Strategic Assessment of Transportation Demand Management Policies: Tehran Case Study

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Abstract

Transportation Demand Management has proved efficacious where increasing transportation supply seems ineffective or financially infeasible. Demand management comprises a wide range of policies most of which are different in nature. Assessing impact of various strategies in Transportation Demand Management and developing a system dynamic model to compare diverse policies are the main outcome of this study. Investigating impact of TDM strategies in Tehran and their impotence specifically in encouraging private vehicle users to use public transportation is the focus of this paper. Visualizing prospective changes in share of these different modes of transportation and presenting potential strategies towards achieving TDM goals are included to substantiate effectiveness of the approach.

Keywords

Transportation Demand Management, TDM, Strategic Assessment, System Dynamics

Introduction

Assessing and quantifying impact of different Transportation Demand Management strategies in urban areas requires a model which is capable of juxtaposing and comparing various policies. This model should also proffer the trend of share of different transportation modes in transporting passengers according to policies taken. As follows, Transportation Demand

Management is explained and then a system dynamic model is developed that comprise main factors affecting transportation demand. In the end, the model is applied to Tehran transportation and traffic data and outputs are compared with existing trends.

The Transportation Demand Management Definition

Costly measures are not always the most appropriate approaches towards solving transportation and traffic problems. On the contrary, there is a growing trend toward efficient inexpensive methods including managerial and technical reforms which result in more efficient use of existing transport resources. One of these methods pertains to Transportation Demand Management (TDM). Generally speaking, TDM is a term for various strategies that increase transportation system efficiency which often results in total vehicle traffic reduction. TDM prioritizes travel based on the value and costs of each trip, giving higher value trips and lower cost modes priority over lower value, higher cost travel, when doing so increases overall system efficiency. It emphasizes the movement of people and goods, rather than motor vehicles, and so gives priority to public transit, ridesharing and non-motorized travel, particularly under congested urban conditions [6]. Figure 1 contains TDM main goals and figure 2 presents related strategies to achieve them as Papaioannou and Georgiou (1999) presented in their article [7].

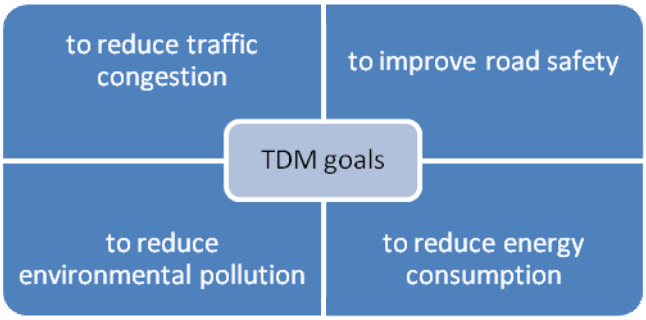

Figure 1 - Classification of TDM goals

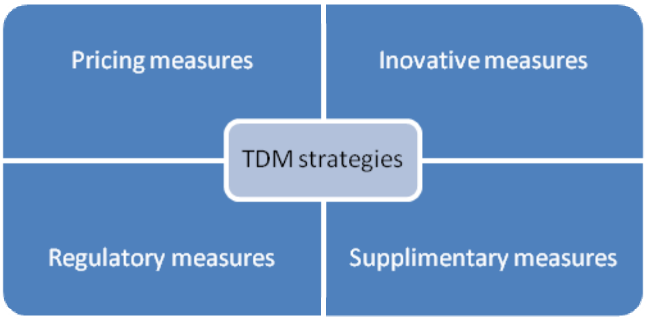

Figure 2 - Classification of TDM strategies

Pricing measures tend to make users save money by behaving in certain ways that result in TDM goals. Road pricing, Parking pricing and Public Transport fare structure fall into this category. Regulatory measures seek to force users behave in pre-determined ways. Access control, parking Management and
Traffic calming zones are examples of regulatory measures. Innovative measures facilitate benefiting from public transportation using Park-and-Ride, Car pooling, Dial-and-Ride and etc. Supplementary measures including HOV lanes, urban traffic control and Ramp metering are combination of previous measures which enforce users' cooperation in reaching TDM goals.

Every strategy comprises a series of measures that may be efficient to some extent. The extent a certain measure proves to be beneficial differs considerably regarding the situation in which it is practiced. It also gets more complicated when the most efficient has to be chosen or interaction of different strategies has to be realized.

Strategic Assessment of TDM Policies

Though strategic assessment tools in TDM domain can play an essential role in choosing the best policy, but few such tools are available now. In addition, most of these available tools are specialized for a particular city or particular situation. Besides, complexity and vast variety of TDM policies, their multi-objective characteristic, and different time-span of their influence, make it hard to develop quantitative generic models to analyze and compare their efficiency. Furthermore, the transport system is highly connected with other complex systems such as society, economy and environment. That is why it is so common to experiment different policies in a number of cities or regions of a city under controlled conditions to assess their efficiency and select the appropriate one. MUSIC[1], OPIUM[2], and SUTRA[3] are such TDM strategies which have been tested in different cities before [8].

System Dynamics models with a qualitative approach and holistic view, can be effective tools for assessing different TDM policies under various conditions. Their transferability of structure and modularity helps policy makers and modelers to easily individualize others' models to match the especial conditions they are confronting. They are also more cost effective and time-saving than most of quantitative models and can capture both long term and short term effects of policies. In addition, they are insightful and help decision makers understand the situation better and make more clever decisions.

A few system dynamics models have been used formerly for the purpose of strategic assessment of TDM policies. "ASTRA-Italia" and "MobiSim" are two samples of such tools which previously have been used [2, 3]. In this study, first a basic model is developed to

[1]- Management of traffic using traffic flow control and other measures
[2]- Operational project for integrated urban management
[3]- Sustainable Urban Transportation

capture the major parts of a TDM structure and then expanded and calibrated the model with the purpose of strategic assessment of two main policies in the special case of Tehran.

Basic Model of TDM

As discussed earlier, all TDM strategies aim to achieve their goals through controlling the demand of different means of transportation, mainly by transferring the demand from private transportation sector to public transportation. Based on this assumption, it is tried to encapsulate the dynamics of demand distribution between these two sectors into a basic model.

Mashayekhi (2003) in his paper on assessing and modeling the market share of rail and road transportation systems used four major factors including, time, quality, price, and availability forming the attractiveness of each option [4]. Certainly, these factors have different weights in shaping the attractiveness of one transportation mode especially due to the purpose of transportation. Therefore, considering weight factors, it sounds logical to assume that total demand in one segment will be divided based on relative attractiveness of different modes of transportation. This outlook is depicted in figure 3.

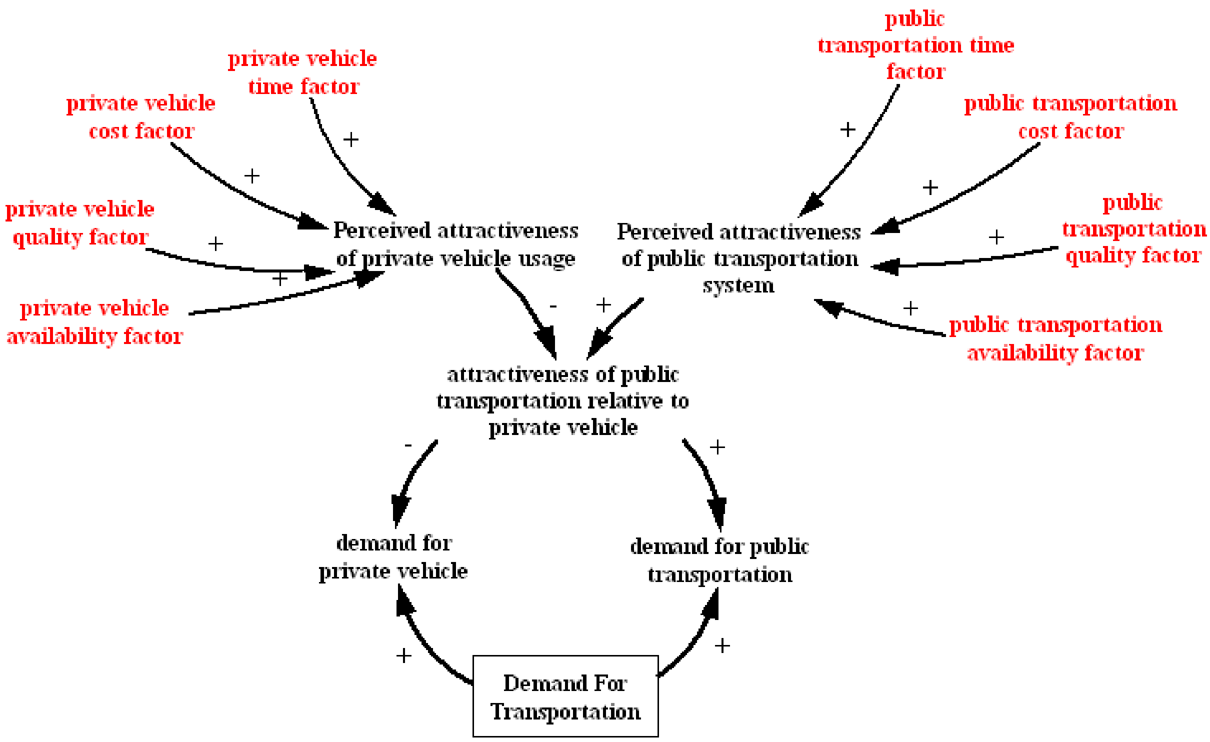

Figure 3 – attractiveness drivers of demand share

To keep model simple and understandable, it is assumed that there are only two types of transportation and one demand segment. Model can be expanded later to include other types and segments. It should be noticed that all different strategies mentioned in the “Transportation Demand Management” section, aim to affect one or more of the four aforesaid factors or their weights.

Each factor, in turn has its own constituting sub-factors. These sub-factors also differ from one transportation type to another. Reviewing the literature of transportation field, three major variables have identified to compose the time factor: time to access the station or parking, waiting time in station, and average trip time by vehicle. Note that access time for private transportation in home-based trip generation is almost zero. These sub-factors and their relations are shown in figure 4.

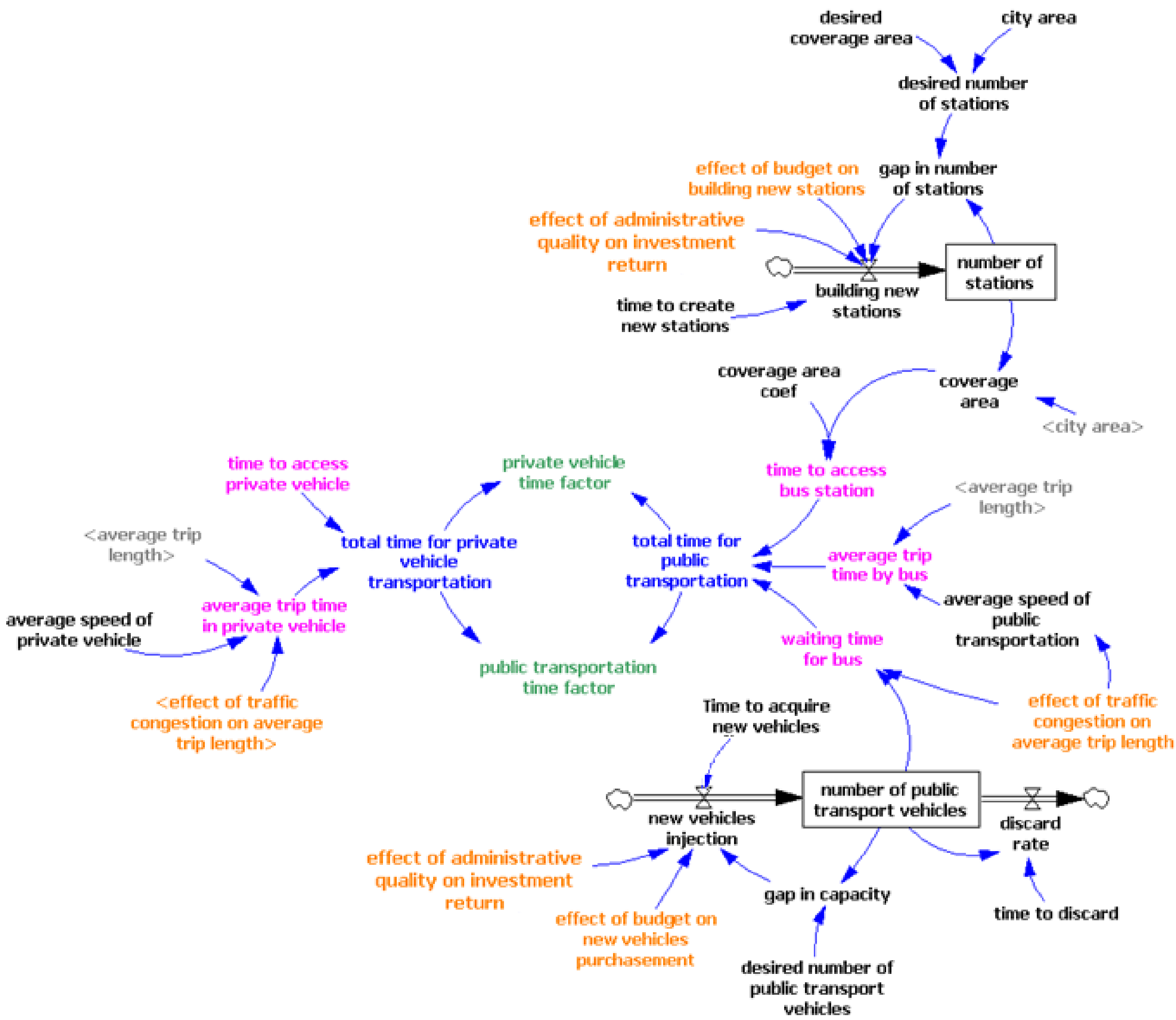

Figure 4 – time factor structure

It can be seen in the figure that, traffic congestion, administrative and labor quality and available budget for improvement is three main factors which affect the total time of public transportation mode. Later, these effects will be discussed in more detail.

Figure 5 depicts the structure of cost factor. As can be seen in the model, there are differences between two modes of transportation in the elements constituting the price factor. Differences come directly from the nature of two modes. Drivers' salary, fuel cost, maintenance costs, management and overhead costs are the main cost elements in public area. In the private sector, insurance cost, fuel and parking cost, and maintenance cost are major elements.

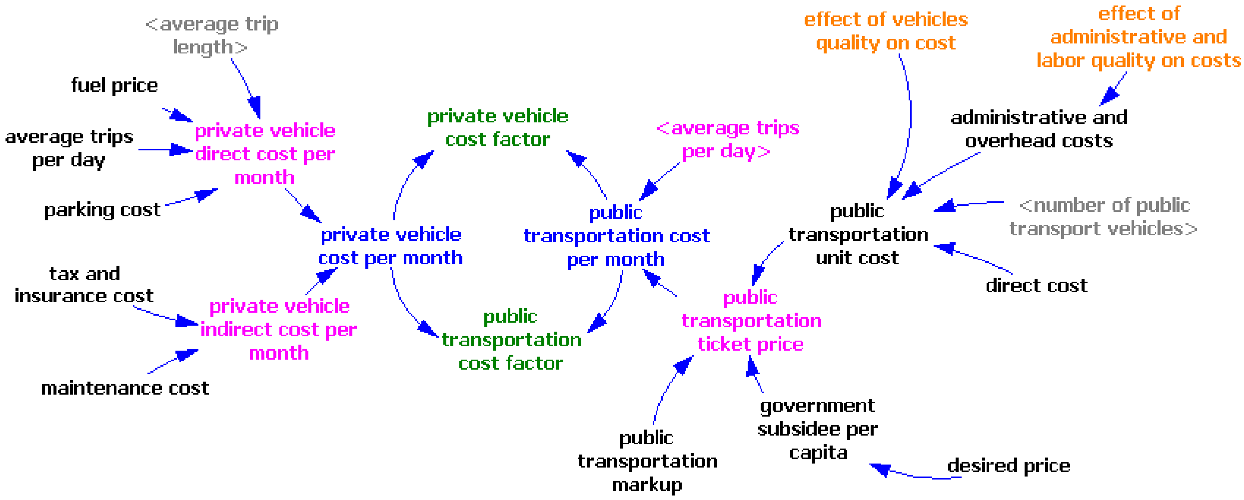

Figure 5 – cost factor structure

Quality factor for public transportation falls into two different categories: Vehicles and system quality (such as facilities of bus stations) and, administrative and labor quality. Availability of fleet and system quality is perceived directly by consumers. But the administrative and labor quality mainly put its effect on the other factors and also on the efficiency and return of investments for improvements. In the private vehicles transportation sector, administrative and labor quality has a minor effect, so it is overlooked in the model.

There are two ways to improve the vehicles and system quality: By investing money on filling the gap between the desired quality level and current level, which in turn is affected by budget level, and by injecting new vehicles in the system. It also depreciates during time. The other factor, administrative and labor quality can be improved by different methods such as management and labor education, taking advantage of managerial decision support systems and other ICT[4] tools, using TDM instruments and etc. All of these methods need intensive investment and supervision in long-term to have effect. Most of the time, this factor is underestimated because of its indirect and ambiguous outcome. The more demand for public transportation is called for, the more administrative and labor quality will be needed. Both structures are shown in figures 6 and 7.

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[4]- Information and Communication Technology

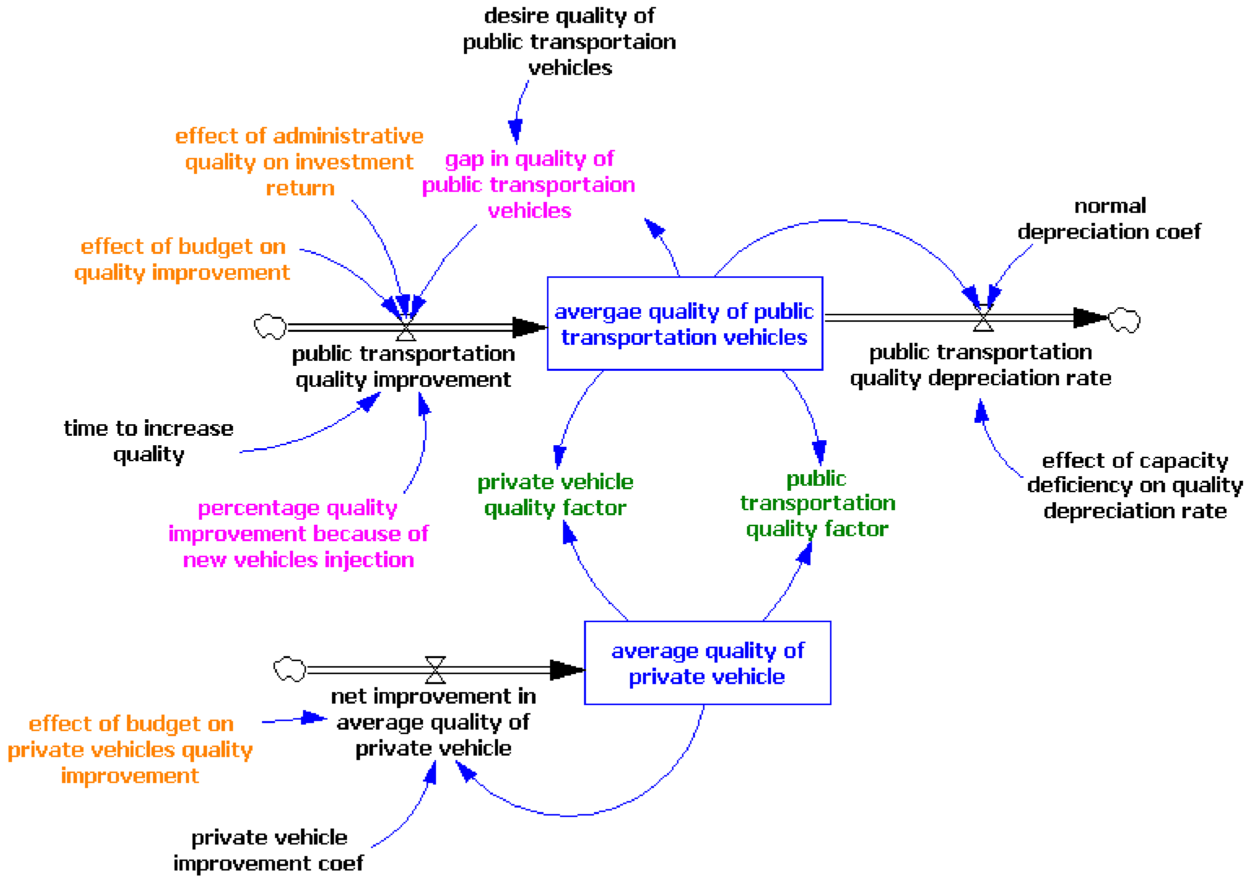

Figure 6 – vehicles and system quality factor structure

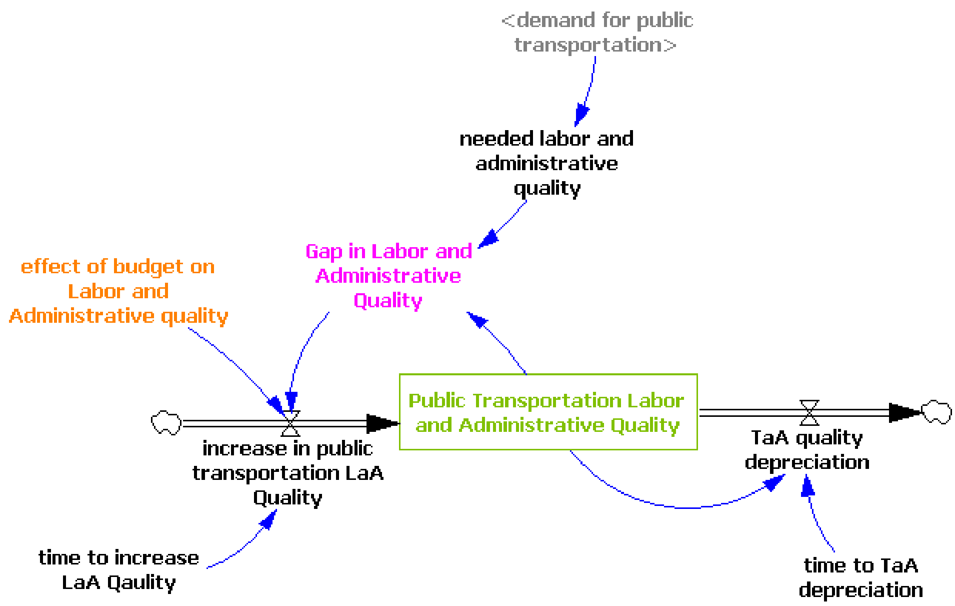

Figure 7 – administrative and labor quality factor structure

Closing the Loops, Traffic and Profit Effects

There are two main feedback structures which shape the behavior of the model: road construction structure (to alleviate the traffic) and budget structure.

Sterman (2000) has identified three main feedback loops which shows how road construction, can increase traffic volume which results in more travel time [9]. Traffic congestion affects both travel time of public and private vehicles except subway and other special transportation modes such as tramway. For larger vehicles such as bus, traffic has a grater effect on the average speed and travel time. These effects have been previously shown in figure 4. The road construction structure is depicted in figure 8.

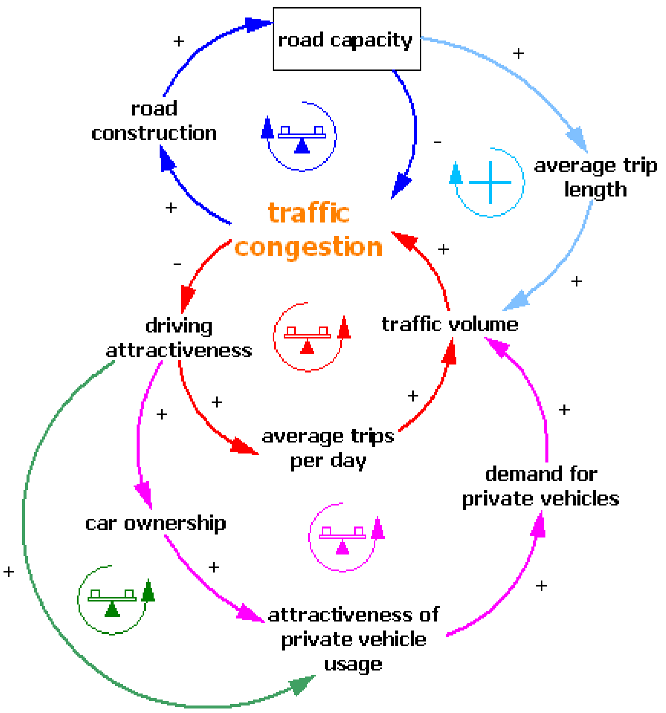

Figure 8 – road construction feedback structure

Mashayekhi (2003) has used the profit factor as the major element which on one side, is affected by the demand share and quality factor and on the other side, affects all the elements in the attractiveness factor dependent upon different strategies of policy makers [4]. The more demand and profit the system gains, the more financial resources will be available for investment. So deciding on how the budget should be allotted for investment in different parts, is one of the essential decisions of policy makers. It should be noticed that the administrative and labor quality factor plays a major role in determining the return ratio of the investments in other parts.

Causal diagram of this phenomenon with the simplified feedback structures is depicted in figure 9. Note that there is a parallel structure for the effect of profit on private vehicles attractiveness and demand, similar to one depicted for public transportation.

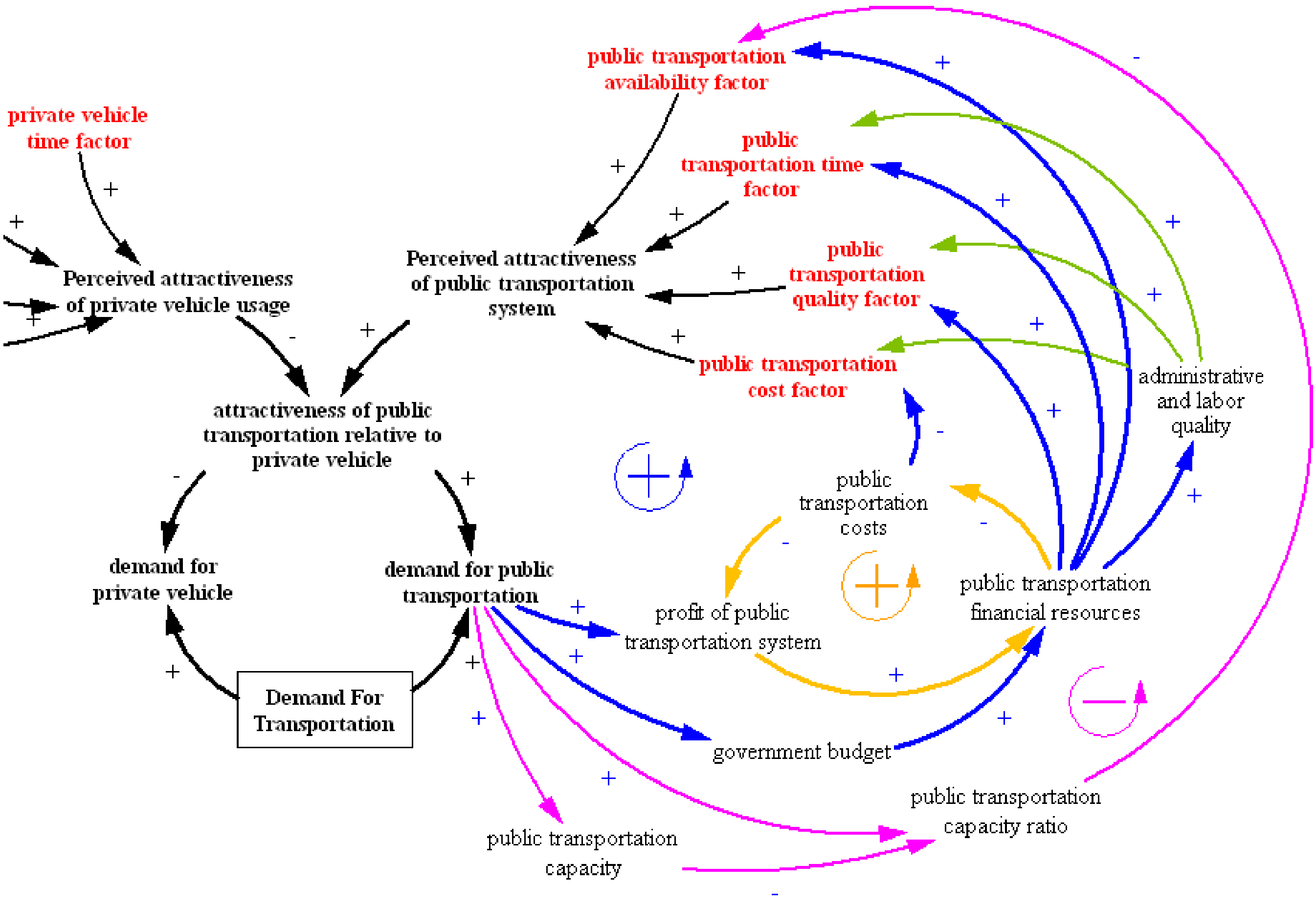

Figure 9 – Budget effect

As a result, one can understand how each mode of transportation can attract more and more demand. On one hand, more demand share can result in more profit and so more financial resources to improve the attractiveness. On the other hand, road construction is a vicious circle which has two major effects: first, it causes more traffic in long term which affects both types of transportation and second, as Sterman (2000) once discussed, it increases the attractiveness of driving and so reduces the public transit ridership [9]. As discussed earlier, profit feedback link includes many other links which is strongly affected by different strategies of policy makers. Deciding on what portion of the profit should be invested on improvement of every elements of attractiveness is one of the main and important decisions which policy makers should decide about. Most of the TDM strategies rely on these policies and decisions. Later it will be argued that one of the main problems of policies undertaken in Tehran is due to the poor distribution of the budget. There are also some TDM strategies which directly affect one or more of exogenous variables of the model. For example, most of pricing measures directly change the cost of one type of transportation for a period of time. Later it will be discussed that not considering the underlying feedback structures, can result in ineffective decisions and waste of huge resources of time and money.

To analyze the behavior of the system, the model is formulated and calibrated with the data of Tehran transportation statistics and structure. First the model is expanded with the special characteristics of Tehran transportation structure and then the behavior of two major TDM strategies which has been undertaken during the previous years will be analyzed by using the model.

Tehran Transportation Structure and TDM History

Tehran, capital of Iran, is one of the most polluted and congested cities in the world. Average vehicles speed is under 20 km/h and one out of every three days people are on the alert for the air pollution. Above 30 percent of diurnal trips in this city are made using private vehicle and public transportation (including metro and bus) has its share under 23 percent. Low technology, dependency on fissile fuels, insufficient budget assigned to mass transportation projects and lack of coherent management are the seeming drawbacks of the Tehran transportation systems [5].

In this egregious situation a few TDM strategies have been practiced but desired results are not reached. These strategies include mainly of Traffic Calming Zones, Parking pricing and enforcement of regulations like alternating between even and odd plates for private vehicles to reduce pollution and peak hour traffic. Air pollution is increasingly taking citizen's lives and the escalating delay of vehicles in the streets has not reduced within the recent years. In this paper, main focus is on the share of bus transportation and private vehicles[5]. Figure 10 depicts the private vehicles and bus transportation shares of diurnal trips in Tehran [5]. In figure 11, the shares are drawn related to each other.

6- Subway system has recently started to operate in Tehran and in contrast to bus transportation system; it is under the supervision of private sector. So we preferred to exclude it from this model to keep our focus on the quality and efficiency of public sector policies. This section can be added to the model later.

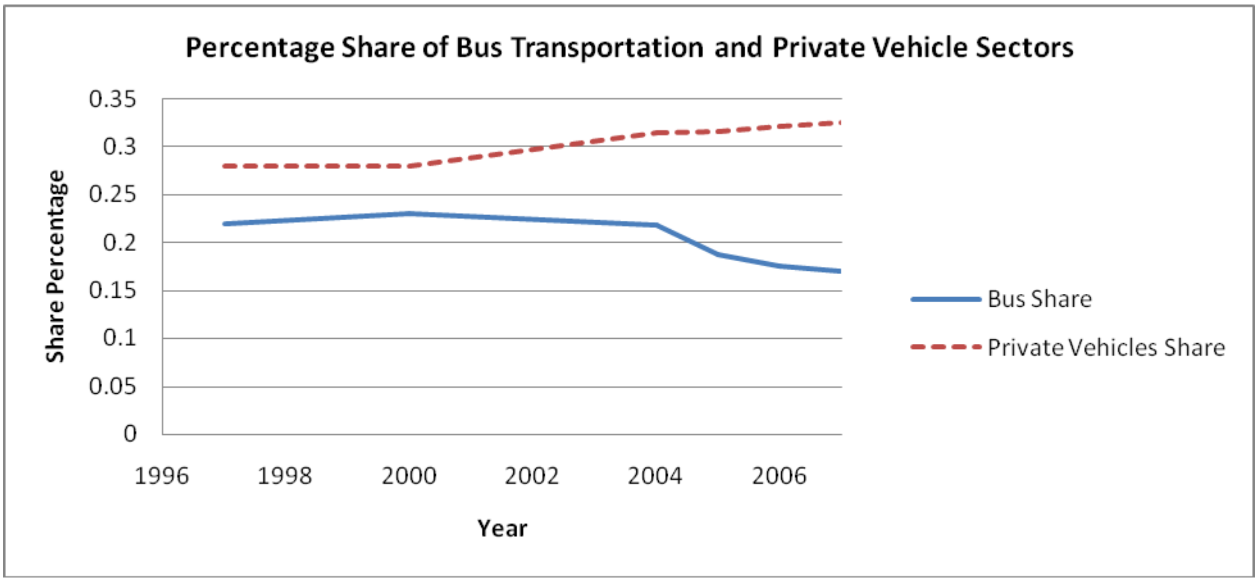

Figure 10 - percentage share of bus transportation and private vehicle sectors of diurnal trips in Tehran

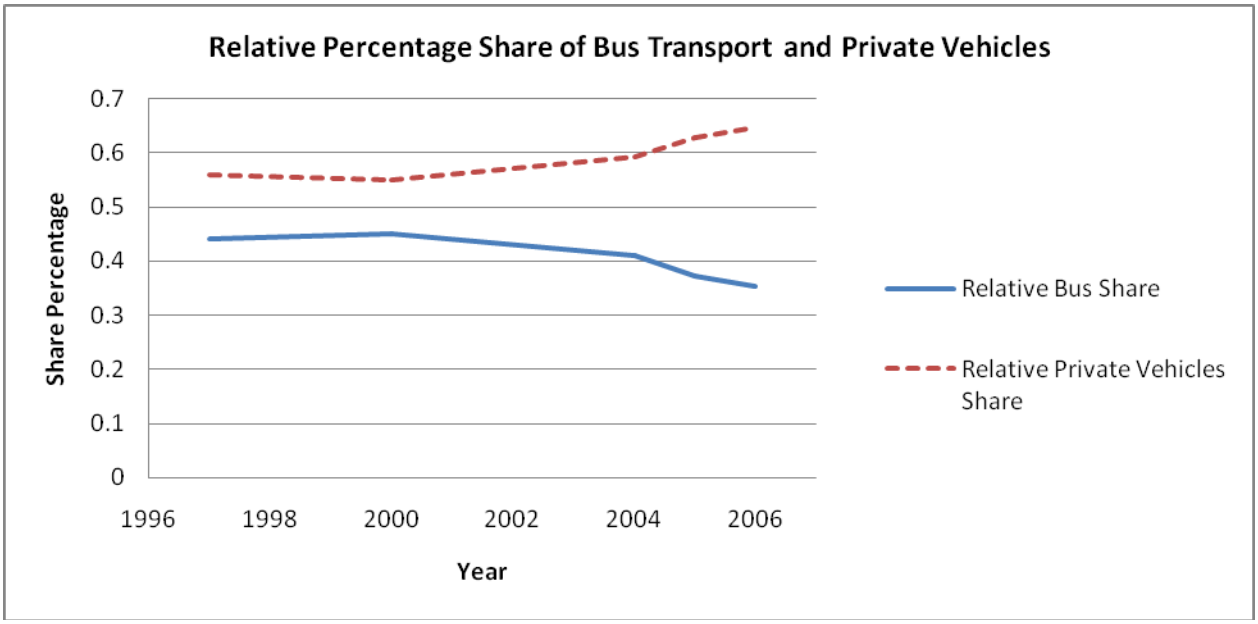

Figure 11 - Relative Percentage Share of Bus Transport and Private Vehicles of diurnal trips in Tehran

Figure 12 and 13 shows the trend of vehicles density and number of buses [5, 10].

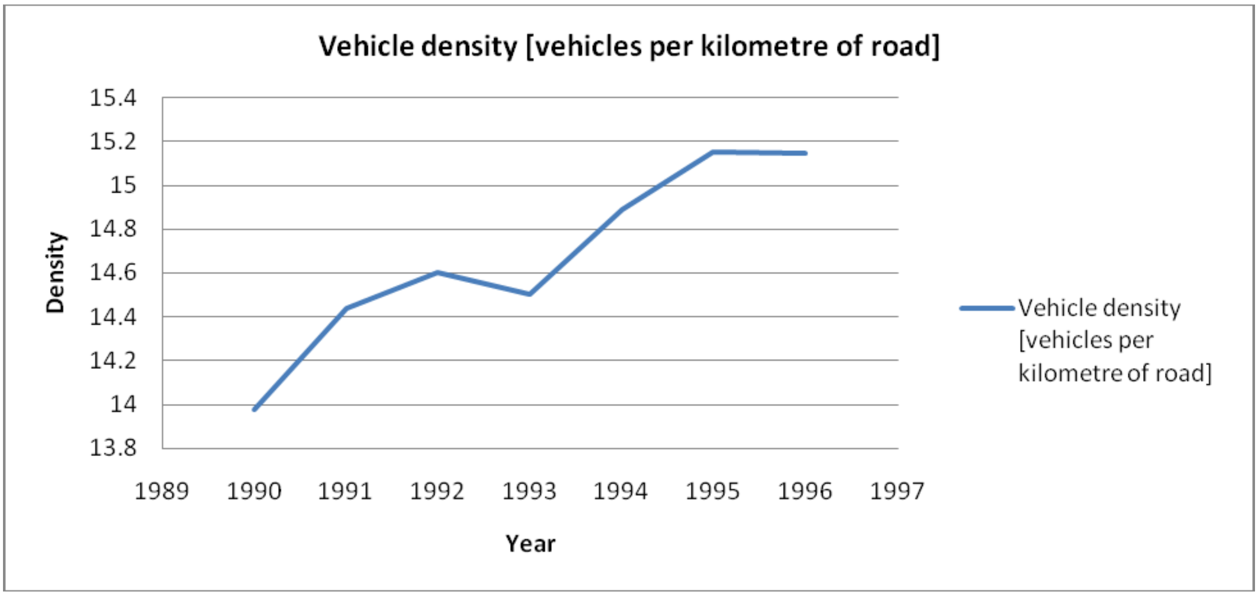

Figure 12 – Tehran vehicle density

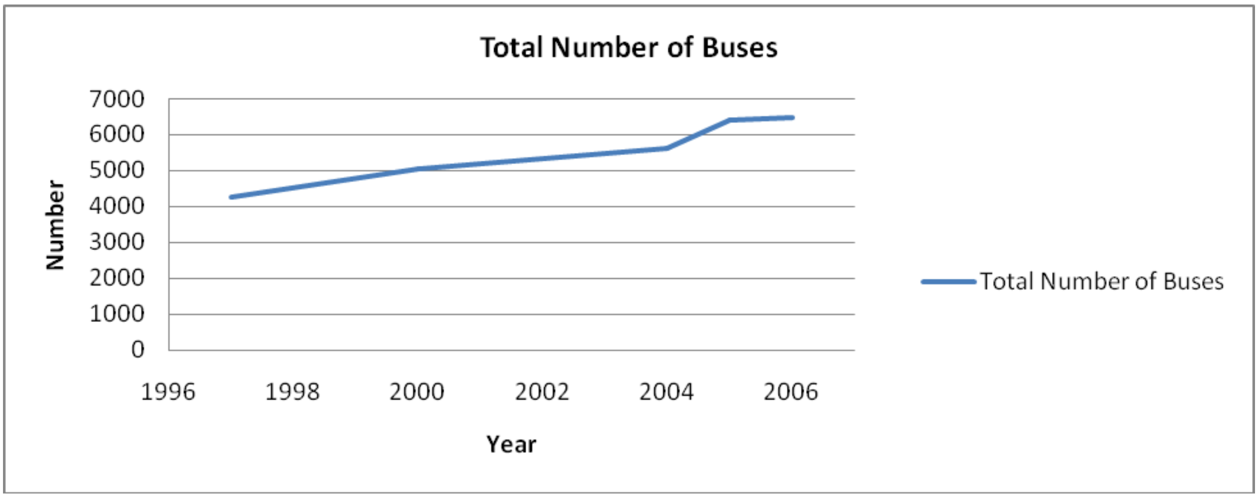

Figure 13 – total number of buses in Tehran

In Figure 14, the carbon dioxide emissions trend in Tehran is depicted [1].

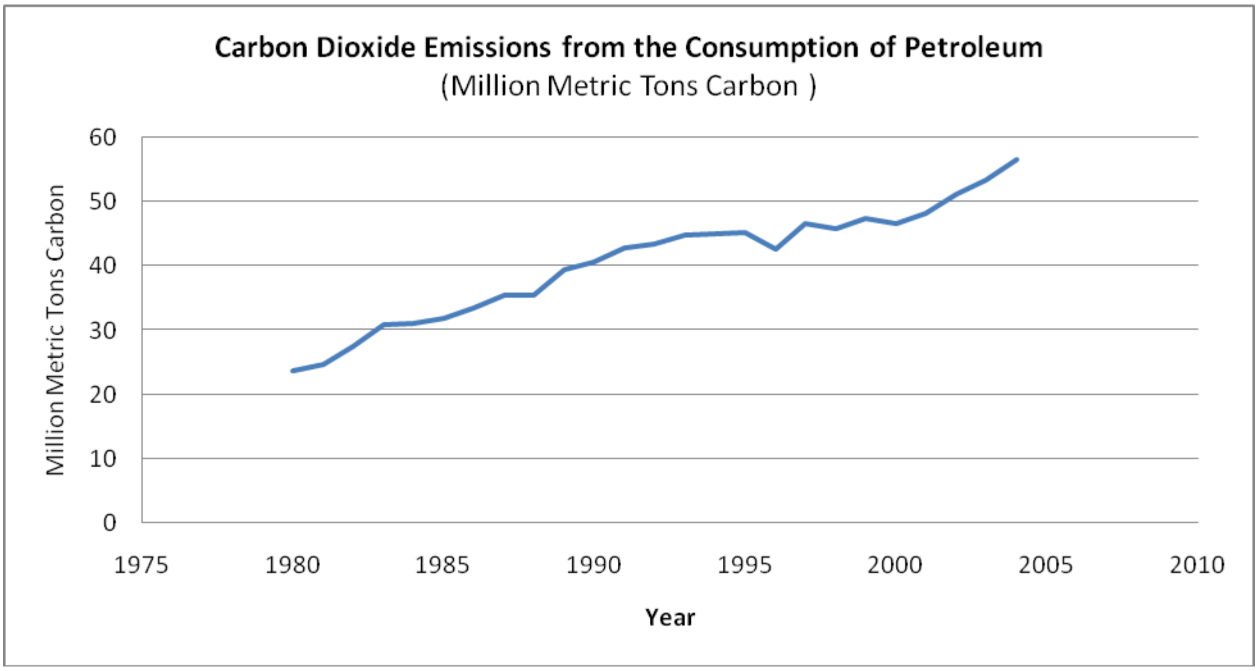

Figure 14- carbon dioxide emissions from the consumption of petroleum

It seems that none of the TDM policies which have been undertaken formerly in Tehran could control the ever-increasing trend of pollution and private vehicles share of transportation. Despite the growing number of buses, share of public transportation has diminished continuously.

To complete the basic model to match Tehran transportation structure, some parts of the model have been changed. In the budgeting section, the government budget has been added to the model. Later, the underlying structure of budget allocation in government sector can be added to the model too. Because of the loose tax structure in Tehran for private vehicles, it is assumed that each year, based on the pressure of traffic congestion and the decision of policy makers, a portion of government budget will be allocated for road construction. Initial values and other parameters are determined based upon the data of Tehran transportation sector. Proper focus has also been on business-travel transportations. The final stock and flow model can be found in supplementary files.

Behavior Analysis

The model is simulated for 48 months. Figure 15 depicts the results for relative share of each transportation mode in the absence of any strategy. It was predictable, that public transportation will lose its share to private vehicles more and more as time passes.

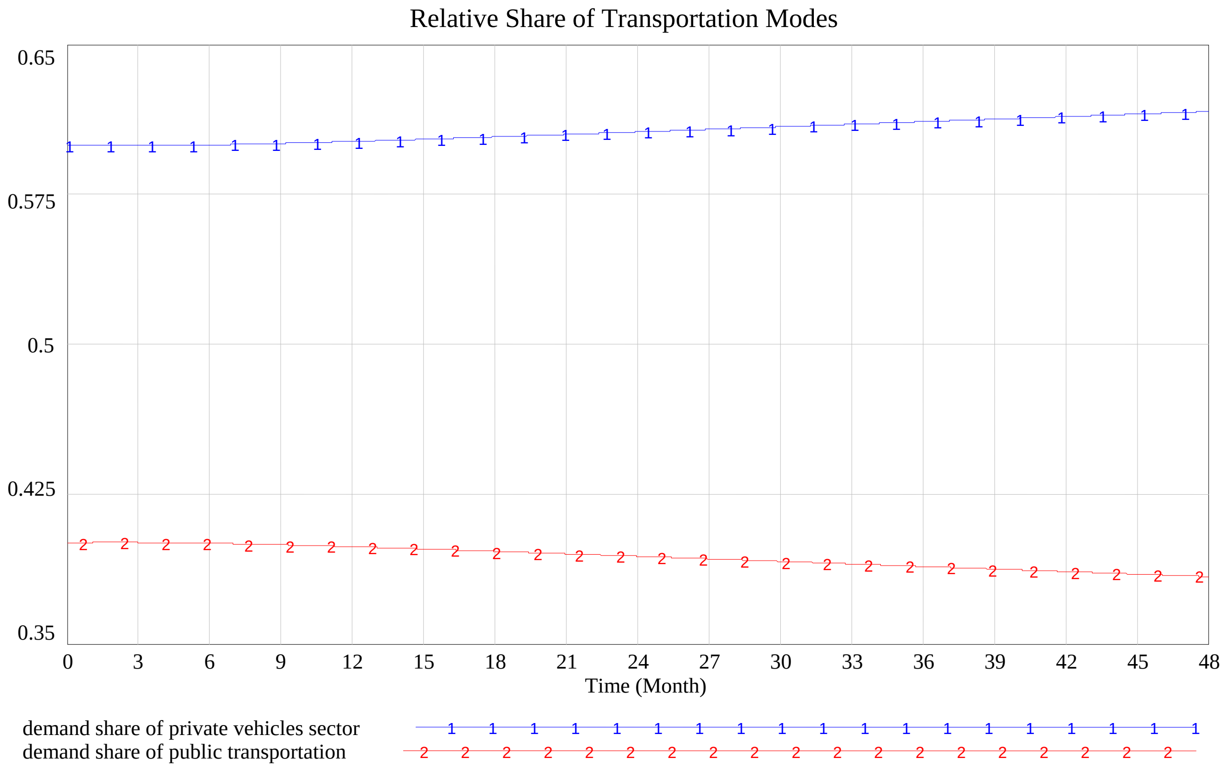

Figure 15 – relative share of transportation modes in the absence of any policy

In the next step, two strategies which have been recently practiced in Tehran were tested. In the first strategy, the availability factor of private vehicles is reduced by 20% which is the objective of most of TMD regulatory measures. In the second strategy, the price factor has increased by a factor of 100% by increasing the fuel and parking price.

In figures 16 and 17, the results of two different TDM strategies are shown. As can be seen, both policies reduce the demand share of private vehicles sector in short term, but in long term, public transportation demand share continues its historical behavior and gradually loses its demand to private vehicles sector.

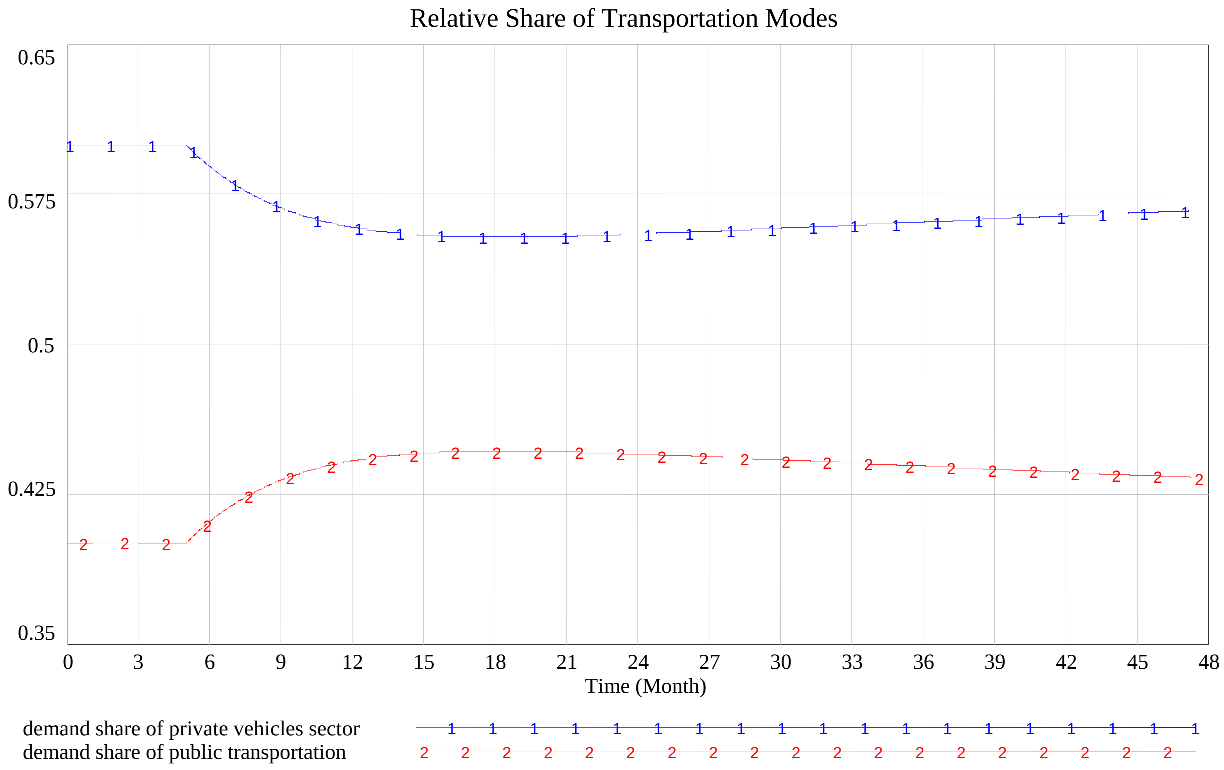

Figure 16 – effect of 20% reduction in private vehicles availability on demand shares behavior

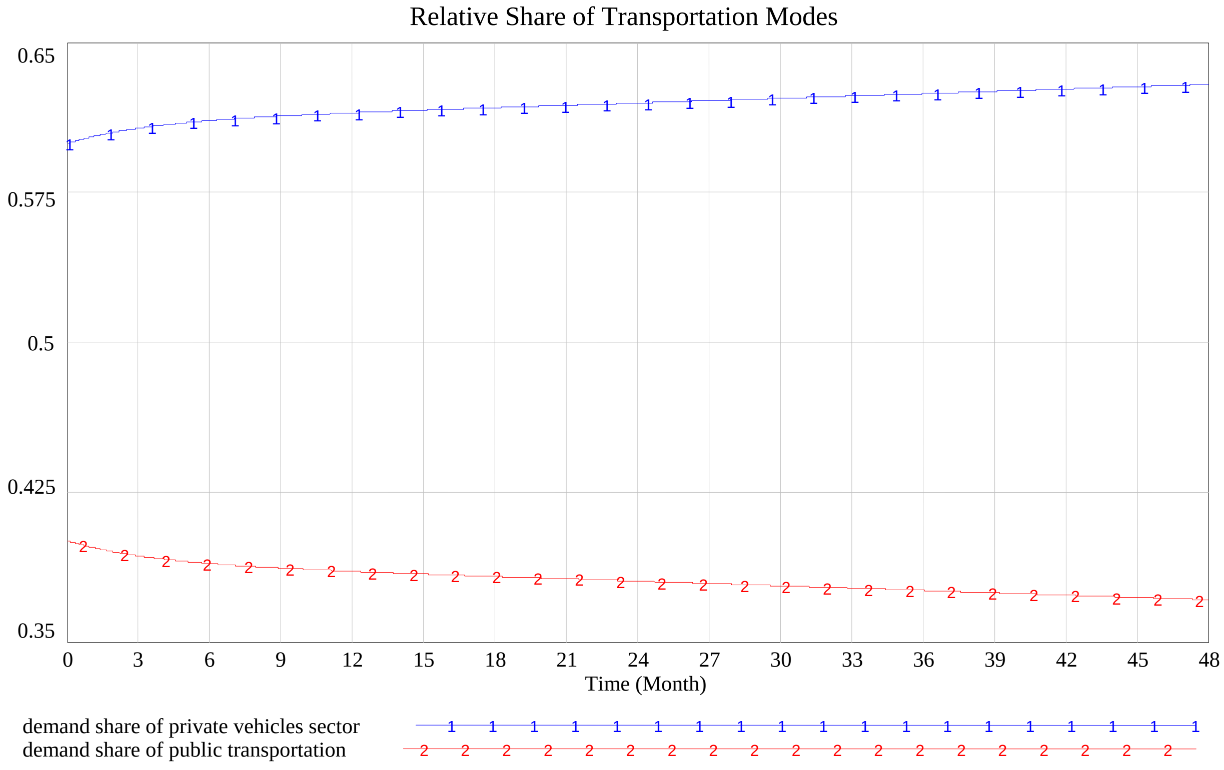

Figure 17 – effect of 100% price increase in private vehicles sector on demand shares behavior

In order to understand the reason of such behavior after implementing the first strategy, some other variables have been depicted in figure 18. The inefficient structure of public transportation, its dependence upon the governmental budget, and low administrative and labor quality have resulted in a growing negative profit of this sector. In turn, it leads to wasting more financial resources each year which is the cause of a descending trend in improvement of the system. Less improvement comparing to the improvement of private vehicle sector, and also the increasing attractiveness of driving private vehicles because of increasing road construction, cause the sliding trend in public transportation demand share and the rising trend in private vehicles demand share. As a result, public transportation loses its demand share which in turn it causes less governmental budget and more negative profit and the cycle goes on.

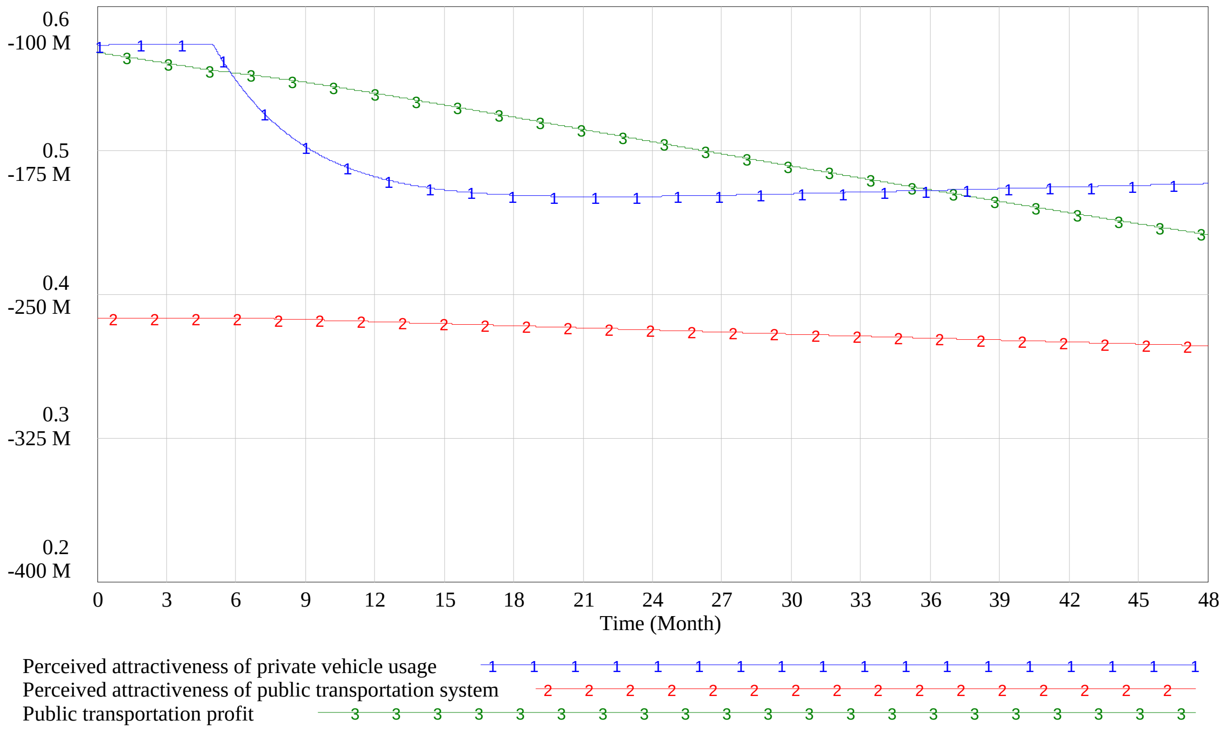

Figure 18 – first strategy effect on the behavior of other variables

Budget distribution also plays an essential role in this upsetting cycle. Putting inordinate pressure to increase road capacity and not investing enough to improve the administrative and public vehicles quality, results in the low return of investment in other factors. It also reduces the attractiveness of public transportation by diminishing the time and cost factor of this mode of transportation due to poor planning and extra administrative costs.

Considering the underlying structure, it is clearly apparent that the root of the problem lies in the unproductive and wasteful structure of public transportation system. So it can be understood that any policy which targets the private vehicle sector without considering any major improvement in the administrative and vehicles quality of public transportation sector will suffer from neglecting the efficiency factor of the system and in long term, will result in huge resource and budget losses.

To test this hypothesis, another strategy is experimented. Putting more pressure to improve the administrative and vehicles quality, and at the same time, reducing the private vehicles availability gradually by some regulatory measures such as calming zones for private vehicles, have been tested by the model. The results are depicted in figure 19.

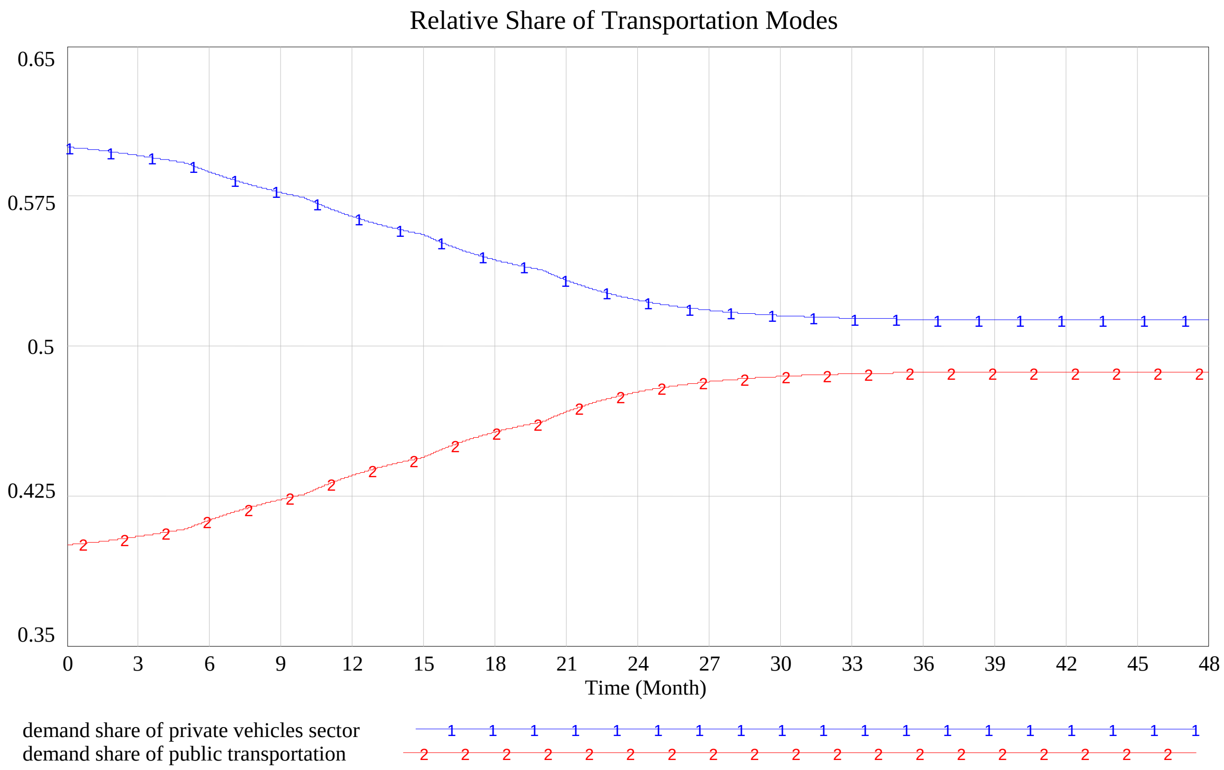

Figure 19 – effect of proposed strategy on relative share of transportation modes

It can be seen that, insisting on quality improvement, results in more perceived attractiveness of public transportation and consequently, on growing demand share of it. It also increases the return of investment in other parts, more efficient time scheduling and reduced overhead costs. It should be noted that despite the fact that this strategy brings the system to a better equilibrium and helps the public transportation gain more demand share relative to the results of previous strategies, but still we can see that it has a steady negative profit in time. Writer of this article believe that private association in public transportation sector can even result in more efficient and profitable situation. Unfortunately, this idea can not be tested by this model and needs some extensions.

Summary and Conclusion

The system dynamic model developed in this study is comprised of main factors affecting private vehicle and public transportation share in transporting passengers and hence is sensitive to variety of demand management strategies and policies. Outputs of the applied model to Tehran transportation and traffic data complied well with the real-world issues and trends. TDM approaches taken in Tehran to encourage more people to use public transportation have been relatively effective in the short term, but in the long run as the model results reveal, have been ineffective. We believe that this trend can be justified due to impotent governmental system of public transportation, lack of administrative quality and limited role of private associations active in public transportation field. This desultory attitude towards public transportation management results in more share of private vehicle of transporting passengers in time.

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