The Effect of Fortification of Urban Arterial Networks on Traffic Flow Parameters

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Abstract: The urban street network is an important factor influencing the formation and development of cities and allocation of land uses. In addition, in order to improve the level of services and performance of such networks, strategies such as increasing the capacity of streets, modifying hierarchies and network development have been developed and implemented. Hence, fortification of the main urban corridors, as a means of enhancing traffic indicators under study, was studied and Tabriz city was chosen as the city for implementing the developed model. The geometry of the street network of Tabriz city, which is influenced by geographical conditions, and the distribution of in-town trips over this city confirm that the North-South corridor, which can provide ease of access to the area, requires to be reinforced. Position of the streets contained in the proposed corridor in the concentrated central area, especially in the bazaar region, was taken care of and two Northern-Southern routes were defined based on the location of the existing routes. Traffic analyses were also performed using the equilibrium allocation method. Scenarios were written for either implementing the proposed plan or keeping the current condition in the plan horizon year. The results were also compared for indicators such as level of service, trip time and air pollutants.
[Alireza Naseri, Ramin Vafaeipour Sorkhabi, Omid Giyasi Tabrizi. **The Effect of Fortification of Urban Arterial Networks on Traffic Flow Parameters.** *J Am Sci* 2013;9(5s):67-66]. (ISSN: 1545-1003). http://www.jofamericanscience.org.

Keywords: Corridor, Trip Demand, Street Network, Traffic Assignment, Trip Time

1. Introduction

Financial Increase in the population of large cities led to an increase in the demand for in-town trips and a decrease in urban capitations. The decrease directly influenced different urban standards and caused various environmental, social and economic problems. It also imposed heavy expenses on the system. The street network, as one of the most important sources of urban capitation, was affected as well. Since the framework of the street network has not changed in proportion to the population growth and adjacent land uses, large cities are faced with the problem of traffic congestion. In addition, in spite of the drastic increase in the number of vehicles and trip demands, most of the existing streets with old functional specifications do not meet the current needs and therefore suffer from lack of enough efficiency.

In order to address this problem various solutions and plans have been proposed at different times. These solutions include: construction and development of highway and street networks and enhancement, development and fortification of the networks. Organization and fortification of the urban street network enhance traffic quality and functional parameters. Administrators and urban planners are aware of the importance of organizing and reinforcing the urban street network because it directly influences the general urban context and determines the level of access to other services. It is necessary and important to add to the share and role of the street network along while also developing cities. Because this way the existing street network can meet future needs and demands and keep up with high traffic congestions as well.

2. Previous Research

Although studies of street networks have been carried out long enough to fit the histories of cities, contemporary studies and professional studies vary greatly from their past counterparts. Perhaps the very first studies of the organization and fortification of urban street networks were conducted in England. For instance, in 1285 a law was ordained by which land owners were assigned responsibilities to maintain the routes. (Ghazi Hesami, 1992) Therefore, it can be said that England was the first country to conduct studies and ordain laws on transportation street networks. It was also the first country to greatly experience with this issue. In Iran perhaps the first planning and studying actions were taken in 1904, when the first automobile or steam carriage was introduced to the Iranians. (Gharib, 1997) The introduction of this new urban element caused changes to street networks and streets wide enough for the traffic of vehicles were built. Moreover, the enforcement of the Street Widening and Development Act of 1933 was another action underlying these changes. In subsequent periods as population and the number of vehicles increased new plans were implemented most of which concentrated on constructing highways over cities. However, these measures were not meant for the entire Iranian street network. (Mojtahed Zadeh, 1998) Therefore, although traffic problems were addressed slightly, a wide range of urban contexts problems still existed. According to the principles of urban planning, new routes are not generally built in low-density areas and they are solely used for meeting the demand of the urban transportation system, which relies on the highways network. The urban transportation network is an integrated network. (Kenneth, 2000) On the other hand, since the master urban development plans allocate a very long period of time to the formation of the overall framework of street networks, sometimes the implementation of plans takes a long time and therefore changes planned for social, economic and city frameworks do not yield the required results. In addition, because of the high costs associated with significantly large street network plans, only urban administrations can implement such plans.

3. Method

For Planning and designing of street networks are carried out based on the combination of two viewpoints: 1) The role played by the route network in the formation of urban context and relating structures, performances, and land uses; 2) The role played by the route network in communications. (Shahi, 2007) Naturally, integration and consistency of network hierarchy influences system performance in managing trip demands. Besides, reinforcing and improving important and arterial corridors can significantly contribute to the improvement of network traffic parameters. Studying network specifications and network functional parameters and defining policies for the development and improvement of main urban corridors help to analyze and assess the effects of these developments through several scenarios. Therefore, the processes of traffic analysis, estimation of network demands in various circumstances, and writing scenarios are described in the following sections.

3.1. Preparation of Network Pathways

For traffic modeling, it is essential to be aware of the information of pathways like streets, junctions and their time table, streets width, the kind of function of each pathway according to its standing in the hierarchy of network and information related to the public transportation including lines, stations and navy (Lewis, 1993). This network is implemented in the arc map software using the information available in urban traffic management investigation system and according to strategic projects of traffic and field observations and investigation and coincidence of public network with physical network of pathways.

In order to build a street network for future horizons an understanding of the associated traffic and construction projects that will be utilized by the defined horizon is necessary. The information, which is vital to urban planning, was obtained from the urban master plan designed for the project horizon.

3.2. Estimation of Trip Demand and Modeling

We in traffic and transportation studies (which form the foundation for meeting trip demands) the city of interest is divided into several study areas. Regions with more population, which are generally the central areas of cities, are smaller in size. As we move from the central area to the marginal regions, urban population is decreased and city area is increased. In addition, the land uses employed in the area under study also affect the process of zoning.

In the process of meeting trip demands, after estimating and predicting the plan horizon trips are divided into public and non-public trips. It must be mentioned that public trip is a trip made by bus or the subway, which provide definite lines, stations and costs. Normally with the introduction of subway and the consequent decrease in trips within the transportation network, the usage of public systems is supposed to be increased in proportion to the decrease in trip time.

Hence, the share of bus compared to other transportation vehicles for each source-destination pair is as follows:

$$mf99 = \frac{mf44}{mf98}$$

(1)

Where:

mf44: the matrix of trips made by bus in the current circumstances.

mf98: the matrix of all trips made in the current circumstances.

mf99: the matrix of the share of bus in the current circumstances.

In the initial allocation phase the public trip time is obtained considering the subway system. The ratio of public trip time in the reference year (mf22) to the public trip time in the year of interest (mf32) is obtained considering the introduction of subway:

$$mf90 = \frac{mf22}{mf32}$$
(2)

In the above relation mf90 refers to the ratio of trip time in the reference year to the trip time in the year of interest for each source-destination pair.

The ratio of the public trip time to the total trip time in the reference year ($mf99 = \frac{mf44}{mf98}$) is increased by the value of mf90 and the result is multiplied by the mf49 matrix (the total trips estimated for the plan year) and this way the matrix of trips made by bus (mf52) is calculated as follows:

$$mf52 = (mf90 \times mf99) \times mf49$$
(3)

Finally, the matrix of non-public trips (mf51) made in 2022 is obtained as follows (in order to estimate trips made in the year of interest the mf51 and mf52 matrixes are updated based on the yearly growth):

$$mf51 = mf49 - mf52$$
(4)

3.3. Traffic Analysis

Traffic analysis is accomplished by modeling of traffic allocation through the equilibrium allocation problem solving method (with capacity restriction) based on Frank & Wolf's Linear approximation algorithm. In this method, it is assumed that every user chooses the shortest path. (Ramming, 2002) This assumption leads to a pattern of flow in the network that satisfies the conditions of user equilibrium of war drop as such after receiving to an equilibrium, no user could choose a shorter path by changing his/her path.(Inro, 1994; Sheffi 1984) Traffic allocation model with constant request is as the following:

$$MINf(v) = \sum_{a \in A} \int_0^{v_a} s_a(v + x_a)dv$$

s.t:

(5)

$$v_a = \sum_{k \in K} \delta_{ak} h_k \qquad a \in A$$

$$\sum_{k \in K_{pq}} h_k = \left(\frac{g_{pq}}{\eta_{pq}}\right) + \gamma_{pq}$$

$$p \in P, q \in Q$$

$$h_k \geq 0 \qquad k \in K_{pq}, p \in P, q \in Q$$

Where:

- $p \in P$: Areas of origin
- $q \in Q$: Areas of destination
- $S_a(v)$: Function of trip time to volume related to arc a.
- $a \in A$: The arcs (streets) of pathways network
- $k \in K_{pq}$: The collection of pathways connecting origin p to destination q.
- δ_{av}: If the arc a is in the path of k, δ_{av} will equal 1.
- g_{pq}: Trip demand (based on individual) from p to q.
- η_{pq}: Aboard Coefficient (individual per vehicle) from p to q.
- γ_{pq}: Extra demand based on vehicle, related to trips with public vehicles.
- x_a: Extra volume on arc a, related to trips with public vehicles.

3.4. Scenario Building

The traffic simulation model accepts two types of input information: demand information and network information. The binary combination of each possibility is known as a scenario. (TCTTS, 2002)

4. Case Study

In order to study the effects of the model described above the city of Tabriz, with its specific street network and traffic characteristics, was chosen. Tabriz city, with an area of 170 km^2, is the capital of East Azarbaijan Province. This city has long been one of the most important economic and commercial centers of the country. The bazaar of Tabriz and various commercial activities going on in this city has turned it into one of the important manufacturing and distribution centers of Iran. The street network of Tabriz city was constructed following to the development of the urban framework, topography and national features of the city.

Table 1: Scenarios designed for traffic analysis of dual corridors

Scenario	Demand	Network	Public system
1	2013	Current reinforced network	Public
2	2013	Current network	Public
3	2022	2022 updated networks (reinforced)	Public + subway
4	2022	2022 updated networks (normal)	Public + subway

The hills located in the North of Tabriz city and the military facilities in the South of the city have prevented the physical expansion of the city in the transverse direction while the geometry of the city has caused its longitudinal expansion. (Andishkar 2005) Hence, the urban street network of the city has expanded in the longitudinal direction as well. The overall appearance of the city suggests that the Northern and Southern streets of the city are more of access roads and lack enough unity. Due to the high density of the residential and commercial contexts of the city and concentration of traffic on the central streets of the city, especially around the bazaar, it is necessary to strengthen the North-South corridor surrounding the bazaar. After studying the concentrated central contexts and the existing street network, a plan was prepared for dislocating the North-South streets. This plan necessitated construction of two corridors in the West and East of the city. In the primary study conducted on these corridors some obstacles such as the heavy costs associated with widening the streets and the impossibility of widening or re-widening some streets were identified. Because of the aforementioned considerations the corridors were revised according to the existing constraints and optimal routes were chosen.

4.1. Specifications of Proposed Corridors

After applying the changes and other technical and economic considerations, the following final plans were approved for the construction of the dual corridors.

4.1.1. North-South (Western) Corridor

In This corridor is located 40 meters from Enqelab Street and crosses the Shahid Sharifi Avenue to meet Azarbaijan-Palestine intersection. It continues along the Palestine Avenue and enters into a region named "Ahrab" and reaches Aboureihan intersection and finally ends to Kasai highway along Aboureihan and Soleiman avenues.

Some of the advantages of the Western Corridor plan include:

- According to field observations it is possible to construct new roads or widen the existing ones (distribution of commercial and residential land uses is planned for as well).
- It is possible to provide proper access to the middle beltway.
- This corridor provides a very desirable access to development plans under study. It shall be mentioned that the existing land uses include old and deteriorated contexts.
- This corridor at some points crosses some areas with residential contexts that are not engineered. Therefore, it is recommended to utilize the aforementioned land uses to implement the project and protect the structures against earthquake and other parameters.

4.1.2. North-South (Eastern) Corridor

Similar to the considerations mentioned in the final plan for the Western corridor, the final plan for the Eastern corridor is designed as follows:

The Eastern corridor starts from Northern Pasdaran highway, continues along Idehlou Avenue and reaches Sarbaz Shahid square. It further continues to pass Abbasi Street and Chay Kenar (Farabi Street) and crosses the Allamah Tabatabai Avenue. Thereon it passes through a region named "Khiaban" and opens into Imam Khomeini Avenue and continues the path to pass Shahid Muhammad Montazeri and new Pastor intersections. Then it reaches Hafez intersection, continues along Hafez Street and opens into Mullasadra boulevard and ends to Shahid Kasai highway.

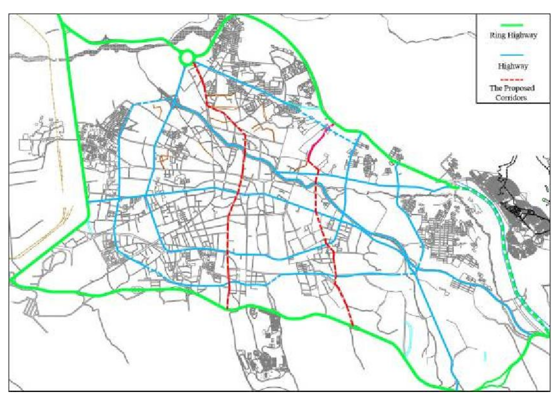

Fig 1: The geographical position of the proposed North-South corridors

Some of the features of this path include:

- This route passes through a region named "Khiaban", which has old and deteriorated contexts. Therefore, rehabilitation of this region and the costs associated with its ownership and release are some of the features of the project.
- The geometrical design (route) proposed for this corridor is finalized such that it is only required to use grade separations in Sarbaz Shahid square, Imam Khomeini Avenue, and Hafez intersection. Therefore, the construction costs associated with this option are considerably lower compared to other options.
- It is tried to construct the Eastern corridor such that it complies with new projects. For instance, according to the finalized plan this corridor crosses Hafez intersection and thereon continues to pass Enqelab neighborhood.

The paths of the proposed corridors are depicted in Figure 1.

Based on the total surveys of source-destination pairs in the aforementioned regions, the matrixes of in-town and out-of-town trips made in the current horizon were divided by vehicle type. The total demand for in-town traveling in 2022 was calculated using the average growth of annual trips in design and current horizons (i=2.764753%). (Andishkar, 2005)

$$D_{2013} = 2969595$$

$$D_{2022} = 3933620$$

It is assumed that the dual corridors will be utilized according to the formulated optimal plan. The scenarios written for each of the corridors to be implemented in 2022 are presented in Table 1. This table also includes the features of each scenario.

Table 2: Scenarios designed for traffic analysis of dual corridors

Policy	Demand	Network	Public system
11301	2013	Current network without dual corridors	Public
21302	2013	Current network with dual corridors	Public
12201	2022	2022 updated network (without dual corridors)	Public + subway
22202	2022	2022 updated network (with dual corridors)	Public + subway

5. Analysis Results

Depending on the problem analysis and decision-making indicators of complications and consequences of traffic projects can be very diverse and numerous. Two types of indicators (i.e., traffic and environmental indicators) are discussed here. These indicators include the ratio of size to capacity and trip time, as well as a few environmental indicators such as estimation of total environmental pollutants (e.g., carbon monoxide, carbon dioxide, methane, nitrogen oxide, sulfur dioxide, and solid particulates) and fuel consumption.

Figures 2 and 3 depict the traffic demands of the streets which are expressed as passenger car equivalents (PCEs). These figures show traffic demands in the current horizon based on various V/Cs of the project implementation scenario (21302) and the existing state scenario (11301). Comparison of these two figures reveals the effect of the dual corridors. As seen in these figures, traffic distribution over the central streets is more uniform with the existence of the dual corridors. In Figure 4 this is shown in another form. This figure demonstrates the comparison made between scenarios 21302 and 11301. The red hachure indicates that the implementation of the project has led to an increase in the traffic volume and the red hachure shows a reduction in the traffic volume. This figure clearly reflects the role of the proposed corridors, as important arterial routes, in reducing the traffic load of central streets.

One of the interesting points about this figure is that the proposed corridors, especially the eastern corridor, reduce the traffic on Azadi boulevard, which significantly contributes to the traffic congestion in Tabriz city. These corridors also conduct the traffic toward further beltways, especially the Southern beltway that has a lighter traffic load (V/C<0.8).

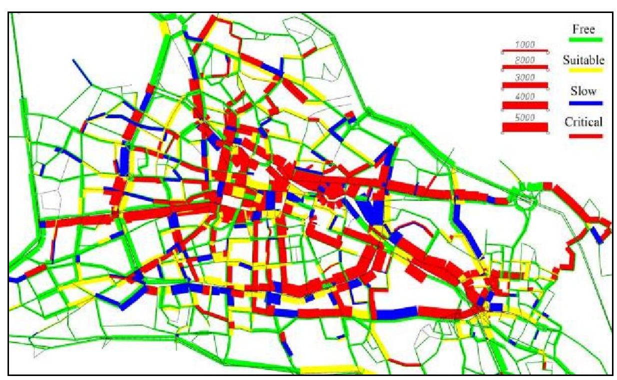

Fig 2: A demonstration of traffic volume and V/C indicators in scenario 11301 (the current network without the proposed corridors)

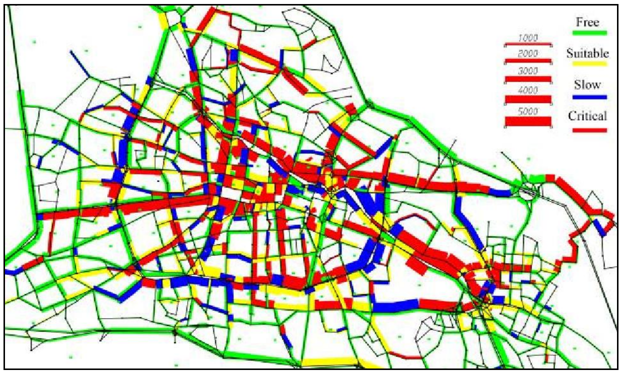

Fig 3: A demonstration of traffic volume and V/C indicators in scenario 21302 (the current network with the proposed corridors)

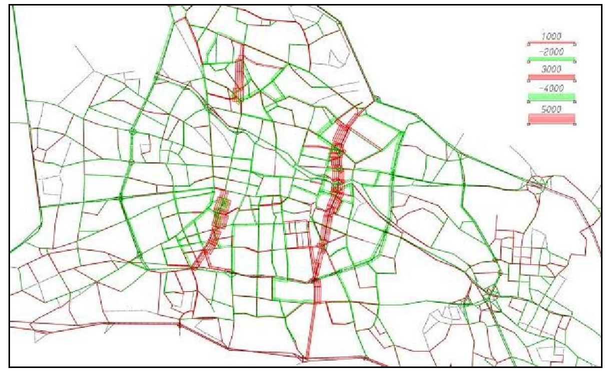

Fig 4: Comparison of traffic volume variations in scenarios 11301 and 21302 (the current network with/without the proposed corridors)

Table 3: Results of the comparative analysis of the amount of generated pollutants and trip times by scenario

	Scenario 21302			**Scenario 11301**		
	Private	Public	**Total**	Private	Public	**Total**
Total pollutant gases	35389	14898	50287	36648	14918	51566
Fuel consumption	65936	5371	71307	68086	5378	73464
Universal index of time (UIT)	939568			1005462		
Percent of Trip Time decrease	6.55					
Percent of Fuel consumption decrease	2.93					
Percent of pollutant gases decrease	2.48					

Table 3 shows the values of trip time and pollutants level in the above mentioned scenarios. As seen in this table, the trip time is reduced by 6.5% and fuel consumption is reduced by about 3%.

The same analysis was also performed for horizon 2022. In the second analysis scenarios 22202 (construction of the dual corridors in 2022) and 12201 (excluding the corridors) were compared. The results of the comparison are shown in Figure 5. As seen in this figure, the effect of these corridors is similar to the ones constructed in 2013. Table 4 also presents the results of the comparison made between the values of trip time and pollutants level in scenarios written for 2022. The results of this comparison are clearly consistent with the results of the comparison made for 2013 scenarios.

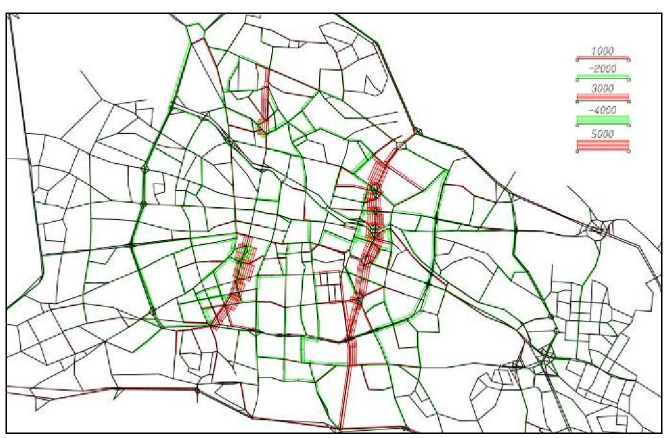

Fig 5: Comparison of traffic volume variations in scenarios 12201 and 22202 (2022 network with/without corridors)

Table 4: Results of the comparative analysis of the amount of generated pollutants and trip times in 2022 scenarios

	Scenario 22202			Scenario 12201		
	Private	Public	**Total**	Private	Public	**Total**
Total pollutant gases	43583	15276	58859	45225	15295	60520
Fuel consumption	86986	5433	92419	89557	5440	94997
Universal index of time (UIT)	1351738			1445162		
Percent of Trip Time decrease	6.46					
Percent of Fuel consumption decrease	2.71					
Percent of pollutant gases decrease	2.74					

The reductions in the trip time, fuel consumption and pollutants generation were 6.4%, 2.7%, and 2.7% respectively. In routing the corridors it was tried to recommend the best route considering implementation features, commercial land uses, deteriorated land uses, and future plans. However, it must be mentioned that planning on the shortage of desirable accesses to the Northern and Southern parts of Tabriz city was performed by considering expert opinions, studying the geometry of Tabriz city network, and reviewing patterns of daily trips.

6. Conclusion

In order to provide balance between supply and demand, utilize the existing transportation structures optimally and meet the need for efficient and proper transportation, it is recommended to consider fortification of arterial networks and main urban corridors. The results of the analysis of the model that was created based on this objective also revealed an improvement in the technical and economic factors influencing the urban transportation system. The case study conducted on Tabriz city showed that fortification of the main street network contributes to the improvement of traffic performance. Based on the results of the analysis of the circumstances of Tabriz transportation network two Northern-Southern corridors were designed and studied for providing a more proper access to the region and utilizing the middle and outer beltways optimally. Traffic analyses suggest that the proposed corridors and their optimal routing have considerable effects on the current horizon and 2022 horizon because the reduction they bring about in trip time and pollutants level. In designing the proposed corridors by performing precise analyses and collecting information about future plans it was tried to consider cultural considerations and fully utilize the current or future potentials of the transportation network and impose the least amount of implementation load caused by the costs associated with land ownership and construction of grade separations.

The results clearly reflect that including the increase in the supply, great expenses and long-run yields in traffic plans cannot enhance traffic performance. Traffic Demand Management (TDM) has also proved to be a very useful tool for optimal utilization of the available supply without the need for high expenses and long-run expectations.

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