

Prince Mohammad Bin Fahd University  
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Civil Engineering Department



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Learning Outcome Assessment III/CIV.

## Qualitative and Quantitative Risk Assessment Models for Al Khalidiya Road

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## **ABSTRACT**

Most of the students and employees of Prince Mohamad Bin Fahd University (PMU) use Al-Khalidiya road due to two reasons, first it is connecting the Highway to the university, and it second thing the road is shorter than Al-Aziziya road. However, this road is considered very risky by its users. “69 deaths happened in this dangerous road and most of them are students, Al-Yaum newspaper (2015)”. Therefore, losing young people life is an issue worth to study in details, in able to find solutions for stopping death risk. The current project is conducting a new prospective management tools to help; (1) the decision makers and municipal engineers to manage Al-Khalidiya road, (2) the road users by alerting them about the level of risk. Two approach models, qualitative and quantitative, are developed to address the risk level of the road. The level of the work and amount of information about the road is the main obstacle for the project to be done within the limited time. Data is collected from municipalities, a questionnaire survey, scientific journal papers to achieve the project objectives.

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## 1.1 Overview

Al Khalidiya road is one of the oldest roads in the Eastern Province, known as "Abandoned Road". Its length is approximately 10 kilometers length and 9.25-meter width/side (Ministry of Municipality and Rural Affairs 2016). The way abbreviated by half-moon highway about 20 kilometers for people who are coming from Dhahran, and Al Khobar City (Al-Yaum Newspaper, 2014). Before 2014 the road was one lane of directions without barriers. After facing a lot of fatal accidents, the municipality of transportation has separated it into two sides by installing concrete barriers to avoid fatal accidents (Eastern Province Municipality, 2016).

Al Khalidiya road was authorized by Ministry of Transportation. Currently it's under the authority of Eastern Province Municipality. The sides of the street have developed by adding concrete barriers at midway of the road to reduce accidents, and lighting up the whole road by the Municipality of Ad-Dammam. (Eastern Province Municipality ,2016).

Before the opening of Prince Muhammad bin Fahad University (P.M.U.), Al Khalidiya road was not frequently used comparing with the current time. There are about 3000 PMU students passing across this road daily (Al-Yaum newspaper, 2014). Officially, it's one of the most dangerous roads according to the accidents rates between the feeder roads in the Eastern Province. Where in a little while, the number of deaths has reached 69, and that most of them are students (Al-Yaum newspaper, 2014).

The competent/special authorities have toured in Al Khalidiya road which known as "death road," they found that, at the beginning of the road there is a sign that states (No-entry for trucks). However, within 12 minutes 7 trucks passed by the road indifferently (Al-Sajaf K. 2014). Subsequently, an illegal truck was the main reason for the death of Turki Al-Rahiem from PMU students. When his car hit a truck that was making an illegal U-turn (Al-Yaum newspaper, 2014).

Another bad news for one of the PMU students. Abdulrahman Al-Eissa was the victim of this road. His car has flipped upside down causing him minor injuries. The main accident happened because of the sands encroachment accumulated at the concrete barriers and excess amount of untreated bumps (Al-Yaum newspaper ,2016).

Al Khalidiya road was closed in December 8th, 2014 as a prelude to rehabilitate fully, by adding bumps and means of safety for the road. Closing the road was done by coordination between the responsible authorities and management of Prince Mohammed Bin Fahd University due to the impact that was caused by the loss of 69 lives in which most of them were students (Al-Yaum newspaper, 2014).

A committee was formed by the municipality of the eastern region, traffic management, and management of roads and transport, as well as, Saudi Aramco for studying Al Khalidiya road situation. The committee reached durable and temporary solutions, as there are some proposals request implementation of the Eastern Province Municipality and Saudi Aramco. Also, his Royal Highness Prince Saud bin Nayef bin Abdul-Aziz, Governor of the Eastern Region has stressed the concerned authorities in the secretariat and management of roads and traffic management in the region; to find instant solutions to prevent this issue from aggravating (Al-Yaum newspaper ,2014).

As a primary solution for the road environmental issue, Management Services of Municipality of Al Khobar has allocated heavy construction equipment operating on a cliff encroached sand accumulated at the concrete barriers (Eastern Province Municipality ,2016).

In any project, the possibility of risk is a must but in different levels. The same in roads and highways, the possibility of risk is natural and maybe bigger than any other engineering project. However, Al Khalidiya road has nine risk factors that can cause fatal accidents. For example, in five years from 2009 – 2014, there was more than 1600 accidents occurred in Al Khalidiya road (Makkah Newspaper ,2014). i.e. 320 accidents yearly.

The number of accidents occurred in Eastern Province in 2013 was about 104,976 accidents (Alamdoonah 2015) Therefore, the percentage of total accidents of EP for Al Khalidiya Road is 0.1% of total accidents occurred in that years. And Al Khalidiya road takes approximately 2% of total accidents happened in Al Khobar City only in 2013. This proportion is a huge portion comparing with a street of 10 Km length and 18.50 meters' width. The following table demonstrate the number of accidents between KSA, Eastern Province, and Al Khalidya road with percentages.

What is worth to mention here, 2 % of total accidents occurred in Al Khobar City is for Al Khalidiya road only. As well as this road is only 10 Km length with 9.25 width per side ( ministry of municipality of Rural Affairs 2016). In result the percentage worth to be under account and analyzed deeply. Subsequently, all of the responses mentioned in chapter 4 are important and economically appropriate. Table 1.1 illustrates the number of accidents happened an Saudi Arabia, Eastern Province, Al Khobar, and Al Kahlidiya with comparing the percentage of accidents between them

**Table 1.1 compares the number of accidents between KSA, Eastern Province, and Al Khalidiya road**

Region	No of Accidents (2013)	Percentage of total accidents in Al Khobar City and EP (2013)	Percentage of total accidents in KSA City (2013)
Saudi Arabia	540,000	-	-
Eastern Province	104976		19 % of total KSA accidents
Al Khobar City	14,997	14 % of total EP accidents	2.5 % of total KSA accidents
<b>Al Khalidiya Road</b>	<b>320</b>	<b>2% of total accidents happened in Al Khobar</b>	<b>0.1% of total KSA accidents</b>

### 1.1 Current practices and their limitations

The process of cleaning the sand enriched by the road is by using wheel bulldozer and sometimes they use the shovels manually. Currently, as a primary solution for separating the street is installing concrete barriers between the two sides of the street. All of mentioned solutions done by Ministry of Municipality and Rural Affairs.

## 1.2 Project Objectives

Several objectives are intended to achieve in this project as listed as follows:

1. Identify risk factors of Al Khalidiya Road.
2. Perform a qualitative risk model (QLRM) for the road users. The model output will be risk category for each risk factor; for example, “Red” for “Risk X”, “Orange” for “Risk Y”, and “Yellow” for “Risk Z”.
3. Carry out a quantitative risk model (QNRM) for decision makers and municipal engineers, who are responsible for the road operations, to consider required plans accordingly to mitigate the current and future risk.
4. Recommend suitable action plans for the future graduation projects.

## 1.4 Project Organization

A project organization is a structure that facilitates the coordination and implementation of project activities. Its main reason is to create an environment that fosters interactions among the team members with a minimum amount of disruptions, overlaps and conflict. One of the important decisions of project management is the form of organizational structure that will be used for the project. This project is divided into five chapters each chapter concern issue aims to study the road risk to develop qualitative and quantitative risk models. The current project is conducting five chapters **(1)** Introduction; divided into four sections, aiming to introduce the project, shows the current practices and their limitations, and focuses on the objectives of the project in details. **(2)** Literature Review; divided into six sections, aiming to show what done before starting this project, also it shows the definitions qualitative and quantitative risk assessment, in addition, introducing the references will be used for finishing the project as a database. **(3)** methodology of the project; divided into four sections, aiming to analysis the qualitative and quantitative models by applying specific mathematical relations to evaluate the risk and ranking the priority of risk factors. **(4)** Risk responses, aiming to find out recommended actions for mitigate the risk in the Al Khalidiya road. **(5)** Conclusion, aiming to summarizing the chapters, concluding the thesis and providing recommendation actions. Figure 1.1 shows the organization structure of the project.

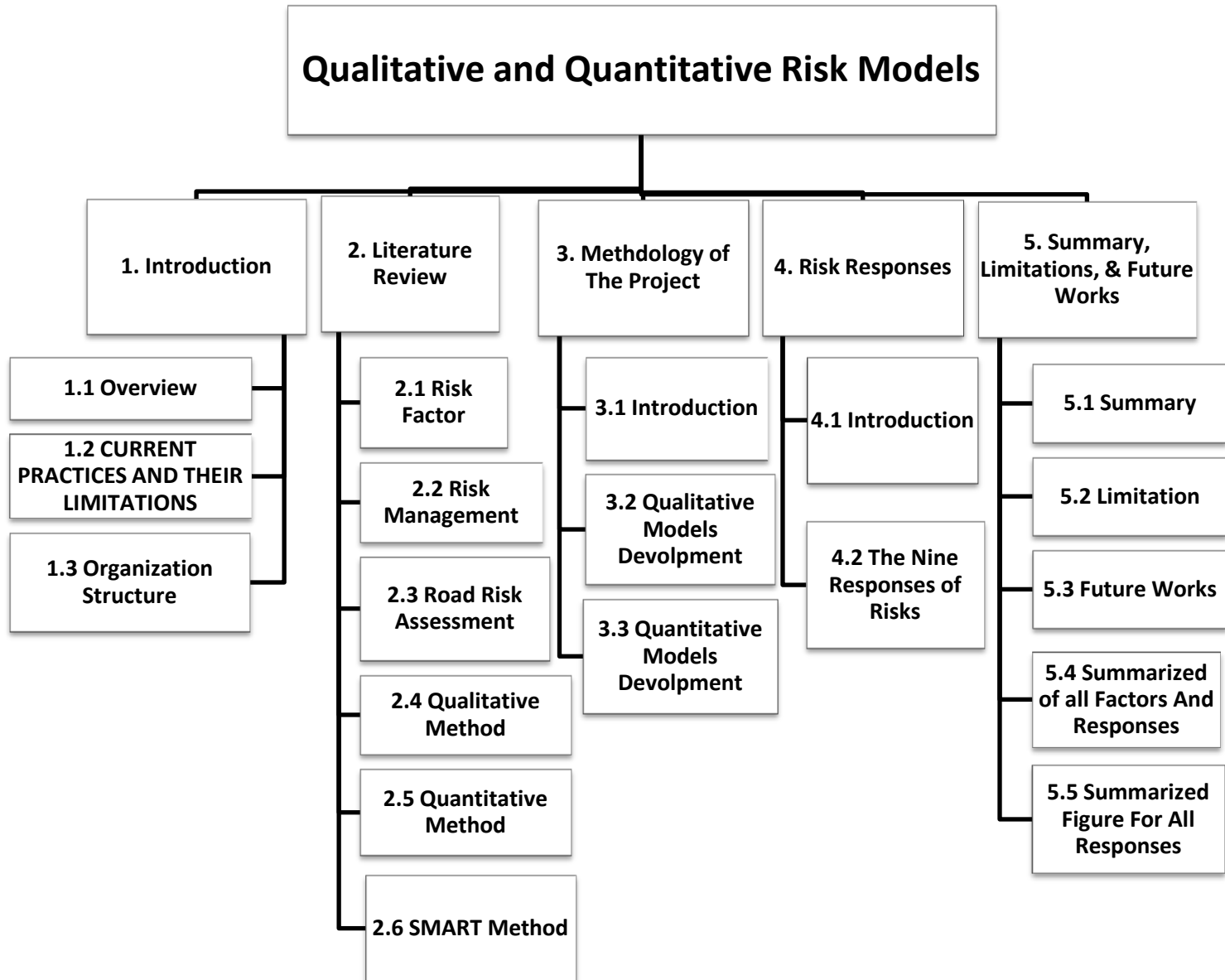


Figure 1.1: Organization Structure For The Project

## 2.1 Risk Factors

Several risk factors can be identified by the road users. Moreover, most of the accidents occurred due to more than one factors. Nine factors are identified and adopted for the current project. These factors are categorized into three categories; **(1)** driving issues, which includes speed, reverse direction and heavy construction equipment. **(2)** road construction and design, which includes concrete barriers and road bumps. **(3)** road environment and safety, which includes sand encroachment, animal passing and road signs. Figure 1.2 illustrate the hierarchy of these risk factor of Al Khalidiya road.

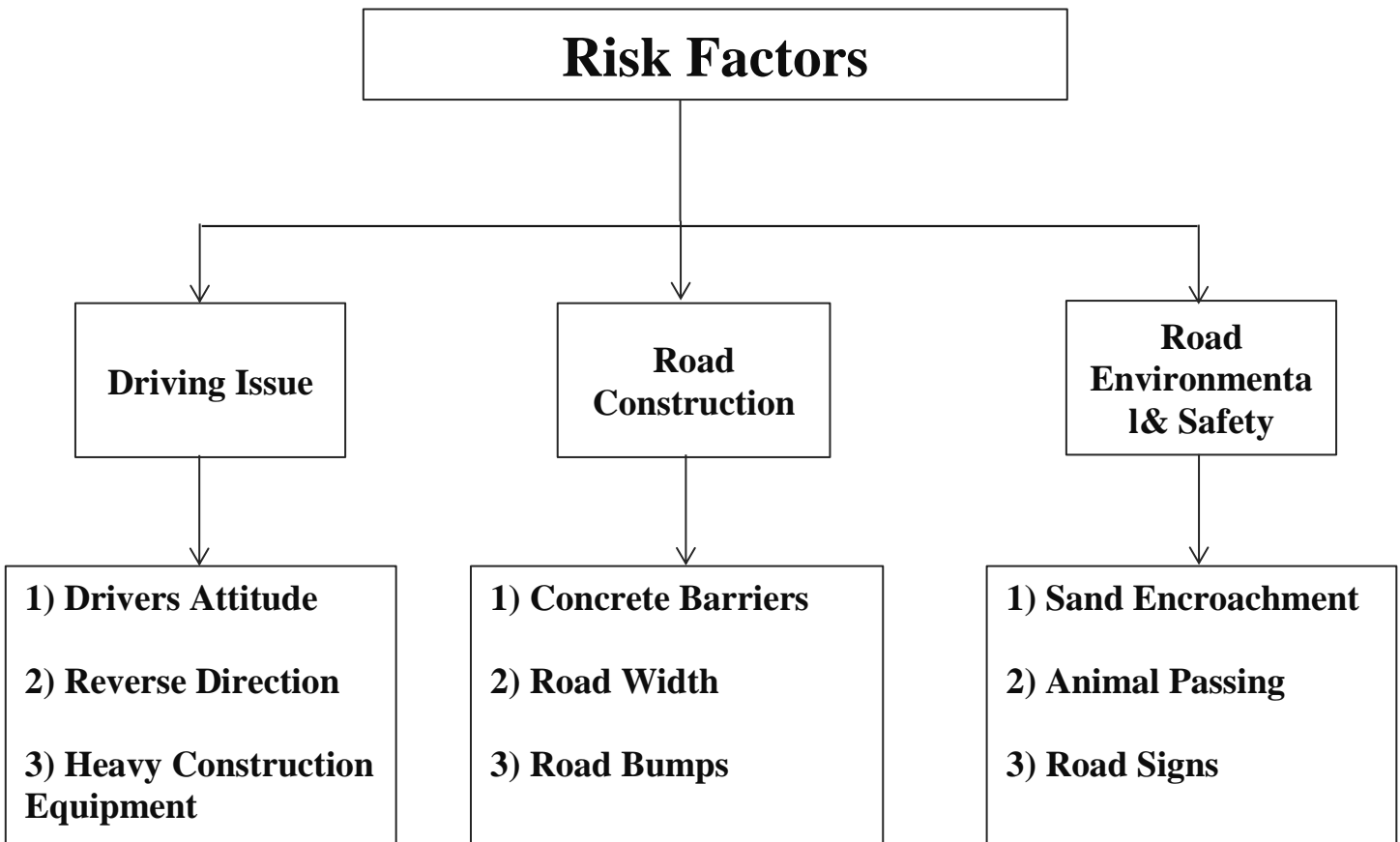


Figure 1.2 Risk Factor of Al Khalidiya Road

### **2.1.1 Driving Issue**

It's the first issue that should be studied and taking care of, where the majority of people who drives on this way are young people some of them are indifferent. Also, there are more than 3000 students are using this road daily. Driving issue categorized under; speed, reverse direction and heavy construction equipment going to be studied in details.

#### **I. Drivers Attitude:**

Driver attitude is a factor which should be taken into account. Thus, what if speed and other behavior are in road like Al Khalidiya? Surly hazard and fatal accidents will occur. All of the nine factors are proportionally with attitude. Bad attitude and illegal U-turn by trucks were the major reason for one of the PMU student's death (Al Sajaf K. 2014). Speed bumps was a solution for decreasing speed in the street. But, it has turned down to be an issue regarding sand encroachment as cars driving at high speed are at high risk of being flipped upside down.

#### **II. Reverse Direction**

Every day; in all times, there are people in Al Khalidiya road drive in reverse direction, due to several reasons; (1) Reckless drivers (2) Construction project related to PMU (3) Intersections of street. Regardless that reversing roads direction is an illegal issue. The problem here is with the width of the road itself, where it does not allow cars driving reversely. Moreover, this street is a feeder road was designed for people who going to Half-Moon beach and buying cattle. Now a day, it's used by university students and heavy construction equipment, according to last statistic; the capacity of the road is 3000 students and employees using the road daily (Makkah Newspaper 2014). Subsequently, PMU students are suffering from those people who reverse the road direction caused fatal accidents. Unfortunately, there is no action implemented for those people to stop them reversing directions of the road. The action should be taken in place is to build up traffic spikes that can prevent people to reverse road direction. This action should be done by municipality of Dammam which is in charge for this road.

### III. Heavy Construction Equipment

Indeed, the road itself is narrow, so existing of mechanical equipment for removing sand accumulated at the concrete barriers make risk for the drivers driving on the road. PMU students facing a big risk from that equipment. Removing concrete barriers will help solving the problem so that, no need to have that equipment. This action should be done by municipality of Dammam which is in charge for this road.



**Figure 2.1: Driving Issues**

### **2.1.2 Road Construction**

Al Khalidiya road before opening Prince Muhammad Bin Fahad University (PMU) was constructed as feeder way abbreviate 20 km for people who are coming from Dhahran and Al Khobar going to Half-moon beach and buying cattle. It was one way serves both directions. After PMU opened the road has become full of thousands students and too many heavy construction equipment work for the projects located at this road. In result, a lot of fatal accidents occurred caused tens of deaths (Al-Yaum Newspaper 2014). After municipality of transportation separate the street into two sides by concrete barriers, the width of the street became narrow. Road construction is categorized under; concrete barriers, width of the street and road bumps.

#### **I. Concrete Barriers**

Concrete barriers is one of the potential hazards facing Al Khalidiya road, these barriers were a solution for the road to separate it into two different sides. Unfortunately, the barriers were posing a risk in the street. Where, the street surrounded by sand which encroaching by the street then the sand accumulated at those barriers, therefore, sand accumulate causing narrowing to make it two or one lane instead of three lanes. The accumulate could cause dangerous accidents. Here is a real example, during work in this project, October 2<sup>nd</sup> of 2016, car has flipped upside down and the main accident happened because of the sands encroachment and excess amount of untreated bumps. Accordingly, people at risk of concrete barriers are in general all cars crossing this road and specially Prince Muhammad bin Fahad (PMU) students. In the risk responses chapter there will be detailed explanation about the solution for this potential hazard. In general, the further action required in this road is to replace concrete barriers by hollowed steel barriers. This action should be done by municipality of Dammam which is in charge for this road.

#### **II. Road Width (Capacity of the Street)**

The total road width is 18.5 m divided into 9.25m per side. (Ministry of Municipality and Rural Affairs 2016). Capacity of the street is only 2 lanes per each side. However, currently the road carries, trucks, heavy construction equipment, and 5000 students daily (Al-Yaum Newspaper

2014). Two lanes are not enough for all of these drivers driving in rush hours. Therefore, road width causing hazard for the road users. Most of the drivers who face the risk are PMU students. The further action required for reducing the risk comes from road width is increasing the road width that can carry all of mentioned drivers in safety and secure conditions. In the risk responses chapter there will be detailed explanation about the solution for this potential hazard. This action must be done by Ministry of Municipality and Rural Affairs, as per proposed plan attached with report.

### **III. Road Bumps**

The amount of speed bumps Al-Khalidiya road have is large, municipality had arranged speed bumps in order to decrease the amount of accidents occurring on a weekly basis. But for every action there is a reaction, by that the potential hazards road bumps have on the road is:

- 1- Drivers trying to avoid bumps run off road onto shoulder.
- 2- Longer emergency response time.
- 3- Potential personal injury if traversed at high speed.

Everyone using the road is potentially at high risk, but taking under consideration that Prince Mohammed student are the ones under high risk. Big example can be taken to one of PMU students (Abdurrahman Al-Eissa ,2016) was trying to avoid a speed bump by running down to inside shoulder and because the inside shoulder fully encroached sand, his car flipped upside down. Further action required in order to decrease potential hazards on the consumers of the road is to balance the amount of bumps and concentrate more on the entrance and exit of the road only.



**Figure 2.2: Concrete barriers**



**Figure 2.3: Road bumps**

### **2.1.3 Road Environmental and Safety**

The road environment is very important for road safety. Infrastructure gives the framework for the physical movement within a society. Infrastructure planning, design, implementation and maintenance involve many levels of activity and disciplines. The aspect of environment and safety will be studied in details in this project divided into the following points:

#### **I. Sand Encroachment**

As mentioned in previous section, sand has a big effect on Al Khalidiya road where its accumulate at concrete barriers. However, sand encroachment itself can cause dangerous accidents where cars may deviate and this may lead to flipping, or hitting another car which finally cause terrible accidents. People at risk of this hazard are all of the drivers driving in this road especially the university students where this street is the shortest way delivering students to their classes on time. According to the survey done for this research, 90% of the students were facing problems caused by sand encroachment while driving in Al Khalidiya road. Unfortunately, there is no action happened already in the road to stop encroaching the sand. The further actions may be taken to reduce the percentage of sand is by planting specific tree called "Tamarisk" with water sprinkles that will irrigate the plant and as a side benefit, the sprinkles will moist the sand then less amount of sand passing the road. In the risk responses chapter there will be detailed explanation about the solution for this potential hazard. These solutions will be explained in details in the responses of risk analysis. This action should be done by Municipality of Dammam which is in charge for this road.

#### **II. Animal Passing**

In Al Khalidiya road, there are animals passing by the street causing dangerous fatal accidents for the road users. Camels and dogs are the most animals passing the road Intermittent. PMU students and all other users of the road face risk comes from these animals. Currently, there is no

action have already taken. The further action required for the road is supporting it by signboards. This action should be done by Ministry of Municipality and Rural Affairs which is in charge for this road.

### **III. Road Signs**

Road signs are very important roads, where signs make the organizational structure of the road. A several problems may occur on a road that without signs. According to questionnaire survey, Al Khalidiya road is currently a random road because of the lack of signs that guide behavior of the drivers in the road. PMU students are the people who face the risk comes from lack of road signs. The action already taken in the road is speed radar cars in which taking tickets for people who exceed speed limit. The further action must be taken for reducing the risk comes from this factor is installing enough signs for the road in which make the driving flow is organized. This action must be done by Ministry of Municipality and Rural Affairs.



**Figure 2.4: Sand encroachment**



**Figure 2.5: Road signs**



**Figure 2.6: Animals passing**

## 2.2 Risk Management

Risk management is basically identification, assessment and prioritization of risks in order to reduce or control the probability of occurrence of negative events followed by lists of possible actions to deal with. Risk management comes from uncertainty in financial markets, project failures, legal actions, regulatory liabilities, accidents, and natural disasters as well without excluding the main factor which is human error. (R. Keith Mobley, 2008). There are 3 stages in risk management structure which are planning, techniques and responses.

**a. Planning:** Planning risk management is to acknowledge and approach the risk activities for a project. Mainly the project manager, customer, stakeholder, experts and others individuals will review the possibilities of risks in a project and will examine ways to handle them. Risk management planning should be adjusted to the size, complexity, experience, skill level of the project. This is the best professional alternative way to deal with risks in a project than a simple standardized checklist.

**b. Techniques:** There are a couple of methodologies or techniques when identifying project risks. The simplest strategy is the scenario based strategy. It basically involves simple brainstorming to come up with positive and negative risks inside the scope of the project. The second strategy is to determine positive and negative risks from possible old projects by reopening past projects. The third strategy is called objective based scenario. This strategy is a mixing combination of both strategies but instead of making up scenarios or using old projects data experiences, risks are measured or identified based on goals and expected outcome for the project.

**c. Responses:** Risk response is the process of developing strategic options, and determining actions, to enhance opportunities and reduce threats to the project's objectives. A project team member is assigned to take responsibility for each risk response. This process ensures that each risk requires a response has an owner monitoring the responses, although the owner may delegate implementation of a response to someone else.

## 2.3 Road Risk Assessment

Road risk assessment is a field that contains standard risk assessment approach to certain amount of potential hazards with driving for work/university, that includes the trip taken, allowing enough time for the journey length, arrangement to take a break, driving posture, route choice and thinking of alternatives to driving.

Road Risk assessment is very important that there are a lot of risk factors coming from natural and human being. The Royal Society for the Prevention of Accidents (RoSPA) encourages this project to create road risk assessment based on the following key steps:

### **Step 1: Audit vehicle usage, accidents and their cost**

Employers should audit the following information:

- The number of vans, lorries, and essential or casual car users;
- Journeys – the current mileage by types of vehicle and the length of journeys;
- The date, time and place of accidents, and the severity of injuries sustained; and
- The annual cost of insurance, repairs and absences from work following road accidents.

### **Step 2: Carry out a risk assessment**

In occupational safety, a hazard is something that has the potential to cause harm. Risk is the likelihood that harm will arise from a hazard. RoSPA recommends using a scoring system to highlight issues of highest concern.

### **Step 3: Introduce safety and control measures**

Many of these ideas are also sound advice for the individual driver:

- Eliminate unnecessary journeys and consider alternative means of communication.
- Change the mode of transport, e.g. take the train, then a bus or taxi.
- Avoid driving in adverse conditions, e.g. at night, or in poor weather.
- Reduce distances – set maximum driving distances (e.g. per day, per week or per year).
- Control drivers' hours. Set upper limits for driving hours each day, week and month.
- Specify the safest routes.
- Specify safer vehicles.
- Set driver capability standards, e.g. by requiring drivers to pass an advanced driving test paid for by the employer.
- Require regular eyesight tests. The legal visual standard for a car or motorbike driver is to be

able to read a number plate at 20.5 meters, with glasses if worn.

- Set clear policies on use of alcohol and other substances. Prohibit the use of mobile phones, including hands-free sets, while on the move.

## 2.4 Qualitative methods

### i. **Process definition:**

Qualitative risk analysis is a process which ranks risk factors from highest to lowest by assessing their probability of occurring and their impact.

Naturally this process uses the definitions of the risk management plan. The Qualitative Risk Analysis is a qualitative risk analysis (and not a quantitative risk analysis) because single risks are "manually" classified by raw types of impacts and probability (and not by really computed values with respect to the whole project and the side effects of other risks) (R. Keith Mobley, 2008).

### ii. **Tools and technique:**

1. Risk probability and impact assessment is a method for "investigating the likelihood that each specific risk will occur" and a method for explicating their "potential effects" on the project which can be positive (risk is an "opportunity") or negative (risk is a "threat")
2. Probability and impact matrix combines the estimated / found values for probability and impact (both represented in a range between 0 and 1) and computes the importance by multiplying the values: risks, which will probably occur and which will have heavy impacts are more important than those which will probably not occur and which will have low impacts.
3. Risk and data quality assessment is a method to evaluate the quality of the basic data, also, there is method called risk urgency assessment used to classify the risks (being already pre classified by the probability – impact - matrix) with respect to the time: even a lower classified risk can become more important than the higher classified, in opposite of site higher classified, occur in the near future

### iii. **Process Output:**

Updates of the Risk Register build an expansion of the initially generated risk registered by following:

- Relative ranking or priority list of project risks based upon the probability-impact-matrix and the urgencies of the risks
- Risks grouped by categories for being able to find collective answers
- List of risks requiring response in the near-term
- List of risks for additional analysis and response
- Watch lists of low priority risks
- Trends in qualitative risk analysis results

## 2.5 Quantitative methods

### i. **Process definition:**

Quantitative Risk Analysis is the process for “numerically analyzing the effect on overall project objectivities of identified risks” (PMBOK 2011).

On the base of the results of the Qualitative Risk Analysis the "Quantitative Risk Analysis is performed on risks that have been prioritized analyses the effects of those risks events and assigns a numerical rating to those risks. Instead of estimating the single impacts by using a raw typology in the process of Quantitative Risk Analysis the impacts to the whole project will be computed for generating a more elaborated total ranking. Useful techniques are for example "SMART" or "decision making theory" (PMBOK 2011).

To sum up, "quantitative risk analysis breaks down risks from a high, medium, and low ranking to actual numerical values and probabilities of occurrence" for being able to compute the overall effects (CROSSWIND7 2009)

### ii. **Tools and techniques:**

**Data gathering and representation techniques** like "Interviewing" and computing the "probability distributions" on the base of "expert judgments" (PMBOK 2011)

Quantitative risk analysis and modeling techniques (PMBOK 2011) like

Sensitivity analysis which results for example may be represented by the "tornado diagram"

*Expected monetary value analysis (EVM)* which is “statistical concept that calculates the average outcome when the future includes scenarios that may or may not happen”. Opportunities are positive values, treated as negative.

Decision tree analysis "is usually structured using a decision tree diagram that describes a situation under considerations, and the implications of each available choices and possible scenarios"

*Modeling and simulation* for computing the whole effects for example by using the Monte Carlo analysis

### **iii. Process output:**

Updates of the Risk Register build an expansion of the initially generated and already updated / widened risk register by the following additional information

- Probabilistic analysis of the project
- Probability of achieving cost and time objectives
- Prioritized list of quantified risks

Trends in quantitative risk analysis results

## **2.6 Simple Multi Attributes Rating Technique (SMART) Method**

Based on Harris (1980), SMART is a decision making Theory, which is “the study of identifying and choosing alternatives based on the values and preferences of the decision maker”. Making a decision implies that there are alternative choices to be considered, and in such a case we want not only to identify as many of these alternatives as possible but to choose the one that best fits with our goals, objectives, desires, values, and so on”. According to Baker et al. (2001), decision making should start with the identification of the decision makers and stakeholders in the decision, reducing the possible disagreement about problem definition, requirements, goals and criteria. Then, a general decision making process can be divided into the following steps:

- 1) Define the Problem
- 2) Determine Requirement
- 3) Establish Goals
- 4) Identify Alternative

- 5) Define Criteria
- 6) Select Decision making theory
- 7) Evaluate Alternative Against Criteria
- 8) Validate Solution Against Problem Statement

Smart is adapted in this project as a decision making method to develop the risk index (RI) mathematical model.

### **3.1 Introduction**

There is no accurate data and statistics for Al Khalidiya road but from local newspaper and students from the university faced fatal accidents that during the five years past, there were almost 1600 accidents in this road, and 69 deaths among those accidents. Based on the data gathered from the newspapers, municipality, and questionnaires, it has been determined that Al Khalidiya Road is risky. Therefore, this project is a new source to manage the road. Figure 3.1 demonstrate the flowchart of the project methodology. It consists of literature review first, questionnaire second, developed mathematical models third, model implementation fourth, result and analysis fifth, and recommended actions is sixth.

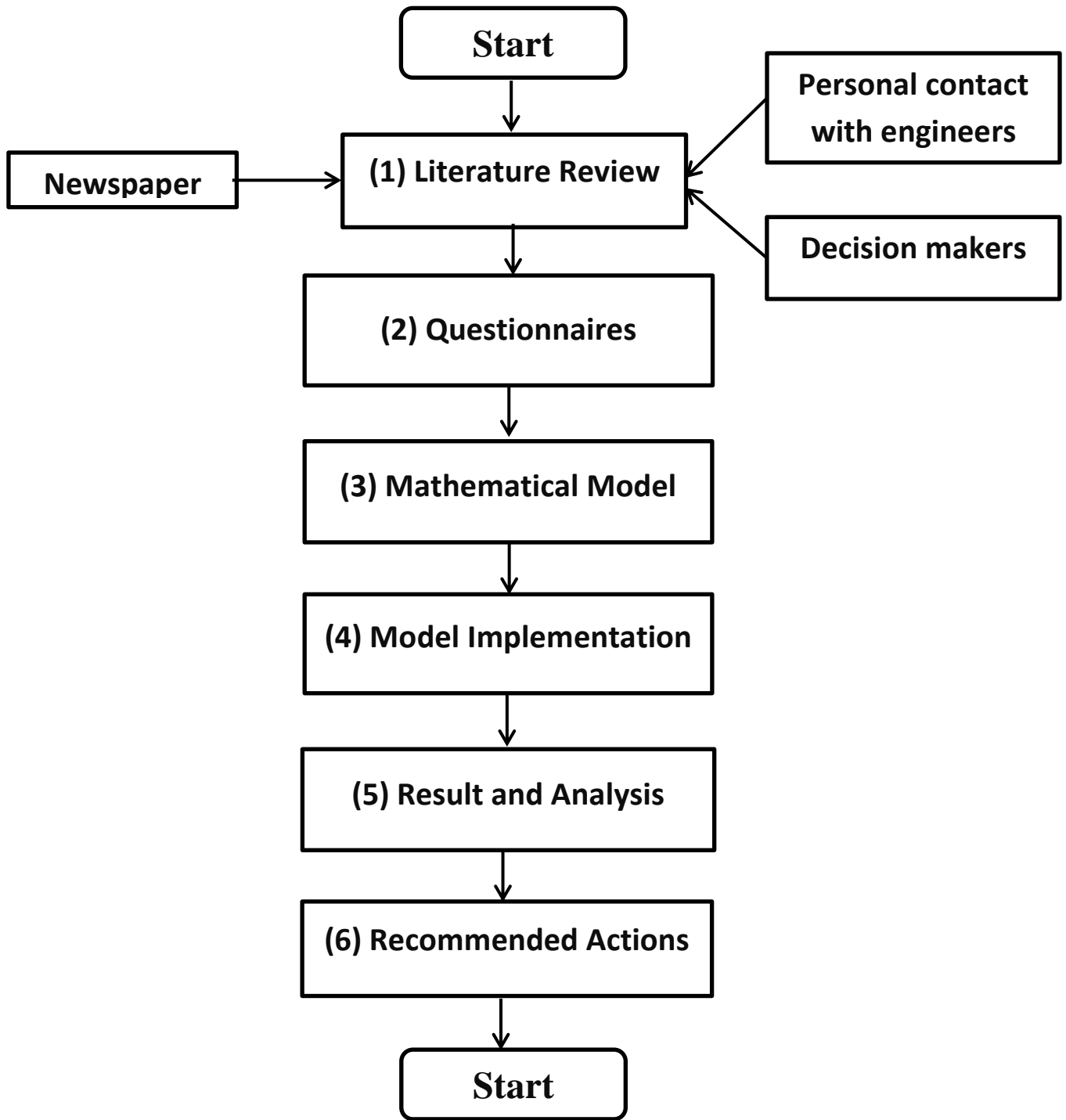


Figure 3.1: Project Methodology Flowchart

### **3.2 Data collections (survey and municipality)**

The survey consists of three questions; 1<sup>st</sup> is general questions for road users. 2<sup>nd</sup> is evaluating the nine risk factors from 1 to 10, where 1 represent no risk and 10 very risky, and 3<sup>rd</sup> question is optional about the required actions to be taken for solving the risk of the road.

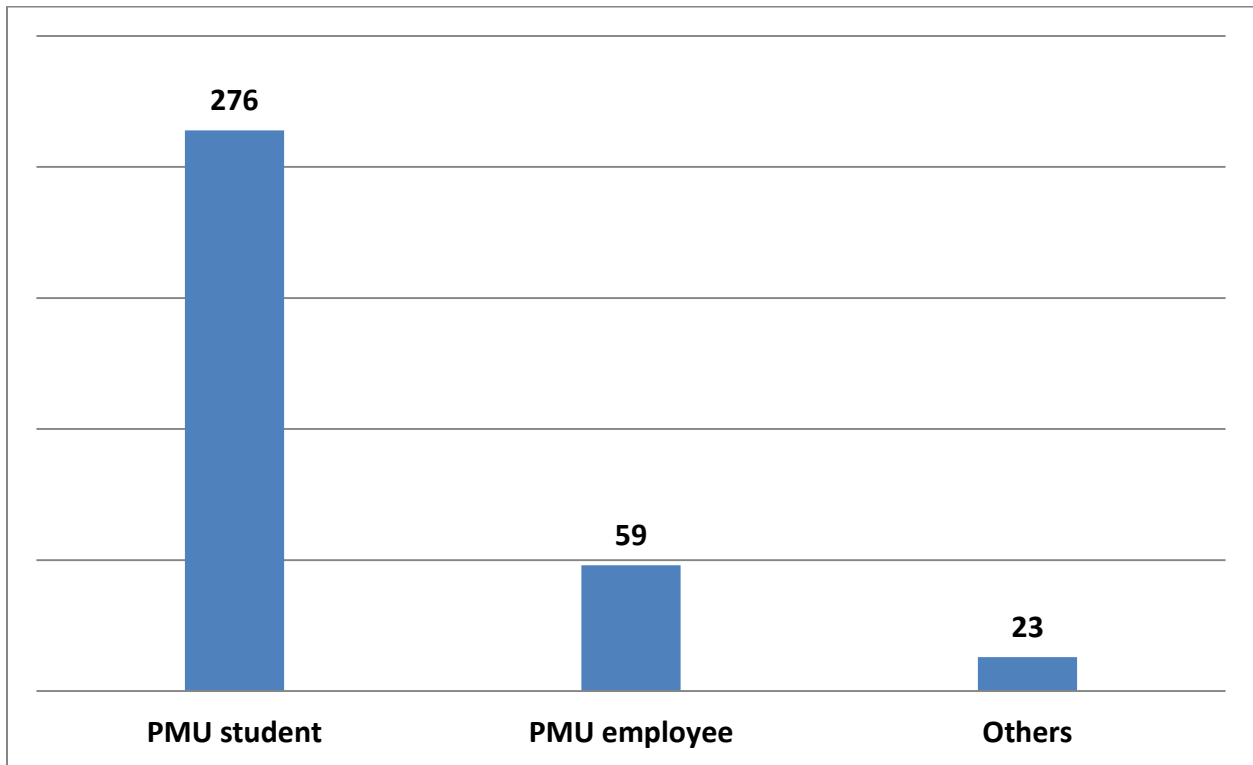
#### **3.2.1 Literature Review**

The main focus of this project is to develop an index for Al Khalidiya road to be compared with other road in Al Khobar city. A research paper is likely to contain a literature review as one of its parts. In a research paper, the review of literature used as a foundation and as support for a new insight that contributes to develop risk assessment for the road. The focus of a literature review, however, is to summarize and synthesize the arguments and ideas of others without adding new contributions.

#### **3.2.2 Questionnaires**

The data collection has been done as a survey conducted in PMU into two phases, Phase one is questionnaire for students using the road at a daily basis. Phase two is the feedback from facilities of PMU, Dammam, KFUPM Universities. In addition, municipality engineers and decision makers are involved in this questionnaire. As a result, their feedback has taken as a correction factor for the risk analysis.

Figure 3.3 represents the number of people from different categories participated in the survey questionnaires. There were 276 students, 59 employees, and 23 others.



**Figure 3.2: Survey results**

There were 316 out of 358 questionnaire stated that this road is very risky for them, which is 88% of all participated. Figure 3.4 shows the number of people answered yes its risky, and who answered no its not.

Figure 3.3 Represents the people who answered Yes the road is risky and, No for the road is not risky

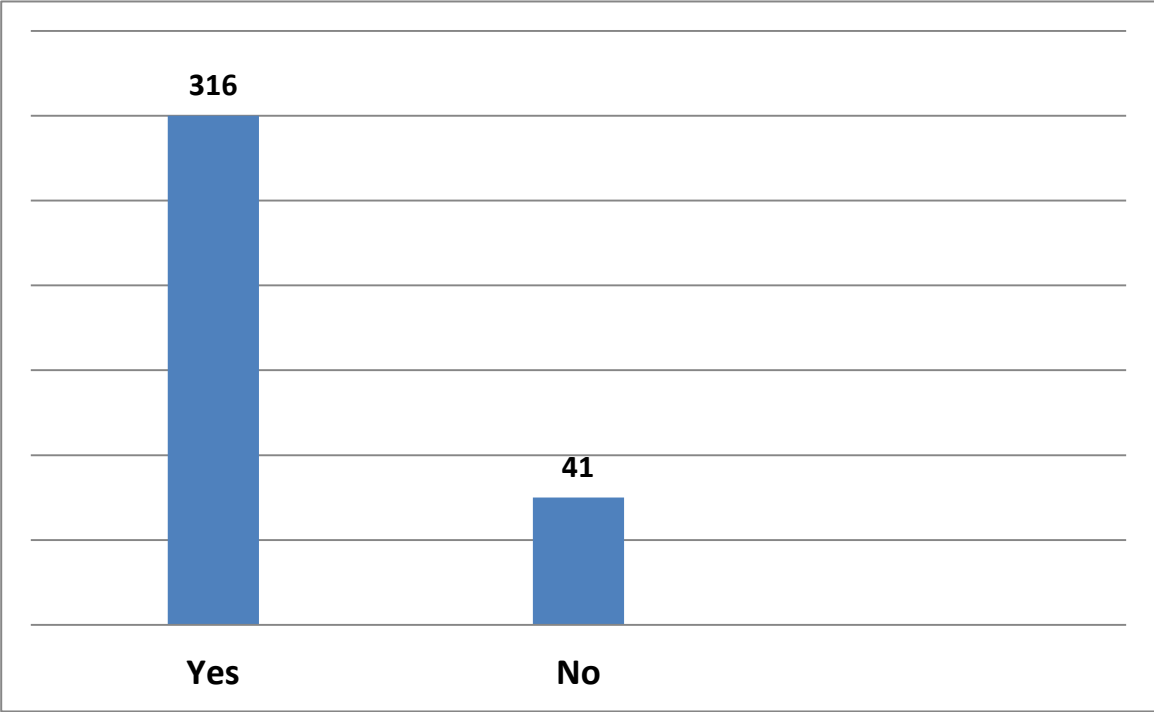


Figure 3.3: Survey Responses

### 3.3 Development of Risk Mathematical Model

Risk can be indicated as a risk index (RI). To obtain the RI value, probability of failure (PoF) used as its function. Hence, when PoF increases RI is increased accordingly as shown in the equation (1)

$$RI \propto PoF \dots\dots\dots (1)$$

To measure PoF several techniques can be utilized to determine it. Direct questionnaire is one of the quick methods based on a scale “1” to “10”. Where, “1” is an indication of there is no probability of failure, while “10” means that the probability of failure is extremely high.

By another hand, one disadvantages of the questionnaire method is the bias of the direct answer. Therefore, another factor is added to the right side of the equation to correct RI value. The correction factor is responses from expertise such as academic professors, municipality engineers, and decision makers. The final shape of the RI equation is shown in equation (2)

$$R_i = PoF_i \times W_i \dots\dots\dots (2)$$

Where,

$R_i$ : Risk index for risk factor  $i^{th}$

$PoF_i$ : Score risk index for risk factor  $i^{th}$  it is obtained from direct questionnaires.

$W_i$ : Weight risk index for risk factor  $i^{th}$ . It is obtained from experts

$$W_i = \frac{Avg.}{\sum Avg.}$$

Where:

Avg.: Average of each risk factor by expert’s results

$\sum Avg.$ : Summation of all average risk factors

To determine the RI for an individual road equation (3) can be used,

$$RI = \sum PoF_i \times W_i \dots\dots\dots (3)$$

Where RI: Risk index for road  $i^{th}$ .

According to equation (3), all risk factors are combined to determine the RI of an indicated road. The RI value can be utilized to prioritize roads according to their risks. Based on this prioritization, repair/replace strategy will be implemented by municipal engineers.

### **3.4 Model Implementation:**

#### **3.4.1 Qualitative Model Development**

Qualitative risk analysis is a project management technique concerned with discovering the probability of a risk event occurring and the impact of the risk if it does occur. All risks have both probability and impact. Probability is the likelihood that a risk event will occur, and impact is the significance of the consequences of the risk event. The technique used in this report as qualitative model is risk ranking scale divided into three categories of colors where, red represents extreme risk, orange medium risk and yellow color is the lowest level of risk. According to survey results, the risk has been ranking as follow. See figure (3.6)

- |  |                |
|--|----------------|
| 1) Driving in wrong way (reverse direction)                  | (Red Color)    |
| 2) Sand encroachment   | (Red Color)    |
| 3) Drivers behavior  | (Red Color)    |
| 4) Operation of trucks and heavy construction equipment      | (Orange Color) |
| 5) Road layout and design (width, curves, pavement problems) | (Orange Color) |
| 6) Road bumps  | (Orange Color) |
| 7) Concrete barriers   | (Yellow Color) |
| 8) Road Signs  | (Yellow Color) |
| 9) Animal passing  | (Yellow Color) |

### 3.4.2 Quantitative Model Development

Contains 9 risk factors that make this road one of the most dangerous roads in Eastern province. Sand, Trucks, Bumps, Concrete barriers, passing animals, drivers exceeds speed limit and its bad design are the main factors that make this road risky. The above factors are ranked in order to show how dangerous each one is.

Like any potential hazard, there is influences that can cause a disaster. The effects are divided into many parts such as, physical, physiological, tolerance, and frequency of existence of the risk. These effects are implemented into the nine factors of risk in Al Khalidiya road. Each factor has different effects. The following sections show how these influences affect the nine factors of risk.

### 3.4.3 Result and Analysis

#### I. Qualitative and Quantitative Risk Priority

Risk Priority			
Quantitative			Qualitative
No.	Risk Factor	Ri	Ranking
1	Driving in wrong way (reverse direction)	1.1050	
2	Sand encroachment	1.0400	
3	Drivers Behavior	1.0360	
4	Operation of trucks and heavy construction equipment	0.9600	
5	Road layout and design (width, curves, pavement problems, etc.)	0.9100	
6	Road Bumps	0.6700	
7	Concrete Barriers	0.6030	
8	Road signs	0.3990	
9	Animal passing	0.3987	

Figure. 3.4: Risk Ranking With Priority

## II. Analysis of some factors of the nine risk factors:

### 1) Sand Encroachment

- **Physical effects**

The physical effect of sand focuses on the damage to cars in accidents mainly, but to cover all aspects of physical effect of sand on Al Khalidiya Road a relationship should be developed to identify the percentage of accidents happened in Al Khalidiya Road, and compare it to the percentage of accidents in KSA and eastern province. While there are no enough data on these aspects, a formula has been developed to estimate the percentage and further analysis will be shown in Physiological effects of sand.

- **Physiological effects**

The riskiest element is physiological effects, because human loses is the worst of what could happen. Unfortunately, 69 deaths have been recorded in the last 5 years. This unexpected accident should be solved as soon as possible. The average deaths on this road is 13.8 per year. Deaths are not the only fatal result but also injuries, accident injuries most of the time are fatal. “Unless action is taken, road traffic injuries are predicted to become the fifth leading cause of death by 2030” (association for safe international road travel).

### Notes:

- 1) These estimations based on observations from 6 students have been driving on this road for the past 4 years.
- 2) Taking in consideration the 4 sections of the road and the Intensity of sand over each section.
- 3) To calculate the probability of being at risk for each car passing this road this formula is applied;

**Average vehicle risk = (Average Traffic per Day × Danger Zone/Speed Limit) \* 100**

**AVR = [(3000\*2)/90] = 66.6%** (Pierson et al., 1990).

Section A has sand encroachment over 30% of its length

**AVR = 66.6 \* 0.3 = 20 %**

Section B has sand encroachment over 70% of its length

**AVR = 66.6 \* 0.7 = 46.6 %**

Section C has sand encroachment over 70% of its length

$$AVR = 66.6 * 0.7 = 46.6 \%$$

Section D has sand encroachment over 50% of its length

$$AVR = 66.6 * 0.5 = 33.3 \%$$

- Tolerance

Risks varies in danger depending on certain factors. In case of sand it depends on width of sand, length of sand, depth or height of sand and percent of sand from total road. At certain levels sand is not considered as a risk. The risk from sand starts when it is more than 10% of road width and more than 5 mm depth. In case of sections B and C, there is no space for tolerating this factor.

- Survey Results of Sand Encroachment

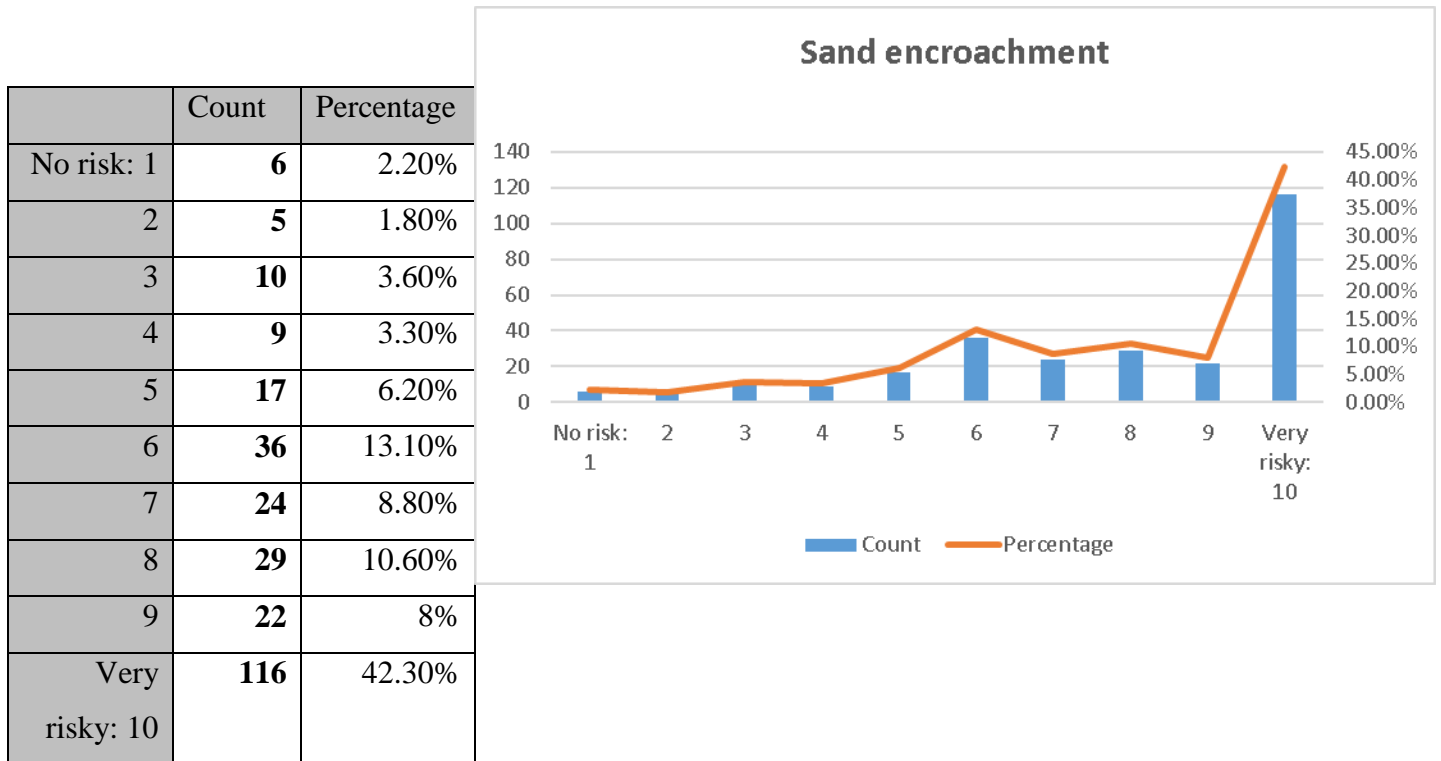


Figure. 3.5 Survey Results of Sand Encroachment

Mean of risk level:  $(1+2+3+4+5+6+7+8+9+10)/10 = 10$

Mean of percentage:  $100/10 = 10$

Variance: (from excel) = 0.014

Standard deviation = 0.118

## 2)Trucks

- Physical effects

The average cost of a fatal crash is over \$3 million. The average cost of a large truck crash that does not involve a death is approximately \$62,000. Considering that a huge percent of accidents caused by trucks involves death shows how much physical damage truck can cause. The worst thing in this part is that trucks are not allowed to use this road, regardless of how much problems they can cause.

- Frequency analysis

There are a lot of reasons behind accidents caused by trucks. The number of accidents caused by trucks can be estimated by the frequency and intensity during the normal times on the road Also, considering the main reasons for trucks accidents which are:

1. Driving in the "No-Zones" -- the areas behind and beside a commercial truck where the truck driver has limited or zero visibility.
2. Changing lanes abruptly in front of a truck.
3. Maneuvering to the right of a truck that is making a right turn.
4. Merging improperly into traffic, causing a truck to maneuver or brake quickly.
5. Failure to slow down or speed up when a truck begins to change lanes or merge.
6. Unsafe passing, particularly passing with insufficient headway.
7. Passing a truck, then being blown out of position by air turbulence or cross-wind.
8. Pulling into traffic from the roadside in front of a truck without accelerating sufficiently.
9. Driving between large trucks.
10. Abandoning a vehicle in a travel lane, or failing to get a disabled vehicle completely off the highway and onto the shoulder.

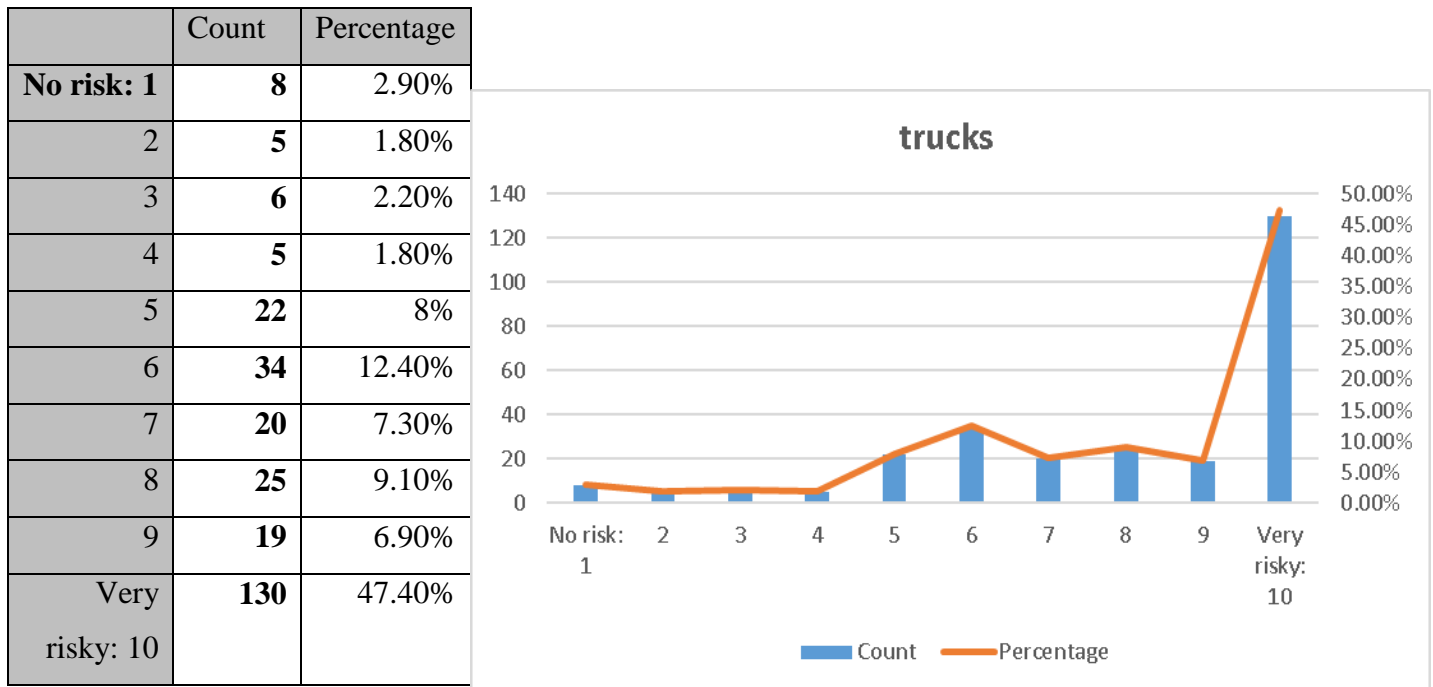
- Tolerance

In case of trucks, tolerance could be in consideration if the trucks pass the road, which is almost nonexistent compared to trucks crossing the road. Also, the fact that it is illegal to drive a truck on this road should eliminate any chance of tolerance.

- Risk calculation

In course of one hour, 13 trucks crossed the road. If we estimate the working time for trucks as 6 hours per day as a result it will be concluded that only 80 % of the trucks cross the road per day. While there is an average of 2000 cars passing in this period, 80 cars per hour will be in risk of a truck crossing the road.

- Survey results for trucks



**Fig. 3.6 Survey Results For Trucks**

### 3) Road bumps

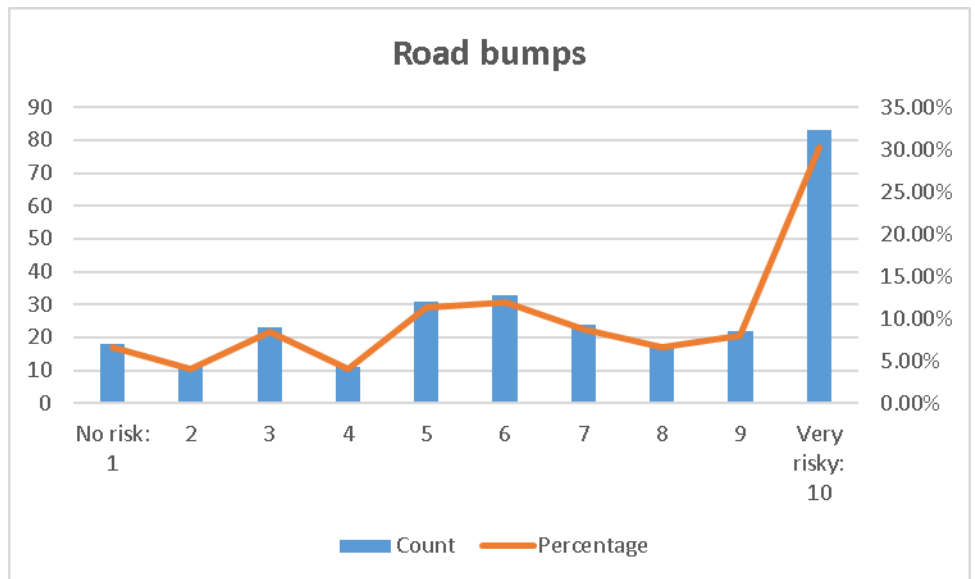
- Physical effects

Bumps cause damage to cars beside causing accidents. The number of bumps in this road is overwhelming. For students who drive every day at this road, going over all these bumps will cause real damage to cars. Furthermore, it is environmentally dangerous as every car has to slow down 20 to 10 Km/h then accelerating 80 – 90 Km/h which burns more fuel and produces more CO2 to the atmosphere.

- Frequency analysis

Every car has to pass over 10 bumps going to PMU and 9 going back from PMU.

Road bumps		
	Count.	Percentage
No risk: 1	<b>18</b>	6.60%
2	<b>11</b>	4%
3	<b>23</b>	8.40%
4	<b>11</b>	4%
5	<b>31</b>	11.30%
6	<b>33</b>	12%
7	<b>24</b>	8.80%
8	<b>18</b>	6.60%
9	<b>22</b>	8%
Very risky: 10	<b>83</b>	30.30%

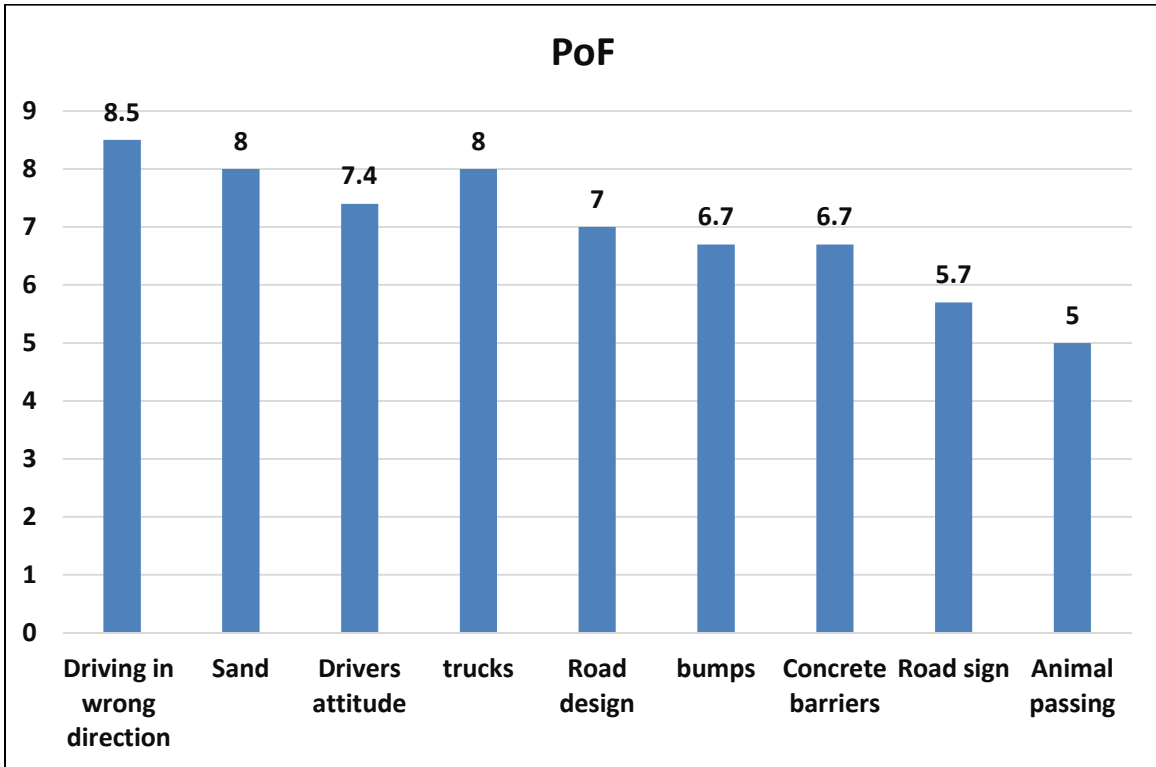


**Figure 3.7 Survey Result For Road Bumps**

### III. Probability of Failure (PoF)

PoF is calculated for individual factor of risk by looking at the potential hazard mechanism that could be susceptible to a general frequency of failures, and management system factors. More details on POF are provided in the American Petroleum Institute's Recommended Practice 580 - Risk Based Inspection (RBI), which contains directions on developing, implementing and

maintaining an effective RBI program. However, in this report, the method used to find the probability of failure is Decision Making Theory (DMT) based on collecting expertise survey's results called (normalization). See next section for more normalization details. PoF is taking the average number of each factor resulting from people who did the survey, where the average number of each risk is the PoF.



**Figure 3.8: Probability Of Failure For Each Factor**

## CHAPTER 3

### IV. Decision Making Theory ( $W_i$ )

**Table 3.1: Decision Making Theory**

Decision Making Theory (SMART Method)												
No.	RISK Factors out of 10	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Expert 6	Expert 7	Expert 8	Expert 9	Expert 10	Avg.
1	Drivers Behavior	8.00	9.00	7.00	8.00	10.00	10.00	9.00	9.00	10.00	10.00	9.00
2	Driving in wrong way (reverse direction)	9.00	5.00	8.00	7.00	10.00	9.00	8.00	8.00	10.00	10.00	8.40
3	Operation of trucks and heavy construction equipment	7.00	7.00	9.00	9.00	7.00	6.00	6.00	8.00	8.00	8.00	7.50
4	Concrete barriers	6.00	2.00	5.00	8.00	8.00	5.00	6.00	5.00	7.00	7.00	5.90
5	Road layout and design (width, curves, pavement problems, etc.)	10.00	5.00	8.00	10.00	7.00	8.00	9.00	7.00	9.00	10.00	8.30
6	Road bumps	5.00	5.00	7.00	8.00	6.00	9.00	7.00	5.00	5.00	4.00	6.10
7	Sand encroachment	7.00	7.00	5.00	9.00	6.00	10.00	10.00	10.00	9.00	10.00	8.30
8	Animal passing	4.00	2.00	4.00	7.00	8.00	7.00	5.00	4.00	2.00	5.00	4.80
9	Road signs	5.00	2.00	5.00	7.00	1.00	7.00	6.00	3.00	4.00	4.00	4.40
											$\Sigma=$	62.70
												<b>62.70</b>
												<b>1.0</b>

V. Measured Risk In Priority ( $R_i$ )

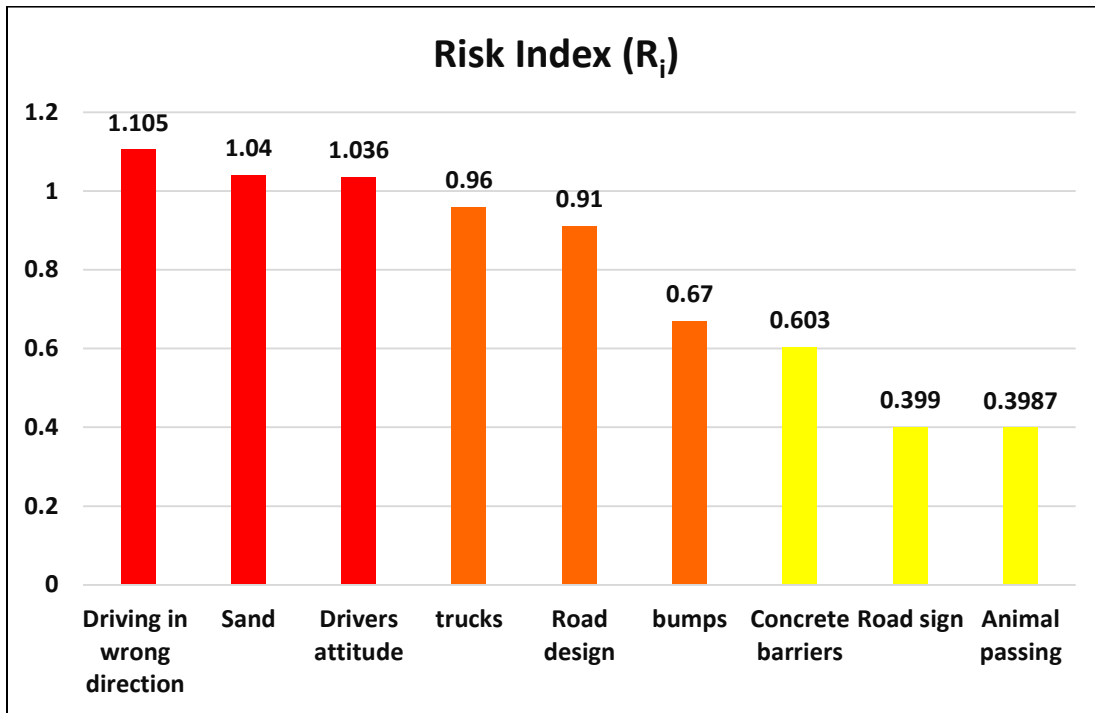


Figure 3.9 Measured Risk For Each Factor In Priority ( $R_i$ )

## **4.1 Risk Responses**

After analyzing and discussing the risks faced Al Khalidiya road, supposed to have responses for those risks. The following list is the suggested solutions for the road and it will be discussed in details in this section with safety and cost wise.

The below is the list of the risk factors ranked from high to low.

- 4.1 Driving in wrong way (Reverse direction).
- 4.2 Operations of trucks and heavy construction equipment's.
- 4.3 Driver behaviors.
- 4.4 Road layout and design (width, curves, pavement problems and etc).
- 4.5 Sand encroachment.
- 4.6 Road bumps.
- 4.7 Concrete barriers.
- 4.8 Animal passing.
- 4.9 Road signs.

### **4.2 Driving in wrong way (Reverse direction)**

In order to prevent drivers from reversing directions is by installing traffic spikes instead of speed bumps throughout the road. These traffic spikes acts as a deterrent to the drivers as reversing the direction will lead to the consequence of flat tires.



**Figure 4.1: Traffic Spikes - Secure Lane LLC (Christine 2013)**

### **4.3 Operations of trucks and heavy construction equipment's**

The most commonly used response for preventing trucks and transportation of construction equipment's from affecting the safety of the road is to implement a schedule that the trucks must follow which is from 1:00 AM to 7:00 AM. This timing was chosen based on university's classes time which are from 8:00AM to 12:00 AM. This ensures that there is no interference between the transportation of students and trucks. This proposed action will mitigate the risk level of the road by this risk factor to the lowest level.

#### 4.4 Driver behaviors

The main issue that is caused by the behaviors of the drivers is exceeding the speed limit of the road. Currently the solution that best fits this situation is installing speed cameras along the entirety of the road. This solution is effective because the speeding fine will force the drivers to think twice before exceeding speeding limit. The speed fine that is currently being enforced on the crime is 300 Saudi Riyals for exceeding the speed limit not more than 25 km/h and 500 Saudi Riyals for exceeding more than 25 km/h above the speed limit with a possibility of keeping the car in custody. (MOI,2016)



**Figure 4.2: Speed Camera (Saher)**

## **4.5 Road layout and design (width, curves, pavement problems and etc.)**

### **4.5.1 As Built Drawings**

#### **Introduction:**

Unlike roads used by the general public, Al Khalidiya road is a secondary road which gives access to the area in the process of exploitation, merging into the main road. In exceptional circumstances, this secondary road can carry traffic required by the general needs of exploitation (students, transport of equipment, heavy construction equipment, trucks, etc.). Thus, this road should be maintaining in advance so that the provided services will be acceptable.

This section is comparing Al Khalidiya road with proposed plan for Al Khalidiya road done by Ministry of Municipality of Rural and Affairs. Where, Al Khalidiya does not fit most of standards requirements of streets in Saudi Arabia according to American Association of State Highway and Transportation Officials (AASHTO) standard. Therefore, the following details showing the standards and criteria have to be done in Al Khalidiya road to meet the safety and security standard:

- **Pavement Design and Layers:**

#### **Standard of pavement Design and Layers**

Like any street, the pavement design must contain three layers; (1) Asphalt/concrete (2) Aggregate base, (3) Subgrade. According to minimum thickness standard for base and subgrade. All of the layers full fit the standards. See tables (1 & 2)

**Table 4.1:** Minimum standard for Asphalt Concrete

<b>Minimum Thickness Standard</b>		
<b>Traffic (ESALs)</b>	<b>HMA (inches)</b>	<b>Aggregate Base *</b>
<50,000	1	4
50,000 – 150,000	2	4
150,001 – 500,000	2.5	4
500,001 – 2 million	3	6
2 million- 7 million	3.5	6
7 million	4	6

AASHTO Standard

**Table 4.2:** Minimum standard for base and subgrade

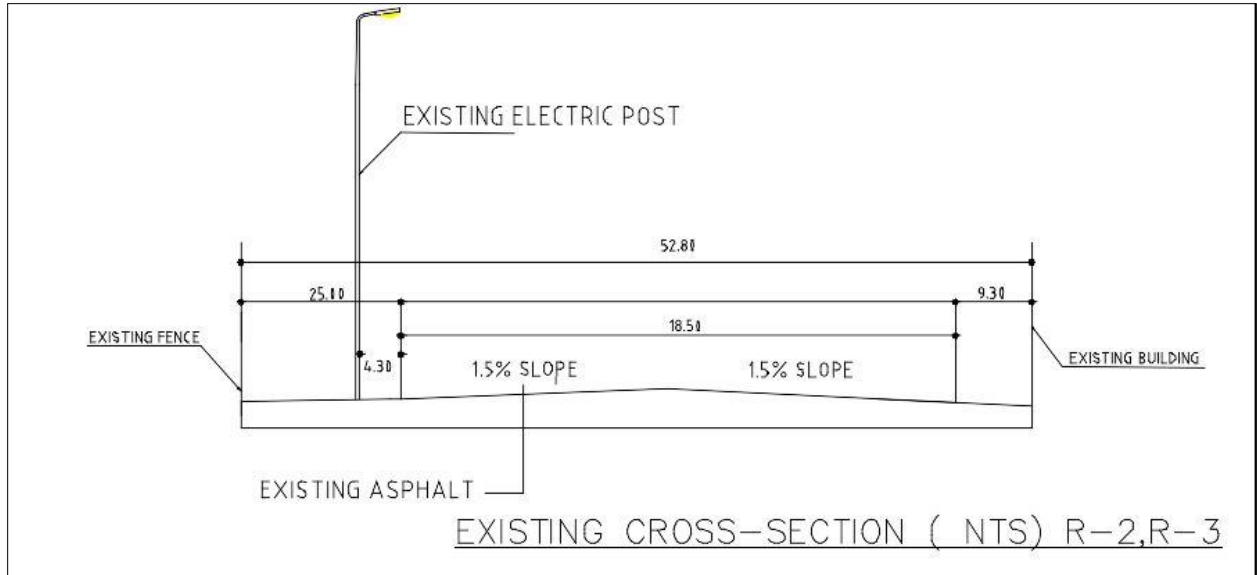
<b>Minimum Thickness Standard</b>		
<b>Traffic (ESALs)</b>	<b>HMA (inches)</b>	<b>Aggregate Base *</b>
<50,000	1	4
50,000 – 150,000	2	4
150,001 – 500,000	2.5	4
500,001 – 2 million	3	6
2 million- 7 million	3.5	6

AASHTO Standard

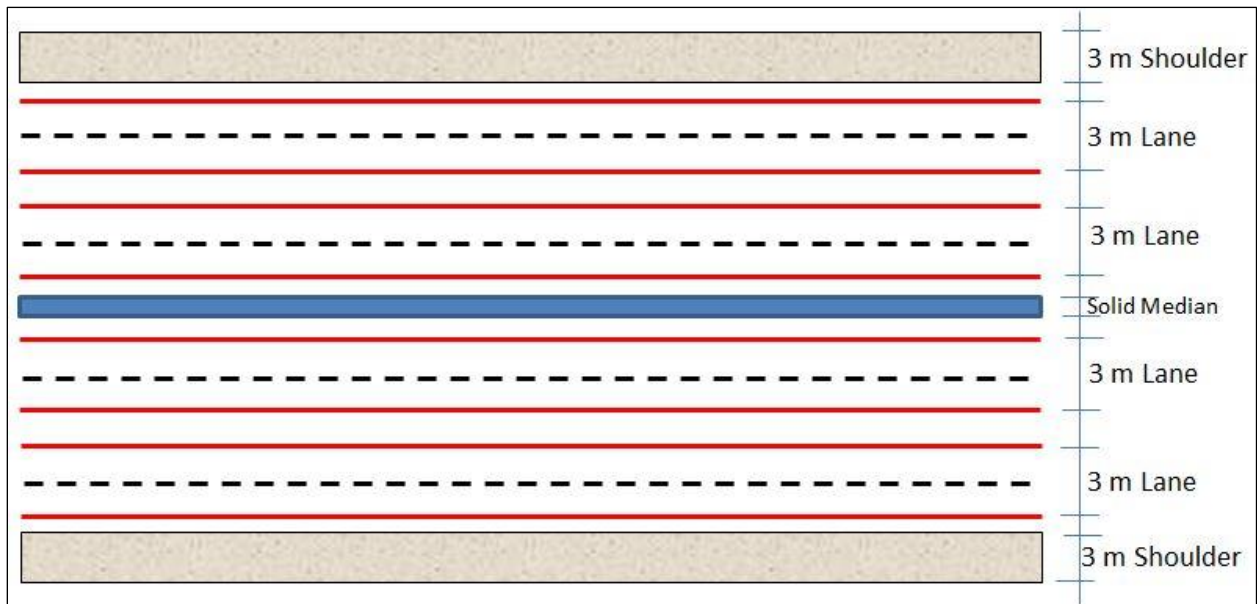
- Lanes

#### **Existing lanes for the road done by Ministry of Municipality and Rural Affairs**

According to the plan of Ministry of Municipality and Rural Affairs, the existing road is 18.50 m width for two sides. Where, each side consists of two lanes and shoulder as shown in the figure1 Each lane is 3.65 m, and the shoulder takes 3 meter of the width per side. Which make the total length of the road per side is 9.25 m. In addition, there is no separator between road sides, but there are electric posts in the shoulder of the road in one the left side only. See figure 4.3



**Figure 4.3: Existing cross section for Al Khalidiya Road** (ministry of Municipality and rural affairs)

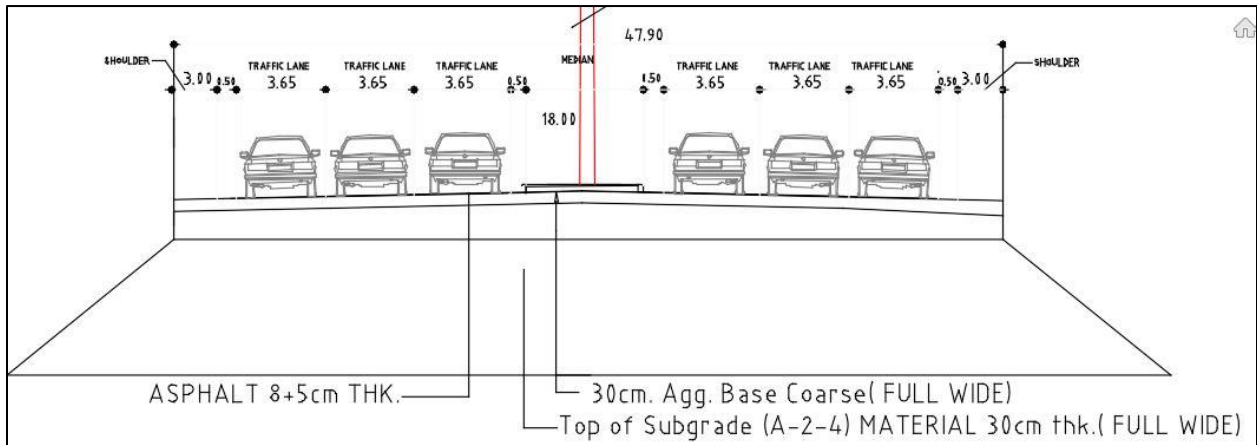


**Figure 4.4: Existing Road (2 Lanes)** (ministry of Municipality and rural affairs)

According to plan of Ministry of Municipality and Rural Affairs, the proposed plan divides the road into 2 sections, A-A and B-B. Where, section A-A is near to prince Mohammad bin Fahad University, and Section B-B is near to Air Force bridge. The proposed plan will be as follow:

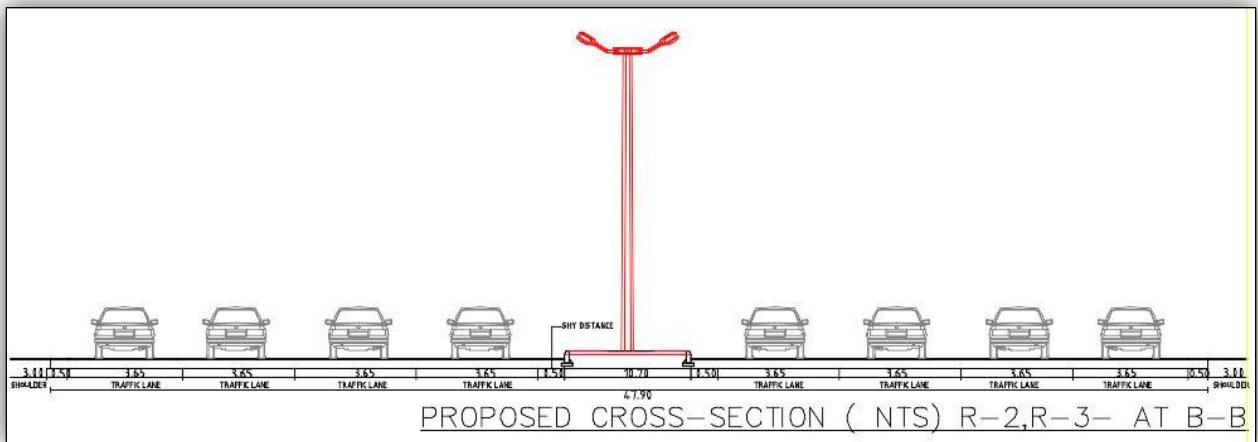
**Section A-A** will be 47.9 m width for two sides. Each side consists of three lanes and shoulder as shown in the figure 3. Each lane is 3.65 m, and the shoulder takes 3 meter of the width per side.

Which make the total length of the road per side is 14.95 m. In addition, the separator between road sides is high mast electric.



**Figure 4.5: Proposed Cross Section (NTS) at A-A** (ministry of Municipality and rural affairs)

**Section B-B** will be 53.9 m width for two sides. Each side consists of four lanes and shoulders as shown in the figure 4. Each lane is 3.65 m, and the shoulder takes 3 meter of the width per side. Which make the total length of the road per side is 18.6 m. In addition, the separator between road sides is high mast electric.



**Figure 4.6: Proposed Cross Section (NTS) at B-B** (ministry of Municipality and rural affairs)

## **Standard width for lanes**

According to American Association of State Highway and Transportation Officials (AASHTO). The minimum lane width of 12 feet (3.7 m)

- **Shoulders**

When a driver has accidentally traveled onto the road shoulder the risk of crashing will be less if the vehicles can either stop on the shoulder or safely travel back into the traffic lane. The vehicle will be better able to do both of these things if the shoulder is wide enough and if the vehicle tires are able to grip the surface of the shoulder. A sealed road surface provides the best grip for tires. When a vehicle leaves the road, and especially when this happens at high speed, stopping and/or steering the vehicle back onto the road will be easier if the vehicle tires are able to grip the shoulder surface. An adequate shoulder width makes it easier for a driver to steer the vehicle back onto the road at a shallower angle, reducing the chances that the driver will 'overcorrect' and travel into oncoming traffic.

## **Existing shoulders for The Road Done by Ministry of Municipality and Rural Affairs**

The existing road has outside & inside shoulders on both sides which lead having hazard for drivers when they accidentally traveled to roadsides. Figure 1 above demonstrates that the road has no shoulders.

According to proposed design, there will be outside & inside shoulders on both sides of the road. The outside shoulder will take 3 meter of the total width of the one side of the road. And inside shoulders will take 0.5 meter out of total width of the one side of the road Figure 2 and 3, demonstrate the shoulders of the road on both its sides.

## **Standard width for shoulder**

According to American Association of State Highway and Transportation Officials (AASHTO). The minimum outside shoulder width of 10.0 ft. (3.0 m) and inside shoulder is 4 ft. (1.2 m)

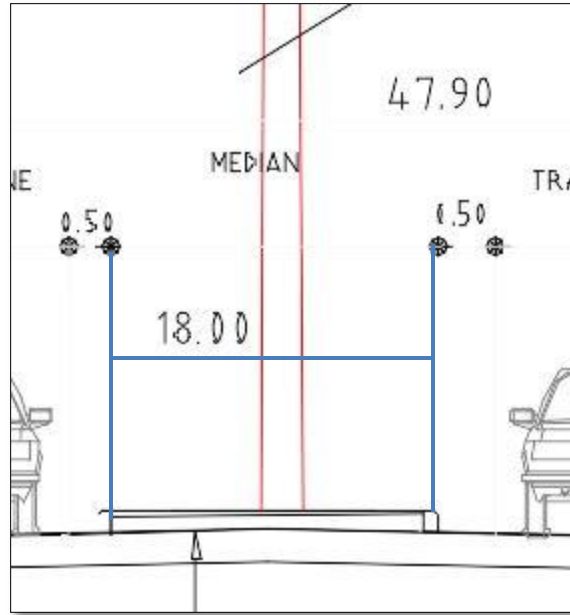
- **Median of the road**

Road median is the portion in between the dual carriageway which separates the traffic flow in opposite direction. There are three types of road median: (1) Travelable median on which vehicles can move in case of emergency, this type of median was in the road before Municipality of Eastern Province of Saudi Arabia allocate concrete barriers as a median for the road. (2) Barrier median on which vehicles cannot approach is known as barrier median. It is made up of concrete or steel. It currently exists in the road by Municipality of Eastern Province (2016). (3) Detering median which is artificial median which may be removed in case of any emergency.

### **Existing Median for the Road Done by Ministry of Municipality and Rural Affairs**

Currently, the existing road median is concrete barriers. But these barriers caused hazard for the drivers because it can accumulate sands surrounding the road area. It takes 0.55 meter of the road width. Does not fit AASHTO standard.

The Median used to separate the directions of the road. According to plan of Ministry of Municipality and Rural Affairs the width of the road median is 18 m. fit the AASHTO standard. See figure 4.7



**Figure 4.7: Width of the Al Khalidiya Road Median** (*Ministry of Municipality and Rural Affairs*)

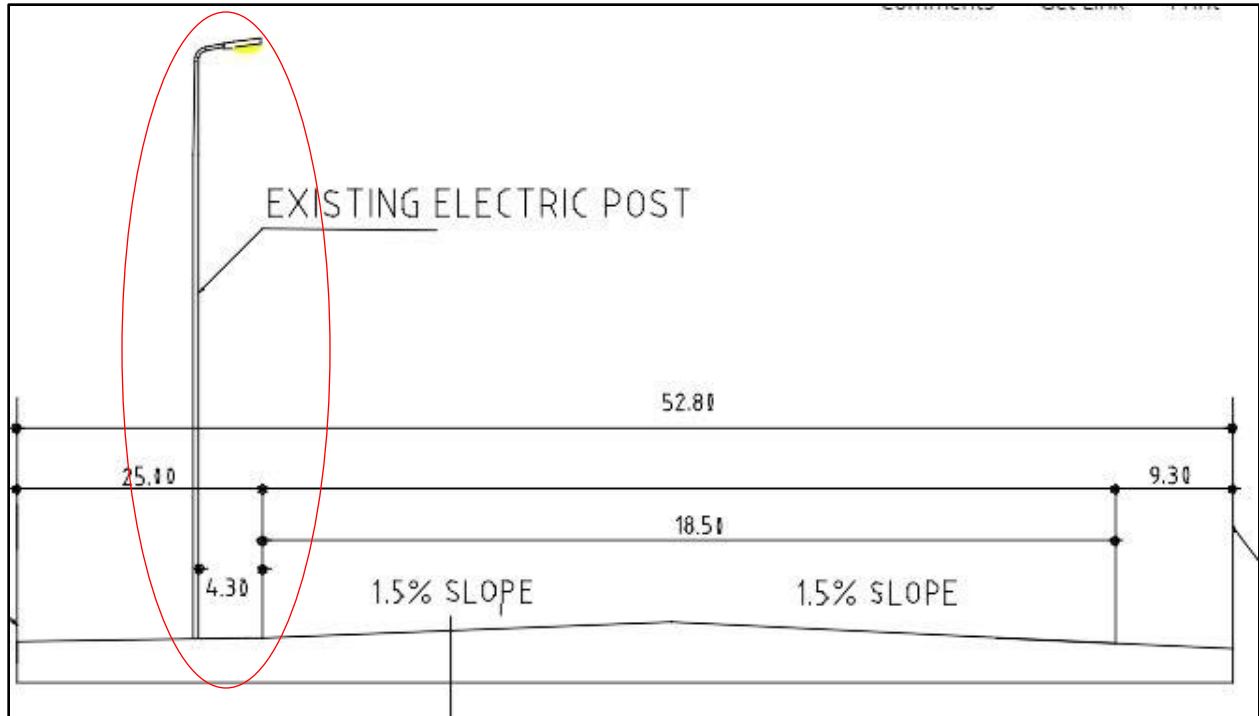
### **Standard width of the road's median**

According to American Association of State Highway and Transportation Officials (AASHTO). Minimum median width of 10 ft. (3 m) in rural areas.

- **Electric Posts**

### **Existing electric posts for The Road Done by Ministry of Municipality and Rural Affairs**

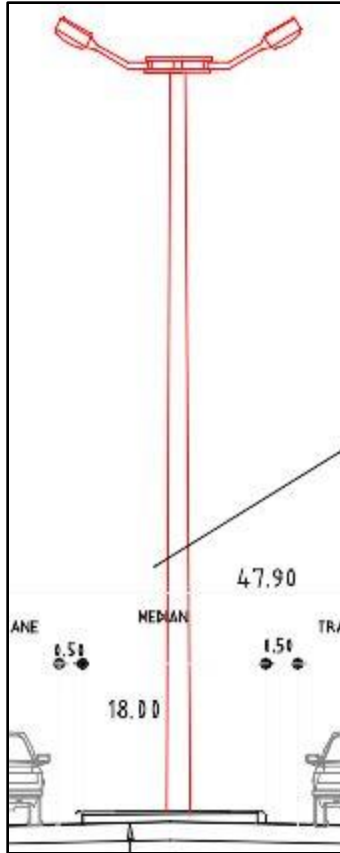
Electric posts are only in the right side of the street. The problem with lighting is in the night, where, the only lighted side is the left side of the road. Figure 6 illustrated the electric posts located on the left side only.



**Figure 4.8: Existing Electric Post**

*(Ministry of Municipality and Rural Affairs)*

According to proposed design, there will be high mast electric posts located in the road median, which can supply both sides by enough light in the night. Figure 7 illustrated the electric posts located on the median of the road



**Figure 4.9:** High Electric Post

*(Ministry of Municipality and Rural Affairs)*

**Table 4.3:** Summarized Table of as Built-Drawings For Al Khalidiya Road

#	Criteria	Existing Criteria	AASHTO standard	Fit – dose not fit
1	Pavement Design	30 cm Aggregate base 30 cm Subgrade	Aggregate Base > 15.24 cm Subgrade > 15.24 cm	Fit the Standard
2	Lanes width	2 lanes of 3.65 m width /side	Minimum width / lane = 3.7 m	Fit the standard
3	Shoulders	Outside shoulder: 0.80 m	Outside Shoulder = 3 m	Fit
		No inside Shoulders exist	Inside Shoulder = 1.2 mm	Does not fit
5	Road Median width	Concrete barriers: 0.55 m width	Minimum width = 3 m	Fit
6	Electric Post	On the left side of the road only	-	Existing: dose not Proposed: Fit

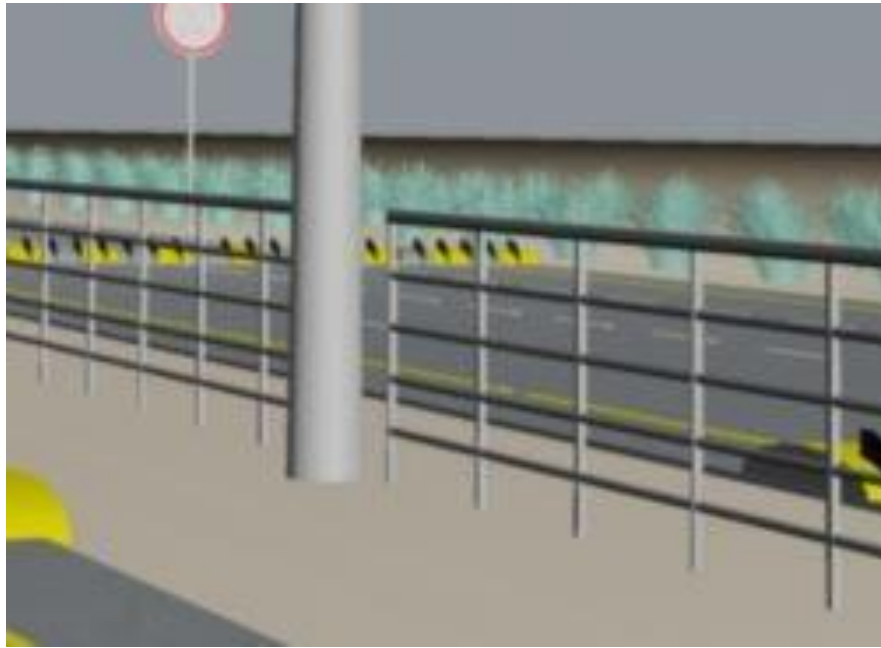
*AASHTO & Ministry of Municipality and Rural Affairs*

## 4.6 Sand Encroachment

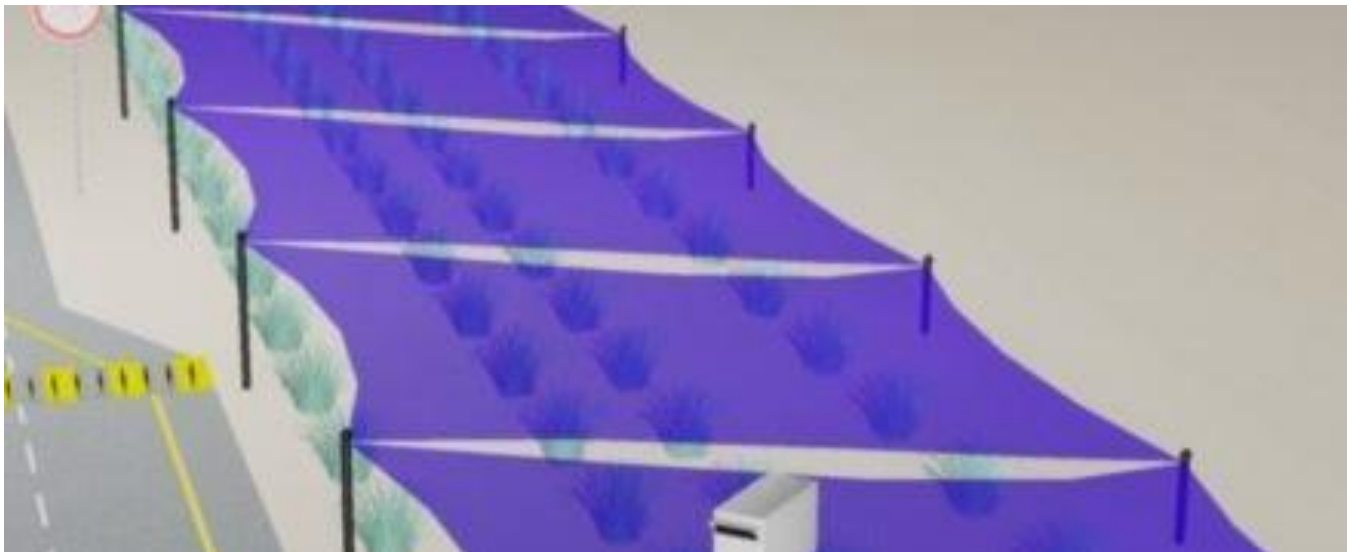
The recommended response for the sand encroachment is subdivided into four parts. The first part is installing hollowed steel barriers which will immediately after installing allow the sand to pass from one side to another to prevent sand from accumulating at the barriers see figure 4.10. The second part is installing sunshade alongside the road with slope see figure 4.11. The third part is planting trees alongside the road to stop the sand from encroaching see figures 4.12, 4.13. The fourth part is installing sprinkles that irrigate the plants. The aim of this sprinkles is when they start flowing vertically, as a result the water spray will drop immediately downward moistening the sand and mitigate encroachment. See figure 4.14

There are two proposed suggestions regarding different kinds of tress:

1. Tamarix plant known as Al Athel, it is a desert plant that mainly used in the desert roads especially in Saudi Arabia to prevent sand encroaching by the street. Installing water sprinkles between the plants will as well solution for stopping sand encroaching where it will moist the sand then no sand will be encroaching by the street see figure 4.12
2. Rhanterium Epapposum plant known as is one of the plants that exists frequently in the desert areas although it is exposed to hunting, and uprooting. Due do that actions, the number of this plant is decreased significantly. Moreover, this plants grow in a sandy, coherent, and fertile soil. This plant can be found mostly in Saudi Arabia, and Kuwait. See figure 4.13



**Figure 4.10: Hollowed Steel Barriers**



**Figure 4.11: Sunshade**



**Figure 4.12: Tamarix Plant**



**Figure 4.13: Rhanterium Epapposum Plant**









**Figure 4.14: Water Sprinkles**

#### 4.7 Road Signs and Animal Passing

Currently, Al Khalidya road has a desperate need for the road signs, and route guidance. Installing enough signs alongside the street was the major action to be taken that will mitigate the road accidents. The following table shows the signs that should be installed:

**Table 4.4: Responses of signs and animal passing**

No.	Sign Name	Location at The Street	Required Number of signs/side	Sign Sample
1	Speed Limit (80)	Each 4 Km alongside the road	3	
2	Speed Limit For Trucks (50)	Each 4 km alongside the road	3	
3	Traffic Spikes	Replacing existing bumps by spikes bumps	5	
4	Turn Ahead	At the 6 <sup>th</sup> Km after Air-force bridge	1	
5	Detour Ahead	At the 6 <sup>th</sup> Km after Air-force bridge	1	
6	Animal Passing	Each 4 km alongside the road	3	

## **5.1 Summary**

In conclusion, the objectives of the project have been done probably based on proposed plan. As a primary step, by collecting data form newspaper, ministry of municipality and rural affairs, and questionnaires the literature review has been done.

The major part in the project was the qualitative and quantitative models done by decision making theory (SMART method). This method used mathematical relations that has assisted in finding the result of the project.

The following objectives have been successfully done:

1. Identify the risk factors of Al Khalidiya Road.
2. Perform a qualitative risk model (QLRM) for the road users. The model output will be risk category for each risk factor.
3. Carry out a quantitative risk model (QNRM) for decision makers and municipal engineers, who are responsible for the road operations, to consider required plans accordingly for mitigating the current and future risk.
4. Recommend suitable action plans for the future graduation projects.

## **5.2 Limitation**

Since the project started from scratch without any previous supporting documents, and the typical project needs more time to meet the requirements. Four months working was the challenge.

There was a lack of literature review. Due to time limitations the expected outcomes were comparing Al Khalidiya road with similar road in the city. Therefore, as full time students, one semester was a challenge to complete full risk assessment study. For example, Consequence of Failure was missing in the project where it was a good source that supports the project.

### **5.2.1 Mathematical Models**

In general, the purpose of the project is to create an index for Al Khalidiya road to be used for future work. The major mathematical models used in this project are as follow, (1) Simple Multi Attributes Rating Technique (SMART), and (2) probability of failure (PoF). These two methods aim to find the risk for each factor along the entirety of the road. Where, PoF is obtained from

the distribution of questionnaires. After that, the average was taken from the feedbacks. In the future, Consequence of Failure (CoF) is a subject that will be focused on by the engineers in the future works.

### **5.2.2 Questionnaires**

First of all, since the project has a direct relation with PMU students particularly, the results of the project will be related to questionnaires analyzed the factors of the risk associated with the use of road. The survey subdivided into three parts; (1) Al Khalidiya road users; (2) Al Khalidiya road risk factors; (3) Al Khalidiya road action plan. The results of the questionnaires were inserted in a software program called Google Form.

### **5.3 Future work**

1. Consequences of Failure (CoF).
2. Incorporate risk software for more analysis.
3. Cost estimation for risk responses.
4. 3D Model for risk responses.

As a result, qualitative and quantitative models have been used to analyze the risk level in Al Khalidiya road. By using SMART model, nine factors of risk have been analyzed. For further analysis, the above points will be completed in the future.

## CHAPTER 5

### 5.4 Summary for all responses and risk factors

**Table 5.1: Summarized Table for all Responses**

No.	Potential hazards	People at risk and how?	Actions already in place.	Further action required	Action by
1	<b>Driving in Wrong way (Reverse Direction)</b>	PMU students, the risk they facing is fatal accidents and deaths	There is no actions taken to reduce or minimize the potential hazard.	Installing and replacing traffic spikes by road bumps.	M.M.R.A
2	<b>Sand encroachment</b>	PMU student mainly, and road users generally. Their cars may deviate, causing serious accidents	Using mechanical equipment and shovel manually.	Planting Tamarix plants alongside the road to stop the sand from encroaching.	M.M.R.A
3	<b>Drivers Behavior</b>	PMU students, the risk they facing is fatal accidents and deaths	Installing Road Bumps	Installing Speed Cameras (Saher)	Police Traffic
4	<b>Operation of Trucks and Heavy Equipment</b>	PMU students. The road capacity is small comparing with number of students and speed limit	Road signs preventing trucks enter the road.	Timing	Police Traffic
5	<b>Road Layout and Design</b>	PMU students. The road capacity is small comparing with number of students and speed limit	Installing concrete barriers that will separate the road into two sides	Increasing the capacity of the street by adding more lanes	M.M.R.A.

6	<b>Road Bumps</b>	PMU students and road users in general. The bumps with sand encroached may cause flipping for cars	the actions that already have taken to reduce or minimize the potential hazard. Is making bumps on the street per 2 kilometer, and installing concrete barriers (Municipality, 2016)	Replacing bumps by traffic spikes and speed cameras	M.M.R.A.
7	<b>Concrete barriers</b>	PMU students. It can accumulate big amount of sand and narrows the street	The separator itself was a solution for street.	Replace the concrete barriers by hollowed steel barriers	M.M.R.A
8 & 9	<b>Animals passing and road signs</b>	Drivers, fatal accidents	Lack of installing signs	Installing all required signs for the road (see table 4.4)	M.M.R.A.

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### 5.5 Summarized Figure with all responses

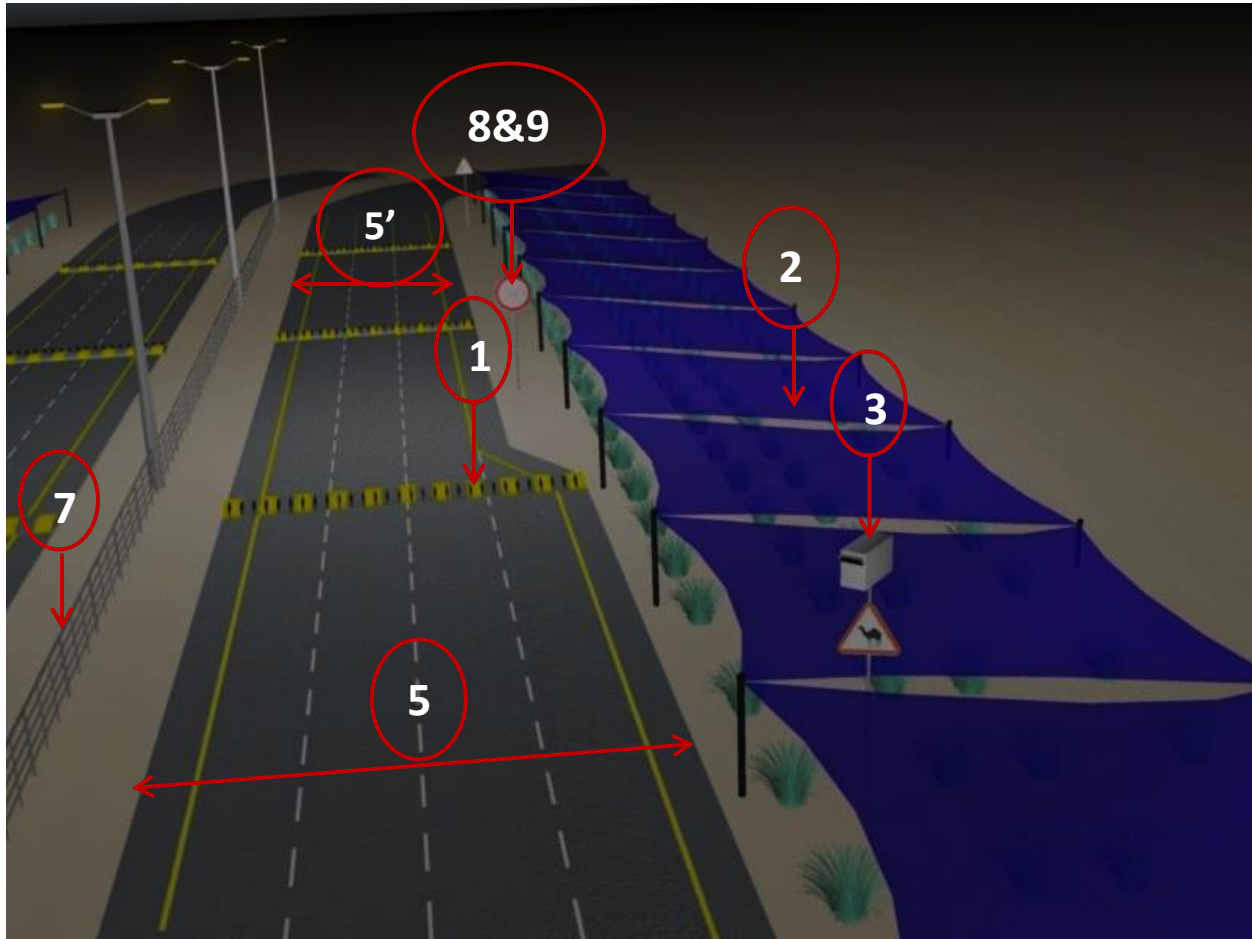


Figure 5.1: All Responses with Priority

Table 5.2 : Risk Responses Ranked According to Priority

No.	Responses
1	Traffic Spikes
2	Tamarisk
3	Speed Camera (SAHER)
5	Road Width (4 Lanes)
5'	Road Width (3 Lane)
7	Hollowed Steel Barriers
8&9	Road Signs include the following:
	1. maximum and minimum speed limits
	2. Animal Passing
	3. Traffic Spikes
	4. Detour Ahead
5. Turn Right	

# Appendix A

**Table A: Work Distributed Throughout the Project**

#	Name	Task	% Contributing
1	Omar G. Abdullah	Collecting Data	33.33 %
	Ahmed Baydoun		33.33 %
	Ahmed Ibrahim		33.33 %
2	Omar G. Abdullah	Survey Distributing	33.33 %
	Ahmed Baydoun		33.33 %
	Ahmed Ibrahim		33.33 %
3	Omar G. Abdullah	Introduction	33.33 %
	Ahmed Baydoun		33.33 %
	Ahmed Ibrahim		33.33 %
4	Omar G. Abdullah	Literature Review	33.33 %
	Ahmed Baydoun		33.33 %
	Ahmed Ibrahim		33.33 %
5	Omar G. Abdullah	Analyzing the Data	33.33 %
	Ahmed Baydoun		33.33 %
	Ahmed Ibrahim		33.33 %
6	Omar G. Abdullah	Performing the Models	33.33 %
	Ahmed Baydoun		33.33 %
	Ahmed Ibrahim		33.33 %
7	Omar G. Abdullah	Risk Responses	33.33 %
	Ahmed Baydoun		33.33 %
	Ahmed Ibrahim		33.33 %
8	Omar G. Abdullah	Conclusion Chapter	33.33 %
	Ahmed Baydoun		33.33 %
	Ahmed Ibrahim		33.33 %

### **A.3 Project Execution Monitoring**

As project members, we had periodic meetings with our advisor and almost daily meetings with the group members.

We have arranged that every Thursday we had a meeting with our advisor and Sunday will arrange a short meeting for feedbacks.

### **A.4 Challenges and Decision Making**

The project was all about collecting data for a road that doesn't really have much data available on net and off net. We as a group tried our maximum efforts to bring out all the available data as much as we can. But of course we had our struggles with meetings with government officials because it's not easy to arrange a meeting with a decision maker.

### **A.5 Project Bill of Materials and Budget (if applicable)**

No budget was recorded.

# Appendix B

## **B.1 Life-long Learning**

In this project we had used a limited amount of programs since our project was concerned about data collection and analyzing with respect to risk management side. We had used 3d Max to accomplish the picture used in risk responses at the end of our report. Time management skills is one of the key success that led us to complete our project since we had a very limited time to accomplish such a huge project with data collection and analyzation and providing some risk responses for it.

We have used some of construction management project techniques and convert it to time techniques. We had a list of finish to start work and finish to finish and so on. We had to manage our work in order to finish the report within the required time line.

For our project, our main helper was googling and books, specially EBooks since we had our research throughout newspapers and articles through google.

## **B.2 Impact of Engineering Solutions**

Alkhalidiya road is one of the dangerous roads in the eastern province, as an engineering students we had to start our career with managing and raising up an important issue to save the lives of thousands of students driving onto the road on a daily basis.

The project itself will be the start of saving a lot of lives, we had made a risk index for the road and raised up some of recommended actions to fix the road on a permanent basis. Our project is just the start; we hope as group members that our voice will be raised to the right ears.

# Appendix C

## Questionnaire

Dear Sir/ Madame,

We are PMU students in the area of Civil Engineering. We are currently conducting a project on the risk assessment of Al Khalidiya Road.

We would like to seek your assistance in our project as we are currently trying to gather information about risk factors of Al Khalidiya Road to be used in our data base. We would be grateful if you could complete the attached questionnaire, **which it takes only 5 minute, and send it back to Mr.Omar Abdullah ([201200201@pmu.edu.sa](mailto:201200201@pmu.edu.sa)) or to Dr.Alaa Salman ([asalman@pmu.edu.sa](mailto:asalman@pmu.edu.sa)).**

Please be assured that all information shared will be strictly confidential and used only for academic purposes. Please do not hesitate to contact us if you need any clarification or additional information. Sharing your valuable information is highly appreciated.

Best regards,

***Omar Abdullah, Ahmed Baydoun, and Ahmad Ibrahim***

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***Supervisor: Dr. Alaa Salman,***

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## **Questionnaire Form**

All responses will remain STRICTLY CONFIDENTIAL and will be used for educational and research purposes only.

### **PART 1: Al-Khalidiya Road users**

Please put a check (√) mark next to one of each of the following questions:

1. Are you: PMU Student  PMU Employee  Others
2. Are you one of Al Khalidiya road users? Yes  No
3. If (Yes), do you think that Al Khalidiya road is a risky for you?  
Yes  No

### **PART 2: Al-Khalidiya Road Risk Factor**

Please select the risk level by putting a check mark (√) next to the following risk factor. "1" is **NO RISK** and "10" is **VERY RISKY**.

No.	Risk Factor	1	2	3	4	5	6	7	8	9	10
1	Drivers exceed speed limits										
2	Driving in wrong-way (reverse direction)										
3	Operations of trucks and heavy construction equipment										
4	Concrete barriers										
5	Road layout and design (width, curves, pavement problems, etc.)										
6	Road bumps										
7	Sand encroachment										
8	Animal passing										
9	Road signs										

### **PART 3: Al-Khalidiya Road Action Plan**

What is (are) the required action(s) that should be taken to make Al-Khalidiya Road safe for you and other road users?

1. Tactical plan (short term):
2. Strategic plan (long term):

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