International Journal of Railway Research, Vol. 7, No. 1, (2020), 51-59

Iran University of Science and Technology

International Journal of

Railway Research

ISSN: 2423-3838

A Method to Design Facility Layout in Passenger Terminals using Optimization and Simulation

Seyed Mohsen Mahmoudi[1], Morteza Bagheri[1*], Navid Khademi[2] , Afshin Shariat Mohaymany[3]

[1]School of Railway Engineering, Iran University of Science and Technology, Tehran, Iran

[2]Faculty of Civil Engineering, College of Engineering, University of Tehran, Tehran, Iran

[3]Faculty of Civil Engineering, Iran University of Science and Technology, Tehran, Iran

ARTICLE INFO

Article history:

Received: 21.02.2020

Accepted: 30.04.2020

Published: 26.06.2020

Keywords:

Facility layout

Hybrid approach

Optimization

Passengers

Simulation

A B S T R A C T

In the passengers' terminal, an appropriate facility layout leads to enhance efficiency and passenger satisfaction. The present study provided a methodology to design facility layout using a hybrid approach of simulation and optimization for passengers in public location, as well as proposed an innovative model to allocate candidate location to the facility. The proposed model results in select the location for the facility with any dimension and without space limitation. Furthermore, it is usable for passenger's terminal and all public locations. The advantages of the proposed model are reducing some parameters such as the movement duration of passengers, experienced passenger density, and flow rate, and increasing the quality of passengers' terminals.

1. Introduction

Recently, improving the quality of public transportation has attracted more attention as an important research field [1]. The starting point of increasing customer satisfaction is service quality assessment [2]. In the public transportation system, an important task for managers is increasing customer satisfaction [3]. The level of passenger satisfaction has a significant effect on the decision making about select public transportation or not [4]. A passenger probably selects a transportation mode again if he/she has good experience from using this mode [5]. Based on a recent study in the EU, the quality of facilities and serviceability are the most important factors of passenger dissatisfaction at European railway stations among the eight examined factors. In this study, 34% of passengers were dissatisfied with the service facilities of the stations. The dissatisfaction amount of station facilities in different countries like Poland, Hungary, and Slovakia was 62%, 54%, and 52%, respectively. In addition, the dissatisfaction amount in Bulgaria, Romania, and the Czech Republic was 51%, 49%, and 49%, respectively [6]. Furthermore, based on an Indian study, serviceability facilities were identified in railway passenger satisfaction among the seven examined factors as the most important effective factor [7].

In Figure 1, the satisfaction pyramid of the railway station includes five levels. Two near levels to the top of the pyramid, comfort, and experience which leads to passenger satisfaction with their presence at the station. The passengers can be satisfied with their travel if all pyramid layers are applied [8]. The quality of the station can have a negative effect if one of these layers

*Corresponding author, Associate professor

Email: Morteza_bagheri@iust.ac.ir

[DOI: 10.22068/IJRARE.7.1.51]

is ignored. The speed and ease of station accessibility are important when the passengers move toward the station, but comfort and experience are vital when the passengers must wait at the station [9].

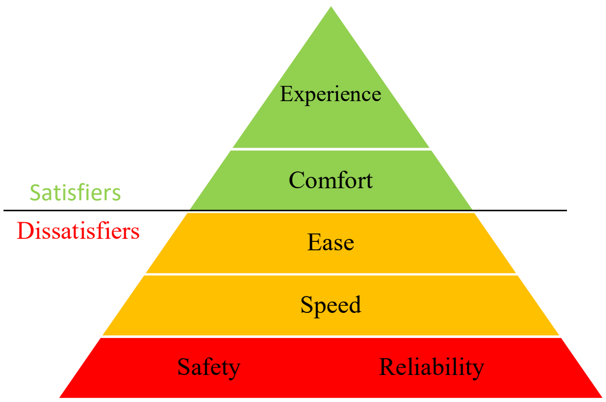

Figure 1. Satisfaction pyramid of Railway station

In Iran, Tehran Railway Station has the highest complaints about 40% by examining the complaints of 65 railway station passengers from on the railway network. Complaints of collection of station lounges, equipment, and facilities are in the second rank of customer complaints. Therefore, the facilities layout can increase the quality of service to passengers at the Tehran Railway Station lounge and leads to increasing the portion of public transportation [10].

The facility layout of the passenger terminal can effect on the utility of their users. In passenger terminals, management decides empirically where each facility should be located. Sometimes, many passengers complain about the facilities' layout, which may lead to select a new layout without conducting scientific studies by the practitioner. In addition, rearranging the layout in passengers' terminal required time, cost, human resources, and a lot of administrative work, which each of these factors leads to management's disinclination to change the layout. Hence, examine different combinations is not possible operationally, which becomes more difficult by increasing facilities and candidate locations, although pedestrian walking is so complex and important that makes it difficult to study or model[11].

The number of researches about facilities layout has an increasing trend in the manufacturing industry, which indicates the importance of this subject. These researches conducted that an appropriate facility layout can reduce at least 10% and up to 30% of costs [12]. Based on State-of-Art, a large number of studies in manufacturing centers and a few studies in the field of service centers are because of 1) increase travel costs and heterogeneous pieces crowding in manufacturing centers, 2) requires of complicated models of human behavior in service centers relative to pieces in manufacturing centers, and 3) private ownership in manufacturing centers and government ownership in service center.

Generally, the facilities in passengers' terminals in which passengers used their facilities lead to increasing efficiency and satisfaction. The layout can change from the optimum state by through time and change in the number and type of passengers and the terminal environment [13]. In the present study, the proposed method is practical a valuable due to creating the combination of many layouts by increasing the number of facilities and candidate locations and limitations in cost, time, and human resources in practice. A periodic review about be suitable facilities layout seems necessary. During the time, the facilities layout may be unsuitable; hence, increasing users' dissatisfaction can indicate the unsuitable location of facilities and take some measures [14]. The facilities must be investigated on a regular and specified plan to guarantee well met the users' needs. The facilities' location must be reviewed each time the evaluation indicates that their location must be updated. Meantime, some facilities must move to a new location and others must stay in their previous location. Facilities and candidate location can create many combinations of layouts, which leads to making a difficult select layout to select the best ones.

There are some guidelines and regulations for designing the railway station, such as Amtrak US "Station Program and Planning Guidelines" [15], UK Network Rail "Station Design Principles for Network Rail" and "Station Capacity Planning Guidance" [16, 17], and Swedish Transport Agency "Railway Stations – Planning Manual" [18]. These guidelines emphasized the importance of facilities location, but no suggestion provided to determine the exact location of the facilities so far.

In previous researches, the facilities' locations in passenger terminals have been addressed rarely. Other gaps in previous

[DOI: 10.22068/IJRARE.7.1.51]

researches are using a model that considers facilities with unequal dimensions and without limitation in the location of these facilities by inspired from real conditions. Therefore, the present study aimed to present a comprehensive methodology to solve facilities layout related to passengers with unequal dimensions by a hybrid approach of simulation and optimization.

In the present study, the literature review of facilities layout was provided firstly. Then, the methodology of optimizations problems of facilities layout and a model to solve this problem with unequal dimensions were proposed. Finally, the advantages of methodology and proposed model and the future works were presented.

2. Literature Review

Dickey and Hopkins (1972) found appropriate locations to16 buildings at the University of Virginia using the TOPAZ model which proposed by Broushi et al. (1970). This study aimed to provide a new layout to reduce the passed distance by students and employees and can be reduced the number of travels to 14% compared to the university development program. This study was the first scientific study about used facilities to increase environmental efficiency although, facilities' layout only was used for manufacturing and service units until then [19]. Ballas (1974) conducted a study on building locations of Montana University in the USA using multiple regression techniques for predictions and collected information from 1971 to 1973. In addition to design buildings location, the enter and exit location of the university and appropriate walking paths for the students were predicted in comparison to previous research. Finally, the number of all transportations to non-residential buildings of the university and the number of classes' chairs were achieved using the proposed model [20].

In the transportation field, Lee (2011) integrated optimization of facilities layout and simulation of passenger behavior and Movement in Taiwan High-Speed Rail and provided a hybrid model using the Ant colony optimization algorithm and social force model. This study aimed to reduce the travel time between different facilities, which reduced the average of during the travel time of passengers to 29.28 seconds by moving 16 facilities at the station [13]. In addition, Lee and Tseng (2012) presented a hybrid method to facilities' layout using integrated ant colony simulation and optimization and simulated Taipei SongShon Airport using Vissim software as a case study. The selected locations were identified by considering different values for the parameters of the ant colony algorithm with a simulation model between 41 proposed locations for 32 available facilities. Their study was similar to Lee (2011), and the difference was in the case study [21]. Özer and Şener (2013) proposed a method using a Genetic algorithm to optimize pedestrian access to architectural designs and answer to this question "Is it possible to optimize pedestrian transfer based on the spatial accessibility index?". The novelty idea was using spatial accessibility indexes, which not addressed in previous studies. Therefore, this problem was investigated by defining the accessibility model based on distance and identifying relation indexes sections of a set. In this study, two layouts were investigated for different parts of two hospitals in Turkey using 11 indexes to evaluate proposed layouts; finally, one layout was used to design the hospital [22]. Lee (2014) again proposed a model to minimize used pedestrian walking time, reconstruction time, and the number of workers to rebuild a villa resort. In this study, 11 parts of a villa resort were selected, and all sections were to be reconstructed. The proposed model was simulated using Vissim software and was optimized by the ant colony algorithm. Simulation, optimization, and project control concept were integrated unlike the previous study [23]. Lin et al. (2015) designed a layout for operating rooms in Shanghai East International Medical Center. The transfer of different people, such as patients, surgeons, and nurses and required equipment for the operating room, were considered. In the previous study, finding an appropriate location of required human facilities was modeled by assuming certainty.

Nevertheless, the objective function and limitations were defined using fuzzy logic as uncertain, which can be closer to the real world. Two objective functions are maximum access to parts and better use of available space, and two limitations are easier management and the possibility of better development in the future. Two layouts were considered to eight desired parts for locating and finally, one layout was selected for final design [12]. Helber et al. (2016)

[DOI: 10.22068/IJRARE.7.1.51]

provided a layout for departments and sections of Hannover Medical School, which consist of educational and medical departments. The design of the department location was performed using hierarchical layout planning. In this study, candidate locations, departments, and sections included 3D-dimensions due to the large dimensions of problem. Decomposition solving algorithm and hierarchical modeling were used to provide the optimal layout to sections of this hospital [24]. Rismanchian and Lee (2017) improved the quad objective using optimization, such as minimize traveled distance to critical and non-critical patients, allocates activities to locations for maximize capabilities in all parts of the hospital, and minimize travel cost of equipment. This optimization was performed using CPLEX 12 software on the emergency department of one of the oldest and largest hospital in South Korea. The traveled distance for non-critical and critical patients was improved to 42.2% and 47.6%, respectively [25]. Bazeghi et al. (2019) developed two models to locate small and large facilities at the Tehran Railway Station with two aims including minimizing travel time of passengers between facilities and cost of relocation facilities. The required information was extracted using Bluetooth-WiFi scanners. The proposed model reduced the travel time of passengers at the station to 2.4 minutes and experienced density to 17%. The differences between this and previous research were considering relocating cost and relation between facilities [26]. Bazeghi et al. were investigated the effect of changing the layout of a railway station on 1) passenger flow, 2) passenger experience density, and 3) average travel time. The flow of passengers was studied in different layouts under four scenarios using simulator software and was assessed using Wireless Internet Scanners. Based on the results, the average travel time and experienced density were reduced to 37% and 17% using optimal layout, respectively. In addition, the travel time can be reduced to 56% by adding an escalator. The results of another scenario indicated that the passengers 24% more exposed to the crowd than the current situation if travel time reduced 61% [27].

In the previous researches, the dimensions of facilities' location were considered equal which reducing the optimal use of available space or facilities' location were categorized without similarity to the real-world and reduced the number of possible layouts dramatically. In the present research, the facilities required optimization space equal to their dimensions and the rest of the space remained empty for using other facilities. The proposed model developed the solution space than previous models and can found near optimum solutions.

Amtrak is one of the largest active companies in management railway stations in US, which monitoring American and Canadian railway stations. "Station Program and Planning Guidelines" of Amtrak in one of the comprehensive guidelines to help local government, transportation agencies, designers, employees, and other stakeholders. This guideline is categorized into four categories based on the importance and dimensions of railway stations. In addition, a different part of the station is defined as seven sections, but the facility location is not described in detail [15]. Network Rail is the owner and manager of infrastructure in most of England's rail networks. This company presented the used principles and policies of new and exited stations as twelve principles in "Station Design Principles" such as retail in the station [16]. Retailers can have a very positive effect on economic condition and public understanding until not prevent the safety and efficiency of the station's operations. The dimensions of retail activity are depended on their location at the station. Generally, this guideline defined the importance of retailers' presence and specified planning for locating. In addition, "Station Capacity Planning Guidance" is presented by Network rail consists of the required information to design stations by considering the convenience and safety of passengers. Based on this guideline, the required facilities of passengers must be located in an appropriate location but was not provided a method for this selection [17]. "Railway Stations – Planning Manual" of the Swedish Transportation Agency's is one of another resource in station design, which noted that the facility location does not prevent the flow of passenger travels [18]. Different types of economic activity and booths can lead to ordinary people coming to the station to purchasing, which promotes the culture of using public transportation between ordinary people. "Manual for Standards and Specifications for Railway Stations" at Indian is another good guideline in designing railway stations, which emphasized that the station must include all

[DOI: 10.22068/IJRARE.7.1.51]

required facilities of passengers [28]. Existing essential facilities are necessitating but not enough, such as public WC water cooler, information, and ticket refund. The station must be included other facilities such as retailers, food court, ATM, etc. Facilities must be located in the public area as balanced, not locating near to enter and exit door so nothing problem with passenger travel. Locating facilities in different sections prevent crowding people in part of the station. The station must be designed to allow maximum comfort to passengers. The designer must be considered that the rail passenger is a customer, and the primary aim of station design is to create a comfort, appropriate, and interest environment to attract and retain passengers. The route between the station entrance to the platform can be ensured passengers to desirable experiences. The importance aims of station design include A) minimize walking distance for passengers and B) provide appropriate facilities. There are no proposals to determine the exact location of facilities by considering guidelines and regulations of designing railway station and their emphasis on the importance of locating facilities.

Based on the literature and guidelines review, using the passenger flow approach has been occurred in redesigning facilities at railway stations, rarely. One of the aims of the present research was to increase access to facilities and station capacity and reducing travel time, which leads to the desirability of passengers' travel.

3. Methodology

The present study provided a new methodology to design facilities layout in passenger terminals. A hybrid approach was provided by combining simulation and optimization, which leads to finding a superior layout by considering the real behavior of passengers. In addition, the location of the facility in different dimensions can be found to optimize the objective function, using proposed modeling. In this model, more states were investigated, and realistic conditions were considered.

3.1. Modeling

In the present research, the locating model of available facilities at Tehran Railway Station was provided. Locating some facilities such as WCs were not considered due to the high cost and time of their displacement and minimum intervention approach in this research. The candidate location used the current locations of facilities, and a new location was not added to use managers' experience in locating current facilities and the lack of more space in the station. The facilities in facing the windows which eliminate the beautiful view of the station if adding more candidate space. Furthermore, the lack of a wall or column besides the facilities leads to disruption to the movement flow of passengers. On the other hand, the facilities near the emergency exit door make difficult the outgoing process of passengers in times of crisis. Hence, in the present research, adding a new location to the candidate locations to locate the facilities was not preferred.

The railway station consists of a set of blocks to locate facilities. All blocks not located besides each other and the ones located besides each other are defined as a segment. Therefore, railway station consists of a set of segments that each of them including one or several blocks. The facilities dimensions of Tehran Railway Station were divided into three categories, small, medium, and large due to. This problem aimed to minimize the average travel time of passengers, and limitations are divided into three types as "second to fourth equations", "fifth to seventh equations", and "eighth to tenth equations". The first type of limitation (second to fourth equations) is related to non-interference of each category of different dimensions of facilities with each other. The second type of limitation (Fifth to Seventh Equations) is related to locating each facility only in one location. The third type of limitation (eighth to tenth equations) guaranteed that each location allocated to one facility maximally. This modeling can be used for facilities locating problems in other locations with different input parameters and some differences. The number of the first type of limitations must be a combination of two from the number of dimensions category of facilities. In addition, the second and third types of limitation must be the number of dimensions category of facilities. The proposed model was modeled in two steps as follows:

First step:

Input parameters:

[DOI: 10.22068/IJRARE.7.1.51]

[DOI: 10.22068/IJRARE.7.1.51]

Number of all passengers (P), Duration transportation of passenger P facility m to facility n ($T_{m.n.p}$), Duration input passenger P to station until use first facility ($T_{En.p}$), Duration using the last facility by passenger P until leaving the station ($T_{Ex.p}$), The number of segments (K), The number of block of each segment (N_k), The number of all facilities (F), The number of large facilities (F_L), The number of medium facilities (F_M), The number of small facilities (F_S), The number of required block of large facilities (A_L), The number of required block of medium facilities (A_M), The number of required block of small facilities (A_S)

Decision variables:

Locating large facility ith in location jth in block kth ($z_{i,j,k} = 1$ or 0), Locating medium facility ith in location jth in block kth ($y_{i,j,k} = 1$ or 0), Locating small facility ith in location jth in block kth ($x_{i,j,k} = 1$ or 0)

Limitations:

Non-interference between large and small facilities (second equation), Non-interference between large and medium facilities (third equation), Non-interference between medium and small facilities (fourth equation), Guaranteed locating each facility only in one location (fifth to seventh equation), Guaranteed allocating each location to one facility maximumly (eighth to tenth equation)

Object:

Minimize average of travel time of passengers

Second step:

The locating facilities problem can be modeled to achieve $z_{i,j,k}$ ‘$y_{i,j,k}$ and $x_{i,j,k}$ variables, as follows:

Minimization:

$$TTA = \frac{\sum_{m=1}^{F}\sum_{n=1}^{F}\sum_{p=1}^{P} T_{m,n,p}}{P} + \frac{\sum_{p=1}^{P} T_{En,p} + \sum_{p=1}^{P} T_{Ex,p}}{P} \quad (1)$$

Where

$$\sum_{i=1}^{F_L} z_{i,j,k} \cdot \left(\sum_{i=1}^{F_S}\sum_{n=1}^{A_L-A_S+1} x_{i,j-1+n,k}\right) = 0 \quad \forall\, j \in \{1,\dots,N_k - A_L + 1\} \wedge k \in \{1,\dots,K\} \quad (2)$$

$$\sum_{i=1}^{F_L} z_{i,j,k} \cdot \left(\sum_{i=1}^{F_M}\sum_{n=1}^{A_L-A_M+1} y_{i,j-1+n,k}\right) = 0 \quad \forall\, j \in \{1,\dots,N_k - A_L + 1\} \wedge k \in \{1,\dots,K\} \quad (3)$$

$$\sum_{i=1}^{F_M} y_{i,j,k} \cdot \left(\sum_{i=1}^{F_S}\sum_{n=1}^{A_M-A_S+1} x_{i,j-1+n,k}\right) = 0 \quad \forall\, j \in \{1,\dots,N_k - A_M + 1\} \wedge k \in \{1,\dots,K\} \quad (4)$$

$$\sum_{j=1}^{N_1-A_L+1} z_{i,j,1} + \cdots + \sum_{j=1}^{N_k-A_L+1} z_{i,j,k} = 1 \quad \forall\, i \in \{1,\dots,F_L\} \quad (5)$$

$$\sum_{j=1}^{N_1-A_M+1} y_{i,j,1} + \cdots + \sum_{j=1}^{N_k-A_M+1} y_{i,j,k} = 1 \quad \forall\, i \in \{1,\dots,F_M\} \quad (6)$$

$$\sum_{j=1}^{N_1-A_S+1} x_{i,j,1} + \cdots + \sum_{j=1}^{N_k-A_S+1} x_{i,j,k} = 1 \quad \forall\, i \in \{1,\dots,F_S\} \quad (7)$$

$$\sum_{i=1}^{F_L} z_{i,j,k} \le 1 \quad \forall\, j \in \{1,\dots,N_k - A_L + 1\} \wedge k \in \{1,\dots,K\} \quad (8)$$

$$\sum_{i=1}^{F_M} y_{i,j,k} \le 1 \quad \forall\, j \in \{1,\dots,N_k - A_M + 1\} \wedge k \in \{1,\dots,K\} \quad (9)$$

$$\sum_{i=1}^{F_S} x_{i,j,k} \le 1 \quad \forall\, j \in \{1,\dots,N_k - A_S + 1\} \wedge k \in \{1,\dots,K\} \quad (10)$$

$x_{i,j,k}$, $y_{i,j,k}$, $z_{i,j,k} = 1$ or 0

All parameters are natural numbers.

There is a large number of software for infrastructure management, such as layout [29], which most of them are appropriate to design manufacturing space and displacement services of goods and initial material between facilities. In addition, finding the best solution to facilities layout not easy using mathematical methods due to different combinations of locating facilities in the environment [30]. Servicing facilities consist of an information box, ATM, buffet, water cooler, etc.

3.2. Proposed framework

According to Figure 2, the available software based on the logic of this model were investigated, and the best one was selected after selecting the behavioral and movement model of pedestrians. In addition, the selected model must be calibrated to superior in accordance with real conditions. The required information was collected to simulating and modeling by selecting the behavioral and movement model of pedestrians and simulator software. The locating facilities model was created using collected information, and collecting further information may be required. The information can be collected by different methods. All previous steps were performed for the hybrid approach section, and the most important part of the methodology was performed in this section. This section consists of two sub-sections, optimization and simulation, that are related closely. The facilities' layout was achieved by performing these steps, and the process was stopped to reach the best nearest optimum solution if reached to the condition. Then, the validation layout was performed by real information, finally, the results were analyzed and concluded.

The relation between optimization and simulation in the hybrid approach was defined as each obtained solution from optimization is a new layout. The value of the objective function can be achieved through locating facilities in simulator software based on that layout. The software output can be considered as the value of the objective function by running the simulation. This return is repeated until achieving the nearest optimum solution.

4. Conclusions

In some previous researches on facilities layout in passenger terminals, the dimensions of facilities location were considered equal, which led to reducing optimum using of available space. In another, the facilities' location was categorized without similarity with the real world and reduced the number of possible layouts dramatically. In the present research, space was allocated to facilities based on their dimensions and the rest of the space was remained for other facilities. The proposed model has increased the solution space than the previous models and can find the nearest optimum solution.

The proposed model and methodology can be used in each passenger terminal to increase efficiency and passenger satisfaction. The advantages of the proposed model and methodology are as follows:

•The proposed model can allocate facilities by users in each location. In previous research, the lack of this capability can lead to reducing candidate location for facilities significantly and cannot find many appropriate layouts.

•The efficiency of the passenger terminal can investigate using the proposed model a methodology quantitatively.

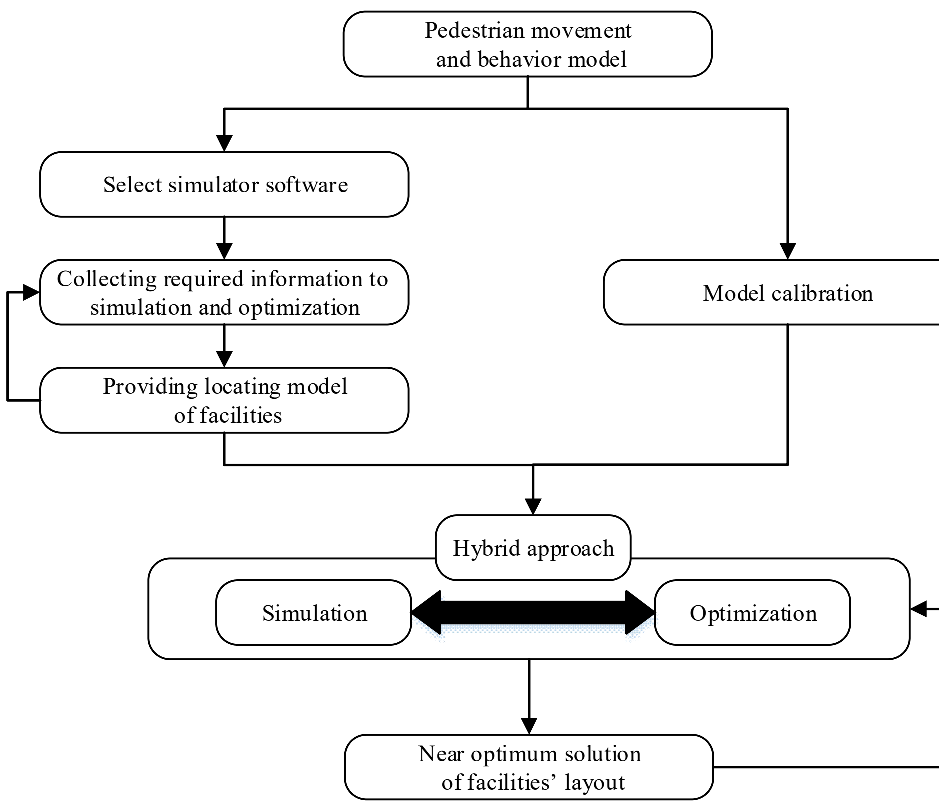

Figure 2. Methodology of Facilities Layout in Passenger Terminals

[DOI: 10.22068/IJRARE.7.1.51]

•In the present research, a hybrid method was provided, which can examine a large number of layouts to achieve the nearest optimum solution. Finally, the best solution was implemented in the desired location practically.

The limitations of the present research were suggested as future works:

•The problem is superior defined as multi-objective. The importance coefficient of each function must reach to the optimum layout using expert decision if multi-objective functions were defined. In addition, sensitivity analysis can be interesting and important.

•The problem could be more realistic if all available facilities at passenger terminals were considered, such as those of minimum and maximum interferences. Hence, the cost objective function must be considered maximum interferences that need to cost based on their amount.

•The proposed methodology can be used in exploiting locations. A model can be achieved, which can be used before exploitation if the passenger behavior can be predicted result in achieving a comprehensive model.

•Add or remove facilities in their locating can creating more changes in layout, which required predicting passenger behavior for new facilities and transportation in new locations.

Acknowledgement

We thank the members of the TSL Lab for their kind, Rail Pardaz Seir for laboratory equipment, and the Republic of Iran Railway Company for their cooperation in collecting information at the Tehran Railway Station.

References

[1] J.U. Becker, S. Albers, The limits of analyzing service quality data in public transport, *Transportation*, Vol. 43,(2016), pp. 823-842.

[2] N. Aydin, A fuzzy-based multi-dimensional and multi-period service quality evaluation outline for rail transit systems, *Transport Policy*, Vol. 55,(2017), pp. 87-98.

[3] N. Aydin, E. Celik, A.T. Gumus, A hierarchical customer satisfaction framework for evaluating rail transit systems of Istanbul, *Transportation Research Part A: Policy and Practice*, Vol. 77,(2015), pp. 61-81.

[4] T.-C.M.T.D.o. Oregon, T.C.R. Program, Customer Satisfaction Index for the Mass Transit Industry, IDEA Program, Transportation Research Board, National Research Council1995.

[5] L. Eboli, G. Mazzulla, A new customer satisfaction index for evaluating transit service quality, *Journal of Public transportation*, Vol. 12,(2009), pp. 2.

[6] T.G. Organization, Survey on passengers' satisfaction with rail services, *European Commission*,(2011).

[7] G. Goel, P. Ghosh, M.K. Ojha, S. Kumar, Journey towards world class stations: An assessment of platform amenities at Allahabad junction, *Journal of Public Transportation*, Vol. 19,(2016), pp. 5.

[8] M. Van Hagen, Effect of Station Improvement Measures on Customer Satisfaction, *Journal of Traffic and Transportation Engineering*, Vol. 3,(2015), pp. 7-18.

[9] K.L. Wakefield, J.G. Blodgett, Customer response to intangible and tangible service factors, *Psychology & Marketing*, Vol. 16,(1999), pp. 51-68.

[10] T.R.o.t.I.R.o. Iran, Railway Complaints Response Information Center of Iran

[11] A. Saeedi, A.A. Rassafi, A Study of Pedestrian Movement on Crosswalks Based on Chaos Theory, *International Journal of Transportation Engineering*, Vol. 6,(2019), pp. 317-329.

[12] Q.-L. Lin, H.-C. Liu, D.-J. Wang, L. Liu, Integrating systematic layout planning with fuzzy constraint theory to design and optimize the facility layout for operating theatre in hospitals, *Journal of Intelligent Manufacturing*, Vol. 26,(2015), pp. 87-95.

[13] H.-Y. Lee, Integrating simulation and ant colony optimization to improve the service facility layout in a station, *Journal of Computing in Civil Engineering*, Vol. 26,(2011), pp. 259-269.

[14] R.G. Mishalani, M.R. McCord, Infrastructure condition assessment, deterioration modeling, and maintenance decision making: Methodological advances and

[DOI: 10.22068/IJRARE.7.1.51]

practical considerations, American Society of Civil Engineers, 2006.

[15] Amtrak, Station Program and Planning Guidelines,(2013).

[16] N. Rail, Station Design Principles for Network Rail,(2015).

[17] N. Rail, Station Capacity Planning Guidance,(2016).

[18] T.S.T. Administration, Railway Stations - Planning Manual,(2018).

[19] J. Dickey, J. Hopkins, Campus building arrangement using TOPAZ, *Transportation Research*, Vol. 6,(1972), pp. 59-68.

[20] J.A. Ballas, Pedestrian traffic on the MSU campus, Montana State University-Bozeman, College of Letters & Science, 1974.

[21] H.-Y. Lee, H.-H. Tseng, A hybrid system for facility layout by integrating simulation and ant colony optimization, *Applied Mathematics and Information Sciences*, Vol. 6,(2012), pp. 387S-396S.

[22] D.G. Özer, S.M. Şener, User accessibility optimization using genetic algorithm: aDA, *A/Z ITU Journal of the Faculty of Architecture*, Vol. 10,(2013), pp. 212-230.

[23] H.-Y. Lee, Planning work crew assignments for pedestrian area renovation to improve its impact on the public, *Journal of Civil Engineering and Management*, Vol. 20,(2014), pp. 338-349.

[24] S. Helber, D. Böhme, F. Oucherif, S. Lagershausen, S. Kasper, A hierarchical facility layout planning approach for large and complex hospitals, *Flexible Services and Manufacturing Journal*, Vol. 28,(2016), pp. 5-29.

[25] F. Rismanchian, Y.H. Lee, Process Mining-Based Method of Designing and Optimizing the Layouts of Emergency Departments in Hospitals, *HERD*, Vol. 10,(2017), pp. 105-120.

[26] P. Bazeghi Kisomi, A. Tadayon, M. Bagheri, V. Pourahmadi, N. Khademi, A. Amirshahi, A bi-objective optimization model for locating service facilities at railway stations using passenger behavior simulation: a case study, *Transportation Research Board Annual Meeting 2019*,(2019).

[27] P. Bazeghi Kisomi, A. Tadayon, M. Bagheri, V. Pourahmadi, Increasing the efficiency of the railway station by relocating the service facilities using simulation, *12th World Congress on Railway Researches*,(2019).

[28] M.O.R.G.O. India, Manual for standards and specifications for railway stations,(2009).

[29] G.W. Flintsch, C. Chen, Soft computing applications in infrastructure management, *Journal of Infrastructure Systems*, Vol. 10,(2004), pp. 157-166.

[30] P. De, A. Bhincher, Dynamic programming and multi objective linear programming approaches, *Appl. Math. Inform. Sci*, Vol. 2,(2011), pp. 253-263.