

## **Investigating the Impact of Using Motorcycle Leg Protectors on Reducing Accident Injuries**

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### **ABSTRACT**

The use of motorcycle and their accident rate has grown significantly in Iran in recent years. Due to the higher vulnerability of motorcycle riders the numbers of injuries in motorcycle accidents are higher than other vehicles (about 54%).

The most vulnerable part of body in motorcycle accidents is the leg; as in about 60 percent of motorcycle accident that cause injuries, leg injuries are perceivable. One of the accessories which can be helpful in reducing leg injury, are the motorcycle leg protectors, especially the front leg protectors. In this paper, collects data and information about the accidents that cause injuries and the number of injured motorcycles which are equipped with leg protectors and of those which are not, and also the rate of using the leg protectors in the community of normal motorcycle riders and those who have had injury accidents, is analyzed. The data has been gathered from available accident data, vehicle counts, and interview with motorcycle riders. For the purpose of statistical analysis of the data, graphical analysis and statistical tests, i.e. the likelihood-ratio test in two communities, and K-test, has been used. Additionally, Chi2 test has been applied for analyzing the results and examining the validity of the data.

Finally, it has been concluded that according to the existing statistics, it can not be inferred that installing the front leg protectors significantly reduces the rate of injury accidents. However, observations and surveys reveal that these protectors have a positive impact on reducing the leg injuries in non-severe motorcycle injury accidents.

### **1- INTRODUCTION**

Accidents costs, life injuries and compensations resulting from accidents in Iran are very high in comparison to other countries of the world. This country is placed first from the viewpoint of ratio of

persons killed in road accidents each year. Large numbers of life, materialistic and intellectual capital is lost annually due to driving accident. More than 25000 persons killed, thousands injured and billions of tomans of compensation resulting from accident (on the basis of researches and estimations carried out, expenses of compensation and damages resulting from accidents in the country in the year 2001 was approximately 4000 million dollars it means more than 3.5% of GNP [1] resulted from driving accidents of the country.

By considering the causes of accidents we observe that the motorcycle riders are the most vulnerable class and that the motorcycle riders have remarkably more probability of losing their life in an accident. Also considering the cheap price of motorcycles, number of the motor vehicle is more in Iran especially in the capital city of Tehran (about one million motorcycles equal to 25% of total motor vehicles of the whole country in the year 2004 (12). Therefore, wide studies should be taken to decrease the damage incurred to motorcycle riders at the time of accident.

By considering the accidents of motorcycles it is evident that the most vulnerable limb of the body in motorcycle accident is legs in such a manner that about 60% of motor cycle accident resulted into leg injury of motorcycle rider (4). One of the effective means of decreasing the injury of this body limb is motor cycle leg protector (Guard) especially front leg protector. At the time of collision of motorcycle with other motor vehicle or ground, the front guards cause into probable decrease in serious injury. Samples of protectors used in Iran are shown in figure 1.

In this paper while considering the studies carried out in connection with injuries incurred to motorcycle riders at the time of occurrence of accident and role of front leg protector in decreasing the injury to motorcycle riders, the raw data relating to accidents of motorcycle in the city of Tehran is collected and a



**Figure1. a sample of leg protector used in Iran** number of motorcycle riders of Tehran city and riders suffered from injury accidents were interviewed. Then the collected data was evaluated using methods present for the analysis of accident data including graphical analysis, equality scale in two populations test in two societies and K test. Also, for the accreditation of results, Chi-square test was applied. Finally, considering the results of analysis carried out on data and information of interviews and questionnaires, the obtained result shows that installation of front leg protector does not cause to meaningful decrease in the ratio of occurrence of body injury of motorcycle riders. Although observations and questionnaires carried out shows that these protectors are effective in decreasing injuries incurred to leg in injury-type accidents especially non-severe collisions.

## 2- LITERATURE REVIEW

Issues followed are usually from researches and studied in the field of safety and accidents of motorcycle riders, are most of the sources used in the local thesis of students in the field of medicine of Iranian universities and also researches of different countries.

### 2-1- Medical Thesis

In studying the physical, mental injuries and death resulting from the accidents of motor vehicles 1000 cases which were registered to legal medicine of Tehran in the year 1997 have been studied. In this study, out of 550 persons died 337 persons were pedestrians and 187 persons were riders. In the group of motor cycle riders in 38% of persons died, the lower limb was reported to be fractured. However in the motorcycle riders group, percent of several bone fractures which resulted in death was 2%. Also, in this study from the 450 injured persons who were interviewed there was 104 motor cycle riders and the most epidemic injury in the motor cycle riders, in the first place is injury of lower limbs with 60%, in the

second place head and face injury with 33% and in the third place injury of upper limbs with 18% and injury of spinal column about 7.5% of all. 24 cases of motor cycle riders, suffered from the fracture of lower limbs (4).

In the prevalence study about types of injuries caused to death resulting from the accidents of motorcycle riders, in the death bodies referred to the anatomy hall of State Forensic Medicine Center in the year 2001, 164 dead bodies which includes mostly all bodies referred to this hall have been studied which in 61.6% samples, there were slight injuries on the lower limbs. Percentage of fracture in the lower limbs was 1.3%.

Vast percentage of severity of injury (caused to death) for lower limbs was 2.7%. In this study it is recommended to install special steel protectors on the motor cycle for protecting the lower limbs.

Also, in a similar study carried out in the years 1994-1997 on 222 cases caused to death due to motorcycle accident in the anatomy hall of legal medicine of Belgrade, following results were obtained. In drivers there were 78.9% of hand injuries and in others this ratio was 37.8%. Also, there were reported 16.7% knee injury and 30.8% injury of lower limbs in injured drivers (5).

### 2-2- research institutes

Leg protectors and airbags are always mentioned in many researches and articles, to be the two main secondary safety devices. Leg injuries account for approximately 60% of serious injuries to motorcyclists, and frequently lead to permanent disability. Leg protectors have been suggested as a way of reducing such injuries.

Researches has resulted in contradictory claims for the efficacy of leg protectors, with some studies suggesting that they would reduce leg injuries, but others suggesting that they might even increase the risk of other kinds of injury. For example crash tests conducted by the International Motorcycle Manufacturers Association produced very different results, in which leg protection was found to be beneficial in three out of eight pairs of tests, but detrimental in five pairs of the eight tests. Overall, this study concluded that leg protectors increased the net risk of head and leg injuries. [7]

ISO standards suggest a series of tests for evaluation purpose of leg protectors. Two sets of paired tests (with and without leg protection), were completed according to the ISO draft standard. The leg protection device reduced the Head Injury Criteria (HIC) value substantially in all except one test comparison against a standard machine. Leg injury

measures were also reduced when using the leg protection device, except in one case.

However, an overall assessment using the ISO injury cost calculation for the four ISO tests (two pairs) shows that the potential injury costs were reduced by 42 % when leg protection was deployed. This is a clear and encouraging indication of the likely benefits of leg protection.

### **2-2-1- TRL researches**

TRL research over a number of years has investigated whether leg protectors would significantly reduce the incidence and severity of leg injuries to motorcyclists. Crash tests of different types of motorcycles, with and without leg protectors, were designed and conducted by TRL. They concluded that leg injuries would have occurred in 55% of the crash tests on motorcycles without leg protectors, but in only 12% of those with leg protectors. They also concluded that the leg protectors used would not have increased the risk of head injuries, and in some cases actually showed potential for reducing them. [7]

### **2-2-2- EEVC researches**

The European Experimental Vehicles Committee (EEVC) in a study programme report in the field of motorcycle safety measures indicates: [8]

Leg injuries account for about 60 percent of all serious injuries to motorcyclists, and an appropriately designed leg protector can reduce the risk of injury to the lower extremities.

In the case of a frontal collision, every force below the centre of gravity of the motorcycle rider will start a rotation of the upper part of the body, and this can increase head velocity. This effect can worsen the risk of injury to the head. Leg protectors can produce these forces if they are not designed in the right way. It is therefore important to design leg protectors which do not trigger this motion.

The different designs seem to have different effects on the rider trajectory. Assessment of leg protection has been confused by differences in test methodology, giving rise to differences in results and interpretations. This has complicated the search for practical safety elements. [8]

### **2-2-3- Evaluation of UKDS Leg Protector based on ISO 13232**

The feasibility of devices intended to protect the legs of motorcyclists in impacts has been researched for three decades; the paper of "AN OVERALL EVALUATION OF UKDS MOTORCYCLIST LEG PROTECTORS BASED ON ISO 13232 " reviews the prior history and presents the latest results of an overall evaluation of a UK Draft Specification

(UKDS) leg protector device, based on the standardized full scale test and simulation methods of ISO 13232. This paper continues after a brief review of the history of leg protector research with the concurrent development of research methodologies, culminating in ISO 13232; application of the ISO 13232 to an overall evaluation of an example UKDS leg protector device; and the conclusions and recommendations reached regarding this type of device.

The impact configurations (IC's) for the full scale tests were the seven IC's required by ISO 13232 for a full scale test evaluation of a proposed device. The effects of leg protectors on rider injuries were assessed by means of seven pairs of full scale impact tests and 200 pairs of calibrated computer simulations. The results of these tests are as follows:

In the implemented full scale tests, upper and lower leg fractures were eliminated in the offset frontal configuration (which ISO 13232 indicates is the least frequently occurring among the seven standard impact configurations) by using the leg protector. However, fitment of UKDS leg protectors resulted in increased head injury severity in 3 out of 7 impact configurations; increased probability of fatality and normalized injury costs in 4 out of 7 impact configurations; and increased neck compression injury index in 5 out of 7 impact configurations. This was observed to be the result of forward and/or lateral torso pitch, caused by a robust restraint of the knee, by leg protectors.

With regard to injury cost, fitment of leg protectors increased the overall normalized injury cost of the seven full scale impact configurations specified by ISO 13232 by more than 300%.

Other harmful effects resulting from UKDS leg protector's fitment include transfer of injury - from the lower leg to the upper leg - in the angled car front impact (the second most frequently occurring of the seven standard full scale impact configurations). This transfer of injury is a fundamental result of the way in which the knee is restrained, which applies large forces and torques sufficient to fracture the femur. Such femur fractures are more severe (and in some cases life threatening) than the lower leg fractures which leg protectors are intended to reduce.

Calibrated computer simulations of 200 pairs of impacts which occur in accidents - with and without leg protectors fitted - indicated that the total injury risks (ie, increases in injury costs resulting from leg protector fitment) exceeded the total injury benefits, with a risk-to-benefit ratio of 116%. This was observed to be much larger than risk-to-benefit ratios of 7% or less observed in car occupant protection systems, such as seatbelts or head restraints. The simulation results also indicated that leg protectors

increased more costly upper leg injuries, whilst decreasing less costly lower leg injuries.

All of the foregoing results indicated that this concept of rider protection would produce a net harmful effect, which is undesirable and unacceptable in any device intended to improve safety. Based on these results and the previous research, this type of device should not be fitted to production motorcycles. For the same reasons, there appears to be no merit in the further development of this protection concept.

There will be more discussion about the credibility of above-mentioned case study in Tehran city.

#### **2-2-4- Otte studies**

Otte also have done a number of researchs in the field of leg injuries in motorcycle accidents. He mentioned about the EEVC report (1993) in his reports and says: "Mackay (1985) suggests two general mechanisms of leg injury, direct impact with the other vehicle and crushing between the motorcycle and the other vehicle, and this distinction between a direct blow and trapping between the two vehicles is clear in many injury studies, for example Hurt et al. (1981) and Nyquist et al. (1985)..."

However, many of the above studies are old and the only recent study is that of the Otte's in which the difference in patterns of accidents compared to what been considered in older analysis, have been considered and analyzed.

Otte completed this study to analyse the risk of leg injuries to motorcyclists in accidents and to find the opportunities for leg protection by comparing risks for those injured on machines with and without leg protectors. Each injury was analysed by type, leg area and severity (AIS) and correlated to the impact situation with impact direction, impulse angle, load and characteristics of kinematic behaviour; 258 motorcycle accidents with cars were analysed specifically for leg injuries.

Otte's study confirms previous findings that some 60% of the motorcyclists in accidents sustained leg injuries mostly fracture of injury severity AIS 2-3.

To establish the leg protection given by fairings, leg injuries were analysed by type, severity and location. Motorcycle collisions with a car, or solo accidents and collisions with solid objects, were included in the analysis.

The results of the analysis showed that the injury severity of the legs was reduced by the presence of a leg fairing. Of casualties riding with a fairing 28.3% sustained a leg injury compared with 33.7% for those without a fairing and furthermore the severity of the leg injuries that did occur was less,

with only 14.2% with a fracture on the faired machines compared with 23% on the unfaired motorcycles. This trend of reduced fracture risk for motorcyclists using machines with leg fairings is repeated in all collisions with cars, solo accidents and for various collision types. Otte claims that these statistics show that even standard fairings provide substantial protection to the legs.

Based on above-mentioned results, the presence of fairings had little effect on the overall incidence of head and thorax injuries.

Otte also quantified the likely benefits for leg injuries. It was estimated that an overall reduction of 21.1% of leg injury costs could be achieved with leg protection.

Constructional suggestions for leg protectors included recommendations for the foot to be covered from the side and front and the design of protection to include the

elimination of compression effects. It was also stated that the tibia must be protected in the front by an energy absorbing element although the rider must be free to leave the motorcycle during the impact. [10]

#### **3- METHODOLOGY OF TACKLING THE ISSUE**

To evaluate the efficiency and ratio of effect of front protectors in preventing damages and decreasing injuries incurred to leg, information and census collection in connection with injury accidents of motorcycle equipped with and without protector have been implemented in ordinary motorcycle riders society and motorcycle riders who have suffered from accident injury. This information includes accident statistics, traffic counts, questionnaire and interview with the motorcycle riders of Tehran city. To analyze the data, in the beginning some of the previous studies presented in section 2 of literature review have been evaluated and the points of strength and weakness of using leg protector were studied in the city of Tehran.

Then the information obtained from questionnaire, traffic data and data about accidents have been studied. To analyze the causes, graphical analysis and equality scale in two populations statistics test in the society and K-test were used. Also, to analyze the result and accreditation of data, Chi-square test was deployed.

Finally, in section 8 conclusion and final results were presented.

#### **4- SCRUTINY OF BASING THE ANALYSIS ON INVESTIGATIONS ABOUT UKDS LEG PROTECTOR**

As you saw in section 2 - "literature review", the implemented researches about the leg protector of UKDS (designed by TRL), by using the investigation procedure given by standard of ISO 13232, show that applying the leg protectors has more negative effects in general and it should not be used to protect the motorcyclist.

Here, we study about the specifications, features and hypotheses considered in UKDS research and compare it to the respective situation in Tehran:

1- The model of the impact types of motorcycle accidents in Tehran is clearly different from the model considered in this research. In these tests, the most negative effects caused by leg protector have been observed in two types of collisions. the first one in the form of T (car in stop condition) and the other one angled collision both front sides; in these two types of accidents as the motorcycle collides with car, the motorcyclist will be thrown toward the vehicle, collide with it and then will suffer more injuries by head.

The study on injured persons in motorcycle accidents in the Sina hospital in Tehran revealed that the total number of accidents of these two types of collision in Tehran city forms less than of 25% of all motorcycle accidents. In the studied collisions, since the cars and motorcycles usually move with low speed, most of the time the riders's falling down causes the injury and the high impact collision of the motorcyclist with the car doesn't occur and the throw of the rider to the front car and serious head injuries rarely occur.

2- Based on the results achieved by studying the injured motorcyclists been confined to bed in Sina hospital, about 50% of motorcycle accidents and injuries in Tehran are related to side by side collisions and fall down of the motorcyclist, that the eventual increase of injury to the head because of leg protector would be minor and negligible. Once again, since in these two types of collisions there is few possibility of the protection guard to apply a force to the rider's leg , then the eventual force applied to femur bone and it's breaking (as it was addressed through the research of UKDS) doesn't exist. The sliding of motorcycle and the falling down of motorcyclist (without any collision with other vehicle) didnot putt into consideration. In accordance to the investigations about the leg protector of UKDS, the collision of the car with the side of the motorcycle, which is the most usual collision in motorcycle accidents in Tehran (more than 30%), didn't reveal the role of the protector to intensify the injuries of the motorcyclist significantly.

3- The speed of the collision in motorcycle accidents plays a key role in the type and intensity of the injuries of motorcyclist. More speed would increase the eventual occurring of more severe injury

and fatal accidents. Also, by increasing the speed of collision, the effectiveness of leg protector decreases and in higher speeds the leg protector may damage the body of motorcyclist itself. In the article of "General evaluation of leg protector UKDS based on ISO 13232", there is no mention of the speed the collision occurred in. But, comparing to the different kinds of motorcycles, the different traffic patterns and behaviors, different kinds of collision types and the prevalence of accidents among European and American cities and Tehran, it seems that the speed of collision considered in these researches was significantly more than the speed of collision in city accidents of Tehran. So, we can conclude since the speed of collision in Tehran is low, thus the leg protectors can be more effective in the accidents of this city.

- Preventing from light injuries (damages to leg's skin, light crevices of bone, cut, etc.) is one of the benefits of leg protectors in minor accidents providing that the number of them is high, especially in Tehran due to its traffic condition and the traffic always move in low speeds. This kind of collisions and the benefits of leg protectors were not addressed in studies of UKDS about the leg protector.

Based on indicated subjects, we can conclude that in accordance with significant differences in hypostasis of mentioned research and the condition of motorcycle traffic in Tehran as well as motorcycle accidents, the gained results of this study are not certain and inevitable for this city and can not be used as a base to conclude that usage of leg protectors increases the injuries of motorcyclist in Tehran.

## **5- DATA COLLECTING AND ASSESSMENT OF THE INFORMATION ABOUT THE MOTORCYCLE ACCIDENTS IN TEHRAN**

In the following sections, the collected data and information about the accidents and the condition of motorcycle traffic in Tehran are given and surveyed.

### **5-1- Interview with injured people of motorcycle accidents (came to Sina hospital)**

In this order, injured motorcyclists were interviewed. 35 injured persons were interviewed totally with 37 accidents.

The following conclusion has been analyzed and extracted from interview documents and questionnaires:

1- In 81 percent of accidents, the motorcycle were not equipped with leg protector.

2- In 57 percent of accidents where the motorcycle was not equipped with leg protector, if

the motorcycle was equipped with leg protector, the motorcyclists would suffer less injuries.

3- In 86 % of accidents where the motorcycle was equipped with leg protector, this equipment has had a positive effects to reduce the leg injuries.

4- 86 percent of injured motorcyclists who were interviewed came to hospital because of motorcycle accident, for the first time. This value has decreased to 10 percent for injured people who have come to hospital because of accident for second times.

5- 86 percent of injured persons, described the effect of metal guard usage, to be "High".

6- 92 % of interviewed injured people have indicated that they did not have observed any accidents that the leg protector increased the injuries of motorcyclist.

7- The type of observed collisions is as follow:

- The collision of motorcycle with the rear of the car: 19 %.

- Front to front collision with other vehicle: 22 %.

- Collision of a car to the side of the motorcycle: 36%

- Falling down of the motorcycle (with no collision with other vehicles): 14%

8- The motorcyclists who didn't use the leg protector indicated the

Following points as an obstacle to apply it:

- No clear reason: 68 %

- Reduction in maneuvers and passing through the cars: 12 %

- Leg protector makes the motorcycle ugly: 8%

- Lack of leg protector due to the type of motorcycle: 8%

Results gained adding up the interviews results:

Adding up the indicated interviews gives up the following results:

1- By putting into consideration the points 2 and 3, it could be concluded that equipping the motorcycle with leg protector plays a significant role to reduce the injures of motorcyclists and due to prevalence of leg injuries in motorcycle accidents (in about 60% of motorcycle accidents the leg of riders has been injured) promotes the secondary safety of motorcycle significantly.

2- Regarding to the point 8 : the indicated reasons to avoid applying the leg protector, it could be finded out that the most people don't have any clear and significant reason to avoid using this equipment and they don't use it because they are not well aware of it's importance. So, forcing the motorcyclists to apply the leg protector doesn't make any problem for them.

3- By putting into consideration the point 6 and other surveys, it seems that equipping the

motorcycle with front leg protector rarely increases the injuries of motorcyclist and this matter can be ignored compared to its significant benefits.

#### **Other observations**

The observations and interviews with injured motorcyclist revealed the positive effectives of leg protector.

1- In front to front severe collisions (accidents) that usually occur with high speed of motorcycle and/or the front car, the leg protector doesn't have any special effects. This kind of accident is more common in inter- city and rural roads.

2-In an accident where a car collides with a motorcycle from the side, the back protector has an effective role for reducing the injuries than the front protector. It seems that the back protector also has a very positive role for reducing the injuries of back rider.

3-The speed is one of the important factors in occurrence of the accidents that end to injury. The speed control of motorcycles and law enforcement to law breakers can ply a very effective role to reduce the number of motorcycle accidents.

4- One of the positive features of applying the protectors is that in case of equipping with protectors, the possibility of the rider passing amongst the cars would decrease and the risk of accidents as well.

#### **5-2- Interview with motorcyclists of Tehran**

Apart from interviews with injured motorcyclists that have been analyzed in previous section, random models of motorcyclists of Tehran were interviewed through the same way. The number of interviews was 30. The following results have been achieved:

1- 70 % of motorcyclists don't apply the protector and about 10 % use it only in cold months (in order to install the wind protector), and only 20% use it continuously.

2-To answer the question about it's importance, 60% of interviewed motorcyclists evaluated it's importance and effects as "high", 23% used the term " medium" and rest 17% evaluated it "low".

3- The number of hospital comings for the accidents, 72% was zero, 24% was once, and 3% was twice.

4- 85% of motorcyclists announced that they haven't observed any case where the protector increased the injuries of motorcyclist so far.

#### **Comparing the under study models in two statistical populationss**

1- In the case related to motorcyclists of Tehran, about 75% were not equipped with protector,

while this value for the injured motorcyclists was 81%.

2- 86% of interviewed and injured motorcyclists indicated the importance of the protector to be "high", while this value in the model of motorcyclists' society was 60%. The comparison of these two values shows that the people who got involved in an accident, have putted a significantly more importance to the safety affaires such as protective equipments.

3-The ratio of people with one coming to hospital and the people with two comings (because of the accident), in both samples is nearly same (nearly 10 to 1).

### 5-3- The information about motorcycle accidents from the authorities

The information about the non-injury, fatal and injury accidents in Tehran in 2002 and 2003 recorded by the police is given in table-1. Since these statistical data only covers the accidents where the police were present in the scene, so many motorcycle accidents (generally injury accidents) have not been included in these statistical data. Thus in this information, the statistical data about non-injury accidents is less than the data about injury accidents.

### 5-4- Motorcycles counting and defining the ratio of motorcycles equipped with protector

For defining the percent of motorcycles equipped with protectors (in order to compare with this ratio in statistical society of injured motorcyclists), 168 motorcycles in Bazar area of Tehran have been counted, 40 of them were equipped with protectors

and the rest (128 cases) were not equipped with this device.

## 6- ANALYSIS AND EVALUATION OF ACCIDENT DATA

In this section by using available methods for analyzing the accidents data, the collected data have evaluated.

### 6-1-Graphical Analysis

Studying the number of accidents during a period is one of the most simple graphical analysis methods. In this method, cumulative number of accidents (grouped by the accident type) as well as cumulative average of every accident type is drawn in a figure.

This method is more appropriate for extensive plans covering broad areas and is not suitable for individual location or routes (because of few accidents occurred).

The gained results through interviews with motorcycle drivers showed that a number of riders (about 15 %) use the metal Leg guards with plastic front windshields on their motorcycles during cold months of the year. Shields are used to protect the driver's face from soft mud also protecting the body specially the legs against the cold wind. In order to install the windshield it is always necessary to install the leg protectors first, and this would eventually protect the rider's leg during the more dangerous cold months of the year, resulting into decrease of injury-type motorcycle accidents in the winters. The graphical analysis method could be deployed to survey this subject and to investigate about the reduction rate of motorcycle injury accidents. This

**Table1- The statistics of motorcycle accidents of Tehran in2002 and 2003[2]**

| <i>Motorcycle accidents in 2003</i> |               |                    | <i>Motorcycle accidents in 2002</i> |               |                    | <b>Month</b>     |
|-------------------------------------|---------------|--------------------|-------------------------------------|---------------|--------------------|------------------|
| <b>fatal</b>                        | <b>injury</b> | <b>Non- injury</b> | <b>fatal</b>                        | <b>injury</b> | <b>Non- injury</b> |                  |
| 4                                   | 409           | 190                | 4                                   | 129           | 87                 | <i>April</i>     |
| 9                                   | 873           | 386                | 2                                   | 279           | 126                | <b>May</b>       |
| 6                                   | 932           | 450                | 4                                   | 270           | 143                | <b>June</b>      |
| 12                                  | 969           | 475                | 5                                   | 318           | 124                | <b>July</b>      |
| 6                                   | 1006          | 464                | 3                                   | 405           | 177                | <b>August</b>    |
| 10                                  | 1055          | 499                | 9                                   | 374           | 174                | <b>September</b> |
| 11                                  | 1117          | 476                | 3                                   | 357           | 162                | <b>October</b>   |
| 10                                  | 918           | 452                | 6                                   | 363           | 171                | <b>November</b>  |
| 11                                  | 734           | 372                | 2                                   | 243           | 147                | <b>December</b>  |
| 3                                   | 699           | 329                | 4                                   | 286           | 148                | <b>January</b>   |
| 7                                   | 758           | 344                | 5                                   | 263           | 162                | <b>February</b>  |
| 13                                  | 702           | 351                | 4                                   | 330           | 180                | <b>march</b>     |

analysis has been done for year 2002 and is showed in table-2 (the data for Farvardin, first month of Iranian year, was not considered because of the 10-day Norouz traditional holidays, and it's specific effect on the accidents. Farvardin is the first month of spring, identical to April). In the second column of this table, the cumulative numbers of non-injury accidents of the year 2002 are listed. In the third column, the collected data for non-injury accidents in cold months of the year (from November to march) are listed in the form of commulative average. It means that the mathematical average of the accident numbers for these 5 months has been calculated and increasing trend of the cumulative accidents number in these 5 months has been shown with this amount (162).

Cumulative average of accidents between November and March

$$= (\text{Cumulative number of accidents in march-cumulative number of accidents in October}) / 5 = (1714-906) / 5 = 162$$

In the forth column, the cumulative number of injury accidents in 2002 has been given. In the fifth column, the cumulative number of injury accidents in the 5 cold months of the year (November to march), in accordance to the increasing rate of the non-injury accidents for the above-mentioned months has been calculated. Comparing to the first 6 months, it means that if no factor had influenced the rate of injury accidents in the cold months of the year and the injury accidents rate would have changed the same as the increasing rate of the non-injury accidents, how many injury accidents would have occurred in these months. The following way of calculation was used to calculate this rate:

$$\text{average of non-injury accidents from May to October} = (\text{cumulative number of accidents of October}) / 6 = 906/6=151$$

$$\text{average of non-injury accidents from November to March} = (\text{cumulative number of accidents of March-cumulative number of accidents of October}) / 5 = (1714-906) = 161.6$$

$$\text{growth rate of non-injury accidents in the end months of the year comparing to the last 6 months} = 161.6 / 151 = 1.07$$

$$\text{average of injury accidents from May to October} = (\text{cumulative number of injury accidents in October}) / 6 = 2003/6=333/8$$

$$\text{cumulative average of accidents in the last 5 months with regard to the growth rate of non-injury accidents} = 333/8 * 1/070 = 357/3$$

**table 2- calculations of graphical analysis**

| Month        | cumulative numbers of non-injury accidents | Cumulative average of non-injury accidents | cumulative number of injury accidents | cumulative number of injury accidents with non-injury average |
|--------------|--|--|---------------------------------------|---|
| May 2002     | 126  | 126  | 279                                   | 279   |
| June         | 269  | 269  | 549                                   | 549   |
| July         | 393  | 393  | 867                                   | 867   |
| August       | 570  | 570  | 1272                                  | 1272  |
| September    | 744  | 744  | 1646                                  | 1646  |
| October      | 906  | 906  | 2003                                  | 2003  |
| November     | 1077                                       | 1068                                       | 2366                                  | 2360  |
| December     | 1224                                       | 1229                                       | 2609                                  | 2718  |
| January 2003 | 1372                                       | 1391                                       | 2895                                  | 3075  |
| February     | 1534                                       | 1552                                       | 3158                                  | 3432  |
| march        | 1714                                       | 1714                                       | 3488                                  | 3789  |

The values of each column have been shown in figure 2. As you see the cumulative value of injury accidents in March, compared to cumulative value of injury accidents with growth rate of non-injury accidents, has showed the decrease of 301 accidents, which can indicate that equipping motorcycle with metal guards in cold months of the year, would decrease the number of injury accidents up to 300. However, it is based on this hypothesis that other factors like driving habits (being more careful) and road conditions (the effect of slippery roads) in cold months and its effect on the type of accident didn't play any role in decreasing the value of injury accidents and /or increasing the non-injury accidents. The statistical analysis of different years is also needed to achieve the correct and reliable results.

### **6-2- Standard statistical tests to evaluate the accident's data**

To evaluate a specific safeguarding program, the two following questions should be answered:

-Has the implemented program been successful and effective?

- If yes, how much and in what fields has it been effective?

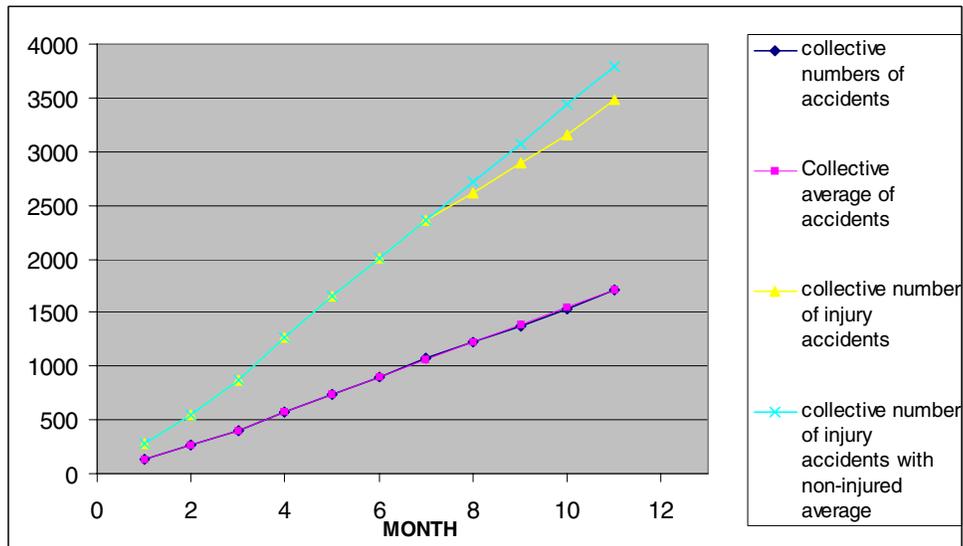


figure2- graphic analysis of data accidents

The random nature of road accidents can make many variances or oscillations in the number of accidents in a place from year to year; even though the "safety level" of that place doesn't change at all. This high changeableness makes the diagnosis and assessment of the effects of a safety program more difficult but the meaningful statistical tests can declare that whether the observed change in rate of accidents has been occurred random or as a result of a certain safety program.

In this section some of the available statistical tests to evaluate the accident data are described. These tests are applied to answer the above-mentioned questions about the success level of the program.

To answer those two questions it is enough to suppose that accidents before and after the improving program, follows the normal distribution. In other words, we assume the accident statistically distributed around the mathematical mean value. This means that the Chi-square test could be applied to answer the first question. If the same program has been done in many places, more analysis would be required to define the overall achieved effects.

In table 3, some tests that are used to assess the transportation projects are shown. The required conditions for each test are defined as well.

### 6-2-1- The test of equality scale in two populations

On the basis of counting in roundabout in Tehran Bazar area (the big traditional marketplace in the center of Tehran city), 40 motorcycles of 168 motorcycles were equipped with guard and the rest were not. The interviews by injured motorcyclists in Sina hospital revealed that only in 7 cases of 37 accidents, the motorcyclists had the guards. In order

to show the crucial role of guards to decrease the eventuality for occurring the injured accidents in Tehran, the scale rate of guards equipping in two populations of the motorcycles of Tehran and the motorcycles whose riders had injured in accidents, are compared to each other. To do this comparison, we use the test of equality scale in two populations.

$$H_0 : p_1 = p_2$$

$$H_1 : p_1 < p_2$$

$$x_1 = 40 \quad n_1 = 168$$

$$x_2 = 7 \quad n_2 = 37$$

$$\hat{p} = \frac{x_1 + x_2}{n_1 + n_2} = \frac{40 + 7}{168 + 37} = 0.229$$

$$Z = \frac{\frac{x_1}{n_1} - \frac{x_2}{n_2}}{\sqrt{\hat{p}(1-\hat{p})\left(\frac{1}{n_1} + \frac{1}{n_2}\right)}} = \frac{\frac{40}{168} - \frac{7}{37}}{\sqrt{0.229(1-0.229)\left(\frac{1}{168} + \frac{1}{37}\right)}} \quad Z = 0.64$$

Since the calculated Z is less than the Z value in the table by confident level of 10 % (1/28), so it is concluded that the difference of equipping scale with guard in these two populations would be meaningless.

The above-mentioned results mean with regard to the type of guards used in Tehran (which are so far from desired condition), this safeguarding instrument is not so effective to prevent the injuries and to protect the

body in relatively severe accidents. It can only diminish the severity of leg injuries to some extents.

### 6-2-2- K-Test

The K-test is always used to show the quality of changes in the number of accidents (for example, in a certain place or area) compared to the controlling data.

The information about the motorcycle accidents recorded in Tehran in first and second 6 months of the year 2003 are as follow:

| type of accident | average of May to October | average of November to March |
|------------------|---------------------------|------------------------------|
| Non-injury       | 458                       | 370                          |
| Injury           | 992                       | 762                          |
| Fatal            | 9                         | 8.8                          |

As it is evident, the number of non-injury and injury accidents in cold months (second half of the year) has been reduced compared to the warm months and the fatal accidents have nearly been identical. Different factors such as driving more carefully, reduction in motorcycle use, reduction of daylight time and motorcycle using time as well and more usage of protection guards, play a key role to reduce the number of injury accidents in winter. All mentioned factors (except the last one) can also change the number of the fatal accidents. Supposing that these factors have relatively the same affect on all types of accidents (fatal, injury and non-injury), it is possible to survey and control the changes in comparison with the non-injury and fatal accidents(controlling data) in order to evaluate the effect of Guard usage in order to reduce the number of injury accidents. In this case, by using the K testing method, one time the number of non-injury accidents and the next time the fatal accidents are considered as controlling data:

#### First case:

Injury accidents: the population influenced by applying the protection guard  
 Damaging accidents: controlling population.

$$\begin{matrix} a=992 \\ b=762 \\ c=458 \\ d=370 \end{matrix} \Rightarrow k = \frac{b/a}{d/c} = \frac{762/992}{370/458} \quad K=0.95$$

$K < 1$ : the value of injury accidents has been reduced compared to the number of damaging accidents.  
 the percent of reduction in injury accidents:  
 $(K-1)*100=5\%$  :

#### The second case:

Injury accidents: the population influenced by applying the protection guard.  
 Fatal accidents: the controlling population.

$$\begin{matrix} a=992 \\ b=762 \\ c=9 \\ d=8.8 \end{matrix} \Rightarrow k = \frac{b/a}{d/c} = \frac{762/992}{8.8/9} \quad K=0.79$$

$K < 1$ =the value of injury accidents has been reduced compared to the number of non-injury accidents.  
 The percent of reduction in injury accidents:  
 $(k-1)*100=21\%$

By doing the K test and the above-mentioned calculations for the accident data in 2003, reduction in injury accidents compared to the non-injury and fatal accidents are 18% and 9% respectively.

## 7- ANALYSIS OF THE RESULTS AND EVALUATION OF THE DATA

The Chi-Square Test can be used to evaluate the data and to indicate whether the change of accidents

**Table 3- statistical tests that used to assess the transportation projects [11]**

| TEST  | DESCRIPTION  |
|---|--|
| STUDENT (t-TEST)                              | Used to determine whether the mean of one set of measerments is significantly different from another set.  |
| KOLMOGOROV-SMIRNOV                            | This "two-tailed" test determines whether two independent samples have been drawn from the same population.  |
| K   | This calculation is used to show how a number of events at a particular site has changed relative to a set of control data.  |
| (CHI-SQUARE)                                  | This calculation used to determine whether a given change (in accident for example) was produced by a given treatment or whether the change may have occurred by chance. |
| equality of given property in two populations | Used to determine whether the given property of one population is significantly different from another population  |

number roots in implementation of safeguarding program or occurred accidentally. Thus, this test indicates that whether the occurred changes in the data mean statistically or not.

In this section the injury accidents of cold and warm months of the 2002 are compared considering the non-injury and fatal accidents as the controlling data. In table 4, information about the average injury and non-injury accidents in cold and warm months of the year is given. In these tests knowing that in end months of the year, more motorcyclists apply the protection guard, the increasing injury accidents in last and starting months of the year are compared to each other in order to assess the role of protection guard in reduction of injury accidents and the reliability of the results gained from K test are surveyed.

**Table 4- Chi-square Test**

|                                      | Injury accidents | Non-injury accidents (controlling data) | SUM    |
|--------------------------------------|------------------|---|--------|
| Average of may to October (before)   | a) 334           | c) 151                                  | g) 485 |
| Average of November to march (after) | b) 297           | d) 162                                  | h) 459 |
| SUM                                  | e) 631           | f) 313                                  | n) 944 |

$$x^2 = \frac{\left(1334 \times 162 - 151 \times 297 - \frac{944}{2}\right)^2}{631 \times 313 \times 485 \times 459} \times 944 \quad x^2 = 1.66$$

By referring to the table of distribution  $\chi^2$  and considering the level of assurance to be 90%, the value of 2/71 could be obtained. Since the calculated rate of  $\chi^2$  is less than this value, it's evident that with assurance level set to 90%, it is not possible to conclude that the difference in average values of accidents in warm and cold months of the year are statistically meaningful.

By taking into account of the fatal accidents in 2002 as the controlling data and doing the same calculations, the  $\chi^2$  value gives 0.045 that once again the same result could be concluded.

In this example, we should consider that the applied data concerning to the injury accidents doesn't exactly shows the situations that are influenced by the safety program (equipping the motorcycle with protection guard), because only 25% (about 25%) of these motorcycles were equipped with the protection guard and in order to study the effects of leg protector

for reducing the number of injury accidents, it is essential to compare the information of injury accidents related to equipped and non-equipped motorcycles with safety guard and these data are not available.

## 8-CONCLUSION

By using the current data and information and on the basis of analysis which have been mentioned in previous sections, it could not be concluded that using the front safety guard brings significant reduction in motorcycle injury accidents, but the findings obtained by studies and interviews of motorcyclists who got involved in accidents and taking into consideration the different viewpoints of motorcyclists population shows that these safety guards play an effective role to diminish the severity of leg injuries and to reduce the severity of injury motorcycle accidents, especially in less severe accidents. However the interviews show that safety guards play a serious role in street accidents which always happen in low speeds. 85% of injured interviewed motorcyclists and 60% of interviewed motorcyclists in Tehran pointed to the importance of guard's usage. Also in accordance to the observations, the most motorcyclists (about 70%) don't have any significant reason to avoid using the front safety guard, so by applying the training programs culture-making and law enforcement schemes as well, people could be encouraged to use the front safety guard and reduce the injuries of motorcyclists significantly.

## 9- REFERENCES

- [1] A.Ayati, "Costs of Tehran Traffic Accidents", Mashhad Ferdoussi University Publications, 2002
- [2] J.Setayesh Valipoor, "Survey of Human Damages and Ways to Reduce It in Motorcycle Accidents in Tehran", Master of Science Thesis, Elm-o-Sanaat (Science and Industry) University, 2004
- [3] Stephen & Setabi, "trauma", Translated by Dr.Porang, 1991
- [4] M.marjai "Survey of body and mental effects and death because of vehicle accidents the sent to anatomy hall (Central Organization of State Medical Jurisprudence) in 1997", Master of Science Thesis, University of Medical Science of Tehran, 1998
- [5] A.Ghorbani, "Survey of dissemination of different kinds of injuries end to dead because of fatal motorcycle accidents in bodies sent to anatomy hall

(Central Organization of State Medical Jurisprudence) in 2001", Master of Science Thesis, University of Medical Science of Tehran, 2002

[6] Wirginia Wind Hompage, "Motorcycles with Airbags and Leg Protectors"

[7] Motorcycle Training Homepage, "The Royal Society for the Prevention of Accidents (RoSPA) Motorcycling Safety Position Paper" ,February 2001

[8] EEVC Ad-Hoc Group on Motorcycle Safety, "A Review of Motorcycle Safety", 1994

[9] Rogers, N- Zellner, j. "AN OVERALL EVALUATION OF UKDS MOTORCYCLIST LEG PROTECTORS BASED ON ISO 13232", Dynamic Research Incorporated, 1998

[10] M A Elliott, C J Baughan, J Broughton, B Chinn, G B Grayson, J Knowles, L R Smith and H Simpson. "Motorcycle safety: a scoping study", TRL, 2003

[11] " PIARC Road Safety Manual", 2004

[12] The company of Tehran Comprehensive Studies of Transportation and Traffic, " A glance to the traffic of Tehran 2004", The Publications of the Company of Tehran Comprehensive Studies of Transportation and Traffic, 2005