Investigation on Index of Accessibility to Public Transportation Services for Developing Feeder Network

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Abstract

Nowadays with developing and city growth, also city systems need to be update and developing parallel to expand of cities. So it is wisely that getting forward the network reforming and city systems with needs and today’s conditions of society and city. Public transportation system is one of the largest and the most complex city systems that has very important rule on speediness of citizen transition; so reforming and making changes for optimization the efficiency amount of system is not easily possible.

In this thesis has been paid attention to introduce and determine the measure of accessibility indices affect to public transportation network with walking mode and present a method for developing feeder network of public transportation system. We calculated the coefficients of accessibility indices by Sampling Statistical in city of Tehran. In this method uses three algorithms for evaluating time and comforting applicants travel and also present and taking result a model for reforming location of public transportation stations and a model for designing feeder routes that with investigating and comparing work has done. In continue with segregate performing models and algorithms we have found the desirable results. The results of performing public transportation network evolution for subway-BRT network in four central areas of Tehran, the number of the least transfers on the shortest paths from a point to another point on network and also the number of the least transfers on paths between two points has presented. Performing place reform model of network stations for a virtual network, results appropriate covering of travel demand routes. The results of routes feeder designing model for area ten of Tehran that from accessibility level to system with making changes for optimization the efficiency amount of system is not easily possible.

In this paper, number of transfers on routes, total walking time, total travel time, and the number of least transfers on paths between two points has been calculated. Considering the number of transfers on routes indicates number of changing stations that is very important to find an appropriate transfer point. Also access and exit from public transportation in two cities and a model for reforming location of public transportation stations and a model for designing feeder routes that with investigating and comparing work has done. In continue with segregate performing models and algorithms we have found the desirable results. The results of performing public transportation network evolution for subway-BRT network in four central areas of Tehran, the number of the least transfers on the shortest paths from a point to another point on network and also the number of the least transfers on paths between two points has presented. Performing place reform model of network stations for a virtual network, results appropriate covering of travel demand routes. The results of routes feeder designing model for area ten of Tehran that from accessibility level to system with making changes for optimization the efficiency amount of system is not easily possible.

Methods of public transportation systems divided into fields of walking mode and non- walking mode which are indicated below:

- Non-walking mode
- Cycling mode
- Private or taxi mode
- Feeder mode service
- Other non-walking mode (motor cycle, skates and etc.)
- Walking mode

Below chart indicates amount of different modes for accessing and exiting from public transportation in two cities and one country which walking mode and bus mode have the most amount of using (Figure 1).
Feeder services mode

Feeder services, endemic services or feeder services are known as the most important non-walking modes. These services are as feeder for users who are inhabitant in weak public transportation access and also are provided in high rise, schools and official institutions. Instruction of this service starts from residential area to the nearest subway or bus rapid transit stop and then back to start node. These services are available to transit more numbers of people in compare with taxi and also they have facilities of travel comforting such as BRT. Another advantage of this mode is providing more selection for users and attracting passengers with short travel.

Basic definitions

Definition of flow is each path of bus or subway from start to end in network (being attention in this chapter, path from start to end is separated; it means each flow is on one way).

Set of main nodes of network (stops) \( N \) and number of member.

Set of nodes which appeared block centers \( Z \) and number of members \( N_z \) is. Also between numbers of this set in overall network there is not any arc.

Sets of \( N_k \), which include nodes from \( N \) is distance (time) of availability from center of block \( K \) to these nodes (stops) is less than or equal with standard time of availability. Also \( N_{max} \) is defined maximum in set of \( \{N_k : k \in Z\} \).

Overall network \( G = (N \cup Z, B) \) of nodes include all nodes of stops and nodes of block centers and set of arcs include all arcs of main network extra all defined arcs between center of blocks and stop sets (e.g. if \( i \in N \) and \( j \in Z \) access time be less or equal with standard time for \( i \) to \( j \), then or if and access time be less or equal with standard time for \( i \) to \( j \) then \( (j,i) \in B \).

Sets of travel in network is (each travel is considered for a person with determination of start and end) \( Q \) and its members. \( Q \).

Set of all flow (roots) is \( R \) and its members. \( R \).

Matrix of flows: matrix \( A \), which is sorted flow from each line. If numbers of nodes be less than number of inline of each line we make other extra inline of that line as zero. In addition numbers of inline in each line in flow matrix are equal with numbers of flow node which has the most numbers of node.

Generic Network Proximity Matrix: cost arc matrix \( C \), which is defined by each incline of this matrix for time of access from one node of generic network to another node (for mode of vehicle and mode of walking has calculated separately base on speed and distance).

In this manuscript two ways for estimating distance between stops are indicated, the initial way is for estimation of distance between stops by population density and the latter way is based on well-known way in England.

Literacy of research

He has worked on number of optimum bus stops in a network; in this research was used from strategic way for measuring maximum degree and non-efficient of it for covering bus stop for public transportation system by bus stop for complete coverage of set (LSCP1). Goal of LSCP is making number of bus stops minimum for providing complete coverage of access in investigated sphere. There are determining measures for standard distance of accessibility in this model and also is used from circles with stop flow and fix radius for accessing to system [1].

They are indicated two ways for optimum locating between stops on flows for balancing the accessibility. Models are written based on p-Median and in models making accessibility maximum is regarded. First model is designed for locating stops from network candidates on flow that each candidate has chosen for being as stop for two-way of flow, but the second model has used in special
condition and locating is done for two-way flow [2].

They have indicated an algorithm for developing accessibility. The objective function of minimizing total cost (total cost of producer and user) with optimizing number and place of stops and regarding to restriction of time value of users is regarded. Producer cost is equal with accessibility to system, waiting time divide on vehicle cost which sum of user cost and producer cost is depended on total cost function [3].

He is mentioned that the best locating of stops is not as appear as it seems, because each of two reasons below could be discussed [4].

1. Many of stops are lucrative because accessibility is high on them.
2. Each stop can increase time of transportation, because each extra stop can increase time of average speed of bus.

One optimum solution can balance two goals by responding to restrictions, but weight or valuation to different and non-unitary goals can be hard.

**Location Set Covering Problem**

Retnani (2008) has presented a way for locating new stops in existed public transportation. In this research there are two kinds of goals. First, minimizing number of stops with coverage demand nude with standard distance condition. Second, fixed number of stops and then minimizing sum of accessibility distance from demand nude. Thereby, there are two separated issues which have their own responses and have wide selection area.

He has presented a model for locating stops by weighting to minimizing goals in access point and number of stops. Also in this model, there is penalty for weak accessing level which can achieve to high amount of accessibility for nude with increasing penalty which make possibility for increasing number of stops [5].

He has presented two steps model for optimizing bus stops. At the first step bus is place throughout the public transportation in microscopic scale while in the same time cost of network is minimized. In the second step, by using microscopic solution which was achieved, stops are locating in microscopic or minor scale in special path of city [6].

He was worked on presenting developing of locating optimum model. Model uses from a continuous approximation and multi-cycle corridor demand for locating stops, minimizing operating costs and the total cost of passengers. The simultaneous model optimizes stops densities and hubs between sequential buses [7].

**Methodology**

In many of city travels, users for arrival to destination need to exchange public travels, thereby can extract precise output by adding new variable R. R is equal with multiplication of exchange travel times average in number of exchanges travel average (for instance if time average of exchange travel be 80 second and two separate travel have 2 and 0 exchange travel amount of R for these two travels is equal with \( \frac{0+2}{2} \times 80 \)), thus by regarding to R equation1 convert to below equation:

\[
T = 2 \frac{X}{F} + \frac{L}{D} + S + B + \frac{L D}{D} - A \frac{D}{V} + R
\]

Main model of this difficult is as

\[
\text{Min } Z = \sum_{i=1}^{I} \sum_{j=1}^{J} \frac{a_i}{d_{ij}} x_{ij} \tag{1}
\]

\[
x_j \geq \sum_{i=1}^{I} x_{ij} \quad \text{for all } i \tag{2}
\]

\[
\sum_{j=1}^{J} x_{ij} = p \quad \text{for all } i,j \tag{3}
\]

\[
z_{ij} \leq x_{ij} \quad \text{for all } i,j \tag{4}
\]

\[
z_{ij} \in \{0,1\} \quad \text{for all } i,j \tag{5}
\]

\[
x_j \in \{0,1\} \quad \text{for all } j \tag{6}
\]

**Data and decision making of this difficult are defined as:**

- \( a_i \): Amount of demand per weight
- \( d_{ij} \): Distance of central weight of l from candidate j
- \( P \): Number of selected nudes from candidate nudes for making stop
- Decision variables:
  - \( z_{ij} \): Coverage variable of me by candidate j
  - \( x_j \): Binary variable for being stop or not candidate j

**Definition of goal function and restriction of model**

Goal function of model is sum of accessibility distance. Restriction number one: each nude allocate demand to only one convenient nude. Restriction number two: number of candidate for being stop are appeared by number of p. restriction number three: selected candidate nude insure allocated demand nude for being stop.

**Data**

- \( c_i \): Cost of selecting nude i for being stop (which can be cost of making stop in nude i)
- \( d_{ij} \): Distance of accessibility of demand nude of j to candidate nude of i
- \( d_{\text{max}} \): Maximum allowed distance for accessing from a point to stop
- \( DN \): Sum of demand nude
- \( CN \): Sum of candidate nudes for being stop

**Decision variables**

- \( x_j \): Binary variable for selecting or non-selecting candidate i for being as stop
- \( y_j \): Determination binary variable for covering or non-covering of j demand nude by candidate nude
Definition of goal function and restriction of model

Goal function is minimizing sum of costs. Restriction number one: allocating one demand nude only necessary one candidate nude. Restriction number two expressed that if one demand nude allocated to candidate nude in allowed distance, that candidate nude should be chosen as stop. Restriction number three and four also express being binary of variables.

In some of transportation networks, parts of route went and back path have distance from each other or it cannot be possible to make both route and back path into same flow. In these kinds of conditions should use from two ways location stops.

At first, define $M_j$ as coincident with $j$ candidate due to against direction from $j$ then $N_j$ which are as candidate nudes of $r$ flow in one way and sum of candidate nude in another direction of $r$ flow are introduced. Collection of these sets constitute set of all candidate nudes $N = \bigcup_{j \in N} (N_j \cap |M_j|)$. Is defined as sum of which are in $N_j$.

Now by expressed changes in below steps in goal function and restriction of model find new model.

First step: $\sum_{ij} (1 - \sum z_{ij})^p$ is found from minimized goal function from totaltime $Z_{\text{min}}$ is removed and replace below expression instead of $Z_{\text{min}}$.

Second step: remove restriction two and replace two below restrictions instead of it:

$\sum_{j \in \text{candidate}} z_{ij} \leq 1 \quad \forall i = 1, ..., l$  \hspace{1cm} (2a)

$\sum_{i \in \text{candidate}} z_{ij} \leq 1 \quad \forall j = 1, ..., j$  \hspace{1cm} (2b)

Third step: adding this new restriction to model:

$x_r - x_j = 0 \quad \forall r = 1, ..., R \& j \in N_j$.

In first step times and costs of attracting demand nudes in goal function is placed in goal function, also should regarded to waiting time for applicants who want demand nude of last stop. In second step revise determined minimum applied in each flow for passengers with start demand nude and with end demand nude. In third step also are introduced restrictions of determined amount of variable (allocated variable of a nude to candidate nude foe accessing to one demand candidate nude).

Response of difficult by using genetic algorithm: executed by MATLAB.

Because of NP-Hard of difficult, investigated locating for huge data should be done by initiative algorithm. For this reason genetic algorithm was used for multi-time response of difficult. In used algorithm each gene is named by a candidate. If amount of named candidate be equal to one, corresponding candidate with gene is chosen as stop and if named amount be equal to zero candidate does not choose as stop. Each chromosome includes 29 genes which are as the number of each candidate stop and 4 stops are fixed in difficult which constitute 33 nudes totally. Stake of cease for algorithm is producing 1000 generations which are included 220 chromosome, it means 220000 response for difficult will be investigated. First generation includes 15 parents and in each 220 chromosome, it means 220000 response for difficult will be investigated. First generation includes 15 parents and in each step 15 parents will choose from the last generation of Crossover chromosome. Possibility of selection a chromosome for each generation for producing next generation will determine by amount of fitness.
Crossover is done by binary method and mutation also is done by decreasing of random digit from 0.07 for each chromosome as changing amount of a random gene from that chromosome. First amount of fitness for each chromosome is equal to zero and for each non-approval of chromosome in a restriction, amount of one will add to fitness amount of that chromosome.

After executing algorithm in 43 minutes, significant response (fitness=0) with the best amount of goal function between responses (chromosome) is caught.

Some of designing Feeder line models

Public transportation system or network line of crowded vehicle (such as subway or BRT) which are used or named as system or main network. Demand stops also defined as pinpoints stops in under study sphere (sphere with low amount of accessibility to system). Models of this section are looking for wide path for feeder passed services from demand stops and want to find other paths such as frequency of services in each line.

Resulted model based on studied model

Based on investigation and comparison of under studying models, we present more precise model with three separated goal model as sum of travel time function, total cost function and total accessibility value function. Accessibility value calculate base on accessing to one main network stop for applicants of demand stop in model. Restriction of response to amount of demand services by decreasing accessibility time to main network stops, restriction of responding to maximum number of main network stop, coefficient restriction of feeder line and closed of feeder line is wield. Amount of average demand per hour and length of path between demand stops as entrance and frequently of service between lines per hour and path of each line are as output of model.

Number of lines has selected before and valuations ( ) also can achieve

\[
\begin{align*}
\text{Min } Z_1 &= \frac{1}{2D} \sum_{i=1}^{l} \sum_{j=1}^{l} Q_{ij} X_{ij} + \frac{1}{2D} \sum_{i=1}^{l} \sum_{j=1}^{l} Q_{ij} X_{ij} \\
\text{& } Z_2 = C_L + C_G + f_k \sum_{i=1}^{l} \sum_{j=1}^{l} L_{ij} X_{ij} \\
\text{& } Z_3 = \sum_{i=1}^{l} \sum_{j=1}^{l} \gamma_{ij} Y_{ij} \\
\text{s.t. } & \sum_{i=1}^{l} \sum_{j=1}^{l} X_{ij} \leq D \quad k = 1, \ldots, K \\
& \sum_{j=1}^{l} X_{ij} \leq 1 \quad i = 1, \ldots, l \\
& \sum_{i=1}^{l} X_{ij} \leq M \quad k = 1, \ldots, K \\
& \sum_{i=1}^{l} X_{ij} - X_{ij} = 0 \quad i = 1, \ldots, l + j \\
\end{align*}
\]

\[\sum_{i=1}^{l} \sum_{j=1}^{l} X_{ij} \geq 1 \quad k = 1, \ldots, K \quad (7)\]
\[\sum_{i=1}^{l} \sum_{j=1}^{l} X_{ij} - y_{ij} \leq 1 \quad i = 1, \ldots, l, j = i + 1, \ldots, l + j, k = 1, \ldots, K \quad (8)\]
\[\sum_{i=1}^{l} \sum_{j=1}^{l} (\delta(i,j,k) + \delta(j,i,k)) \geq 1 \quad \forall s \in N \quad (9)\]
\[y_{ij} \in \{0,1\} \quad i = 1, \ldots, l, j = i + 1, \ldots, l + j, k = 1, \ldots, K \quad (10)\]
\[f_k \in \mathbb{N} \quad k = 1, \ldots, K \quad (11)\]

Conclusion

Win this research initially worked on investigation on accessibility index to public transportation systems and presenting way to calculate accessibility time and presented the way for determining accessibility level, then indicate algorithms for evaluating public transportation network based on accessibility time, time of travel and number of travel replacement; In the following, presented a model for locating and revising place of public transportation network; Finally indicated a model for designing feeder lines in low amount of accessibility sphere of public transportation.

Mentioned steps should be done for optimizing public transportation network. The most important processes which are considered in this corrective research are:

Accessibility of people to systems, time of people accessibility to system and time of exit, waiting time of applicants in system stops for accessing to system, time of vehicle or time of traveling by vehicle, number of traveling replacement for traveling of applicants, cost of applicants and operator cost.

Each mentioned item is very important and achieving of each one value is not possible as easy as it seems. Time is a runner who never look at his back and exchange is not something that could catch easy, thus time and cost which we paid for research and study and in the following present the method to correcting structure, across sum of these time and extra cost which are paid because of inefficiency or weak efficiency of social system such as public transportation system is very poor, so high amount of attempt for presenting more precise and profitable ways can help society to

References

6. TFL group; measuring public transport accessibility levels.
31. Westenite/Aspelin, Karen; Estabishing Pedestrian Walking Speeds.
32. University of Missouri; Lecture np.
40. Mitchell CGB, Stokes RGF. Walking as a Mode Transport, TRRL Laboratory Report 1064, Transport and Road Research Laboratory, Department of the Environmental, Department of Transport. 1982.
42. Loutzenheiser DR. Pedestrian Access to Transit, Model of Walk Trip and their Design and Urban Form Determinants around Bay Area Rapid Transit Stations, Transportation Research Record No 1604, Transportation Research Board, National Research Council. 1997;40-49.
Investigation on Index of Accessibility to Public Transportation Services for Developing Feeder Network

PTRC Annual Transport Practitioners’ Meeting, UK. 2005.
47. Bhat CR, Bricka S, La Mondia J, Kapur A, Guo JY, Sen S. Metropolitan Area Transit Accessibility Analysis Tool, University of Texas, Austin; Texas Department of Transportation. TxDOT Project 0-5178-P3. 2006.