

The Use of Hybrid BWM and GA in Estimating the Importance Rate of Planning Principles of Livable Urban Transportation

Abolfazl Khishdari^a- Hamid Mirzahosseini^{b*} - Seyyed Komeil Salehi Kamamardakhi^c- Ramin Ansari^d

^a Ph.D. Candidate in Civil Engineering-Transportation Planning, Faculty of Technology and Engineering, Imam Khomeini International University, Qazvin, Iran.

^b Associate Professor of Civil Engineering-Transportation Planning, Faculty of Engineering, Imam Khomeini International University, Qazvin, Iran (Corresponding Author).

^c Assistant Professor of Public Administration and Urban Management, Faculty of Management and Accounting, Allameh Tabatabaee University, Tehran, Iran.

^d Associate Professor of Civil Engineering, Faculty of Engineering and Technology, Imam Khomeini International University, Qazvin, Iran.

Received 20 January 2024;

Revised 07 June 2024;

Accepted 18 August 2024;

Available Online 18 March 2025

ABSTRACT

Now, the increasing growth of urbanism and inconsistency between transportation infrastructures and demand for personal car use have made it necessary to adopt proper plans to match the existing supply and demand. In this case, transportation planning based on sharing various modes is an appropriate technique of planning matched with the space and design of urban elements structured based on ten fundamental principles. This paper aims to determine the importance rate of these principles in the field of livable urban transportation planning. For this purpose, the optimal weight of defined principles is estimated by using the hybrid Best-Worst Method (BWM) and Genetic Algorithm (GA) technique. To implement the proposed technique, the Tehran metropolis which is one of the overpopulated cities in the Middle East is considered a case study. First, a questionnaire for detecting the best (most important) and worst (less important) principles was designed to collect experts' ideas, and the second questionnaire was then used to examine the weight of the ten principles introduced in the references. Results of the first questionnaire showed that among 10 introduced principles for Tehran, the principle of simultaneous transportation and city planning had the highest importance, and the principle of determining fair carfare for different transportation modes had the lowest importance. According to the analysis of the second questionnaire and implementation of GA until response stability is reached, the principle of simultaneous transportation and city planning is three times more important than other principles, and it must receive special attention in urban transportation planning. The reason may be related to the considerable gap between Tehran and livable principles; thus, synergy in solutions obtained from integrated and simultaneous points of view can solve the sophisticated urban issues.

Keywords: Urban Transportation Planning, Livable City, Best-Worst, GA.

* E_mail: mirzahosseini@eng.ikiu.ac.ir

1. INTRODUCTION

Transportation planning has always had a special position in urban studies. The role of a transportation planner is to use skills and capabilities to direct and improve urban transportation policies in favor of people and the urban environment. The different alternatives that transportation planners may consider in this field can appear in the form of investment in and construction of new ways, new railways, channels,

setting public transportation fees, parking use rates, changing infrastructural rules of urban transportation, etc. In many of the mentioned cases, policies can change economic and social growth, and its outcome is a change in individuals' travel characteristics. Therefore, the purpose of transportation planning is to shape individuals' travel habits appropriately. Figure 1 depicts the general structure of transportation planning (Starkie 1976).

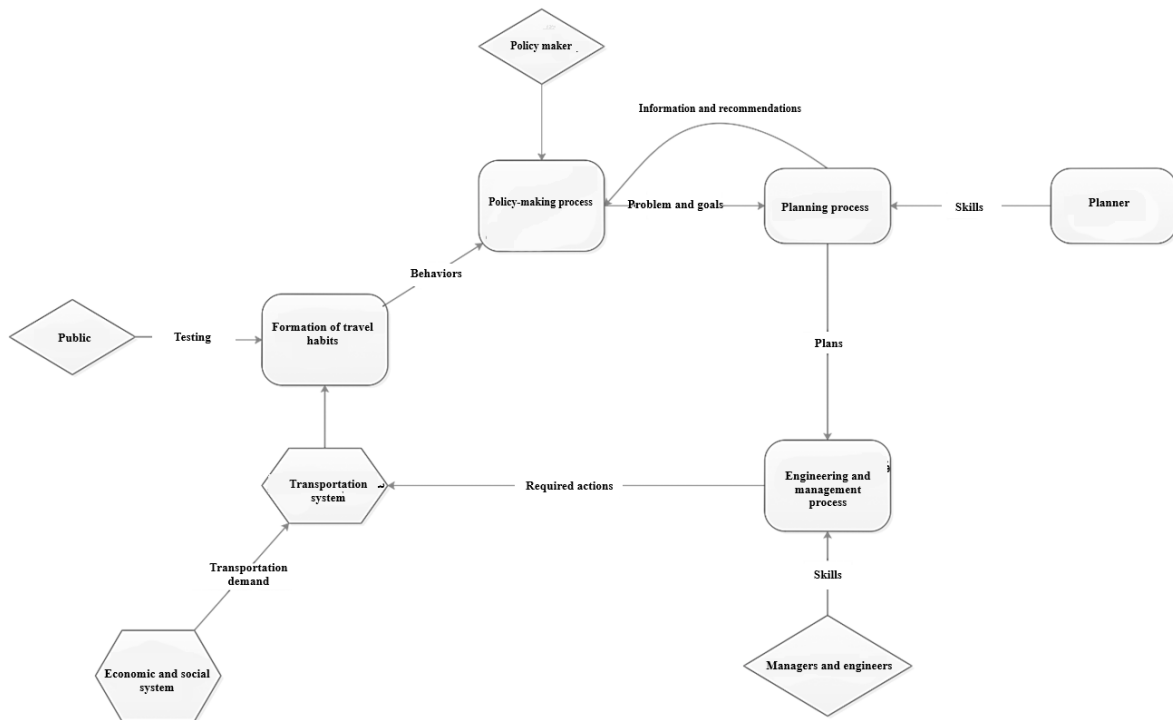


Fig. 1. The General Structure of Transportation Planning

(Derived from Gwilliam 1974)

This case has been considered since 1974, and proper planning requires changing individuals' travel habits through policy-making control, appropriate planning, and presenting transportation systems affecting demand regarding the economic and social dimensions of households. In the recent decade, however, the advent of some technologies such as Autonomous Vehicles (AVs) and so forth has made it necessary to set a comprehensive plan that can meet urban needs.

Estimates imply the presence of 10 million AVs in the world by 2020 (Tech 2016). In the opinion of

researchers, this subject is the sixth wave of change that has been started since 2012 and can be considered concerning the big data age, coordination tracking, and development of smart technologies (Angelo and Vormann 2018). As shown in Figure 2, any big change in the world indeed includes four general steps: creating initial disorder in the existing system, creating severe disorder in a system, balance with the system and harmony of the two, and finally maturity of the relevant change.

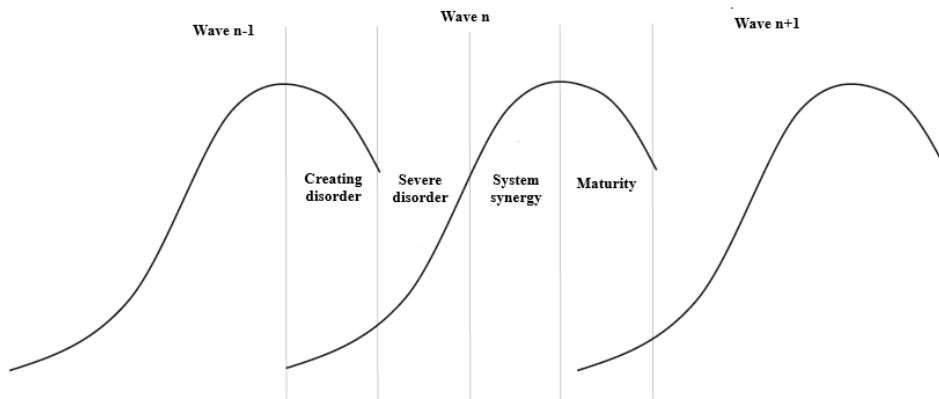


Fig. 2. Four-Step Changes
(Derived from Angelo and Vormann 2018)

2. PLANNING PRINCIPLES FOR A DYNAMIC AND LIVABLE CITY

Studies have confirmed that the increasing growth of urbanism has led to more traffic congestion, delays in vehicles, longer travel time, more accident statistics, and shorter life age (Goetz 2019). In the case of increased traffic congestion, the studies conducted on 200 cities in 23 countries with their reports published in 2018 showed that drivers have wasted time more than an average of 100 hours annually in most of these cities (INRIX 2018). Also, studies have indicated that a growing increase in commutation may cause accidents and unpleasant consequences. Accordingly, half of the annual deaths caused by urban traffic accidents are related to vulnerable people in society, including pedestrians, motorcyclists, and cyclists (WHO 2018).

Dynamic and livable city indeed refers to a set of solutions and policies through which, individuals can

have a good life and interaction in an urban space (Gunn and Davern 2020). A livable and dynamic city is indeed a city that meets all considered needs of humans, such as housing, employment, education, services, transportation, health, and a proper social-visual environment (Lowe et al. 2015). Dynamic and livable cities have become a serious and important concept in local and regional planning (Badland et al. 2014). As mentioned, appropriate transportation that is available for the public is one of the most underlying cases for actualizing a dynamic and livable city. In 2019, some researchers introduced ten principles under the supervision of Professor Robin Chase and the support of an International NGO. These principles provide the field for having access to sustainable transportation matched with the goals of a dynamic and livable city (SMP 2017). The introduced 10 principles are shown in Figure 3, and each principle is elaborated in the following paragraphs.



Fig. 3. Ten Planning Principles for a Dynamic and Livable City

(Derived from SMP 2017)

Principle 1) planning for transportation and urban development simultaneously

These principles express that development, design of the city and its environment, legislation on different urban uses and areas, and other use properties of urban passages and its policies must be made in a way to have a city with compact, accessible, and dynamic uses covering various dimensions of sustainable development (SMP 2017).

Principle 2) human-centeredness view instead of car-centeredness

This principle aims to consider human-centeredness and prioritize pedestrian transport modes, cycling, public transport, and other shared transport modes (SMP 2017).

Principle 3) proper use of available space in transportation planning

According to this principle, the need for streets and required space for movement and car parking must be minimized, so the development of oversized infrastructures, mass production of oversized

vehicles, and oversupply of marginal parking must be prevented (SMP 2017).

Principles 4) making proper relationships with beneficiaries and stakeholders making them engaged in planning case

The optimal option in the planning process is to engage with all mentioned users step by step in the design and implementation of plans (SMP 2017).

Principle 5) observing the principle of social justice in transport planning

Transport planning must be made to ensure all individuals have access to transportation regardless of age, gender, beliefs and religion, income level, and other characteristics (SMP 2017).

Principle 6) Planning must be led towards zero rates of pollutants and the use of renewable energies.

The use of public and shared transport and electric vehicles can dramatically reduce pollutants, which must be considered in plans (SMP 2017).

Principle 7) Fair fees for various transportation modes
Every transportation mode should pay a fair fee for

the use of infrastructural road use, single or shared use of vehicles, the traffic congestion they create, produced emissions, and the use of marginal parking space (SMP 2017).

Principle 8) proper and free access to transportation data must be provided for the public

The field must be provided in planning to share transport and infrastructural data of roads between different companies while ensuring privacy, security, and reliability of data (SMP 2017).

Principle 9) planning must provide the field for integrated communications of different shared transport modes, etc.

All transport services shall be integrated from the viewpoint of operators, different geographical locations, and various modes (SMP 2017).

Principle 10) it is recommended in urban transport planning (especially in dense urban spaces) to use AVs in the form of shared transport mode.

Regarding the suitable transformational potential of AVs, AVs must be part of shared fleets; while their legislation must be done accurately in a way to reduce or even make pollutants zero (SMP 2017).

3. METHOD

The points mentioned herein were about planning principles of livable urban transport. The effectiveness rate of these principles must be measured to achieve a plan to actualize them. Since no study has been done in this field, the extant study tries to fill this research gap. The method mentioned above is more appropriately explained in the following paragraphs.

3.1. Collection of Required Information

As mentioned before, the ten principles introduced in Figure 3 are necessary for the realization of livable

urban transportation planning. In this study, Tehran City has been evaluated as a case study. Because simultaneous implementation of all principles has not been actualized in Tehran, observation methods cannot be used to collect the required statistics and information for estimating the importance of these ten principles. On the other hand, the collection of required statistical information, such as traffic flow in the road network of Tehran, and other information, such as citizens' preferences for travel modes and use of autonomous systems is highly costly, and sometimes no data is available for it. Hence, this study has attempted to examine these ten principles by using a questionnaire-based qualitative approach. In this paper, BWM is used as a simpler and more precise method than the common Analytic Hierarchy Process (AHP) (Rezaei 2015). To achieve the research goal, two stages of the questionnaire are used to analyze principles for livable urban transportation planning.

In this research, 50 experts participated in this research whose fields were fully related to research goals, indicating their suitable opinions about transportation planning principles. Figure 4 (A-C) depicts a schematic of the expert's characteristics. In terms of demography, respondents were mainly men with MA degrees and long technical experience of 1-3 years. According to assessments, questionnaires had content validity. To evaluate the reliability of questionnaires in this research, Cronbach's alpha coefficient was calculated. Assessments show when this coefficient varies between 0.75 and 0.95 the reliability of questionnaires is confirmed (Cronbach and Shavelson 2009). The Cronbach's alpha coefficient calculated for this study equaled 0.925, which showed the reliability of the questionnaires.

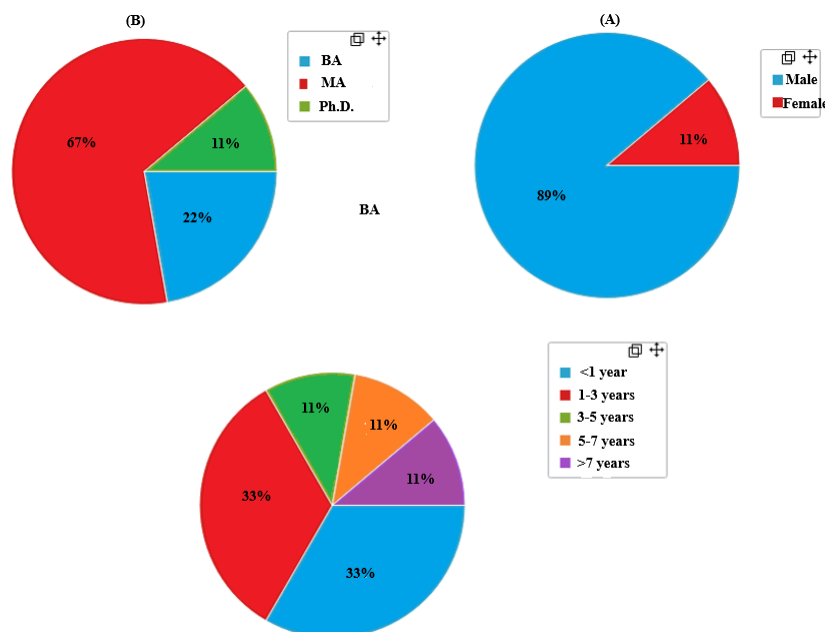


Fig. 4. Experts' Descriptive Analysis of the Questionnaire; A) Distribution of Gender, B) Distribution of Education, and C) Distribution of Experience

First, 25 experts who were familiar with the research field were chosen to detect the best and worst principles. Examination of the first questionnaire was subject to the question about the best and worst principle among 10 principles. According to assessments, the principle of simultaneous urban development and transport planning was the best (most important), and determining fair fees for various transportation modes was the worst (least

important). In the next step, the rest of the 25 experts filled out the second questionnaire to evaluate the best criterion compared to other criteria and evaluate other criteria compared to the worst criterion. It is worth noting that the index of criteria evaluated in Table 1 is matched with the order of criteria introduced in the second part of this paper. Each comparison (Table 1) was then averaged, and mean values were rounded to the nearest integer.

Table 1. Pair Comparisons of Evaluation in BWM

Row	Comparison	Ratio Rate	Row	Comparison	Ratio Rate
1	(Importance of Principle 2 / Importance of Principle 1) = a_{B2}	4	10	(Importance of Principle 7 / Importance of Principle 2) = a_{2w}	3
2	(Importance of Principle 3 / Importance of Principle 1) = a_{B3}	4	11	(Importance of Principle 7 / Importance of Principle 3) = a_{3w}	5
3	(Importance of Principle 4 / Importance of Principle 1) = a_{B4}	4	12	(Importance of Principle 7 / Importance of Principle 4) = a_{4w}	5
4	(Importance of Principle 5 / Importance of Principle 1) = a_{B5}	3	13	(Importance of Principle 7 / Importance of Principle 5) = a_{5w}	4
5	(Importance of Principle 6 / Importance of Principle 1) = a_{B6}	5	14	(Importance of Principle 7 / Importance of Principle 6) = a_{6w}	3
6	(Importance of Principle 7 / Importance of Principle 1) = a_{B7}	4	15	(Importance of Principle 7 / Importance of Principle 8) = a_{8w}	4
7	(Importance of Principle 8 / Importance of Principle 1) = a_{B8}	3	16	(Importance of Principle 7 / Importance of Principle 9) = a_{9w}	4
8	(Importance of Principle 9 / importance of Principle 1) = a_{B9}	5	17	(Importance of Principle 7 / Importance of Principle 9) = a_{10w}	2
9	(Importance of Principle 10 / Importance of Principle 1) = a_{B10}	6			

3.2. 3.2. Analysis of Questionnaires based on BWM

Problem-solving in BWM is done to determine the weight of studied principles based on inequalities (1) and (2) under constraint conditions (3). Equations

$$(1) \quad \left| \frac{w_B}{w_j} - a_{Bj} \right| \leq \xi; \text{ per all } j \text{ values}$$

$$(2) \quad \left| \frac{w_j}{w_w} - a_{jw} \right| \leq \xi; \text{ per all } j \text{ values}$$

$$(3) \quad \sum_{i=1}^n w_j = 1$$

In equation (3), w_j represents the weight of importance of criterion j , and in equations (1) and (2), w_B and w_w indicate the importance weight of best and worst criteria, and ξ shows the objective variable that we tend to find its minimum value.

To find the minimum value of ξ , inequalities must be shaped in the first step and then be solved Through proper techniques. Regarding the conditions of BWM, when many studied criteria whose importance weights must be measured exceed 3 criteria, the

(1)-(3) are indeed optimization problems to find the lowest value of variable ξ in a way that inequalities (1) and (2) are satisfied under constraints (3) (Rezaei 2016). In this method, the weight of the principle's importance is shown with a w sign. Therefore, w_1 shows the weight of the first principle's importance.

problem's solution will not be unique because inequalities are nonlinear. In this lieu, a study has developed BWM to linearize the inequalities (Rezaei 2016). In this technique, a new problem is considered instead of solving the problem with inequalities (1) and (2) and constraint conditions (3). The objective of this new problem is to minimize the new variable ξ^L by satisfying inequalities (4) and (5) and constraint equation (6).

$$(4) \quad |w_B - a_{Bj}w_j| \leq \xi^L; \text{ per all } j \text{ values}$$

$$(5) \quad |w_j - a_{jW}w_W| \leq \xi^L; \text{ per all } j \text{ values}$$

$$(6) \quad \sum_{i=1}^n w_j = 1$$

It must be considered that the weights of criteria (examined principles) belong to the interval of [0, 1] based on the constraint conditions (6). On the other hand, ξ^L is a value less than 1 (although it can be greater than 1 based on the problem's conditions) to achieve a compatible condition. Now, assuming computations are done to three decimal places, the problem must be solved 100010 times; thus, achieving the final result is time-consuming and may take several days. Therefore, the problem is considered NP-Hard type that almost cannot be solved through explicit methods.

The more optimal approach is the use of optimization concepts such as GA, which has been used in many studies in the field of transport engineering. Some these attempts include supply chain management and scheduling to decrease load of activities (Zegordi and Beheshti Nia 2009), optimizing process of transportation stations to examine effect of various structural factors such as traffic volume of freight vehicles, number of fixed and portable freight stations, and also rate on performance of freight stations (Mahmoudabadi and Tavakkoli-Moghaddam 2011), solving problem of supply chain in distribution stations to optimize processes from manufacturing to distribution center (Antony Arokia Durai Raj and Rajendran 2012), solving problem of modeling and allocation of hazardous materials' transportation (Ardjmand et al. 2016), solving nonlinear transportation costs problem (Ghassemi Tari and Hashemi 2016), solving location-routing problem and transportation supply chain considering multimodal transportations (Fazayeli, Eydi, and Kamalabadi 2018), modeling rent and use of shared bicycles (Gao

and Lee 2019), solving problem of hydrogen freight distribution network considering two transportation modes (Woo and Kim 2019), solving problem of freight network optimization (Chandra et al. 2021), and solving problem of optimization of crew scheduling (Hanczar and Zandi 2021).

In this paper, GA is used to solve inequalities (4) and (5) under constraint terms (6). A basic GA consists of an input, output, and algorithm iteration loop until reaching the optimum results (Katoch, Chauhan, and Kumar 2020).

According to the concepts used in GA, the parents are randomly chosen to produce a new child, and multiple solutions may be obtained each time the optimization GA is solved. To decrease this phenomenon in the present paper, the problem was solved ten times to allow the optional assignment of initial values that are randomly given to the weight of criteria. Ten times of iteration were chosen due to the closeness of values of importance weight of measured principles obtained from 10 iterations of the algorithm run to achieve reliable results.

4. RESULTS

Because BWM is used in this study, 17 comparisons must be made between ten principles. According to assessments obtained from the questionnaire, values related to experts' comments showed average results reported in Table 2, which are used to form inequalities. In GA problems, objective functions shall usually reach an optimum (minimum, for instance) value.

Table 2. Pairwise Comparisons of Evaluation in BWM

Row	Comparison	Ratio Rate	Row	Comparison	Ratio Rate
1	$a_{b_2}=4$	4	10	$a_{2w}=3$	3
2	$a_{b_3}=4$	4	11	$a_{3w}=5$	5
3	$a_{b_4}=4$	4	12	$a_{4w}=5$	5
4	$a_{b_5}=3$	3	13	$a_{5w}=5$	4
5	$a_{b_6}=5$	5	14	$a_{6w}=5$	3
6	$a_{b_7}=4$	4	15	$a_{8w}=5$	4
7	$a_{b_8}=3$	3	16	$a_{9w}=5$	4
8	$a_{b_9}=5$	5	17	$a_{10w}=5$	2
9	$a_{b_{10}}=6$	6			

In terms of the objective function, the ξ^L value is greater than or equal to zero; in an extreme mode, therefore, the numerical value of the left hand of inequalities (4) will maximumly equal ξ^L . Hence, the

objective function can be considered as an algebraic sum of values in the left-hand of inequalities (4) and (5). In other words, the objective function of this study is written as equation (7), which must be minimized.

$$f = |w_B - 4w_2| + |w_B - 4w_3| + |w_B - 4w_4| + |w_B - 3w_5| + |w_B - 5w_6| + |w_B - 4w_7| + |w_B - 3w_8| + |w_B - 5w_9| + |w_B - 6w_{10}| + |w_2 - 3w_W| + |w_3 - 5w_W| + |w_4 - 5w_W| + |w_5 - 4w_W| + |w_6 - 3w_W| + |w_8 - 4w_W| + |w_9 - 4w_W| + |w_{10} - 2w_W| \quad (7)$$

This objective function is solved under the constraint terms of equation (6), considering that the importance weight of measured principles belongs to the [0, 1] interval. The results of 10 iterations of analysis

related to GA are described in Table 3. The mean value of measured digits reported in the one row left to the end expresses the importance weight of livable urban transportation planning principles.

Table 3. Results of GA Optimization within 10 Iterations

Iteration	w ₁	w ₂	w ₃	w ₄	w ₅	w ₆	w ₇	w ₈	w ₉	w ₁₀	ξ^L
1	0.327	0.081	0.082	0.082	0.107	0.068	0.025	0.107	0.066	0.054	0.4407
2	0.313	0.078	0.111	0.078	0.105	0.065	0.026	0.107	0.063	0.052	0.5216
3	0.329	0.084	0.081	0.081	0.109	0.066	0.024	0.110	0.066	0.049	0.4683
4	0.325	0.081	0.081	0.081	0.108	0.070	0.026	0.108	0.066	0.054	0.4354
5	0.331	0.082	0.083	0.113	0.089	0.066	0.022	0.091	0.066	0.055	0.5909
6	0.320	0.080	0.084	0.081	0.106	0.069	0.026	0.107	0.068	0.059	0.4947
7	0.315	0.078	0.096	0.079	0.104	0.063	0.023	0.125	0.064	0.053	0.5324
8	0.327	0.083	0.083	0.083	0.108	0.070	0.023	0.101	0.066	0.056	0.4734
9	0.328	0.082	0.082	0.084	0.105	0.065	0.021	0.108	0.070	0.055	0.4506
10	0.318	0.079	0.084	0.101	0.104	0.064	0.026	0.108	0.064	0.053	0.4931
Mean	0.323	0.081	0.087	0.086	0.105	0.067	0.024	0.107	0.066	0.054	0.490
SD	0.006	0.002	0.009	0.011	0.005	0.002	0.002	0.008	0.002	0.003	0.0455

Results of standard deviation (SD) of measured weights (last row of Table 2) indicate the closeness of results of 10 GA run iterations, so they are reliable. One can prioritize the planning principles for livable

urban transportation as shown in the diagram of Figure 5 by measuring the mean value of weighted digits.

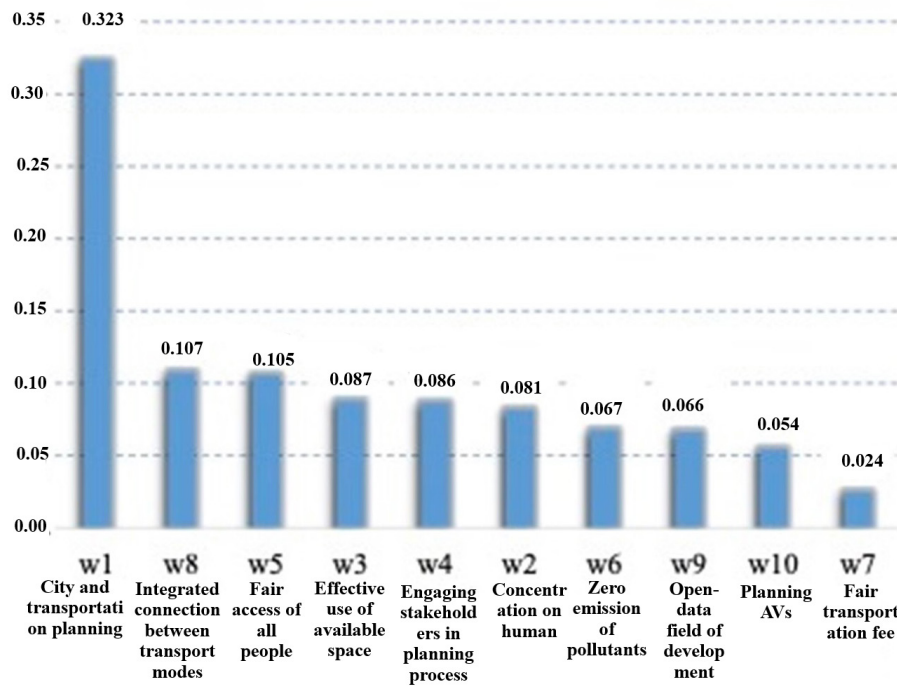


Fig. 5. Prioritizing the Importance of Planning Principles of Livable Urban Transportation

As seen in Figure 5, three principles of simultaneous city and transportation planning, integrated connection between transport modes, and fair access of all people to transportation have had the highest importance, respectively. The reason for these results of each principle is explained and then they are compared with the conditions of Tehran as the selected sample:

- 1) Principle of simultaneous transportation and urban planning: normally, when transportation planning is considered in integration with urban planning, it can synergically strengthen the strengths and reveal the weaknesses to provide the field for presenting comprehensive projects in terms of design, planning, and implementation. This subject is highly important from the viewpoint of experts because there are comprehensive and detailed transportation and urbanism projects in the Tehran Metropolis, but this city is far from a citizen with the definition of livability principles. Therefore, synergy in solutions that can be achieved from an integrated and simultaneous view can pave the way for solving complex urban issues.
- 2) Principle of integrated connection between transport modes: this principle has the second rank of importance among planning principles for livable urban transportation with a considerable gap between simultaneous transportation and urban planning in the first rank. It seems the absence of this principle has led to heavy traffic in Tehran. For example, mass transportation lines such as subway and express buses in Tehran have been distributed in Tehran as a backbone of the public transportation network, but capillaries of the network that are feeders of

these lines have not been well-matched with these dimensions. These feeders can be bicycle-specific lines or pedestrian networks, which are welcomed as complete streets in the world, while this case has received less attention in Tehran.

- 3) Principle of fair access of all people to transportation: this case introduces access to transportation networks as one of the key elements in urban development and improving transportation facilities. Consideration of access becomes essential particularly when some transportation facilities just belong to some people and others cannot use it. This case become more critical in the central area of Tehran where the traffic limit project is implemented. In the traffic limit areas where vehicles cannot commute freely, motorcycle is highly used, for instance. However, this project has narrowed the women's access. In another example, when planning is done without paying attention to principle 5 then personal car is used more than before and the elderly or children and adolescents who cannot use personal cars are ignored in the planning.

5. CONCLUSION

Nowadays, cities' transportation planning is highly substantial. Hence, cities' planning must be done in a way to meet access and movement needs, while providing a dynamic and livable space. This study aims to determine the importance weight of 10 principles for livable urban transportation planning. These principles have been formulated based on international studies conducted by some experts under

the support of the World Resources Institute (WRI). Questionnaires and comparisons between principles have been used to actualize the research goals. To do so, questionnaires were structured based on the BWM which is a more authentic and suitable method than the AHP technique. It first tried to identify the best (most important) and worst (least important) principles based on the experts' opinions. The best and worst principles were simultaneous transportation and city planning and determining fair fees for various transport modes, respectively. It was then attempted to distribute questionnaires for 17 comparisons between different principles, including two categories of comparison: a comparison between the best principle and other principles and a comparison between other principles and the worst one. Finally, computations of principles' weights were analyzed based on the best-worst inequalities under the constraint terms (sum of equivalent principles; weight with one). Regarding the problem-solving conditions and requirement of

a high number of trials and errors, the optimization GA algorithm was used to estimate the weights of principles. This algorithm was run 10 times and weights of principles were measured. According to assessments, the weights of these principles were close to each other within 10 iterations, so these values can be taken into account in the final weights. Mean values of criteria's weights were prioritized as shown in Figure 4. The results indicated that the weight of simultaneous transportation and city planning was almost three times greater than the weights of other principles, which can be considered the main goal in livable urban transportation planning. Some of the limitations in this study included a lack of study on various zones of Tehran in separate cases. Hence, the authors are trying to examine the heterogeneity effect of the 10 principles' importance in different areas of Tehran while involving a larger statistical society of experts related to Tehran districts in future studies.

ACKNOWLEDGMENTS

This article wasn't supported by any financial or spiritual sponsors.

CONFLICT OF INTEREST

The authors have no conflicts of interest to declare.

MORAL APPROVAL

The authors commit to observe all the ethical principles of the publication of the scientific work based on the ethical principles of COPE. In case of any violation of the ethical principles, even after the publication of the article, they give the journal the right to delete the article and follow up on the matter.

PARTICIPATION PERCENTAGE

The authors state that they have directly participated in the stages of conducting research and writing the article.

REFERENCES

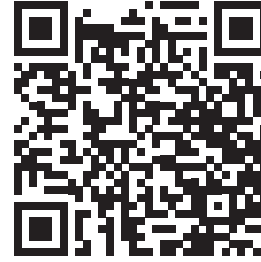
- Angelo, Hillary, and Boris Vormann. 2018. "Long waves of urban reform." *City* 22(5-6): 782-800. <https://doi.org/10.1080/13604813.2018.1549850>.
- Antony Arokia Durai Raj, K., and Chandrasekharan Rajendran. 2012. "A genetic algorithm for solving the fixed-charge transportation model: Two-stage problem." *Computers & Operations Research* 39(9): 2016-2032. <https://doi.org/https://doi.org/10.1016/j.cor.2011.09.020>.
- Ardjmand, Ehsan, William A. Young, Gary R. Weckman, Omid Sanei Bajgiran, Bizhan Aminipour, and Namkyu Park. 2016. "Applying genetic algorithm to a new bi-objective stochastic model for transportation, location, and allocation of hazardous materials." *Expert Systems with Applications* 51: 49-58. <https://doi.org/https://doi.org/10.1016/j.eswa.2015.12.036>.
- Chandra, Aitichya, M. N. Sharath, Agnivesh Pani, and Prasanta K. Sahu. 2021. "A multi-objective genetic algorithm approach to design optimal zoning systems for freight transportation planning." *Journal of Transport Geography* 92: 103037. <https://doi.org/https://doi.org/10.1016/j.jtrangeo.2021.103037>.
- Fazayeli, Saeed, Alireza Eydi, and Isa Nakhai Kamalabadi. 2018. "Location-routing problem in multimodal transportation network with time windows and fuzzy demands: Presenting a two-part genetic algorithm." *Computers & Industrial Engineering* 119: 233-246. <https://doi.org/https://doi.org/10.1016/j.cie.2018.03.041>.
- Gao, Xuehong, and Gyu M. Lee. 2019. "Moment-based rental prediction for bicycle-sharing transportation systems using a hybrid genetic algorithm and machine learning." *Computers & Industrial Engineering* 128: 60-69. <https://doi.org/https://doi.org/10.1016/j.cie.2018.12.023>.
- Ghassemi Tari, Farhad, and Zahra Hashemi. 2016. "A priority based genetic algorithm for nonlinear transportation costs problems." *Computers & Industrial Engineering* 96: 86-95. <https://doi.org/https://doi.org/10.1016/j.cie.2016.03.010>.
- Goetz, Andrew R. 2019. "Transport challenges in rapidly growing cities: is there a magic bullet?" *Transport Reviews* 39(6): 701-705. <https://doi.org/10.1080/01441647.2019.1654201>.
- Gwilliam, K. M. 1974. "Appraising urban transport policy - the new regime." Projection of population and households : PTRC summer annual meeting.
- Hanczar, Paweł, and Arash Zandi. 2021. "A novel model and solution algorithm to improve crew scheduling in railway transportation: A real world case study." *Computers & Industrial Engineering* 154: 107132. <https://doi.org/https://doi.org/10.1016/j.cie.2021.107132>.
- INRIX. 2018. "Global traffic scorecard." <http://inrix.com/scorecard/>.
- Katoch, S., S. S. Chauhan, and V. Kumar. 2020. "A review on genetic algorithm: past, present, and future." *Multimed Tools Appl* (80): 8091-8126. <https://doi.org/https://doi.org/10.1007/s11042-020-10139-6>.
- Mahmoudabadi, Abbas, and Reza Tavakkoli-Moghaddam. 2011. "The use of a genetic algorithm for clustering the weighing station performance in transportation – A case study." *Expert Systems with Applications* 38(9): 11744-11750. <https://doi.org/https://doi.org/10.1016/j.eswa.2011.03.061>.
- Rezaei, Jafar. 2015. "Best-worst multi-criteria decision-making method." *Omega* 53: 49-57. <https://doi.org/https://doi.org/10.1016/j.omega.2014.11.009>.
- SMP. 2017. "Shared Mobility Principles for Livable Cities Launched by Consortium of Transport Experts." <https://www.sharedmobilityprinciples.org/>.
- Starkie, D. N. M. 1976. "Transportation Planning, Policy and Analysis." Elsevier.
- Tech Business Insider. 2016. 10 million self-driving cars will be on the road by 2020. <https://www.businessinsider.com/report-10-million-selfdriving-cars-will-be-on-the-road-by-2020-2015-5-6>.
- WHO. 2018. Road traffic injuries. <https://www.who.int/newsroom/fact-sheets/detail/road-traffic-injuries>.
- Woo, Young-Bin, and Byung Soo Kim. 2019. "A genetic algorithm-based matheuristic for hydrogen supply chain network problem with two transportation modes and replenishment cycles." *Computers & Industrial Engineering* 127: 981-997. <https://doi.org/https://doi.org/10.1016/j.cie.2018.11.027>.
- Zegordi, S. H., and M. A. Beheshti Nia. 2009. "A multi-population genetic algorithm for transportation scheduling." *Transportation Research Part E: Logistics and Transportation Review* 45(6): 946-959. <https://doi.org/https://doi.org/10.1016/j.tre.2009.05.002>.

HOW TO CITE THIS ARTICLE

Khishdari, Abolfazl, Hamid Mirzahosseini, Seyyed Komeil Salehi Kamamardakhi, and Behzadfar. 2025. The Use of Hybrid BWM and GA in Estimating the Importance Rate of Planning Principles of Livable Urban Transportation. *Armanshahr Architecture & Urban Development Journal* 17(49): 85-96.

DOI: 10.22034/AAUD.2024.436788.2859

URL: https://www.armanshahrjournal.com/article_213353.html

**COPYRIGHTS**

Copyright for this article is retained by the author(s), with publication rights granted to the Armanshahr Architecture & Urban Development Journal. This is an open-access article distributed under the terms and conditions of the Creative Commons Attribution License.

<http://creativecommons.org/licenses/by/4.0/>

