Abstract: Perusing three important elements (economic, safety and traffic) is the overall objective of decision evaluation across all transport projects. In this study, we investigate the feasibility of development of city interchanges, and road connections for network users. In order to achieve this goal, a series of smaller goals are required including determining benefits, costs of implementing new highway interchanges, quantifying the effective parameters, quantifying the increase in fuel consumption, quantifying the reduction in travel time and growth in travel speeds. In this study, geometric advancement of Hakim highway, and Yadegar-e-Emam highway was investigated just Macro from cloverleaf intersection with a low capacity to three-level directional intersection and enhanced cloverleaf. For this purpose, the simulation was done by EMME/2 software. The results of the method of net present value (NPV) were evaluated economically, and the benefit and cost of each one was stated precisely in different years (%28 improvement). The sensitivity analysis indicated that the cost of fuel, cost of travel time, cost of accidents and cost of pollutants have the highest impact factor in this assessment respectively.

Keywords: Urban Interchanges; Macroscopic Analysis; EMME/2 Software, Case Study

1. INTRODUCTION

Annually, billion IRRs is spent for traffic performance improvement, smoothing traffic flow and reducing travel time in metropolises [1]. Construction of a grade-separated interchange is a high-cost project, which takes place for physical separation of traffic routes, continuous traffic flow, decreasing delay time and increasing capacity of intersections. However, evidence has shown that construction of a grade-separated interchange can increase travel time and delay time in the adjacent intersection [2]. So, choosing the best type of Interchange under different traffic conditions can greatly mitigate this adverse effect [3], [4], and [5].

One of the most important processes of planning is evaluating several different options to achieve a common goal to ensure that the best option is chosen and other options are excluded. Increasing the financial value of the project leads to the increasing importance of economic evaluation [6].

The purpose of constructing interchanges is to creating levels through which vehicles can move in different directions without collisions with other vehicles. Traffic capacity per line decreases in at-grade
interchanges [7]. Constructing interchanges with different levels, are the best, safest, fastest and at the same time the most expensive solution to passing in cross directions. Accordingly, due to increasing traffic volume at the intersection of roads, increasing accidents, massive waste of time and subsequently increased fuel consumption and vehicle operating costs and intensified environmental pollution such as noise pollution and air pollution, interchanges were used inevitably [8], and [9]. Over time, it was found that the construction of an interchange cannot be a permanent solution to problems caused by the increasing number of vehicles and population of cities.

Finally, we need to increase the capacity of highway interchanges. One of the ways to increasing the capacity of interchanges is promoting the geometric characteristics of interchanges [10], and [11].

An interchange can be a useful and an adaptable solution to improve many intersection conditions either by reducing existing traffic bottlenecks or by reducing crash frequency [12]. However, the high cost of constructing an interchange limits its use to those cases where the additional expenditure can be justified. Enumeration of the specific conditions or warrants justifying an interchange at a given intersection is difficult and, in some instances, cannot be conclusively stated. Because of the wide variety of site conditions, traffic volumes, highway types, and interchange layouts, the warrants that justify an interchange may differ at each location. The following six conditions, or warrants, should be considered when determining if an interchange is justified at a particular site [13]:

- Design designation
- Reduction of bottlenecks or spot congestion
- Reduction of crash frequency and severity
- Site topography
- Road-user benefits
- Traffic volume warrant

The first cloverleaf was opened in Woodbridge Township, New Jersey (quite the surprise) in 1929, at the junction of Routes 4 and 25. This is now the intersection of US 1/9 and NJ 35, and as of about 2004, the interchange is no longer a cloverleaf. (Fittingly, an adjacent cemetery is named Cloverleaf Cemetery). The classic cloverleaf allows "non-stop" full access between two busy roads. Traffic merges and weaves, but does not cross at-grade; unless the interchange is too congested, no stopping is required. The colloquial "cloverleaf" is the same as the more technical "full cloverleaf", as one can omit ramps to get a partial one. The cloverleaf is (on paper) the simplest way to connecting two freeways. Bridges are only required to separate the two roadways. If land is expensive, so too can be the cloverleaf, which becomes a choice between tight turning radii (and lower design speed) or lots of consumed land. Note that most loop ramps are banked to counteract centrifugal forces [13].

Typically, a cloverleaf is used where a freeway intersects a busy surface street, though many older freeway-freeway interchanges are also cloverleaves [14], and [15]. As we will see, the full cloverleaf is not considered as applicable in some situations now as it might have been a few decades ago. In several places cloverleaves have been replaced with either signalized interchanges or higher-capacity directional interchanges with flyovers [16].

2. METHODOLOGY

Basically, implementation and exploitation of each transportation plan in road networks can have a positive effect on transport and traffic of a city, region or area, resulting in improved traffic conditions. But what is of considerable importance is comparing the benefits and costs of implementing the plan in order to assess its economic value [17]. In this study, a general method is presented for economic evaluation of implementation of traffic plan as a grade-separated interchange. According to Fig. (1), in this study, there is a new way to looking at the highway interchanges, which is a macroscopic view. Thus, it is expressed as a member of the urban transportation network with a very broad sphere of influence and effects of trans-regional and macroscopic view. Therefore, two logical scenarios were defined and after the simulation in macroscopic software EMME/2, network information was obtained. In order to compare the parameters of
travel time, safety, environment, and fuel, these parameters are converted to economic values (IRR) to
determine to what extent the plan is justified.

In this study, the microscopic view was not discussed. Using the statistical models based on Tehran
Transport and Traffic Studies and EMME / 2, the macroeconomic software, all effects of the change in the
highway network were investigated, as well as the upgrading of the geometric characteristics of macroscopic
exchanges in the Tehran highway network was evaluated. In this case, only the base year of the plan was
not enough, and for 15 years, these effects on the highway network, due to the increase in the population
and ownership of the car, and the use of personal and public car were reviewed.

Fig. 1. Methodology of the study

Previous studies have shown that these long-term changes are also beneficial or possibly harmful to the
community. On the other hand, the point that is often not seen in this assessment (despite the great
The importance of highway exchanges projects is the costs incurred by users of the urban transportation network during the execution of such projects. These costs include costs of inaccessibility, increasing the length of the route, changing certain routes that were used in the past, land use, etc. Typically, peak traffic hours at 2 stages in the morning and at night are the basis for designing the traffic load. But the point that is very important is that in analyzing and evaluating projects, especially at very large levels, it should not be evaluated economically all day according to the peak hours of the city. During the night hours, there are times like midnight, evening, etc. Due to the low traffic volume of vehicles, the time spent and the increase in fuel consumption, there is no increase in environmental pollution. So, as the peak-based design is considered to be an overestimated design, it can be useful, but the economic assessment based on peak hours of the city has a high error rate and is somewhat irrefutable. But in the current research methodology, the evaluation is based on 24 hours a day, which indicates high accuracy.

2.1 BENEFITS

As can be seen in Tab. 1, the benefits of the project are as follows.

| Benefits of the project [18], [19] |
|-----------------------------------|

2.2 COSTS OF AT-GRADE SEPARATED INTERSECTION CONSTRUCTION

Based on studies, the most important elements of the cost of constructing an intersection are: land ownership, engineering studies, monitoring of implementation activities, post-construction maintenance, and costs due to the limitations imposed on citizens for delays in network to carry out the construction [21].

2.3 ECONOMIC EVALUATION OF AT-GRADE SEPARATED INTERSECTION

In this study, the method of "net present value" is recommended to assess the economic value of intersections. Net Present Value (NPV) is a formula used to determine the present value of an investment by the discounted sum of all cash flows received from the project [22]. The formula for the discounted sum of all cash flows can be rewritten as:

\[
NPV = -C_0 + \sum_{i=1}^{T} \frac{C_i}{(1 + r)^i}
\]
When a company or investor takes on a project or investment, it is important to calculate an estimate of how profitable the project or investment will be \[22\]. NPV is equal to the equivalent value of the profits from the investment to the start of project exploitation, where the value of operational costs, maintenance cost and cost of final equipment exploitation at the start of operation are deducted \[23\].

### 2.4 Determining the Period of Profitability of At-Grade Separated Intersection

Based on economic principles, exploitation of an at-grade separated intersection would be economically justified when the desired profitability is reached before the end of useful life \[24\]. The basis for determining the profitability index will be "net present value", where the values for each of the years after the start of exploitation is calculated, and the first year in which the index "NPV" has non-negative values, will be considered as the year of project profitability. Costs and benefits of the project in the years after the start of exploitation will be the basis for determining this index, in which "NPV" benefits related to different years will be determined with software EMME/2 and based on the proposed methods using travel demand of the same year.

### 2.5 Characteristics of Proposed Plans

In order to evaluate the effectiveness of the proposed method, two different designs of at-grade separated intersections were considered at the current intersection.

#### 2.5.1 The Proposed Plan of Directional Intersection

The proposed plan of alternative intersection is outlined in Fig. 2, which is a three-level directional intersection, where all of the turnings are grade-separated and independent, which will be done with high speed. The movements are:
- The two left-turn movements and major route of Mohammad Ali Jinnah in the underpass of Hakim Highway Bridge.
- The turn-right movement at the ground floor.
- The two left-turn movement on the upper floor.

According to the proposed plan, the intersection is combined of six bridges where two of them are the main link between the eastern and western parts of the city and the other four bridges are for ramp. Including improved areas in the main highways, this plan has about 8 KM circulation paths and ramp, 25000\(m^2\) bridges and more than 1000\(m^2\) walls.

#### 2.5.2 The Proposed Plan for Enhanced Cloverleaf Intersection

The current plan of Hakim and Yadegar-e Emam highway is cloverleaf intersection (Fig. 2), but the northwest ramp has occupied a very large area, increasing the length of the route and reduces driver sight distance in parts of the route. Further, at this intersection because of the low width at the main bridge, ramps and loops, current demand cannot be satisfied. In particular, there will be enormous queues during peak hours. In this plan, current cloverleaf intersection will grow, and also the width of ramps, loops and bridge will increase. The geometric design of northwest loop will become a standard loop with appropriate sight distance and enhanced cloverleaf intersection will develop with more capacity. This plan has been shown in Fig. 3.
2.6 SIMULATION PROCESS OF TRANSPORT SYSTEMS AND TRAFFIC IN TEHRAN

As the simulation process in the current situation, in construction phase and years after exploitation is the most important step in estimation of costs imposed on citizens during the construction as well as the benefits arising from the utilization of the intersection, this section deals with the simulation process of transport systems and traffic in Tehran, with the latter implemented in EMME/2 software.

2.6.1 SUPPLY

Supply includes transit and street network information. Street network information includes information relating to each street as a link, each intersection in the street network as nodes, forbidden turning information and traffic lights. Further, transit information including bus lines, the number of stops per bus line, the length, speed of the bus line, and origin-destination path were imported to EMME/2 software.

2.6.2 DEMAND ESTIMATING

Fig. 4 demonstrates the general trend of demand estimated for internal trips of residents of Tehran. The demand estimation process of other trips of residents and non-residents travel are showed in Fig. 5. According to the Fig. 4, at first using calibrated models of generation and attraction, the generation and attraction of daily trips of 560 traffic zones of Tehran is predicted for the future. The prediction is based on non-home based trips and home base trips (7). Trip distribution models have various types, and growth models have acceptable accuracy in estimating trips between zones with regards to the intended planning horizon in Tehran transportation master plans. The Fratar model was suitable more than conventional growth models.

Due to trip purpose, some important vehicles are imported in the modeling. Note that the important vehicles are those vehicles with a major contribution in travel (9). Table (2) shows the calibration result of trip generation and attraction model, and Table (3) provides the result of vehicle choice model calibration in Tehran. Vehicle choice models are Logit in this study [25].
### Tab. 2 Trip generation and attraction models of Tehran for each trip purpose

| Trip purpose                        | Trip generation models                                                                 |
|-------------------------------------|----------------------------------------------------------------------------------------|
| **work**                            | \( T_{iw}^w = \frac{0}{569VP_i} \times ER_i + 1/107ER_i \)                            |
| **Education**                       | \( T_{i}^e = \frac{3}{070VP_i} \times STR_i + 0/903STUR_i + 0/020DIST_i \times P_i \) |
| **Buy**                             | \( T_{i}^{ab} = \frac{0}{061P_i} + 0/414VP_i \times P_i \)                            |
| **Entertainment and other**         | \( T_{i}^{en} = \frac{0}{073P_i} + 0/373VP_i \times P_i \)                            |
| **Non home base**                   | \( T_{i}^{nhb} = \frac{0}{490EMPE_i} + 10/213VP_i \times SHOP_i + 14485DB_i + 951DQ_i \) |

| Trip purpose                        | Trip attraction models                                                                 |
|-------------------------------------|----------------------------------------------------------------------------------------|
| **work**                            | \( TA_{i}^w = \frac{1}{620EMPE_i} + 2/420SHOP_i + 62694DB_i \)                         |
| **Education**                       | \( TA_{i}^e = \frac{3}{833VP_i} \times ST_i + 0/500STU_i + 26789DT_i + 9299D_{128i} \) |
| **Buy**                             | \( TA_{i}^{ab} = \frac{15}{760VP_i} \times SHOP_i + 0/195EMPE_i + 0/825HOSB_i + 15456DB_i + 3469DQ_i + 7474DF_i + 4607D_{444i} - 0/889SHOP_i \times DRA_i \) |
| **Entertainment and other**         | \( TA_{i}^{en} = \frac{122}{140PARK_i} + 0/040P_i + 7/364VP_i \times SHOP_i + 0/304EMPE_i + 4098DR_i + 1937DF_i + 1532DQ_i - 0/279SHOP_i \times DRA_i - 0/208EMPE_i \times DRA_i \) |
| **Non home base**                   | \( TA_{i}^{nhb} = \frac{0}{458EMPE_i} + 11/526VP_i \times SHOP_i + 11706DB_i + 1173DQ_i \) |

\( P_i \) = Traffic zone population  
\( VP_i \) = Per capita ownership of private car in traffic zone \( i \)  
\( ER_i \) = Resident employment in traffic zone \( i \)  
\( STR_i \) = The number of resident school students in traffic zone \( i \)  
\( STU_i \) = The number of resident university students in traffic zone \( i \)  
\( EMPE_i \) = The number of staff in place of employment in traffic zone \( i \)  
\( SHOP_i \) = The number of shops in traffic zone \( i \)  
\( ST_i \) = The number of students at school in traffic zone \( i \)  
\( STU_i \) = The number of students at university in traffic zone \( i \)  
\( HOSPB_i \) = The number of hospital beds in traffic zone \( i \)  
\( PARK_i \) = The number of parks in traffic zone \( i \)  
\( DRA_i \) = Traffic zones covariate in traffic plan zone  
\( DB_i \) = Tehran Bazaar covariate (Traffic zone 1)  
\( DT_i \) = Tehran university covariate (Traffic zone 150)  
\( DQ_i \) = Main squares covariate (Imam Hossein, Enghelab, Valiasr, Khorasan, Tajrish, and Imam Khomeini) in traffic zones 16, 174, 151, 121, 401, 537.  
\( DF_i \) = Covariate of Ghezel Ghale square, second Square of Sadeghieh mall, second mall of Nazi Abad in traffic zones 197, 232, 139.  
\( DR_i \) = Covariate of Mellat park, laleh park, Shahbdalzym and Behesht Zahra in traffic zones 452, 274, 148, and 444.  
\( D_{128} \) = Covariate of Amirkabir university, Art university and Alborz High School (Traffic zone 128)  
\( D_{444} \) = Covariate of Ray city (Traffic zone 444)
Tab. 3 Vehicle choice models of Tehran for each trip purpose

### Work trip

| First level          | Car                       | $U_{ij}^{e} = 0.697568 - 0.034575 \times \text{TIMCAR}^{ij} + 9.008179 \times \text{OWNCAR}^{i} - 0.588848 \times \text{DESFLAG}^{j}$ |
|----------------------|---------------------------|-----------------------------------------------------------------------------------------------------------------|
|                      | Motorcycle                | $U_{ij}^{\text{MOT}} = -0.480759 \times 0.047222 \times \text{TIMMOT}^{ij} + 1834525 \times \text{OWNMOT}^{i}$ |
|                      | Public transportation     | $U_{ij}^{\text{BUS,TAX}} = \theta \ln \left( \exp \left( U_{ij}^{\text{BUS}} \right) + \exp \left( U_{ij}^{\text{TAX}} \right) \right)$ |
| Second level         | Bus                       | $U_{ij}^{\text{BUS}} = 0.330393 - 0.020389 \times \text{TIMIN}^{\text{BUS}} - 0.026496 \times \text{TIMBOT}^{ij}$ |
|                      | Taxi                      | $U_{ij}^{\text{TAXI}} = -0.048415 \times \text{TIMTAX}^{ij} + 3.100169 \times \text{OWNCAR}^{i}$ |

### Educational trip

|            | Bus                       | $U_{ij}^{\text{BUS}} = 0.88116900.012004 \times \left( \text{TIMBIN}^{ij} + \text{TIMBOT}^{ij} \right)$ |
|------------|---------------------------|-------------------------------------------------------------------------------------------------------------|
|            | Taxi                      | $U_{ij}^{\text{TAX}} = -0.03655720.030786 \times \text{TIMTAX}^{ij} + 8.253327 \times \text{OWNCAR}^{i}$ |
|            | Car                       | $U_{ij}^{\text{CAR}} = -1.044833 - 0.041592 \times \text{TIMCAR}^{ij} + 11.324764 \times \text{OWNCAR}^{i} - 0.582493 \times \text{DESFLAG}^{j}$ |
|            | Minibus                   | $U_{ij}^{\text{MIB}} = -1.104768 \times \text{DIST}^{ij} + 6.648515 \times \text{OWNcar}^{i}$ |

### Shopping trip

|            | Bus                       | $U_{ij}^{\text{BUS}} = 2.794484 - 0.013595 \times \text{TIMBIN}^{ij} - 0.015329 \times \text{TIMBOT}^{ij}$ |
|------------|---------------------------|-------------------------------------------------------------------------------------------------------------|
|            | Taxi                      | $U_{ij}^{\text{TAX}} = 1.967395 - 0.037180 \times \text{TIMTAX}^{ij} + 6.596312 \times \text{OWNCAR}^{i}$ |
|            | Car                       | $U_{ij}^{\text{CAR}} = -0.015029 \times \text{TIMCAR}^{ij} + 12443686 \times \text{OWNCAR}^{i} - 0.689367 \times \text{DESFLAG}^{j}$ |

### Recreational trip

|            | Bus                       | $U_{ij}^{\text{BUS}} = 2.725886 - 0.009414 \times \left( \text{TIMBIN}^{ij} + \text{TIMBOT}^{ij} \right)$ |
|------------|---------------------------|-------------------------------------------------------------------------------------------------------------|
|            | Taxi                      | $U_{ij}^{\text{TAX}} = 2.393202 - 0.033543 \times \text{TIMTAX}^{ij} + 5.379732 \times \text{OWNCAR}^{i}$ |
|            | Car                       | $U_{ij}^{\text{CAR}} = -0.015114 \times \text{TIMCAR}^{ij} + 13957626 \times \text{OWNCAR}^{i} - 0.374195 \times \text{DESFLAG}^{j}$ |

### Non home base trip

|            | Bus                       | $U_{ij}^{\text{BUS}} = 0.390002 - 0.008689 \times \text{TIMBIN}^{ij} - 0.041852 \times \text{TIMBOT}^{ij}$ |
|------------|---------------------------|-------------------------------------------------------------------------------------------------------------|
|            | Taxi                      | $U_{ij}^{\text{TAX}} = 0.334293 - 0.020176 \times \text{TIMTAX}^{ij}$ |
|            | Car                       | $U_{ij}^{\text{CAR}} = -0.012662 \times \text{TIMCAR}^{ij} - 0.705396 \times \text{DESFLAG}^{j}$ |
The results of deviation of demand models from various vehicles (Except bus) to public transportation due to new technology are provided in Table (4). Note that these models are the same for all types of intracity trips of residents (all trip purposes).

### Tab. 4 Results of calibration of demand deviation models

| Vehicle type | \( b^m \) | \( a^m \) |
|--------------|---------|---------|
| Car          | 19/198  | 1/559   |
| Taxi         | 2/668   | 4/794   |
| Minibus      | 19/198  | 1/652   |
| Bicycle      | 19/198  | 1/652   |

#### 2.6.3 CONVERSION OF TRAVEL DEMAND TO TRAVEL DEMAND MATRIX

What is important in urban transportation planning is travel demand based on vehicle [26]. Therefore, demand matrix \( T \bar{P}_{v}^{wm} \) must be converted to travel demand matrix based on vehicle, for all vehicles except bus. As shown in Table (4), this is done using information about the average number of passengers. By adding freighter trips to the mentioned matrix, the final travel demand based on vehicle in any time period \( t \) can be achieved (except bus). According to the considered Passenger Car Equivalent for each vehicle, these matrixes are converted as demand matrix in terms of Passenger Car Equivalent for each vehicle. Passenger Car Equivalent for each vehicle is provided in Table (5).

### Tab. 5 Passenger Car Equivalent

| Vehicle Type | Car | Pickups | Taxi | Minibus | Bus | Motorcycle | Lorry |
|--------------|-----|---------|------|---------|-----|------------|-------|
| Passenger Car Equivalent | 1   | 1   | 2    | 2.5     | 2.5 | 0.5        | 2.5   |

#### 2.6.4 ASSIGNMENT

Assignment is the last step of transportation planning (UTPS) which consists of two parts. The first part is known as car Assignment. It is related to vehicles which have no fixed and certain route. Given the network that users can use, they try to minimize their travel time. The second part is public transportation assignment, which is related to vehicles with fixed and predetermined route, such as bus and subway. Users, according to a certain plan, prefer to minimize the expected travel time [1].

#### 2.7 ESTIMATING COSTS OF CONSTRUCTION AND EXPLOITATION OF INTERCHANGE

Based on the evidence in the Technical Organization of Tehran Municipality, the approximate costs of the items listed in each of the two proposals of standard cloverleaf and directional interchanges are provided in Table (6).

### Tab. 6 Direct costs of construction and operation of the proposed Hakim-Yadegar-E-Emam interchange

| Cost type      | Monetary equivalent (million IRR) |
|----------------|-----------------------------------|
|                | Standard cloverleaf interchange   | Directional interchange          |
| Construction   | 314000                            | 403000                           |
| Acquisition and release | -                                | 164000                           |
| Annual Maintenance | 5500                            | 5500                             |

#### 3. RESULTS

Estimation of the costs imposed on citizens during the operation and construction of interchanges will be done according to the methods proposed in the previous chapter. Simulation of the street network of Tehran in both the status quo and network status during the operation and construction is the basis of estimating
these costs. For this purpose, the transport and traffic model in Tehran will be used in software EMME / 2. The changes in network performance indicators because of constraints caused by interchanges construction are demonstrated in Table (7).

| Index          | Distance Increasing (%) | Volume reduction (%) | Pollutants emission increasing (%) | Fuel consumption increasing (Litter) | waste time increasing (Hour) |
|----------------|--------------------------|----------------------|------------------------------------|-------------------------------------|-----------------------------|
| Change rate    | Directional              | 4.32                 | 0.04                              | 4.33                                | 28620924                    |
|                | Cloverleaf               | 35.8                 | 0.028                             | 3.51                                | 22912723                    |

3.1 COSTS DUE TO INCREASED TRAVEL TIME DURING CONSTRUCTION

Based on the method proposed in this study, the average value of travel time per person is required. For this purpose, the results of Tehran transportation master plan will be used, which is calculated by dividing GDP by the number of annual production hours of employed people. This index was calculated to be 20049.5 IRR per hour in 2013. With increasing 28620924 hours in network travel time, due to construction of the directional interchange, 576 billion IRR will be imposed on citizens. Moreover, the costs resulting from cloverleaf construction operation is estimated as 329 billion riyals.

3.2 COSTS DUE TO INCREASING FUEL CONSUMPTION

According to Statistics of fuel consumption optimization organizations, fuel consumption in Tehran is 14% gasoline and 88% petrol. Due to the low percentage of gasoline and the low price, petrol is considered for all fuel consumption. Price of 1 litter petrol was equal to 7000 IRR. Given 124325265 litters increase in fuel consumption caused by limitations resulting from construction of directional interchange, costs imposed on society is estimated as 866 billion IRR. Also, such costs are considered to be 495 billion IRR for constructing cloverleaf interchange.

3.3 COSTS DUE TO INCREASING ACCIDENTS

The total direct costs resulting from accidents in Tehran are around 1100 billion IRR (based on the statistics presented by Division of Insurance). Out of this value, around 4% are fatal accidents, 24% are injury accidents, and 72% are property damage accidents. With a growth of 4.32% in the traveled distances and increasing accidents, their costs are estimated to be 47 billion IRR, which will further increase the finished cost of the project. On the other hand, the amount of traffic passing through the black spots in the area of interest is very influential in the damage caused by accidents due to geometric promotion of the interchange.

According to information of Tehran traffic police and Tehran central insurance office, 3 important hot spots were determined in the plan area as demonstrated in Fig. 7. There is a direct relationship between the number of vehicles passing through the hot spots and number of accidents and consequently the cost of accidents. A major change in the network leads to increase or decrease in the capacity through the link. With estimating the traffic volume passing through these points before and after promotion of the intended interchange, one can determine what percentage was the former traffic volume crossing the black spots and what percentage of the alternative will pass through routes or Bypass.

3.4 COSTS DUE TO INCREASING IN EMISSION OF POLLUTANTS

In 2006, the World Bank published a report stating that pollutants cost in Tehran traffic network is around 700 million Dollars per year. These costs include: deaths from air pollution, treatment including hospital stays, outpatient treatments and the number of working days lost.

Tab. 8 The cost of different air pollutants in Iran
Accordingly, with respect to the 4.33% increase in pollutants emission of HC, CO and NOx based on Table (9), the additional costs imposed on the society caused by construction operation during construction of the directional interchange are estimated as about 366 billion IRR. Under similar circumstances, 215 billion IRR is estimated for cloverleaf interchange.

| Iran | $NO_x$ | $SO_2$ | CO | $NMVOC_s$ |
|------|--------|--------|----|-----------|
| Value ($/tonne) | 600 | 1.825 | 188 | 0.5 |

Thus, according to the description mentioned above, the total cost of the proposal of 0directional interchange and standard cloverleaf interchange in the beginning of the exploitation 2013 is according to Table (10).

| Pollutant | During construction (Kg) | Status quo (Kg) |
|-----------|--------------------------|-----------------|
| CO        | 898952107.3              | 86243217.6      |
| HC        | 113958772.6              | 108149728.5     |
| NOx       | 20669540.7               | 19821223.1      |

3.5 ESTIMATING THE INTERESTS OF INTERCHANGE CONSTRUCTION

The basis of estimating these benefits is estimation of the values of each cost factor and extent of reduction as the benefits of the plan. Thus, implementation of the three options will be discussed, including: the "status quo", "directional interchange" and " standard cloverleaf interchange". These options were implemented in Tehran transportation system simulation model with EMME/2 software in the years after the operation.

Based on the results presented in the above tables and comparing the two options of standard cloverleaf and directional interchanges, the advantages of using this interchanges in the network in each of the studied years are provided in Fig. 4-7.

In Figs. 4-7, the comparison between benefits of using directional and cloverleaf interchanges is illustrated in different operation years for each of the benefits: reducing travel time, reducing fuel consumption, reducing accidents and reducing pollutants.
In the comparison between the two proposed options for geometric promotion of the interchange, the directional interchange is 28% better than standard cloverleaf interchange. Also, during the construction of interchanges, this superiority is maintained. This shows that in spite of the initial higher cost, directional option has higher interests during the operation.

3.6 FINANCIAL EVALUATION OF PLAN

Comparison of costs and interests of directional and cloverleaf interchange in different years can be seen in Figs. 8 and 9, based on Net Present Value index. According to Figs. 8 and 9, both plans have a non-negative "net present value" in the third year. Since the profitability of the project is prior to the end of the plan’s useful life, therefore, the construction and exploitation of the studied interchanges are economically justified. It can be clearly proven that geometric promotion in highway interchanges has a strong justification from an economic standpoint, safety and traffic.
4. SENSITIVITY ANALYSIS

This section presents the sensitivity of final interest rate changes (or cost) of each option with respect to changes in measurement parameters. In other words, we want to know if the price (or cost) of a parameter changes, how much the ultimate benefit will change in return.
- The average change in total is 56% for every 1% change in the fuel price.
- The average change in total is 37% for every 1% change in the time value.
- The average change in total is 4% for every 1% change in the accident costs.
- The average change in total is 3% for every 1% change in the pollutant costs.

As shown in Fig. 10, in sensitivity analysis, the parameter of fuel cost has 55% efficacy in assessing the highway interchanges and changing in network. It is followed by travel costs, accident costs and environmental costs with 38%, 4% and 3% respectively.
5- CONCLUSION
There have been two scenarios for improving the geometry characteristics of the interchange. The first one has been for increasing the capacity and transforming the status quo to improve cloverleaf interchange. The second one has been directional exchange with the three-story bridge design. Table (11) shows the process and analysis results of EMME/2 software.

Tab. 11 The process and analysis results of EMME/2 software

| Type      | Reduction of travelled distance (%) | Reduction of fuel consumption (million litter) | Reduction of air pollution (%) | Reduction of travel time (million hour) |
|-----------|-------------------------------------|-----------------------------------------------|-------------------------------|----------------------------------------|
| Directional | 2.67                                | 74                                            | 2.88                          | 16                                     |
| Cloverleaf | 1.25                                | 33                                            | 1.25                          | 7                                      |

There are two methods for geometric improving of the interchanges:
- Method 1. Line capacity increasing.
- Method 2. Changing the interchange to another interchange with a higher capacity.

With geometric improving of the cloverleaf interchange, it is concluded that method 2 has 27% economic superiority.
- Directional interchange plan has a B/C=1 between the second and third years. After that, with much higher benefits than costs it will have a very favorable impact on the network.
- Directional interchange plan has a B/C=1 between the third and fourth years. Benefits increase with a lower slope than the directional option.
- A sensitivity analysis indicated that the fluctuations in the fuel price is most effective in improving geometric interchanges (coefficient: %55). Also, travel costs, accidents costs and environmental costs are 38%, 4% and 3% respectively.

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