

# A Model for Estimating the Friction Cost of Accidents in Urban Roads

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## Abstract

Injuries caused by accidents have various economic, social, cultural, environmental, health and human impacts, and in order to understand the extensive range of these losses and allocate sufficient resources to control it, the amount and quantity of losses must be properly specified. One of the subjects related to accidents is the costs that it imposes on the government and society, and in order to reduce these costs, it is essential to take serious measures. Given the fact that various aspects of the cost of accidents have been discussed in other studies, while the friction cost has not been adequately addressed, the present research attempted to estimate the friction cost of urban accidents. In this approach, the types of urban road accidents are separated in terms of severity, and a calculation method is provided to calculate the friction cost, which includes the cost of replacement, new employment, and training caused by accidents. Finally, due to the importance of Tehran and the high number of accidents in this city, the friction cost was estimated for this city. The friction costs imposed on the economic system as a result of the accidents occurred in Tehran in 2020 are equal to 730, 911, 800, 000 Rials. The results of these studies can be utilized for a more accurate estimation of the cost of accidents and the allocation of safety budgets to urban roads and urban areas.

**Keywords:** accident costs, friction costs, urban roads

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## 1. Introduction

A traffic accident is a street or road traffic accident in which at least one vehicle collides with another vehicle, or with another road user, or a stationary object on the side of the road, or any other dangerous situation that usually results in financial or life damage. Accidents are one of the main causes of death worldwide. Statistics presented in Iran denote that after cardiovascular diseases, traffic accidents are the second cause of death in all age groups and the first cause of death in the age group under 40 [Sheikholeslami et al., 2020]. Pedestrians, cyclists and motorcyclists are more at risk than drivers and passengers of cars and other vehicles and are referred to as vulnerable road users. Accidents have different factors, including road and environmental hazards, human factors (cognition [Asadamraji et al., 2022], hazard perception, etc.) and vehicles. Meanwhile, drivers have one of the most crucial roles in preventing traffic accidents [Nadimi et al, 2022], so that a driver endangers not only his life, but also the lives of others by driving unsafely.

At the same time, the significant effects of environmental factors, unsafe cars, etc. on the occurrence of traffic accidents or their prevention should not be ignored.

Injuries caused by accidents have various economic, social, cultural, environmental, health and human dimensions, and in order to understand the extensive range of these losses and allocate sufficient resources to control it, the amount and quantity of losses should be properly specified. For this reason, different countries of the world, especially developed countries, have been regularly and systematically calculating traffic accident losses and injuries, especially from the economic aspect, for about 60 years, and the results obtained have been seriously considered in decisions about the way of resource allocation.

In addition to the many sufferings that the victims endure, road accidents can make a family poor, and the survivors and their families are involved in the long-term effects of this event, including the costs of medical care and rehabilitation, as well as the cost of funeral expenses, and loss of the head of household (Kazemi et al., 2014) Traffic accidents and events can also put pressure on the country's health system, which is mostly due to insufficient resources. Low and middle income countries have a high burden of deaths caused by traffic accidents [Sugiyanto, 2017].

In recent years, the Islamic Republic of Iran has also become one of the countries with a high incidence of accidents, so that in the studies and reviews of the World Bank, Iran's situation has been mentioned as a critical situation concerning traffic accidents (Mehrgan et al., 2010). Nevertheless the studies related to the economic dimensions of traffic on the roads in a safe way, the improvement of commuting conditions in cities and outside the cities, safety processes in the roads, equipment and controls, and in general traffic safety in the country, and especially the cost of accidents, have been rarer (Hanifezadeh and Chehrenejad, 2016).

In addition to the growing heavy costs of casualties, injuries, and the loss of objects, deep psychological, cultural, and social costs of traffic accidents are an important issue for officials, managers, policymakers, and police forces. Thus, it is necessary to calculate the cost of traffic accidents and find scientific, logical and systematic ways to solve the problem And For optimal budget allocation (Asadamraji, 2022). Determining the cost of traffic accidents, in addition to showing the heavy burden it imposes on the society, sheds light on the contribution of the departments involved in the accident.

One of the most important challenges in the traffic safety management process at the micro and macro levels is introducing the subject of the accident cost and its related concepts to the public [Harmon et al., 2018], because it is

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necessary to familiarize the officials and planners and decision-makers of the society at the macro level and even the public people with the huge risks and heavy losses of accidents and the profitability of investing in improving traffic safety, which the people might have difficulty in understanding and accepting it [Rajeev and Bhandarkar, 2022].

Due to the high number of accidents and the heavy and growing cost of casualties, injuries, and the loss of objects, as well as the deep mental, psychological, cultural and social costs of traffic accidents, the problem of accidents and the resulting costs are a matter of concern for the authorities, managers, and policy makers, as well as for experts and specialists in different planning departments of transportation systems and economic evaluation of safety and transportation projects. Therefore, planners at the micro and macro levels of transportation-related sectors undertake more and more serious measures to investigate the cost of accidents and find scientific, logical and systematic ways for performing the related calculations [Zhong and Sun, 2022].

For example, the quality of life lost due to death or injury can be quantified by estimating the value people place on their lives (e.g., by determining the cost they would pay to avoid the risk of death or injury) [Mon et al., 2018], which is often determined based on the expressed preferences of people. These consequences of injury accidents are considered as parameters that can impose secondary costs on the system, because double pain and sorrow, reduce the efficiency of the individuals, or decrease the quality of life.

The costs of accidents are divided into two components: internal costs and external costs, where external costs are considered more important. External costs include the cost of human lives and the negative economic effects of disabilities and psychological injuries, which may persist long after the accident. It does not mean that other costs, which are interpreted as internal costs, are not important, but

considering that human life cannot be valued with any scale, therefore it will be placed in the first step in prioritizing costs [Elvis, 1994].

On the other hand, social justice is one of the implications of the concept of justice, which means the fair allocation of resources in a society. In this sense, the law must achieve an acceptable level of real and formal justice and must guarantee a fair distribution of resources and equal opportunities. One of the explicit examples of this principle is the establishment of safety in transportation and the absence of traffic accidents for road users, or the incident with the least effects and injuries and the fastest compensation process. Considering that in most countries, including the developing countries, traffic accidents that target the active labor force not only cause the primary costs of accidents, but also lead to secondary costs. Thus, it is necessary to take measures to minimize or reduce these costs.

In this regard, it is necessary to conduct adequate and correct studies regarding the investigation and estimation of the cost of accidents in urban roads in all developed and developing countries. One of the costs that is usually ignored in estimating the cost of accidents is friction costs. These costs include the costs of replacing a person who died in an accident or a person with a permanent disability, as well as education costs and employment costs. The present study aims to present a model for estimating the frictional costs of accidents, and finally it is estimated for one year in Tehran. For this purpose, it was assumed that the costs of accidents include direct and indirect costs, and in order to calculate the friction costs, the latest figures of salaries and benefits of the last year were used.

## 2. Literature Review

The economic costs of accidents can include all the costs that arise from accidents or as a result of accidents. The cost of traffic accidents includes several components, such as medical costs, cost of lost production, cost of damage to

equipment, administrative costs, etc., some of which are tangible and some are intangible. Also, the cost of the lost time should also be considered in costs caused by traffic accidents. In general, the costs caused by accidents constitute a large part of the total traffic costs imposed on the economy of a country.

It should also be noted that part of the costs related to road accidents are considered as the external costs. In other words, the people involved in the accident and the insurance companies are not required to pay them, while other costs, such as the costs of pain and grief are generally defined as non-economic costs (which, it should be noted, can also be converted into economic costs). Overall, external costs are considered as any adverse effects that are not seen in the main process (such as production and consumption), but these costs have arisen as a result of the secondary activities of each of the components, while none of the components of the process are required to pay it. Previous studies have divided the external costs of accidents into the following three groups [Maibach et al., 2008].

Systemic external costs that are generally imposed on the government and are not borne by any of the road user groups;

Physical external costs imposed by one of the parties involved in a traffic accident to another;

External costs related to the volume of traffic, which is related to adding another road user to the consequences of a traffic accident.

The sum of the first two costs is expressed in terms of kilometers traveled and presents the average external cost of an accident. In order to clarify the calculations, the third part (limit cost) is considered, which can be regarded as bigger, smaller, or equal to the average cost according to the existing conditions.

In different countries, even in less developed countries, various studies, reviews, experiments and modeling have been conducted in order to identify, predict and evaluate accidents and their costs. Naturally, countries like China, which are always faced with a high volume of

vehicles on the roads due to their high population and continuous transportation needs, encounter a higher probability of accidents compared to less populated countries like Sweden. Therefore, it is necessary to carry out time, cost, individual and social analyzes related to traffic accidents according to the existing conditions in populous countries.

The comprehensive costs of accidents are a combination of the visible effects caused by accidents (such as economic costs) and the costs related to the pain and suffering caused by the accident (lost quality of life), and the comprehensive costs are expressed in order to include all the effects resulting from an accident [Blincoe et al., 2015].

In the studies that were conducted in 2010 in the United States concerning the calculation of the social and economic cost of accidents and were revised in 2015, the most important components of the cost of accidents in this country were introduced [Pukalskas et al. 2015].

Accident cost components introduced in this study include lost productivity, property damage, medical costs, rehabilitation costs, legal and court costs, cost of emergency services such as medical, police and fire services, insurance administration costs, and employer costs.

Some claim costs are easily estimated from insurance data. These include not only handling insurance claims and legal fees, but also property damage. Insurance data is also important when analyzing accident costs.

To analyze insurance costs in the United States, information on premiums collected and claims paid by insurers was obtained from the Insurance Service Office (ISO), a data collection agency. The company, which collects data from a wide range of car insurers, used this data, along with national insurance statistics and accident data, to analyze the following: [Lemaire, 2013].

In general, in studies conducted in European countries, accident costs are classified into six groups. These costs include medical and non-

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medical rehabilitation costs, lost production, human costs, property damage, administrative costs, and other costs [Kasnatscheew et al., 2016].

The Victoria Transport Policy Institute in Canada prepared a report in order to review the effects of accidents and the resulting costs. Types of accident costs, how to measure these costs and their changes according to the type of vehicle and existing conditions, are among the cases presented in this report.

Estimating market costs, such as car damages, medical costs, and disability compensation, is relatively easy and can be calculated by various accident cost estimation methods, some of which are mentioned in this report as follows. These methods include the following:

- Willingness to pay (WTP) Method
- The Potential Years of Life Lost (PYLL) Method
- Disability Adjusted Life Years (DALYs) Method
- Human capital method
- Comprehensive approach [Litman, 2013].

In the studies conducted by the Ministry of Transport of New Zealand, which was prepared in 2018 on the social costs of fatal and injury accidents, the average social costs of accidents for each injured person and each accident were estimated based on market prices in 2018. In the aforementioned report, the details of the cost of social accidents and its calculation steps are presented [Best and Burke, 2019].

Although studies confirm the much higher costs of annual accident casualties and the resulting costs in developing countries than in developed countries, the development and application of economic models for estimating the costs of accidents, as well as the resulting casualties and injuries, are generally focused on developed countries and less research has been done on the developing countries. Nevertheless, different models have been used in these countries in recent years and the costs have been estimated [Bougna et al., 2022].

In the studies conducted on the cost estimation in Kuwait, the human capital method has been introduced as one of the most important methods for estimating the cost of accidents [Al-Rukaibi et al., 2020].

In studies conducted in China, the economic costs of accidents include the following:

- Expenses related to objects and assets
- Human costs
- Other costs [Tan et al., 2020].

As one of the top countries in accidents, Thailand needs to increase public awareness about the economic losses caused by accidents. In this regard, several studies have been conducted in Thailand on identifying accident cost factors and cost calculation methods. The safety assessment of Thailand's roads, the cost of traffic accidents in Thailand, the possibility of calculating the loss of income over time in case of death, and the collection and analysis of extensive data are among the measures taken in this regard. The survey showed that the major accident-related costs in Thailand are related to severe injuries and disabilities, and the costs caused by the deaths are in the next rank, followed by the minor injuries. Studies have indicated that the cost of accidents in Thailand constitutes about 0.8% of the gross domestic product of the country [Chantith et al., 2021].

Examining the costs of accidents in recent years in different countries has provided new approaches for estimation. For example, Bangladesh has also estimated the cost of accidents based on an in-depth analysis of fatal and injured accidents [Ahsan et al., 2021].

One of the weaknesses of most proposed models is not paying attention to driver's behavioral issues and feelings while driving and quantifying it [Sheikholeslami et al., 2023]. Of course, there were researchers who paid attention to this issue and their studies were consistent with the positive psychology paradigm that shows emotional responses to positive outcomes are not necessarily equivalent (in size) to the emotional responses

of equivalent negative outcomes, leading to asymmetric responses (Fry and Farrell, 2023). The investigation of different countries indicated that the costs of accidents include different parts, but less attention has been paid to the friction cost, which consists of the real costs of recruiting and training new employees and the real costs of professional rehabilitation.

### 3. Research Method

Friction cost is created due to the temporary or permanent absence of the injured from the workplace and includes the costs that the employer spends on the training and replacement of new staff, as well as finding a new job for the person, the variables needed to calculate the non-friction costs of the injured, and his retraining.

#### 3.1 Parameters for Calculating the Friction Cost of Accident

To calculate non-friction costs, the following parameters are needed:

- A. The average cost of training a new person to start a career in the work environment;
- B. The average cost of finding a new job for the injured person and retraining.

It is also assumed that the statistics and information received about accidents and costs from organizations are valid

#### 3.2 Data Collection

The data collection was based on the review of data sources of reliable organizations such as insurance, police, emergency organization, Iran Statistics Center and the Central Bank of the Islamic Republic of Iran. Of course, other organizations were also considered, but the main organizations whose data was collected for the last three years and which have the main violation in frictional cost of accident were the mentioned ones.

#### 3.3 Estimating the Total Friction Cost

In order to calculate the friction cost, it is necessary to divide the injury accidents according to severity. According to the available data, the accidents are divided into three categories: severe, moderate, and mild

injuries, and the analysis and review of the studies showed that the two cases of severe and moderate injuries have friction costs, and usually mild injury accidents does not require the replacement of the injured person. In line with the proposal of relations for estimating related costs, including education, advertisement and recruitment, it was considered that mathematical relations were proposed in a simple way. The total cost for fatal and injury accidents resulting in disability is calculated using the relevant relationships, the details of which are presented in the following.

- Friction cost

$$C_F = C_{FF} + C_{FD} + C_{FI} \quad (1)$$

$C_F$  = friction cost in total accidents;

$C_{FF}$  = friction cost in fatal accidents;

$C_{FD}$  = friction cost in severe injury accidents (resulting in disability);

$C_{FI}$  = friction cost in moderate injury accidents.

- Friction cost in fatal accidents

$$C_{FF} = C_{FH} * N_F \quad (2)$$

$C_{FF}$  = friction cost in fatal accidents;

$C_{FH}$  = cost of recruiting and replacing new staff;

$N_F$  = number of fatalities.

- Friction cost in severe injury accidents (leading to disability)

$$C_{FD} = (C_{FH} + C_{FE}) * N_{ID} \quad (3)$$

$C_{FD}$  = friction cost in severe injury accidents (resulting in disability);

$C_{FI}$  = friction cost in severe injury accidents (resulting in disability);

$C_{FH}$  = cost of hiring new staff;

$C_{FE}$  = cost of retraining and finding a new job for the injured person.

- Friction cost in moderate injury accidents

$$C_{FI} = (C_{FH} + C_{FE}) * N_{II} \quad (4)$$

$C_{FI}$  = friction cost in moderate injury accidents;

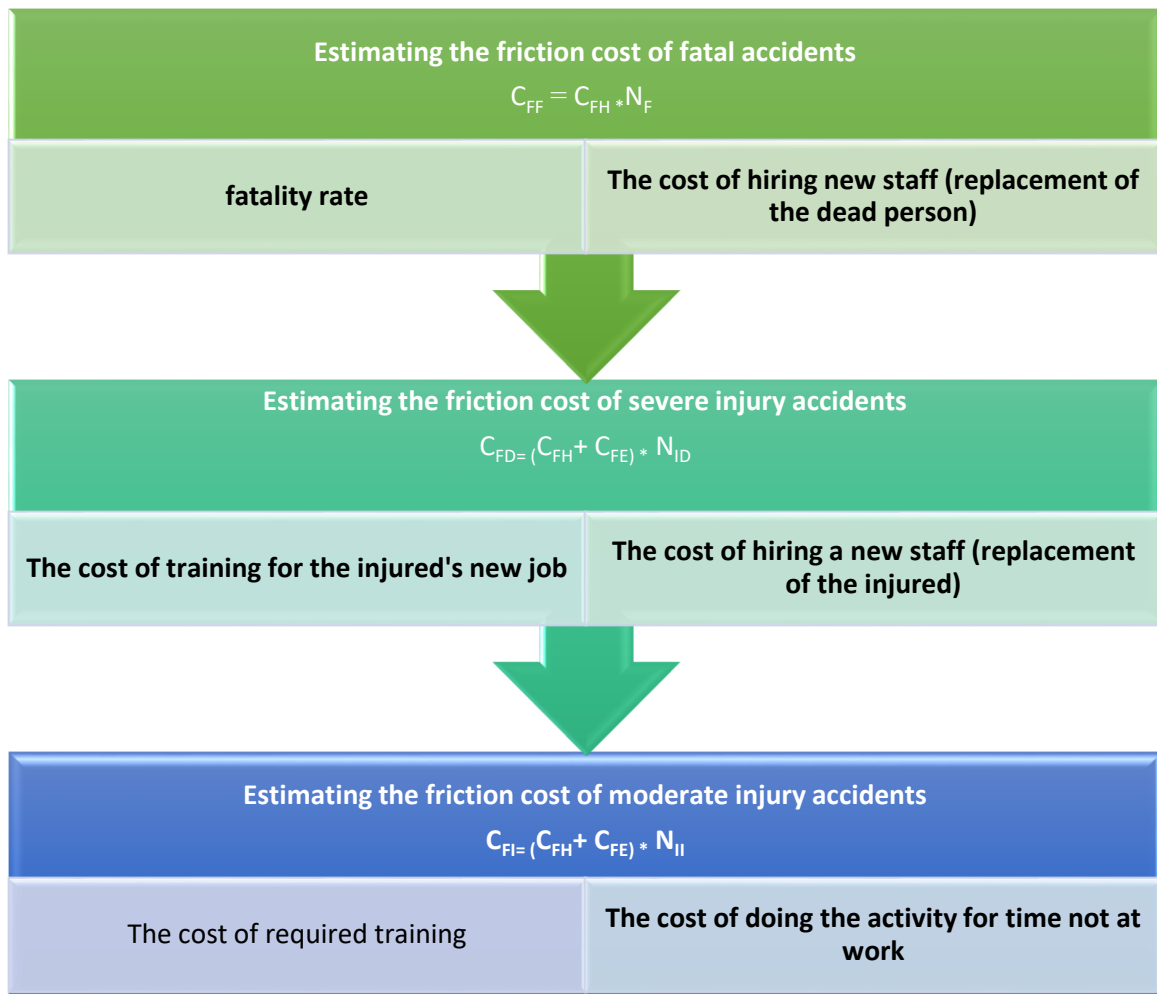
$C_{FH}$  = cost of hiring new staff;

$C_{FE}$  = cost of retraining and finding a new job for the injured person;

$N_{II}$  = number of people with moderate injuries.

The model used is shown in Figure 4..

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**Figure 1. Steps for calculating the friction cost of accidents**

### 4. Findings

In order to collect data and implement the presented model, the city of Tehran was chosen. The reason for choosing this city is the high number of accidents and fatalities caused by driving, as well as its being the capital, while it was easier to access data on the cost of accidents in Tehran. Some of the characteristics of traffic Table 1 shows the number of deaths and injury accidents in Tehran for the last two years, 2019 and 2020.

safety and accidents in Tehran are mentioned below.

#### 4.1 Details of Accidents in Tehran

Figure 2 shows the trend of deaths caused by accidents in Tehran. As Figure 2 shows, during the 10 years from 2009 to 2019, the trend of accident deaths has been decreasing, although the number of deaths is still high.

**Table 1. The number of deaths and injury accidents in Tehran in 2019 and 2020 (Tehran Municipality Transport and Traffic Organization, 2019-2020)**

Title	Year	
Criterion	2019	2020
Number of deaths	591	583
Number of injury accidents	20145	16419

As

Table 1 shows, the number of deaths caused by accidents in Tehran has decreased from 2019 to 2020, reaching 583. Moreover, Figure 3 indicates the risk comparison of the number of deaths per 100,000 between Tehran and some cities in the world. As observed, among the cities in the figure, the city of Tehran ranks fourth with a risk of 7.14 deaths per 100,000 populations, and it has an unfavorable situation in terms of traffic safety and accidents. This figure justifies the reason for choosing Tehran as a case study and investigating and estimating the friction cost of accidents in it. For the accidents of the last year of studies, in order to calculate their friction cost, more detailed analyzes were also carried out, the results of which are shown in Figure 3.

The items analyzed and evaluated in Figure 4 are as follows:

- Separation of accident fatalities into pedestrians, motorcyclists and drivers or car passengers
- Separation of the location of the fatal accidents
- Separation of the vehicle involved in the accident

Examining Figure 4 shows that more than 80% of the accident deaths in Tehran are vulnerable users, i.e. motorcyclists and pedestrians. In addition, most of the deaths have occurred on the highway, which shows that high speed and

improper passing across the wrong place are the causes of accidents, and special attention should be paid to these facts. Most of the accidents involving vulnerable users have also occurred due to car collisions, which have resulted in the deaths of users due to their vulnerability.

#### 4.2 Calculating the Friction Costs of Accidents in Tehran

In addition to the mentioned cases, the statistics of 2020 in Tehran indicated that 6,491 people were permanently disabled due to accidents and 15,579 ones were moderately injured. In the current study, it is assumed that if a person has a limb defect and permanent disability, his accident was of severe injury type, and if he suffered temporary disability, his accident was of moderate injury type.

In order to collect data on accidents and costs, the information of the Forensic Medicine Organization and the Police were used for the number of deaths, and for the information on the injuries caused by accidents, the information of emergency departments and hospitals were used. Among the data collected for this research, the data related to emergency was more accurate.

Tables 2 to 5 show the number of fatalities and the friction cost of fatal accidents and the number of injured people and the friction cost of injury accidents of different types.

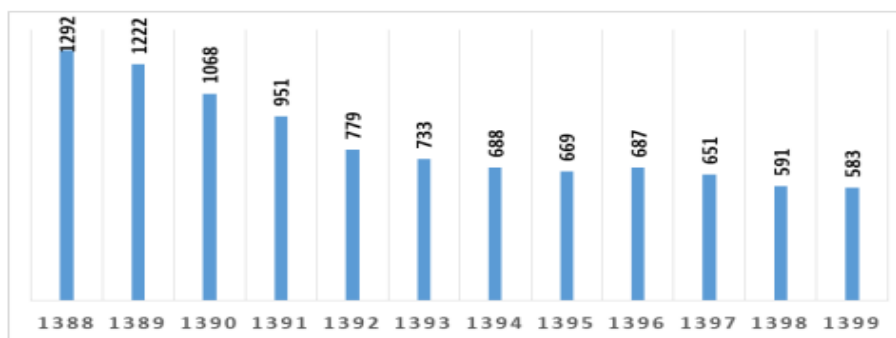
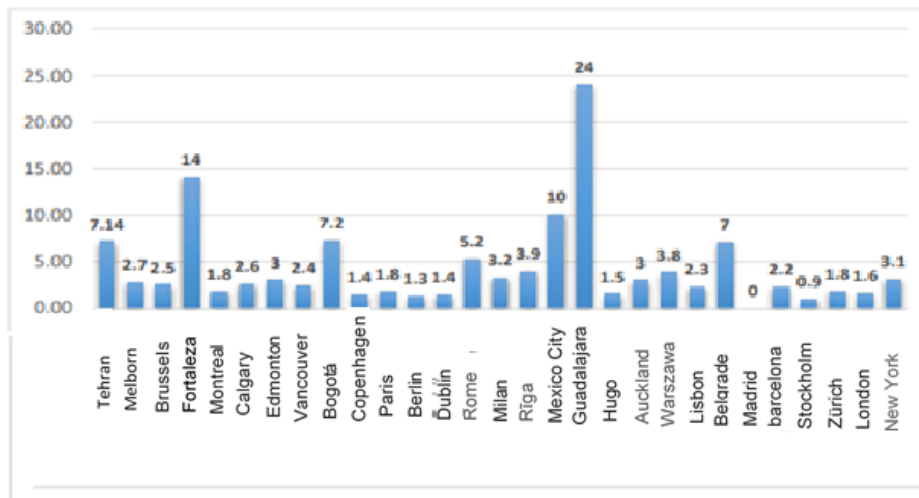
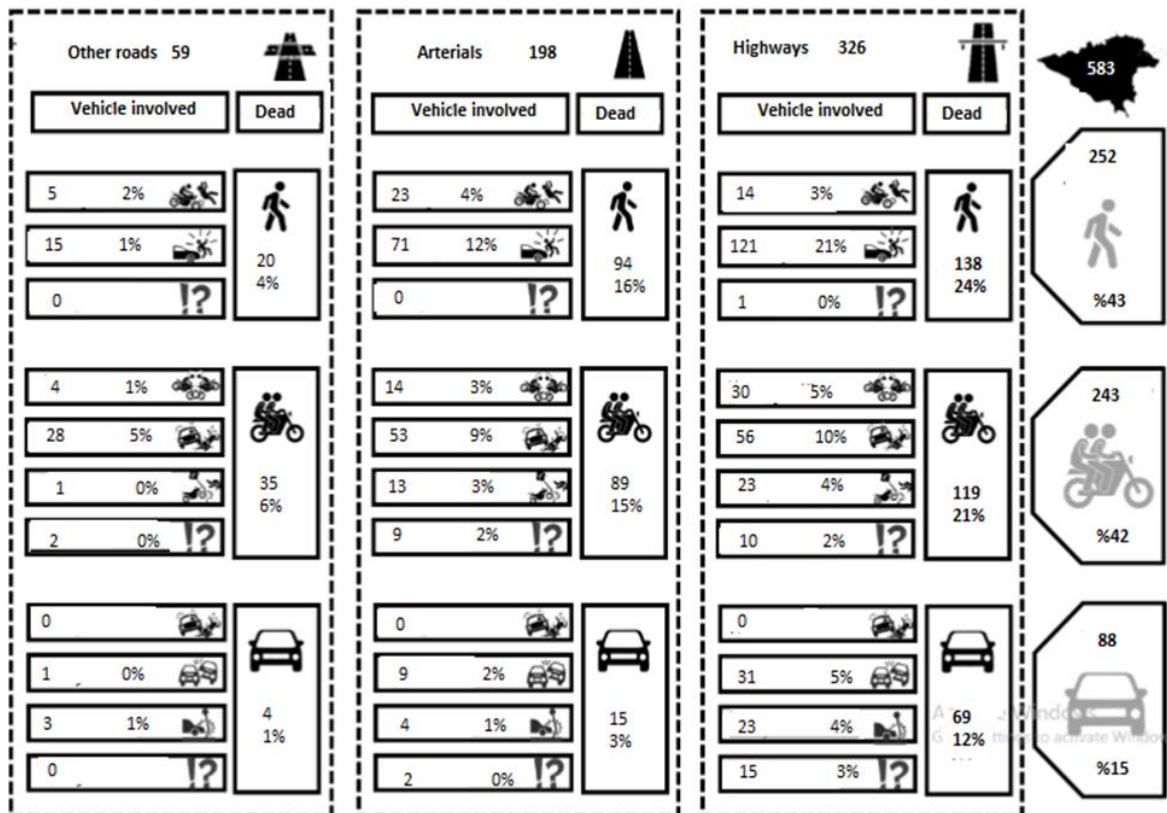


Figure 2. The number of fatalities resulting from Tehran city accidents during 2009-2019 (Tehran Urban Research and Planning Center (TURPC), 2021)

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**Figure 3. Comparison of the risk of accidents in Tehran compared to the big cities of the world (Tehran Urban Research and Planning Center (TURPC), 2021)**



**Figure 4. Analysis of fatal accidents in 2020 in Tehran**

**Table 2. Estimation of friction cost in fatal accidents in 2020 in Tehran**

Friction cost in fatal accidents	2,157,100,000
$C_{FH}$ = The cost of hiring and replacing new staff and training	3,700,000
NF = Number of fatal accidents	583

**Table 3. Estimation of friction cost in injury accidents in 2020 in Tehran**

The friction cost in severe injury accidents (resulting in disability)	59,717,200,000
$CFH$ = The cost of hiring new staff and training	3,700,000
$CFE$ = The cost of retraining and finding a new job for the injured person	550,000
Number of severe injury accidents (resulting in disability) = NID	6,491

**Table 4. Estimation of friction cost in moderate injury accidents in 2020 in Tehran**

friction cost in moderate injury accidents	11,216,880,000
$C_{FH}$ = The cost of hiring new staff	720,000
$C_{FE}$ = The cost of retraining and finding a new job for the injured person	0
NID = Number of moderate injury accidents	15,579

**Table 5. Estimation of the friction cost of accidents in 2020 in Tehran**

$C_F$ = Friction cost in total accidents	73,091,180,000
$C_{FF}$ = Friction cost in fatal accidents	2,157,100,000
$C_{FD}$ = The friction cost in severe injury accidents (resulting in disability)	59,717,200,000
$C_{FI}$ = Friction cost in moderate injury accidents	11,216,880,000

Table 3 also shows that people who are permanently disabled cannot work in their previous jobs and based on the data of Tehran city, the replacement costs are about 37,000,000 Rials and the new workforce needs training, which these costs are also friction costs. This is not the case for accidents with moderate injuries as much as for accidents with severe injuries. However, since there is one or several months of replacement due to an accident, a cost amount should be considered for it. In total, considering the friction costs of fatal and injury accidents, the results obtained for the friction cost of Tehran city in 2020 were estimated as 730,000,800,911,000 Rials (Table ).

## 5. Summary and Conclusion

Accidents are one of the current problems of Tehran city. This problem causes a considerable economic, social and psychological burden in different cities of the country and its consequences have involved many families. Various research studies have been conducted on the accident costs worldwide and each of them has adopted a specific approach and perspective toward these costs. Conventional methods for calculating accident costs include human capital, compensation and willingness to pay, each of which has its own approach and is used in different developed and developing countries. One of the costs that has not been paid much attention in different countries and is the focus of the present study is the friction costs of accidents. The friction costs of accident are the costs that are imposed due to the death or injury of people for replacement and

recruitment and new training. According to the studies, severe injury that leads to permanent disability or organ failure incurs the most friction cost, followed by fatal accidents, and after them moderate injury accidents also cause friction cost. The greatest friction cost is related to the cost of retraining and finding a job for the injured person.

One of the limitations of this research is the access to all statistics and information related to the cost of accidents and the difference in accident data of different organizations.

There are differences between the accident data and the costs caused by it in different organizations, and in order for the results of the analysis to be more accurate, all these statistics should be checked. The main reason is the lack of a suitable database and the lack of accurate communication between the scene of the accident and the hospital afterwards.

The findings of the present study can be used in the estimation of accident costs and in the prioritization of urban road safety solutions, budget allocation, traffic safety credit, and geometric design. In order to prioritize safety solutions, complementary studies, such as determining the crash reduction factor (CRF), will also be helpful. According to the classification of accidents in terms of severity, the identification of accident-prone points and their selection procedures can be reviewed) Considering the different coefficients of the types of accidents according to the costs (, which will lead to reforms in the budget allocated to urban areas. For future research, it is recommended that the cost of pedestrian,

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motorcyclist and cyclist accidents be estimated based on the willingness to pay method using the criteria convertible to the cost.

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