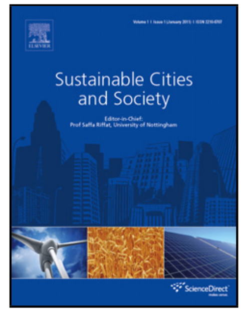
Accepted Manuscript



Title: Determining the relative importance of sustainability evaluation criteria of urban transportation network

Authors: Reza Mahmoudi, Seyyed-Nader Shetab-Boushehri, Seyed Reza Hejazi, Ali Emrouznejad

PII: S2210-6707(18)32337-0
DOI: https://doi.org/10.1016/j.scs.2019.101493
Article Number: 101493

Reference: SCS 101493

To appear in:

Received date: 11 November 2018
Revised date: 25 February 2019
Accepted date: 27 February 2019

Please cite this article as: Mahmoudi R, Shetab-Boushehri S-Nader, Hejazi SR, Emrouznejad A, Determining the relative importance of sustainability evaluation criteria of urban transportation network, *Sustainable Cities and Society* (2019), https://doi.org/10.1016/j.scs.2019.101493

Determining the relative importance of sustainability evaluation criteria of urban transportation network

Reza Mahmoudi, Seyyed-Nader Shetab-Boushehri, Seyed Reza Hejazi, Ali Emrouznejad

Reza Mahmoudi
Department of Industrial and Systems Engineering
Isfahan University of Technology
84156-83111 Isfahan, Iran
E-mail: r.mahmoudi@in.iut.ac.ir

Seyyed-Nader Shetab-Boushehri
Department of Industrial and Systems Engineering
Isfahan University of Technology
84156-83111 Isfahan, Iran
E-mail: shetab@cc.iut.ac.ir

Seyed Reza Hejazi
Department of Industrial and Systems Engineering
Isfahan University of Technology
84156-83111 Isfahan, Iran
E-mail: rehejazi@cc.iut.ac.ir

Ali Emrouznejad
Corresponding author
Aston Business School
Aston University
Birmingham, B47ET, UK
E-mail: a.emrouznejad@aston.ac.uk
URL: http://www.Emrouznejad.com

Highlights

- Define a comprehensive sustainable urban transportation network (SUTN)
- Evaluation criteria for SUTN based on economic, social and environmental factors
- Propose a framework based on Best Worst Method (BWM) to define a SUTN

Abstract

A truly sustainable urban transportation network (SUTN) needs to be sustainable in all aspects including economic, social and environmental dimensions. Identifying the evaluation criteria for sustainability of urban transportation network (UTN) and evaluating importance of these criteria, are completely critical. While most researches have only focused on economic aspect of transportation systems (TSs), in this paper, by considering economic, social and environmental dimensions, the evaluation criteria for evaluating the sustainability of UTN have been identified. Then a framework based on Best Worst Method, has been proposed to evaluate and prioritize sustainability dimensions and evaluation criteria. To show the usefulness of the proposed model, it is applied to a real-world case study of transportation in Isfahan, one of the largest cities in Iran. The results from this study are used for evaluating and selecting real transportation projects. We have also shown how the proposed framework helps managers and experts for analyzing sustainability of existing UTN, identifying potential strategies, evaluating and selecting new policies or constructing projects to achieve sustainability goals.

Keywords: Sustainability; Urban transportation network; Sustainable transportation network design; Multi criteria decision making; Best worst method.

1. Introduction

Although transportation has positive effects on economic boom and developing different industries, it can have negative impacts on the society for example producing emission, increasing traffic, etc. Due to the importance of these impacts, managers and experts of TSs, constantly try to improve the performance of existing systems and achieve sustainability targets by making new policies or constructing new infrastructures. Making decisions about new policies or candidate construction projects in urban transportation systems (TSs) to achieve sustainability targets, is known as sustainable urban transportation network design (SUTND) problem. Because of financial limitations, technical limitations, and plurality of beneficiaries, objectives and evaluation criteria, SUTND is one of the most challenging and complex problems for researchers and decision makers. First step to start SUTND is identifying weaknesses of existing network. For this purpose, first the criteria for evaluating the sustainability of an UTN, must be identified; then the importance of each criterion should be determined. The relative importance of each criterion as well as each sustainability dimension, is a determinative key knowledge for managers/experts to make better decisions. In this study, we particularly focus on this phase. First, by surveying the literature, a list of evaluation criteria and indicators has been provided. Then by using Best Worst method (BWM), as a novel multi criteria decision making method, a framework for evaluating importance of criteria and prioritizing them, has been suggested. Using survey data from a sample of transportation experts/managers, academic experts and network users from different areas of Isfahan (a city in Iran), the proposed framework has been applied to evaluate the criteria from three different points of view. Then a comprehensive analysis and some suggestions have been provided to improve the performance of Isfahan's UTN. Finally, the results have been applied for evaluating and selecting the real transportation projects in Isfahan.

The proposed framework and results of this study could be useful for any SUTN policy makings. Focusing on UTN of Isfahan, and the users', academic experts' and transportation experts' point of view, in this article, we particularly use BWM to address the following research questions:

1) What are the evaluation criteria for sustainability of UTNs?
2) Which sustainability dimension is more/less important? How much is the relative importance value of each dimension?
3) In each dimension, which criterion is more/less important? How much is the relative importance value of each evaluation criterion?
4) How the sustainability performance of an UTN can be improved?
5) What are the managerial and practical implications and results of this study?
6) Based on the relative importance of criteria/dimensions, which project should be selected and constructed?

To answer these questions, we first reviewed the related literatures of SUTNs to identify potential economic, social and environmental criteria. Then using BWM and based on survey data, the relative importance (weights) of each dimension and criterion have been obtained.

The rest of this paper is organized as follows: Surveying related literature and evaluation criteria has been reported in section 2. Section 3 presents the proposed framework. The real-world application of TS is discussed in section 4. The results, related analysis and recommendation to policy makers are presented in section 5. The results have been used for evaluating candidate projects in section 6. In section 7, some important findings are presented as well as the recommendation to policy makers. Finally, concluding remarks and some directions for future research are provided in Section 8.

2. literature review

One of the first definitions of sustainability and sustainable development was presented in Brundtland commission in 1987, that defined sustainability development as: "a development which tries to meet humans present needs without compromising the ability of future generations to meet their own needs" (Brundtland et al., 1987). Sustainability is defined in three main dimensions: social, environmental, and economic. As shown in Figure 1, a truly sustainable system needs to be sustainable in all three dimensions (Mahmoudi and Rasti-Barzoki, 2018).

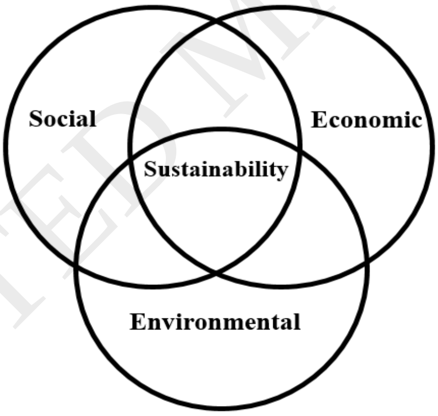


Figure 1. Sustainability dimensions and sustainability state.

Quality of performance of an UTN has significant effects on the social life and activities, spatial equity, satisfaction, economic and business, costs, emissions and many other indexes which directly affect related citizens lives. Therefore, when managers of a UTN are aiming to achieve sustainability targets, all dimensions should be taken into account. As it was mentioned by Gilbert et al. (2003), a sustainable TS must have three important features:

- Trying to have equity within and between generations, a sustainable TS provides basic access needs for each network user, safely.

- A sustainable TS must be affordable and performs efficiently. It should offer choice of transport mode. A sustainable TS leads to a vibrant economy.
- A sustainable TS minimizes waste, land use, greenhouse gas (GHG) emissions, noise pollution, and consumption of non-renewable resources. It promotes consuming renewable resources, reusing and recycling.

By introducing the concept of sustainability and sustainable transportation, recently a lot of researches have focused on designing and developing different sustainable transportation networks and systems (Mahmoudi et al., 2018). Sinha (2003) surveyed the relationship between urban public transportation and sustainability. He mentioned that for achieving a sustainable situation in urban TSs, use of private vehicles must be decreased and the users must be encouraged to use public transportation systems. They just applied statistical methods to analyze historical data. They did not propose mathematical model to make decision and did not consider important criteria such as accessibility and spatial equity, etc. Basbas and Politis (2008) analyzed the effects of different pricing strategies on the users' behavior, traffic volume, environmental impacts, etc., in the city center of Thessaloniki, Greece (see also Wann-Ming (2019)). They showed that pricing is a powerful tool to control the trip patterns in urban areas. Li et al. (2014) used Shannon Entropy and the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) and considered nine criteria to evaluate sustainable development of highway transportation capacity in China (see also Zhang et al. (2018)). Their study showed that "rate of cement highway to administrative villages" was the most important criterion for the sustainable development of highways. They only analyzed the performance of a highway transportation network, not an UTN. Considering some constraints and criteria in probability form, Wang et al. (2015) developed a bi-level model to solve the SUTND problem. Their numerical analysis showed that travel time reliability strongly affects network reserve capacity and optimal design solution. Although they considered emission as an environmental constraint, they did not consider lots of important criteria and different perspectives in their modeling. Szeto et al. (2015) proposed a multi-objective bi-level optimization model to design a sustainable road transportation network. They considered all three sustainability dimensions and developed an artificial bee colony algorithm to solve the proposed model. Cheshmehzangi and Thomas (2016) prioritized different transportation systems in Mumbai to achieve sustainable urban development. They recommended some short/long term suggestions to policy makers to improve the performance of existing TSs. Considering sustainability indicators, de Almeida Guimarães and Leal Junior (2017) evaluated eco-efficiency of urban passenger transportation system in Rio de Janeiro (Brazil) and suggested some actions to improve the performance. Considering only service value and environmental influences, they just evaluated the passenger transportation system, not the whole network. Mansourianfar and Haghshenas (2018) analyzed the effects of different infrastructure projects on the sustainability of an UTN. They considered nine construction scenarios, simulated the network under each scenario and then compared the results. Oses et al. (2018) developed a Multi-Criteria Decision Making (MCDM) method to investigate sustainability of UTNs by local governments. They only considered the mangers perspective and applied their proposed approach for performance evaluation of UTN of different metropolitan areas in Donostia-San Sebastian to identify weaknesses in each area.

Based on the above literature review, there are various studies that have tried to evaluate, analyze, design and develop a sustainable transportation network. Most of these studies have considered only economic sustainability, with a few studies considered environmental and social sustainability, too. They applied multi-objective decision making methods to obtain optimal or near to optimal policies, but they did not focus on identifying evaluation criteria in other sustainability dimensions. While a transportation network is a socio-economic system that users are the most important beneficiaries, most of the studies only considered the managers'/owners' perspectives in their decision making process. To the best of authors' knowledge, there are few studies in literature which have tried to identify evaluation sustainability criteria in TSs and their importance. Therefore, we felt that this study is necessary and important. Using BWM, this is the first study which has focused on identifying, evaluating and prioritizing the evaluation criteria for sustainability of UTNs in all three dimensions including environmental, economic and social dimensions. Three different perspectives are considered in this study: transportation experts as the managers of the system, academic experts and users. Moreover, this study analyzed the importance of evaluation criteria in different administrative areas, separately. In order to make a comprehensive decision in TS, in addition to whole network, the performance of existing system in each area should be considered. The proposed procedure in this study can be used to evaluate the candidate transportation projects in any UTN.

According to literature, 38 sustainability criteria related to urban transportation networks, are identified. These criteria have been presented in Table 1. Methodology: Best Worst Method

As it is clear from Table 1, existence of a large number of evaluation criteria have convinced researchers to consider SUTND problem as an MCDM problem. There are different approaches to solve the MCDM problems which have been applied in different issues (Zopounidis and Doumpos, 2016), but in this study we have used BWM as one of the latest developed MCDM methods. BWM has not been used in the SUTND field before, and this is a unique advantage of this study.

By considering various evaluation criteria, decision making process will be more complex, because decision makers have to consider all criteria to make best decision. There are a lot of approaches to obtain a good solution in any MCDM problems, in all of them weights of the criteria must be calculated. BWM is recently developed by Rezaei (2015) and has been applied in different areas (Ahmad et al., 2017; Ahmadi et al., 2017; van de Kaa et al., 2017). This method obtains the weights of criteria. The main idea of BWM is using pairwise comparison of the best with other criteria and the worst with other criteria. Indeed, this idea leads to less pairwise comparison. Compared to other methods, BWM has some advantages as follows (Rezaei, 2015):

- BWM needs less pairwise comparison data compared to other methods. This advantage reduces complexity and needed time for the decision process for experts/decision makers.
- Pairwise comparison data gathered by BWM is highly consistent; therefore, the obtained results by this method will be highly reliable.
- BWM can be used to obtain weights of criteria, or it can be used with other methods to prioritize alternatives.
- Since BWM uses integer numbers for pairwise comparison, it is easy to be apply it in any field.

These advantages are main reasons that convinced authors to use BWM in this research. To obtain the weights of criteria using BWM, Rezaei (2016) suggested following steps:

Step 1. Identify the set of evaluation criteria, $C = \{c_1, c_2, ..., c_n\}$.

Step 2. In this step the decision maker (DM) must specify the best criterion and the worst criterion. The best criterion is the most desirable or important criterion while the worst criterion is the least desirable or important one.

Step 3. The Best-to-Other (BO) vector must be determined by DM. BO vector includes the preference of DM about the best criterion over all other criteria. DM must specify his/her preference by an integer number between 1 and 9, which 1 shows equal preference and 9 shows maximum preference. (BO vector: $A_B = (a_{B1}, a_{B2}, ..., a_{Bn})$, which a_{Bj} shows the preference of the best criterion (B) over criterion *j*).

Step 4. In this step, the Others-to-Worst (OW) vector must be determined by DM. OW vector includes the preference of DM about all criteria over the worst one which has been obtained with pairwise comparison. DM must specify his/her preference by an integer number from 1 to 9. (OW vector: $A_W = (a_{1W}, a_{2W}, ..., a_{nW})^T$, which a_{jW} shows the preference of criterion *j* over the worst criterion (W)). In step 3 and 4 it is clear that $a_{BB} = 1, a_{WW} = 1$.

Step 5. Calculate the optimal weights of criteria ($W^* = (w_1^*, w_2^*, ..., w_n^*)$), using following model:

$$\begin{aligned} &\min \max_j \left\{ \left| w_B - a_{Bj} w_j \right|, \left| w_j - a_{jW} w_w \right| \right\} \\ &s.t \\ &\quad \sum_j w_j = 1 \\ &\quad w_j \geq 0, \quad \forall j \end{aligned} \tag{1}$$

In fully consistent pairwise comparison we will have $w_B / w_j = a_{Bj}$ and $w_j / w_w = a_{jW}$, but because of inconsistency it rarely happens. Therefore, for satisfying these conditions the objective functions of model (1) minimizes the maximum absolute differences $\left| w_B - a_{Bj} w_j \right|$ and $\left| w_j - a_{jW} w_w \right|$ for all criteria ($\forall j$). The first constraint shows that the summation of obtained weights must be equal to 1 and the second constraint is related to non-negativity condition for obtained weights. Model (1) is in non-linear form, while by considering $\varepsilon = \max_j \left\{ \left| w_b - a_{Bj} w_j \right|, \left| w_j - a_{jW} w_w \right| \right\}$, it can be presented in linear form as follows (Rezaei, 2016):

$$\begin{aligned} & \min \ \varepsilon \\ & s.t \\ & \quad \left| w_B - a_{Bj} w_j \right| \le \varepsilon \qquad \forall j \\ & \quad \left| w_j - a_{jW} w_w \right| \le \varepsilon \qquad \forall j \\ & \quad \sum_j w_j = 1 \\ & \quad w_j \ge 0, \quad \forall j \end{aligned} \tag{2}$$

The lower value of ε, shows the higher level of consistency and consequently higher level of reliability of the comparisons and results. Rezaei (2015) suggested eq. (3) to calculate the consistency ratio:

$$Consistency\ Ratio\ (CR) = \frac{\varepsilon}{Consistency\ Index} \tag{3}$$

where consistency index proposed by Rezaei (2015) is presented in Table 2 (See more details about BWM in Rezaei (2015) and Rezaei (2016)).

3. An application

In this section BWM is applied to identify the importance of criteria for evaluating the sustainability of UTN of Isfahan city in Iran. Isfahan is one of the major cities located in central region of Iran, with high traffic volume in urban area. Isfahan city has 15 administrative divisions (areas) (see Figure 2). Isfahan is known as one of the most polluted cities in Iran. Figure 3 shows the report of Isfahan Department of Environment (IDE) about the air quality of Isfahan during 2014-2017. Based on IDE (2018) report, only 9 days were excellent from 2014 to 2017. More than 5 days in year, the schools were closed because of pollution. Also Isfahan University of Medical Sciences (IUMS) reported that in 2017, 15% of deaths in Isfahan have been caused by pollution (IUMS, 2018). As shown in Figure 4, 76% of pollution in Isfahan is related to TS (IDE, 2018).

An efficient UTN has good effects on the economic development and performance of industries of related city. Isfahan is the center of several small and major industries and known as an industrial city in Iran. A large number of companies and factories have been located in different areas of the city (in north, south, west, east, and even inside the city) and all of them need an efficient urban transportation system to serve their consumers or to do their production and non-production activities. From citizens' perspective, direct and indirect travel costs are high for users which is affected by heavy traffic, especially in peak hours. Inefficient UTN will have high governmental cost and achieving a SUTN also will be costly.

Figure 2. Map of 15 areas of Isfahan

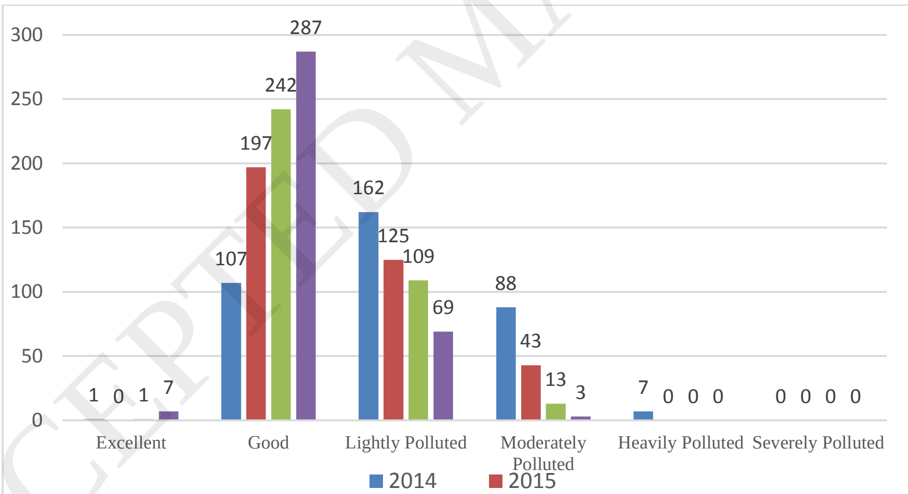


Figure 3. Air quality in Isfahan from 2014 to 2017 (IDE, 2018).

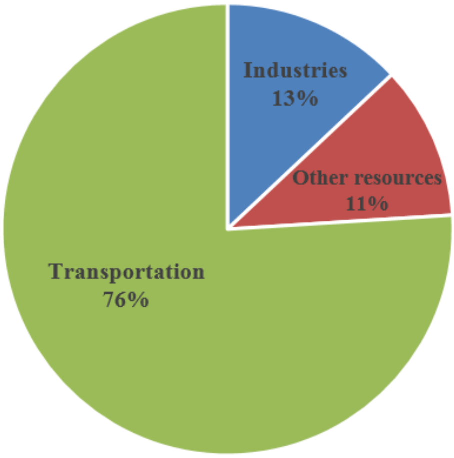


Figure 4. Sources of air pollution in Isfahan (IDE, 2018).

Urban transportation system significantly affects the quality of social and urban life quality indexes, such as equity, satisfaction, community cohesion, etc. Isfahan is a developing city with more than 2 million population. The Transportation Department of Municipality of Isfahan (TDMI) is planning a lot of transportation projects such as subway, new bus rapid transit (BRT) lines, etc. At the same time, Isfahan is known as one of the most important and famous historical cities in the world which retains much of its past glory. Most of the archaeological resources, boulevards, covered bridges, palaces, mosques, and minarets of Isfahan have been designated by UNESCO (2018). Therefore, in addition to lots of technical and financial limitations, the government also should consider the archaeological resources and historical places in their planning and evaluating candidate projects.

According to Table 1, through the literature review 38 evaluation criteria, including 15 social criteria, 10 economic criteria and 13 environmental criteria, have been identified. Considering that a large number of criteria will lead to a large number of pairwise comparison and consequently more professional knowledge and more time is needed to interview. It should be noted that users are not experts and also in many cases they are not even educated enough. Therefore, the authors suggest using a smaller number of criteria that must comprehensible for all users. Based on this explanation, before designing the questionnaire, all identified criteria (Table 3) presented to both academic and TDMI experts. Then we asked them, by considering several conditions including frequency of repetitions in literature, similarity and correlation between criteria, measurability, available data, to specify which criteria should be considered in the questionnaire forms. According to the feedback we received from the experts, finally the research team considered 7 social, 5 economic and 5 environmental criteria. The details of the feedback are reported in the supplementary file.

According to the final selected criteria, a questionnaire was developed. Hardcopies of questionnaire were used to gather answer of users in all 15 areas, academic experts and managers/experts of TDMI. All data related to users were gathered by interview. Although we interviewed with many academics and TDMI experts, we sent softcopy of questionnaire to some experts by email and received their responses. An example of the questionnaire structure and how it should be answered, is provided in the supplementary file.

4. Results and discussions

The data collection process was a completely random process. Forty students were employed as the interviewers. These students have a bachelor's degree in industrial engineering and all of them at least had passed one course related to urban transportation system management. Each interviewer was responsible just for a specific area. Some candidate sub-areas were considered in each area, and randomly four or five sub-areas out of them were selected to conduct the interviews. Also, the interviewers used a random method to choose people whom they wanted to do interview with. In different time periods of a day and different days of a week, they stood in a random location, then started counting people crossing through. Regardless considering gender, age, being pedestrian or driver, type of vehicle, etc. In the first round, based on Krejcie and Morgan sampling table (Krejcie and Morgan, 1970) and population of Isfahan, 384 interviews were done over a period of 1 month. In order to gather acceptable data and have comments of all areas, interviews were done in all 15 areas. In this round, 45 responses were unusable. We considered 0.1 as the maximum acceptable CR. In the second round, 65 other interviews were done that 5 responses were unusable. Finally, 399 responses were gathered. As for the academic experts, we interviewed 10 professors from Isfahan university of technology including 2 full professors, 3 associate professors and 5 assistant professors. The selected academics were faculty of industrial and system engineering, civil engineering and transportation engineering departments. All of them had a Ph.D. degree and some published papers in urban transportation and network design filed. With about 10 years work experience, they have taught at least one course related to transportation network design. The academic experts did not have any financial relationship with TDMI. As the transportation experts, 7 senior managers of TDMI (who were knowledgeable about UTN of Isfahan, transportation systems design and management) were interviewed. Average work experience of the TDMI's experts was 9.42 years (Please see the supplementary file for the respondents' profile and all data related to each area and each group). One of the main purposes of this study is considering all beneficiaries in an UTN in order to evaluating any candidate project or policy related to that network. To achieve a truly SUTN, the performance of the system and any changes should satisfy all beneficiaries. Specially, it is undeniable that the users are the most important beneficiary group in an UTN. Also, any new changes will be planned to increase the satisfaction of the users. On the other hand, users are not the experts of the UTN and theoretically they do not have enough knowledge and comprehensive view on the whole network. Therefore, the experts' comments should be considered, too. The transportation experts of TDMI's are the managers of the system who decide about the projects and pay all construction costs. These facts also can lead to inevitable bias in TDMI's experts' comments. Therefore, in addition to TDMI's experts, we considered other experts that do not have any conflict with TDMI and are very expert in this field: the academic experts.

Table 4 shows the frequency of criterion/dimension selected as the best/worst from different perspectives. A_7, B_3 and C_4 have been selected as the worst criterion in social, economic and environmental dimensions, prospectively. Therefore, community cohesion, transportation cost for government and space/land consumption are not the main concerns in UTN of Isfahan, compared to other criteria.

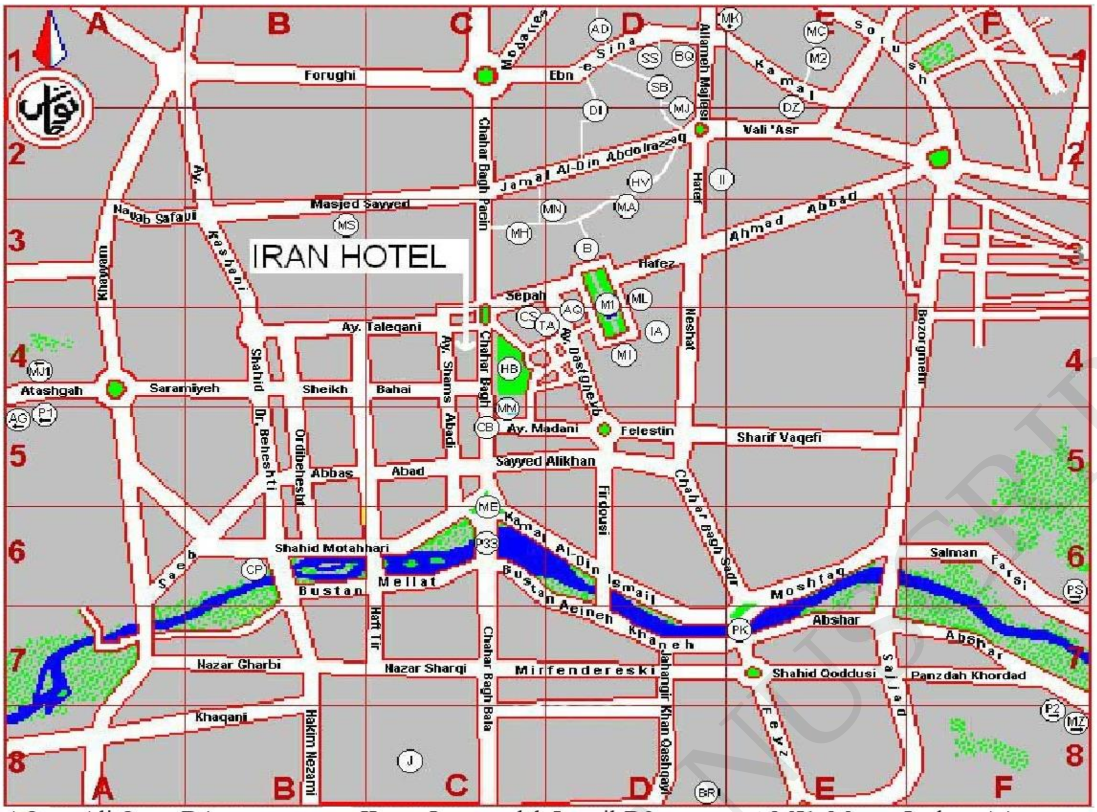
According to the results on Table 5 the issue about importance of dimensions is a little different. The results show that both academic and transportation experts perceive environmental stability as the most important dimension. Although from the users' point of view, economic dimension is more important than environmental dimension, comparing the weights of these dimensions shows that this difference is not significant. Therefore, the users also are concerned about the environmental sustainability. The only common point about the best criteria is C_2, that is the most selected criterion as the best criterion and the most important criterion in environmental dimension for all groups ($W_{C_2} = 0.370$). It means that all groups are convinced that the situation of air pollution and GHG emission are in critical condition. Therefore, achieving a desirable level in this criterion will lead to higher level of sustainability. Analyzing the importance of criteria/dimensions and existing UTN of Isfahan provides key findings that can help the policy makers to make better decisions about potential projects and policies.

- **Public transportation services (PTS).** According to these results, PTS is not within the acceptable level. BRT only serves limited area in Isfahan and just one line of metro (south-north line) serves the users. All three groups believe that access to PTS is an important criterion to achieve a sustainable performance in UTN of Isfahan. This can be seen in Table 5b where $W_{A_5} = 0.184$ and rank of A_5 is 2 among social criteria. Therefore, improving PTS level by constructing related projects can be one of the most influential activities to increase the social and environmental sustainability simultaneously.
- **Energy consumption.** In the environmental dimensions, "energy and non-renewable material use", such as petrol, is one of the main concerns of all groups. This fact can be easily recognized from Table 5d ($W_{C_5} = 0.199,\ R_{C_5} = 2$). Some suggestions can be presented to deal with this concern: first, the quality of supplied petrol in Iran is very low (the standard is Euro 2 and 3). As a long term strategy, government should try to improve the quality of the petrol. Second, because of the economic sanctions, well-known automobile manufacturers in the world are not active in Iran. Therefore, more than 90% of cars in UTNs in Iran are low quality products of IKCO and SAIPA (two major Iranian automobile manufacturers) with an average age of more than 10 years (IDE, 2018). Even best products of these companies hardly have minimum international standards for quality of produced automobiles. Since, as another macro policy, to achieve an environmentally sustainable situation, the government should improve the quality of supplied petrol. Using subsides, government can encourage users to sell their old cars and buy new ones to rejuvenate the fleet of transport. By taking stricter policies towards IKCO and SAIPA, government should try to increase the quality of produced automobiles by these companies. Third, TDMI should consider "energy and non-renewable material use" in evaluating any candidate transportation policy or project.
- **The more traffic congestion, the more travel time, energy use and GHG emission.** In Iran, after Tehran, Isfahan has the highest traffic congestion. From users' point of view by W_{A4}=0.197, the traffic congestion is the most important social criterion. Widening existing streets, construction new streets and other new infrastructure projects will lead to reduce the traffic congestion significantly and consequently travel time as the most important economic criteria will be decreased and reserve capacity will be increased. Finally, the sustainability performance of network in all three dimensions will be improved. Given that "Transportation cost for government" and "Space/land

consumption" are the least important criteria in the economic and environmental dimensions, respectively, academic experts and users significantly expect that the managers must construct new projects and the transportation experts have realized this issue.

- **Although construction new transportation projects seem inevitable, the candidate projects must be analyzed comprehensively.** Weights and ranks of "Archaeological resources (A_1)", "Economic efficiency and development (B_5)" and "Biodiversity and protected sectors (C_1)" show that all three groups agree that projects should be selected in such a way that leads to:
  (a) Minimum damage to biodiversity, protected sectors, parks, etc. Isfahan has limited natural parks and greenspaces.
  (b) Maximum economic efficiency.
  (c) Maximum protection from archaeological resources, boulevards, covered bridges, palaces, mosques, and minarets.

A_1 is one of the important social criteria for academic experts and users (specially for users in areas 1, 3, 5 and 7; since most of these resources are located in these areas, see supplementary file). Since, Isfahan is known by these resources and the revenue from the tourism industry constitutes a major part of the income of the people of Isfahan. But A_1 is the least important social criterion for transportation experts, because as the managers of UTN they only try to satisfy the users by new projects and since most of historical places are located in the downtown and busy areas (see Figure 5), they found these resources as a serious obstacle to achieve their goals.



AQ	Ali Qapu-D4	II	Imamzadeh Ismail-D2	MJ1	Monar Jonban-A4
AG	Atashgah-A6	J	Jolfa-C8	M2	Monar-e-sareban-E1
AD	Avicenna's Dorne-D1	MM	Madrasa Mader-e-shah-C5	MZ	Monar-e-Ziar-F8
B	Bazaar-D3	MN	Madrasa-ye-Nimavar-D3	P1	Pigeon Towers-Atashgah-A5
BQ	Baba Qassem-D1	MA	Masjed Ali-D3	P2	Pigeon Towers-Road to Ziar-F8
BR	Baba Rokn Al Din-D8	MH	Majad-e-Hakim-C3	PK	Pol-e-Khajou-E7
CB	Chahar Bagh-C5	MI	Majad-e-Imam-D4	PS	Pol-e-Shahrestan-F6
CP	Chardin Park-B6	MJ	Majad-e-Jomeh-D2	MH	The Portal of Jorjir-C3
CS	Chahel Sotoon-C4	MS	Majad-e-Sayyed-B3	P33	Si-o-she Pol-C6
DZ	Dar Al Ziyafieh-E1	ML	Majad-e-Sheikh Lotfallah-D3	TA	Talar-e-Ashraf-D4
DI	Darb-e-Imam-D2	ME	Meidan-e-Enghelab-C6		
HB	Hasht Behesht-C4	MK	Monar-e-Bagh-e-Kush Khaneh-E1		
IA	Imamzadeh Ahmad-D4	MC	Monar-e-Chahel Dokhtaran-E1		

Figure 5. Location of some of important historical places in Isfahan.

Based on the results, safety is the most important social criterion. Considering number of car accidents in the UTN, Isfahan has the third rank among all cities of Iran, and in 2017, more than 400 people are died in the accidents. Also accidents are the main reason of traffics in urban highways of Isfahan (ISNA, 2018). It can be expected that improving safety level of UTN in Isfahan will lead to higher level of sustainability. There are some suggestions to achieve this goal:

- Increasing traffic controls by police and using traffic camera**.** Traffic control in Isfahan, especially in highways, is not in acceptable level.
- Installing smart traffic boards in the city to inform users traffic information, especially at the entrance of streets and highways.

- Eliminating potential reasons of accidents such as speed bumps, etc.
- Prohibition of pedestrians from crossing the streets by constructing pedestrian bridges, fencing, using crosswalk and installing pedestrian crossing signals. The infrastructures for pedestrians are not sufficient in Isfahan.

To achieve more sustainable performance, in evaluating candidate projects and policies, travel time and travel cost must be considered as the most important economic criteria. Constructing infrastructure projects, reducing traffic congestion and more PTS will lead to lower travel time. Developing affordable public transport systems in Isfahan can reduce travel cost in the network.

The results show that the consistency ratio of the comparisons of all dimensions and criteria are highly consistent. Among all calculations, the highest CR is 0.069.

5. Evaluating candidate projects

Based on performance of existing UTN, the Iranian government and TDMI have considered some transportation goals for 2025 horizon and identified a lot of transportation projects to achieve these goals. Some of the important goals are: decreasing traffic congestion and environmental impacts, developing green transportation systems and infrastructures, increasing accessibility, safety and parking lot, developing mass transit systems and mixed land-use. The number of potential candidate projects is significantly large that according to financial and technical limitation, conducting all of them is impossible. Hence, evaluating and selecting suitable projects is a challenging problem for TDMI. As a part of the identified projects, TDMI is planning to construct 10 new streets in UTN of Isfahan (See Figure 6).

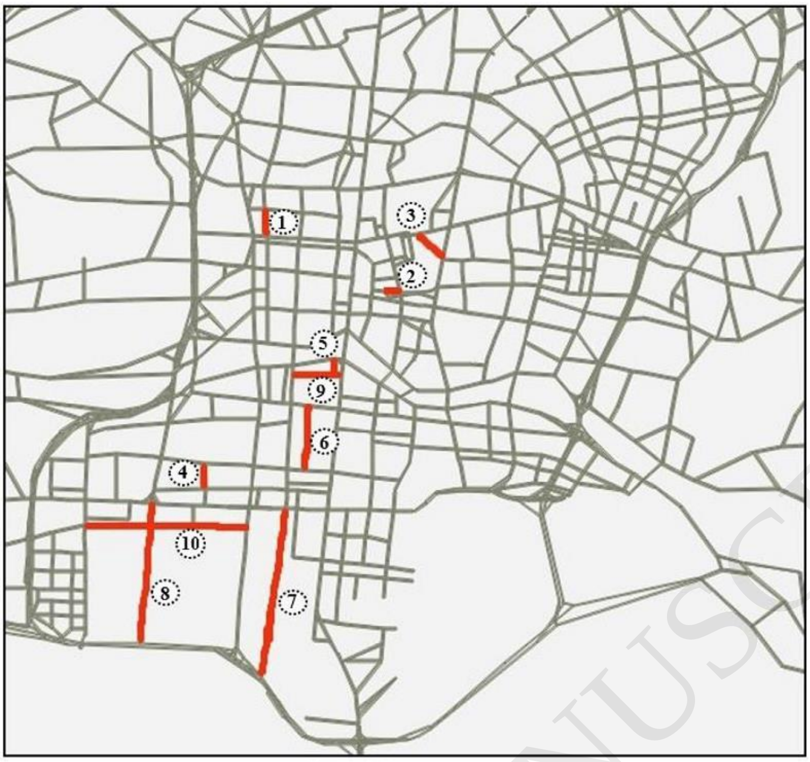


Figure 6. Location of suggested new streets to construct.

Based on the limitations, a three-year time-period (2019-2021) as the planning horizon and six-year time-period (2019-2024) as evaluation horizon, TDMI identified 10 construction scenarios. Using EMME, as the most trusted and popular transportation planning software (EMME, 2017), traffic situation simulation for each scenario is forecasted. Using this information, the values of all indices for each scenario are obtained. Table 6 shows rank of each scenario from different perspectives as well as an overall rank. The simple additive weighting method is used to obtain rank of the scenarios.

Details of the indices' values for each scenario and rank of the scenarios in each area are provided in the supplementary file. Based on the results, the best scenario is the second one ((2,1,0,1,0,0,3,0,3,2)). Compared to the other scenarios, most improvement in the GHG emission, mobility cost and traffic congestion will happen in the second scenario. A key finding from the results can be seen in Table . As it was mentioned before, most of the previous studies only considered one evaluation criterion/sustainability dimension. For example, in our case study if we only consider A2 or B3 or C4, selected strategies will be different; especially considering A2 or A6, first strategy will be selected, where considering all dimensions and criteria, strategy 1 will be ranked seventh. As it is clear from Table , by increasing the number of considered criteria, the results are converged to the final results. This finding shows the importance of the contribution of this study. Although, we used the final weights to rank the candidate scenarios, the weight of criteria in the areas involved with the project can be used too.

After we made all calculations, the results were sent to TDMI. We asked the feedback opinions of 7 senior managers of TDMI. Especially we asked the opinion of the head of traffic control center of TDMI, about our results. The transportation department of municipality of Isfahan is responsible for these projects and the head of traffic control center, as a member of management group, is one of the influential manager in the decision process about these projects. According to them, the results met their expectation. Especially, they confirmed %83 of results as the completely in accordance with their expectation. Details of the feedback opinion are reported in supplementary file.

6. Recommendation to policy makers

Although the obtained results have been analyzed in the previous sections and various solutions are suggested, in this section five main recommendations are summarized.

The results show that environmental dimension is the most important dimension; safety, travel time and GHG emissions are the most important criteria in social, economic and environmental dimensions, respectively. Based on the results, to achieve a sustainable situation, the main suggestion provided by this study are as follows:

- PTS must be improved. As a short-term policy, BRT services must be developed in all areas of Isfahan and as the long-term policy new metro lines must be constructed.
- Existing pedestrian infrastructures should be improved, and new ones must be constructed.
- Quality of supplied petrol by government and produced automobiles by IKCO and SAIPA must be increased.
- Old cars must be replaced with new ones. Government should use subsides to encourage the users.
- New transportation infrastructure projects such as constructing new streets or widening existing streets are necessary. Also, to achieve a sustainable situation, the candidate projects should be evaluated considering all perspectives, including users and experts.

7. Conclusions and direction for future works.

Identifying criteria for evaluating the sustainability of TSs and their importance can help managers and policy makers to improve performance of TSs, suggest new transportation projects or select the best project among candidate projects. In this study to achieve these goals, first based on the literature review, potential evaluation criteria for the sustainability of UTNs, considering different dimensions have been identified. Then based on survey data from users of UTN of Isfahan, academic experts and TDMI's experts and using BWM, ranks of dimensions/criteria and their importance (weight) were calculated. Indeed, there are four main contributions in this study: first, the evaluation criteria for sustainability of UTN in economic, social and environmental dimensions were identified. Secondly, this study is one of the limited studies that considered all three sustainability dimensions in urban transportation issues. Thirdly, data, results and analysis of this study, present rich findings to managers and policy makers to future decisions. Fourthly, for the first time BWM is used to evaluate the importance of each criterion in evaluating the sustainability of UTN and ranking them and then ranking candidate transportation projects in a real application.

There are some research directions: this study analyzed data of UTN of Isfahan as one of the major polluted and congested cities of Iran. For future researches the proposed approach and identified criteria can be used to analyze the UTN of other cities. BWM is used in this study to rank the criteria and calculate their importance, future studies can use other MCDM methods and compare their results by results of BWM. In addition, this study was a single period survey, using multi-period data for dynamic analysis (for example for analyzing changes in importance of criteria before and after some projects) can be another subject. The proposed approach can be used to analyze any policy or project to make a decision in order to achieve sustainable situation. For example, pricing policies, constructing BRT projects, developing any public transportation system such as subway, constructing new streets, widening streets etc., all are examples that can be analyzed by the proposed method. Finally, the proposed approach can be adopted by other large cities to evaluate their sustainability criteria of urban transportation network.

Acknowledgement

The authors would like to thank *Professor Fariborz Haghighat*, the editor in chief of Sustainable Cities and Society, and four anonymous reviewers for their insightful comments and suggestions. As results this paper has been improved substantially. We would also like to thank the transportation department of municipality of Isfahan and all parties involved in in the interview process including students and professors of Isfahan University of Technology, for their valuable helps.

References

Ahmad, W.N.K.W., Rezaei, J., Sadaghiani, S., Tavasszy, L.A., 2017. Evaluation of the external forces affecting the sustainability of oil and gas supply chain using Best Worst Method. Journal of Cleaner Production 153, 242-252.

Ahmadi, H.B., Kusi-Sarpong, S., Rezaei, J., 2017. Assessing the social sustainability of supply chains using Best Worst Method. Resources, Conservation and Recycling 126, 99-106.

Balasubramaniam, A., Paul, A., Hong, W.H., Seo, H.C., Kim, J.H., 2017. Comparative analysis of intelligent transportation systems for sustainable environment in Smart Cities. Sustainability (Switzerland) 9.

Basbas, S., Politis, I., 2008. Urban road pricing and sustainable transportation systems: The Thessaloniki central area case. International Journal of Sustainable Development and Planning 3, 1-15.

Black, J.A., Paez, A., Suthanaya, P.A., 2002. Sustainable urban transportation: Performance indicators and some analytical approaches. Journal of Urban Planning and Development 128, 184-209.

Brundtland, G., Khalid, M., Agnelli, S., Al-Athel, S., Chidzero, B., Fadika, L., Hauff, V., Lang, I., Shijun, M., de Botero, M.M., 1987. Our common future (\'brundtland report\').

Cheshmehzangi, A., Thomas, S.M., 2016. Prioritizing accessible transit systems for sustainable urban development: Understanding and evaluating the parameters of a transportation system in Mumbai. Journal of Urban Planning and Development 142.

de Almeida Guimarães, V., Leal Junior, I.C., 2017. Performance assessment and evaluation method for passenger transportation: a step toward sustainability. Journal of Cleaner Production 142, 297-307.

EMME, 2017. The world's most trusted transportation planning software. https://www.inrosoftware.com/index.php/en/products/emme/.

Gilbert, R., Irwin, N., Hollingworth, B., Blais, P., 2003. Sustainable transportation performance indicators (STPI). Transportation Research Board (TRB), CD ROM.

Haghshenas, H., Vaziri, M., Gholamialam, A., 2015. Evaluation of sustainable policy in urban transportation using system dynamics and world cities data: A case study in Isfahan. Cities 45, 104-115.

Hosseininasab, S.-M., Shetab-Boushehri, S.-N., Hejazi, S.R., Karimi, H., 2018. A multi-objective integrated model for selecting, scheduling, and budgeting road construction projects. European Journal of Operational Research.

IDE, 2018. Isfahan Department of Environment.

Iniestra, J.G., Gutiérrez, J.G., 2009. Multicriteria decisions on interdependent infrastructure transportation projects using an evolutionary-based framework. Applied Soft Computing 9, 512-526.

ISNA, 2018. iranian students news agency.

IUMS, 2018. Isfahan University of Medical Sciences

Jeon, C.M., Amekudzi, A.A., Guensler, R.L., 2013. Sustainability assessment at the transportation planning level: Performance measures and indexes. Transport Policy 25, 10-21.

Joumard, R., Nicolas, J.-P., 2010. Transport project assessment methodology within the framework of sustainable development. Ecological Indicators 10, 136-142.

Krejcie, R.V., Morgan, D.W., 1970. Determining sample size for research activities. Educational and psychological measurement 30, 607-610.

Li, Y., Zhao, L., Suo, J., 2014. Comprehensive assessment on sustainable development of highway transportation capacity based on entropy weight and TOPSIS. Sustainability (Switzerland) 6, 4685-4693.

Li, Z., Meng, N., Yao, X., 2017. Sustainability performance for China's transportation industry under the environmental regulation. Journal of Cleaner Production 142, 688-696.

Lopez-Carreiro, I., Monzon, A., 2018. Evaluating sustainability and innovation of mobility patterns in Spanish cities. Analysis by size and urban typology. Sustainable Cities and Society 38, 684-696.

Lu, M., Hsu, S.-C., Chen, P.-C., Lee, W.-Y., 2018. Improving the sustainability of integrated transportation system with bike-sharing: A spatial agent-based approach. Sustainable Cities and Society 41, 44-51.

Mahmoudi, R., Emrouznejad, A., Shetab-Boushehri, S.-N., Hejazi, S.R., 2018. The origins, development and future directions of Data Envelopment Analysis approach in transportation systems. Socio-Economic Planning Sciences.

Mahmoudi, R., Rasti-Barzoki, M., 2018. Sustainable supply chains under government intervention with a real-world case study: An evolutionary game theoretic approach. Computers and Industrial Engineering 116, 130-143.

Mansourianfar, M.H., Haghshenas, H., 2018. Micro-scale sustainability assessment of infrastructure projects on urban transportation systems: Case study of Azadi district, Isfahan, Iran. Cities 72, 149-159.

Miandoabchi, E., Daneshzand, F., Szeto, W.Y., Farahani, R.Z., 2013. Multi-objective discrete urban road network design. Computers & Operations Research 40, 2429-2449.

Miandoabchi, E., Farahani, R.Z., 2011. Optimizing reserve capacity of urban road networks in a discrete network design problem. Advances in Engineering Software 42, 1041-1050.

Mitropoulos, L.K., Prevedouros, P.D., 2016. Incorporating sustainability assessment in transportation planning: an urban transportation vehicle-based approach. Transportation Planning and Technology, 1-25.

Nadafianshahamabadi, R., Tayarani, M., Rowangould, G.M., 2017. Differences in expertise and values: Comparing community and expert assessments of a transportation project. Sustainable cities and society 28, 67-75.

Nanaki, E., Koroneos, C., Roset, J., Susca, T., Christensen, T.H., Hurtado, S.D.G., Rybka, A., Kopitovic, J., Heidrich, O., López-Jiménez, P.A., 2017. Environmental assessment of 9 European public bus transportation systems. Sustainable cities and society 28, 42-52.

Oses, U., Rojí, E., Cuadrado, J., Larrauri, M., 2018. Multiple-criteria decision-making tool for local governments to evaluate the global and local sustainability of transportation systems in Urban Areas: Case study. Journal of Urban Planning and Development 144.

Rezaei, J., 2015. Best-worst multi-criteria decision-making method. Omega 53, 49-57.

Rezaei, J., 2016. Best-worst multi-criteria decision-making method: Some properties and a linear model. Omega 64, 126-130.

Sinha, K.C., 2003. Sustainability and urban public transportation. Journal of Transportation Engineering 129, 331-341.

Sinha, K.C., Labi, S., 2011. Transportation decision making: Principles of project evaluation and programming. John Wiley & Sons.

Szeto, W., Jiang, Y., Wang, D., Sumalee, A., 2015. A sustainable road network design problem with land use transportation interaction over time. Networks and Spatial Economics 15, 791-822.

UNESCO, 2018. United Nations Educational, Scientific and Cultural Organisation (UNESCO), World Heritage Site.

van de Kaa, G., Kamp, L., Rezaei, J., 2017. Selection of biomass thermochemical conversion technology in the Netherlands: A best worst method approach. Journal of Cleaner Production 166, 32-39.

Van Geenhuizen, M., Rietveld, P., 2016. Policy analysis of transport networks. Routledge.

Wang, H., Lam, W.H., Zhang, X., Shao, H., 2015. Sustainable transportation network design with stochastic demands and chance constraints. International Journal of Sustainable Transportation 9, 126-144.

Wann-Ming, W., 2019. Constructing urban dynamic transportation planning strategies for improving quality of life and urban sustainability under emerging growth management principles. Sustainable Cities and Society 44, 275-290.

Yang, H., Wang, J., 2002. Travel time minimization versus reserve capacity maximization in the network design problem. Transportation Research Record: Journal of the Transportation Research Board, 17-26.

Yedla, S., Shrestha, R.M., Anandarajah, G., 2005. Environmentally sustainable urban transportation - Comparative analysis of local emission mitigation strategies vis-à-vis GHG mitigation strategies. Transport Policy 12, 245-254.

Zhang, X., Zhang, Q., Sun, T., Zou, Y., Chen, H., 2018. Evaluation of urban public transport priority performance based on the improved TOPSIS method: A case study of Wuhan. Sustainable cities and society 43, 357-365.

Zopounidis, C., Doumpos, M., 2016. Multiple criteria decision making: applications in management and engineering. Springer.

Table 1. Most used sustainability criteria related urban transportation networks.

Dimension	Criteria	References
Social	Accessibility to employment	Joumard and Nicolas (2010); Sinha and Labi (2011); Jeon et al. (2013); Haghshenas et al. (2015); de Almeida Guimarães and Leal Junior (2017);
	Accessibility to major public services	Joumard and Nicolas (2010); Sinha and Labi (2011); Jeon et al. (2013); Haghshenas et al. (2015); de Almeida Guimarães and Leal Junior (2017); Mansourianfar and Haghshenas (2018);
	Spatial equity	Joumard and Nicolas (2010); Jeon et al. (2013); de Almeida Guimarães and Leal Junior (2017); Basbas and Politis (2008);
	Satisfaction	Hosseininasab et al. (2018); Mitropoulos and Prevedouros (2016); Mansourianfar and Haghshenas (2018);
	Community cohesion	Sinha and Labi (2011);
	Safety (accidents and etc.)	Black et al. (2002); Basbas and Politis (2008); Joumard and Nicolas (2010); Jeon et al. (2013); Haghshenas et al. (2015); Balasubramaniam et al. (2017); de Almeida Guimarães and Leal Junior (2017); Mitropoulos and Prevedouros (2016); Oses et al. (2018);
	Visual quality	Sinha and Labi (2011)
	Transportation variety	Haghshenas et al. (2015);
	Social interaction	Basbas and Politis (2008); Sinha and Labi (2011);
	Archaeological resources	Sinha and Labi (2011)
	Social equity	Basbas and Politis (2008); Jeon et al. (2013); Mansourianfar and Haghshenas (2018);
	Reserve capacity	Yang and Wang (2002); Miandoabchi and Farahani (2011)
	Robustness and reliability	Van Geenhuizen and Rietveld (2016)
	Traffic congestion	Iniestra and Gutiérrez (2009)
	Comfort of public transportation	Oses et al. (2018);
Economic	Travel time	Miandoabchi et al. (2013); de Almeida Guimarães and Leal Junior (2017); Lu et al. (2018); Mansourianfar and Haghshenas (2018);
	Global surplus	Joumard and Nicolas (2010)
	Variation in surplus of the economic actors	Joumard and Nicolas (2010)
	Employment Evolution	Basbas and Politis (2008); Joumard and Nicolas (2010);
	Travel cost/ Mobility costs	Joumard and Nicolas (2010); Sinha and Labi (2011); Haghshenas et al. (2015);
	Transportation cost for government	Haghshenas et al. (2015);
	Indirect transportation cost for user	Haghshenas et al. (2015);
	Economic efficiency	Basbas and Politis (2008); Jeon et al. (2013);
	Affordability	Basbas and Politis (2008); Jeon et al. (2013);
	Economic development	Jeon et al. (2013);
Environmental	Biodiversity and protected sectors	Basbas and Politis (2008); Joumard and Nicolas (2010);

	GHG emissions	Black et al. (2002); Yedla et al. (2005); Basbas and Politis (2008); Joumard and Nicolas (2010); Jeon et al. (2013); Haghshenas et al. (2015); Mitropoulos and Prevedouros (2016); Li et al. (2017); de Almeida Guimarães and Leal Junior (2017); Nanaki et al. (2017); Oses et al. (2018); Mansourianfar and Haghshenas (2018);
	Local air quality	Black et al. (2002); Joumard and Nicolas (2010); Sinha and Labi (2011); Jeon et al. (2013); Oses et al. (2018);
	Noise pollution	Black et al. (2002); Sinha and Labi (2011); Jeon et al. (2013); Mitropoulos and Prevedouros (2016); de Almeida Guimarães and Leal Junior (2017); Nadafianshahamabadi et al. (2017); Oses et al. (2018); Mansourianfar and Haghshenas (2018);
	Energy use	Black et al. (2002); Joumard and Nicolas (2010); Jeon et al. (2013); Haghshenas et al. (2015); Mitropoulos and Prevedouros (2016); de Almeida Guimarães and Leal Junior (2017); Mansourianfar and Haghshenas (2018);
	Water pollution	de Almeida Guimarães and Leal Junior (2017);
	Regional air quality (smog)	Black et al. (2002); Joumard and Nicolas (2010); Jeon et al. (2013);
	Water quality use and regime	Joumard and Nicolas (2010); Jeon et al. (2013);
	Natural and technological risks	Joumard and Nicolas (2010)
	Acoustic and light disturbance;	Joumard and Nicolas (2010)
	Site, landscape and man-made heritage	Joumard and Nicolas (2010)
	Space/land consumption	Joumard and Nicolas (2010); Jeon et al. (2013); Haghshenas et al. (2015); de Almeida Guimarães and Leal Junior (2017); Lopez-Carreiro and Monzon (2018); Mansourianfar and Haghshenas (2018);
	Consumption of non-renewable materials	Joumard and Nicolas (2010); Jeon et al. (2013); de Almeida Guimarães and Leal Junior (2017); Mansourianfar and Haghshenas (2018);

Note. Here follows an explanation of those of the criteria that might not be self-explaining to the reader: “Satisfaction” is related to users’ satisfaction over time, which is very important for managers and planners. Any new policy or project in an UTN will change the users’ satisfaction. As it is mentioned by Hosseininasab et al. (2018), “Network users always compare their current situation with the past, and if they feel that the current situation is worse, considering a certain threshold, dissatisfaction will occur”. “Visual quality” is simply the excellence of the viewing experience. Although this criterion seems to be a subjective measure, several approaches are proposed to assess it (see Sinha and Labi (2011) for more details). "Global surplus" has been considered by Joumard and Nicolas (2010) in order to indicate whether a project is interesting or not to users from an economic point of view. Joumard and Nicolas (2010) defined “global surplus” as the discounted sum of the annual costs and advantages of a project calculated over a specific time period after constructing that project. Also Joumard and Nicolas (2010) considered “variation in surplus of the economic actors” as a criterion to differentiate between the winners and the losers by aggregating economic losses and benefits. For this purpose, they separated the positive and negative surplus for different sub-groups, such as road users, local authorities, private investors, etc.

Table 2. Consistency Index.

a_{BW}	1	2	3	4	5	6	7	8	9
Consistency Index	0.00	0.44	1.00	1.63	2.30	3.00	3.73	4.47	5.23

Table 3. Selected evaluation criteria.

Social criteria	**Economic criteria**	**Environmental criteria**
Archaeological resources (A_1) Spatial equity (A_2) Safety (A_3) Traffic congestion (A_4) Accessibility to public transportation services (A_5) Reserve capacity (A_6) Community cohesion (A_7)	Travel cost/ Mobility costs (B_1) Travel time (B_2) Transportation cost for government (B_3) Indirect transportation cost for user (B_4) Economic efficiency and development (B_5)	Biodiversity and protected sectors (C_1) GHG emissions (C_2) Noise pollution (C_3) Space/land consumption (C_4) Energy and non-renewable materials use (C_5)

Table 4. Frequency of selected criterion/dimension as the best/worst.

	A_1		**A_2**		**A_3**		**A_4**		**A_5**		**A_6**		**A_7**	
Group	Best	Worst	Best	Worst	Best	Worst	Best	Worst	Best	Worst	Best	Worst	Best	Worst
Users	71	70	46	37	53	7	119	26	86	16	20	36	4	207
A.E. *	3	0	1	1	3	0	1	2	2	1	0	1	0	5
T.E. *	0	2	0	2	4	0	0	0	3	0	0	0	0	3
	B_1		B_2		B_3		B_4		B_5		C_1		C_2	
Group	Best	Worst	Best	Worst	Best	Worst	Best	Worst	Best	Worst	Best	Worst	Best	Worst
Users	169	20	158	16	7	248	15	75	50	40	110	16	255	2
A.E.	2	1	3	1	0	4	0	3	5	1	0	1	8	0
T.E.	0	1	4	0	0	4	2	2	1	0	0	1	6	0
	C_3		C_4		C_5		Economic		Social		Environmental			
Group	Best	Worst	Best	Worst	Best	Worst	Best	Worst	Best	Worst	Best	Worst		
Users	11	117	8	194	15	70	211	103	46	214	142	82		
A.E.	0	3	0	4	2	2	1	7	3	3	6	0		
T.E.	0	0	0	5	1	1	0	5	0	2	7	0		

*Note: A.E. i.e. Academic Experts & T.E. i.e. Transportation Experts

Table 5a. The importance of sustainability dimensions.

Group	Economic			Social			Environmental			ε	CR	S.D.
	W.	R.	S.D.	W.	R.	S.D.	W.	R.	S.D.			
Users	0.434	1	0.260	0.205	3	0.184	0.361	2	0.238	0.115	0.030	0.033
A.E.	0.190	3	0.176	0.336	2	0.201	0.474	1	0.216	0.136	0.069	0.074
T.E.	0.175	3	0.099	0.228	2	0.097	0.597	1	0.96	0.059	0.032	0.13
F.W.	0.266	3	0.261	0.256	2	0.183	0.477	1	0.238	0.115	0.031	0.034

Table 5b. The importance of each criterion in the social dimension.

Group	A_1			A_2			A_3			A_4		
	W.	R.	S.D.	W.	R.	S.D.	W.	R.	S.D.	W.	R.	S.D.
Users	0.148	4	0.109	0.133	5	0.087	0.163	3	0.090	0.197	1	0.115
A.E.	0.216	1	0.122	0.093	6	0.042	0.195	2	0.098	0.149	4	0.076
T.E.	0.076	7	0.035	0.199	3	0.058	0.286	1	0.122	0.107	4	0.031
F.W.	0.147	4	0.108	0.142	5	0.086	0.215	1	0.092	0.151	3	0.115

Group	A_5			A_6			A_7			ε	CR	S.D.
	W.	R.	S.D.	W.	R.	S.D.	W.	R.	S.D.			
Users	0.185	2	0.101	0.113	6	0.072	0.061	7	0.049	0.044	0.02	0.016
A.E.	0.156	3	0.093	0.115	5	0.032	0.077	7	0.057	0.071	0.018	0.014
T.E.	0.210	2	0.104	0.105	5	0.03	0.098	6	0.064	0.067	0.018	0.006
F.W.	0.184	2	0.101	0.111	6	0.071	0.079	7	0.050	0.045	0.02	0.016

Table 5c. The importance of each criterion in the economic dimension.

Group	B_1			B_2			B_3			B_4		
	W.	R.	S.D.	W.	R.	S.D.	W.	R.	S.D.	W.	R.	S.D.
Users	0.318	2	0.141	0.307	1	0.136	0.077	5	0.063	0.122	4	0.076
A.E.	0.219	3	0.109	0.251	2	0.155	0.144	4	0.097	0.118	5	0.049
T.E.	0.147	4	0.059	0.319	1	0.136	0.092	5	0.038	0.261	2	0.203
F.W.	0.228	2	0.142	0.292	1	0.136	0.104	5	0.063	0.167	4	0.081

Group	B_5			ε	CR	S.D.
	W.	R.	S.D.			
Users	0.176	3	0.122	0.118	0.024	0.022
A.E.	0.269	1	0.153	0.085	0.022	0.16
T.E.	0.182	3	0.108	0.088	0.032	0.012
F.W.	0.209	3	0.122	0.117	0.024	0.022

Table 5d. The importance of each criterion in the environmental dimension.

Group	C_1			C_2			C_3			C_4		
	W.	R.	S.D.	W.	R.	S.D.	W.	R.	S.D.	W.	R.	S.D.
Total	0.259	2	0.086	0.365	1	0.121	0.144	3	0.091	0.095	5	0.076
A.E.	0.159	3	0.063	0.384	1	0.078	0.126	4	0.057	0.118	5	0.069
T.E.	0.155	3	0.076	0.361	1	0.109	0.143	4	0.039	0.092	5	0.052
F.W.	0.191	3	0.128	0.370	1	0.120	0.138	4	0.090	0.102	5	0.075

Group	C_5			E	CR	S.D.
	W.	R.	S.D.			
Total	0.136	4	0.086	0.114	0.026	0.02
A.E.	0.213	2	0.106	0.072	0.022	0.015
T.E.	0.249	2	0.176	0.098	0.035	0.011
F.W.	0.199	2	0.089	0.113	0.026	0.019

Main reasons that have led to significant concern about GHG emission in Isfahan are:

Table 6. Rank of the scenarios from different perspectives.

Scenario	Users		Academic experts		Transportation experts		Final Rank	
	SAW	R.	SAW	R.	SAW	R.	SAW	R.
(3,1,0,1,0,0,2,0,3,3)	0.692820	9	0.680338	6	0.692410	7	0.684449	7
(2,1,0,1,0,0,3,0,3,2)	0.870793	1	0.842856	1	0.838644	1	0.846752	1
(3,1,3,3,0,0,0,2,0,3)	0.747526	4	0.721860	5	0.747268	4	0.737842	4
(0,1,2,0,0,0,1,2,3,3)	0.677284	10	0.667326	9	0.617507	10	0.656515	10
(3,1,3,1,0,0,2,0,3,3)	0.802892	3	0.786655	3	0.761332	3	0.780880	3
(3,1,0,1,0,0,0,0,3,3)	0.719469	5	0.734614	4	0.732594	5	0.724756	5
(0,1,0,0,0,0,1,2,3,3)	0.694023	8	0.679996	8	0.639879	9	0.673647	9
(3,0,0,1,0,0,0,2,0,3)	0.706654	7	0.652737	10	0.712650	6	0.691065	6
(3,1,1,0,0,0,0,1,3,3)	0.709600	6	0.685598	6	0.660105	7	0.683956	7
(3,1,0,1,0,0,2,3,0,3)	0.860237	2	0.799197	2	0.825720	2	0.829036	2

Note. For example, (3,1,0,1,0,0,2,0,3,3) means projects 1, 9 and 10 will be operated in period 3, projects 2 and 4 will be operated in period 1, project 7 will be operated in period 2 and projects 3, 5, 6 and 8 will not be constructed.

Table 7. Rank of the scenarios considering different evaluation criteria.

Scenario	considered criteria									All criteria
	A_2	A_6	B_2	B_3	C_2	C_4	C_5	A_6, B_2, C_2	A2, A6, B2, B3, C2, C4, C5	
1	1	1	4	8	4	5	4	4	6	7
2	2	1	1	8	1	6	1	1	1	1
3	5	9	6	2	5	7	6	6	7	4
4	9	1	10	6	8	2	10	9	9	10
5	7	1	2	10	2	4	2	2	2	3
6	6	7	5	4	6	10	5	5	3	5
7	10	1	9	5	7	3	9	7	8	9
8	4	9	7	1	10	9	7	10	10	6
9	8	7	8	7	8	8	8	8	5	7
10	3	1	3	3	3	1	3	3	4	2