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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 slowly walking is four feeder routes with covering all elected stops for covering area. Also we perform developing feeder network method for virtual network that results are 76 percent increase in accessibility measure. At end also we perform said method for virtual network that result is 81 percent increase in accessibility measure to system in standard time and 16.5 percent decrease of summation traveling time.

Keywords: Public transportation system; access to system; evaluation of network; transfer; travels time; locating; feeder routes;

Introduction

Shape of a city has regarding effect on lifestyle of inhabitant of that city. For expanding downtowns need to have special strategy which do not make quality of life in contrast of development. Transportation programming is an important strategic theory. Optimum usage of facilities and systems are one of the most up to date cases in technology worlds which is used for less use of energy and more saving of it and also wiled for fast reaction, saving time and cost, diminish of contamination, spoilt of nature and echo systems for fauna and Fiona. Hence, organs and scientific centers are attempted to make these amounts optimum and making possible damages minimum. One of the most important problems of human from the first to now is increasing of transportation speed from a point to another point which is solved by daily progress of science and industry fortunately; on the other hand technology can control different types of business and education travels which are made by today needs, but for more retaining of these problems face to use of different kinds of technologies and sciences. Science of optimizing and fast type of algorithms can be more helpful in this field.

Transportation optimizing case includes different parts such as management and programming, designing and modeling which is either includes designing transportation network, facility location in transportation network and itinerary of services. For more domination on systems should find different aspects and features and investigate on variety of conditions. Also investigation and studying of other countries used city systems can help either.

Types of modalities for access to the public transportation system

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).

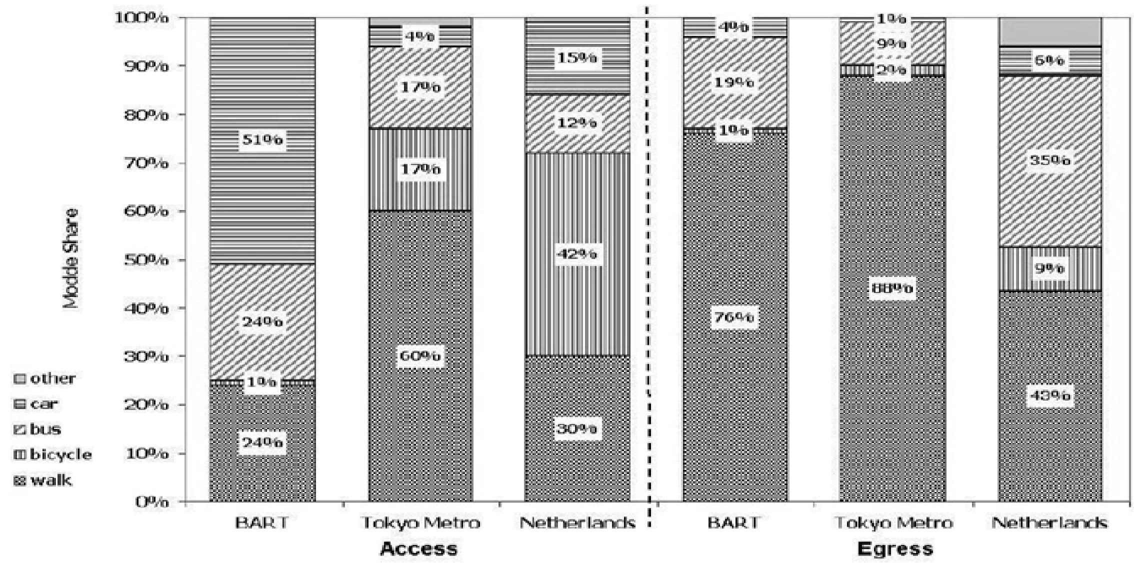

Figure 1: Amount of using modes for accessing and exiting

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 nude. 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 nudes of network (stops) N and number of member.

Set of nudes which appeared block centers Z and number of members N_0 is. Also between numbers of this set in overall network there is not any arc.

Sets of N_k which are include nudes from N is distance (time) of availability from center of block K to these nudes (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 $\bar{G} = (N \cup Z, B)$ of nudes include all nudes of stops and nudes 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_0

Set of all flow (roots) is R and its members. R_0

Matrix of flows: matrix A, which is sorted flow from each line. If numbers of nudes 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 nude which has the most numbers of nude.

Generic Network Proximity Matrix: cost arc matrix C, which is defined by each incline of this matrix for time of access from one nude of generic network to another nude (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 nudes 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 nudes 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:

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

Main model of this difficult is as

$$Min\ Z = \sum_{i=1}^{I}\sum_{j=1}^{N} a_i d_{ij} z_{ij} \qquad (1)$$

$$s.t \sum_j z_{ij} = 1 \ for\ all\ i \qquad (2)$$

$$\sum_j x_j = p \quad for\ all\ i, j \qquad (3)$$

$$z_{ij} \le x_j \quad for\ all\ i, j \qquad (4)$$

$$z_{ij} \in \{0,1\} \quad for\ all\ i, j \qquad (5)$$

$$x_j \in \{0,1\} \ for\ all\ j \qquad (6)$$

Data and decision making of this difficult are defined as:

a_i Amount of demand per weight

d_{ij} Distance of central weight of I 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

$d_{\max}$: 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_i: Binary variable foe selecting or non-selecting candidate i for being as stop

y_i: 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 of direction from j then $\vec{N}_r$ 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 $\bar{N}_r = \{j | j \in \vec{N}_r \cap |M_j| \neq \phi\}$. Is defined as sum of which are in $\vec{N}_r$.

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

First step: $\Sigma_{i=1}^{I}(1-\Sigma_{j=1}^{N} z_{ij})P$ is found from minimized goal function from totaltime Z_{time} is removed and replace below expression instead of Z_{time} :

$$\sum_{i=1}^{I}\left(2-\sum_{j=1}^{N} z_{ij}\right)P$$

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

$$\sum_{j\in\bigcup_{r\in R}\bar{N}_r} z_{ij} \le 1 \qquad \forall\, i=1,\dots,I \qquad (2a)$$

$$\sum_{j\in\bigcup_{r\in R}\bar{N}_r} z_{ij} \le 1 \qquad \forall\, i=1,\dots,I \qquad (2b)$$

Third step: adding this new restriction to model:

$$x_j - x_{m_j} = 0 \qquad \forall\, r=1,\dots,R \ \&\ j\in\bar{N}_r$$

First step obliged each demand nude allocated at least to two candidate nudes. Presented restrictions in second step ensue to each demand nude be allocated to one stop in each direction. Presented restriction in third step caused that if one candidate nude selected as stop, candidate nude also selected in another direction as stop.

If in city network use from accessibility index for measuring distance or time, some of route way and back pass will be different together. Locating model for this condition can be achieved by mentioned locating model. Expressed changes in below steps and restrictions were defined can make new model.

First define new variables. z_{ij} is coverage variable for demand nude i by candidate j for route way; z_{ij} is coverage demand nude variable i by candidate j for back path; d_{ij} is distance of accessing from demand nude i to candidate j; a_i is accessing distance from demand nude i to candidate j; a'_i is amount of producing travel in demand nude of j; a'_i Is amount of attracting travel in demand nude i; θ_{ij} is average number of traveling from nude j and j nude for accessing of user to demand nude i and exit user from demand nude i V_{ij} and is average time of traveling from nude j to j for travel applicants to demand nude of i and exit applicants from demand nude i. Now with these expressed changes in goal function and restrictions, new model can be achieved:

First step: goal functions of Z_{time} and Z_{cost} change as:

$$Z_{time} = \frac{1}{v_u}\sum_{i=1}^{I}\sum_{j=1}^{N}(a_i d_{ij} z_{ij} + a'_i d'_{ij} z'_{ij}) + \sum_{i=1}^{I} a_i \frac{h_i}{2} + \sum_{i=1}^{I}\sum_{j=1}^{N}(a_i V_{ij} z_{ij} + a'_i V_{ij} z'_{ij}) + \sum_{i=1}^{I}\left(1-\sum_{j=1}^{N} z_{ij}\right)P + \sum_{i=1}^{I}\left(1-\sum_{j=1}^{N} z'_{ij}\right)P$$

$$Z_{cost} = u_u \sum_{i=1}^{I}\sum_{j=1}^{N}(a_i(\theta_{ij}+1)z_{ij} + a'_i(\theta_{ij}+1)z'_{ij}) + \sum_{r=1}^{R} u_r F_r$$

Second step: remove restriction 8 and replace below restriction:

$$\gamma\sum_{i=1}^{I}\sum_{j=1}^{N}(a_i y_{jr} z_{ij} + a'_i y_{jr} z'_{ij}) \le F_r c_F \qquad \forall\, r=1,\dots,R \qquad (8)$$

Third step: adding these restrictions to model:

$$\sum_{j=1}^{N} z'_{ij} \le 1 \qquad \forall\, i=1,\dots,I \qquad (2b)$$

$$d'_{ij} \le d_{max} \qquad \forall\, i=1,\dots,I \ \&\ j=1,\dots,N \qquad (3b)$$

$$z'_{ij} \le x_j \qquad \forall\, i=1,\dots,I \ \&\ j=1,\dots,N \qquad (4b)$$

$$z'_{ij} \in \{0,1\} \qquad \forall\, i=1,\dots,I \ \&\ j=1,\dots,N \qquad (12b)$$

In first step times and costs of attracting demand nudes in goal function is placed in goal function, also should regarded to non-waiting time for applicants who want demand nude of last stop. In second step revise determined minimum abundance 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 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.

$$P(Chromosome\ i) = \frac{\frac{1}{Fitness(i)}}{\sum_{j\in Generation(g)}\frac{1}{Fitness(j)}}$$

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 below 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 achie

$$Min\ Z_1 = \frac{1}{2U}\sum_{k=1}^{K}\sum_{i=1}^{I}\sum_{h=1}^{I+J} Q_i L_{ih} X_{ihk} + \sum_{k=1}^{K}\frac{1}{2f_k}\sum_{i=1}^{I}\sum_{h=1}^{I+J} Q_i X_{ihk}$$

$$\&Z_2 = C_u\sum_{i=1}^{I} Q_i + C_O\sum_{k=1}^{K} f_k \sum_{i=1}^{I+J}\sum_{h=1}^{I+J} L_{ih} X_{ihk}$$

$$\&Z_3 = -\sum_{i=1}^{I}\sum_{j=I+1}^{I+J} v_{ij} y_{ij} \qquad (1)$$

$$s.t \qquad \sum_{i=1}^{I+J}\sum_{h=1}^{I+J} L_{ih} X_{ihk} \le D \quad k = 1,\dots,K \qquad (2)$$

$$\gamma\sum_{i=1}^{I}\left(Q_i\sum_{h=1}^{I+J} X_{ihk}\right) \le cf_k \qquad k = 1,\dots,K \qquad (3)$$

$$\sum_{k=1}^{K}\sum_{h=1}^{I+J} X_{ihk} = 1 \qquad i = 1,\dots,I \qquad (4)$$

$$\sum_{i=1}^{I}\sum_{j=I+1}^{I+J} X_{ijk} \le M \quad k = 1,\dots,K \qquad (5)$$

$$\sum_{k=1}^{K}\left(\sum_{h=1}^{I+J} X_{ihk} - \sum_{l=1}^{I+J} X_{lik}\right) = 0 \quad i = 1,\dots,I+J \qquad (6)$$

$$\sum_{i=1}^{I}\sum_{j=I+1}^{I+J} X_{ijk} \ge 1 \quad k = 1,\dots,K \qquad (7)$$

$$\sum_{h=1}^{I+J} X_{ihk} + \sum_{l=1}^{I} X_{ljk} - y_{ij} \le 1 \quad i = 1,\dots,I\ ,j = I+1,\dots,I+J\ ,k = 1,\dots,K \qquad (8)$$

$$\sum_{k=1}^{K}\sum_{i\in S}\sum_{j\in N-S}(x[i,j,k] + x[j,i,k]) \ge 1 \quad \forall S \subset N \qquad (9)$$

$$X_{ijk} \in \{0,1\} \quad i = 1,\dots,I\ ,j = 1,\dots,I+J\ ,k = 1,\dots,K \qquad (10)$$

$$y_{ij} \in \{0,1\} \quad i = 1,\dots,I\ ,j = I+1,\dots,I+J \qquad (11)$$

$$f_k \in \mathbb{N} \quad k = 1,\dots,K \qquad (12)$$

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

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