Risk Analysis and Management: A Case study along Phuentsholing-Thimphu Highway

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Dorji CHEKI[1], Kuenga Eudon KARMA[2], Tashi PEMA[3], Gayleg Namgyel PHUTNSHO[4]

[1]Department of Civil Engineering
College of Science and Technology
Telephone +975-5-16551120, Fax. +975-5-240055
E-mail: cdorji@cst.edu.bt

[2]Department of Civil Engineering
College of Science and Technology
Telephone +975-17640749, Fax. +975-5-240055
E-mail: karkueneudo@yahoo.com

[3]Department of Civil Engineering
College of Science and Technology
Telephone +975-17701905, Fax. +975-5-240055
E-mail: Gongsar@hotmail.com

[4]Department of Civil Engineering
College of Science and Technology
Telephone +975-17923920, Fax. +975-5-240055
E-mail: namdup@yahoo.com

Abstract

The Thimphu-Phuentsholing Highway (AH-48) is the most important highway for Bhutan. With the increasing rate of development, the efficient road networks are essential. This particular highway is the most risky route as per the study conducted between 1991 to 2002.The major portion of country's economy is being endangered due to the blockages along the highway. The purpose of the study is to identify the risks along this highway and its effects on the society and the economy of the country. In the year 2004 to 2009, the number of road accidents recorded occurred mostly due to human error followed by natural calamities. The various black spots on the highway depending on the number of blockages have been identified and the loss due to road blockage and the accidents has been estimated to be Nu.51 million per day which is 11.73 % of the Gross Domestic Product of the country for the year 2009.

Keywords: Risk analysis, Landslides, Highway, Bhutan

1. Introduction

1.1 General

As Bhutan being a developing country and also due to the geographical conditions and other factors like economy, land transportation is considered as the most suitable and economical means of communication. The roads constructed in the past are of 3.5m to 4m width along which a huge number of light and medium vehicles travel. Further the road constructed has sharp turnings and the load carrying capacity of the road was not very high, which means the heavy vehicles required for construction could damage the road.

In Bhutan, there is a total stretch of 4544.73 km road and there are two highways, namely, Thimphu-Phuentsholing highway (Asian highway 48) and Thimphu-Trashigang highway. Out of these two, Thimphu-Phuentsholing highway is the main route being used for travelling and transportation of goods to most of the dzongkhags. This highway is maintained by project DANTAK and the divisions of road are given in Table 1.

Table 1 Stretch of Thimphu–Phuentsholing highway

Road Name	Length (km)
Phuentsholing - Rinchending	5
Rinchending – Ganglakha	24
Ganglakha – Jumja	13
Jumja – Gedu	4
Gedu – Chhukha	42
Chhukha - Tshimasham	10
Tshimasham - Bunakha	8
Bunakha - Chapcha	14
Chapcha - Chunzom	24
Chunzom - Khasadrapchu	14
Khasadrapchu - Semtokha	8
Semtokha – Thimphu	5
Thimphu - Dechenchholing	8
Total	179

The Thimphu – Phuentsholing highway has a total length of 179 km (kilometers). Along the Thimphu-Phuentsholing highway, there are a lot of risks involved and these risks are mainly due to accidents and road blockages. A similar study on the risks involved due to road blockage has already been conducted by previous authors. However this particular study includes the risk due to accident along with the risk due to road blockage.

For this study, the definition of risk has been taken from the study, Determination of risk scores for road network in Bhutan done by Cheki. D. and Shibayama. T,which defines risk as a combination of the probability, or frequency, of occurrence of a defined hazard and the magnitude of the consequences of the occurrence. As there are many accidents occurring along the highway and the reasons for these accidents are divided into four main categories, namely, Human error, Mechanical defects, Natural calamities and Road conditions.

Accidents which are listed below human error are those accidents which occur mainly due to the road-users. Human errors include careless driving, unlicensed driving, drink and driving, over-speeding, right of way, unsafe over-taking and pedestrian fault. The second category, that is, Mechanical defect includes accidents due to the failure of the vehicle, such as, brake failure, steering lock and bursting of tyres. Accidents due to landslides, falling boulders, foggy weather and loose soil are named as Natural calamities. And the accidents that have occurred due to slippery road conditions, marshy road and other road conditions form another category called as Road conditions. Due to these reasons, there have been casualties and minor injuries. It is important to study the risks involved due to these accidents, so that timely information could be provided to the public and to take up preventive measures to reduce the risk.

As Phuentsholing is located near the Indo-Bhutan border, most of the goods are transported from Phuentsholing to Thimphu and also to other dzongkhags. Even the resources required for the mega-projects that are being constructed with assistance from the government of India, are also being transported through Phuentsholing. So, the risks involved due to the road blockages have a huge effect on the economy of the country.

This study indicates the risks involved along the Thimphu-Phuentsholing highway due to accidents and road blockages. It determines the loss that has occurred due to road blockages and accidents, and also provides preventive measures to reduce these losses.

1.2 Objectives

The main objective of the study is to determine the risk and losses due to accidents and road blockages, along Thimphu – Phuentsholing highway. The other specific objectives are;

1. To identify different types of risks
2. To determine the effect of the risks on the society
3. To determine the effect of risks on the economy of the country
4. To improve the road operation management system.

2. Literature Review

According to the expert meeting organized by the Office of United Nations Disaster Relief Coordinator (UNDRO) in 1979, the term risk refers to the expected losses from a given hazard to a given element at risk, over a specified future time period. According to the way in which the element at risk is defined, the risk may be measured in terms of expected economic loss, or in terms of numbers of lives lost or the extent of physical damage to property.

Mickim (1992) states risk as the uncertainty associated with any outcome. The probability of the possible event or consequence of the possible event is taken as the uncertainty and risk management is often preceded in terms of cost or monetary assessment.

Sato. Y et al., (2005) defines risk as a factor of change causing social loss as a result of impeding the achievement of a goal. Definition of risk is based on the understanding that there is no special need to separately consider risk as the chance of loss, as the possibility of loss and as an uncertainty because risk in terms of social capital development tend to be a mixture of these three categories of risk.

Cheki. D & Shibayama. T, (2007) defines risk as the combination of the probability, or frequency of occurrence of a defined hazard and the magnitude of the consequences of the occurrence. The probability in this study is taken as the events by total durations or total traffics which are expected to increase with increase in economic development. The study had determined the risk score for the road networks of Bhutan. Considering all the road networks in Bhutan and the maximum freight loss per day as well as fare loss per day due to the blockages along Thimphu – Phuentsholing Highway. This particular study had identified this highway to be at a very high risky status compared to other road networks of Bhutan. It was also indicated that the major portion of country's economy is being endangered due to the blockages along the Thimphu-Phuentsholing Highway.

Risk can be a somewhat ambiguous term unless its definition and convention are clearly stated. The concept of risk mentioned above has been used in this research to identify the risk along the Thimphu-Phuentsholing Highway (AH 48) which is the most risky road, of all the roads in Bhutan.

3. Methodology

3.1 Data Collection

For this study, the data on road accident and its causes for the past six years (2004 to 2009) have been collected from different traffic police branches (Phuentsholing, Gedu, Chukha and Thimphu).

Data was also collected from the Revenue and Customs (at Rinchending check post) regarding types of goods being transported (construction items, groceries and stationeries), quantity, rate and amount of goods and the Location to which the goods is being transported.

4. Results

For this study, the vehicles have been classified into four categories as shown in Table 2.

Table 2 Categories of vehicles

Categories of vehicles	Types of vehicles
Heavy vehicles	Construction equipments, trailers and trucks
Medium vehicles	Bus, DCM, hilux and similar kinds of vehicles
Light vehicles	All the other kinds of vehicles (especially cars)
Two-wheelers	Bikes and Scooters

As per the traffic volume study, the numbers of vehicles travelling along Sorchen-Jumja route of the highway in a particular day was found out and is shown in Figure 1.

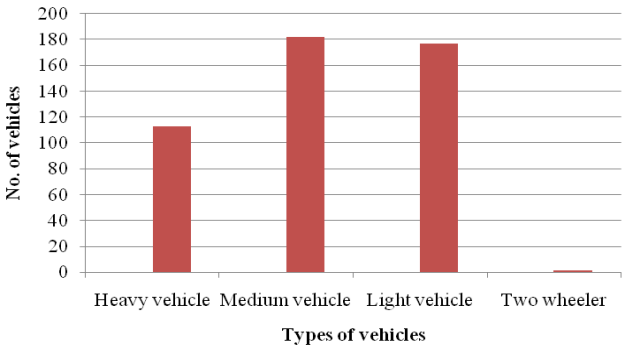

Fig. 1 Number of up-traveling vehicles per day along Sorchen-Jumja route

From Figure 1, it can be seen that the maximum number of vehicles traveling along the highway are the medium vehicles. So, for the analysis of accidents, the medium vehicles have been considered as most of the people travel on public transport and for the analysis on road blockages, we have used the number of heavy vehicles travelling along the highway because the goods carried by these vehicles are maximum.

From the data collected, it showed that the total number of vehicles travelling (both up and down) is 946 vehicles per day excluding the government and army vehicles which is identified after spot survey. According to the spot survey conducted, the total traffic volume has come out to be 2046 vehicles per day which include private

vehicles, government and army vehicles and vehicles whose destination is in and around Pasakha that are not registered in the police data. The total traffic volume per day along the highway has been shown in Table 3.

Table 3 Total vehicles passing through the highway

heavy	medium	light	Two-wheeler	Govt. & army vehicle	Total traffic volume per day
226	364	354	2	72	1018

So, for the calculation of losses due to road blockages, as said earlier that the heavy vehicles have been considered, the number of heavy vehicles travelling per day can be taken as 226.

4.1 Economic analysis

As per the data collected from Revenue and Customs, the amount of goods that have been transported to different dzongkhags could be calculated and the variation of the transporation of goods to various dzongkhags in a week has been shown in Figure 2.

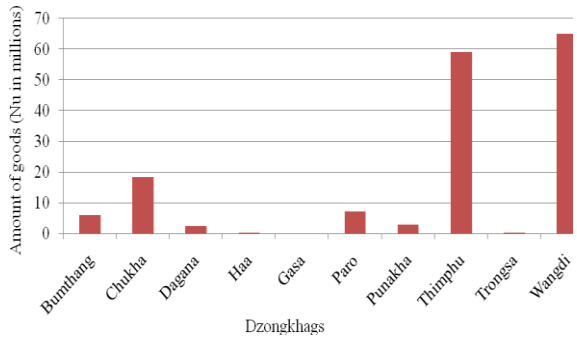

Fig. 2 Amount of goods transported to different dzongkhags

As most of the goods are being transported to Wangdi and Thimphu, to compare the types of goods that are being transported to these two dzongkhags, the data for a particular day which has the highest amount of goods being transported have been considered and it is shown in Figure 3 and Figure 4.

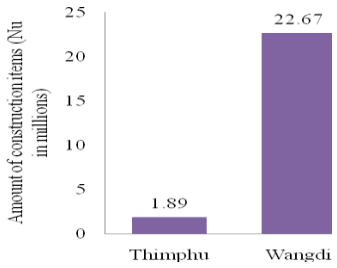

Fig.3 Amount of construction items

From Figure 3, it can be seen that most of the construction items are being transported to Wangdi which is about Nu. 22.67 millions worth of goods where as only Nu. 1.89 millions worth of goods are being transported to Thimphu. This clearly indicates that most of the resources required for the construction of the power projects in Wangdi are being transported from Phuentsholing.

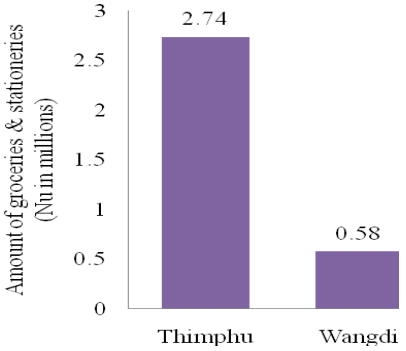

Fig. 4 Groceries and Stationeries being transported to Thimphu and Wangdi

From Figure 4, it clearly shows that mostly groceries and stationeries are being transported to Thimphu, as Thimphu being the capital of Bhutan the population is higher compared to the other dzongkhags.

From the analyzed results, it is seen that if there are any delay of these goods then the projects won't have the resources required to continue or complete the project and also, the people would be affected if the goods were not available. With the delay in the project, the production will not begin at the scheduled time which will affect the country's economy.

The delays of these goods are caused mainly by road blockages and road blockages occur mainly due to landslides, as said earlier. A set of questionnaires had been distributed among the road-users to find out when and why the road

blockages occur and for how long it lasts, and the results got are shown in Figure 5, Figure 6, Figure 7 and Figure 8.

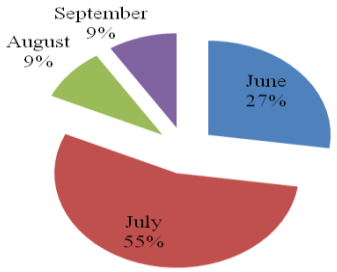

Fig. 5 Occurrence of road blockage

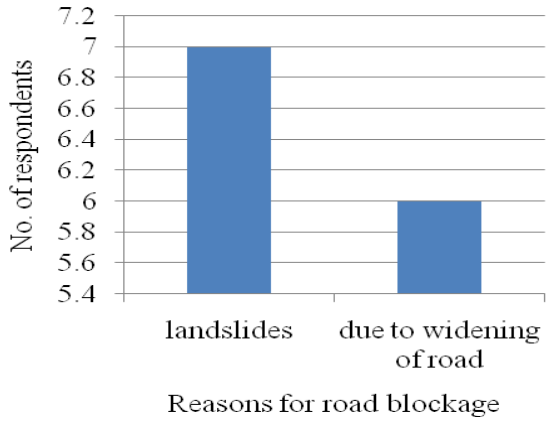

Fig. 6 Reasons for road blockages

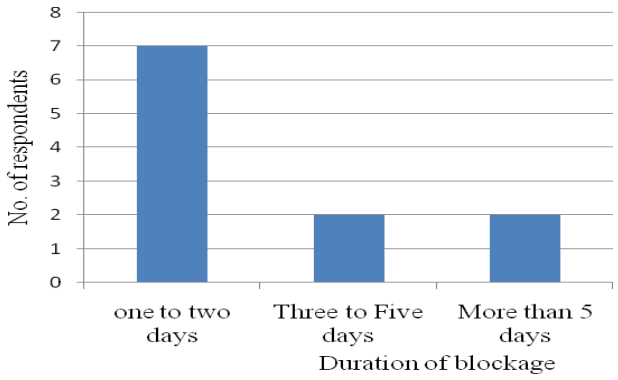

Fig. 7 Duration of blockage in days

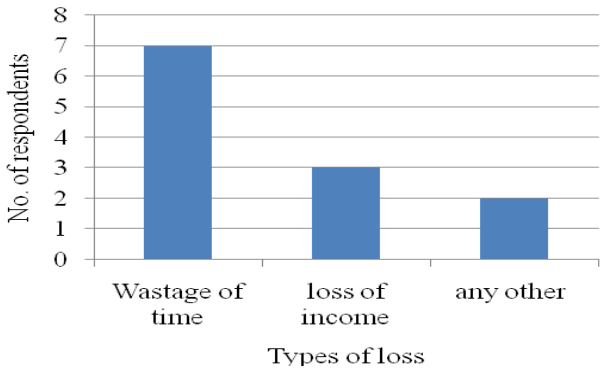

Fig. 8 Different types of losses due to road blockages

After analyzing the results, it was found out that the road blockage mostly occurs during the month of July as shown in Figure 5, because in that month there is heavy rainfall which causes landslides. From Figure 6, the road remains blocked mostly for one to two days, and then the main reason for road blockage is due to landslide which is shown in Figure 7. When there is a road blockage (see Figure 8), valuable time of the road-users and the passengers are wasted, and for the shopkeepers, taxi drivers and the truck drivers, they face loss of income

4.2 Accident Analysis

From the data on road accidents, the cause for most of the accidents has been shown in Figure 9.

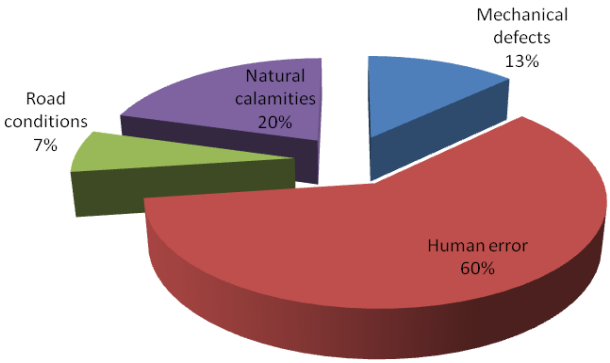

Fig. 9 Percentage of accidents due to different causes

From Figure 9, it can be seen that the major cause of accidents is human error which is about 60% of the total accidents in the past six years. To reduce human errors it will surely take a lot of time

because of different mentalities of people, so the next major cause of accident have been taken into consideration, that is natural calamities which can be reduced and controlled. Natural calamities cause about 20% of total accidents and it even causes road blockages.

The types and numbers of vehicles involved in accidents have been shown in Table 4 and the percentage of types of vehicles involved in accidents is shown in Figure 10.

Table 4 Types and numbers of vehicles involved in accidents from year 2004 to 2009

Sl. No.	Type of vehicle	No. of accidents
1	Heavy	211
2	Medium	203
3	Light	184
4	Two-wheelers	4
Total		602

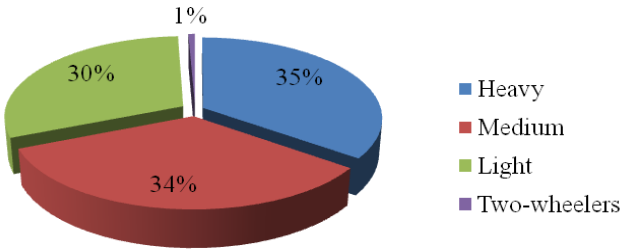

Fig. 10 Types of vehicles involved in accidents

The past records of accidents along Thimphu-Phuentsholing highway, a total of 602 accidents were recorded from 2004 to 2009. From which 211 accidents occurred due to heavy vehicles, 203 accidents occurred due to medium vehicles contributing to 35.05% and 34% of the total accidents respectively. The accident record of light vehicles is 184 which are 30% of the total accidents and the least accidents occurred with two-wheelers which is almost 1% of the total accidents recorded. From the data collected, the total number of accidents that have occurred in the past six years have been figure out in Figure 11.

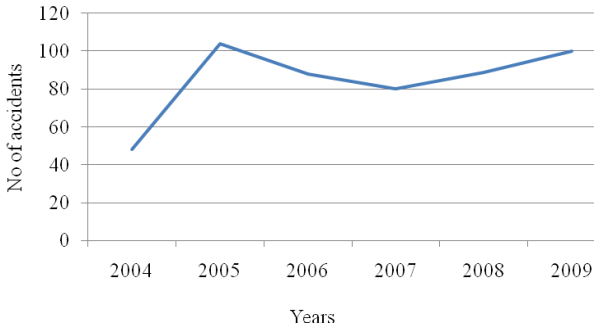

Fig. 11 Total numbers of accidents from 2004 to 2009

In Figure 11, the numbers of accidents has doubled from 2005 onwards while comparing to 2004 which has only 48 numbers of accidents. From 2005, as the construction of road for double-laning had begun, the stability of slope had been disturbed which resulted in falling of debris and landslides causing more accidents. But in 2008 and 2009, the numbers of accidents had increased again which were mainly due to human errors. Accidents due to human errors have occurred due to many reason and these reasons have been shown in Figure 12.

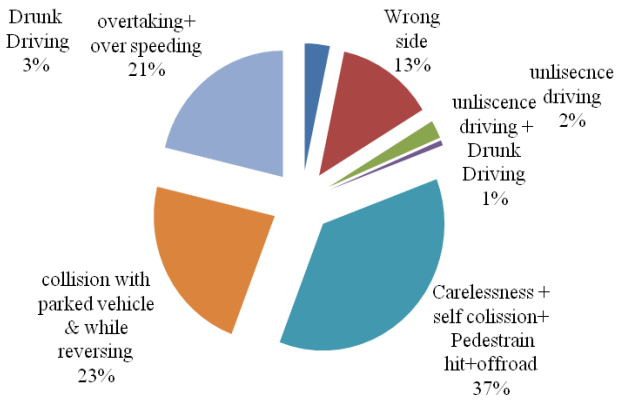

Fig. 12 Accidents caused due to human errors

As said earlier, natural calamities can be reduced by taking up some preventive measures, so firstly the reasons for occurrence of natural calamities have been shown in Figure 13.

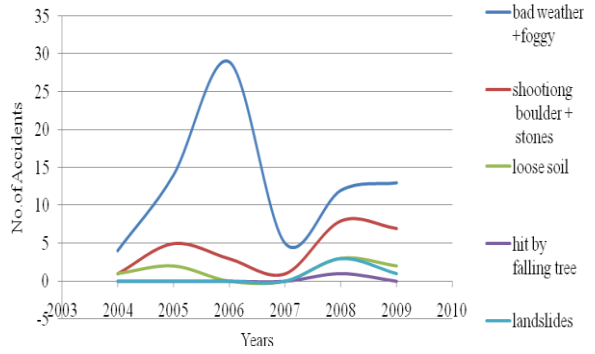

Fig. 13 Accidents caused due to natural calamities

From Figure 13, the major reason for occurrence of natural calamities is found out to be bad weather, but weather cannot be controlled, so keeping aside this reason, the other reasons are falling boulders/debris and landslides. As per the data collected from traffic police, the accident-prone areas have been identified as Taktikothi, Sorchen and below Kamji.

Due to accidents, there have been a certain number of deaths and injuries, and it is shown in Table 5 and Figure 14.

Table 5 Death and injuries caused by accident

Cause	Death	Injuries
Human error	14	32
Mechanical Defects	1	14
Natural Calamities	14	10
Road Conditions	1	13

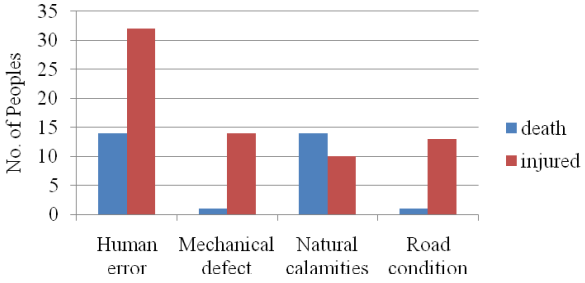

Fig. 14 Fatalities and injuries due to vehicle accidents

From Figure 14, the deaths caused by human error and natural calamities have found out to be the highest with 14 numbers of death each and the minor injuries occur mostly due to human error and mechanical defects. As landslide is one of the main reasons causing accidents and even road blockages, the data for the last two years (2008 to 2009) about the number of deaths and injuries caused by landslides have been collected and are shown in Table 6.

Table 6 Accident caused due to landslide at Taktikothi for 2007 – 2009

Sl. no.	Type of vehicle	Death	Injuries
1	Medium	8	1
2	Light	1	0
3	Heavy	3	0

From the above, it can be concluded that landslide is one of the major reasons for the occurrence of road blockages and accidents. As said earlier, about the distribution of questionnaires, the results analyzed from the questionnaires is shown in Figure 15.

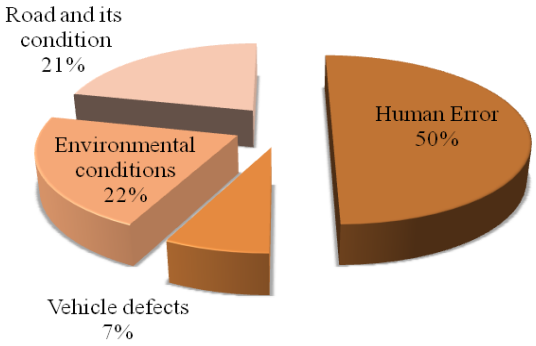

Fig. 15 Causes of accidents along the highway

So, after comparing these results, it is found out that most of the accidents occur mostly due to human errors followed by the natural calamities.

4.3 Calculation of Total Loss

The data collected from traffic police contained the information regarding the blockage of road in hours for one year which came out to a total of 387 hours for the Sorchen – Jumja route. Now, to find out the total days blocked in a year,

Along Sorchen – Jumja route, Total days blocked in a year, TD = 387/24 = 16.125 days

Now, to calculate the rate of blockage per day (ROB) along the two routes, the total days blocked in a year have to be divided by the number of days.

For Sorchen – Jumja route, rate of blockage per day = 16.125/364 = 0.0443

From the traffic volume study, the total traffic volume per day (TTV) along the Sorchen – Jumja route was found out to be 1018 no. of vehicles out of which there are 226 total heavy vehicles (THV). Using the above calculations, the loss of heavy vehicles per day has been calculated in Table 7.

Table 7 Loss of heavy vehicle per day

TD (1)	ROB (2)	TTV (3)	THV volume per day (4)	Total vehicle loss per day (2)*(3)	HV L (2)*(4)
16.125	0.0443	1018	226	45.097	10.012

After calculating the heavy vehicle loss per day, it has been found out to be 10.012 per day which has been caused due to road blockage and heavy vehicles along the Sorchen – Jumja route have faced more losses. To find out the total loss of heavy vehicle in terms of goods along the Thimphu– Phuentsholing highway, the truck hiring rate of Nu. 6.53/mt/km has been used, which has been taken from letter no. RSTA/TDD/TR/2008/3024 issued on June 27th, 2008 by Ministry of Information and Communications, Road Safety and Transport Authority, Royal Government of Bhutan. For the calculation of total loss along the highway, the above heavy vehicle loss per day has been taken along the 179 km stretch of road. The freight loss per day is the product of heavy vehicle loss per day (no.), total distance (km) and the truck hiring rate. The highest amount of goods that were transported per day was taken from the economic analysis done earlier, which comes out to be Nu. 50.47 millions. The fare loss per day of the passenger traveling in buses has been calculated as per the data collected from RSTA and it has been found out that the total fare loss per day (TFL) is Nu. 20.30 millions and this amount have been taken as the basis for the calculation of total loss (TL in millions) of goods which is shown in Table 8. But the fare losses for taxis could not be calculated as the rate for taxi varies with vary in the price of fuel and there is no data available for taxis along the highway.

Table 8 Total loss along the highway

HVL (A)	Dist (km) (B)	FL C=(A*B)*6.53	Amount of goods per day (D)	TFL (E)	TL (D+E)
10.012	179	11703	50.47	20.3	50.68

FL = Freight loss per day

The total loss occurring due to road blockages for the goods carried by the heavy vehicles and the passengers' fares losses from the buses along the Thimphu–Phuentsholing highway is calculated to be Nu. 50.68 million.

Now, to find out the loss due to accidents, firstly the accident rate is calculated using the data collected from traffic police based on the number of accidents that have occurred and to calculate the accident rate, the traffic volume per day for the year 2009 has been taken, as the data collected for this year was found to be accurate. The calculation of accident rate has been shown in Table 9.

Table 9 Calculation of accident rate for 2009

No. of accident (A)	total traffic volume per day (V)	Length (L) (km)	Accident rate A_r=A/(365*V*L) (in 10^6)
99	1018	179	1.488

Accident rate for the year 2009, A_r = 1.488
Freight loss per day = Nu. 11703
Fare loss per day (passengers in bus) = Nu. 202,996
Probability of loss due to accident = (202996 + 11703)*1.488 = Nu. 319,472.112=**Nu. 0.32 million**
As calculated earlier,
Probability of loss due to blockage
=Nu. 50,680,85= **Nu. 50.68 million**
Therefore,
Total loss per day = 0.32 + 50.68 = Nu. 51 million
Total loss per day due to accidents and road blockages = Nu. 51 million
Our country's GDP per year = Nu. 158.31 billion
GDP per day = Nu. 434.92 million
Due to accidents and blockage,
percentage loss = (51/434.92)*100
=11.73% of GDP per day

The total percentage of loss of GDP per year due to the combination of accidents and road blockages in a day is estimated to be 11.73%.

5. Conclusion

5.1 Conclusion

The Thimphu – Phuentsholing highway being one of the national highway and the main route that connects the capital of Bhutan, Thimphu and one of the largest commercial town, Phuentsholing. The risk analysis of this highway has been studied to observe the effect of losses due to the risks on the two dzongkhags and also on some other dzongkhags that are dependent on the highway. The risks along the Thimphu – Phuentsholing have been identified as accidents and road blockages. From the accident records, the accident-prone areas have been identified as Taktikhothi, Sorchen and below Kamji, out of which most of the major accidents have occurred at Takti. After analyzing the data, human error was found out to be the major cause of accidents and the other major cause of accidents and road blockages was found out to be natural calamities, especially landslides. So, the losses occurring in terms of lives and cost due to landslides have been calculated. The probability of loss due to accidents was found out to be Nu. 0.32 million per day and the loss due to heavy vehicles as Nu. 50.68 million. The total loss of Nu. 51 million per day, equivalent to 11.73% loss of GDP in a day was estimated.

6. Acknowledgment

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