Why Achieving a Sustainable Transportation System Seems Impossible for Tehran

Mehdi Moghadam Manesh
moghadam_manesh@yahoo.com

Farboud Khatami
fkhatami@email.sc.edu

Abstract

The issue of traffic congestion in Tehran, the capital city of Iran, has become a Gordian knot. Numerous studies have been conducted to find the optimal solution for this problem, many of which not being successful in practice. The city's public transportation development, namely the subway system, which many experts believe is the key to solving Tehran's traffic problem, has not received enough attention. In this article, using the dynamic system approach, we intend to explain: (1) Why the subway system in Tehran is underdeveloped, in favor of more highway construction, despite its importance in reducing traffic congestion having been realized? (2) Why weren't the past policies successful in Tehran, despite the same policies making positive changes in other metropolises around the world? (3) Can the development of the subway system really solve the problem of traffic and pollution in Tehran? To answer these questions, Sterman's model [17, P.177] is adopted, and two new sectors are added to it. Additionally, fifteen policies in the literature are systematically reviewed, and the reasons for their failure are investigated. In the end, we propose a policy which helps mitigate the problem of traffic congestion in Tehran.

Keywords:

Traffic Congestion, transportation planning, urban development, success for the successful archetype, shifting the burden archetype

Reviewer#1:
Paper posed and evaluated 14 traffic related polices to reduce traffic congestion as a urban planning support tool in Tehran. This paper provided some insights into Tehran's public and private transportation system using Sterman's model as a guide.
(Only to Author): A few things were a little unclear. How were the policies chosen? Was there input from key stakeholders? There appears to be a lack of references for the policies chosen. Furthermore, it may be helpful to add some high-level background about how policies are enacted and changed in Tehran.

1. Introduction

An urban area without a proper transportation system may suffer, among other things, from problems such as traffic congestion (decreased travel speed), insufficient parking space, increased travel distance, increased travel time by vehicle, inadequate public transport and service quality, hindrance of non-motorized transport modes (walk/cycle), land consumption by the transport sector, environmental issues (i.e., air

pollution and noise), excessive energy and fuel consumption , accident and fatality, and political hindrance resulted by decision-makers feeling obligated to support the domestic private vehicle manufacturing facilities [9, 14, 19].

According to Numbeo [13], Tehran ranks the 15th worst city in terms of traffic congestions (Figure 1). In an intercity trip, the average citizen of Tehran wastes 53 minutes of his time and creates about 8067 grams of carbon pollution. For comparison, the same numbers for the city of Basel in Switzerland (the best city in terms of traffic) is only 20 minutes and 1387 grams, which is 83% less than those of Tehran.

Rank	City	Traffic Index	Time Index (in minutes)	Time Exp. Index	Inefficiency Index	CO_2 Emission Index
1	Lagos, Nigeria	348.01	67.39	26581.09	500.51	9065.21
2	Los Angeles, CA, United States	342.74	60.88	16901.67	804.32	15252.11
3	San Jose, Costa Rica	336.78	64.62	22130.99	367.81	10860.00
4	Colombo, Sri Lanka	314.45	63.00	19755.33	433.13	8114.83
5	Sharjah, United Arab Emirates	288.13	55.57	10957.59	332.08	12025.00
6	Delhi, India	282.66	57.01	12406.54	316.08	9311.18
7	Dhaka, Bangladesh	279.72	60.05	15868.79	351.23	5618.00
8	Nairobi, Kenya	279.63	57.24	12648.53	304.36	8552.43
9	Kolkata, India	275.97	60.38	16277.54	295.68	5014.76
10	San Francisco, CA, United States	273.83	53.50	9058.80	638.41	9978.75
11	Manila, Philippines	268.58	56.02	11398.36	288.95	7885.08
12	Mumbai, India	263.06	55.77	11149.16	280.58	7216.67
13	Mexico City, Mexico	255.83	51.69	7587.72	351.19	9661.53
14	Jakarta, Indonesia	255.77	53.10	8720.51	289.44	8514.78
15	Tehran, Iran	251.48	52.88	8535.69	268.70	8067.55
16	Istanbul, Turkey	250.15	53.05	8677.11	261.21	7706.41
17	Bangalore, India	249.48	53.03	8666.50	280.41	7501.08
18	Cairo, Egypt	248.72	50.74	6882.87	302.22	9531.10
19	Guatemala City, Guatemala	243.83	47.47	4766.61	264.60	12333.53
20	Sao Paulo, Brazil	236.88	51.03	7089.40	281.53	7203.98
21	Rio de Janeiro, Brazil	235.34	52.24	8019.02	244.39	6071.36
22	Detroit, MI, United States	234.40	46.21	4079.71	352.89	11136.94
23	Pretoria, South Africa	229.43	45.35	3652.34	314.12	11219.84
24	Moscow, Russia	225.46	52.24	8015.97	231.72	4688.64
25	Lima, Peru	225.27	50.14	6458.13	271.83	6127.96

Figure 1: Traffic Index by City 2020 Mid-Year[13]

Over the past years, substantial investments have been made to improve the traffic flow in Tehran. In the last decade alone, Tehran's highways have increased by 80% in size, from 304 km to 548 km. However, due to the tremendous increase in the number of private cars (Figure 2, 3), Tehran's traffic situation has worsened day by day, and the average speed of vehicles has dropped dramatically, especially during peak hours (Figure 4).

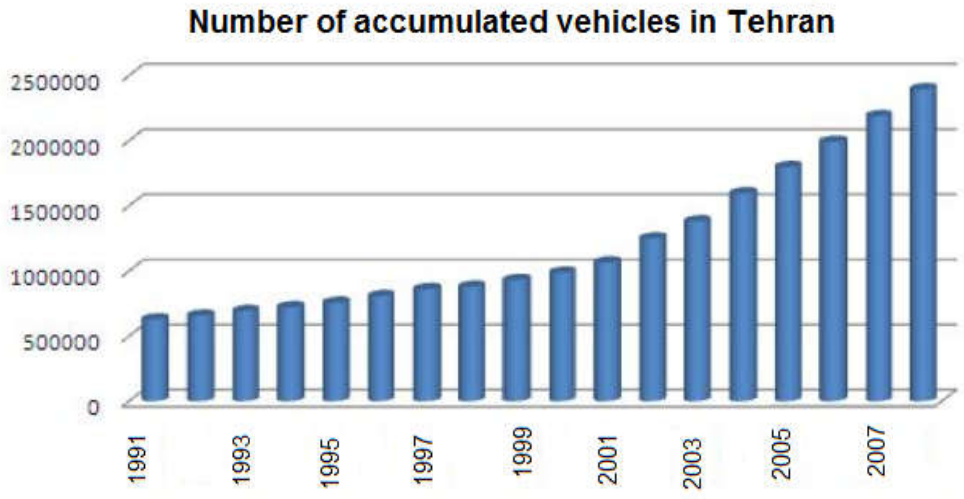

Figure 2: Number of Cars in Tehran [2]

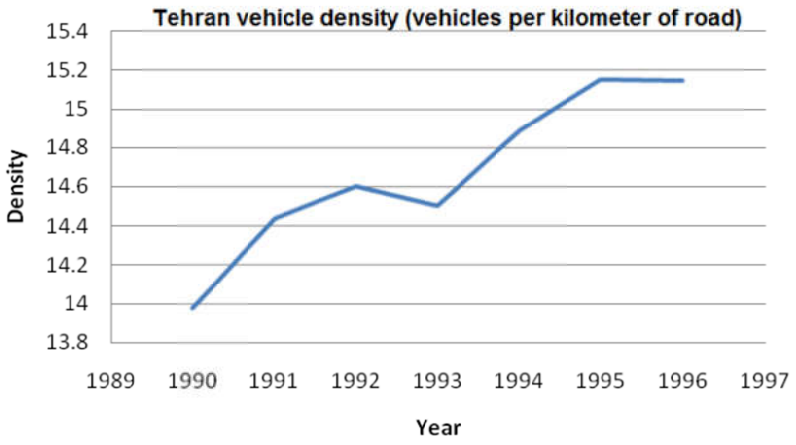

Figure 3: Density of Cars in Tehran [18]

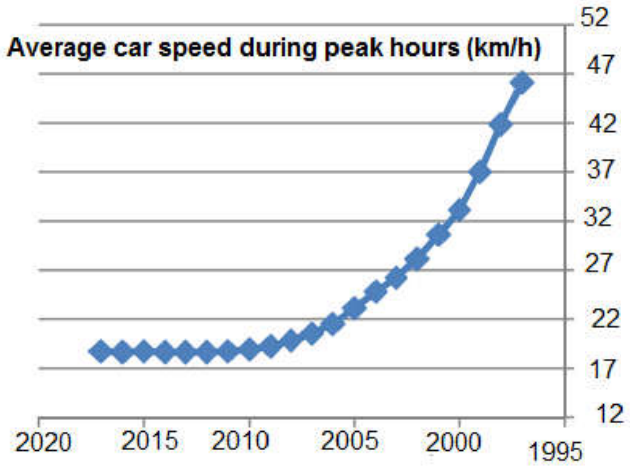

Figure 4: Average Cars' Speed [6]

According to the latest report of the Iranian traffic police (Rahvar), there are currently 4,193,946 cars in driving in the streets of Tehran, operated by a population of 8,900,000 people. In other words, in the city of Tehran, almost one in every two people owns a car. Statistics of the municipality also show that the number of daily trips within the city of Tehran is 18 million and 600 thousand trips, which is almost half of those done by private vehicles; and the share of the subway system in the daily trips is only 16% (while in European metropolises it is about 40%).

Traffic also has caused severe air pollution in Tehran. About 1,840 tons of carbon monoxide is added daily to Tehran's air, and the amount of carbon dioxide is increasing on a daily basis (Figure 5).

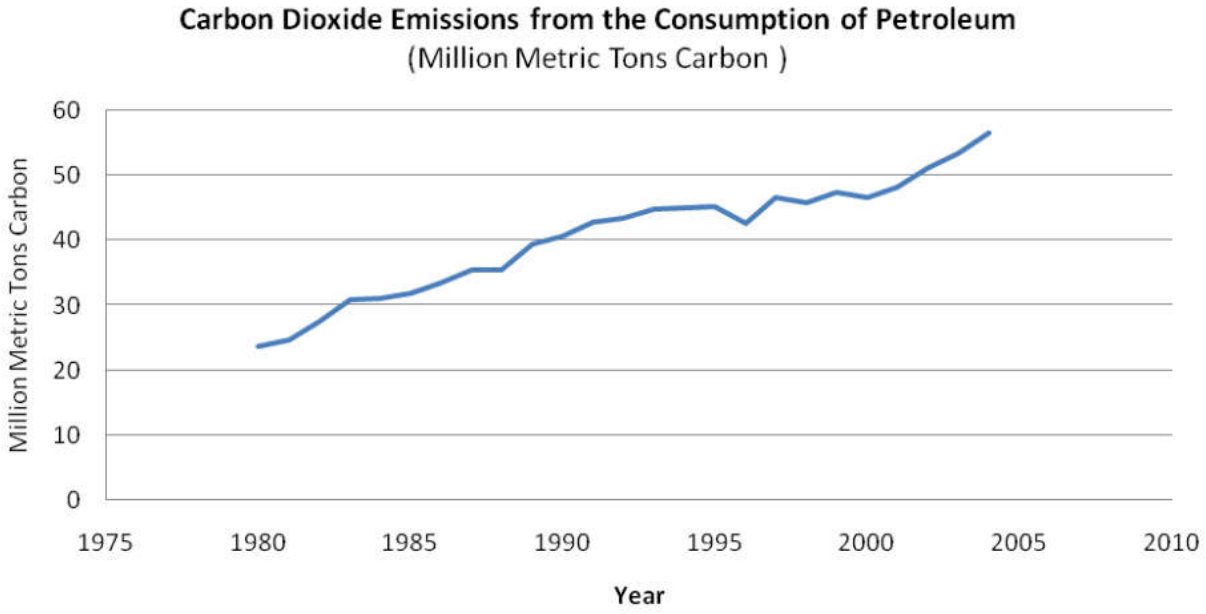

Figure 5: carbon dioxide emissions trend in Tehran [5, 18]

In this article, using the dynamic system approach, we seek to explain:

(1) Why Tehran's subway system is underdeveloped despite its importance in solving the issue of traffic congestion having been acknowledged time and again? Yet, why are highways still being developed in Tehran instead of on the public transportation system?
(2) Why weren't the same policies implemented in other metropolitan areas, successful in Tehran?
(3) Will the development of the subway system really solve the problem of traffic and pollution in Tehran?

To build the model presented in this paper, Sterman's model [17, P.177] is used as a basis for work. In this model, Sterman examines the dynamics of "attractiveness of driving" and the impact of highway construction on traffic congestion. In this paper, Sterman's model is slightly modified. Then two other sectors are added: the attractiveness of using public transport and the dynamics of competition between road construction and expanding subway system capacity on the municipal budget.

The article is organized as follows: first, we review the literature. Then, in section 3, we propose a qualitative SD model to answer the aforementioned questions. In section 4, fifteen policies for managing the traffic are introduced and

investigated in details. In Section 5, we talk about the potential solutions to the issue of Tehran's the traffic congestion. Finally, in last section, summary and conclusions are presented.

2. Literature Review

Sterman [17, P.177] examined the dynamics of "attractiveness of driving" and the impact of highway construction on traffic congestion. Mashayekhi [12] using system dynamics tried to explain why railroad market share in cargo transportation is decreasing while it has some clear competitive advantages over roads. He also combined system dynamics with a market-product segmentation matrix to design the strategy to change the trend. Stave and Dwyer [16] Using a group model building process, representatives of key municipal entities and resource management agencies developed a model for examining the potential effects of changes in land use and transportation planning on air quality, traffic congestion, and other quality of life factors. Vakili et al. [18] focused on investigating impact of TDM (Transportation Demand Management) strategies in Tehran and their impotence specifically in encouraging private vehicle users to use public transportation. Armah et al. [3] provided a qualitative system dynamics model for the problems of traffic congestion and environmental health risks in Accra, the capital of Ghana. The paper further suggested mechanisms by which the negative externalities associated with road transport in the city of Accra can be addressed. In Sharifian et al. [15], a system dynamics approach is applied to study the consequences of highway construction projects in Tehran and their effects on traffic congestion when the method of funding is through selling excess building permits. Benaich and Pruyt [4] , considering Brussels as a case study, and investigated the extent to which a cellular approach can be applied for traffic modeling and its advantages compared to more conventional approaches such as the four-step models. Jittrapirom [9] addressed the challenge of developing and implementing sustainable transport policies to mitigate negative environmental impacts caused by rapid growth of urbanized city areas within Southeast Asia. Jafino et al. [8] provided a systemic perspective of the traffic congestion, air pollution and its health impact issues in Jakarta, through the identification of relevant interrelated feedback loops, the exploration of various policy options, and the assessment of the effectiveness of these policies under deep uncertainty. Akbari et al. [1] tried to determine the most important parameters of environmental pollutant emissions in the urban transport sector and developed a system dynamics model for Tehran urban transport. Then, six scenarios including Business As Usual, Priority to the Development of Public Transport, Technical Progress, Administrative Rules and Regulations Management (ARM), Travel Demand Management (TDM), and Comprehensive Policy (CP) were quantitatively analyzed. Gonzalez and Winch [7] proposed systemic studies to find out what kind of industrial synergies would arise and how large the society's leverage to deal with heavy traffic could be.

3. Dynamic Hypothesis

3.1. Sector Map

The proposed model has 3 sectors (as shown in Figure 6): (1) travel by private car (2) travel by public transport (PT) and (3) budget.

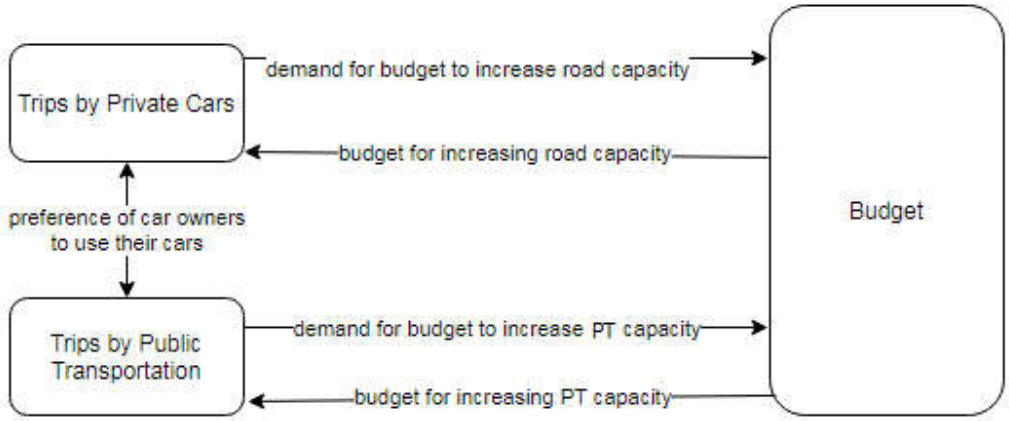

Figure 6: Sector Map

The first sector describes the total number of trips by car. The main variables in this sector are perceived attractiveness of using car, road capacity, the amount of traffic congestion, the number of car owners, percentage of car owners prefer to use their cars, and the total number of trips by car.

The second sector categorizes all trips made by public transport. The main variables in this sector are perceived attractiveness of using public transport, the total demand for public transport, the capacity of public transport, and the quality of public transport services. The "perceived attractiveness of using one's own vehicle" and "perceived attractiveness of using public transport" are the two key variables of the model, which link these two sectors. In this way, if the perceived attractiveness of using public transportation increases compared to the perceived attractiveness of using personal vehicles, a higher percentage of car owners will prefer to use public transportation.

The third sector considers the budget and how the budget is allocated. The two aforementioned sectors are both competing for more funding to increase their own capacity.

3.2. Model Description

The total number of trips made by personal vehicles are a function of:

1. The number of car owners (or the number of vehicles).
2. The percentage of car owners who prefer to use their vehicle.
3. The number of trips per person.

As road capacity is limited, traffic congestion increases as the share of personal vehicle use increases. When traffic congestion increases, the perceived attractiveness of using a personal vehicle decreases, which in turn affects the three variables of "buying a car" (that shows the number of cars sold), "the percentage of people using their private car", and "the number of trips per person". These relationships create three goal-seeking loops which determine the amount of traffic (Figure 7). A similar relationship for parking space can also be formed. Searching for a parking space can increase driving time and traffic congestion. That is, the lack of parking space and spending time and money on parking space can reduce the attractiveness of using a car. Nevertheless, this relationship is ignored here for the sake of simplicity. Yet, if investigating the effectiveness of the policy of "increasing parking space" in controlling traffic is desired, it can be added to the framework presented here.

- ***B1-buying car:*** traffic congestion↑ ⇨ perceived attractiveness of using car↓ ⇨ buying rate of cars↓ ⇨ car owners↓ ⇨ number of trips by car per month↓ ⇨ traffic congestion↓
- ***B2-percentage of using car1:*** traffic congestion↑ ⇨ perceived attractiveness of using personal car↓ ⇨ percentage of car owners who prefer to use their cars↓ ⇨ number of trips by car per month↓ ⇨ traffic congestion↓
- ***B3-car trips per person:*** traffic congestion↑ ⇨ perceived attractiveness of using car↓ ⇨ number of trips per person per month↓ ⇨ number of trips by car per month↓ ⇨ traffic congestion↓

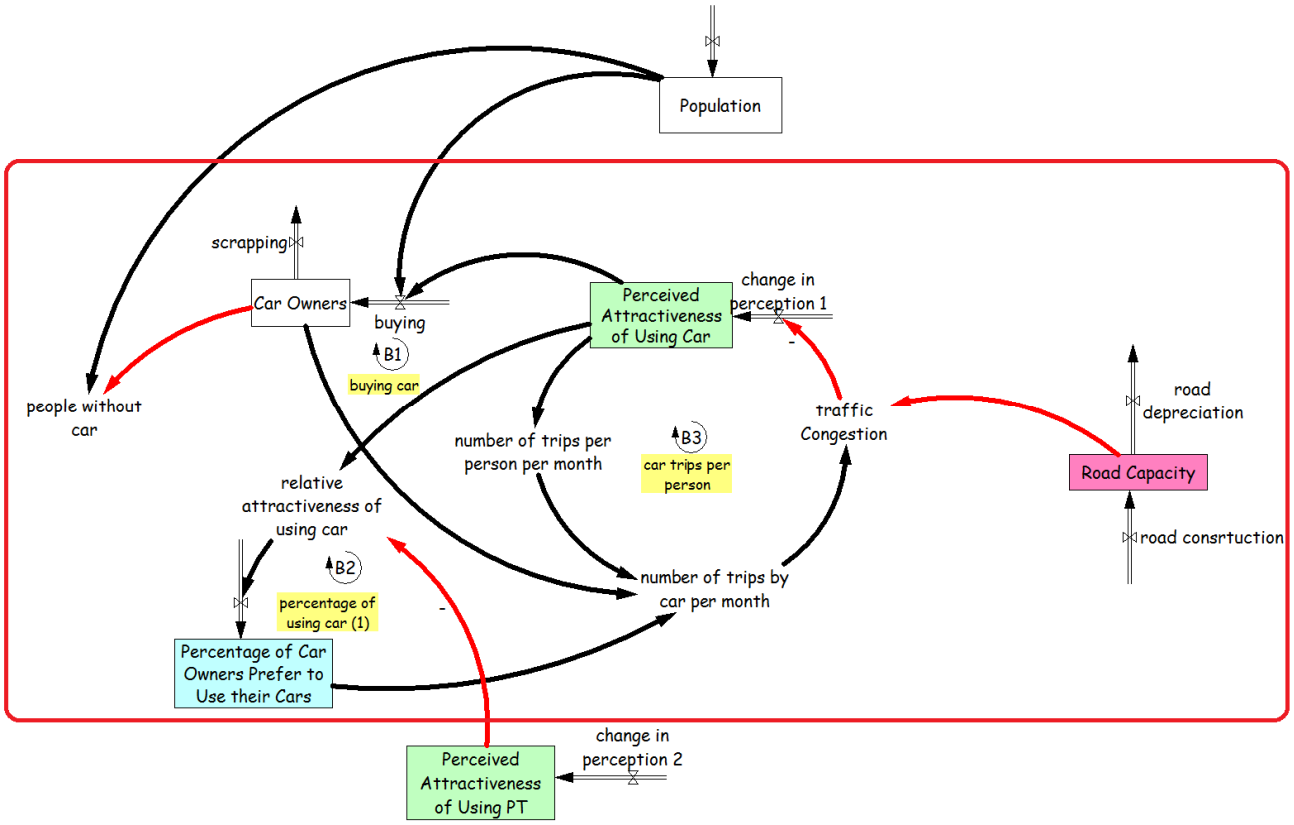

Figure 7: Sector (1)- Trips by Private Cars

In Figure 8, the second sector, travel by public transport, is added. The total demand for public transport is a function of the total number of people using public transport and the number of public transport trips per person. The total number of people using public transportation is also equal to the sum of people without cars and people with cars who prefer to use public transit.

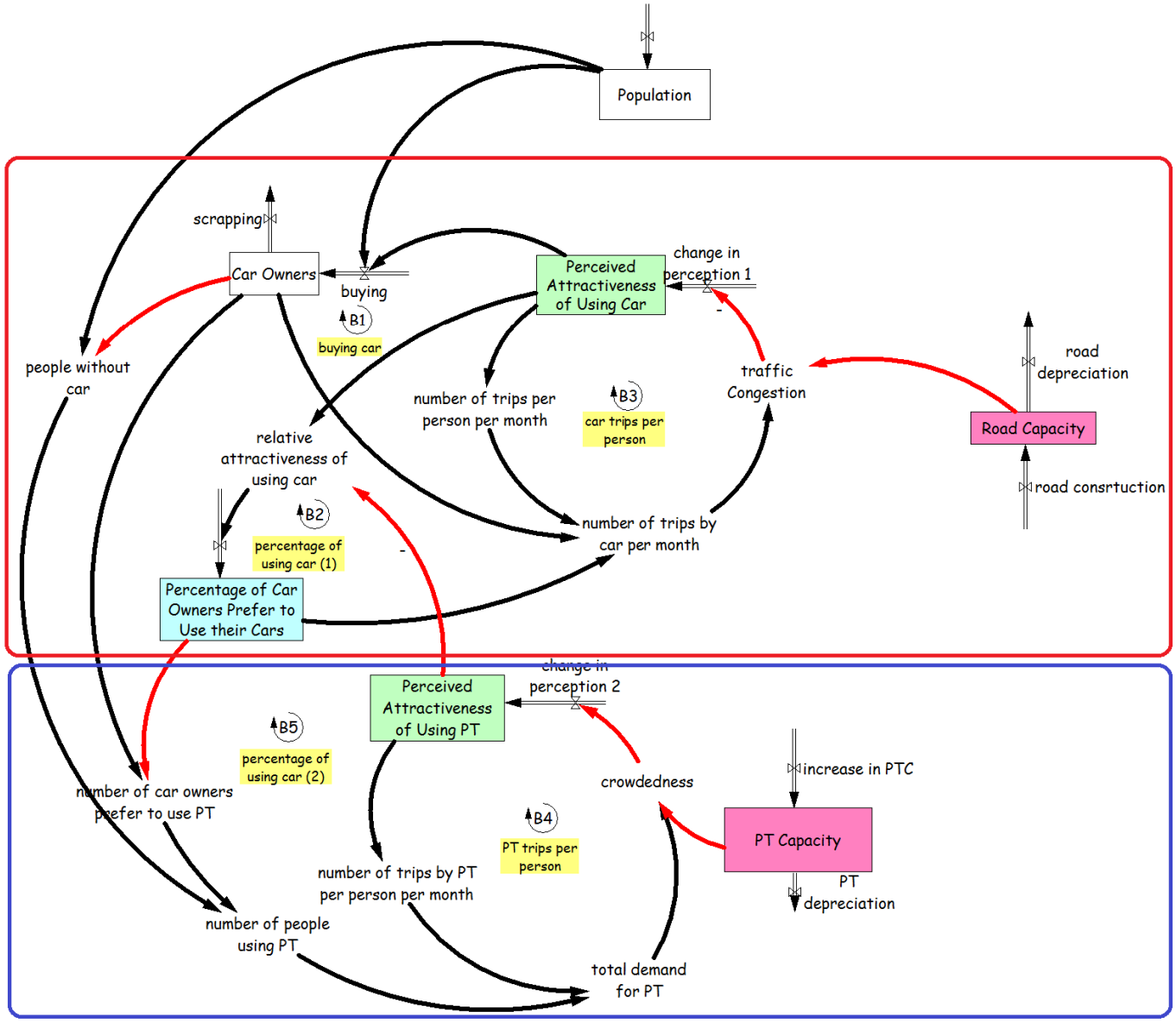

Figure 8: Sector 2 – Trips by Public Transportation

Here, crowdedness is also a driving factor that affects the perceived attractiveness of using public transportation, that is, the more crowded public transportation systems are, the less their attractiveness is perceived to be. As shown in the figure 7, there are two negative loops in the system that can control the amount of public transport crowdedness:

- ***B4-PT trips per person:*** crowdedness↑ ⇨ perceived attractiveness of using PT↓ ⇨ number of trips by PT per person per month↓ ⇨ total demand for PT↓ ⇨ crowdedness↓
- ***B5-percentage of using car2:*** crowdedness↑ ⇨ perceived attractiveness of using PT↓ ⇨ relative attractiveness of using car↑ ⇨ percentage of car owners prefer to use their cars↑ ⇨ number of people using PT↓ ⇨ total demand for PT↓ ⇨ crowdedness↓

The third sector is the budget sector. Road tolls and revenue from subways and other public transportation are added to the municipal budget. The municipality then has to decide how to allocate the budget. One of the decision criteria is assumed to be the amount of traffic congestion. Traffic congestion can increase people's dissatisfaction, so decision-makers will try to control people's dissatisfaction over traffic congestion by allocating funds towards mitigating it. This adds two negative loops and two more positive loops to the system (Figure 8). Two goal-seeking loops are looking to increase capacity to reduce traffic, and two positive loops are also related to budget allocation:

- ***B6- road construction:*** traffic congestion↑ ⇨ road construction↑ ⇨ road capacity↑ ⇨ traffic congestion↓
- ***B7- PT development:*** crowdedness↑ ⇨ PT capacity↑ ⇨ crowdedness↓
- ***R1-Road budget***: traffic congestion↓ ⇨ perceived attractiveness of using car↑ ⇨ number of trips by car per month↑ ⇨ income of road tax↑ ⇨ budget↑ ⇨ road expansion↑ ⇨ road capacity↑ ⇨ Traffic congestion↓
- ***R2-PT budget***: crowdedness↓ ⇨ perceived attractiveness of using PT↑ ⇨ total demand for PT↑ ⇨ income of PT↑ ⇨ budget↑ ⇨ increase in PT capacity↑ ⇨ PT capacity↑ ⇨ crowdedness↓

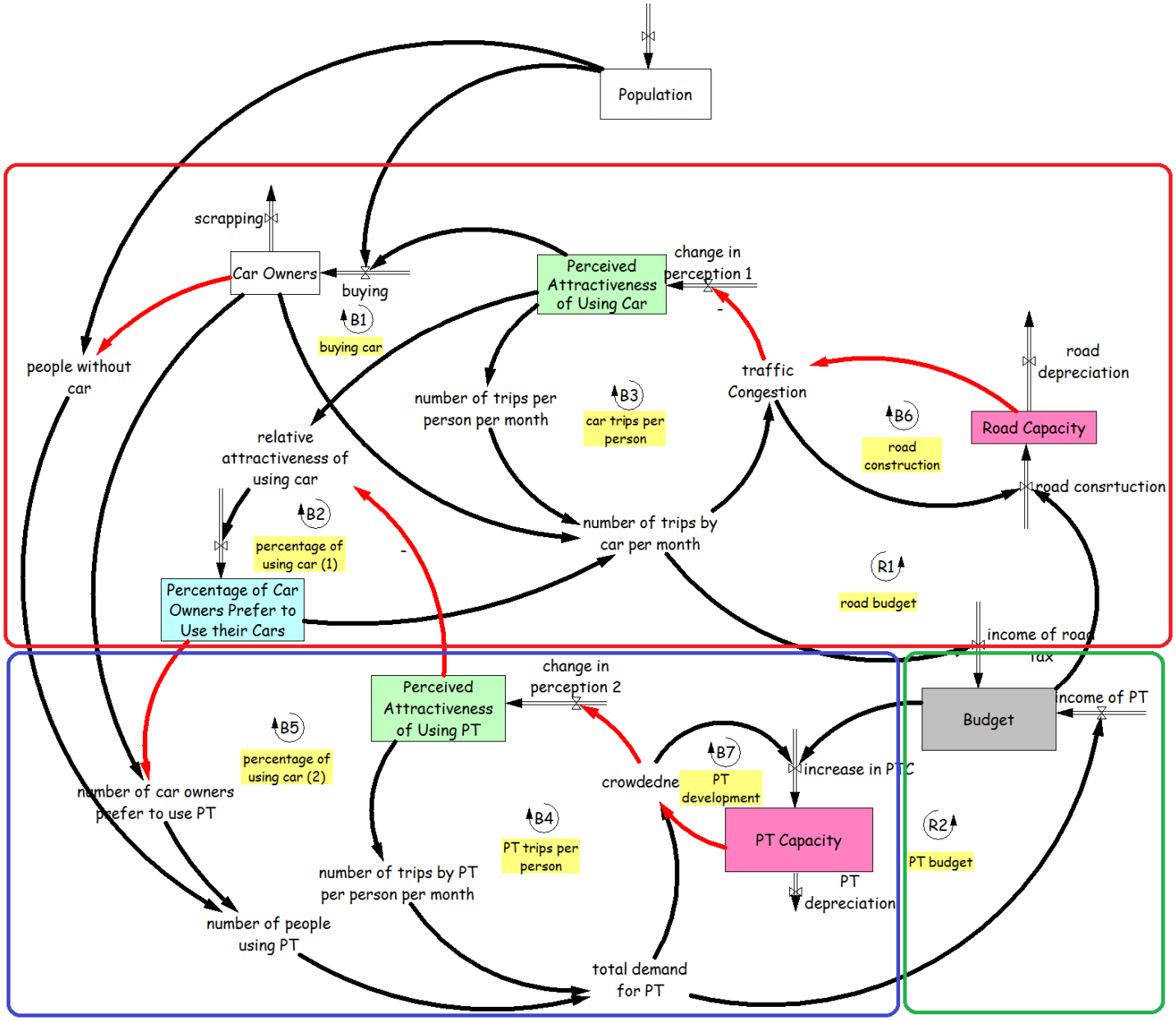

Figure 9: Casual Loop Diagram including three sectors of the system

4. Policies to manage traffic congestion

Fifteen of the policies for managing traffic congestion, as mentioned in the literature are listed in Table 1. These policies are divided into four categories:

(1) policies that seek to reduce the attractiveness of using private cars
(2) policies that seek to increase the attractiveness of using the subway or other forms of public transportation
(3) policies seeking to increase the municipal revenues (to achieve a higher budget for improving the transportation system or roadways)
(4) policies that aim to reduce the demand for transportation

Table 1: Sixteen policies in the literate to manage traffic congestion

	Policy Category	Policies
1	reducing the attractiveness of using private cars	1. halting the construction of more highways and allocating their budget to the public transit sector 2. Increasing the gasoline prices 3. Increasing traffic tolls (green tax) and assigning it to public transport development 4. increasing annual car taxes 5. limiting the growth of parking lots or increasing the cost of on-street parking lots 6. warning people about air pollution
2	increasing the attractiveness of using the subway	7. reducing public transport fares
3	increasing the municipal revenues	8. increasing the price of subway tickets and allocating its revenue to further development 9. selling licenses for high-density housing (skyscraper) by the municipality 10. selling the municipal bonds to finance subway and public transit development
4	reducing the demand for transportation	11. promoting the use of non-motor vehicles 12. increasing the urban density 13. changing the culture of ride-sharing and reducing unnecessary travel 14. temporal distribution of demand 15. development of electronic services

4.1. Stopping the construction of the highway

City managers of Tehran have usually resorted to developing highways to solve the traffic problem, a short-term solution that virtually increases the attractiveness of using personal vehicles and exacerbates the problem in the long run. Therefore, on the surface, it seems that the municipality should stop constructing more highways. But is this a feasible solution? To answer this question, it first needs to be determined why the

development of highways is a more attractive option to the city managers in practice, despite them also acknowledging the better effectiveness of public transportation systems such as subways. Also, it needs to be determined why the cycle of highway and road capacity expansion continues.

This is explained in loops R1 and R2 in the model. These two positive loops are competing in practice on a common, limited resource, which can form a "success to successful" archetype (Figure 9). In this structure, if one person or group (A) is given more resources than the other equally capable group (B), A has a higher likelihood of succeeding. The archetype hypothesizes that A's initial success justifies devoting more resources to A, further widening the performance gap between the two groups over time [10].

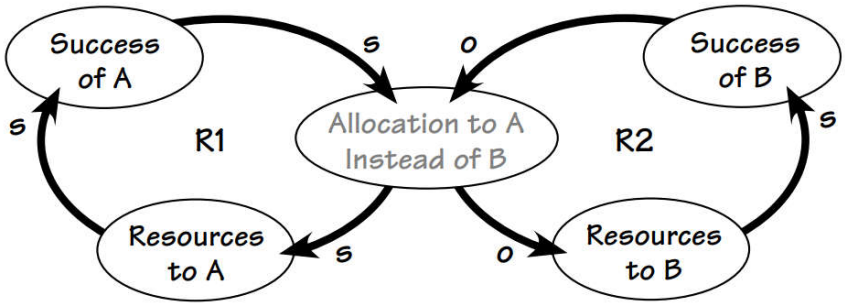

Figure 10: Success to successful archetype

As mentioned in the Section introduction, similar behavior in recent decades can be witnessed between developing subways and highways in Tehran. This means that more and more funds have been spent on highway construction, and highways have been created. On the other hand, not enough funds have been allocated to the subway system, causing it to remain underdeveloped. In the success to successful archetype, as mentioned, if one player receives more attention in the first place (for any reason), that player keeps being successful, and the other player keeps falling behind. Here, the question arises as to why highway construction was preferred over subway development in the first place?

One reason was the "high technology" required for subway construction compared to road construction. Due to the lack of knowledge and technology of subway construction, subway construction projects should have been handed over to third-party foreign contractors with proper knowledge or required equipment should have been imported into the country. But as it seemed, the planners had various reasons to oppose this idea:

(1) It makes Iran dependent on foreign countries
(2) It causes the national wealth to leave the country (to acquire needed technology and facilities)

On the other hand, with the construction of the highway, the same budget will be spent on job creation in the country and internal empowerment of road construction companies. Since the Iranian revolution of 1979, the authorities have always tried hard to avoid depending on foreign powers or handing over projects to foreigners. Besides, they intended to create jobs in the country as well. As such, the construction of a subway system didn't fare well against other more suitable alternatives.

The second reason was the "high cost of building a subway system" compared to building a highway. Because the government had a limited budget at the time, it had to choose between two options, and the authorities chose the latter for the following reasons:

(1) creating a high-cost subway system to solve the traffic problem wasn't as economically attractive as building highways
(2) building highways and spending the rest of the money on the infrastructure of remote and deprived areas would reduce immigration to the capital and other bigger metropolitan areas (due to improper distribution of facilities between the capital and cities).

But why this trend is still going on? Why don't the policymakers change their practice now that the metro's underdevelopment has been made evident? This can be explained by the "shifting the burden" archetype. In this archetype, the decision-maker knows the fundamental solution. Still, because it is more difficult and requires more effort, budget, or time than the symptomatic solution, the decision-maker tends to choose a symptomatic solution. The symptomatic solution solves the problem temporarily, but it does uproot the problem. In addition, it also provides more opportunity for the problem to expand its roots and make it even more difficult to choose the fundamental solution in the future. For example, in the case of traffic congestion, the development of highways has led to the creation of large and powerful road construction companies that can influence municipal decisions and cause the budget to be inclined towards road construction. Also, many workers have been employed in the road construction sector. Not allocating funds to them, instead rerouting funds to the public transport sector, or handing over subway system construction projects to foreign contractors will cause a high unemployment rate for road construction workers. Moreover, road construction projects are usually assigned to the, exclusive contractor companies with close ties to the government. So, many roads lack enough quality and need to be repaired in short intervals. Road construction projects assigned to those rental companies are usually implemented with many delays and a much higher expense, leading to an even lower budget left to be spent on the development of public transportation and subway systems.

Other unforeseen consequence of increasing the road capacity was the spiking the "interest in cars", that is, it compelled people to buy and use cars, instead of using public transportation. This led to the growth of car companies and increased popular access to cars. In addition, the existing monopoly in the domestic vehicle market (despite being kept in place with the good intention of supporting the domestic car manufacturing companies) also led to low-quality cars and high fuel consumption compared to international standards, which further intensified gasoline consumption and pollution. The low safety of these vehicles and the poor quality of the roads also went hand in hand to raise the annual number of road accidents in Iran to very high numbers.

Therefore, due to "technical and financial problems" for the development of the subway system, the "lobby of road construction companies", and the "culture and interest of the people in the use of cars", it does not seem possible for the construction of the highway to stop anytime soon. So, it is predicted that the traffic will get worse day by day and the pressure of the people and the lobby of the road construction companies to build more roads will also increase.

4.2. Increasing the gasoline prices

In Iran, due to the lack of fuel duties and more supply than demand, gasoline is relatively cheap (at about 12 cents per liter). On the other hand, gasoline subsidies impose a high cost on the government. This pressure increases year by year, reducing the government's financial ability to develop better public transportation. Eliminating this subsidy and allocating it to better infrastructure can solve pollution and traffic in Tehran. One might think by increasing fuel prices through elimination of gasoline subsidies the government can reduce the attractiveness of using a personal vehicle, but that is not the case.

The first issue is price elasticity. Increasing the price of gasoline can be effective if there is an alternative to using private cars. Even now, with only 15 percent of daily commute being via the subway system, the low-capacity of the subway trains cannot satisfy the demand. In other words, since transportation is an essential good and there is no proper alternative for using cars, the gasoline price increase will only increase dissatisfaction, unrest, and protest. In addition, raising fuel prices will increase general inflation and put more pressure on households. The country is currently suffering from high inflation rates, and the people are getting poorer day by day. Political and economic dissatisfaction is high, and rising gasoline prices could spark the flames of anger and dissatisfaction, which the government never wants. In a word, it can be said that the political and security costs of increasing gasoline are too high, and a simple cost-benefit analysis is enough for the policymakers to avoid it (shifting the burden archetype).

Besides, Iran suffers from the issue of populism in politics. If a party currently at power raises the price of petrol, the rival parties will present it as the government's incompetence. They will in turn promise to decrease the price of gasoline again. The rival party will use the rise in prices as a propaganda tool to gain power and acceptance in the next series of elections. However, after being elected, they too fall in the economic traps involved with interfering with market prices. This, in turn, is then used by their rivals and the vicious circle continues.

4.3. Imposing higher carbon tax

Carbon tax on gasoline has two effects as depicted in figure 14. Firstly, the tax discourages the use of personal vehicles, thereby lowering carbon emission (B8), and secondly, if the income from taxes was to be invested in public transportation, automobile usage would be further discouraged (B9). On the other hand, if the taxes are used to finance new roads, it encourages the use of personal vehicles and further intensifies carbon emissions (R3) [11].

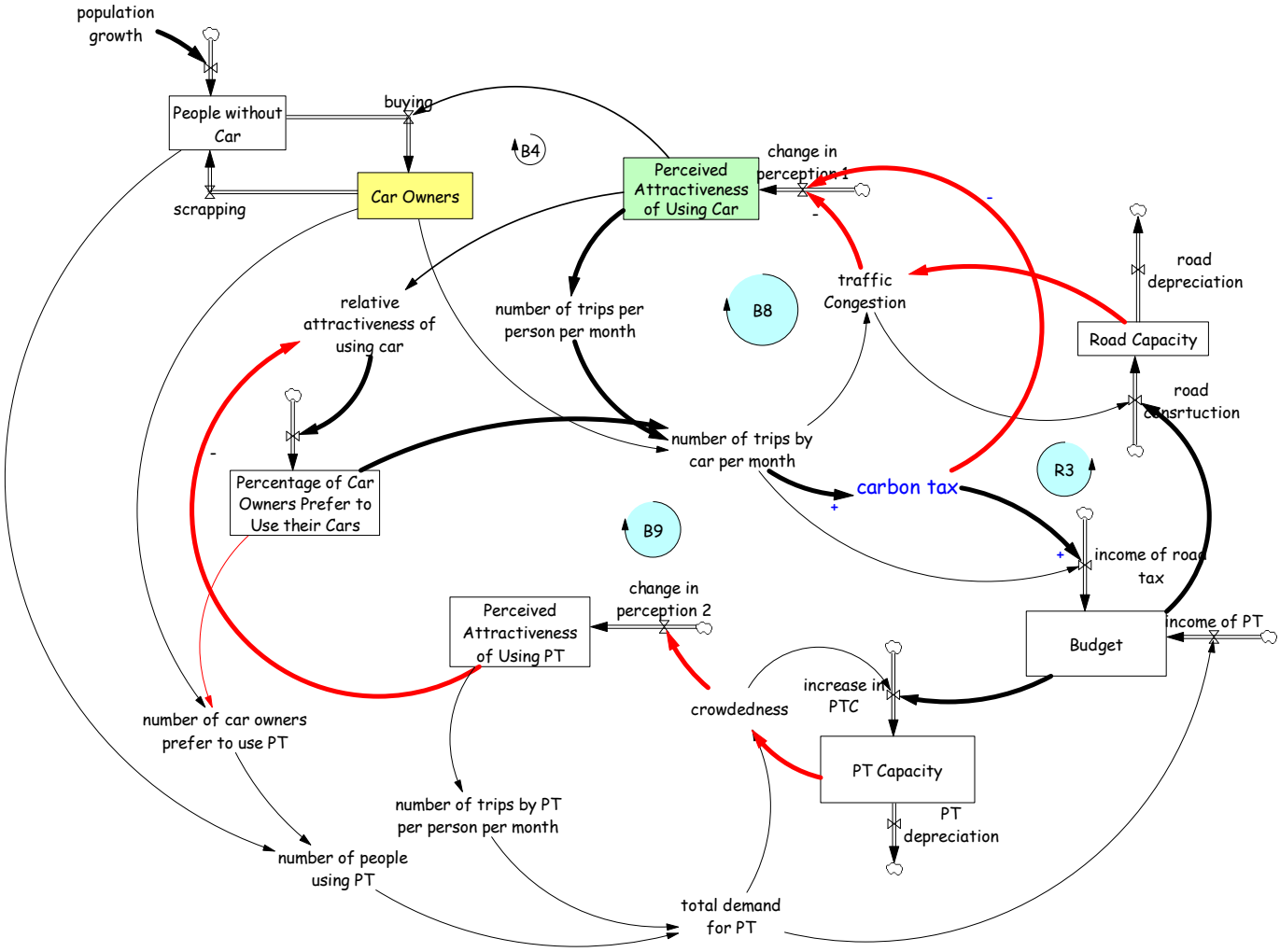

Figure 12. Causal loop diagram of imposing higher carbon taxes

Currently, the city has restricted access of personal vehicles to the more polluted parts of the city, giving the option to drivers to buy entry permits if they choose to drive their personal vehicles. The average cost of entering the traffic plan area however, is relatively low. With the increase in the traffic plan price, it seems that a percentage of people who use private cars will switch to the subway instead. However, it should be taken into account that Tehran's subway system does not have enough capacity to meet the people's demands as it is, and the government does not have the financial ability to develop it to great extents. Therefore, forcing car owners to use the subway will increase the metro's crowdedness, reducing the attractiveness of using the subway. It may be assumed that even if this policy does not change the traffic in the short term, the profits from the traffic plan will increase the revenue of the municipality, which can be spent on the development of the subway system. Although this mentality seems true to some extent, this policy can also increase people's dissatisfaction. It is very important for the government to keep the citizens of Tehran politically satisfied and avoid any social unrest. Moreover, it encourages people to look for ways to bypass the traffic plan laws, by entering without the permit.

4.4. Increasing the annual duty of cars

Increasing annual car taxes may be able to reduce the attractiveness of buying cars. In Tehran, these tolls are equal to 0.1 percent of the car's value, while in most cities around the world, this number is about 10 percent. Therefore, car tolls cannot effectively control the use of private cars. But can increasing tolls in Tehran encourage people to use the subway system? Transportation is an essential good with a low elasticity of demand. Essential goods are relatively inelastic because consumers rely on them as necessities rather than luxuries. So, increasing the car tolls will not make a significant difference unless a suitable replacement is provided. The subway is very crowded at the moment and also does not cover many areas of the city. Another alternative that people may resort to is motorcycles, which suffer from low safety standards and are the cause of many road accidents and deaths. Therefore, this policy does not seem to make a big difference until the quality and capacity of the subway system improves.

4.5. Increasing the price of on-street parking

As mentioned earlier, on-street parking is not included in the models for the sake of simplicity. The time spent searching a parking space as well as the cost of parking (especially on-street parking) might be able to effectively control the use of a private car. But on the other hand, if there is no suitable alternative for transportation, people will have no choice except spending more time finding parking space, which will increase traffic congestion, will waste more time and will increase fuel consumption. Therefore, only when the subway network and its capacity are increased can this policy be effective.

4.6. Warning people about air pollution and encourage them to use public transportation instead of private cars

As air pollution increases, many car owners may tend to use the subway and other forms of public transportation to decrease air pollution. Besides, the government will be motivated to spend more money on the subway than on road construction. Based on these assumptions, some believe that experts' warnings can highlight this concern among the people and the authorities alike, encouraging them to take action.

This mental model is shown in the figure 13. As car use increases, air pollution increases, environmental and health concerns increase, and the tendency to use cars decreases (loop B1). As pollution and public concerns increase, the authorities' concern rises as well (Loop R3), and they will spend more money on public transportation. This increases the capacity and quality of public transport after a delay, so the tendency to use

public transport increases, which reduces the use of private cars (loop B2). As people use public transportation, the culture and habit of using public transit gradually increase, and more people will use public transportation in the future (loop R1).

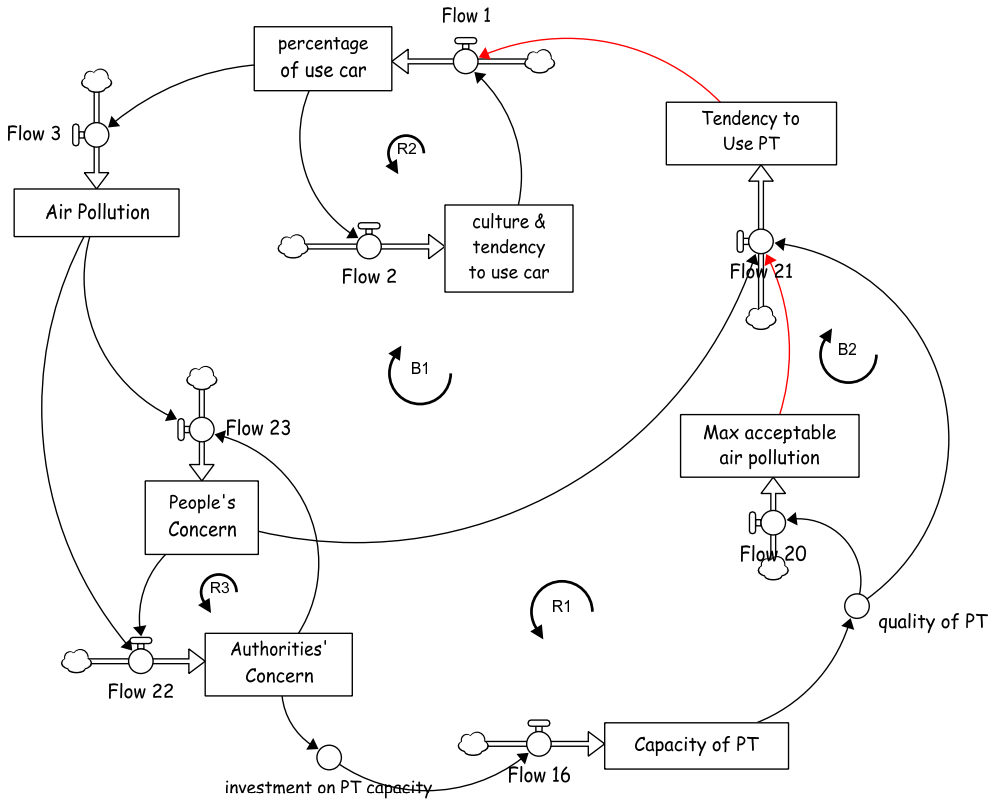

Figure 13: Awareness towards pollution

But such mental model misses a feedback element. When air is polluted every day, and the suitable alternative (subway) is not sufficiently developed, in reality people may slowly "get used" to the conditions and become "indifferent" to air pollution and the number of deaths and health issues resulted by it. This indifference can weaken the loops in the above mental model. This loop may not be very active in developed countries, but people in many third world countries in an effort to make life more bearable, are learning to be indifferent to many unfavorable conditions

The effect of this feedback is similar to the “drifting goals” archetype shown in figure 14. The gap between the current situation and desired situation leads to dissatisfaction. There are two possible ways to bridge this gap: trying to achieve the desired state and eroding the goal.

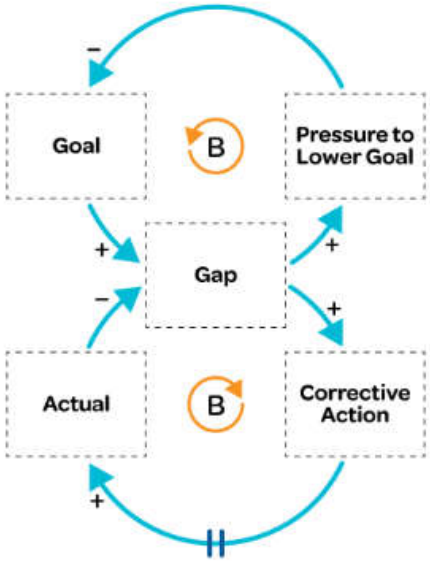

Figure 14: Drifting goals archetype

Another critical point, often overlooked in the above model is the "tragedy of the commons". That is, everyone thinking of their own short-term personal interests instead of long-term public interests.

The other point to consider is that an increase in air pollution may even have the opposite effect, encouraging more people to use a private car in order for them to spend as little time as possible outside. In this mental model, we have ignored people who cycle or walk as their numbers are small. But if we consider this group of people, air pollution intensification can make them give up walking and cycling and use public transportation or private cars instead.

vehicle use↑ ⇨ air pollution↑ ⇨ walking & cycling attractiveness↓ ⇨ walking & cycling trips↓ ⇨ vehicle use↑

4.7. Decreasing the public transport fare

Some believe that by reducing the price of subway fares, the attractiveness of using the subway can be increased. However, it should be borne in mind that currently, the reason why people do not use the subway as much is not its high price. The poor quality of the subway system, its over-crowdedness, the long waiting time at the station, the long time required to access the subway station itself, and the lack of an extensive transportation network are the main reasons for the subway system not being used as much as it should.

Reducing subway tickets can happen to have the opposite effect. It can increase unnecessary trips for people without a car, so the metro will become even more crowded, and car owners will prefer to use their own vehicle. The subway bust also can give pickpockets and sexually ill people more opportunities to loiter, and harass women and children. Another drawback of this policy is the more significant financial pressure on the government. Currently, public transport subsidies have put a lot of pressure on the government. Increasing public transport subsidies will put even more financial pressure on the government, increase government debt to municipalities, and reduce the government's ability to invest in public transportation.

4.8. Increasing the public transport fare (decreasing the subsidies of the metro)

Raising metro fares will reduce the financial burden on the government. It also increases government revenue, which can be spent on metro development. But this has two unintended consequences:

(1) It encourages people to use their personal cars
(2) Most of those who use the subway are middle and lower class facing severe economic problems. Increasing the fares, further imposes financial pressure from the government on these users and could lead to unrest and widespread protests, something the government never wants.

4.9. Selling licenses for high-density housing (skyscraper) by the municipality

This policy has been investigated by Sharifian et al. [15]. This policy may be effective in the short term, increasing access to housing and lowering housing prices as well. High prices and the lack of housing in fact limits the growth of the city, and removing these growth limitations will lower housing prices in the capital, increasing the immigration rate, increasing population and exacerbating Tehran's traffic, pollution, and transportation problems as a result.

4.10. Selling municipal bonds to finance the development of the subway system

Bond issuance has been historically unsuccessful for two reasons:

(1) Due to the enormous debts of Tehran municipality, banks are not willing to guarantee the municipal bonds.
(2) Due to the low-interest rate of the bonds and high inflation, the real interest rate of these bonds may even be negative, and people will have little incentive to invest in these bonds

4.11. Promoting the use of non-motor vehicles

Bicycles are a cheap and fast means of traveling short distances. In addition to reducing traffic and environmental pollution, the use of bicycles can be a form of physical activity and improve the user's health.

One of the solutions that municipal managers have resorted to in recent years is to encourage people to use bicycles. But it has not been very successful for five main reasons:

(1) People usually need to travel long distances in Tehran to get to their destination.
(2) The air is too polluted for extended outdoor physical activities.
(3) Routes are rarely flat, with constant hills and slopes making it difficult for cyclists to maneuver.
(4) The overall cyclists' safety in the city is not ideal.
(5) The current culture has caused an interest in using cars.

4.12. Increasing the urban density

As a city grows in population, that city may grow horizontally, vertically, or both. The city of Tehran has grown more horizontally than vertically over the past decades. As shown in the figure 15, the horizontal growth of cities leads to an increase in traffic. Therefore, some people believe vertical growth should replace horizontal growth. However, this also has two main drawbacks. First, high urban density will reduce green space and exacerbate air pollution. Second, high-rise buildings can close air corridors, impede ventilation, and exacerbate air pollution.

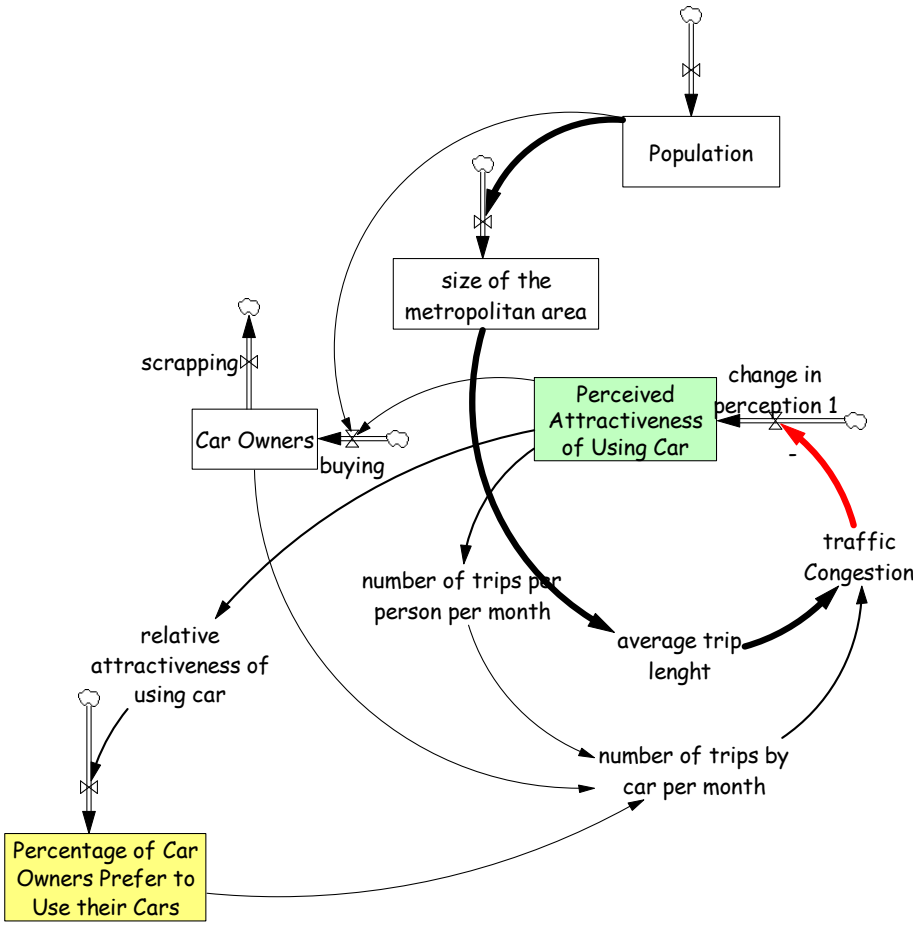

Figure 15. Traffic in growing cities

4.13. Ride-sharing culture and reducing unnecessary travel

Over the years, efforts have been made to incentivize ride-sharing and eliminating unnecessary travel. However, it has not had much success, for a variety of reasons:

(1) Co-workers do not usually live in one area of the city, so rarely can they share a car to go to work together. There is no platform or infrastructure put in place for people with the same starting point and destination to find each other.
(2) In big cities, rarely do people trust strangers due to the fear of being killed or extorted of their properties by the drivers or passengers.
(3) It's also important to note that Iran has a state-owned economy. The government has been responsible for provision of everything for decades and has rarely involved masses in important decisions. The people have learned over time that the government is the guardian of the people, and the government is the one who has the responsibility to solve the problems of the country and the cities. The spread of this way of thinking in society has caused people to wait for the government to do something instead of changing their behavior. In other words, the "sense of social responsibility" in people has decreased, making them less likely to take the initiative through a process known to social psychologists as "diffusion of responsibility". In other words, the "bystander effect" or "Genovese syndrome" happens. In game theory it is also called "volunteer's dilemma", and "the murder of Kitty Genovese" is a classic example of this.

(4) The gap between the people and the authorities has widened over the decades. People disagree with how the budget is allocated and spent, and they are opposing widespread corruption at the highest levels of the government. When ordinary people are ask not to use their personal car because of pollution and traffic, they mostly answer by criticizing how the government spends its budget in all the wrong places instead of developing infrastructure, building hospitals, universities, roads, and subways. The government officials not using public transit also sets a negative precedence on ordinary people.

4.14. Temporal distribution of demand

In general, intercity trips have three primary purposes: work-related trips, trips to schools and universities, and other purposes, mostly for leisure. The peak of traffic is due to trips for going to work and schools. So, it seems that the time distribution of demand can lessen the congestion in rush hour. For example, schools and universities can start and end a few hours after offices. However, this policy cannot necessarily improve the situation, even might exacerbate it. Many parents now take their children to school or university before going to work. If the hours shift, parents will have to go out once to pick up their children, return home, and come out again to go to work, which defeats the purpose of the policy in the first place

4.15. Development of electronic services

The development of e-services, telecommuting, and distant learning can significantly reduce the demand for intercity travel. Nevertheless, in addition to drawbacks which are usually associated with remote working and virtual learning, this policy is more likely not to be as effective as it seems at first glance due to the "rebound effect". To illustrate, traffic congestion is a factor that decreases the attractiveness of using private cars and makes people use their cars as much as possible. When streets get less crowded, the attractiveness of using personal vehicles will go up, leading to more traffic congestion.

5. What is the solution?

All previously mentioned policies seek to increase the capacity of roads and subways, encourage or force people to use public transportation instead of private cars, or keep people at home and do their jobs via the internet. However, they all ignore the critical fact that the underlying cause of traffic congestion in Tehran is the supplies growing faster than demands due to the exponential increase in population. If the migration to the capital and population growth slows down, then supply in the transportation system has the opportunity to meet demand, and the system becomes stable.

As mentioned before, increasing the population, on the one hand, increases the demand for transportation and, on the other hand, makes the city larger and increases the transportation distance. The reason for the increase in the city of Tehran's population is that most of the country's amenities are concentrated in this city. From a more general point of view, the "*success for successful*" archetype has caused the amenities to not be distributed equally in the country. Most of the villages and small towns are not sufficiently developed, and people migrate to the capital for work, education, receiving healthcare services, among other reasons. In a larger frame, Tehran not only suffers from traffic and air pollution, but also suffers from a shortage of medical, recreational and educational centers, housing problems, and slum housing, and many other issues, and officials are constantly forced to spend more funds trying to solve the city's problems. Figure 16 shows the "*shifting the burden*" archetype, which explains why these problems have arisen in Tehran and continue to exist.

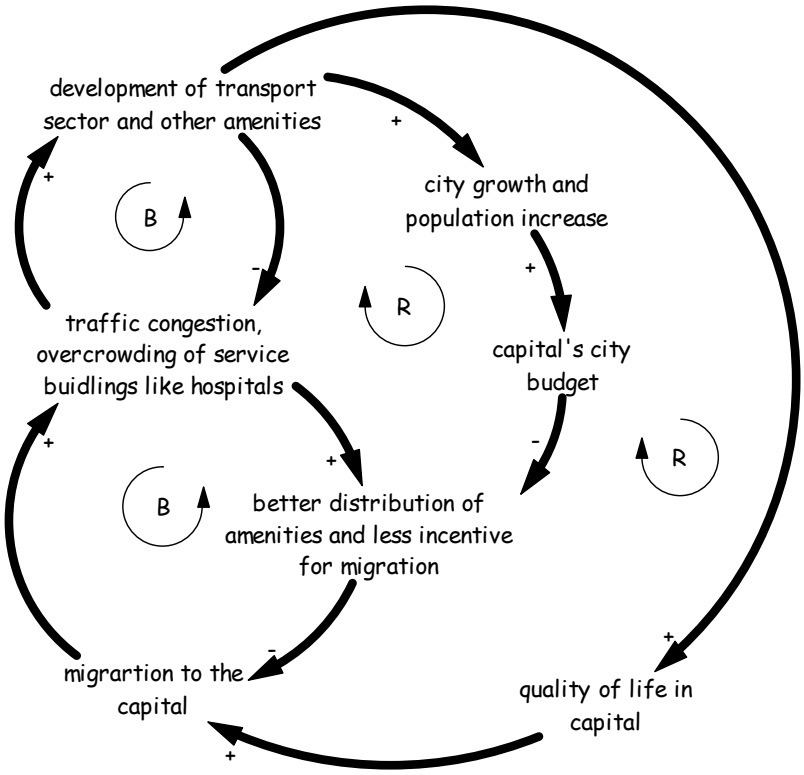

Figure 16. Shifting the burden

Due to the disproportionate distribution of facilities and their concentration in Tehran, people in smaller cities tend to migrate to the capital. This migration and population increase will raise the demand in different urban sectors (transportation, health services, education, etc.), and the government will have to spend more funds to meet these demands. Under these circumstances the government generally is faced with two options:

(1) increasing the service capacity and trying to satisfy the ever-increasing demand
(2) changing the distribution of wealth and facilities in the country proportionately.

Since Iran is a vast country with a limited government income, the disproportionate distribution of wealth throughout the country has caused minor cities to receive a small budget, hindering their growth. In addition, the satisfaction of Tehran's citizens is very important for the government politically and security-wise. Yet, the small city dwellers are accustomed to this lack of facilities and no longer expect the government to make significant improvements. For these reasons, the officials have chosen the first solution to concentrate the amenities in Tehran. But it has two side effects that cause the above loop to be repeated. First side effect is more people migrating to Tehran to benefit from the improved amenities and quality of life in the capital. The second side effect is that the budget required for the development of the capital's urban facilities increases the bigger the city gets, and as a result, less budget remains for other cities, that is, the distribution of facilities will be even more disproportionate from year to year, drifting other cities away from Tehran in terms of quality of life. This difference in opportunities leads to an increase in migration and population.

With these explanations, it can be concluded that no solution should be expected to stabilize Tehran's transportation system until widening facility gaps between the capital city and other smaller cities of the country get bridged.

6. Summary and Conclusion

The city of Tehran has chronically suffered from traffic congestion for many years. Highway development has traditionally been used to solve this problem, while according to the experts, subway system development is the solution for this problem. In this article, we first used the “success for successful” archetypes to explain why the emphasis was put on highway development from the beginning instead of the subway system. Then, with the “shifting the burden” archetype, it was explained why the authorities are still developing highways instead of subways. Based on the explanations given, it can be concluded that in three types of countries, there is the potential succumbing to these architypes:

(1) Countries that do not have access to the technology of building subways, and do not want to become dependent on foreign companies, or political reasons
(2) Countries facing financial difficulties that forego the development of high-cost subway systems and spend the rest of the budget on cheaper alternatives.
(3) Countries where populism is a key factor in their political scene. Fundamental solutions can solve the problem in the long run, but they take much more time than temporarily dealing with the symptomatic issues. Populism is a key factor that can cause politicians to lose the support of the people and the elections. Rival groups also seize the opportunity, accusing the ruling party of incompetence and try to win popular votes with widespread propaganda and fundamental reform promises.

After that, sixteen usual policies to manage the traffic congestion were examined. Adopting system thinking, we explained why each of those policies is not implemented in real life and why they may not have a significant impact even if implemented. As a result, any action to reduce the attractiveness of using a private car will not be effective unless the subway system’s capacity is sufficiently increased.

Then it was discussed that even if public transportation is to be developed instead of highways, this would still not be a fundamental solution, and the transportation system in Tehran would not be sustainable. The “success for successful” archetype has caused the facilities not to be distributed evenly in the country, and the facility differences between Tehran and other cities are increasing day by day, motivating people of smaller towns to immigrate to the capital. Subway system expansion is also a short-term solution, according to the “shifting the burden” archetype. Increasing the subway capacity improves the traffic problem; however, we will still face transportation problems in the near future, and we will keep investing the transportation facilities in matching supply and demand.

Finally, it seems that the only way to solve Tehran's traffic congestion is the decentralization of facilities from Tehran. So, the government should spend the budget initially allocated to developing the subway system and highways in Tehran on improving the living conditions in smaller to decrease the immigration rate. They should also consider handing over the development and management of the subways and highways in Tehran

to the private sector. Of course, even then, enough incentive needs to be provided for potential domestic or foreign investors.

To simultaneously develop the Tehran’s subway system as well as improving living conditions in smaller cities, officials may decide to do the opposite of what was proposed here. That is, they themselves try to develop Tehran's facilities without utilizing the help of the private sector. Despite the private investors' reluctance to invest in Tehran, the "success for successful" archetype here also makes the private investor much more motivated to invest in Tehran rather than in other cities.

Finally, and most importantly, the government should prevent the assignment of the infrastructure projects to the rental and exclusive companies, because in the end, according to the previous experience, it will end in significant time and cost overruns, and the projects will be finished with much lower quality.

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