*University of Jordan*
*Faculty of Graduate Studies*

# *RANKING OF HIGH ACCIDENT LINKS ON SELECTED ARTERIAL STREETS IN AMMAN*

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*TO MY MOTHER AND WIFE*

*FOR ALL THEIR SUPPORT*

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# *LIST OF ABBREVIATIONS*

| | |
|---|---|
| **AAAR** | Annual Average Accident Rate. |
| **AAAT** | Annual Average Accident Total. |
| **AAIA** | Annual Average Injury Accident. |
| **ADT** | Average Daily Traffic. |
| **AIAR** | Annual Injury Accident Rate. |
| **INTRACS** | Indiana Traffic Accident Record System. |
| **LORASS** | Lothian Road Accident Statistic System. |
| **M.V.Km** | Million Vehicle Kilometers. |
| **NIS** | Network Information System. |
| **PAAR** | Potential for Annual Accident Reduction. |
| **PAIAR** | Potential for Annual Injury Accident Reduction. |
| **RSU** | Road Side Unit. |
| **U.K.** | United Kingdom. |
| **USA** | United States of America. |

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# ABSTRACT

Nine arterial streets in the city of Amman were subdivided into 27 links. Traffic volumes and accidents on their lengths were collected and relationships have been established between accidents (total/injury and traffic flow index). These relations showed that as traffic volume increases, accidents also increases (total and injury). These relations could be used to predict accidents on similar arterial streets from traffic volume. Three criteria for ranking links with regard to accidents were applied on selected arterial streets in the city of Amman. These criteria were: Accident Total, Accident Rate and Potential for Accident Reduction. The most hazardous links of the selected arterial streets in Amman were determined and then ranked by a combination of two criteria of accident ranking: accident total and accident rate. A new ranking for the hazardous links was arrived at by considering the potential for accident reduction for those links.

# *CHAPTER ONE*

## *INTRODUCTION*

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# INTRODUCTION

## 1.1 Introduction

The function of a street or a highway is to serve the public in getting to their desired destinations efficiently, economically and most important of all, safely. None-the-less, the history of the road is also a history of conflicts and accidents. It can be stated that deaths and injuries caused by accidents on the highway have now reached very high proportion in the whole world.

It is estimated that 0.25 million deaths and over 10 million injuries occur worldwide as a result of road accidents every year. Road accidents are now the greatest cause of death for young people in the age group 15-25 years [1].

Jordan, like many developing countries, is experiencing a worsening situation with road accidents. They constitute one of the main causes of human suffering and economical losses.

The total number of accidents on the Jordan highway system has been continuously increasing over the last 15-years. The number of people killed in road accidents each year since 1975 has generally been within the range of (250 - 525) [2].

In Jordan in 1971, vehicle accidents were ranked as the 11th highest cause of human death among all other causes. However, by 1985, they became the 4th highest death cause [3].

In 1991 the total cost of accidents in Jordan was estimated to be approximately 52.8 million J.D. [4]. whatever measure one may use, this clearly indicates that Jordan roads have become more and more dangerous with respect to fatalities and economical losses.

## 1.2 Identification of the problem

Approximately 58% of accidents in Jordan occur in the capital city Amman, and its suburbs.

This is a result of the increasing concentration of vehicle population and activities in the capital in comparison to all other cities in the country. What leads to a very high number of accidents which are taking place in this city more frequently than in other cities.

The ability to predict the frequency of road accidents for some locations has many useful applications in the field of both highway and traffic engineering. Such applications include the improvement of design standards for new roads, the identification of high accident locations and design of road improvement measures.

This research deals with accidents on selected arterial streets in Amman in order to predict the most hazardous locations.

## 1.3 Objectives of this thesis

The direct objectives of this research are:

- To try to link accident rates to traffic flow at the selected locations.
- To construct a model which relates accident rates with traffic flow which could predict road accident rates when given traffic volume under similar conditions to those

locations considered in this study.

- To rank the selected sites according to the highest to lowest accident rates.
- To identify the high accident sections on the selected study locations and analyze the accident situation on such locations.

As a result of fulfilling the above objectives together with certain economical analysis, a useful tool for the highway and traffic engineers may enable them:

- To help relevant authorities in preparing proposals for providing regional priorities.
- To assess the relative needs within the region.

It is hoped that the results of this research can be used to improve the efficiency of identifying hazardous road locations on arterial roads in Jordan under similar conditions.

# *CHAPTER TWO*

## *LITERATURE REVIEW*

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# *LITERATURE REVIEW*

## 2.1 Introduction

Various research works [5,6,7,8,9,10,11,12] were carried out on the identification of hazardous road locations in rural and urban areas. These works were mainly based on the relationship between the number of accidents and accident rates for traffic volumes at junctions and along road sections between junctions.

The main objectives of the above research efforts were to establish methodologies which can be followed to reduce the number and rates of accidents on certain locations and to develop new standards and techniques for improving traffic safety programs.

The following is a general review for some of the previous work conducted on this subject, including studies on the relationships between accidents and traffic volumes, and including the ranking of hazardous road locations based on a number of criteria.

## 2.2 The relationship between accidents and traffic flow

There is a considerable variation between accident rates per a number of licensed vehicles. The composition of traffic and the types of transport used in different countries in how they can affect accident rates and patterns. It is obvious that accidents along roads and at junctions are affected by traffic flow.

The precise nature of this relationship has been the subject of several studies and attempts which have been made to use traffic flow in mathematical models to predict future accident levels.

In general, accidents increase as traffic flow increases up to a "Saturation" level, after which congestion slows vehicles down to a speed at which injury is unlikely to be caused.

Several trends emerge when looking at the accident/flow relationship. The underlying nature of the relationship is likely to be different for links as compared to junctions. This is because at junctions some movements are inherently more dangerous.

Figure 2.1 shows the generalized patterns that might be expected to emerge [13].

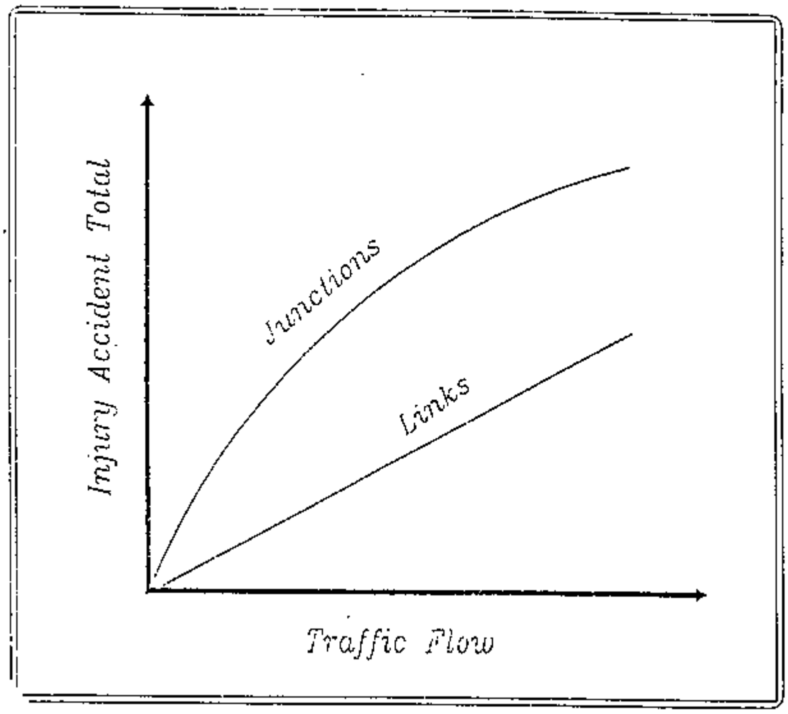



*FIGURE 2.1 THE RELATIONSHIP BETWEEN INJURY ACCIDENT TOTAL AND TRAFFIC FLOW [13].*

The most common way of expressing the relationship between accidents and flow is to use an accident "rate". This is usually expressed as the number of injury accidents per vehicle kilometer per year.

Thipatai and James O'Day [14] suggested that vehicle miles of travel is a common measure of exposure and this rate (involvement per vehicle mile of travel) provide a more useful comparison of the accident experience of vehicles.

Jacobs and Bardsley [15] presented a study of accident rates on rural roads in developing countries which have correlated the personal injury accident rate occurring on rural roads in developing countries with the design characteristics of the road in order to obtain information which would be of use in formulating principles for the design of safer roads in developing countries. Data were obtained on main roads in Jamaica and on the Nairobi-Mombasa road, Kenya. Relationships were established, using simple and multiple regression analysis techniques. The accident rates per kilometer of road per annum were found to be related to the vehicle flow per hour as follows:

$$y_k = 0.116 + 0.0091\ X$$

$$y_j = 0.158 + 0.0126\ X$$

Where:

$y_k$, $y_j$ = accidents/km/annum in Kenya and Jamaica.

X = average vehicle flow/hour with values ranging from 20 to 180 veh/h (relationships significant at the 5% level).

Multiple regression analysis, in which the accident rate is expressed as a function of several "independent" variables simultaneously, was used to correlate the accidents per million vehicle kilometers, with geometric design features.

The following equations were derived:

For data obtained for Kenya:

$y = 1.45 + 102\ X_5 + 0.017\ X_3$ (at 5% level)

$y = 1.09 + 0.031\ X + 0.62\ X_5 + 0.0003\ X_4 + 0.062\ X_2$ (at 10% level).

For data obtained for Jamaica:

$y = 5.77 - 0.755\ X_1 + 0.275\ X_5$ (at 5% level, no other factors enter at 10% level).

where:

$y$= accident rate per million vehicle kilometers.

$X_1$= road width (meters).

$X_2$= vertical curvature (meters/kilometer).

$X_3$= horizontal curvature (degree/kilometer).

$X_4$= surface irregularity (milimeter/kilometer).

$X_5$= Junctions per kilometer.

Silyanov V. V. [cited in Ref. 15] compared the above relationships derived in Kenya and Jamaica with those obtained from a number of developed countries. The accident rates (per million vehicle kilometers) in Kenya and Jamaica were considerably higher than those in the developed countries for similar levels of geometric design.



Satterthwaite S.P [5] presented a comprehensive literature review for for several research work related to various attempts for correlating accidents and traffic flow. Most of the studies considered a number of road sections and established relationships whereby the vehicle-distance traveled ($X_i$) was the independent variable and the number of accidents ($y_i$) was the dependent variable.

Mckerral [cited in Ref. 5] analyzed accident data from South Wales in 1961. He fitted curves in the form of $y= a + b_x + c_2$ where y is the number of accidents per year per mile and X is the ADT. The constant "a" proved to be close to zero, and both b and c are found to be positive ($147 \times 10^{-5}$ and $238 \times 10^{-10}$ respectively, for all accidents), implying an increase in accident rate with increasing traffic flow.

An analysis by Lundy [cited in Ref. 5] of accident data on Californian freeways regressed accident rates against Average Daily Traffic (ADT). Different regressions are calculated for roads with different number of lanes.

The analyses have also shown that the accident rate increases with increasing traffic flow.

Vey and Raft [cited in Ref. 5] stated that a general trend exists between accident rates and traffic flow, whereby accident rate rises from zero at zero traffic and increases with increasing traffic up to a saturation level, after which there is a decrease related to reaching congestions.

Caburn, Kihlberg, Tharp, Nelsson and Duncan [cited in Ref. 5] found that accidents involving two vehicles or more are positively correlated with ADT, but the correlation between single-vehicle accidents and ADT is insignificant.

Caburn [cited in Ref. 5] studied accident rates on rural roads in Buckingamshire in the years 1947-1950. Some definite trends observed in the rates of different types of accident were: the single-vehicle accident rate decreases with increasing traffic; the two-vehicle accident rate increases and the rate of accidents involving more than two vehicles increases sharply.

The conclusions reached by Kihlbery and Tharp is similar to Cuburn about the relationship between accident and traffic flow. They show that single-vehicle accident rates decrease with increasing ADT and that collision rates increase with increasing traffic.

Nilsson's study results [cited in Ref. 5], based on data from rural main roads in Sweden in 1962-1964 have also shown that the single-vehicle accident rate decreases with ADT and the collision rates increase with ADT.

Duncan [cited in Ref. 5] analyzed British data from 30 feet wide Carriageways (main roads in predominantly rural areas) and found that accidents involving two vehicles or more are positively correlated with ADT, but the correlation between single-vehicle accidents and ADT is insignificant.

Tanner, Foldvary and Belmont [cited in Ref. 5] computed accident rates for a range of different volumes to determine the form of relationships that could be found between accident rates and traffic volumes. Tanner and Foldvary looked at accident data (from Britain and Queensland, respectively) and compared the proportions of accidents occurring at different times of day with the proportions of vehicle mileage estimated from traffic counts. It was generally found that hours with the lightest traffic tend to have the highest accident rates.

Belmont [cited in Ref. 5] examined accident data from two-lane roads in California and compared accident rates per vehicle mile with hourly traffic volumes. Whilst the single-car accident rate tended to decrease with traffic, multi-car accident rates increased sharply until an hourly volume of 600-700 vehicles was reached and then the rates declined.

The objectives and conclusions of Turner and Thomas [6] highlighted the relatively high number of injury accidents on the motorway network. In particular, they tried to examine the influence of traffic flow and volume upon the value of total injury accidents and accident rates. A great understanding of motorway accidents can be obtained by describing accidents in terms of severity and vehicle involvements, and by examining accident occurrence by time of day.

Also accident frequency was used as a measure of accident rate (i.e injury accidents per Km) where a different picture emerges. The low value of total road length associated with motorways tends to produce a high value of accident rate.

Calculations were first undertaken to determine values of accident rate and traffic flow; the former being expressed both in terms of injury accidents per Km and injury accidents per veh-Km. The results of the regression analysis were [6]:

a- Injury accident totals: Both linear and polynomial regression analysis were undertaken using some form of injury accident total as the dependent variable and traffic flow (veh-Km) as the independent variable.
   Table (2.1) and (2.2) presents the results of both form of equations and the coefficients of determination ($R^2$).

b- Injury accident rates: Significant relationships existed between injury accident rate and the volume of traffic.

*TABLE 2.1 RELATIONSHIPS BETWEEN TOTAL INJURY ACCIDENTS AND TRAFFIC FLOW (DUAL 2 - LANE MOTORWAYS) REF. [6]*

| *Description Of Accident Variable* | *Form Of Equation* | $R^2$ |
|---|---|---|
| Total Annual Injury Accidents | = -2998 + 0.177 X1 | 0.763 |
| Total Annual Serious Injury Accidents | = -0.9625 + 0.0567 X1 | 0.54 |
| Total Annual Slight Injury Accidents | = -2.17 + 0.117 X1 | 0.797 |

*X1 = Is the two-way annual traffic flow (M. V. KM)*

*TABLE 2.2 RELATIONSHIPS BETWEEN TOTAL INJURY ACCIDENTS AND TRAFFIC FLOW (DUAL 3 - LANE MOTORWAYS) REF. [6]*

| *Description Of Accident Variable* | *Form Of Equation* | $R^2$ |
|---|---|---|
| Total Annual Injury Accidents | = -4.281 + 0.152 X1 | 0.739 |
| Total Annual Serious Injury Accidents | = -0.90 + 0.038 X1 | 0.568 |
| Total Annual Slight Injury Accidents | = -3.109 + 0.105 X1 | 0.676 |

*X1 = Is the two-way annual traffic flow (M. V. KM)*

Table 2.3 and 2.4 give the results of regression analysis using similar forms of the dependent variable as given in paragraph a. above.

It may be observed that the values of $R^2$ are not as high as those quoted in Tables 2.1 and 2.2 and that the form of the independent variable producing the most significant form of the equation linking injury accident rate with traffic volume does on occasions involve a higher power of traffic volumes.

The following conclusions reflect the relationship between injury accident and traffic flow [6]:

a- Mean values of injury accident rate per veh-Km equal to $10.316 \times 10^{-8}$ and $9.983 \times 10^{-8}$ for dual 2-lane and dual 3-lane motorways, respectively.

b- The high values of injury accident rate occur on those sections of motorways having high injury accident totals and large traffic volumes.

c- If injury accident rate is adopted as the dependent variable, then the most appropriate form is injury accident per Km.

d- Single and multiple vehicle accident rates increase with increasing levels of traffic.

e- A high percentage of fatal and serious injury accidents on highly trafficked motorways and high value of slight

*TABLE 2.3 RELATIONSHIPS BETWEEN INJURY ACCIDENT RATE AND TRAFFIC VOLUME (DUAL 2 - LANE MOTORWAYS) REF. [6]*

| *Description Of Accident Variable* | *Form Of Equation* | $R^2$ |
|---|---|---|
| Total Annual Injury Accidents Per Km | $= -0.289 + 0.173\ X2$ | 0.712 |
| Total Annual Serious Injury Accidents Per Km | $= 0.0805 + 0.0532\ X2$ | 0.415 |
| Total Annual Slight Injury Accidents Per Km | $= 0.222 + 0.1167\ X2$ | 0.742 |

*X2 = Is the two - way annual traffic volume (M. V. KM)*

*TABLE 2.4 RELATIONSHIPS BETWEEN INJURY ACCIDENT RATE AND TRAFFIC VOLUME (DUAL 3 - LANE MOTORWAYS) REF. [6]*

| *Description Of Accident Variable* | *Form Of Equation* | $R^2$ |
|---|---|---|
| Total Annual Injury Accidents Per Km | $= 0.515 + 0.00426(X2)$ | 0.369 |
| Total Annual Serious Injury Accidents Per Km | $= 0.159 + 0.00095(X2)$ | 0.167 |
| Total Annual Slight Injury Accidents Per Km | $= -1.54 - 0.31\ X2 + 0.027(X2)^2 - 0.0052(X2)^3$ | 0.4 |

*X2 = Is the two - way annual traffic volume (M. V. KM)* injury accident correspond with motorways on which high traffic volumes can be expected.

The strong relationship between accidents and traffic flow is used in predicting the number of accidents occurring from a knowledge of the level of traffic flow and in the identification of accident black spots or problematic lengths of road; also it can be used in the international comparison of accident statistics.

## 2.3 Link accidents

A road link is defined as the section of carrigeway between two major junctions but excluding minor junctions and those lengths of road 20 meters either side of all junction [7,16,17].

An overlapping of accidents exist between the intersection and link rating analysis. The data file used defined radius of intersection from its center. The link data, however, are recorded from the centers of intersections, thus, a link may contain part of a major intersection. The use of accident files and a criterion (e.g radius= 61.0m) to separate intersection accidents from link accidents can solve this problem [8].

Lawson [16], excluded accidents occurring at junctions because of the large individual differences between junctions. Accident patterns at these sites tend to reflect the style of the junction rather than any characteristics of the link on which they are located.

## 2.4 Criteria used into identification of high accident locations

### 2.4.1 The criterion of the relationship between accident and traffic flow

McGuigan [7] used the relationships between road accidents and traffic flow in "blackspot identification" and used a measure of the potential for accident reduction as a ranking criterion for high accident locations. Some 118 single - carriageways and two-way road links were selected by a random number process, from the Lothian Road Accident Statistic System (LORASS) road network.

For each link the data were abstracted as follows:

I. Vehicle kilometers traveled (link length * 1979 traffic flow).

II. Annual accident total (average of three years accident total, 1977-1973).

III. Land use type (Urban/rural).

The results of simple linear regression analysis with million vehicle kilometers (M.V.Km) as the traffic index was undertaken in three groupings of sample data:

- Urban links: Sample size 94 links

  $y = 0.085 + 0.856\ X$

  $r = 0.67$

- Rural links: Sample size 24 links

  $y = 0.033 + 0.549\ X$

  $r = 0.702$

- All links: Sample size= 24 + 94 = 118 links

  $y = 0.078 + 0.737\ X$

  $r = 0.637$

Where: $y$ = annual accident total.

$X$ = million vehicle kilometers.

$r$ = correlation coefficient.

McGuigan [7] stated that it is possible, to use these relationships to calculate expected number of accidents for location ($\hat{y_i}$) as follows:

$(\hat{y_i}) = X_i.Rcat.$

where: $X_i$= is the selected traffic flow index. Rcat.

Rcat: the average accident rate for the appropriate category and traffic flow index.

The actual number of accidents ($y_i$) which can be expressed as follows:

$$y_i = X_i \cdot R_i + e_i$$

where:

$R_i$= is the true accident rate at location i.

$e_i$= a random error (i.e the effect of the natural variability of accident occurrence).

The difference ($d_i$) between actual and expected accident total can then be calculated as:

$$d_i = (y_i - \hat{y_i}) = X_i\ (R_i - R_{cat}) + e_i$$

where $d_i$ is large and positive. There is evidence to suggest that accidents on location (i) occur more frequently than at other locations of similar type; therefore, location (i) could be termed a "blackspot", then $d_i$ is a measure of the potential accident reduction. Consequently, a list of black-spots could be ranked in descending order of $d_i$.

Lalani and Walker [9] attempted to obtain a relatively simple correlation between accident frequency and average daily volume on major arterial streets in Phoenix, Arizona (U.S.A).

The 500 km used for the study include arterial and collector streets in Phoenix for which volumes of traffic are available. One year accident data and volume for 1979 were obtained for every 1.6 km segment. The segments were sub-classified into two categories:

1- Improved arterial streets: Roads with six or more than six lanes which included a left turn Channel and segments with median islands separating the two directions of traffic.

2- Unimproved arterial streets: Roads with two or four through lanes with no left turn channel in the center.

The 150 segments for each of the two categories were separately plotted on graphs and results indicated that fairly good curvilinear relationships could be obtained for each category. The derived curvilinear relationships were as follows:

I. For improved arterial streets

$$y_1 = 0.833\ X + 0.025\ X^2 + 0.00060\ X^3$$

II. For unimproved arterial streets

$$y_2 = 0.750\ X + 0.025\ X^2 + 0.0010\ X^3$$

Where:

$y_1$= Mid-block accident (link accident) frequency on improved arterial streets.

$y_2$= Mid-block accident frequency on unimproved major arterial streets.

X= Average daily volume in thousands of vehicals.

The previous equations indicated that the frequency of mid-block accidents on unimproved arterial streets increase more rapidly once volume rises above 2000 veh/day.

Lalani and Walker [9] indicated that the above correlations have been used by the authorities of the city of Phoenix to estimate the accident cost reductions that can be anticipated by the provision of a continuous two-way left turn channel on major arterial street segments.

Further research for McGuigan [10] based on a larger sample of road links in Lothian Region (U.K.) to determine the relationships that exist between accident and traffic on road links categorized by both roadside development and road type.

The following data werw obtained from the LORASS for each link:

-Length: Meters.

-Accident total: personal injury road accidents for the 45-month period from January 1977 to September 1980.

-Carriageway type: One-way street, single or dual Carriageway.

-Traffic flow: estimate of annual traffic flow for 1979.

The ground level development at each side of the road was coded for each link. The following codes were used:

1- Shops.

2- Commercial premises.

3- Residential premises.

4- Industrial premises.

5- Open (recreational, ...etc. but not rural).

6- Rural.

They provided 28 potential developments when both sides of the road were considered. In this way, data of 2581 links were obtained which involved 3652 accidents along 600 km and more than 1660 million vehicle kilometers traveled in 1979.

A number of fundamental statistics were calculated which included accident rates and correlation coefficients for the relationships between accidents and M.V.Km and the following observations were made:

- Shopping developments were found to be in the top list of ranking.
- Dual Carriageway categories lie in the bottom.
- The rate of accidents for single-Carriageway shopping streets was in the order of 12 times greater than that for rural dual Carriageway.
- Rural development type were in the lowest ranked categories.

In categories where significant correlations do exist, the concept of accident rate becomes more useful.

There was an evidence to suggest that accident rate can be used as a means of predicting accident totals.

To find a relationship between accidents and annual million vehicle kilometer, McGuigan [7] provided the following least square linear regression equation which could statistically describe the relationship:

$$y= A + BX$$

Where:

y= annual average accident total.

X= annual million vehicle kilometers.

A= regression constant.

B= regression coefficient.

According to McGiugan [7] this relationship can be used in the identification of high accident locations.

Thus, the difference between the observed (O) and the expected (E) annual average accident can be calculated. This difference (O-E) can be called potential annual accident reduction in preference to accident rate and annual average accident total.

The use of potential accident reduction as a ranking criterion is more likely to maximize the cost-effectiveness of road safety improvement program than the use of other ranking critera.

### 2.4.2 Other criteria used in identification of high accident locations

Silcock and Smyth [18] surveyed methods which are used by British Highway Authorities to identify accident blackspots. The criterion used by the British Highway Authorities included the following main classes:

I. Annual accident total.

II. Accident total severity index.

III. Accident total per unit length.

IV. Accident rates based on traffic flow.

V. Multifactor.

VI. Subjective.

VII. Others.

Four out of five Highway Authorities (excluding the individual London boroughs) make use of annual accident total alone, without reference to any measure of exposure, such as traffic flow.

In their analysis, none of the considered Authorities defined black spot on the basis of accident rates with respect to traffic flow. In two cases, one largely urban and the other largely rural, a parallel list of sites was compiled on the basis of accident totals.

Another Highway Authorities made use of traffic flow-based accident rates and the probability of an increase in the number of accidents at a given site, in determining the ranking of the black-spots.

One Highway Authority which within its boundary has a large industrial area, employs a multi-factor ranking process for accident black-spots. However, in this case the various considered factors did not include the vehicle flow.

The Baltimore County (USA) [11] used several factors based on the county maintenance functions, including physical cross section, present serviceability rating, capacity and safety factors to rate road sections defined by the county.

The number and type of accidents occurring on each roadway section were the most important measures of roadway hazardousness.

The first step adopted by the county was preparing the accident data for use in the road rating to select the Baltimore county accident records for each study year and put all these records into one file. So for the three-year period studied (1975-1977), 33091 accident records which had occurred on routes in Baltimore county were obtained.

The Baltimore County [11] inventory road sections was developed around intersections and landmarks, whereas, the accident files have milepoints to locate accidents. The road section begins at the intersection of the subject route with a specific route or at some distance from an intersection, but the end point is a physical landmark or intersection and has no relation to the state accident-mile point system. The accidents could be matched to the roadway sections, and then the safety analysis was performed.

The main objective of the Baltimore road-rating project and the basis for safety analysis was to identify those road sections that were more hazardous than others.

The common measure used for ranking hazardousness of road sections is the accident rate, expressed as accident per million vehicle-kilometers. When there was a significant difference in average daily traffic (ADT) among sections, the accident rate was expressed as accidents per kilometer when the volumes over the road sections were relatively uniform. The Baltimore County road rating program was designed to identify deficient road sections in the county system. Deficiencies with regard to safety were defined as those that involve the risk for human life directly.

Safety deficiencies were evaluated by means of several measures. Initial measures were total accidents (measure 1), and accident rates (measures 2 and 3). Subsequent consideration was given to other measures, which involved quality control and variation in the sample for each functional classification.

The most hazardous section with regard to accident rate was a minor arterial that had a rate of more than 31 Acc/M.V.Km, compared with the average of 2.9 Acc/M.V.Km and an accident number of more than 50. This section had a rate 10 times the average.

Datta T.K. and others [8] developed a methodology that would stratify the highway locations in an area in a manner that would eliminate the possibility of selecting non critical locations for remedial action, because defining high, moderate and low accident locations is an essential prerequisite for any plan to reduce safety hazards on a highway.

Indiana traffic-accident record system (INTRACS) [19] was developed to produce special summaries of locations having high accident rates. High-accident sections can be determined on the basis of the number of accidents that occur or the rate of accidents occurring when compared with million vehicle kilometers.

To determine locations having high rates of accidents the system first computes the accident rate at each section by dividing the number of accidents by million vehicle kilometers of travel for each section and then computes the average rate for all sections in the designated class. The accident rate at each section is then compared with that of the average. Sections at which the rate exceeds the average rate by a specified value are listed as high accidents links.

Mahalel [20] used means of risk and exposure to define the safety level of a transport system. Risk elements were used to describe the safety level of transportation system in a manner that is invariable to their exposure level. The risk varied in accordance with the traffic-flow condition under which the system exists during exposure measurements. According to the widespread approach, risk is defined as the ratio between the number of accidents and the amount of exposure.

The use of accident rates as risk estimators, though wide spread, presented a potential error. This occurred when the relationship between exposure and accidents was not linear. But if a certain exposure measure shows a linear relationship with the number of accidents, accident rates could then be used as a risk measure such as accident rate due to the relationship between accidents and million vehicle kilometers.

## 2.5 Criteria used in accident ranking

The most commonly used criteria to identify and rank high accident locations are the average annual accident total taken over three years (usually applied to high-risk locations, such as intersections or small areas) and the accident rate per million vehicle kilometers (applied to road lengths) [1].

Rospa [13] defined five methods for ranking of accidents:

1- "Accident total"

The most straight forword method is to select sites in descending order of accident total, this does not necessarily produce a list of sites that are "treatable" using an accident remedial measure.

2- "Accident rates"

Accident rates also used at the site of specific level to rank sites within a black site list. In this case the total number of accidents is divided by an index of traffic flow for each site, since it is thought that accident levels are related to the vehicles traveling through the site. But it is not to define a simple linear relationship between accidents and flow at sites. Flow is only for a series of "dependent variable" that generate the accident frequency.

3- "Potential for Accident Reduction"

A more complex rate (accident blacksites list) involves the method known as the potential for accident reduction. This method involves a series of lists that compare rates at individual sites with an average for that type of site. The sites are ranked in descending order of difference from the mean. Those sites at the top of the list provide the greatest potential for accident reduction. Therefore in Figure 2.2 the black site list will be ranked as follows:

| | |
|---|---|
| 1- (worst site) | B |
| 2- | C |
| 3- | A |
| 4- | O |
| 5- | D |

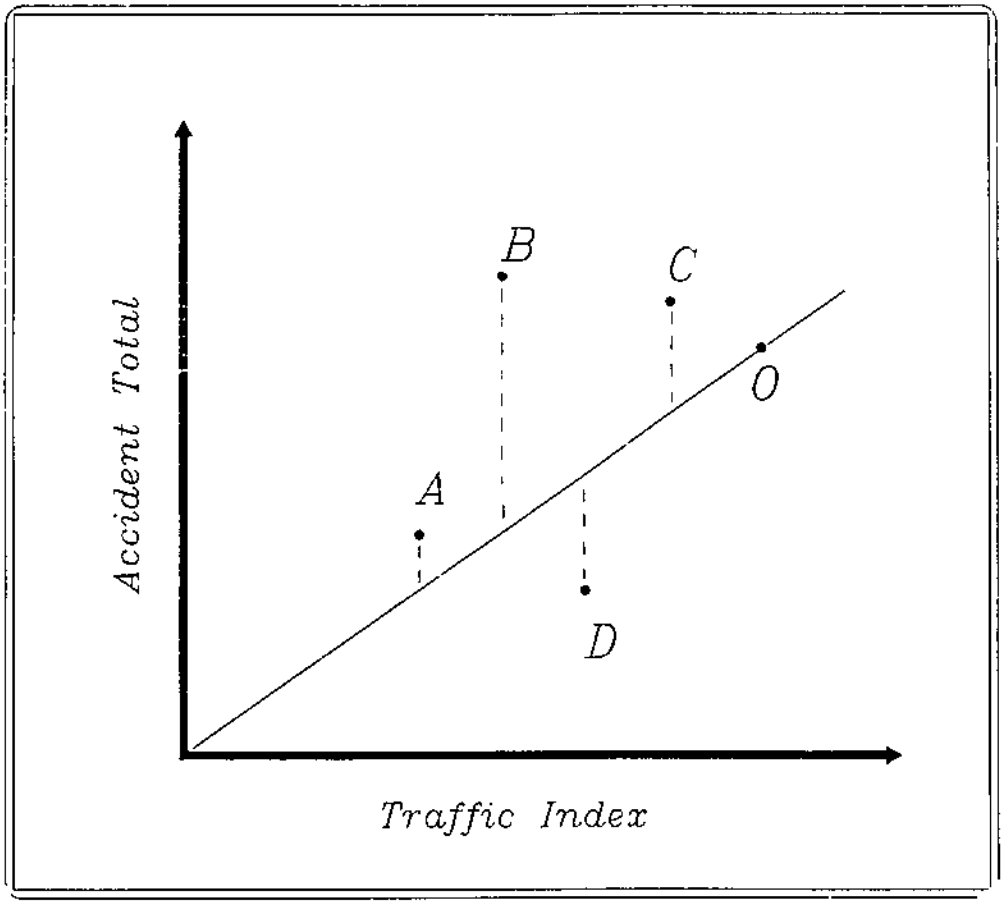



*FIGURE 2.2 THE RANK OF THE BLACK SITES USING POTENTIAL FOR ACCIDENT REDUCTION METHOD [13].*

4- "weighted" methods.

Some authorities in the U.K., decided to "weight" their blacksite lists by giving an extra score to various factors including accident severity and pedestrian accidents. This is usually done by using a list produced initially by accident total. It has the advantage of allowing a particular policy to be reflected in the blacksites ranking system.

5- The "composite treatable" blacksites list.

The composite list provides the engineer with a list of sites that have treatable problems. It is generated by combining specialized accident total list with sites that are notified to the authority by members of the public. Each site on the list satisfies a criterion of a minimum number of treatable accidents recorded during a 3 or 5 years time period.

Recently J. Hayes [12] provided an idea about a system which was developed in the traffic section of the Yorkshire and Humberside regional offices. This system identifies and ranks trunk road sites with their clusters of accidents. The system used a national database of road network information which is called Network Information System (NIS) and contains a comprehensive record of accident details and traffic flow for the whole of the trunk road network in the county.

The above system was first devised in 1986 and based on accident records covering the preceding five year period. The process has been repeated for each year since then and each time the system was almost complete with minimum changes.

Records from the NIS were obtained in the form of accident locations plotted to a scale of 1:50,000 on transparent sheets. Clusters of accidents were picked out and the sections of road within which accidents took place were determined.

As far as it was practicable, the length of each section was fixed at approximately 2Kms and the coordinates of the end points were recorded. Clusters of 15 or more accidents in five years were included in the list of sites for ranking.

The first step in the ranking process was to obtain a detailed accident record for each of the sites identified, then ranking is done using two factors: accident number and accident rates. For accident numbers, higher ranking is given to those sites with more accidents. The accident rate used for ranking is accidents per million vehicle kilometers, so the rank of the site varied with the method of ranking.

The result of this work were compared with the national average (1.2 Acc/M.V.Km for urban and 0.39 Acc/M.V.Km for rural), some sites identified and ranked had much higher accident rates.

# *CHAPTER THREE*

## *DATA COLLECTION*

# *CHAPTER THREE*
# *DATA COLLECTION*

## 3.1 Introduction

The data collection process for this research was carried out with certain difficulties because of the following main reasons:

1- There was no complete data system for highway information including, detailed road accident statistics, volumes and composition of traffic.

2- The information obtained from various resources is not properly arranged in a simple and useful way.

3- There was no available facilities which could be used to collect adequate information related to traffic volumes and exact locations of accidents.

## 3.2 Selection of sites

The accident records which are available in the police traffic department were initially surveyed to have a rough idea about the method which was adopted in recording accidents and their locations with a reasonable accuracy.

It was found that it is quite difficult to determine precisely spots or sections where accidents took place on rural areas. This is because these roads have long distances with no kilometer signs and road numbers which simplified the process of determining the accident location.

Therefore, selected Urban multilane divided arterial streets which are defined as signalized streets that primarily serve through traffic and provide access to abutting properties as a secondary function [21] were chosen within the boundary of Greater Amman Municipality.

Several aspects were taken into consideration while selecting the sites, as will be shown in the following sections:

### 3.2.1 Types of selected sites

The selected arterial roads were located in the western area of Greater Amman, where the highway network contains an adequate number of divided arterial streets and have nearly the same level of activities. Fig. (3.1)

These arterial streets are located between collector and downtown streets on one side and multilane suburban highway and rural roads on the other side of those streets. These streets have no significant differences in their functions, characteristics and intensity of roadside development.

Along such streets there are a large number of well known places and/or public locations which were used to determine the approximate locations of accident. In recording accidents, along such streets, the police officers refer to these locations since there is no complete numbering system for streets in the country.

### 3.2.2 Geometric and traffic characteristics

The selected arterial streets have a identical geometrical characteristics, such as:

1- Divided by median island.

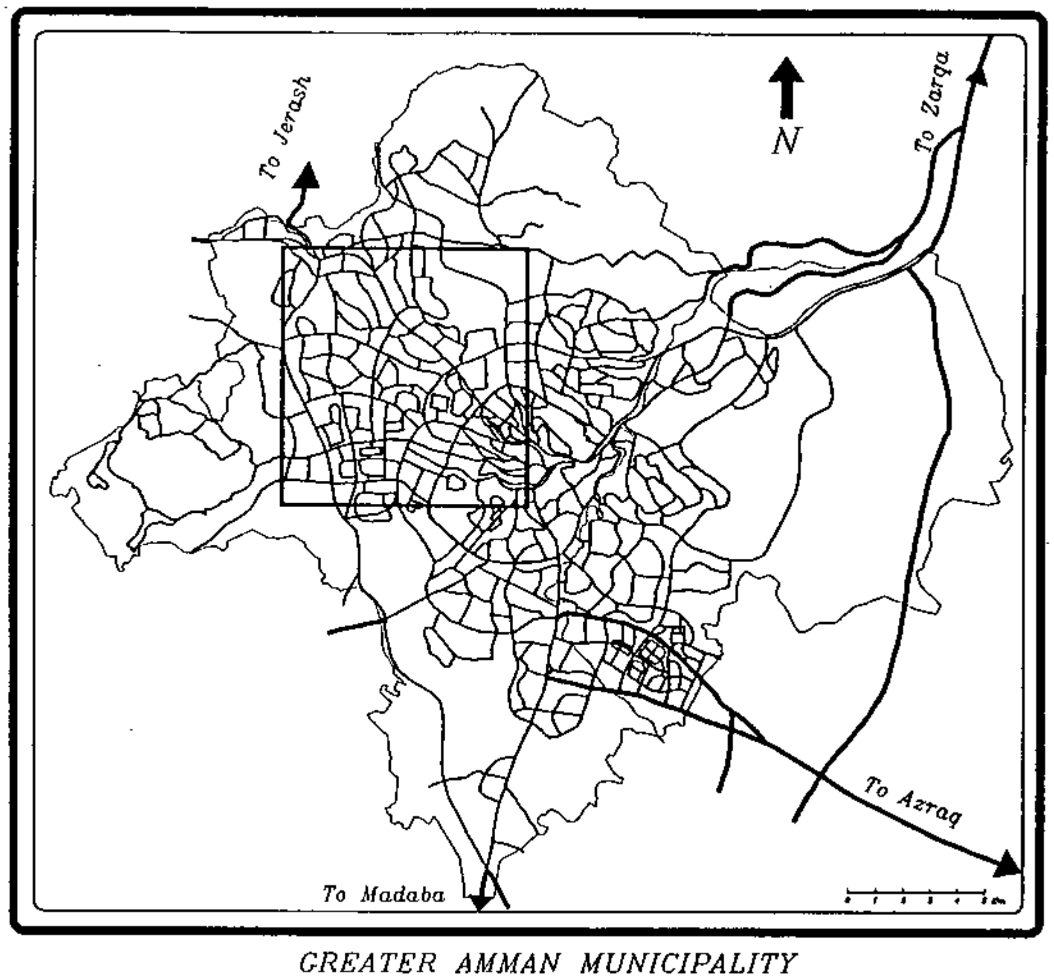



***FIGURE 3.1 LOCATION OF THE SELECTED ARTERIAL STREETS***

2- Two or three lanes in each direction.

3- sidewalk for the pedestrians.

4- Each section lies between signalized intersection and/or some of them lie between signalized intersections and interchanges.

5- There are no significant differences in the longitudinal grades between these streets.

6- They have similar drainage systems.

7- The same level of traffic signs such as stop signs or giveway signs at exits from minor to major streets.

8- All arterial streets are lighted at night.

9- Composition of traffic is almost the same along these streets.

### 3.2.3 Accident frequency

Some of the selected arterial streets have a high accident frequency and extensive arguments about frequency and about the hazardousness of such streets are usually the subject of social discussions and complaints, therefore, these streets were chosen to be the subject of the investigation.

### 3.2.4 The selected streets

The selected streets which have been investigated in this thesis are the following:

1- Queen Alia street.

2- Zahran street.

3- Mecca street.

4- Queen Nour street.

5- Al-Sharif Naser Ben Jameel street.

6- Al-Kenndy street.

7- Al-Sharif Hussien Ben Ali street.

8- Al-Madinnah Al-Mounawara street.

9- AbdAllah Gosheh street.

Each one of the selected streets was divided into links. Every link was connected to a node and every node could be either signalized intersection, interchange and/or a roundabout. Therefore, almost every link has a different level of traffic volume.

Figure 3.2 illustrates the description of the link.

Figure 3.3 shows links code (both directions).

Figure 3.4 shows the code for each direction of the links.

Tables 3.1 through 3.9 show the start and the end points of every selected street as well as the code of each link which lies between two nodes and the code for each direction of the link.

Figure 3.5 illustrate the first link of Queen Alia street as an example for the selected links.

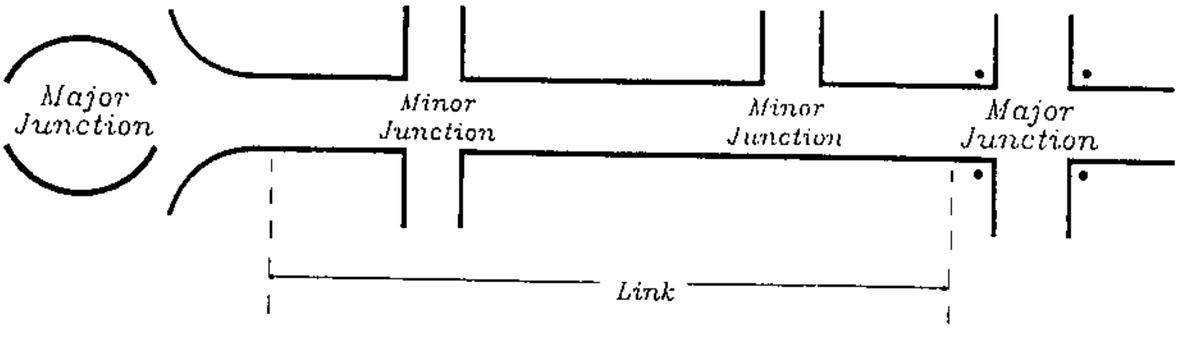
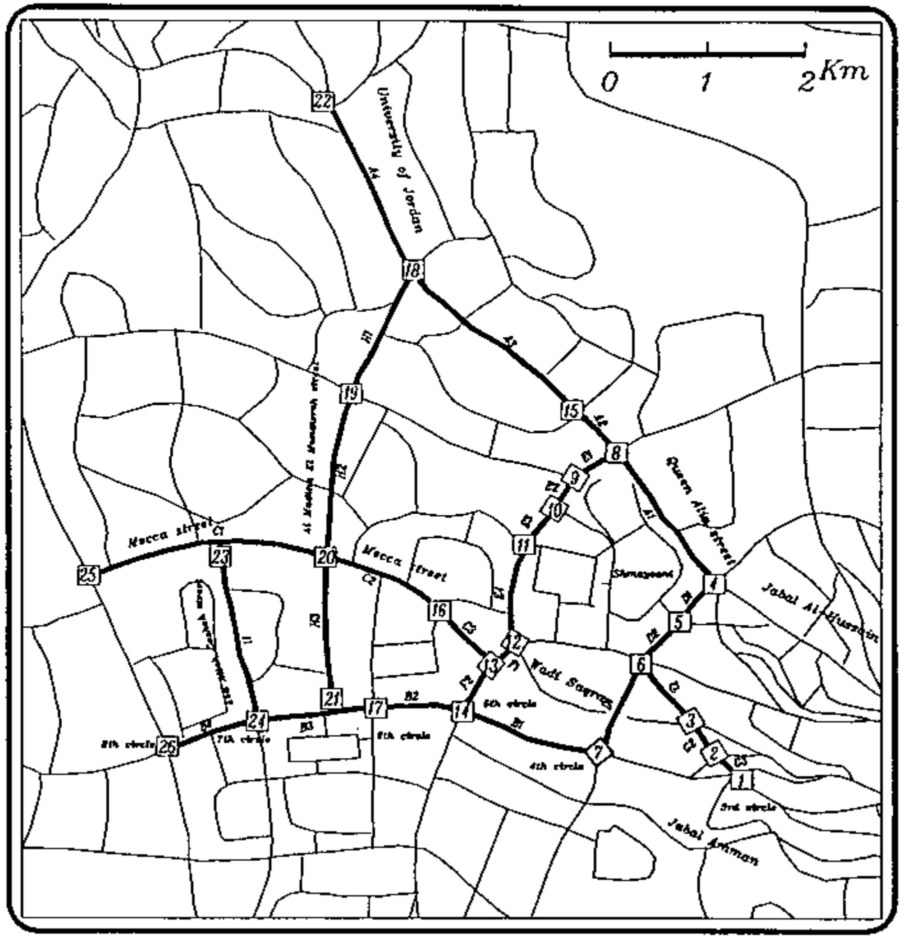
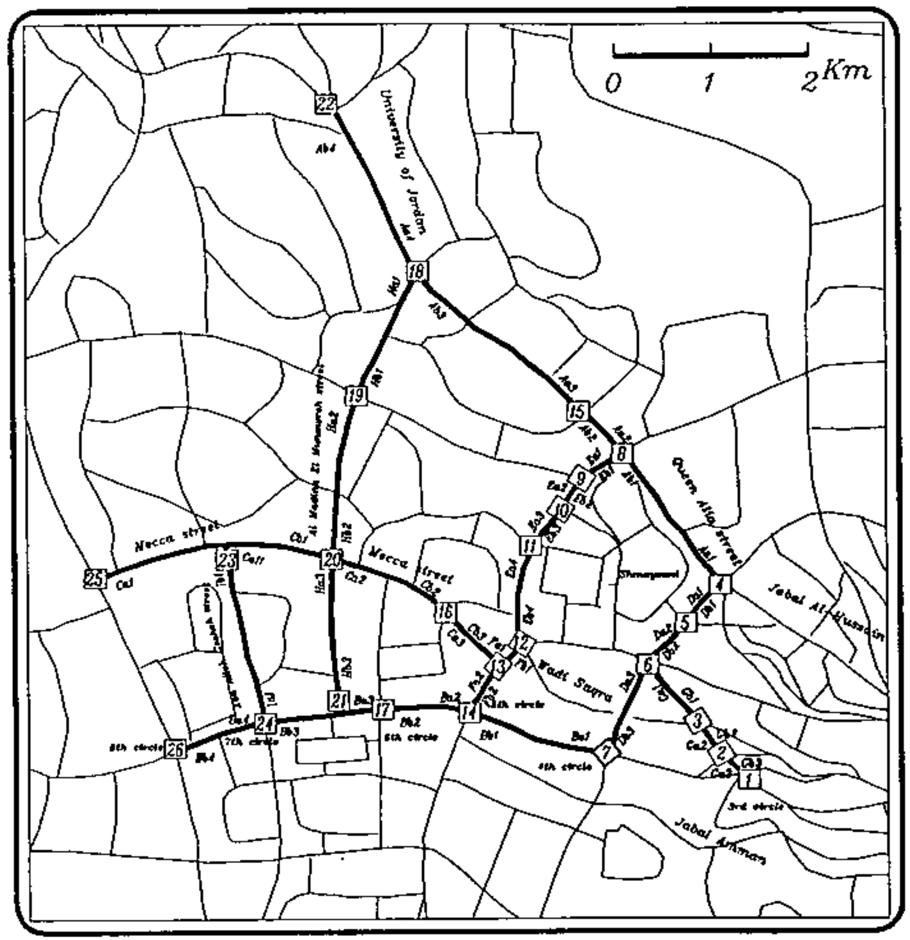



*FIGURE 3.2 LINK DEFINITION*




SELECTED ARTERIAL STREETS

***FIGURE 3.3 NODES NUMBER AND LINKS CODE, (BOTH DIRECTIONS)***




SELECTED ARTERIAL STREETS

**FIGURE 3.4 NODES NUMBER AND CODE FOR EACH DIRECTION OF THE LINKS**

## *TABLE 3.1 QUEEN ALIA STREET (A)*

*Start Node: Ministry of Interior*

*End Node: Traffic Light of University Mosque*

*Number of Sections: 4*

| Link No. | Link Code (Both Directions) | Code for Each Direction | From Node | To Node |
|---|---|---|---|---|
| 1 | A1 | Aa1 | 4 | 8 |
| | | Ab1 | 8 | 4 |
| 2 | A2 | Aa2 | 8 | 15 |
| | | Ab2 | 15 | 8 |
| 3 | A3 | Aa3 | 15 | 18 |
| | | Ab3 | 18 | 15 |
| 4 | A4 | Aa4 | 18 | 22 |
| | | Ab4 | 22 | 18 |

## *TABLE 3.2 ZAHRAN STREET (B)*

*Start Node: 4-th Circle*

*End Node: 8-th Circle*

*Number of Sections: 4*

| Link No. | Link Code (Both Directions) | Code for Each Direction | From Node | To Node |
|---|---|---|---|---|
| 5 | B1 | Ba1 | 7 | 14 |
| | | Bb1 | 14 | 7 |
| 6 | B2 | Ba2 | 14 | 17 |
| | | Bb2 | 17 | 14 |
| 7 | B3 | Ba3 | 17 | 24 |
| | | Bb3 | 24 | 17 |
| 8 | B4 | Ba4 | 24 | 26 |
| | | Bb4 | 26 | 24 |

### *TABLE 3.3 MECCA STREET (C)*

*From: Kenndy Street*

*To: Medical City Street*

*Number of Sections: 3*

| *Link No.* | *Link Code (Both Directions)* | *Code for Each Direction* | *From Node* | *To Node* |
|---|---|---|---|---|
| 9 | C1 | Ca1 - Ca2 | 25–23 | 23–20 |
| | | Cb1 | 20 | 25 |
| 10 | C2 | Ca2 | 20 | 16 |
| | | Cb3 | 16 | 20 |
| 11 | C3 | Ca4 | 16 | 13 |
| | | Cb3 | 13 | 16 |

### *TABLE 3.4 QUEEN NOUR STREET (D)*

*From: Ministry of Interion Interchange*

*To: 4–th Circle*

*Number of Sections: 3*

| *Link No.* | *Link Code (Both Directions)* | *Code for Each Direction* | *From Node* | *To Node* |
|---|---|---|---|---|
| 12 | D1 | Da1 | 4 | 5 |
| | | Db1 | 5 | 4 |
| 13 | D2 | Da2 | 5 | 6 |
| | | Db2 | 6 | 5 |
| 14 | D3 | Da3 | 6 | 7 |
| | | Db3 | 7 | 6 |

### *TABLE 3.5 AL-SHAREEF NASER BEN JAMEEL STREET (E)*

*From: Sport City Interchange*

*To: Wadi Saqra Interchange*

*Number of Sections: 4*

| *Link No.* | *Link Code (Both Directions)* | *Code for Each Direction* | *From Node* | *To Node* |
|---|---|---|---|---|
| 15 | E1 | Ea1 | 8 | 9 |
| | | Eb1 | 9 | 8 |
| 16 | E2 | Ea2 | 9 | 10 |
| | | Eb2 | 10 | 9 |
| 17 | E3 | Ea3 | 10 | 11 |
| | | Eb3 | 11 | 10 |
| 18 | E4 | Ea4 | 11 | 12 |
| | | Eb4 | 12 | 11 |

### *TABLE 3.6 AL-KENNDY STREET (F)*

*From: Wadi Saqra Intersection*

*To: 4-th Circle*

*Number of Sections: 2*

| *Link No.* | *Link Code's (Both Directions)* | *Code for Each Direction* | *From Node* | *To Node* |
|---|---|---|---|---|
| 19 | F1 | Fa1 | 12 | 13 |
| | | Fb1 | 13 | 12 |
| 20 | F2 | Fa2 | 13 | 14 |
| | | Fb2 | 14 | 13 |

### *TABLE 3.7 AL-HUSSIEN BEN ALI STREET (G)*

*From: Shmaysani*

*To: 3-rd Circle*

*Number of Sections: 3*

| Link No. | Link Code (Both Directions) | Code for Each Direction | From Node | To Node |
|---|---|---|---|---|
| 21 | G1 | Ga1 | 6 | 3 |
| | | Gb1 | 3 | 6 |
| 22 | G2 | Ga2 | 3 | 2 |
| | | Gb2 | 2 | 3 |
| 23 | G3 | Ga3 | 2 | 1 |
| | | Gb3 | 1 | 2 |

### *TABLE 3.8 MADINA MOUNAWARA STREET (H)*

*From: University Bridge*

*To: Intersect with Zahran*

*Number of Section: 3*

| Link No. | Link Code (Both Directions) | Code for Each Direction | From Node | To Node |
|---|---|---|---|---|
| 24 | H1 | Ha1 | 18 | 19 |
| | | Hb1 | 19 | 18 |
| 25 | H2 | Ha2 | 19 | 20 |
| | | Hb2 | 20 | 19 |
| 26 | H3 | Ha3 | 20 | 21 |
| | | Hb3 | 21 | 20 |

### *TABLE 3.9 ABD-ALLA GOUSHEH (I)*

*From: 7-th Circle*

*To: Mecca Street*

*Number of Section: 1*

| Link No. | Link Code (Both Directions) | Code for Each Direction | From Node | To Node |
|---|---|---|---|---|
| 27 | I1 | Ia1 | 24 | 23 |
| | | Ib1 | 23 | 24 |

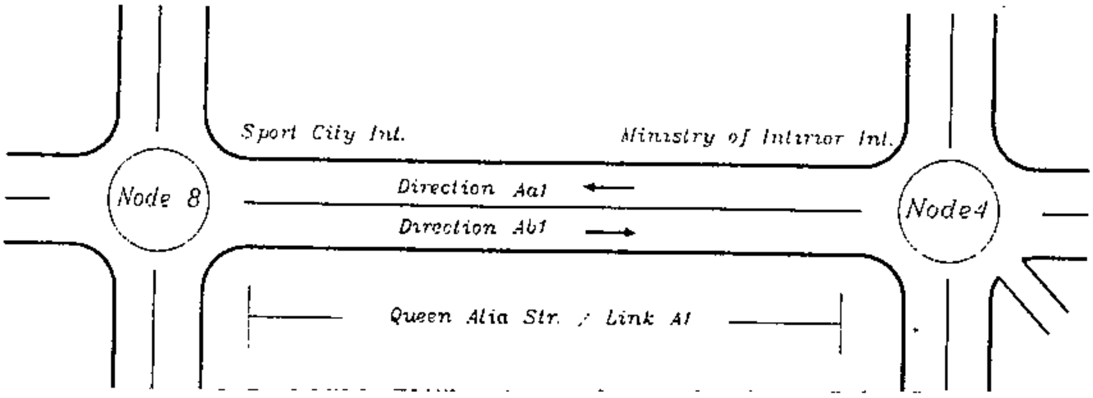



*FIGURE 3.5 LINK A1 (QUEEN ALIA STREET)*

## 3.3 Accident data

The accident data collection was the most time consuming due to the lack of properly arranged road accidents data bank.

In Jordan, like in many other developing and developed countries, accident data are maintained in a file in which each accident is represented by an accident record which forms the police accident report.

These records contain information such as details concerning day of the week, date and time of the accident, the approximate location of the accident, a brief description of the movement of vehicles involved in the accident, indication of lit roads and surface conditions, number of vehicles involved in the accident, number of injuries and fatalities and a sketch for the accident location provided with the accident form.

Due to the lack of detailed information related to the exact locations of accidents, there were many difficulties which had to be partly overcome by phoning those who were involved in the accidents to arrive at more detailed information. Thousands of accident records have been investigated during this process. Two and a half years of accident records were covered.

The number of accidents which have occurred on the selected arterial streets were determined and only those accidents which occurred between two adjacent intersections were included in this study (link's accidents for each side of link). Accidents which occurred at intersections (within 20m either side of the intersections) or on the minor junctions were excluded, since these accidents at those sites tend to reflect the style of the major and minor junctions rather than any characteristics of the link on which they are located.

Table 3.10 shows the traffic accident data for each direction of the links.

Table 3.11 shows the traffic accident data for both directions of the links.

## 3.4 Traffic volume survey

The traffic volume counts for each section or link for the selected arterial streets were carried out due to the unavailability of previous traffic counts records.

### 3.4.1 Automatic traffic counts

Automatic traffic counters were used to survey the traffic volume for each link in each direction. Automatic traffic counters were installed at each link of the selected arterial streets.

TABLE 3.10 TRAFFIC ACCIDENT DATA FOR EACH DIRECTION OF THE LINKS

| Direction Number | Code For Each Direction | Total Number Of Accidents | | | Annual Average Accident Total (AAAT) | Total Number Of Injury Accidents | | | Annual Average Injury Accident (AAIA) |
|---|---|---|---|---|---|---|---|---|---|
| | | 1988 6 mon. | 1989 | 1990 | | 1988 6 mon. | 1989 | 1990 | |
| 1 | Aa1 | 11 | 43 | 37 | 36.4 | 4 | 18 | 13 | 14 |
| 2 | Ab1 | 20 | 40 | 42 | 40.8 | 8 | 10 | 12 | 12 |
| 3 | Aa2 | 16 | 44 | 39 | 39.6 | 3 | 10 | 7 | 8 |
| 4 | Ab2 | 17 | 17 | 22 | 22.4 | 5 | 5 | 3 | 5.2 |
| 5 | Aa3 | 17 | 43 | 37 | 38.8 | 7 | 10 | 11 | 11.2 |
| 6 | Ab3 | 33 | 39 | 43 | 46 | 7 | 7 | 6 | 8 |
| 7 | Aa4 | 16 | 36 | 30 | 32.8 | 4 | 15 | 14 | 13.2 |
| 8 | Ab4 | 22 | 57 | 43 | 48.8 | 10 | 24 | 16 | 20 |
| 9 | Ba1 | 10 | 17 | 17 | 17.6 | 2 | 3 | 4 | 3.6 |
| 10 | Bb1 | 12 | 27 | 29 | 27.2 | 2 | 7 | 6 | 6 |
| 11 | Ba2 | 13 | 28 | 22 | 25.2 | 0 | 8 | 3 | 4.4 |
| 12 | Bb2 | 5 | 17 | 21 | 17.2 | 1 | 3 | 2 | 2.4 |
| 13 | Ba3 | 14 | 34 | 28 | 30.4 | 4 | 7 | 4 | 6 |
| 14 | Bb3 | 24 | 36 | 35 | 38 | 3 | 6 | 7 | 6.4 |
| 15 | Ba4 | 4 | 9 | 10 | 9.2 | 1 | 4 | 2 | 2.8 |
| 16 | Bb4 | 3 | 7 | 6 | 6.4 | 1 | 3 | 2 | 2.4 |
| 17 | Ca1 | 2 | 3 | 4 | 3.6 | 0 | 0 | 0 | 0 |
| 18 | Ca2 | 6 | 17 | 16 | 15.6 | 2 | 5 | 3 | 4 |
| 19 | Cb1 | 5 | 13 | 9 | 10.8 | 1 | 6 | 2 | 3.6 |
| 20 | Ca3 | 6 | 9 | 8 | 9.2 | 2 | 2 | 3 | 2.8 |
| 21 | Cb2 | 0 | 6 | 4 | 4 | 0 | 3 | 0 | 1.2 |
| 22 | Ca4 | 4 | 9 | 10 | 9.2 | 0 | 3 | 1 | 1.6 |
| 23 | Cb3 | 1 | 11 | 7 | 7.6 | 0 | 3 | 2 | 2 |
| 24 | Da1 | 2 | 11 | 13 | 10.4 | 1 | 7 | 2 | 4 |
| 25 | Db1 | 12 | 7 | 14 | 13.2 | 3 | 3 | 5 | 4.4 |
| 26 | Da2 | 3 | 5 | 4 | 4.8 | 2 | 1 | 2 | 2 |
| 27 | Db2 | 7 | 14 | 15 | 14.4 | 1 | 2 | 3 | 2.4 |
| 28 | Da3 | 1 | 10 | 6 | 6.8 | 0 | 2 | 1 | 1.2 |
| 29 | Db3 | 2 | 9 | 8 | 7.6 | 1 | 1 | 0 | 0.8 |
| 30 | Ea1 | 1 | 6 | 7 | 5.6 | 0 | 1 | 2 | 1.2 |
| 31 | Eb1 | 0 | 4 | 2 | 2.4 | 0 | 1 | 0 | 0.4 |
| 32 | Ea2 | 2 | 4 | 5 | 4.4 | 0 | 0 | 1 | 0.4 |
| 33 | Eb2 | 0 | 8 | 3 | 4.4 | 0 | 0 | 1 | 0.4 |
| 34 | Ea3 | 3 | 4 | 3 | 4 | 0 | 0 | 0 | 0 |
| 35 | Eb3 | 0 | 1 | 2 | 1.2 | 0 | 0 | 0 | 0 |
| 36 | Ea4 | 3 | 18 | 21 | 16.8 | 1 | 5 | 6 | 4.8 |
| 37 | Eb4 | 2 | 11 | 7 | 8 | 1 | 2 | 2 | 2 |
| 38 | Fa1 | 3 | 8 | 9 | 8 | 2 | 1 | 3 | 2.4 |
| 39 | Fb1 | 4 | 9 | 8 | 8.4 | 0 | 1 | 2 | 1.2 |
| 40 | Fa2 | 1 | 4 | 3 | 3.2 | 0 | 1 | 0 | 0.4 |
| 41 | Fb2 | 1 | 4 | 3 | 3.2 | 0 | 0 | 1 | 0.4 |
| 42 | Ga1 | 3 | 5 | 6 | 5.6 | 0 | 0 | 0 | 0 |
| 43 | Gb1 | 2 | 4 | 3 | 3.6 | 1 | 0 | 0 | 0.4 |
| 44 | Ga2 | 2 | 2 | 3 | 2.8 | 1 | 0 | 0 | 0.4 |
| 45 | Gb2 | 5 | 4 | 7 | 6.4 | 1 | 0 | 1 | 0.8 |
| 46 | Ga3 | 3 | 12 | 9 | 9.6 | 0 | 2 | 2 | 1.6 |
| 47 | Gb3 | 4 | 11 | 13 | 11.2 | 0 | 3 | 3 | 2.4 |
| 48 | Ha1 | 5 | 5 | 7 | 6.8 | 1 | 3 | 3 | 2.8 |
| 49 | Hb1 | 3 | 2 | 4 | 3.6 | 0 | 1 | 2 | 1.2 |
| 50 | Ha2 | 11 | 11 | 9 | 12.4 | 4 | 3 | 3 | 4 |
| 51 | Hb2 | 2 | 5 | 3 | 4 | 1 | 0 | 0 | 0.4 |
| 52 | Ha3 | 1 | 8 | 7 | 6.4 | 0 | 2 | 1 | 1.2 |
| 53 | Hb3 | 2 | 5 | 4 | 4.4 | 0 | 2 | 0 | 0.8 |
| 54 | Ia1 | 8 | 12 | 15 | 14 | 1 | 5 | 4 | 4 |
| 55 | Ib1 | 5 | 7 | 9 | 8.4 | 3 | 2 | 3 | 3.2 |

*TABLE 3.11 TRAFFIC ACCIDENT DATA FOR LINKS IN BOTH DIRECTIONS*

| Link Number | Link Code | Total Number Of Accidents | | | Annual Average Accident Total (AAAT) | Total Number Of Injury Accidents | | | Annual Average Injury Accident (AAIA) |
|---|---|---|---|---|---|---|---|---|---|
| | | 1988 6 mon. | 1989 | 1990 | | 1988 6 mon. | 1989 | 1990 | |
| 1 | A1 | 31 | 83 | 79 | 77.2 | 12 | 30 | 30 | 28.8 |
| 2 | A2 | 33 | 61 | 61 | 62 | 9 | 17 | 12 | 15.2 |
| 3 | A3 | 50 | 82 | 80 | 84.8 | 15 | 16 | 14 | 18 |
| 4 | A4 | 38 | 93 | 73 | 81.6 | 14 | 39 | 30 | 33.2 |
| 5 | B1 | 22 | 44 | 46 | 44.8 | 4 | 10 | 10 | 9.6 |
| 6 | B2 | 18 | 45 | 43 | 42.4 | 1 | 11 | 5 | 6.8 |
| 7 | B3 | 38 | 70 | 63 | 68.4 | 7 | 13 | 11 | 12.4 |
| 8 | B4 | 7 | 16 | 16 | 15.6 | 2 | 7 | 4 | 5.2 |
| 9 | C1 | 13 | 33 | 29 | 30 | 3 | 11 | 5 | 7.6 |
| 10 | C2 | 6 | 15 | 12 | 13.2 | 2 | 5 | 3 | 4 |
| 11 | C3 | 5 | 20 | 17 | 16.8 | 0 | 6 | 3 | 3.6 |
| 12 | D1 | 14 | 18 | 27 | 23.6 | 4 | 10 | 7 | 8.4 |
| 13 | D2 | 10 | 19 | 19 | 19.2 | 3 | 3 | 5 | 4.4 |
| 14 | D3 | 3 | 19 | 14 | 14.4 | 1 | 3 | 1 | 2 |
| 15 | E1 | 1 | 10 | 9 | 8 | 0 | 2 | 2 | 1.6 |
| 16 | E2 | 2 | 12 | 8 | 8.8 | 0 | 0 | 2 | 0.8 |
| 17 | E3 | 3 | 5 | 5 | 5.2 | 0 | 0 | 0 | 0 |
| 18 | E4 | 5 | 29 | 28 | 24.8 | 2 | 7 | 8 | 6.8 |
| 19 | F1 | 7 | 17 | 17 | 16.4 | 2 | 2 | 5 | 3.6 |
| 20 | F2 | 2 | 8 | 6 | 6.4 | 0 | 1 | 1 | 0.8 |
| 21 | G1 | 5 | 9 | 9 | 9.2 | 1 | 0 | 0 | 0.4 |
| 22 | G2 | 7 | 6 | 10 | 9.2 | 2 | 0 | 1 | 1.2 |
| 23 | G3 | 7 | 23 | 22 | 20.8 | 0 | 5 | 5 | 4 |
| 24 | H1 | 8 | 7 | 11 | 10.4 | 1 | 4 | 5 | 4 |
| 25 | H2 | 13 | 16 | 12 | 16.4 | 5 | 3 | 3 | 4.4 |
| 26 | H3 | 3 | 13 | 11 | 10.8 | 0 | 3 | 2 | 2 |
| 27 | I1 | 13 | 19 | 24 | 22.4 | 4 | 7 | 7 | 7.2 |

The counters were located in certain locations ensuring equivalent numbers of excess streets on both sides. This was necessary to ensure a full coverage of traffic volumes.

The counting process covered twenty four hours of counting for each link in both directions and in some locations for one week, to determine the day-to-day fluctuations in traffic volume.

Sarasota counters were used, which were available in the Ministry of Public Work and Housing in Jordan. The counters consist of solid-state equipment [RSU: Road Side Unit], with dual channel recording and re-chargeable batteries. A hunter (retriever) with a screen and disposable batteries were used with the counters to monitor and collect the stored data.

The road side unit (RSU) was located on the median islands of the devided arterial streets and connected to follow rubber tubes stretched across the road surface in each direction. The hunter was then connected by means of a standard connection to the (RSU). Parameters such as site number, date and time period were programmed.

After twenty-four hours of counting, the hunter was connected again to retrieve the new data. At the end of the counting period the (RSU) unit was moved to another location and the hunter was used again to reset installation of the device. For subsequent validation, editing and analysis, the hunter was connected to an IBM personal computer by means of a standard connection.

The accuracy of the automatic traffic counts were checked by:

1- Manual count which was conducted for one hour at the same time the automatic traffic counts were carried out. In general there were no significant differences between the two counts.

2- Monitoring the data on a Hunter's screen for a short period of time (i.e 10 minutes) and observing the process of counting directly.

### 3.4.2 Traffic volume from available data

A few number of sections or links of the selected arterial streets have previous traffic volume records. These records are available and have been used by the Greater Amman Municipality.

Figure 3.6 illustrates the locations of the traffic survey stations.

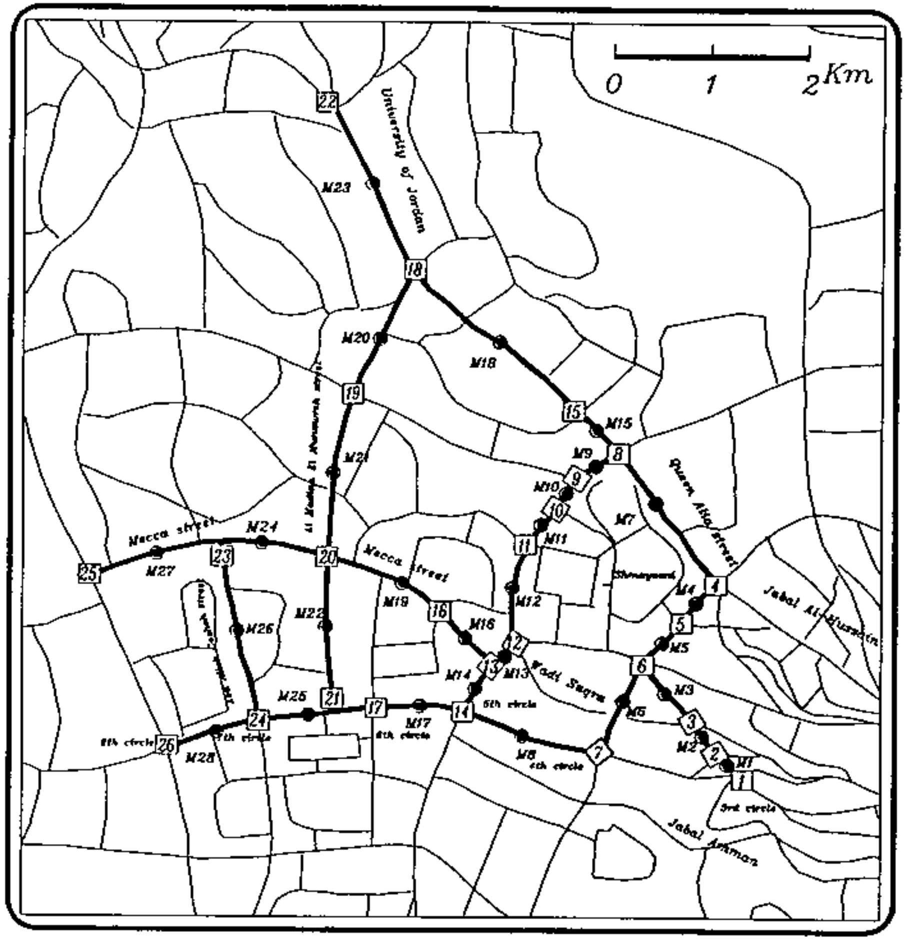
## 3.5 Lengths measurements

The lengths of the selected links were measured by using Halda Rally computer device mounted on four wheel drive vehicle.

### 3.5.1 Device calibration

The necessary calibration for the computer was carried out before taking the measurements and the process of calibration consisted of the following steps:

1- Define one kilometer of length on an even section of certain route, the start and end points of the section were painted.




Selected Arterial Streets

**FIGURE 3.6 LOCATIONS OF THE TRAFFIC SURVEY STATIONS**

2- The device was switched on as the front wheel of the vehicle matched the starting point.

3- The length was then measured as the vehicle starts moving slowly through the defined section towards the end point. The procedure was repeated five times. The figure displayed on the device was recorded each time and this figure represents the length of this route as measured by the device. However, this figure does not represent the length of the section in metric units.

4- The average value of the recorded figures was used in the calculation of the calibration factor (which is equal to the measured length of the section in km divided by the average value of the recorded figures).

5- The average value of recorded figures was installed in the device as a factor by which the actual length of any section is directly measured.

### 3.5.2 Measurement process

The measurement of the selected links were carried out by the Halda Rally computer device. To achieve higher degree of accuracy, the measurements were repeated for three times and the average length was determined.

Tables 3.12 and 3.13 show the lengths and average daily traffic for links in both directions and each direction, respectively.

*TABLE 3.12 LENGTH AND AVERAGE DAILY TRAFFIC FOR SELECTED LINKS (BOTH DIRECTIONS)*

| *Link Number* | *Link Code* | *Link Length (Meters)* | *Average Daily Traffic (ADT) (Veh/day)* |
|---|---|---|---|
| 1 | A1 | 1420 | 69984 |
| 2 | A2 | 850 | 72970 |
| 3 | A3 | 1800 | 64644 |
| 4 | A4 | 1940 | 48468 |
| 5 | B1 | 1510 | 38874 |
| 6 | B2 | 920 | 46822 |
| 7 | B3 | 1180 | 45619 |
| 8 | B4 | 890 | 32937 |
| 9 | C1 | 2510 | 27145 |
| 10 | C2 | 1300 | 31515 |
| 11 | C3 | 750 | 27956 |
| 12 | D1 | 500 | 62063 |
| 13 | D2 | 500 | 63962 |
| 14 | D3 | 880 | 31811 |
| 15 | E1 | 420 | 62112 |
| 16 | E2 | 140 | 48734 |
| 17 | E3 | 630 | 34515 |
| 18 | E4 | 1040 | 30041 |
| 19 | F1 | 330 | 46326 |
| 20 | F2 | 410 | 27181 |
| 21 | G1 | 320 | 42926 |
| 22 | G2 | 340 | 39951 |
| 23 | G3 | 400 | 42392 |
| 24 | H1 | 1210 | 29732 |
| 25 | H2 | 1780 | 32140 |
| 26 | H3 | 1550 | 15227 |
| 27 | I1 | 1860 | 17921 |

*TABLE 3.13 LENGTHS AND AVERAGE DAILY TRAFFIC FOR SELECTED LINKS (EACH DIRECTION)*

| *Direction Number* | *Code For Each Direction* | *Link Length (Meters)* | *Average Daily Traffic (ADT) (Veh/day)* |
|---|---|---|---|
| 1 | Aa1 | 1420 | 30337 |
| 2 | Ab1 | 1420 | 39647 |
| 3 | Aa2 | 850 | 35512 |
| 4 | Ab2 | 850 | 37458 |
| 5 | Aa3 | 1800 | 30386 |
| 6 | Ab3 | 1800 | 34260 |
| 7 | Aa4 | 1940 | 22677 |
| 8 | Ab4 | 1940 | 25789 |
| 9 | Ba1 | 1510 | 19666 |
| 10 | Bb1 | 1510 | 19214 |
| 11 | Ba2 | 920 | 24079 |
| 12 | Bb2 | 920 | 22745 |
| 13 | Ba3 | 1180 | 24304 |
| 14 | Bb3 | 1180 | 21315 |
| 15 | Ba4 | 890 | 16112 |
| 16 | Bb4 | 890 | 16827 |
| 17 | Ca1 | 1150 | 8677 |
| 18 | Ca2 | 1360 | 18041 |
| 19 | Cb1 | 2510 | 13786 |
| 20 | Ca3 | 1300 | 12923 |
| 21 | Cb2 | 1300 | 12551 |
| 22 | Ca4 | 720 | 14712 |
| 23 | Cb3 | 750 | 13244 |
| 24 | Da1 | 500 | 29838 |
| 25 | Db1 | 500 | 32225 |
| 26 | Da2 | 500 | 30252 |
| 27 | Db2 | 500 | 33696 |
| 28 | Da3 | 880 | 15540 |
| 29 | Db3 | 880 | 16271 |
| 30 | Ea1 | 420 | 30427 |
| 31 | Eb1 | 420 | 31740 |
| 32 | Ea2 | 140 | 24849 |
| 33 | Eb2 | 140 | 23885 |
| 34 | Ea3 | 630 | 16860 |
| 35 | Eb3 | 630 | 17655 |
| 36 | Ea4 | 1040 | 16263 |
| 37 | Eb4 | 1040 | 13775 |
| 38 | Fa1 | 330 | 22474 |
| 39 | Fb1 | 330 | 23849 |
| 40 | Fa2 | 410 | 13562 |
| 41 | Fb2 | 410 | 13619 |
| 42 | Ga1 | 320 | 21734 |
| 43 | Gb1 | 320 | 21195 |
| 44 | Ga2 | 340 | 19932 |
| 45 | Gb2 | 340 | 20022 |
| 46 | Ga3 | 400 | 23140 |
| 47 | Gb3 | 400 | 19252 |
| 48 | Ha1 | 1210 | 14485 |
| 49 | Hb1 | 1210 | 15249 |
| 50 | Ha2 | 1780 | 14997 |
| 51 | Hb2 | 1780 | 17142 |
| 52 | Ha3 | 1550 | 7515 |
| 53 | Hb3 | 1550 | 7712 |
| 54 | Ia1 | 1860 | 12762 |
| 55 | Ib1 | 1860 | 6808 |

# *CHAPTER FOUR*

## *DATA ANALYSIS*

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# *DATA ANALYSIS*

## 4.1 Introduction

The first objective of this research was to rank links of selected arterial streets according to the highest to lowest accident frequency to determine the most hazardous links. The second objective was to construct a model which relating accident rates with traffic flow to predict road accident rates when given traffic volumes of similar conditions.

The following three criteria were used in the accident ranking:

1- Accident total.

2- Accident rate.

3- Potential for accident reduction.

## 4.2 Traffic flow analysis

When the volumes of traffic were collected for each section of the selected arterial streets, the following steps were undertaken:

1- The traffic volume for each section was converted to Average Daily Traffic (ADT) for the year 1992. The annual traffic volume for each section was then calculated by multiplying the ADT by 365 (days of year).

2- The average annual traffic flow for years 1988, 1989 and 1990 was computed by defining a growth factor for each year.

This growth factor depended on the increase in the number of vehicles in Jordan through the period from 1988 to 1992 and on comparing previous traffic volumes (which are available for the same sections) with the recent traffic volumes obtained in this study.

3- The average annual traffic flow for the years 1988,1989 and 1990 was then calculated.

## 4.3 Traffic flow index

Traffic flow index is calculated by multiplying the length of a link with the average annual traffic flow of that link. The results are presented by million vehicle kilometers (M.V.KM).

## 4.4 The relationship between accidents and traffic flow index

Relationships between accidents (total, injury and fatal) and traffic flow index for urban and rural links were found by several investigators to be linear. [5,6,7,9,14]

In this research, since there where a few number of fatal accidents only total and injury accidents were correlated with the traffic flow index for the 27 links and 55 locations for each direction of those links.

Regression analysis is frequently used to develop mathematical models for many different engineering applications. In this research, the number of accidents (injury accidents and total accidents) are plotted on the y-axis of an x-y graph while the traffic flow index is plotted on the x-axis.

Regression lines were fitted between the points using special software to defined the relationship between the two variables.

The equations of the regression lines were established and are presented in the following form:

$$y = a + bx$$

Where: y= Number of accidents (dependent variable)

x= Traffic flow index (independent variable)rm:

$$y = a + bx$$

Where: y= Number of accidents (dependent variable)

x= Traffic flow index (independent variable)

Similarly, McGuigan [7] used this form of equation to relate accident total with traffic flow index. His results for the considered linear regression analysis for 94 urban links were presented as follows:

$$y = 0.085 + 0.856x$$

$$R^2 = 0.45$$

$$r = 0.67$$

Where: y= annual accident total

x= traffic flow index (million vehicle kilometer).

The coefficient of determination ($R^2$) of 45% indicated that the variable in accident totals on urban links considered by McGuigan are explained by the traffic flow indices.

The following results were obtained in this research when relating accident total with traffic flow index for the selected arterial urban links in Amman, for links in both directions and for each direction of the links.

The results of the regression equation for links in both directions are presented as follows:-

$y = -3.195 + 2.54x$ ................................1

$R^2 = 0.787$

$r = 0.887$

y = Annual accident total for both directions of the links (dependent variable).

x = Traffic flow index for both directions of the links (independent variable).

Figure 4.1 shows the regression line which represents the equation 1.

- For each direction of the links, the equation is presented as follows:-

$y = -1.67 + 2.167x$ ....................................2

$R^2 = 0.747$

$r = 0.864$

Where: y= Annual accident total for each direction of the links (dependent variable).

x= Traffic flow index for each direction of the links (independent variable).

Figure 4.2 shows this relationship.

The coefficient of determination ($R^2$) is equivalent to 0.787 and 0.747 for equations 1 and 2, respectively.

$R^2$ indicates that 78.7% and 74.7% of the variation in accident total are explained by traffic flow index for both and each direction, respectively.

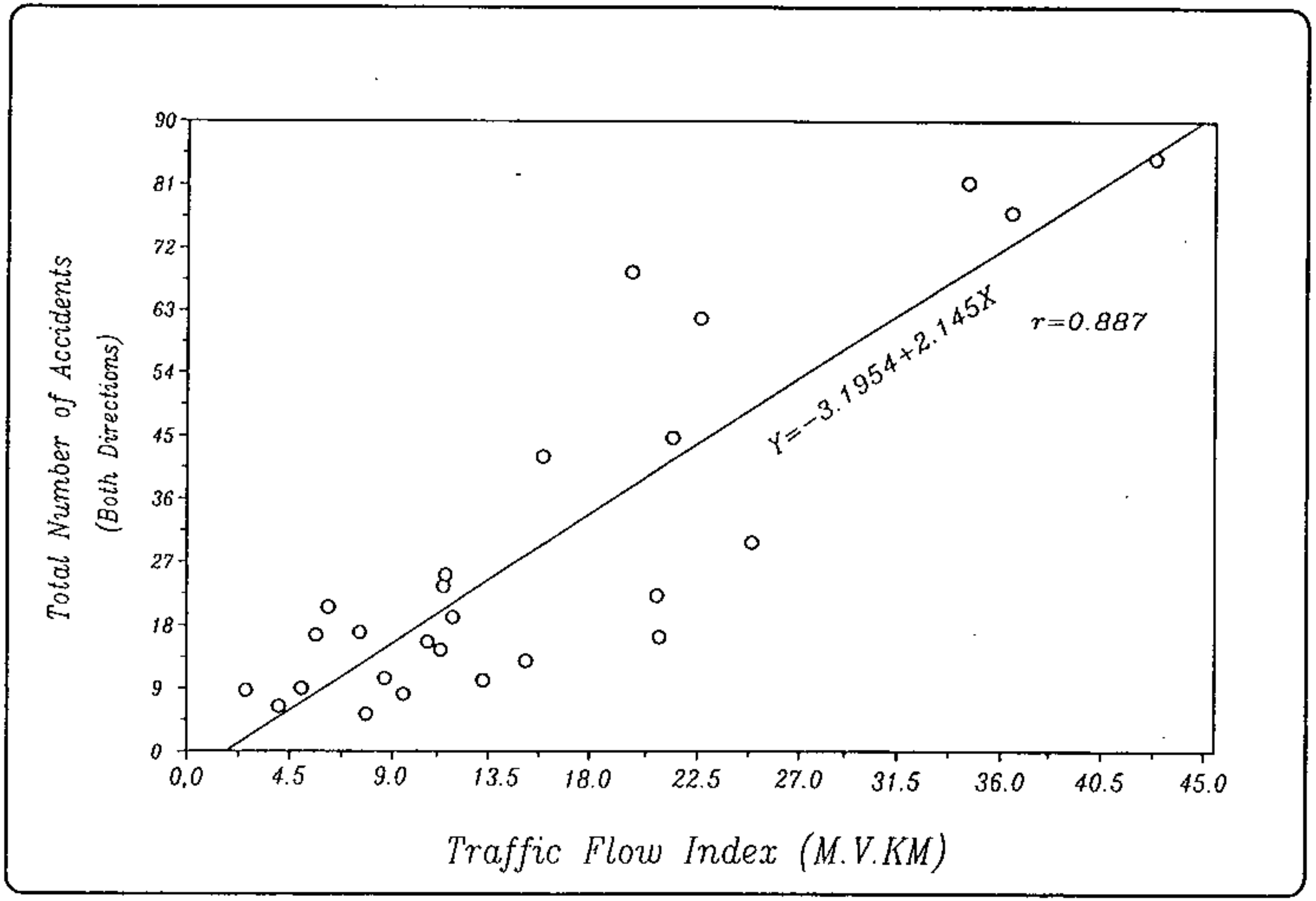



**FIGURE 4.1 THE RELATIONSHIP BETWEEN TOTAL NUMBER OF ACCIDENTS AND TRAFFIC FLOW INDEX FOR THE SELECTED LINKS, (BOTH DIRECTIONS)**

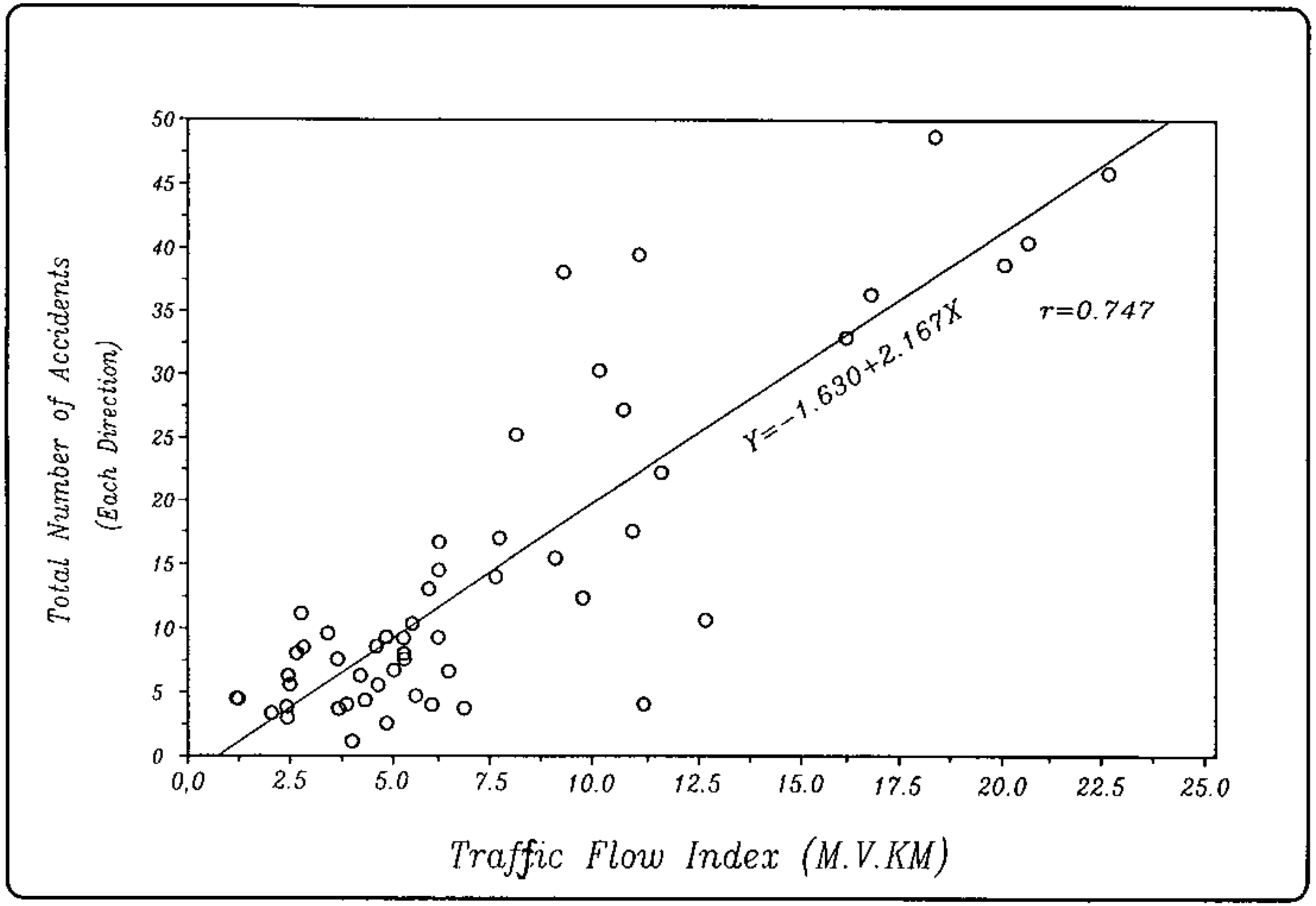



**FIGURE 4.2 THE RELATIONSHIP BETWEEN TOTAL NUMBER OF ACCIDENTS AND TRAFFIC FLOW INDEX FOR EACH DIRECTION OF THE SELECTED LINKS**

The coefficients of determination for equations 1 and 2 ($R^2$= 0.787 and 0.747) were higher than the coefficients of determination obtained by McGuigan [7] ($R^2$= 0.45). This could be explained by the fact that McGuigan's sample consisted of different types of urban links compared to 27 links of the same category (arterial urban) considered in this study.

Furthermore, the relationships between accident and traffic flow index for rural links were not considered due to the considerable difficulties in collecting data related to rural links. However, it is interesting to note that McGuigan related accident total with traffic flow index for rural links as follows:

$y = -0.033 + 0.549x$

$R^2 = 0.443$

$r = 0.702$

Where: y= Annual accident total.

x= Traffic flow index (million vehicle kilometers).

It was observed from his results that the slope of the regression line for the relationship between accident total and traffic flow index for urban links was steeper than that for rural links. This indicates that the predicted number of accidents on urban links is more than that on rural links for the same traffic flow index. This may be due to the involvement of higher number of pedestrian accidents as a result of their exposure to traffic. Also, the road environment in urban areas may have higher distraction to drivers.

Linear regression analyses were undertaken by D. J Turner [6] to determine the relationship between total annual injury accidents per kilometer and annual traffic volume for multi-lane motorways, the form of the resulting equation fitted was:

$y = -0.289 + 0.173x$

$R^2 = 0.712$

Where: y= Total annual injury accidents per Km.

x= Two-way annual traffic flow.

In this thesis, the relationships between the number of injury accidents and traffic flow index for both directions and for each direction of the considered links were developed on the selected urban arterial links.

The following relationships were established.

- For both directions of the links

$y = -2.676 + 0.669x$ ....................................3

$R^2 = 0.755$

$r = 0.869$

y= Annual injury accidents for both directions of the links (dependent variable).

x= Traffic flow index for both directions of the links (independent variable).

Figure 4.3 shows this linear equation.

- For each direction of the links, the equation developed was:

$y = -1.258 + 0.674x$ ....................................4

$R^2 = 0.721$

$r = 0.849$

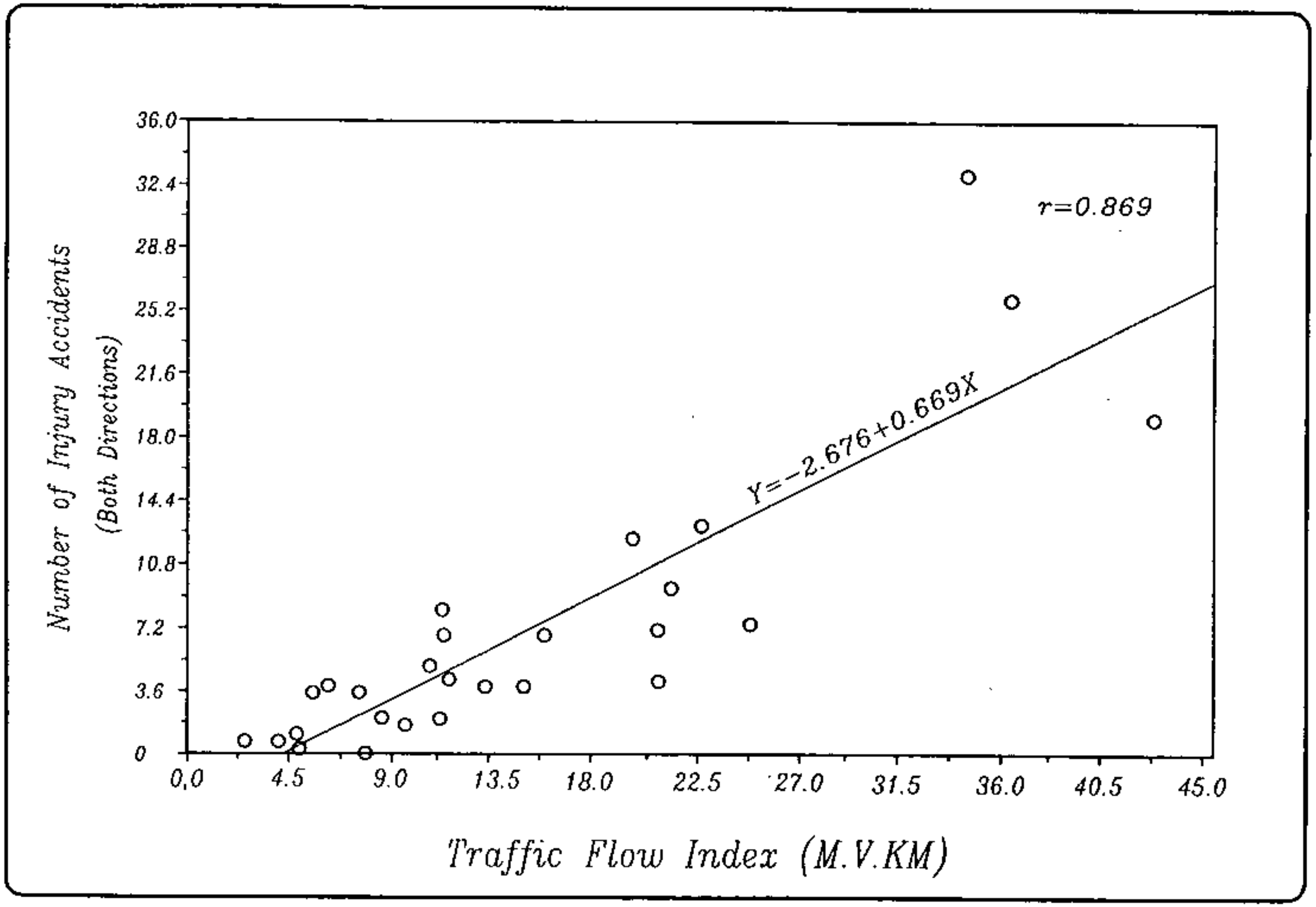



**FIGURE 4.3 THE RELATIONSHIP BETWEEN INJURY ACCIDENTS AND TRAFFIC FLOW INDEX FOR THE SELECTED LINKS, (BOTH DIRECTIONS)**

y = Annual injury accidents for each direction of the links (dependent variable).

x = Traffic flow index for each direction of the links (independent variable).

Figure 4.4 shows the best fit line which represents this equation.

Equations 3 and 4 are linear having correlation coefficients equivalent to 0.869 and 0.849, respectively. They are statistically significant at the 0.05 significance level.

It is observed that the coefficients of determination for the relationships between accident total and traffic flow index were nearly similar to the coefficients of determination for the relationships between number of injury accidents and traffic flow index.

In order to investigate the linearity of the previous four equations, a goodness of fit "F test" was carried out. The calculated F values were compared with the tabulated F values for the four equations at the 0.05 significance level. The results are presented in Table 4.1. As shown in the table, the calculated values exceed the tabulated values therefore it is concluded that the relationships are linear [22].

Furthermore, the t-test was carried out for the regression coefficients in order to test the hypothesis regarding the slope of the lines, whether it is different from zero or not. The results are shown in table 4.1 and indicate that the calculated t values exceed the tabulated t values at the 0.05 significance level which imply that the slopes are different from zero and the relationships are, therefore, linear.

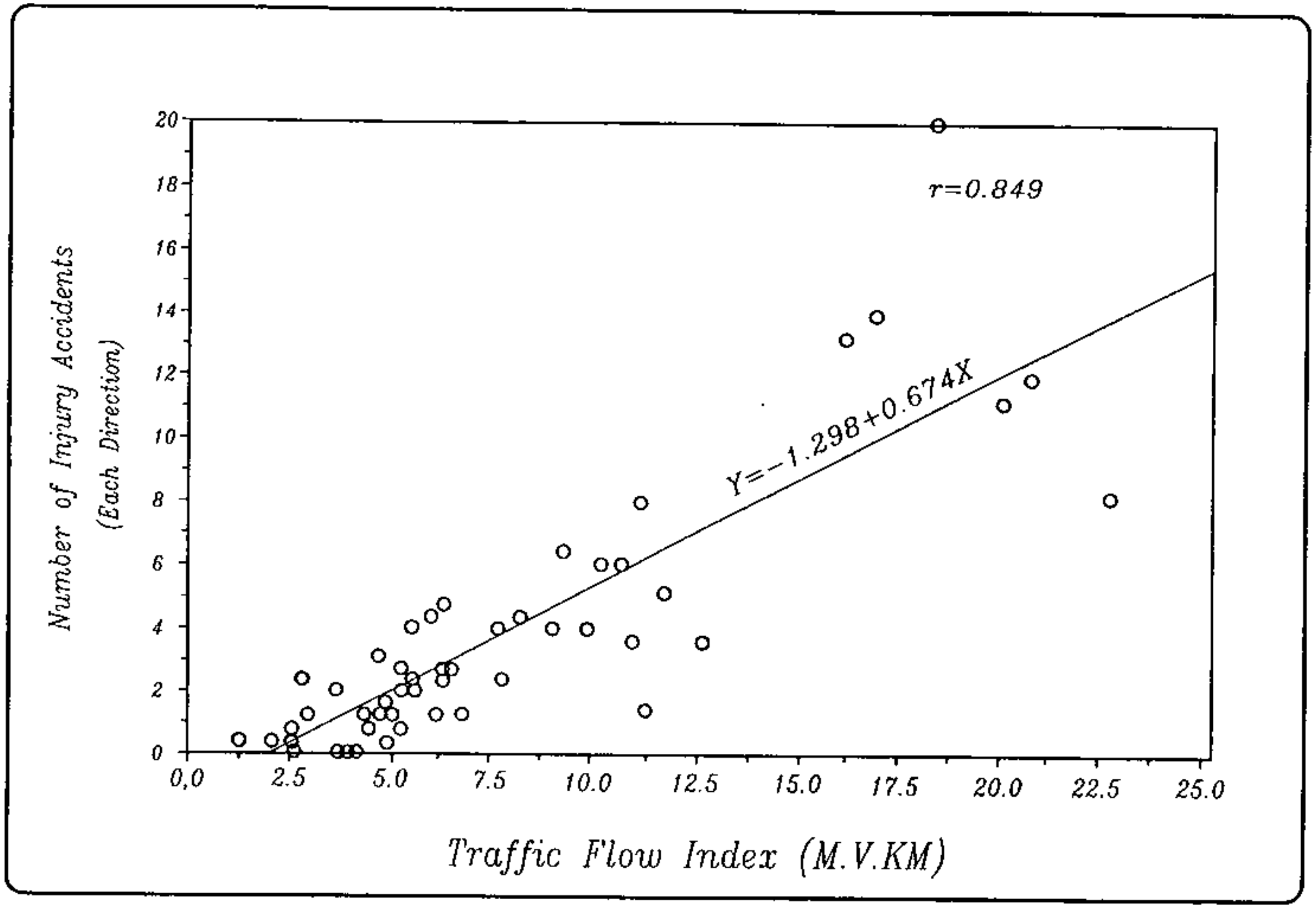



***FIGURE 4.4 THE RELATIONSHIP BETWEEN INJURY ACCIDENTS AND TRAFFIC FLOW INDEX FOR EACH DIRECTION OF THE SELECTED LINKS***

*TABLE 4.1 F–TEST, t–TEST (CALCULATED VALUES AND TABULATED VALUES)*

| *Equation Number* | *Number Of Points* | *F–Calculated* | *F–Tabulated* | *t–Calculated* | *t–Tabulated* |
|---|---|---|---|---|---|
| 1 | 27 | 92.454 | 4.24 | 9.615 | 1.71 |
| 2 | 55 | 156.544 | 4 | 12.512 | 1.645 |
| 3 | 27 | 77.011 | 4.24 | 8.776 | 1.71 |
| 4 | 55 | 136.7 | 4 | 11.692 | 1.645 |

From the previous results, it could be concluded that the number of accidents (total accidents and injury accidents) for any given urban arterial link for both and for each direction of the link can be predicted, provided that the chosen link is similar to those investigated in this research.

## 4.5 Accident ranking

The data base which has been established in this thesis and the relationships between accidents and traffic flow index have been used to rank the hazardousness of the selected arterial links in Amman and to identify the most hazardous links.

Accident rates and number of accidents have been used in this research and in many earlier researches in developed countries as ranking criteria.

In Oakland and in Baltimore [8,11], the high-hazard locations were identified by using a combination of the two criteria of accident rates and accident total. Also, Hayes [12] used these two criteria for accident ranking in Yorkshire.

Another criterion used in this research was developed by McGuigan [7]. This criterion depends on the relationship between accident and traffic flow index by determining the potential for accident reduction in each location.

This criterion was used by McGuigan [10] in his research in addition to the above two criteria (accident total and accident rate), in accident ranking and in identifying high hazardous locations.

It is true that there were many other methods [7,13] used in accident ranking and in the identification of high hazardous locations, but the three criteria which were mentioned above have been used in this research.

### 4.5.1 Accident total

This criterion is a straight forward method for ranking sites in descending order of hazardousness depending on accident total. Annual Average Accident Total (AAAT) and Annual Average Injury Accident (AAIA) for the selected links have been ranked in descending order for links in both directions and for each direction of the links as shown in tables 4.2 through 4.5.

Table 4.2 shows accident ranking due to AAAT for both directions of the links. It was observed that the fourth link of University street (A4) has the top rank.

Table 4.3 shows the ranking of accidents for each direction of the links due to AAAT, it was also observed that the direction of the link (A4) from traffic light of University mosque to University bridge (Ab4) has the top rank.

The number of Annual Average Injury Accidents (AAIA) is also used in accident ranking. Tables 4.4 and 4.5 show the ranking for links in both directions and for each direction of the links respectively. The fourth link of University street in both direction is in the top of the ranking list. This may be explained by the pedestrian accidents which have occurred in that section because there were no available facilities for crossing that street by a large number of pedestrians.

### 4.5.2 Accident rate

Annual Average Accident Rate (AAAR) and Annual Average Injury Accident Rate (AIAR) for the selected links have been ranked in descending order for links in both directions and for each direction of the links as shown in Tables 4.2, 4.3, 4.4 and 4.5.

It was observed that the fourth link of the University street A4 has the highest annual average injury accident rate, but the third link of Zahran street between the 7th circle and the 6th circle (direction Bb3) has the highest AAAR. This might be explained by the fact that a large number of property damage accidents occurred in that direction of that link, while, the traffic flow index is relatively small.

### 4.5.3 Potential for Accident Reduction

Potential for Annual Accident Reduction (PAAR) and Potential for Annual Injury Accident Reduction (PAIAR) depend on the relationships between accident and traffic flow index. These relationships are presented by the regression equations shown in section (4.4).

The equations in section 4.4 (equations 1,2,3 and 4) were used to calculate the potential for accident reduction. This was achieved by calculating the difference (D) between the expected number of accidents (E) and the observed number of accidents (O) using the following equation:

$$PAR = D = E - O$$

Where:

PAR = Potential for Accident Reduction.

*TABLE 4.2 COMPARISON OF RANKING CRITERIA FOR BOTH DIRECTIONS OF THE LINKS, (ACCIDENT TOTAL)*

| Link Number | Link Code | Annual Average Accident Total (AAAT) | Traffic Flow Index (M.V.KM) | Annual Accident Rate (AAAR) | Potential Annual Accident Reduction (PAAR) | Rank by AAAT | Rank by AAAR | Rank by PAAR |
|---|---|---|---|---|---|---|---|---|
| 3 | A3 | 84.8 | 42.471 | 1.997 | -3.105 | 1 | 13 | 18 |
| 4 | A4 | 81.6 | 34.321 | 2.378 | 11.18 | 2 | 7 | 4 |
| 1 | A1 | 77.2 | 36.272 | 2.128 | 2.592 | 3 | 10 | 10 |
| 7 | B3 | 68.4 | 19.648 | 3.481 | 29.452 | 4 | 2 | 1 |
| 2 | A2 | 62 | 22.639 | 2.739 | 16.636 | 5 | 5 | 2 |
| 5 | B1 | 44.8 | 21.425 | 2.091 | 2.04 | 6 | 11 | 12 |
| 6 | B2 | 42.4 | 15.723 | 2.697 | 11.87 | 7 | 6 | 3 |
| 9 | C1 | 30 | 24.869 | 1.206 | -20.148 | 8 | 22 | 26 |
| 18 | E4 | 24.8 | 11.404 | 2.175 | 3.536 | 9 | 9 | 9 |
| 12 | D1 | 23.6 | 11.327 | 2.084 | 2.5 | 10 | 12 | 11 |
| 27 | I1 | 22.4 | 12.166 | 1.841 | -0.5 | 11 | 15 | 16 |
| 23 | G3 | 20.8 | 6.189 | 3.361 | 10.702 | 12 | 3 | 5 |
| 13 | D2 | 19.2 | 11.673 | 1.645 | -2.643 | 13 | 17 | 17 |
| 11 | C3 | 16.8 | 7.653 | 2.195 | 3.58 | 14 | 8 | 8 |
| 19 | F1 | 16.4 | 5.580 | 2.939 | 7.627 | 15 | 4 | 6 |
| 25 | H2 | 16.4 | 20.881 | 0.785 | -25.193 | 15 | 26 | 27 |
| 8 | B4 | 15.6 | 10.700 | 1.458 | -4.156 | 17 | 19 | 19 |
| 14 | D3 | 14.4 | 10.218 | 1.409 | -4.322 | 18 | 20 | 20 |
| 10 | C2 | 13.2 | 14.954 | 0.883 | 15.679 | 19 | 23 | 25 |
| 26 | H3 | 10.8 | 8.615 | 1.254 | -4.484 | 20 | 21 | 21 |
| 24 | H1 | 10.4 | 13.131 | 0.792 | -14.57 | 21 | 25 | 24 |
| 22 | G2 | 9.2 | 4.958 | 1.856 | 1.761 | 22 | 14 | 13 |
| 21 | G1 | 9.2 | 5.014 | 1.835 | 1.641 | 22 | 16 | 14 |
| 16 | E2 | 8.8 | 2.490 | 3.534 | 6.654 | 24 | 1 | 7 |
| 15 | E1 | 8 | 9.522 | 0.84 | -9.229 | 25 | 24 | 23 |
| 20 | F2 | 6.4 | 4.068 | 1.573 | 0.87 | 26 | 18 | 15 |
| 17 | E3 | 5.2 | 7.937 | 0.655 | -8.629 | 27 | 27 | 22 |

*TABLE 4.3 COMPARISON OF RANKING CRITERIA FOR EACH DIRECTION OF THE LINKS, (ACCIDENT TOTAL)*

| Direction Number | Code For Each Direction | Annual Average Accident Total (AAAT) | Traffic Flow Index (M.V.KM) | Annual Accident Rate (AAAR) | Potential Annual Accident Reduction (PAAR) | Rank by AAAT | Rank by AAAR | Rank by PAAR |
|---|---|---|---|---|---|---|---|---|
| 8 | Ab4 | 48.8 | 18.261 | 2.576 | 10.853 | 1 | 12 | 3 |
| 6 | Ab3 | 46 | 22.509 | 2.044 | -1.15 | 2 | 22 | 31 |
| 2 | Ab1 | 40.8 | 20.549 | 1.986 | -2.103 | 3 | 24 | 36 |
| 3 | Aa2 | 39.6 | 11.018 | 3.594 | 17.353 | 4 | 4 | 2 |
| 5 | Aa3 | 38.8 | 19.964 | 1.944 | -2.835 | 5 | 25 | 42 |
| 14 | Bb3 | 38 | 9.180 | 4.139 | 19.734 | 6 | 1 | 1 |
| 1 | Aa1 | 36.4 | 15.724 | 2.315 | 3.953 | 7 | 16 | 9 |
| 7 | Aa4 | 32.8 | 16.057 | 2.043 | -0.372 | 8 | 23 | 27 |
| 13 | Ba3 | 30.4 | 10.468 | 2.904 | 9.345 | 9 | 8 | 4 |
| 10 | Bb1 | 27.2 | 10.590 | 2.569 | 5.881 | 10 | 14 | 7 |
| 11 | Ba2 | 25.2 | 8.086 | 3.117 | 9.307 | 11 | 6 | 5 |
| 4 | Ab2 | 22.4 | 11.621 | 1.928 | -1.16 | 12 | 26 | 32 |
| 9 | Ba1 | 17.6 | 10.839 | 1.624 | -4.253 | 13 | 32 | 46 |
| 12 | Bb2 | 17.2 | 7.638 | 2.252 | 2.278 | 14 | 18 | 17 |
| 36 | Ea4 | 16.8 | 6.173 | 2.721 | 5.05 | 15 | 11 | 8 |
| 18 | Ca2 | 15.6 | 8.956 | 1.742 | -2.179 | 16 | 31 | 37 |
| 27 | Db2 | 14 4 | 6.150 | 2.342 | 2 703 | 17 | 15 | 15 |
| 54 | Ia1 | 14 | 8.664 | 1.855 | -0.719 | 18 | 28 | 29 |
| 25 | Db1 | 13.2 | 5.881 | 2.245 | 2.085 | 19 | 19 | 19 |
| 50 | Ha2 | 12.4 | 9.744 | 1.273 | -7.086 | 20 | 41 | 51 |
| 47 | Gb3 | 11.2 | 2.811 | 3.985 | 6.738 | 21 | 2 | 6 |
| 19 | Cb1 | 10.8 | 12.630 | 0.855 | -14.942 | 22 | 50 | 54 |
| 24 | Da1 | 10.4 | 5.446 | 1.91 | 0.229 | 23 | 27 | 24 |
| 46 | Ga3 | 9.6 | 3.378 | 2.842 | 3.909 | 24 | 10 | 10 |
| 22 | Ca4 | 9.2 | 3.866 | 2.284 | 2.101 | 25 | 17 | 18 |
| 15 | Ba4 | 9.2 | 5.234 | 1.758 | -0.512 | 25 | 30 | 28 |
| 20 | Ca3 | 9.2 | 6.132 | 1.5 | -2.46 | 25 | 37 | 39 |
| 55 | Ib1 | 8.4 | 4.622 | 1.817 | 0.013 | 28 | 29 | 25 |
| 39 | Fb1 | 8.4 | 2.873 | 2.924 | 3.804 | 28 | 8 | 11 |
| 37 | Eb4 | 8 | 5.229 | 1.53 | -1.703 | 30 | 35 | 34 |
| 38 | Fa1 | 8 | 2.707 | 2.955 | 3.763 | 30 | 7 | 12 |
| 23 | Cb3 | 7.6 | 3.626 | 2.096 | 1.373 | 32 | 21 | 21 |
| 29 | Db3 | 7.6 | 5.226 | 1.454 | -2.096 | 32 | 38 | 35 |
| 28 | Da3 | 6.8 | 4.991 | 1.362 | -2.387 | 34 | 40 | 38 |
| 48 | Ha1 | 6.8 | 6.397 | 1.063 | -5.433 | 34 | 45 | 47 |
| 45 | Gb2 | 6.4 | 2.485 | 2.576 | 2.645 | 36 | 13 | 16 |
| 52 | Ha3 | 6.4 | 4.252 | 1.505 | -1.184 | 36 | 36 | 33 |
| 16 | Bb4 | 6.4 | 5.466 | 1.171 | -3.817 | 36 | 43 | 45 |
| 30 | Ea1 | 5.6 | 4.665 | 1.201 | -2.879 | 39 | 42 | 43 |
| 42 | Ga1 | 5.6 | 2.539 | 2.206 | 1.729 | 39 | 20 | 20 |
| 26 | Da2 | 4.8 | 5.521 | 0.869 | -5.541 | 41 | 49 | 48 |
| 33 | Eb2 | 4.4 | 1.221 | 3.605 | 3.385 | 42 | 3 | 13 |
| 53 | Hb3 | 4.4 | 4.363 | 1.008 | -3.427 | 42 | 47 | 44 |
| 32 | Ea2 | 4.4 | 1.270 | 3.465 | 3.278 | 42 | 5 | 14 |
| 34 | Ea3 | 4 | 3.877 | 1.032 | -2.772 | 45 | 46 | 41 |
| 21 | Cb2 | 4 | 5.955 | 0.672 | -7.277 | 45 | 51 | 52 |
| 51 | Hb2 | 4 | 11.137 | 0.359 | -18.507 | 45 | 54 | 55 |
| 17 | Ca1 | 3.6 | 3.642 | 0.988 | -2.663 | 48 | 48 | 40 |
| 49 | Hb1 | 3.6 | 6.735 | 0.535 | -9.365 | 48 | 52 | 53 |
| 43 | Gb1 | 3.6 | 2.476 | 1.454 | -0.135 | 48 | 38 | 26 |
| 40 | Fa2 | 3.2 | 2.030 | 1.577 | 0.431 | 51 | 33 | 22 |
| 41 | Fb2 | 3.2 | 2.038 | 1.57 | 0.413 | 51 | 34 | 23 |
| 44 | Ga2 | 2 8 | 2.474 | 1.132 | -0.93 | 53 | 44 | 30 |
| 31 | Eb1 | 2.4 | 4.866 | 0.494 | -6.497 | 54 | 53 | 50 |
| 35 | Eb3 | 1.2 | 4.060 | 0.296 | -5.969 | 55 | 55 | 49 |

*TABLE 4.4 COMPARISON OF RANKING CRITERIA FOR BOTH DIRECTIONS THE LINKS, (INIJURY ACCIDENTS)*

| Link Number | Link Code | Annual Average Injury Accident (AAIA) | Traffic Flow Index (M.V.KM) | Annual Injury Accident Rate (AIAR) | Potential Annual Injury Accident Reduction (PAIAR) | Rank by AAIA | Rank by AIAR | Rank by PAIAR |
|---|---|---|---|---|---|---|---|---|
| 4 | A4 | 33.2 | 34.321 | 0.967 | 12.931 | 1 | 1 | 1 |
| 1 | A1 | 26 | 36.272 | 0.77 | 4.425 | 2 | 3 | 2 |
| 3 | A3 | 19.2 | 42.471 | 0.452 | -6.519 | 3 | 12 | 26 |
| 2 | A2 | 13.2 | 22.639 | 0.583 | 0.74 | 4 | 9 | 12 |
| 7 | B3 | 12.4 | 19.648 | 0.631 | 0.722 | 5 | 6 | 6 |
| 5 | B1 | 9.6 | 21.425 | 0.448 | -2.048 | 6 | 13 | 19 |
| 12 | D1 | 8.4 | 11.327 | 0.742 | 3.503 | 7 | 2 | 3 |
| 9 | C1 | 7.6 | 24.869 | 0.306 | -6.351 | 8 | 17 | 25 |
| 27 | I1 | 7.2 | 12.166 | 0.592 | 1.742 | 9 | 8 | 9 |
| 18 | E4 | 6.8 | 11.404 | 0.596 | 1.852 | 10 | 7 | 7 |
| 6 | B2 | 6.8 | 15.723 | 0.432 | -1.036 | 10 | 14 | 17 |
| 8 | B4 | 5.2 | 10.700 | 0.486 | 0.722 | 12 | 10 | 13 |
| 13 | D2 | 4.4 | 11.673 | 0.377 | -0.728 | 13 | 15 | 16 |
| 25 | H2 | 4.4 | 20.881 | 0.211 | -6.884 | 13 | 22 | 27 |
| 23 | G3 | 4 | 6.189 | 0.646 | 2.538 | 15 | 4 | 5 |
| 24 | H1 | 4 | 13.131 | 0.305 | -2.103 | 15 | 18 | 21 |
| 10 | C2 | 4 | 14.954 | 0.267 | -3.321 | 15 | 19 | 24 |
| 19 | F1 | 3.6 | 5.580 | 0.645 | 2.545 | 18 | 5 | 4 |
| 11 | C3 | 3.6 | 7.653 | 0.47 | 1.159 | 18 | 11 | 10 |
| 26 | H3 | 2 | 8.615 | 0.232 | -1.084 | 20 | 21 | 18 |
| 14 | D3 | 2 | 10.218 | 0.196 | -2.156 | 20 | 24 | 22 |
| 15 | E1 | 1.6 | 9.522 | 0.168 | -2.09 | 22 | 25 | 20 |
| 22 | G2 | 1.2 | 4.958 | 0.242 | 0.561 | 23 | 20 | 14 |
| 16 | E2 | 0.8 | 2.490 | 0.321 | 1.811 | 24 | 16 | 8 |
| 20 | F2 | 0.8 | 4.068 | 0.197 | 0.756 | 24 | 23 | 11 |
| 21 | G1 | 0.4 | 5.014 | 0.08 | -0.276 | 26 | 26 | 15 |
| 17 | E3 | 0 | 7.937 | 0 | -2.63 | 27 | 27 | 23 |

*TABLE 4.5 COMPARISON OF RANKING CRITERIA FOR EACH DIRECTION OF THE LINKS, (INIJURY ACCIDENTS)*

| *Direction Number* | *Code For Each Direction* | *Annual Average Injury Accident (AAIA)* | *Traffic Flow Index (M.V.KM)* | *Annual Injury Accident Rate (AIAR)* | *Potential Annual Injury Accident Reduction (PAIAR)* | *Rank by AAIA* | *Rank by AIAR* | *Rank by PAIAR* |
|---|---|---|---|---|---|---|---|---|
| 8 | Ab4 | 20 | 18.261 | 1.095 | 8.994 | 1 | 1 | 1 |
| 1 | Aa1 | 14 | 15.724 | 0.89 | 4.704 | 2 | 2 | 2 |
| 7 | Aa4 | 13.2 | 16.057 | 0.822 | 3.679 | 3 | 5 | 3 |
| 2 | Ab1 | 12 | 20.549 | 0.584 | -0.546 | 4 | 12 | 36 |
| 5 | Aa3 | 11.2 | 19.964 | 0.561 | -0.952 | 5 | 15 | 41 |
| 6 | Ab3 | 8.2 | 22.509 | 0.364 | -5.667 | 6 | 31 | 55 |
| 3 | Aa2 | 8 | 11.018 | 0.726 | 1.875 | 7 | 9 | 5 |
| 14 | Bb3 | 6.4 | 9.180 | 0.697 | 1.513 | 8 | 10 | 10 |
| 13 | Ba3 | 6 | 10.468 | 0.573 | 0.246 | 9 | 13 | 22 |
| 10 | Bb1 | 6 | 10.590 | 0.567 | 0.164 | 9 | 14 | 25 |
| 4 | Ab2 | 5.2 | 11.621 | 0.447 | -1.331 | 11 | 22 | 45 |
| 36 | Ea4 | 4.8 | 6.173 | 0.778 | 1.939 | 12 | 6 | 4 |
| 25 | Db1 | 4.4 | 5.881 | 0.748 | 1.736 | 13 | 7 | 8 |
| 11 | Ba2 | 4.4 | 8.086 | 0.544 | 0.251 | 13 | 17 | 21 |
| 24 | Da1 | 4 | 5.446 | 0.735 | 1.63 | 15 | 8 | 9 |
| 54 | Ia1 | 4 | 7.548 | 0.53 | 0.216 | 15 | 19 | 23 |
| 18 | Ca2 | 4 | 8.956 | 0.447 | -0.736 | 15 | 22 | 38 |
| 50 | Ha2 | 4 | 9.744 | 0.411 | -1.266 | 15 | 27 | 43 |
| 19 | Cb1 | 3.6 | 12.630 | 0.285 | -3.611 | 19 | 38 | 53 |
| 9 | Ba1 | 3.6 | 10.839 | 0.332 | -2.402 | 19 | 33 | 52 |
| 55 | Ib1 | 3.2 | 4.622 | 0.692 | 1.384 | 21 | 11 | 11 |
| 15 | Ba4 | 2.8 | 5.234 | 0.535 | 0.572 | 22 | 18 | 16 |
| 20 | Ca3 | 2.8 | 6.132 | 0.457 | -0.033 | 22 | 21 | 29 |
| 48 | Ha1 | 2.8 | 6.397 | 0.438 | -0.212 | 22 | 25 | 30 |
| 38 | Fa1 | 2.4 | 2.707 | 0.887 | 1.875 | 25 | 3 | 5 |
| 47 | Gb3 | 2.4 | 2.811 | 0.854 | 1.805 | 25 | 4 | 7 |
| 16 | Bb4 | 2.4 | 5.466 | 0.439 | 0.015 | 25 | 24 | 28 |
| 27 | Db2 | 2.4 | 6.150 | 0.39 | -0.445 | 25 | 29 | 35 |
| 12 | Bb2 | 2.4 | 7.638 | 0.314 | -1.447 | 25 | 37 | 48 |
| 23 | Cb3 | 2 | 3.626 | 0.552 | 0.856 | 30 | 16 | 13 |
| 37 | Eb4 | 2 | 5.229 | 0.382 | -0.225 | 30 | 30 | 31 |
| 26 | Da2 | 2 | 5.521 | 0.362 | -0.423 | 30 | 32 | 34 |
| 46 | Ga3 | 1.6 | 3.378 | 0.474 | 0.622 | 33 | 20 | 15 |
| 22 | Ca4 | 1.6 | 4.028 | 0.397 | 0.185 | 33 | 28 | 24 |
| 51 | Hb2 | 1.4 | 11.137 | 0.126 | -4.805 | 35 | 50 | 54 |
| 39 | Fb1 | 1.2 | 2.873 | 0.418 | 0.563 | 36 | 26 | 17 |
| 52 | Ha3 | 1.2 | 4.252 | 0.282 | -0.366 | 36 | 39 | 32 |
| 30 | Ea1 | 1.2 | 4.665 | 0.257 | -0.644 | 36 | 40 | 37 |
| 28 | Da3 | 1.2 | 4.991 | 0.24 | -0.864 | 36 | 41 | 40 |
| 21 | Cb2 | 1.2 | 5.955 | 0.202 | -1.514 | 36 | 42 | 49 |
| 49 | Hb1 | 1.2 | 6.735 | 0.178 | -2.039 | 36 | 46 | 51 |
| 45 | Gb2 | 0.8 | 2.485 | 0.322 | 0.424 | 42 | 35 | 18 |
| 29 | Db3 | 0.8 | ERR | 0.153 | -1.423 | 42 | 49 | 46 |
| 53 | Hb3 | 0.8 | 4.363 | 0.183 | -0.842 | 42 | 45 | 39 |
| 33 | Eb2 | 0.4 | 1.221 | 0.328 | 0.876 | 45 | 34 | 12 |
| 32 | Ea2 | 0.4 | 1.270 | 0.315 | 0.843 | 45 | 36 | 14 |
| 40 | Fa2 | 0.4 | 2.030 | 0.197 | 0.331 | 45 | 43 | 19 |
| 43 | Gb1 | 0.4 | 2.476 | 0.162 | 0.031 | 45 | 47 | 27 |
| 44 | Ga2 | 0.4 | 2.474 | 0.162 | 0.032 | 45 | 47 | 26 |
| 31 | Eb1 | 0.4 | 4.857 | 0.082 | -1.574 | 45 | 51 | 50 |
| 41 | Fb2 | 0.4 | 2.038 | 0.196 | 0.325 | 45 | 44 | 20 |
| 34 | Ea3 | 0 | 3.877 | 0 | -1.314 | 52 | 52 | 44 |
| 35 | Eb3 | 0 | 4.060 | 0 | -1.437 | 52 | 52 | 47 |
| 42 | Ga1 | 0 | 2.539 | 0 | -0.412 | 52 | 52 | 33 |
| 17 | Ca1 | 0 | 3.642 | 0 | -1.126 | 52 | 52 | 42 |

The potential for accident reduction for each of the four cases (PAAR for both directions and each direction of the link and PAIAR for both directions and each direction of the link) were ranked in descending order.

Tables 4.2, 4.3, 4.4 and 4.5 also show the ranking as a result of using potential for accident reduction (Note: the negative values in the tables indicate that the observed number of accidents on the particular link was lower than the expected number of accidents predicted by the equations).

The fourth link of the University street (A4) was ranked the highest in ranking order of potential for injury accident reduction. This implies that link (A4) has the highest potentiality to reduce injury accidents. Furthermore, the third link of Zahran street (B3) was ranked the highest in the ranking for potentiality to reduce accident total.

Potential for accident reduction is clearly not a direct measure of cost-effectiveness since it does not include the cost of remedial measures. However, it provides a strong indication of the likely accident reduction.

## 4.6 Identification of the highest hazardous links

Renshaw and Carter [11] indicated that no literature was available to enable them to identify the most hazardous links. Accordingly, they have identified the highest hazardous links based on an accident rate being greater than twice the average of accident rates for considered links as well as those links which have number of accidents greater than the average of accidents for that links. Links that had an accident number less than the average and an accident rate less than twice the average were excluded.

Tapan and others [8] also developed methodology which categorized accident links depending on their accident total and rates. This methodology was based on a simultaneous consideration of accident rate and accident number by using a matrix format as shown in Figure 4.5. In this figure the horizontal axis of the matrix is divided into 10 increasing increments of annual accident total, and the vertical axis is divided into 10 increasing increments of accident rates. The location of a cell in the matrix defines a certain level of hazard. The most hazardous links in the system are located in the upper right-hand cell of the matrix, {i.e, cell (10,10)}. Decreasing level of hazard was presented by other cells in the matrix towards the lower left-hand corner, {i.e, cell (1,1)}.

In this research similar criteria were used to determine and rank the highest hazardous links by both their number of accidents and accident rates, as will be shown here after.

### 4.6.1 Total number of accidents

The horizontal axis of the matrix was divided into 10 increasing increments of Annual Average Accident Rates (AAAR), and the vertical axis was divided into 10 increasing increments of Annual Average Accident Total (AAAT). The links which had accident totals and accident rates greater than the average of accident rate and accident total of the considered links were defined as hazardous links. However, links that had accident

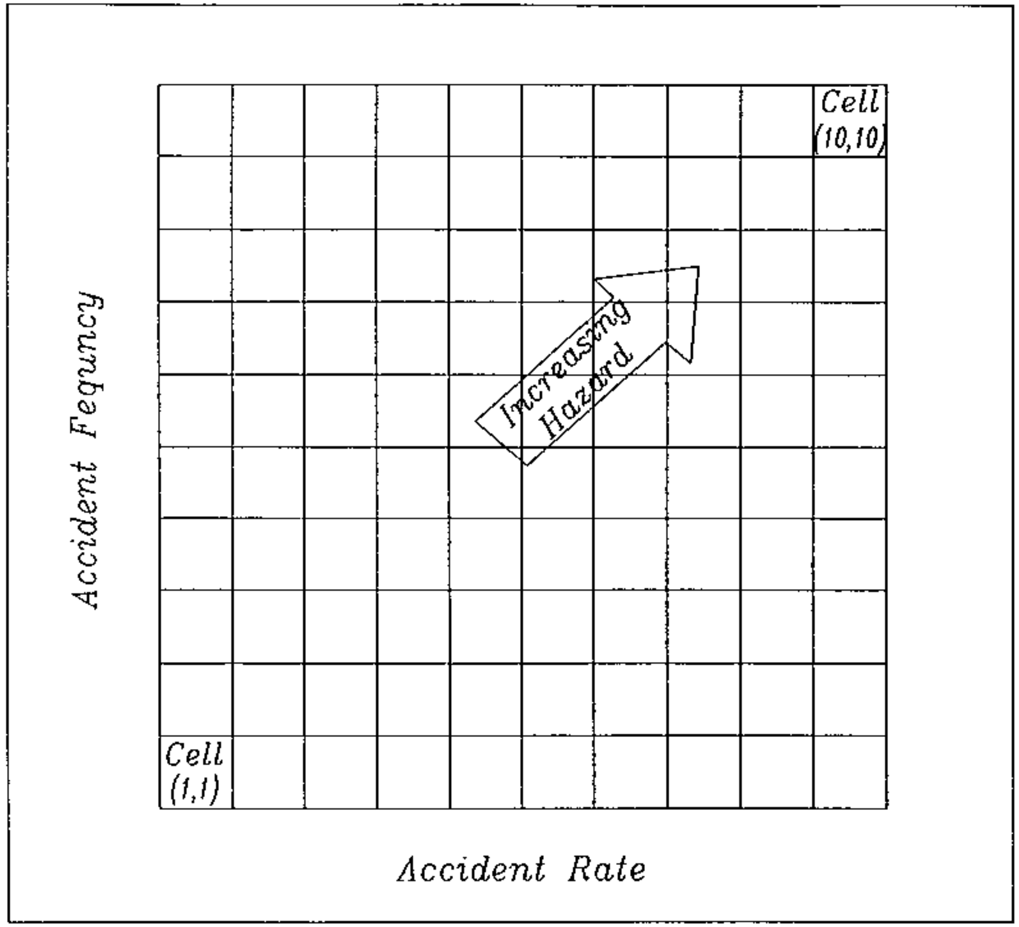



**FIGURE 4.5 TYPICAL RATE AND FREQUNCY ANALYSIS MATRIX**

totals and accident rates less than the average of the considered links were excluded (those links fall in the hatch area on the matrices). The hazardous links were then ranked according to the locations of the cells in the matrices.

Figures 4.6 and 4.7 show the two matrices and the ranking of the highest hazardous links by the combination of the number of total accidents and rates of accident total for links in both directions and for each direction of the links, respectively.

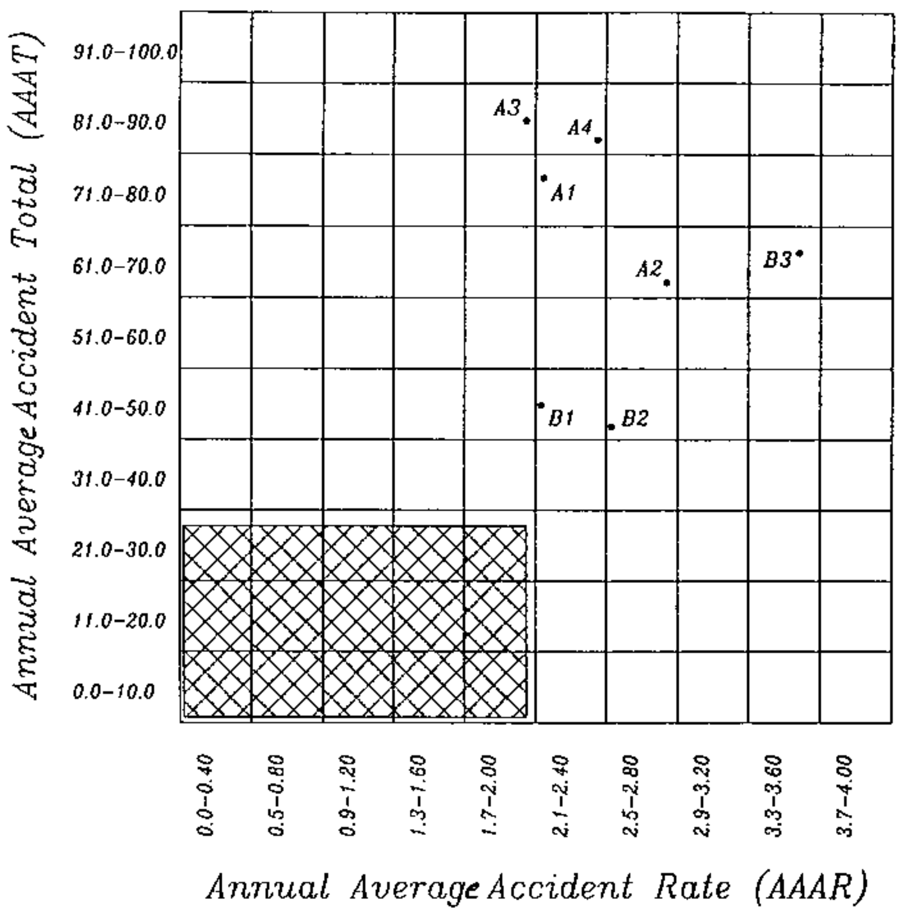
### 4.6.2 Injury accidents

The horizontal axis of the matrix is divided into 10 increasing increments of Annual Injury Accident Rate (AIAR), and the vertical axis is divided into 10 increasing increments of Annual Average Injury Accident (AAIA) for links in both directions and for each direction of the links.

Links which had injury accidents and injury accident totals greater than the average of the considered links were defined as hazardous links due to injury accidents.

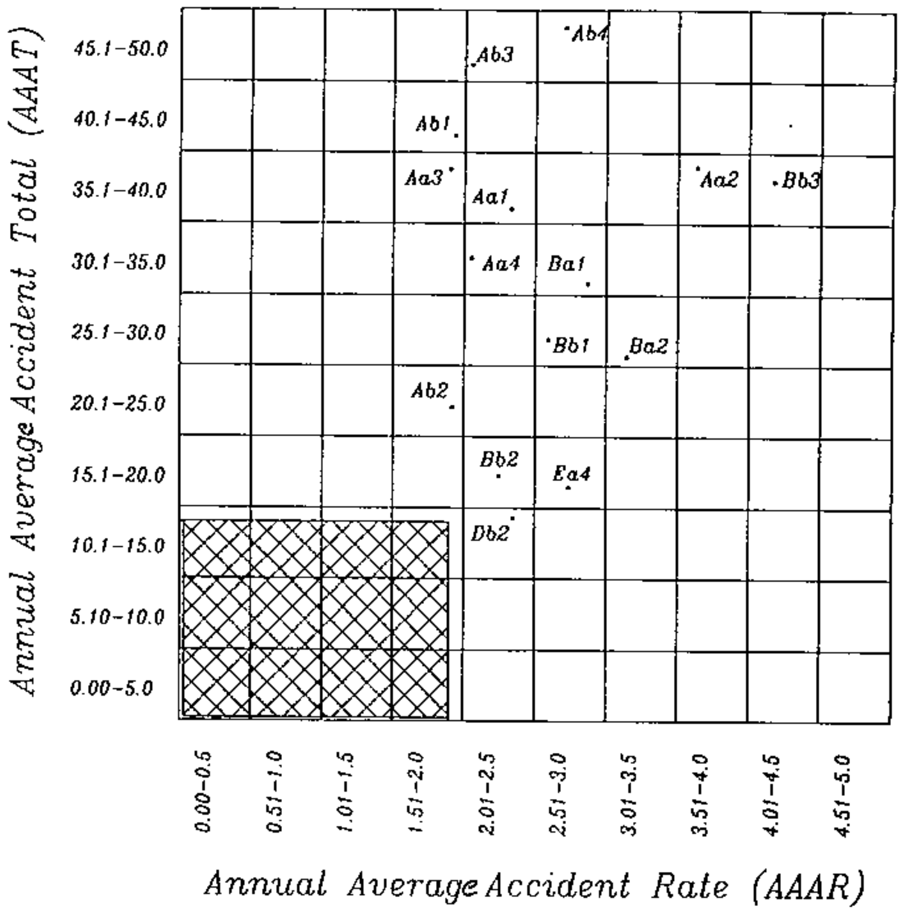
Links which had injury accidents and injury accident rates less than the average of the considered links were excluded (those links fall in the hatch area on the matrices), and then, the hazardous links were ranked in descending order.

Figures 4.8 and 4.9 illustrate these two matrices and the ranking of highest hazardous links by the number of injury accidents and injury accident rates for links in both directions and for each direction of the links respectively.



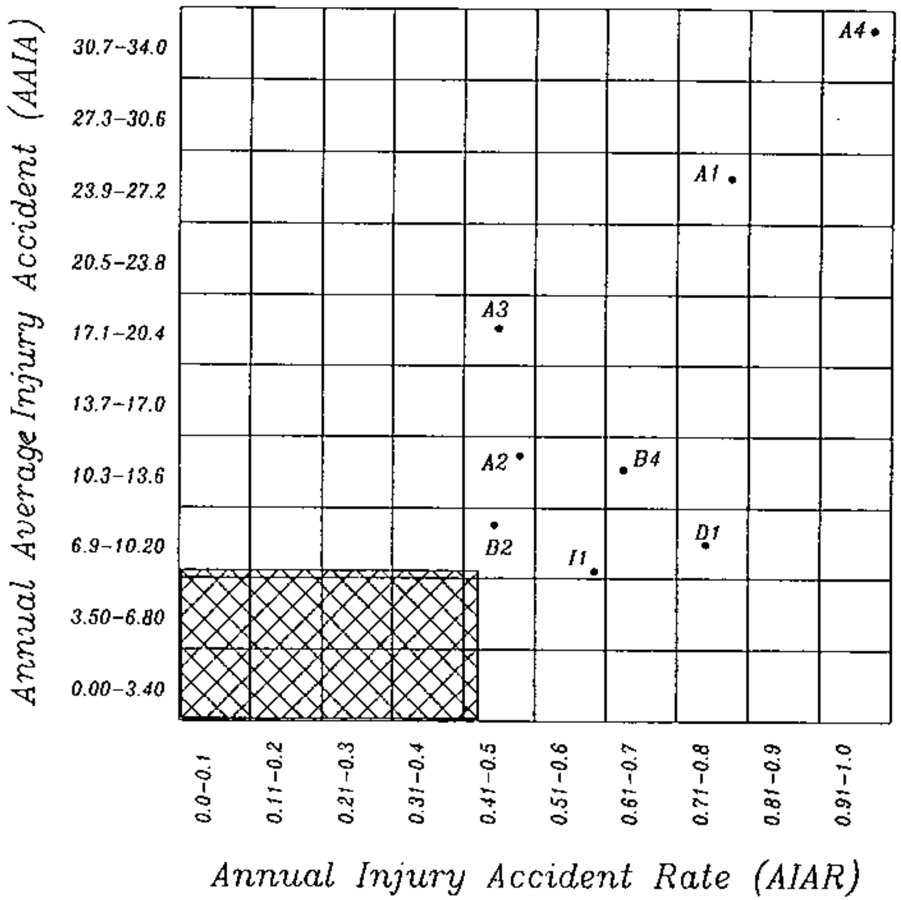

| LINK CODE | RANK |
|---|---|
| B3 | 1 |
| A4 | 2 |
| A2 | 3 |
| A1 | 4 |
| A3 | 5 |
| B2 | 6 |
| B1 | 7 |

***FIGURE 4.6 ANALYSIS MATRIX AND RANKING OF THE MOST HAZARDOUS LINKS, (ACCIDENT TOTAL)***



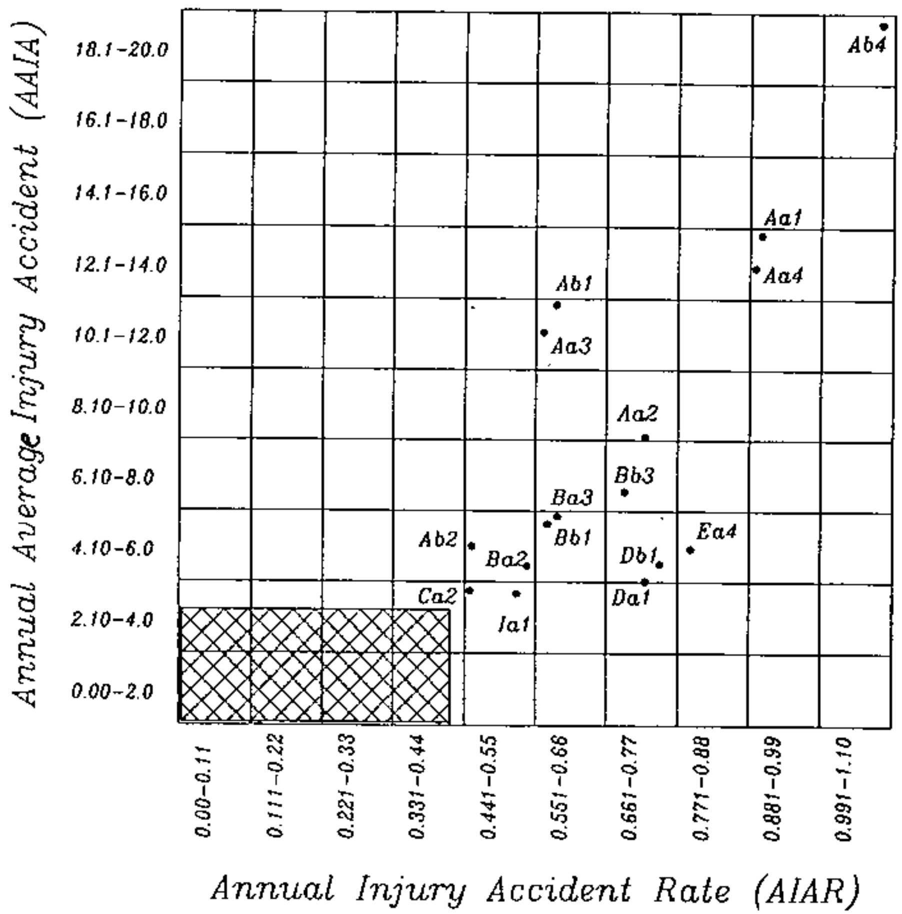

| DIRECTION CODE | DIRECTION RANK |
|---|---|
| Bb3 | 1 |
| Aa2 | 2 |
| Ab4 | 3 |
| Ab3 | 4 |
| Ab1 | 5 |
| Ba1 | 6 |
| Ba2 | 7 |
| Aa1 | 8 |
| Bb1 | 9 |
| Aa4 | 10 |
| Aa3 | 11 |
| Ea4 | 12 |
| Ab2 | 13 |
| Bb2 | 14 |
| Db2 | 15 |

**FIGURE 4.7 ANALYSIS MATRIX AND RANKING OF THE MOST HAZARDOUS DIRECTIONS (ACCIDENT TOTAL)**




| LINK CODE | RANK |
|---|---|
| A4 | 1 |
| A1 | 2 |
| A3 | 3 |
| B4 | 4 |
| D1 | 5 |
| A2 | 6 |
| I1 | 7 |
| B2 | 8 |

***FIGURE 4.8 ANALYSIS MATRIX AND RANKING OF THE MOST HAZARDOUS LINKS, (INJURY ACCIDENTS)***




| DIRECTION CODE | DIRECTION RANK |
|---|---|
| Ab4 | 1 |
| Aa1 | 2 |
| Aa4 | 3 |
| Ab1 | 4 |
| Aa3 | 5 |
| Aa2 | 6 |
| Bb3 | 7 |
| Ea4 | 8 |
| Db1 | 9 |
| Da1 | 10 |
| Ba3 | 11 |
| Bb1 | 12 |
| Ba2 | 13 |
| Ab2 | 14 |
| Ia1 | 15 |
| Ca2 | 16 |

**FIGURE 4.9 ANALYSIS MATRIX AND RANKING OF THE MOST HAZARDOUS DIRECTIONS (INJURY ACCIDENTS)**

In this thesis, the most hazardous links of the selected arterial streets in Amman were determined depending on the type of accidents, total number of accidents or injury accidents. This was determined by a combination of two criteria of accident ranking, accident totals and accident rates. However, it was found that most of the highest hazardous links had a positive potential for accident reduction which means that any road safety improvement program for these hazardous links would maximize the revenues of such measures and therefore maximize the cost-effectiveness.

Thus, a new ranking for the hazardous links was arrived at by considering the potential for accident reductions for those links in order to suggest remedial action programs.

Tables 4.5 and 4.6 show the ranking of the most hazardous links that have been indicated in Figures 4.6 through 4.9 due to the potential for accident reduction for each case.

*TABLE 4.6 RANKING OF THE MOST HAZARDOUS LINKS DUE TO POTENTIAL FOR ANNUAL ACCIDENT TOTAL REDUCTION*

| *Both Directins* | | *Each Direction* | |
|---|---|---|---|
| *Link Code* | *Link Rank* | *Direction Code* | *Direction Rank* |
| B3 | 1 | Bb3 | 1 |
| A2 | 2 | Aa2 | 2 |
| B2 | 3 | Ab4 | 3 |
| A4 | 4 | Ba2 | 4 |
| A1 | 5 | Bb1 | 5 |
| B1 | 6 | Ea4 | 6 |
| A3 | 7 | Aa1 | 7 |
| | | Db2 | 8 |
| | | Bb2 | 9 |
| | | Aa4 | 10 |
| | | Ab3 | 11 |
| | | Ab2 | 12 |
| | | Ab1 | 13 |
| | | Aa3 | 14 |
| | | Ba1 | 15 |

*TABLE 4.7 RANKING OF THE MOST HAZARDOUS LINKS DUE TO POTENTIAL FOR ANNUAL INJURY ACCIDENT REDUCTION*

| *Both Directions* | | *Each Direction* | |
|---|---|---|---|
| *Link Code* | *Link Rank* | *Direction Code* | *Direction Rank* |
| A4 | 1 | Ab4 | 1 |
| A1 | 2 | Aa1 | 2 |
| D1 | 3 | Aa4 | 3 |
| I1 | 4 | Ea4 | 4 |
| A2 | 5 | Aa2 | 5 |
| B4 | 6 | Bb1 | 6 |
| B2 | 7 | Da1 | 7 |
| A3 | 8 | Bb3 | 8 |
| | | Ba2 | 9 |
| | | Ba3 | 10 |
| | | Ia1 | 11 |
| | | Bb1 | 12 |
| | | Ab1 | 13 |
| | | Ca2 | 14 |
| | | Aa3 | 15 |
| | | Ab2 | 16 |

# *CHAPTER FIVE*

## *CONCLUSIONS AND RECOMMENDATIONS*

# CHAPTER FIVE
# CONCLUSIONS AND RECOMMENDATIONS

## 5.1 Conclusions

The main conclusions of this thesis are summarized as follows:

1- The relationships between accident total and traffic flow index are linear. Also, the relationships between injury accidents and traffic flow index are linear; however, slightly higher correlation coefficients were evident for the relationships between accident total and the traffic flow index when compared with the relationships between injury accidents and the traffic flow index.

2- The slopes of the best-fit lines for the equations describing the relationships between accidents and traffic flow index, were positive. This suggests that as the volume of traffic increases the number of accidents also increases.

3- According to the results of this study, it was assumed that the most hazardous links could be defined as those links that have more than or equal to 42 accident totals per year and their accident rates are equal to or more than 2 accidents per million vehicle kilometers per year. However, when considering injury accidents the definition will be modified as follow: the most hazardous links are those links that have more than 5 injury accidents per year and injury accidents rate equal to or more than 0.45 injury accidents per million vehicle kilometers per year.

4- The most hazardous link of the selected links in this study when considering injury accidents, was the fourth link of the University street from University bridge to the University Mosque (A4). However, the most hazardous link when considering the total number of accidents was the third link of Zahran street, extending from the 6th circle to the 7th circle (B3).

## 5.2 Recommendations

1- It is recommended to use the following relationships between accidents and traffic flow index in the prediction of accidents in urban arterial streets:

- $y = -3.195 + 2.54x$ ................................1

Where: y= Annual accident total for both directions of the links (dependent variable).

x= Traffic flow index for both directions of the links (independent variable).

- $y = -1.67 + 2.167x$ ................................2

Where: y= Annual accident total for each direction of the links (dependent variable).

x= Traffic flow index for each direction of the links (independent variable).

- $y = -2.676 + 0.669x$ ................................3

Where: y= Annual injury accidents for both directions of the links (dependent variable).

x= Traffic flow index for both directions of the links (independent variable).

- $y = -1.258 + 0.674x$ ................................4

Where: y= Annual injury accidents for each direction of the links (dependent variable).

x= Traffic flow index for each direction of the links (independent variable).

2- Proper traffic management and traffic control devices (e.g. signing, markings, bus lanes and bus stops) are required in order to organize traffic at the arterial streets which could greatly reduce conflicts, number of accidents and accident rates.

3- Further investigation is required into the relationships between different types of accidents and traffic flows on different categories of highways in Jordan.

# REFERENCES


1. Oflaherty, Highway Traffic Planning & Engineering, Third edition, Volume 4, pp 451-459, 1988.
2. Jordan Road Society, Axle Loads Symposium, pp. 52-62, Decemper 1991.
3. Abu-Sheikh A., Identification of Hazardous Locations: A Suggested Methodology Through Comprehensive Accident Survey and Analysis for Irbid city, Master Thesis, Yarmouk University, Irbid-Jordan, 1987.
4. Al-Omari N., A Study of Road Accidents' Costs in Jordan, University of Jordan, April 1992.
5. Satterthwaite S.P., A survey of Research into Relationships Between Traffic Accidents and Traffic Volumes, Transport and Road Research Laboratory, Crowthorne, Berkshire, 1981.
6. Turner D.J. and Thomas R., Motorway Accidents: An Examination of Accident Totals Rates and Severity and their Relationship with Traffic Flow, Traffic Engineering & Control, pp. 377-383, July/August 1986.
7. McGuigan D.R.D., The Use of Relationships Between Road Accidents and Traffic Flow in 'Black-Spot' Identification, Traffic Engineering & Control, pp. 448-453, August/September 1981.
8. Datta T.K., Opiela K.S. and Smith R.J., Analysis of Countwide Accident Data by Rate and Frequency, Transportation Research Record 643, pp. 12-18, 1977.
9. Lalani N. and Walker D., Correlating Accidents and Volumes at Intersections and on Urban Arterial Street Segments, Traffic Engineering & Control, pp. 359-363, June 1981.

10. McGuigan D.R.D., Non-Junction Accident Rates and Their Use in 'Black-Spot' Identification, Traffic Engineering & Control, pp. 60-65, February 1982.

11. Renshaw D.L. and Carter E.C., Identification of High-Hazard Locations in the Baltimore County Road-Rating Project, Transportation Research Record 753, pp. 1-8, 1980.

12. Hayes J., Accident Ranking, Highway & Transportation, No.5, Vol. 36, pp. 53-54, May 1989.

13. Rospa, Blacksite Ranking Method, London, pp. 13-34, 1987.

14. Chirachavala T. and O'Day J., Accident Model of the Traffic Mix: Use of Vehicle Miles to Predict Accidents, Transportation Research Record. 910, pp. 27-29, 1983.

15. Jacobs G.D. and Bardsley M.N., Research on Road Accidents in Developing Countries, Traffic Engineering Control, pp. 166-170, April 1977.

16. Lawson S.D., Descriptions and Predictions of Accidents on Urban Radial Routes, Traffic Engineering & Control, pp. 310-319, June 1986.

17. Hoque M.M., Traffic Accidents in Dhaka, Traffic Planning and Safety, Volume 13, Part 2, pp. 1-14, 1986.

18. Silcock D. and smyth A.W., The Methods Used by British Highway Authorities to Identify Accident Blackspots, Traffic Engineering & Control, pp. 542-545, November 1984.

19. Klausmeier J.P. and Kmack G., Indiana Traffic Accident Record System (INTRACS), Transportation Research Record 643, pp. 1-6, 1977.

20. Mahalel D., A Note on Accident Risk, Transportation Research Record 1068, pp. 85-89, 1986.

21. National Research Council, Highway Capacity Manual, Transportation Research Board Special Report 209, 1985.

22. Mendenhall W., Introduction to Propability and Statistics, 7th edition, Duxbury Press, 1987.

# الملخص

طُبقت ثلاثة اساليب رئيسية لترتيب خطورة الحوادث على مقاطع الطرق المحصورة بين التقاطعات الرئيسية في عدد من الشوارع الشريانية داخل مدينة عمان وهذه الاساليب هي عدد الحوادث، معدلات الحوادث وامكانية تقليل عدد الحوادث على المقطع. وقد جُمعت معلومات عن حجم السير على تلك المواقع بواسطة عدادات آلية وتم إيجاد اطوال تلك المقاطع كما جُمعت معلومات وافية عن الحوادث التي وقعت على تلك المقاطع من سجلات الحوادث الاصلية في دائرة السير. أدخلت المعلومات التي تم جمعها الى جهاز الكمبيوتر وحُللت إحصائياً وذلك لدراسة العلاقة بين حجم السير وعدد الحوادث. تبين بأن عدد الحوادث يتناسب طردياً مع حجم السير وطول المقطع. تم تحديد وترتيب المقاطع الاكثر خطورة بإستخدام طريقة تجمع بين اسلوبين لترتيب خطورة المقاطع هما عدد الحوادث ومعدلات الحوادث. رُتبت المقاطع الأكثر خطورة التي حُددت مرة أخرى اعتماداً على امكانية تقليل الحوادث على تلك المقاطع وذلك من أجل إعطاء دلالات لمعدي برامج تحسين امور السلامة المرورية على تلك المقاطع.