	18	20	38.18
	Route 4	1,827	13	26	24.35

Tab. 6.

Consistency ratios

Criteria	Consistency Ratio
Length (track length in km)	0.255
Bridges (numbers of bridges)	1.770
Security (number of terrorist attacks on track route)	2.406
Cities (number of cities on track route)	0.634
Population (population of cities on track route)	1.528

Tab. 7.

Final ranking matrix

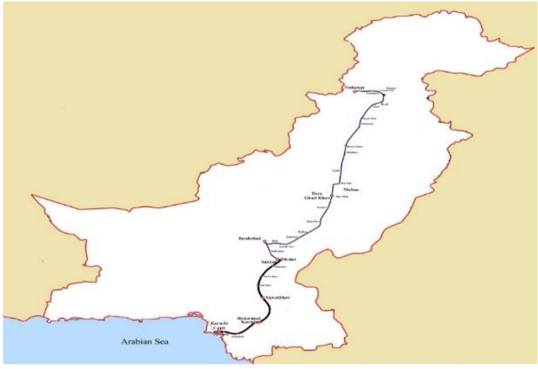
Criteria/Alternative	Route 1	Route 2	Route 3	Route 4
Si*	1.861	2.138	0.450	2.679
Si'	1.639	1.280	2.676	0.531
Si*+Si'	3.501	3.419	3.126	3.210
S'/(Si*+Si')	0.468	0.375	0.556	0.165

6. DISCUSSION

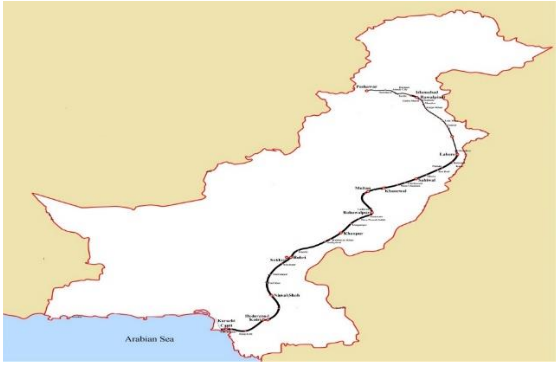
The results indicate that rail is the best alternative in the post-CPEC investment in PR. The primary reason is that after the ML-1 up-gradation under the CPEC investment, the rail speed (hence travel time) will improve significantly between Peshawar – Karachi, compared to the current travel time of over 33 hours. The travel time improvement will make the rail more competitive compared to bus and air travel. Additionally, railways can produce more passenger miles compared to buses and airlines, keeping other things constant. The railways would also become more economical with improved travel time reliability.

This study can conclude that PR will have higher revenue (given that PR's primary revenue source is the ML-1) in the post-CPEC investment in PR. This will not only reduce their current final losses but perhaps can convert the railways to a profit-earning public sector enterprise.

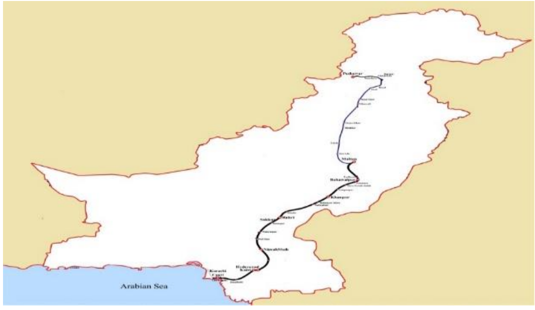
The best route selected is route 3, connecting the following cities on its proposed route from Karachi to Peshawer; Karachi → Hyderabad → Nawab Shah → Sukkur → Rahim Yar Khan → Khanpur → Bahawalpur → Multan → DI Khan → Mianwali → Jand → Basal → Taxila → Attock → Nowshehra → Peshawar. There are various reasons for this route being the best PR route in the post – CPEC investment in PR. First, this route is safer as fewer attacks have been reported on this track in past years. This automatically induces potential rail travellers to use other transportation modes on the same route for safety reasons. Second, the route is the shortest in track length, reducing the repair and maintenance cost, and ensuring faster travel. Finally, the selected routes cover about 38 million people (the cities on route) on a higher side than other alternative routes. Thus, these collectively make route 3 the more attractive route among all considered routes for PR while making its trip from Karachi to Peshawar.



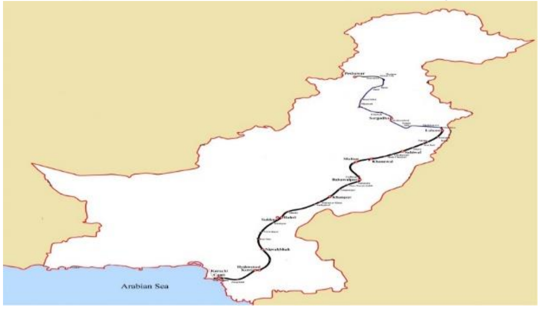
Route 1 via Karachi-Sukkar-Jacobabad-Multan-Mianwali-Peshawar



Route 2 via Karachi-Sukkar-Lahore-Rawalpindi-Peshawar (Proposed by CPEC)



Route 3 via Karachi-Lodhran-Multan-Mianwali-Peshawar



Route 4 via Karachi-Sukkar-Lahore-Gujranwala-Miawali-Peshawar

Fig. 3. Alternative routes

7. CONCLUSION

Pakistan Railways have suffered losses, becoming less competitive than airlines and buses over the last few decades. Pakistan and China started the China – Pakistan Economic Corridor (CPEC), under which both countries agreed on a US$ 50 billion expenditure plan on infrastructure and connectivity in Pakistan by 2030. Besides spending considerable sums on other connectivity projects, CPEC also looks to spend money on PR, particularly that of up-grading ML-1 links connecting two cities of Pakistan, namely Karachi and Peshawar.

This research was undertaken with multiple objectives. First, it aimed to study the mode choice decision among the three primary public transportation modes: bus, airline, and the post-CPEC investment in PR. Second, it also studied the best link route between Karachi and Peshawar for railways. In addition, this work's novelty uses multi-criteria decision techniques for transportation mode and route choice decisions. It employed TOPSIS and AHP-TOPSIS (Hybrid model) to investigate transportation modes and route choice decisions.

The study concluded that the best public transportation mode is travel by train (compared to bus and airline) in the post-CPEC investment in PR. The AHP-TOPSIS hybrid model identified an optimum route for the connection between Karachi – Peshawar based on the track length, connecting cities, and the population benefits.

The study would be useful for researchers working on mode-route choice decisions in applying MCDM with relatively lesser data requirements. Additionally, it would be equally useful for policymakers involved in CPEC-related infrastructure investments of PR. They may consider these findings while making route choice decisions in the post-CPEC investment in railways. The application of MCDM to infrastructure-related projects suggests that such techniques can be employed on decisions related to other infrastructure-related projects of CPEC.

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