

UNIVERSITY OF NAIROBI



DEPARTMENT OF CIVIL & CONSTRUCTION ENGINEERING

ASSESSMENT OF OPERATIONS OF WEIGHBRIDGES IN KENYA: A CASE OF GILGIL WEIGHBRIDGE STATION

By:

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F56/82445/2012

**A thesis submitted to the School of Engineering of the University of
Nairobi in partial fulfillment of the requirements for the Degree of
Master of Science in Civil & Construction Engineering
(Transportation Engineering)**

September, 2016

DECLARATION

I hereby declare that this thesis is my original work. To the best of my knowledge, the work presented here has not been presented for a degree in any other institution of higher learning.

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ACKNOWLEDGEMENT

I would like to acknowledge the support and guidance of my Supervisor, Prof. Mbeche in the Department of Civil and Construction Engineering. I also thank the Department for support and facilitation during the course of this research.

I would also like to thank my former employer, Eng. Otieno Odongo, who urged me to start the MSc course and provided me with financial support to get started.

I further acknowledge the support and cooperation of the management of Gilgil Weighbridge station during collection of the data for this research.

Finally, I wish to thank my parents for their continued encouragement and support during the course of this research.

ABSTRACT

Overloading by trucks has been one of the major causes of rapid deterioration of the Kenyan road network especially the Northern Corridor Road which has the largest percentage of truck traffic in Kenya. Gilgil Weighbridge station is one of the stations established along the northern corridor to control overloading. The stations have been characterized by a lot of delays in the past and this greatly compromises cargo movement along the corridor to neighbouring landlocked countries especially Uganda and Rwanda. This research assesses the operations of Gilgil weighbridge station with a view to making it more efficient and facilitating cargo movement.

This study used the queuing model to analyze the efficiency of the station in terms of various queuing parameters such as flow rate, arrival rate, service rate, waiting and service times and system utilization. In addition, the study assessed the station layout in terms of location and design of existing facilities and plans for future improvements in order to give a perspective on their adequacy and relationship with station efficiency. Various traffic surveys such as truck traffic counts in queues, parking surveys at the holding bay, axle load surveys have been conducted to aid in the analysis.

The study established that Gilgil weighbridge station had some inadequacies in planning and design that have greatly compromised the operations and efficiency of the station through long queues and service times leading to congestion. The findings of this study were compared with the planning, design and operations guidelines for a typical weighbridge station of its traffic level.

In conclusion, a number of recommendations have been proposed in order to optimize the efficiency of the weighbridge station in terms of axle load control and facilitating cargo movement. They include redesign of the weighbridge layout, proper maintenance framework and implementation of axle load control information monitoring system.

GLOSSARY OF ACRONYMS AND ABBREVIATIONS

ADT	Average Daily Traffic
ADTT	Average Daily Truck Traffic
ALC	Axle Load Control
ALCS	Axle Load Control Station
CCTV	Close Circuit Television
DRC	Democratic Republic of Congo
DWT	Design Weighbridge Traffic
EAC	East African Community
FTCC	Full Traffic Control Centre
GoK	Government of Kenya
HSWIM	High Speed Weigh-in-motion
HGV	Heavy Goods Vehicle
JICA	Japan International Cooperation Agency
KeNHA	Kenya National Highways Authority
LCC	Lay-by Control Centre
LSWIM	Low Speed Weigh-in-motion
MSWIM	Medium Speed Weigh-in-motion
NITP	National Integrated Transport Policy
PHF	Peak Hour Factor
SATPP	Sub-Saharan Transport Policy Program
SGS	Société Générale de Surveillance
TCC	Traffic Control Centre
TrafMan	Traffic Management
WIM	Weigh-in-motion

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CHAPTER 1

1.0 Introduction

1.1 Background

Gilgil weighbridge is one of the five Axle Load Control Stations located along the Northern Corridor road in Kenya and the third busiest. Mariakani and Athi River weighbridge stations which were busier than Gilgil weighbridge station had been redesigned and new constructions were on-going. The facilities at the station include three weighbridges, holding bays, offices, toilets, public display units, digital readers, screening lane, CCTV Cameras, entrances and exits. The main operations at the weighbridge involved weighing of heavy commercial vehicles with at least 7 tonnes of cargo. Those vehicles with loads exceeding the allowable legal limit were stopped from proceeding by the Kenya Police and corrective measures applied in accordance with the Traffic (Amendment) Act 2013.

Prior to 1978/1979 there had been good enforcement of load limits. These had been relaxed with almost no control from 1979 in response to an appeal from Rwanda, where the legal limits had been much higher. In 1984 the enforcement of the load limits was re-introduced, but again in response to an appeal from inland countries, this was relaxed. Then in 1997 the El Nino rains had triggered the almost total collapse of the Northern Corridor Road (European Union, 2006).

In 1998 the Government of Kenya took action to strengthen the enforcement of existing laws to control axle-loads. This became necessary because a large proportion of heavy goods vehicles plying the Northern Corridor were grossly overloaded. Furthermore, it was realized that roads with a theoretical design life of fifteen years were failing after less than five years. The enforcement of existing laws on axle load limits now constitutes a firm commitment of the Government of Kenya to establish a sound-operating framework for the rehabilitation of the deteriorated transport infrastructure in the country. In addition, the Government agreed to vigorously enforce axle load limits as part of the accompanying measures established with the European Commission for support to the road sector in general and to the rehabilitation of the Sultan Hamud – Mtito Andei and Mai Mahiu – Naivasha – Lanet roads (European Union, 2006).

The Government further agreed that an independent monitoring of axle load enforcement be carried out. The objective of the independent monitoring was to determine the enforcement and effectiveness of existing measures to control axle loads and to make recommendations to ensure greater conformity and compliance. This exercise was carried out by a consultant (Otieno Odongo & Partners) between February 1999 and March 2001 with random monthly visits to the static weighbridge stations at Mariakani, Athi River, Gilgil and Webuye (European Union, 2006).

The Ministry of Roads' Road Sector Investment Programme (2010-2014) report estimated a maintenance backlog for the paved network at Kshs. 230 billion. In addition, there was an annual maintenance cost of Kshs. 40 billion as at 2014. These requirements against approximately Kshs. 24 billion available for road maintenance indicate the inadequacy of available funds. Axle Load Control aims to eliminate overloading on the roads, thereby reducing maintenance costs burden on the government.

According to the Ministry of Transport's National Integrated Transport Policy (2009), road transport carries over 93% of all freight and passenger traffic in the country. Having an adequately developed and well maintained roads network improves road transport; reduces operating costs (business, fuel and spare parts); supports growth in other sectors such as tourism, agriculture and industrial sector with consequent increase in employment and income opportunities; road safety; and improves the socio-economic wellbeing of a nation by stimulating overall economic growth in both domestic and international trade and facilitating easy flow and access to manufactured goods.

The Northern Corridor is the busiest and most important transport route in East and Central Africa. It provides a lifeline through Kenya to the landlocked economies of Uganda, Rwanda, Burundi and DR Congo. An extensive network of transport routes originate from the Port of Mombasa, through Uganda, then branching off to Rwanda, Burundi and the eastern parts of DRC, with the largest mode being road transport (East African Online Transport Agency, 2012). Therefore, efficiency in the performance and operations at Gilgil weighbridge station is critical to the enhancement of cargo movement along the corridor and overall trade among the East African countries, especially Kenya, Uganda and Rwanda.

1.2 Problem Statement

Control of overloading through setting up of weighbridges is intended to eliminate the huge damaging effects of overloaded vehicles on pavements. However, a joint study by JICA and PADECO (2008) stressed that the effectiveness of any weighbridge station is dependent on the type of weighbridges provided, the accompanying facilities, management set up and location among other factors. Chan (2008) noted in his study that sometimes weighbridges have just been provided without careful consideration of their adequacy and the requirements. Some of the problems associated with the design and operations of Gilgil Weighbridge Station are listed below:

1. There is inadequate capacity at the weighbridge station to handle the HGV traffic at the station as evidenced by long queues shown in plate 1. The delays mean it takes longer to transport cargo along the corridor and this translates to higher transport costs. The congestion also affects the free flow of other vehicles passing through the weighbridge area especially where the queues extend beyond the start of the screening lane.
2. The existing weighbridges at the station are weighing one axle at a time (see plate 2) which results into longer service times per vehicle. This further contributes to the long delays experienced at the station.



Plate 1: Queue of trucks waiting to be weighed at Gilgil

Source: Author (2014)



Plate 2: One axle being weighed at a time at Gilgil

Source: Author (2014)

- The weighbridges at the station have been in use for a long time and currently require more frequent maintenance and calibration. The frequent breakdowns also contribute to congestion as only one weighbridge is able to operate at such instance. Plate 3 shows one of the weighbridges that was closed for repair and rehabilitation at the time of the visit. All the traffic it was previously handling were now being handled by the other weighbridge which was then overwhelmed. Murage (2012), reported that traffic at the Gilgil weighbridge station stretched for 15km on either side of the road after one of the weighbridges broke down the previous day and trucks and truck drivers were overlapping and blocked the section. He further reported that in the traffic, a trailer rolled backwards ramming into three vehicles including a bus ferrying school children injuring scores of them. Plate 4 shows the traffic congestion on the fateful day.



Plate 3: 2nd weighbridge closed for repair at Gilgil

Source: Author (2014)



Plate 4: Traffic congestion after breakdown of weighbridge

Source: The Star Newspaper (November 12, 2012)

- Kenya National Highways Authority (KeNHA) which is responsible for the Gilgil Weighbridge Station, is unable to monitor in real time the operations at the weighbridge station, where they have contracted a Management Contractor to manage the operations and supervise improvements. They rely on data relayed later and this possibly contributes to some level of reduced transparency and accountability and creates room for manipulation of data to satisfy the requirements and targets set by KeNHA.

5. There is poor lighting at the station at night with the exception of the weighbridges themselves. The entrances and exits have no lighting and the clerks and each policeman stationed there usually use a torch to record or verify some data. The poor lighting also contributes to some of the malpractices at the station, considering that majority of the reported cases of malpractice are usually at night.
6. There is no fence around the weighbridge station and anybody can access it from any side. This makes it difficult to control the people coming into the station and increases the probability of malpractices which usually involves alot of idlers at the station. It is required that only the weighbridge management staff on duty are present at the station alongside any official visitors but this is not the case with hawkers and many others roaming around freely as shown in Plate 5.
7. There are no controls/barriers at the entrances and exits that can prevent trucks from bypassing the weighbridge by going through the holding bay and out of the station without necessarily being weighed. This contributes to the high number of un-diverted truck traffic and becomes a hindrance to overload control. Plate 6 shows redistribution of cargo by axially overloaded trucks. They are required to be re-weighed after re-distribution but there is very little preventing them from just leaving through collusion with some weighbridge officials.



Plate 5: Hawkers at the weighbridge

Source: Author (2014)



Plate 6: Cargo redistribution near the exit

Source: Author (2014)

8. Due to separated command structure for the Management Contractors and the Traffic Police, operations may be compromised where there is disagreement. The Management Contractors report to KeNHA while the Traffic Police report to the Traffic Commandant.

9. The Manager at the station should be able to monitor the weighing operations from his office after installation of CCTV Cameras for both the Nakuru bound and Nairobi bound weighbridges at the station. However due to the weighbridges having separate servers, the Manager is unable to monitor the weighing operations on the Nairobi-bound weighbridge from his office and has to physically go to the weighing room on the Nairobi-bound side to monitor the weighing operations which is not an effective way to monitor the process.
10. There are incidences of abuse of computerized system by clerks by taking low readings when the wheel is not centrally positioned or stable. This has been discovered when mobile weighbridges have been set up independently by consultants on behalf of Kenya Roads Board ahead of the station and the loadings recorded at the mobile weighbridge compared with those earlier recorded at the station. Significant differences were observed in the readings whereby the mobile weighbridges recorded far much higher overloads than had been recorded at the station (CAS Consultants Ltd, 2013).
11. As part of improvements at the weighbridge, a new multi-deck weighbridge was installed and operationalized at the weighbridge station on the Nakuru-Bound side in November 2013. However, it had broken down more than 6 times as at the time of reconnaissance in June 2014. During such breakdowns, the vehicles are directed to the single axle weighbridge on the Nairobi-bound side and this reduces the efficiency of the station as more time is taken from the time one joins the queue to the time one exits the weighbridge. It was noted that there was a single axle weighbridge adjacent to the multi-deck weighbridge but it could not be used since its components such as the computer, data readers and cables were the ones transferred to another room for use by the multi-deck weighbridge. Plates 7 and 8 show an idle multi-deck weighbridge awaiting repair and the single axle weighbridge in use prior to the operationalization of the multi-deck weighbridge respectively.



Plate 7: Broken down multi-deck weighbridge
Source: Author (2014)



Plate 8: Adjacent single axle unit in use
Source: Author (2014)

12. Lastly, weighing using the old weighbridges does not take place during the rainy periods because the signals from the scale to the digital readers are affected resulting in wrong readings. This limits the effectiveness of Axle Load Control especially during the rainy seasons whereby transporters tend to take advantage to overload knowing that weighing would not be undertaken.

1.3 Research Questions

The research questions seek to provide some guidelines during the study whereby the questions asked seek the solutions of operations assessment of Weighbridges in Kenya.

The research questions for this study are as follows:

1. Are there planning, design and operation guidelines of a Weighbridge Station?
2. Are there challenges facing Gilgil Weighbridge Station?
3. Will the planned improvements affect operations at the Gilgil Weighbridge Station?
4. Are there outstanding design and operations concerns with the planned improvements and will they be addressed?

1.4 Objectives

The objectives aimed to address the research objectives. Each objective was intended to be addressed during the study in order to successfully complete it. The aim was to assess the Operations at the Gilgil Weighbridge Station.

Specific objectives were:

1. To establish the operation guidelines for a weighbridge station.
2. To find out the challenges facing Gilgil Weighbridge Station.
3. To determine how the planned improvements affect operations at the Gilgil Weighbridge Station.
4. To find out if there were outstanding design and operations concerns with the planned improvements and propose ways of addressing them.

1.5 Scope and limitation of the Study

This research assessed the operations of weighbridges in Kenya. Gilgil weighbridge station was the case study for this research because the two busier stations of Mariakani and Athir River respectively had already been redesigned and new constructions were on-going at the time of the study. This study looked at guidelines for selection and operation of weighbridges, review previous studies abroad, in Africa and in Kenya while also reviewing the relevant legislative framework.

This study included collection of data such as traffic, facilities, axle loads, queuing which was then analyzed. The traffic data collected shall be limited to the Heavy Goods Vehicle data.

1.6 Justification of the Study

Over the past 50 years there had a been a steady increase in the use of road haulage and due to ineffectiveness of the rail network, there had been a massive surge in the number of heavy goods vehicles all over the country which has resulted into increased incidences of overloading, the largest percentage of the heavy goods vehicles using the Northern Corridor (Ministry of Transport, 2009). This has resulted into the concentration of the static weighbridges along the corridor with Gilgil station being one of them.

Overloading had been identified as one of the major causes of road deterioration along Kenyan roads among others such as poor design and construction methods and lack of maintenance. The deterioration of roads imposed an extra cost onto society in terms of future costs of road maintenance and rehabilitation which must be financed by the Government (Ministry of Roads, 2011).

The Kenya Government had made it a priority to facilitate cargo movement on the Northern Corridor Road (Mombasa-Malaba/ Busia) in a bid to reduce transportation costs and boost trade with the neighbouring countries of Uganda, Rwanda, DRC and South Sudan. It is against this backdrop that the Minister for Transport and Infrastructure proposed amendments to the Traffic Act in 2013. The amendments were currently being enforced by the Kenya National Highways Authority and were aimed at enhancing movement of cargo at the time of this study. This study was therefore critical to the realization of the government's goal.

The Axle Load Control Programme promotes fair and efficient competition in the trucking industry by not giving unfair advantage to operators who do not comply with rules and regulations pertaining to loading of vehicles. This study seeks to improve the Axle Load Control Programme at Gilgil and thereby contributing to promotion of fair and efficient competition in the trucking industry.

CHAPTER 2

2.0 Literature Review

2.1 Selection, Installation and Operation of Weighbridges.

2.1.1 General

The selection, installation and operation of weighbridges constitute important elements of any country’s overload control activities. The selection of a weighbridge is largely determined by the purpose it will serve. The purpose will, in turn, be determined by the strategy adopted by the relevant institution.

2.1.2 Weighbridges Types

There is a wide array of weighbridge types and related methods of weighing that can be used for overload control purposes. In general, there are two types of weighbridges and two methods of weighing as follows:

- Types of weighbridge: Fixed versus mobile scales
- Methods of weighing: Static versus dynamic

The relative characteristics of the types of weighbridges and methods of weighing are illustrated in Table 2.1.

Table 2.1: Weighbridge Types and Methods of weighing

Type of weighbridges Method of weighing		Fixed weighbridges	Mobile weighbridges
			<ul style="list-style-type: none"> • Easy to operate • Minimum personnel • Cargo off-loading • High installation costs • Limited placement
Static	<ul style="list-style-type: none"> • More precision • Accepted for legal enforcement • Slower 	<ul style="list-style-type: none"> • Easiest to operate • Highest level of precision • Can weigh and register axle groups 	<ul style="list-style-type: none"> • Lowest investment • Optimal for enforcement
Dynamic	<ul style="list-style-type: none"> • Rapid monitoring • Lower precision • Not acceptable for enforcement 	<ul style="list-style-type: none"> • Rapid monitoring • Requires large installation • Requires careful direction of vehicles • Generally not accepted for enforcement 	<ul style="list-style-type: none"> • Minimum disruption of commercial traffic • Lowest accuracy • Excellent for statistical monitoring

Source: Sub-Saharan Africa Transport Policy Program (SATPP), Working Paper No. 90 (2010)

The types of weighbridges, their advantages and disadvantages were discussed in the Sub-Saharan Africa Transport Policy Program (SATPP), Working Paper No. 90 (2010) and are highlighted below:

Fixed Weighbridges

- a) **Single axle weighbridge:** These weighbridges (see Plate 9), irrespective of the technology used to conduct the weighing operation, are widely used throughout the region. They are small transversal devices that weigh one axle of a vehicle at a time. The weighing operator then has to add the masses of the individual axles to determine the total vehicle mass; total combination mass; and axle unit masses. Due to their small size, these scales can be moved from site to site where they are installed in a pre-prepared recess.

Although single axle scales have proven to be effective in the past, they have certain drawbacks:

- The sites have to be constructed to very precise level requirements which are not easily met.
- Weighing of multi-axle vehicles is cumbersome and time-consuming.
- Placing the required number of test weights on the small deck area is difficult and dangerous.
- They are very heavy to transport from one site to another.
- Setting up the site for overloading enforcement is time consuming.

Due to pressure from the courts with regard to the accuracy of these scales/sites, as well as other shortcomings, as indicated above, it was recommended that this type of scale should be phased out in the Eastern and Southern Africa (SATPP, 2010).

This is the one of the types of weighbridges that was operational at the Gilgil Weighbridge Station at the time of the study. It was serving the Nairobi- bound commercial vehicles.

- b) **Axle unit weighbridges:** These weighbridges consist of a single deck supported on the weighing mechanism (usually 4 load cells) as shown in Plate 10. The size of these weighbridges is typically 3.2 m x 3 m to 3.2 m x 4 m.



Plate 9: 3.2x1m Single Axle Scale
Source: JICA, PADECO, 2011



Plate 10: 3.2x4m Axle Unit Scale
Source: JICA, PADECO, 2011

Some of the benefits of the axle unit scale are as follows:

- They can weigh any axle unit of a truck (single axle, tandem or tridem unit).
- Level tolerances on the approach slabs do not have to be as accurate as for the single axle weighbridge, as all axle units (tandems and tridems) are weighed in single operations.
- Testing the weighbridge is easier (in terms of limitations for stacking of test weights).
- It is far quicker to weigh multi-axle vehicles.

The main disadvantage of a single deck scale is that it takes a number of operations to weigh one multi-axle vehicle. It is however still considerably more efficient than a single axle scale.

- c) **Multi-deck scales:** These scales comprise a number of decks of different lengths. Each deck is individually supported by its own weighing mechanism (typically four load cells, one on each corner). The main benefit of a multi-deck scale is that it enables the majority of multi-axle heavy vehicles to be weighed in one operation. Their length therefore is determined by the permissible maximum length of vehicle combinations in the country or the region. Multi-deck scales are usually equipped with four decks although some have five, three or even two decks. Two deck scales, however, negate the main advantage of a multi-deck scale, namely ability to weigh all axles at one go,

Some of the benefits of a multi-deck scale are as follows:

- Level tolerances on the approach slabs are no longer a problem for as in most cases the whole vehicle is weighed in one operation.
- Vehicle weighing is very efficient.
- Short calibration tests can easily be done without test weights (any axle or axle unit is weighed on each of the weighbridge decks and the results should be consistent).
- It is more difficult to “manipulate” the weighing process, as in most cases the whole vehicle is weighed in a single operation (with an axle unit scale it is easy to weigh only part of an axle unit or to weigh one unit twice and skip an overloaded unit).

The decision with regards whether a single or a multi-deck scale should be installed is mostly influenced by the throughput requirements of the weighbridge facility. On routes where large numbers of heavy vehicles need to be weighed (see Table 2.2), it was recommended that multi-deck scales be installed (SATPP, 2010).

The type and cost of weighbridge facilities can vary considerably depending on the level of requirement which might include (JICA, PADECO, 2011):

- Small office or many offices (i.e. also used as a regional office)
- Size of park-off area
- Canopy over the weighing area for protection against inclement weather
- Staff accommodation facilities

Mobile Weighbridges

They involve the use of portable weighing equipment which consists of wheel scales, which are placed on the road surface. The axle load is obtained by summing the wheel loads. Although these are sometimes used to weigh the wheels on only one side of a vehicle, it is far more accurate to weigh all the wheels of a vehicle simultaneously.

Portable weighing equipment in use is usually light and can be set-up by two operators in a few minutes. They can be transported in a light truck together with the accessories such as leveling mats, computer and cables. Leveling mats or ramps are required to align the levels of all the axles in an axle

unit, unless the scales are used in a specially constructed pit in a lay-by. If the levels of all the axles in the axle unit are not within the required tolerance, the scale readings will not be sufficiently accurate for law enforcement purposes.

Weigh-in-motion scales

- a) **High speed weigh in motion scales:** High speed weigh in motion (HSWIM) scales are axle load scales that are placed in the road surface and designed to weigh the axles of heavy (and other) vehicles travelling at normal operating speeds. The most common HSWIMs on the market make use of bending plate technology. The scale deck consists of a metal plate that bends as a wheel travels over it and the variation in electrical current due to the changing properties of the metal is measured and translated into a mass.

A HSWIM installation usually consists of electromagnetic loops in the road behind and in front of the scales. This total system is able to weigh each axle as it moves across the scale at a constant speed, classify the configuration of the vehicle and calculate if the heavy vehicle is potentially overloaded.

Variation in speed does affect accuracy of measurements and heavy vehicle operators are known to manipulate the measurements by either braking or accelerating across the scales. A number of parameters can be measured simultaneously including total vehicle mass, steering axle mass, axle unit mass, axle spacing and vehicle speed.

The two primary uses of a HSWIM system are screening and data collection.

- At weighbridges where large numbers of heavy vehicles have to be processed, the use of a HSWIM as a screening device is valuable. In this application only the potentially overloaded heavy vehicles are screened (sent to the fixed scale) to be weighed statically. This type of application is also a good way of reducing the human factor in the selection of vehicles to be weighed.
- The second use of a WIM system is for data collection. Road authorities need traffic loading data for their pavement management systems and long-term maintenance planning. HSWIMs provide this information. HSWIMs could – and should – be used for both the above purposes

simultaneously. Continuous data collection on alternative routes by WIMs is also useful to detect patterns of weighbridge avoidance.

- b) **Low speed weigh in motion (LSWIM) scales:** This is a relatively new type of technology in the region and is essentially a small fixed scale. It operates optimally at constant speeds of about 5 km/h. It is also equipped with a rigid deck, supported on four load cells designed to weigh one axle at a time. The weighing algorithms are similar to those of a HSWIM as all axle loads are recorded and the vehicle's dimensions are derived from the movement across the scale. LSWIMs are purported to be more accurate than HSWIMs but less accurate than fixed scales, due to the dynamic loads induced by the moving vehicle.

To date LSWIMs have not been used for prosecution, but studies are being conducted to accredit these scales for prosecution purposes. The advantages that could be accrued from the use of LSWIMs are cost and ease of operation. They are cheaper than large multi-deck scales and potentially increase throughput (SATPP, Working Paper No. 90, 2010).

2.1.3 Selection of Weighbridges

The selection of a weighbridge is largely determined by the purpose that it will serve. In this regard, the expected heavy vehicle traffic on a route is the most important determinant. The type of weighbridge scale and other equipment, the size of the buildings, parking areas, queuing space and the number of staff required are all determined by the current and future traffic. Even secondary design parameters, such as office space, furniture or office equipment, size of water and sewerage handling facilities and number of telephones are determined by the heavy vehicle traffic.

A weighbridge facility that is inadequate to cope with traffic on a busy route is ineffective and a waste of resources whereas a facility that is too large on a quiet road could be regarded as a white elephant. Similarly, a weighbridge kept open 24 hrs when there is hardly any night time traffic would be wasteful. Table 2.2 provides guidance on the type of weighbridge that is most suited for handling various heavy vehicle traffic volumes on different road classes.

Table 2.2: Types of weighbridges in relation to heavy vehicle traffic volumes and road class

Weighbridge type	Traffic volumes (Heavy vehicles/day)	Road class
Multi deck scale (both sides of freeway)	> 4 000	A
Multi deck scales (four decks)	1 000 – 4 000	B
Multi deck scale (four decks)	500 – 1 000	C
Axle unit scale	< 500	D
Single axle scale	< 500	D

Source: SATPP, Working Paper No.90 (2010)

The study area is along a Class A road which shows a requirement of multi-deck weighbridges on both sides of the road. Weighbridges on Class A and B roads are relatively costly due to the required equipment and site facilities, such as type of scale, the use of pre-screening WIMs, the size of parking and stacking facilities and the type office accommodation required to handle larger numbers of heavy vehicles and staff. These weighbridges will have the greatest impact on heavy vehicle overloading and thus justify larger capital and operational expenditure (SATPP, Working Paper No. 90, 2010).

2.1.3.1 Ultimate choice of weighbridge facility

Although traffic is the most important determinant in the decision to procure a particular type of weighbridge there are other factors that should also be considered. They include:

- Experience with equipment already in use
- Manufacturer’s guarantee
- Maintenance, calibration and operation complexity

In the final analysis, the choice of weighbridge facility should be decided by carrying out a full life cycle analysis of the status quo versus the proposed option which may be either an upgraded or new facility. The life-cycle cost analysis would typically include the following:

Project costs

Initial costs

Operating costs

Project benefits

Fees collected for overloading

Saving in road damage

Maintenance costs

With effective overload control there will be a reduction in the income from fees as the incidence of overloading reduces. Thus, as a project, overload control is normally not self-sustainable based on income from fees. It is therefore critically necessary that road authorities appreciate this important point and take it into account when considering different funding mechanisms.

2.1.4 Weighbridge Facility Layout and Installation

The layout of weighbridges can vary considerably depending on a variety of factors including:

- Purpose of the facility
- Prosecution of overloaded heavy vehicles
- Screening heavy vehicles only
- Volume of heavy vehicles to be weighed

The types of facility that can be provided in relation to the factors indicated above were described in the SATPP Working Paper No. 90 (2010). They include:

- Full Traffic Control Centre (FTCC)
- Type 1 Traffic Control Centre (TCC 1)
- Type 5 Traffic Control Centre (TCC 5)
- Lay-by Control Centre (LCC)

Full Traffic Control Centre

As the name implies, a FTCC as shown in figure 2.1 includes a full range of facilities to efficiently and effectively undertake an overload control process at minimum disruption to relatively large volumes of heavy vehicle traffic. Such a facility would normally operate on both sides of the road and would typically include within its operational system the following:

- A high-speed weigh-in-motion (HSWIM) screening device in the main traffic lane
- A low-speed weigh-in-motion (LSWIM) screening device to confirm vehicles suspected to be overloaded as indicated by the HSWIM
- A static platform scale for accurately weighing axle and axle unit loads and total vehicle or combination mass for prosecution purposes.

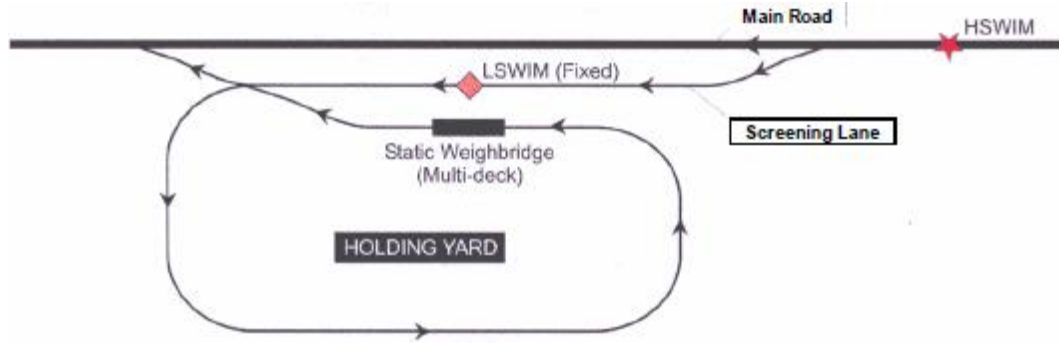


Figure 2.1: Typical Layout of a full traffic control centre (FTCC)

Source: SATPP, Working Paper No. 90 (2010)

The capacity of a FTCC for undertaking various aspects of the overload control process is given in Table 2.3.

Table 2.3: Capacity characteristics of a FTCC facility

Activity	Typical Capacity
Screening capacity (veh/h)	200
Weighing capacity (veh/h)	50
Prosecution capacity (veh/h)	10
Maximum System Average Daily Truck Traffic (ADTT)	2,000

Source: SATPP, Working Paper No. 90 (2010)

Type 1 Traffic Control Centre (TCC1)

A TCC 1 is essentially the same as a FTCC except that it operates on only one side of the road and the SWIM in the main road is located on an internal screening lane. The drawback of this system is that any vehicles travelling in one direction that are identified as overloaded by the HSWIM must cross over the opposing traffic stream to be weighed. Thus, this type of facility is ideally suited for use where access across the road is provided by an interchange or where traffic flows are not so high as to frustrate the passage of vehicles across the road to the weighbridge.

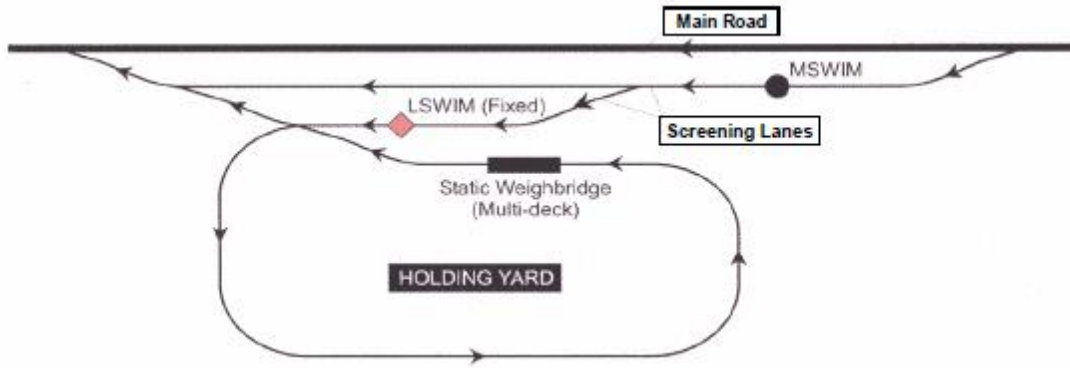


Figure 2.2: Typical Layout of a TCC 1 facility

Source: SATPP, Working Paper No. 90 (2010)

The capacity of a TCC 1 is very similar to that of an FTCC (see Table 2.4). This type of facility is less costly to operate than an FTCC as only one team is required to control the station.

Type 5 Traffic Control Centre (TCC5)

A type 5 TCC has fewer control facilities than either a FTCC or TCC 1 in that it does not have in-lane traffic screening but requires all heavy vehicles to leave the main carriageway and crossover a LSWIM. In this layout arrangement (see Figure 2.3) legally loaded vehicles can immediately continue with their journey, but overloaded vehicles must proceed to the static weighbridge for weighing and prosecution.

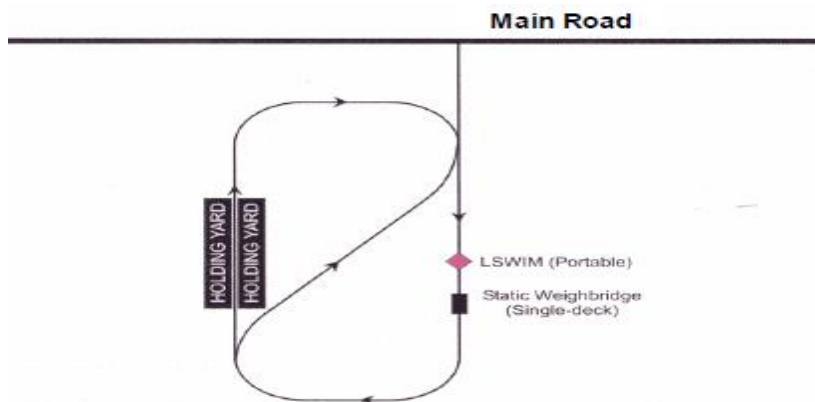


Figure 2.3: Typical Layout of a TCC 5 facility

Source: SATPP, Working Paper No. 90 (2010)

The capacity of a TCC 5 for undertaking various aspects of the overload control process is given in Table 2.4.

Table 2.4: Capacity characteristics of a TCC 5 facility

Activity	Typical Capacity
Screening capacity (veh/h)	40
Weighing capacity (veh/h)	15
Prosecution capacity (veh/h)	5
Maximum System Average Daily Truck Traffic (ADTT)	400

Source: SATPP, Working Paper No. 90 (2010)

As indicated above, a TCC 5 facility has the capacity to prosecute approximately 100 overloaded vehicles in an 18 hour-day. Thus, from a technical point of view, it is appropriate where the traffic stream carries up to 1,000 heavy vpd in both directions.

2.1.4.4 Lay-by Control Centre (LCC)

A LCC facility essentially consists of a road lay-by at which either a static or mobile weighbridge is installed (see Figure 2.4). The facility comprises a suitably constructed level concrete platform adjacent to the road where the weighbridge is installed (or in the case of a mobile vehicle scale – with provision for easy installation of such a scale. The installed weighbridge may be operated in conjunction with a HSWIM as a screening device.

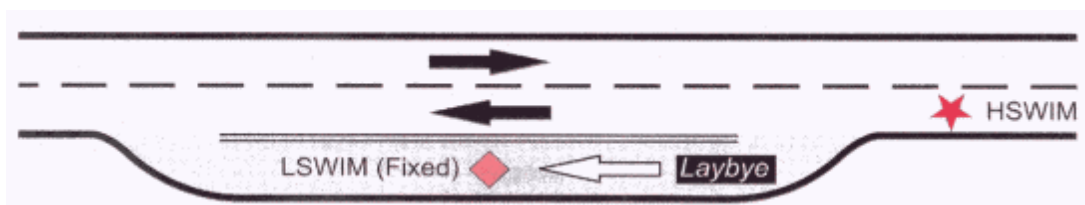


Figure 2.4: Typical Layout of a LCC facility

Source: SATPP, Working Paper No. 90 (2010)

2.1.5 Weighbridge Operations

The operation of a weighbridge facility is multi-faceted in that it involves a variety of processes to be carried out by well trained personnel with a range of skills applicable to all aspects of overload control. Guidelines could take the form of a General Manual for the Operation of Weighbridges or be a general information document.

The following should be addressed as discussed by Chan (2008):

a) Legislative guidelines

Typically legislative guidelines should include:

- An interpretation of the legislation – specifically a simplification of what the purpose of the specific portion of the legislation is, how it should be applied in practice and how it relates to other pieces of legislation.
- The powers, roles and responsibilities of overload control officers, private sector operator’s staff, the police and other role players.

b) Procedural guidelines

Procedural guidelines should cover aspects such as screening, weighing of a heavy vehicle, how to charge an offender, how to deal with arrest cases, dangerous goods and incidences at weighbridges. They should also include how to deal with the public, data collection and reporting.

c) Institutional, management and maintenance guidelines

Guidelines assisting with giving direction and providing consistency with regard to the institutional (personnel), management and maintenance of weighbridge sites are also site- specific and should include:

- Specification of type and number of personnel required at each site
- Signs and signals, type and location for the slowing down and stopping of vehicles to be checked
- Legitimacy of the authorized control personnel including the use of proper uniforms
- Behavior of the control personnel in carrying out their duties
- The roles and responsibilities of the weighbridge personnel including weighbridge manager, supervisors, administrative staff and maintenance staff

- Job descriptions and training requirements for each post
- Maintenance procedures, specific to each item of equipment
- Routine preventative maintenance procedures
- Guidelines for maintenance term-contracts with specialists for specialist maintenance including Scale maintenance and calibration, software systems maintenance, among others.
- Emergency procedures and incident management
- Health and safety requirements
- Site security
- Environmental management
- Asset management

The preparation of guidelines and training of staff in their application is often neglected as a result of which, the optimal use of the weighbridge facility is jeopardized.

The guidelines for selection, installation and operation of weighbridges discussed in section 2.1 were adopted by Southern African Development Community (SADC) and member countries were at the time of this study required to adhere by the provisions. In the study for harmonization of vehicle overload control in the East African Community, JICA and PADECO (2011) borrowed from these guidelines in terms of the facilities at different capacities and operations at weighbridges. Therefore, the guidelines were adopted in this study for the assessment of design and operations at Gilgil weighbridge station.

2.2 Queuing Theory

Queuing theory is a mathematical approach to the analysis of waiting lines. In order to assess the operations of Gilgil weighbridge station, it was to be used to analyse the performance and adequacy of the weighbridge based on the existing and future traffic flows at the station. However, different models were considered to analyse the queuing system at the weighbridge.

Trimbitas (2011) discussed the queuing theory in his contribution to the Journal of Transportation Engineering. He noted that customer waiting lines are a short-term phenomenon, and the employees who serve customers are frequently inactive while they wait for customers to arrive. If service capacity

is increased, waiting lines should become smaller, but then employees (called servers) would be idle more often as they wait for customers. A manager can examine the trade-off between capacity and service delays using queuing analysis. Specifically, when considering improvements in services, the health care manager weighs the cost of providing a given level of service against the potential costs from having patients wait.

Slavik (2009) noted that the goal of queuing is to minimize total costs. The two basic costs are those associated with customers having to wait for service and those associated with capacity. Capacity costs are the costs of maintaining the ability to provide the service such as operators and managers' salaries. Note that as service capacity increases, so does its cost; service capacity costs are shown as incremental (rising in steps for given service levels). As capacity increases, however, the number of customers waiting and the time they wait tend to decrease, so the waiting costs decrease. A total cost curve is then added to the graph to reflect the trade-off between those two costs (see Figure 2.5 below).

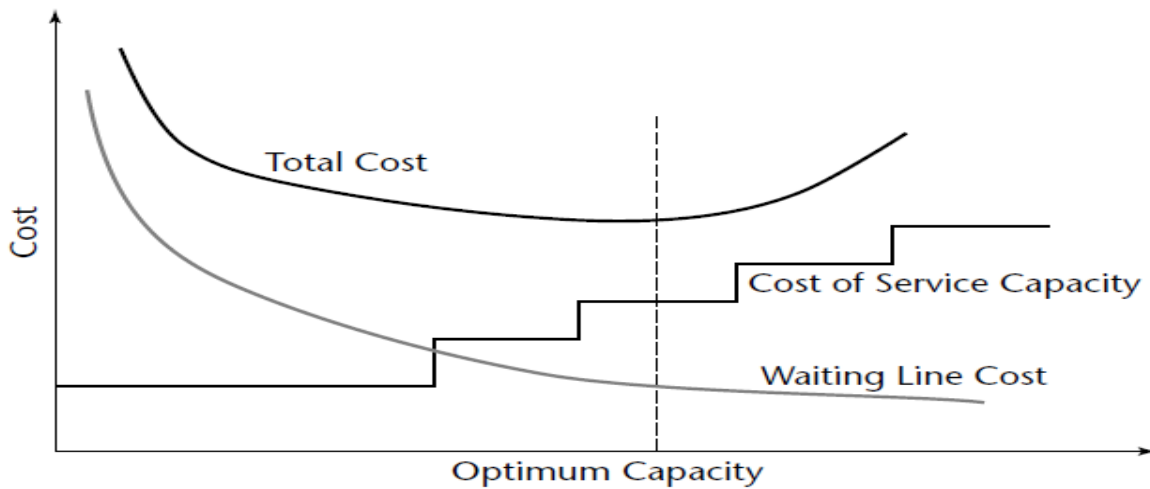


Figure 2.5: Service Capacity and Costs

Source: Slavik, M. (2009)

2.2.1 Queuing Models

Queuing models are identified by their characteristics. From a methods perspective, a nomenclature of A/B/C/D/E is used to describe them as shown below (Vandael et al. 2000):

A: Specification of arrival process, measured by inter-arrival time or arrival rate.

M: Negative exponential or Poisson distribution.

D: Constant Value

K: Erlang Distribution

G: A General distribution with known mean and variance

B: Specification of service process, measured by inter-service time or service rate.

M: Negative exponential or Poisson distribution.

D: Constant Value

K: Erlang Distribution

G: A General distribution with known mean and variance

C: Specification of number of servers—“s”.

D: Specification of queue or the maximum numbers allowed in a queuing system.

E: Specification of customer population.

The last two components, D and E, of the nomenclature are not usually used. Two examples of nomenclature in use are: 1) a queuing model with Poisson arrival and service rates with three servers is described by M/M/3. The commonly used models are M/M/s=1 and M/M/s>1.

Vandael et al. (2000) added that five key relationships provide the basis for queuing formulations and are common for all infinite-source models:

1. The average number of customers being served is the ratio of arrival to service rate.

$$r = \lambda / \mu$$

2. The average number of customers in the system is the average number in line plus the average number being served.

$$L = L_q + r$$

3. The average time in line is the average number in line divided by the arrival rate.

$$W_q = L_q / \lambda$$

4. The average time in the system is the sum of the time in line plus the service time.

$$W = W_q + 1/\mu$$

5. System utilization is the ratio of arrival rate to service capacity.

$$\rho = \lambda / s\mu, \text{ where}$$

λ	arrival rate
μ	service rate
L_q	average number of customers waiting for service
L	average number of customers in the system (waiting or being served)
W_q	average time customers wait in line
W	average time customers spend in the system
P	system utilization
$1/\mu$	service time
P_o	probability of zero units in system
P_n	probability of n units in system

2.2.1.1 The M/M/1 Model

The simplest model represents a system that has one server. The queue discipline is first-come, first-served, and it is assumed that the customer arrival rate can be approximated by a Poisson distribution and service time by a negative exponential distribution, or Poisson service rate. The length of queue can be endless just as a demand for a given facility is. The formulae (performance measures) for the single-channel model are as follows (Vandael et al. 2000):

$$L_q = \frac{\lambda^2}{\mu(\mu - \lambda)} \quad (2-1)$$

$$P_o = 1 - \lambda / \mu \quad (2-2)$$

$$P_n = P_o(\lambda / \mu)^n \quad (2-3)$$

or

$$P_n = (1 - \lambda / \mu) (\lambda / \mu)^n, \text{ where,} \quad (2-4)$$

Once arrival (λ) and service (μ) rates are determined, length of the queue (L_q), probability of no arrival (P_o), and n arrivals (P_n) can be determined easily from the formulae.

2.2.2 Modelling of queues using Fourier series

Fourier series is a way to represent a wave-like function as a combination of simple sine waves. More formally, it decomposes any periodic function or periodic signal into the sum of a (possibly infinite) set of simple oscillating functions, namely sines and cosines (or, equivalently, complex exponentials) (Whitt et.al, 1993).

Consider the following equations:

$$s_N(x) = \frac{A_0}{2} + \sum_{n=1}^N A_n \cdot \sin\left(\frac{2\pi nx}{P} + \phi_n\right), \quad \text{for integer } N \geq 1. \quad (2-5)$$

$s_N(x)$ is a periodic function with period P . Using the identities:

$$\begin{aligned} \sin\left(\frac{2\pi nx}{P} + \phi_n\right) &\equiv \sin(\phi_n) \cos\left(\frac{2\pi nx}{P}\right) + \cos(\phi_n) \sin\left(\frac{2\pi nx}{P}\right) & (2-6) \\ \sin\left(\frac{2\pi nx}{P} + \phi_n\right) &\equiv \operatorname{Re} \left\{ \frac{1}{i} \cdot e^{i\left(\frac{2\pi nx}{P} + \phi_n\right)} \right\} = \frac{1}{2i} \cdot e^{i\left(\frac{2\pi nx}{P} + \phi_n\right)} + \left(\frac{1}{2i} \cdot e^{i\left(\frac{2\pi nx}{P} + \phi_n\right)} \right)^* \end{aligned}$$

$s(x)$ denotes a function of the real variable x , and s is integrable on an interval $[x_0, x_0 + P]$, for real numbers x_0 and P . s will be represented in that interval as an infinite sum, or series, of harmonically related sinusoidal functions. Outside the interval, the series is periodic with period P (frequency $1/P$). It follows that if s also has that property, the approximation is valid on the entire real line (Walker, 2001).

When the coefficients (known as **Fourier coefficients**) are computed as follows:

$$\begin{aligned} a_n &= \frac{2}{P} \int_{x_0}^{x_0+P} s(x) \cdot \cos\left(\frac{2\pi nx}{P}\right) dx \\ b_n &= \frac{2}{P} \int_{x_0}^{x_0+P} s(x) \cdot \sin\left(\frac{2\pi nx}{P}\right) dx \quad (6) \end{aligned} \quad c_n = \frac{1}{P} \int_{x_0}^{x_0+P} s(x) \cdot e^{-i\frac{2\pi nx}{P}} dx$$

$s_N(x)$ approximates $s(x)$ on $[x_0, x_0+P]$, and the approximation improves as $N \rightarrow \infty$.

The infinite sum, $\sum_{-\infty}^{\infty} s_{\infty}(x)$, is called the Fourier series representation of s .

$s_N(x)$

2.2.2.1 M_t/G/ ∞ Queues

For an M_t/G/ ∞ model with appropriate initial conditions, it is known that the number of busy servers at a time t has Poisson distribution for each t , so that the full distribution is characterized by its mean. The simple formulae can also be regarded as consequences of linear system theory, because the mean function can be regarded as the image of a linear operator applied to the arrival rate function.

Assume that the M_t/G/ ∞ model starts empty in the infinite past. Primarily, periodic arrival rate functions are considered to give a dynamic steady state. In general, assume that λ is nonnegative, measurable and integrable over any bounded interval. For applications, it can also be assumed that λ is piecewise smooth, which means it has a continuous derivative everywhere except at finitely many points (Whitt et.al, 1993).

2.2.2.2 General Periodic arrival rate

Assume that λ is a general periodic function on $(0, 2\pi/\gamma)$. Note that periodic case essentially covers a general arrival rate function on a finite interval, because any such arrival can be extended to a periodic function. The only difficulty is the end effect at the left boundary in the aperiodic function, which can usually be represented by appropriately modifying the periodic function. To treat general λ , it is assumed that λ can be approximated by the partial sums of its Fourier series, that is,

$$\lambda_n(t) = a_0 + \sum_{k=1}^n (a_k \sin k\gamma t + b_k \cos k\gamma t),$$

where

$$a_k = \frac{1}{\pi} \int_0^{2\pi} \lambda(t) \sin k\gamma t dt \quad \text{and} \quad b_k = \frac{1}{\pi} \int_0^{2\pi} \lambda(t) \cos k\gamma t dt. \tag{2-7}$$

To guarantee convergence of λ_n as n approaches ∞ , it is assumed that λ is piecewise smooth on $(0, 2\pi/\gamma)$.

Then $\lambda_n(t) \rightarrow \lambda(t)$ as $n \rightarrow \infty$ for each t that is a point of continuity of λ and

$$\lambda_n(t) \rightarrow [\lambda(t^+) + \lambda(t^-)] / 2 \tag{2-8}$$

at each point of discontinuity. Moreover, the convergence is uniform if λ is continuous everywhere.

For sinusoidal λ ,

$$m(t) = \lambda E(S) + \beta (\sin(\gamma t) E(\cos(\gamma S_e)) - \cos(\gamma t) E(\sin(\gamma S_e))) E[S] \quad \text{where,} \tag{2-9}$$

m is periodic with period (cycle length) $\Psi=2\pi/\gamma$ just like λ . Moreover, the long-run average (and average over one cycle) is

$$\bar{m} = \lim_{t \rightarrow \infty} t^{-1} \int^t m(s) ds = \lambda E(S). \tag{2-10}$$

Whitt et.al (1993) further show that the last formula implies that the approximations simple stationary approximations (SSA) and point wise stationary approximations (PSA) are both exact in average sense. Note that this is a distinct contrast with the behavior of queues with finitely many servers. Additionally, it is seen that the mean function m_n associated with λ_n converges uniformly to λ and,

$$m_n(t) = a_0 + \sum_{k=1}^n (a_k mk1(t) + b_k mk2(t)) \tag{2-11}$$

where $mk2(t) = mk1(t + \pi/2\gamma)$ because $\cos(kt) = \sin(kt + \pi/2\gamma)$ (2-12)

Green et.al (1995) showed that a Fourier series model for a simple queuing system while using either the simple stationary approximations or the point-wise stationary approximations can seriously underestimate delays even when the arrival rate is only modestly non-stationary (for example, when the amplitude of the arrival process is only 10% of its average). However, for a complex system with multiple servers, balking and renegeing possibilities, then Fourier series modeling becomes ideal as it will provide the most reliable simulation.

2.2.3 Comparison between M/M/s Queue Models and Fourier series Model

Comparison of the Queue and Fourier Series models was done with respect to the existing system at Gilgil Weighbridge Station that was to be analysed. The station represented, at the time of the study, a simple system with a single server and different arrival and service times. Elements of balking and renegeing do not exist since the customers (in this case the truck drivers) are joining the queue to be weighed as part of a government requirement and the nature of the queue also makes it impossible to renege once one has joined the queue. Table 2.5 gives a summary of the strengths and weaknesses of each model.

Table 2.5: Comparison between M/M/s models and Fourier series models

Model	Strengths	Weaknesses
M/M/S Models	Applicable for simple systems which are in use at a weighbridge station	Low accuracy levels when balking and renegeing allowed
	High levels of accuracy even when the arrival rate is non-stationary	
	Easy derivation of parameters such as arrival rates, service rates, utilization and lengths of queue	
Fourier Series model	Best for complex systems modelling	With stationary approximations in use, not applicable for systems with non-stationary arrival rate
	Allows for renegeing and balking in the Estimations. However, these are not options at a weighbridge station. A truck has to join the queue and cannot pull out of the queue.	Underestimation of delays for a simple system such as a weighbridge station

Source: Author (2015)

Considering the simplicity of the weighbridge facility system based on the key parameters of concern i.e. arrival rate, waiting time, service rate, service time and the existence of a single server at the facility, M/M/1 model was the most appropriate model to be used for queuing analysis of Gilgil weighbridge station.

2.2.4 Measures of Queuing System Performance

The management must consider five typical measures when evaluating existing or proposed service systems. Those measures are:

1. Average number of customers waiting (in queue or in the system).
2. Average time the customers wait (in queue or in the system).
3. Capacity utilization.
4. Costs of a given level of capacity.

5. Probability that an arriving customer will have to wait for service.

The system utilization measure reflects the extent to which the servers are busy rather than idle. On the surface, it might seem that management would seek 100 percent system utilization. However, increases in system utilization are achieved only at the expense of increases in both the length of the waiting line and the average waiting time, with values becoming exceedingly large as utilization approaches 100 percent. Under normal circumstances, 100 percent utilization may not be realistic; a manager should try to achieve a system that minimizes the sum of waiting costs and capacity costs. In queue modeling, the management also must ensure that average arrival and service rates are stable, indicating that the system is in a steady state, a fundamental assumption (Vandael et al. 2000).

2.3 Traffic Flow Theory

The knowledge of traffic characteristics is critical in developing roads, transportation plans, performing economic analyses, establishing geometric criteria, selecting and implementing traffic control measures and evaluating performance of transportation facilities such as the case of a Weighbridge Station.

2.3 .1 Volume, Density, Flow and Speed

Valentin (2008) observed that traffic flow characteristics – traffic speed, travel time, volume and density – are fundamental for planning, design and operation of roads and motorways (highways) and transport facilities. Determination of relationships between concentration, density, speed and volume is of primary interest in traffic flow theory, which involves the development of mathematical relationships among the primary elements of a traffic stream – flow, speed, density.

From the Highway Capacity Manual (2010), the traffic flow characteristics are defined as follows:

- Volume- the total number of vehicles that pass over a given point or section of a lane or roadway during a given time interval such as annually, daily, hourly among others.
- Flow rate that is, the equivalent hourly rate at which vehicles pass over a given point or section of a lane or roadway during a given time interval of less than one hour, usually 15 minutes.
- Peak Hour Factor being the ratio of total hourly volume to the peak flow rate within the hour

- Density/Concentration- number of vehicles occupying a given length of lane or roadway at a particular instant.
- Speed- which is rate of motion expressed as distance per unit of time, generally as kilometers per hour

In the relationship between flow, speed and density, a zero flow rate occurs under two different conditions. Firstly is when there are no vehicles in the facility- density is zero, and flow rate is zero. Speed is theoretical for this condition and will be selected by the first driver (presumably at a high value). This speed is represented by S_f in the graphs. Lastly, is when density becomes so high that all vehicles must stop- the speed is zero, and the flow rate is zero, because there is no movement and vehicles cannot pass a point on the roadway. The density at which all movement stops is called the jam density, denoted by D_j shown in Figure 2.6 (HCM, 2010).

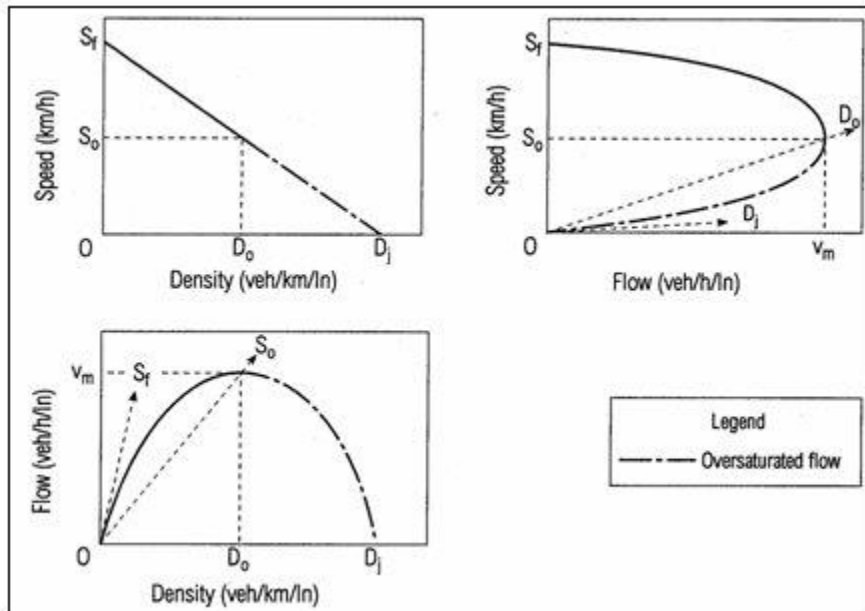


Figure 2.6: Speed, Density and Flow Relationship

Source: Highway Capacity Manual (2010)

The traffic characteristics affect the efficiency of a weighbridge station. For example, low speeds are equivalent to high densities and low flow rate resulting in congestion at the weighbridge station and vice versa. In conjunction with the queuing theory, one will be able to further look at the waiting times

and service times in order to analyze the congestion and determine whether these are purely due to capacity constraints or service times are also unnecessarily high.

2.3.2 Peak Hour Factor (PHF)

Essentially, any traffic facility is designed to accommodate the peak hour demand. Further analysis should be done to consider the demand on the Weighbridge station during the peak traffic time. This involves analysis of hourly variation of traffic volumes which shall be adjusted using the Peak Hour Factor.

From the Highway Capacity Manual (2010),

$$PHF = \frac{\text{Hourly Volume}}{\text{Peak flow rate (within the hour)}} \quad (2-13)$$

If 15-minute periods are used, the PHF may be computed as below:

$$PHF = \frac{\text{Volume}}{(4 \times \text{Volume}_{15})} \quad (2-14)$$

Where Volume_{15} is the volume during the peak 15 minutes of the peak hour

2.3.3 Design Weighbridge Traffic Volume (DWT)

Bell et.al. (2001) summarized the design weighbridge traffic volume as follows:

$$DWT = \text{Peak \% overloading} \times \text{peak hour factor} \times ADT \text{ where,}$$

DWT = Design Weighbridge Traffic Volume

Peak % overloading

= % of truck volume that is expected to be screened off into the axle load station for further weighing

ADT = Average Daily Traffic = Arithmetic average of the daily traffic volume

Currently, all the loaded trucks are to be diverted into the weighbridge for weighing as there is no screening on-going. Therefore the peak percentage overloading does not apply in assessing the existing facility as all the loaded trucks are expected to be weighed. However, considering that there are plans to install High speed weigh-in-motion system with a screening lane already in place, the peak percentage overloading shall also be analyzed to factor the planned improvements and how they would affect the capacity and efficiency of the weighbridge.

2.4 Previous Studies Abroad

2.4.1 Weight Limit Enforcement in the US

Taylor et al. (2000) showed in their study the general functional form between enforcement visibility and overweight violation rate based on several studies performed by seven state enforcement agencies in the US as shown in the table 2.6.

Table 2.6: Violation rates at different enforcement levels in US States

State (No. of Weighbridges sampled)	High Enforcement Level Violation Rate	Low Enforcement Level Violation Rate
Virginia (2)	0.5-2%	12-27%
Maryland (2)	1.0%	34%
Arizona (2)	1.5%	30%
Wisconsin (3)	1.0%	20%
Idaho (4)	11.9%	32%
Florida (5)	1.4%	13%
Montana (6)	1.0%	29%

Source: Taylor et al. (2000)

They further indicated that when the average overload on a truck was 12% in excess of the legal weight, it could cause 57% extra damage of the original truck weight when the traditional fourth power rule (the rate at which a vehicle destroys a road is proportional not to its weight but to the *fourth power* of its weight) is applied. Figure 2.7 shows that pavement life can be reduced by approximately 50% if axles are overloaded by 35%.

Although other factors, such as drainage, material properties and construction quality also affect pavement life, overloaded axles are by far the dominant factor in reducing pavement life. Adequate enforcement has acted as deterrent by declaring that those travelling in disregard of laws and regulations would be apprehended and would face effective punishment. Studies such as the one shown in table 2.6 aided the Government’s resolve not to relent on high enforcement levels at the weighbridges (Strathman, 2001).

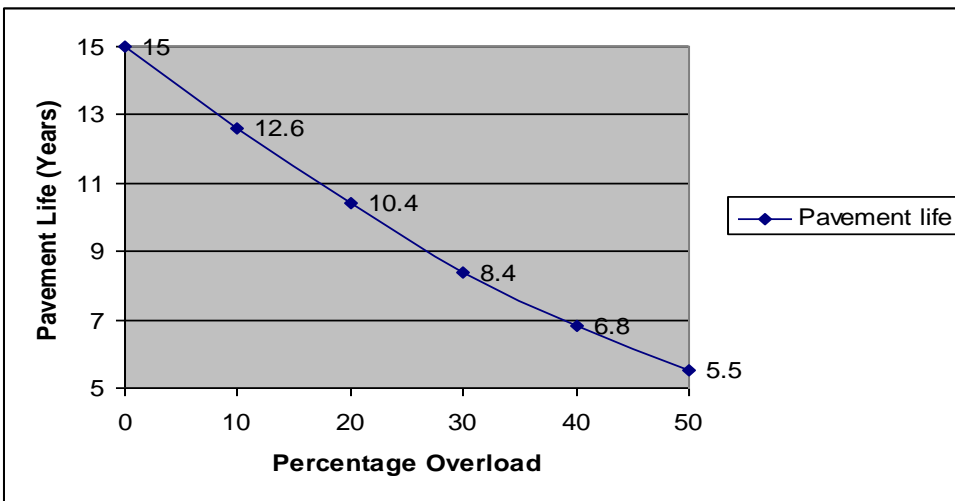


Figure 2.7: Pavement Life Reduction due to Overloading

Source: Taylor et.al. (2000)

2.4.2 Cost Benefit Evaluation Study of the Computerized Interstate Check Posts of Gujarat State, India.

The Indian Institute of Management, (2002) reported that the transport companies, with an intention to maximize their revenue per truck, tended to load their trucks beyond permissible axle load, creating a serious safety hazard. It was estimated that about 70% of the commercial vehicles crossing the state borders were overloaded. The existing scenario at the check posts, changes implemented and the outcome has been highlighted in subsequent paragraphs under this section.

Check posts were set up on the state borders by the state government to check if vehicles passing through these borders had paid all the road taxes, carried proper documents, and conformed to the loading and dimensioning norms. The Regional Transport Offices (RTO) of the state’s Transport Department managed these check-posts. The state of Gujarat had set up 10 check posts positioned at

the border with three neighboring Indian states. Nearly 25,000 transport vehicles passed these check posts on a daily basis at the time.

The process of verification of documents, estimation of penalty amount and its collection at any traditional check post was manual, judgmental and time consuming. Due to these lengthy and cumbersome procedures, the state governments had not been effective at reducing the number of overloaded vehicles. With the manual system, the inspection of 100% of commercial vehicles was impossible thus resulting in slippage and heavy revenue losses to the state. Due to manual intervention, it was perceived that truck drivers were harassed at the check posts, held up for several hours, and arbitrary penalty charges and speed money are collected from most of them.

In 1999 in order to improve the situation at check posts, the transport department of Gujarat redesigned the processes at its check posts. Large yards were created at the check posts and processes of inspection and estimation were mechanized by deploying electronic weighbridges, video cameras and computers. Such modernized check posts called the Computerized Interstate Check Posts (CICP) were created at all the 10 interstate sites.

The interaction with the Regional Transport Office (RTO) team at the check-post gave an optimistic view of the effectiveness of CICP, which appeared to be a well-conceived system, developed and executed with the total cooperation of the RTO staff amidst tight deadlines. The various technology components of the computerized system such as electronic weighbridge, video camera, video server, computer and hardware appeared to have been seamlessly integrated to fulfill the objectives of the project. Financial reports presented to the study team reveal that the revenue from the check posts had increased significantly within a year of implementation.

The Transport Commissioner ensured that all the government officials, who may have viewed CICP as a potential threat, were made parties to the implementation of the project right from its conception. They were given training on computers and some of them were involved in developing programming modules of the software. This process inculcated a sense of ownership of the computerized system in the RTO officials.

The drivers interviewed gave mixed responses on the impact of CICP. Most of them expressed satisfaction over the electronic weighbridge, which had become an integral part of check post operations. The drivers found that the waiting lanes and parking lanes were spacious and comfortable at the time. During the exploratory study, it was observed that a transaction (the process of weighing, penalty calculation and document checking) took about 2 to 3 minutes, which was much less compared to the 10+ minutes it took at a manual check post.

2.4.3 Weigh-in-motion experiment in France

Dolcemascolo (2008) in his presentation to the 5th International Symposium on Weigh-in-motion discussed the French experience in Bridge Weigh-in-motion. He noted that overload enforcement at the time was performed by static weighing which was money consuming, and led to less and less dissuasive enforcement. Overload screening and enforcement efficiency therefore needed to be improved. This led to the development of weigh-in-motion.

SiWIM is a bridge weigh in motion system developed by CESTEL in Slovenia and adopted in France. Dolcemascolo (2008) further noted that it allowed measurement of traffic data: silhouette, vehicle length, speed, axle weight and it was impossible for a driver to avoid the overloading controls. It had cameras that supported identification of vehicles and provided an advantage through invisible detection of vehicles.

The French test showed that the accuracy is good although it depended on the site characteristics, the quality of the calibration and the skills of the team. Dolcemascolo (2008) noted that the installation of weigh-in-motion scales contributed greatly to the reduction in overloading cases by over 50% and greatly improved transparency at the weighbridge stations.

2.5 Previous Studies in Africa

2.5.1 Progressive Overload Control in Namibia

Similar to the Kenyan situation, effects of Heavy Goods Vehicles overloading on the road networks in Namibia had been an issue of discussion in national and regional forums for many years and as such, in 2001 the road sector coordinating agencies identified heavy vehicle overloading as one of the priority areas that required urgent consideration to reduce the rate of deterioration of the networks.

Pinard (2011) noted that Namibia had for a long time recognized the negative impact of overloading on its road network and the country developed strategy to curb the impact, through the following measures:

i. Effective Criteria for Weighbridge Siting and Design

The criteria for the selection of weighbridge sites at strategic points on the road network were:

- The level of heavy vehicle traffic on the road sections.
- The presence of essential services to minimize inconvenience to the heavy vehicle operators and the overload control personnel.
- Future road network development and potential to generate heavy vehicle traffic.

Because of the different levels of traffic, two classes of weighbridge facilities were adopted, Class A for construction at sites with high daily heavy vehicle traffic and Class B for relatively low daily heavy vehicle traffic with provision for upgrading to Class A when traffic volume justifies. The following facilities are provided for each of the classes:

Class A

- weighing facilities, comprising a multi-deck platform
- slow speed weigh-in-motion for screening
- control room
- ablution facilities
- parking area for apprehended vehicles
- Water connection/ borehole for reliable water supply

Class B

- 3x 4 m single-deck platform
- control room
- parking area for apprehended vehicles
- Minimum ablution facilities

ii. Weigh-in-Motion and vehicle load monitors

Two weigh-in-motion sensors, one in the south-bound lane and one in the north-bound lane have been installed at Brakwater weighbridge north of Windhoek, Namibia to screen vehicles. Only vehicles

suspected of being overloaded are sent to the weighbridge. Weigh-in-motion equipment has also been installed at Walvis Bay weighbridge in Walvis Bay city, Namibia. The Roads Authority has five vehicle load monitors used to monitor escape routes and other minor roads.

The weighing in motion helps relieve the weighbridges of congestion through faster process and although not installed in the Western Kenya weighbridges, there is an on-going project whereby the weighbridges are being upgraded by installation of weigh-in-motion sensors.

iii. Weighbridge Management and Dedicated Personnel

The recognition of the damage potential of overloaded heavy goods vehicles to pavements and the associated costs prompted the Roads Authority, as the road network manager, to establish within its organizational structure a section dedicated to traffic law enforcement. By so doing, the authority is focusing on one of its core functions as provided by the Roads Authority Act, that is, “prevention of excessive damage of roads by road users or any other parties”.

The Road Transport Inspection Services has representation country wide and is responsible amongst others for overload control operations at all the existing weighbridge facilities. The operations include weighing of heavy vehicles, issuing of fines and prosecuting operators that exceed the prescribed load maximums on axles, axle units, axle combinations and total vehicle/comboination mass. The countrywide representation consists of five regional offices headed by Regional Control Inspectors working with between five and nine inspectors and between one and four scale operators who perform the weighing of vehicles while inspectors perform the law enforcement aspects. The weighing operations are coordinated by the manager of the section at head office.

iv. Training of Dedicated Personnel

The requirements to be appointed as a Road Transport Inspector are grade 12 (Standard 10) with a basic diploma in road transport and traffic officer’s course. After the officers have been appointed, they undergo training in basic advanced overload control course. Officers also attend criminal procedure courses, weighing competence and TrafMan software courses for them to be issued with competency certificates accepted by courts.

v. Overload Control Financing

The overload control operations are financed by the Road Fund administration through the Roads Authority budget. The fines collected in respect of overloading offences are paid to the State account thereafter collected by the Road Fund administration.

vi. Overload Control Information Monitoring System

One of the problems facing overload control in the region is the occurrence of corruption at weighbridge facilities due to human interventions. The Roads Authority has implemented overload control computer- based information through the TrafMan system to network the operations of all weighbridges.

The system has the capability of transmitting the live weighing data to a central system at the head office for easy access by the data manager and the Roads Management System. In addition, a fully integrated management information system at each weighbridge record processes and produces the following reports amongst others:

- offence information including number of offences, max overloads and fine notices issued
- audit trail
- incident reports
- status of activities at the stations
- loading profile statistics
- effectiveness of overload control operations
- measurable indicators of pavement loading in terms of Equivalent Standard Axles.

vii. Stakeholders' participation and cooperation

The Road Authority conducts regular meetings and workshops to educate operators, drivers and sensitize magistrates and prosecutors on the effects of overloading. An Overload Control Technical Committee was recently established consisting of representatives from the Ministry of Justice and Attorney-General, the Road Authority, the Ministry of Works, Transport & Communication and the Ministry of Trade and Industry. Its mandate is to formulate weighbridge guidelines and deliberate on technical and legal issues relating to overloading.

A number of the measures implemented in Namibia had been recommended in Kenya following the Best Options Study on Axle Load Control Practices in Kenya in 2006 by the European Commission. However, they have only been partially implemented. For example, weighbridge management has improved as a result of the privatization, there is increased awareness. There are still deficiencies in training of personnel, effective design criteria for the weighbridges, overload control information monitoring system and even stakeholder participation. These present gaps in the current design, operations and management that this thesis seeks to address.

2.5.2 Process-related load control program in Zambia

Pinard (2011) asserted that road transport is an important component in the economy of Zambia as a large proportion of goods are transported by road. The proportion of overloaded vehicles (above the legal axle load limit of 10 tons) has typically been in the range of 20 to 40 percent depending on the district and the season of the year. Single axle loads above 20 tons were often recorded during previous surveys. Heavy vehicles are often involved in road accidents in Zambia, and some of these accidents are caused by overloaded vehicles.

Like many other countries in the region, the Zambian Road Authority has long recognized the importance of axle load control. Weighbridges have been constructed and operated for a long time. However, the efforts at controlling overloading have generally been ineffective for various reasons such as no training, inadequate supervision, inadequate services and facilities at the weighbridges and corruption. (Pinard, 2011).

Based on the regional recommendations, Zambia has developed its own initiative called *A Process Related Axle Load Control Programme for Zambia*. Pinard (2011) added that the initiative was taken by the Zambian Road Authority and the donor community in 2001 to develop a program and establish a project with a timeframe of four years to regain control over the situation. The development of the program was funded by the Norwegian Government based on institutional cooperation between road authorities and the Norwegian Public Road Administration (NPRA). NPRA had previously worked within the same fields and conditions in Tanzania. Zambia later decided to use the same mode of cooperation and the same institution as a counterpart in the implementation of the project. The project started officially in June 2004 and was substantially completed in 2009.

The Program Design

Pinard (2011) noted that the program was a process-related one which covered the most important shortfalls identified in the previous system. The main elements of the program were as follows:

- Undertaking information and awareness campaigns;
- Improving organization arrangements and procedures;
- Pursuing legal initiatives where necessary;
- Revising current overload control procedures and training;
- Ensuring appropriate selection of weighbridge equipment and sites;
- Minimizing corrupt practices;
- Establishing a Vehicle Overload Management Information System;
- Commercialization/privatization of weighbridges;
- Undertaking stronger project monitoring; and
- Improving project administration and management of budgets.

The component of weighbridge equipment and site consisted of planning activities and investments. All the standards required for the development of new fixed weighbridges have been developed. These are as follows:

- Standard drawings and proposed weighbridge layout for small and large weighbridges
- Technical specification for weighbridges including modification of the Bilanciai platforms
- Architectural plans
- Standards for traffic signs
- Standards for lay-bys
- Standards for computerized program and printouts

The generated outputs from the project include:

- A greater awareness of the importance of overload control to the national economy has been provided to the transport industry in Zambia and neighboring countries through awareness and information campaigns. This helps give the transport industry an opportunity to adjust their practices and comply with the regulations ahead of the new government enforcement routines.

- The development of a management system consisting of necessary changes to existing management processes, procedures and documentation for the implementation of practical system to curtail overloading. This includes sustainable and reliable data collection.
- The development of a training manual for weighbridge operators so as to adequately train the operators. This will facilitate the smooth implementation of the new system.
- The upgrading of weighbridges and updating of weighbridge controls on the road network including the construction of reliable weighbridges and accurate means of recording the weighing results.
- Greater satisfaction from the drivers regarding facilities and services provided at the major weighbridges.

Pinard (2011) acknowledged that the significance of the program cannot be over emphasized. There was no doubt that it would contribute significantly to the improvement of the road network in Zambia. The legislation provided the legal backing necessary to control overloading in a firm but reasonable manner. It also reduced the unfortunate practice that negates the enforcement process and unfair competition against those who do not practice it as a matter of policy.

Zambia had started to reap the benefits of its process-related axle load control program in terms of a significant reduction in overloading since 2008.

2.5.3 Privatization of Weighbridge Operations in Western Cape, South Africa

Pinard (2011) reviewed the privatization of weighbridge operations in Western Cape, South Africa. He noted that the first important strategic decision taken by the Roads Infrastructure Branch, under the Department of Transport and Public Works, was that the long term benefits of allocating a portion of the road maintenance budget to overload control exceeded the short term losses due to having less funds available for the ever increasing demand for road infrastructure maintenance and improvements.

The first step however, was to come up with a new dispensation on how the problem of overload control should be tackled in order to make best use of the funds allocated to this function. Key aspects that provided guidance on the model selected for implementation were identified from the onset, namely:

- Only traffic officers employed by the provincial government or local authorities might perform law enforcement duties on the provincial roads;
- All fines collected go to the local authority in whose area of jurisdiction the weighbridge is situated, and not to the authority providing the law enforcement nor to the Department of Justice that provides the judicial system;
- The Office of the Public Prosecutor must be satisfied that the new dispensation does not compromise their position of prosecuting offenders successfully.

Essentially two models were considered. Pinard (2011) discussed the models as detailed below:

i. Public-private partnership model

In this model, the facilities and the law enforcement function are handed over to the private sector for a predetermined period. Performance standards are set for the facility maintenance, the law enforcement effort and to what extent fines have been recovered and payment are based on whether these standards are met or not.

Factors that played a role in not opting for this model were:

1. The Roads Infrastructure Branch realized that they are in a better position to negotiate the law enforcement effort with the provincial traffic authority than putting the onus on the private partner to do so.
2. The Director of Public Prosecution provided strict guidelines on the involvement of the private partner's personnel and what they may or may not do in order not to compromise the prosecution process. Aspects that played a role were:
 - Involvement of the private partner's personnel may only be at a level where it would not be necessary to appear in court for neither the prosecutor nor the defense.
 - The private partner should have minimal duties concerning fine recovery, and payment based on performance which entails that fine recovery will not be allowed. The main reason for this is that overload control could be seen as vindictive if the private partner receives financial gain based on recovered fines.

ii. Private sector participation model

In this model selective tasks to be performed at the weighbridge were offered to the private sector on tender basis. This model was first implemented as a pilot project at the Beaufort West weighbridge site before the services were outsourced on a tender basis.

The tasks outsourced can be categorized in two main categories – Facility management and support staff.

1. Facility management

- Maintenance and upkeep of the fixed assets
- Scale repairs and the regular calibration (verification) thereof
- Maintenance and upkeep of office equipment and furniture
- Maintenance and upkeep of mobile screening devices and other equipment used by the traffic officers in their duties
- Services to the site which include water, electricity and telephone

2. Support staff

- Site agent to oversee the operations and provide vital link with the law enforcement agency
- Staff to assist the traffic officers in their task of overload control according to procedures approved by the Director of Public Prosecutions
- Site clerk to provide administrative support for the site agent and the law enforcement agency
- Cleaning and gardening staff to tend to the cleanliness of the working environment and the daily upkeep of the grounds
- Caretaker to provide 24-hour 7 days a week presence, especially during hours when there is no weighing activity

The advantages of this model over the old dispensation where the sites were handed over to the provincial traffic department for overload control purposes are:

- Previously overload control was done on an ad hoc basis and it was easily seen as a non-essential task, especially when traffic officer resources were low. With the private sector involvement overload control became an essential task (similar to providing point duty at a busy intersection on a daily basis). It could be considered fruitless expenditure paying for

support staff whilst the traffic officers do not report for duty at the weighbridge site, an aspect that they are very aware of and try to avoid.

- Aspects that caused frustration with the traffic officers such as the cleaning and maintenance of the facilities and equipment are taken care of on a daily basis with a lot less hassles as previously experienced.
- Responsibility of the working environment lay with a single person, the site agent, whereas in the past it rotated depending on the officer in charge for a specific period or day. Time delays resulting from lost keys or lack of printing paper due to the previous team not ordering new stock were thus eliminated.

Pinard (2011) noted in his summary that there had been a beneficial difference with the new initiative with overloading being reduced by up to 30% as a result of privatization. Weighing is now continuous while the weighbridges are well maintained, water services and communication facilities adequately provided and expansion of the weighbridge facilities in terms of buildings, accommodation for staff, and wash rooms are on-going. The satisfaction of drivers with the weighbridge operations has greatly improved with a large proportion noting improved efficiency and transparency in the operation.

The Kenya Government through Kenya National Highways Authority adopted a similar privatization model in January 2013 when management consultants were contracted to manage the weighbridges and supervise any on-going or planned improvements at the respective weighbridges. There are already some improvements in the operations of the weighbridges and if the model is emulated, similar and higher levels of success can be achieved in the Kenyan scenario.

2.6 Previous Studies in Kenya

2.6.1 Best options study “Assessing the current Axle Load Control (ALC) in Kenya” Recommendations

The purpose of the Study was to determine options for axle load control (ALC) of the road network in Kenya and recommend the best solution for the implementation of a sustainable system for enforcement of axle load limits in the country.

Implementation of this study was supposed to be undertaken in the long term, subject to available information regarding Heavy Goods Vehicle traffic flows and also after subsequent assessments of the proposed details. This implementation programme was to be initiated in three phases.

A review of the above implementation phases have captured at least one or more of the following key components of “*Axle Load Best Options Study*” conducted by the European Union in 2006 namely:

- Options for facilities at weighbridges located on the road network.
- Options relating to the location of weighbridges to control heavy vehicle traffic on the road network.
- Options relating to the management of the facilities at the weighbridges.
- Options for the operation of the facilities.

2.6.1.1 Component 1 – Implementation Phase 1

(i) Proposed Activities

The following activities were recommended under this component:

1. Upgrading the existing facilities on the Northern corridor encompassing establishing a TCC1 facility at Gilgil as part of the Mai Mahiu to Lanet Road Project
 2. Establishing a new screening facility at the port
 3. Initiating of necessary amendments to the Traffic Act to legitimize recommendations
 4. Developing, compiling & submitting of privatization documents as required in the Privatization Act, 2005, to facilitate the privatization of the weighbridges
 5. Preparing management contracts (including for installation and maintenance of equipment)
- ;

2.6.1.2 Component 2 – Implementation Phase 2

(i) Proposed Activities

The following activities were recommended under this component:

1. Establishing of main stations on the Northern Corridor

2. Upgrading of the Webuye Station to a TCC5 (off road facility without in lane screening) facility
3. Establishing of a LCC facility at Busia Town on the Kisumu- Busia road and at Mai Mahiu on the Mai Mahiu – Narok road (subject to traffic counts)

2.6.1.3 Component 3– Implementation Phase 3

(i) Proposed Activities

The following activities were recommended under this component:

1. Controlling overloading of Heavy Vehicles to 10% or less
2. Establishing of Traffic Count Facilities to assess Heavy Vehicle traffic data on secondary and feeder routes
3. Contract out strategic Axle Load Control programme to a consultant
4. Creating of the proposed Kenya National Highways Authority and conferring it overall responsibility for the Axle Load Control.
5. Comprehensively automate procedures. Reporting must also be provided for and information analyzed and checked by both private contractor and consultant.
6. Recommend & implement regular calibration of weighbridges
7. Training of weighbridge operators and police officers in Axle Load Control, court procedures, overloads as well as the technical background to overload control
8. Installation and implementation of a computerized traffic management system that supports weighing prosecutions with connectivity to register of vehicles.

Some of the recommendations made in the study have been implemented by the Government.

These include:

- KeNHA was established as a State Corporation under the Kenya Roads Act, 2007 & granted the responsibility to carry out Axle Load Control within the national roads of classes A, B and C.
- Privatization Act has been put into force with KeNHA subsequently developing the weighbridge management contracts. This activity has been fully achieved. Gilgil Weighbridge Station and the other static weighbridges along the northern corridor are

currently under the management of SGS management consultants with effect from January, 2013.

- Traffic Act has been duly amended and the axle load control laws are now provided for in the provisions of the Traffic Act (Cap 403).
- Public Display Units have been installed at Gilgil Weighbridge Station
- Computerization of Gilgil weighbridge
- Regular calibration of the weighbridge equipment

2.6.2 Addressing the persistent delays at the weighbridges

Anyango (2011) highlighted the following in his study on persistent delays at the weighbridges in Kenya:

- Weighbridges in Kenya play an important role within the broader regional framework of the Northern Corridor; there are seven (7) fixed weighbridges between Mombasa and Malaba. Three have been licensed to private sector operators. Mariakani and Athi River are busiest with delays of between 3-4 hours compared to others at 1-2 hours
- Lack of awareness by the business community, more particularly transporters, on the consequences of overloading is a problem;
- There are two main reasons for non-compliant cargo loads (*Deliberate overloading of trucks by transporters and overloading at the Port of Mombasa despite smart cranes*);
- Overloading and corruption are related, with transporters keen on maximizing profits, being ready to bribe their way at the weighbridges
- Over 90% of trucks along the weighbridges are however compliant. Poor law enforcement is another area of concern.

Anyango (2011) further identified 24 bottlenecks which caused delays, in one way or another, eighteen (18) at the port of Mombasa and six (6) at the Weighbridges. These bottlenecks are presented in a Fact Sheet format. Each *Fact Sheet* contains the bottleneck, background, cause(s), current status and the outstanding issues (if any), and the institutions responsible. The fact sheets on weighbridges included:

Fact Sheet No 1: The overloading of trucks at the Port of Mombasa (*despite smart cranes*) and at the Ports of origin which generally contribute to non-compliance at the weigh bridges.

Fact Sheet No 2: The infrastructural facilities at most of the weigh bridges are old and dilapidated.

Fact Sheet No 3: The weigh bridge processes are to a large extent manual and can be manipulated.

Fact Sheet No 4: The presence of police within the weighing area as a precursor to delays and malpractices such as corruption.

Fact Sheet No 5: Short and unrealistic contract periods for the weighbridge managers.

Fact Sheet No 6: The failure to ensure strict adherence to the law with regard to enforcing the existing penalties.

The concerns raised in the study were legitimate and applied to all the static weighbridges in Kenya. While weighing process was not manual in Gilgil, it was still prone to manipulation and the infrastructural facilities, with the exception of the offices, were old and needed of upgrading.

2.6.3 Improving Axle Load Control- Current and Future Interventions

Ogege (2011), in a presentation to a stakeholder's forum at the Kenya Ports Authority, Mombasa, highlighted current and future interventions towards improving axle load control in Kenya being undertaken by Kenya National Highways Authority. Below is a summary of his presentation:

There were a total of 13 weigh bridges in Kenya, with 12 being fully operational. 3 of these were under private managers. The desire of KeNHA was to privatize all the weighbridges. With regard to improvements at the weighbridges, KeNHA had begun installing new scales to address the problems of discrepancies in weights; installing automated systems; unless there was a breakdown, tickets were not manually generated. Public Display Units were also installed conspicuously, and a driver could then see the whole weighing procedures.

Improving the facilities ongoing – *Mtwapa, MaaiMahiu, Gilgil* - two weigh bridges would be ultra-modern (*rolling out contracts for Mariakani and Athi River*). When funds allow, this would be

replicated at Webuye, Gilgil and Eldoret. KeNHA had installed weigh in motion scales at Athi River, Mariakani, and was planning to install them at Maai Mahiu and Gilgil. Compliant trucks would move through green channel without any stopping.

Construction of an additional lane at Mariakani – 80 million shillings; to construct auxiliary lane approach to weigh bridge station and installing new static scales; Fencing of the weighbridge station to preclude idlers and construction of lay by's at Malaba, Mai Mahiu and Busia and the establishment of weighbridge Oversight Committee. These were expected to be implemented within the next two years but were yet to be implemented as at 2016.

With regard to corruption, approximately 30 staff had been fired at Athi River alone, during the joint sting operations, conducted in partnership with the Ethics and Anti-Corruption Commission. KeNHA was also working with transporters around Nairobi to encourage self-regulation which was to minimize incidences of overloading.

2.7 Policy, Regulations and Legislative Framework

The Penal Code classifies offences and specifies maximum penalties for these offences. The Criminal Procedure Code determines the procedures for prosecution and the Courts that can deal with offences relating to overload control. The Traffic Act (Cap 403) that provides for the control of axle and vehicle loads, as well as other Acts specific to this study, is therefore governed by these general public laws.

2.7.1 Traffic Act Cap 403 / Traffic (Amendment) Act 2013

The Traffic Act regulates the technical aspects of axle loads and prosecutions. Sections 55, 56, 57, 58, 72, 16, 107 and 108 of the Act are relevant to the regulation of axle loads and prosecution of offenders. Rules 39, 41 and Schedule 12 to the Rules are relevant to axle loads.

These provisions provide for the following:

- Prohibits the use of a vehicle that exceeds the maximum weights or dimensions (Section 55(2)).
- Prohibits the use of a vehicle that exceeds the load limits specified by the manufacturer of the vehicle concerned (Section 56(2)).

- Prohibits the use of vehicle that is loaded in such a way as to cause danger other persons (Section 56(2)).
- Provides for abnormal load permits (Section 57(1)) to deal with loads that are too large to be carried on normal transport.
- Provides for the maximum fines for offences, including overloading [Section 58(1)] and that a different fines may be imposed for a second or subsequent commission of a similar offence; in other words, this section empowers the Minister to prescribe heavier fines for repeat offenders.
- Provides that the person responsible for loading a vehicle may be held responsible for the use of the vehicle on the road [Section 58(2)].
- Provides that the licence of a vehicle that has been used in two or more overloading offences within a period of 12 months must be suspended for six months. [Section 58(3)].
- Empowers the highway authority to recover the cost of the repair of damage caused by a vehicle to a bridge from the owner of such vehicle (Section 72).
- Empowers a police officer to remove a vehicle from the road if it is used in contravention of the Act (Section 106(1)) and detain a vehicle that is overloaded until the load is adjusted (Section 106(2)).
- Requires the name and address of the owner, as well as the tare and maximum weight of a commercial vehicle to be painted on the vehicle (Rule 39).
- Limits the volume of fluids to be carried in tankers (Rule 41)

In exercise of the powers conferred to the Cabinet Secretary for Transport and Infrastructure by section 119 (1) of the Traffic Act, he amended the previous Traffic Act on maximum allowable gross vehicle weights as summarized in the table 2.7. Their corresponding axle configurations are expressed in brackets after the descriptions with T standing for tonnes. These changes cited as the Traffic (Amendment) Rules, 2013, were duly enforced (from 1st June 2013) and were in operation at the time of this study.

Table 2.7: Axle Configuration and Limits

Description (axle configuration)	Previous Limit (in Kg)	Current Limit (in Kg)
Rigid Chassis vehicle with 2 axles (8T+10T)	18,000	18,000
Rigid Chassis vehicle with 3 axles (8T+18T)	24,000	26,000
Rigid Chassis vehicle with 4 axles (12T+ 18T)	28,000	30,000
Vehicle & Semi trailer with 3 axles (8T+10T+10T)	28,000	28,000
Vehicle & Semi trailer with 4 axles (8T+10T+18T)	34,000	36,000
Vehicle & Semi trailer with 5 axles (8T+18T+18T)	42,000	44,000
Vehicle & Semi trailer with 6 axles (8T+18T+24T)	48,000	50,000
Vehicle & drawbar trailer with 4 axles (8T+18T+10T)	36,000	36,000
Vehicle & drawbar trailer with 5 axles (8T+18T+8T+10T)	42,000	44,000
Vehicle & drawbar trailer with 6 axles (8T+18T+8T+18T)	48,000	52,000

Source: Traffic (Amendment) Act 2013

The amendment further granted an operational allowance of 5% on the above legal axle and axle group weights limits. Any vehicle established to be overloaded on the Axle or Axle Group but was within the prescribed Gross Vehicle Weight as per the Axle configuration was to be allowed to redistribute its cargo to within tolerance before being re-weighed and allowed to proceed with its journey. Such vehicles were not be charged. Any vehicle which was overloaded on the Axle and Axle Group and could not redistribute its cargo to within allowable tolerance was to be charged.

Table 2.8: Overloading fines

Degree of Each Axle Overloading or Excess Gross Vehicle Weight in Kilograms (kg.)	Fine (KSh.)	
	Fine on First Conviction (KSh.)	Fine on Second or Subsequent Conviction (KSh.)
Less than 1,000 kgs	5,000	10,000
1,000 kgs or more but less than 2,000 kgs	10,000	20,000
2,000 kgs or more but less than 3,000 kgs	15,000	30,000
3,000 kgs or more but less than 4,000 kgs	20,000	40,000
4,000 kgs or more but less than 5,000 kgs	30,000	60,000
5,000 kgs or more but less than 6,000 kgs	50,000	100,000
6,000 kgs or more but less than 7,000 kgs	75,000	150,000
7,000 kgs or more but less than 8,000 kgs	100,000	200,000
8,000 kgs or more but less than 9,000 kgs	150,000	300,000
9,000 kgs or more but less than 10,000 kgs	175,000	350,000
10,000 kgs or more	200,000	400,000

Source: The Traffic Act, Legal Notice No. 65, Kenya Gazette Supplement No. 65, 12 September 2008

Currently, overloading is regarded as a criminal offence and the fines are defined as “Overloading fines”. These fines are collected by the courts and allocated to the country’s general budget as opposed to the ‘Road Maintenance Fund’. Hence the fines collected end up in other development projects/areas other than contributing to road maintenance.

2.7.2 Integrated National Transport Policy, 2009

The *Recommendations on Integrated National Transport Policy: Moving a Working Nation Main Document Volume I*, states the following regarding regulation and control:

“The management, regulation or control of elements of the transport system may result in financial income (charges for inspections, or fines etc.) or in non-monetary benefits (reduction of casualties, or preventing abuse of monopoly power etc.) It is proposed that a more direct linkage be established between the tangible and intangible benefits of these activities and defraying the costs of such management, regulation and control.”

“This includes the management of the road traffic system to promote safety, security, and a higher level of service. In this case a closer relationship between expenditure and the revenue generated (e.g. the revenue from traffic law enforcement, or insurance) should be established. The GoK will strive to be consistent ensuring that revenues generated in a transport subsector are ploughed back, although it recognizes that it may not be applicable in all cases. Where it has to deviate, it will strive to make financing transparent. In particular, all subsidies will be made transparent. In all cases of GoK financing the return on investment (whether financial, economic or social) of monetary and other resources will be justified.”

There are four issues that can be identified with regard to the current fines that are prescribed for overloading: the level of the fines, the absence of higher fines for second and third-time offenders; the absence of a differentiation in fines for the driver, the operator and the “loader” and the fact that fines are paid into the Consolidated Revenue Fund.

2.7.3 EAC Vehicle Load Control Bill, 2012

Owing to the merger of the East African Countries to form the EAC, through research and scientific studies regarding vehicle load control, the East African Legislative assembly passed EAC Vehicle Load Control Bill, 2012. The bill is yet to be assented to by the EAC heads of state. It is deemed to lower the cost of doing business if properly implemented. Below is a summary of the Bill highlights;

- Decriminalization of overloading by partner states and fees to be set based on the recovery of road damaged costs (this is however subject to further consultations during formulation of regulations).
- Reviewing of maximum permissible load to 56 tonnes and introduction of seven axles.
- Revoking of quadruple axle groups.
- Allowance of 5% on the legal axle loads.
- Undertake standardized training of weighbridge staff at a regional training institution following a regionally prescribed syllabus. The outputs of such training should be certified and accredited with a regional educational body.
- All weighbridges on the regional road network to be networked and to be linked electronically to a regional data centre to facilitate sharing of information on overload control.
- Development of a regional weighbridge certificate and mutual recognition by all EAC Partner States of such a certificate and related documentation issued by an accredited weighing station.
- Development of a weighbridge operator's manual to ensure that all weighbridge operations are carried out in a proper, consistent and standardized manner in all EAC Partner States.
- In principle, the private sector should be involved in some aspect(s) of overload control operations.
- More extensive use of WIMS is recommended, in conjunction with static weighbridges, to reduce the number of commercial vehicles that need to be weighed.
- An audit of existing weighbridge infrastructure that has been identified as forming part of the regional weighbridge system should be carried out. This should include an evaluation of the existing facilities in terms of weighbridge type (single axle, axle unit,

multi-deck), computerization, staff and driver facilities, parking-off areas, etc. in order to determine the required upgrading and estimated cost implications.

Although the bill is not yet ratified by the member states, it contributed to the revision of the axle load limits in Kenya from 48 tonnes to 52 tonnes for 6 axles and introduction of 7 axles with 56-tonne load axle load limit while awaiting ratification. It also contributed to the allowance of 5% on the legal axle loads. These formed part of the amendments to the traffic act in June 2013.

2.8 Literature Review Summary

A summary of the literature review has been presented in table 2.8 and highlights the main strengths of each reference and their corresponding gaps.

Table 2.8: Literature review summary

	AUTHOR, YEAR	TITLE	STRENGTHS	GAPS
Design Manual/ Guidelines				
1.	Sub-Saharan Africa Transport Policy Program, Working Paper No. (2010).	Guidelines on Vehicle Overload Control in Eastern and Southern Africa.	-Insight on types of weighbridges, their merits & demerits -Guidelines on facility Layouts Vs traffic -Guidelines on operations of weighbridges	-No detailed guidelines on services and support facilities corresponding to different facility layouts
2.	Vandael et.al. (2000)	A queuing Based Traffic Model	-Gives classification of Queuing models -Shows relationship Between various queuing parameters -Describes measures of	-It does not take into account the possibility of renegeing or balking

	AUTHOR, YEAR	TITLE	STRENGTHS	GAPS
			queuing system performance	
3	Highway Capacity Manual (2010)	Traffic flow characteristics	-It shows the relationship between flow, speed and density -It describes the Peak hour factor	-It does not show the application of the traffic characteristics in analysis of a weighbridge facility
Previous Studies Abroad				
1.	Dolcemascolo, V. (2008).	Weigh-in-motion Experiment in France	-Highlights the impact of introducing weigh- in-motion system in France.	-Does not explore challenges faced in implementation of the system.
2.	Indian Institute of Management, Ahmedabad (2002).	Cost Benefit Evaluation Study of the Computerized Interstate Check Posts of Gujarat State, India	-Gives a brief of situation before improvement -Discusses comprehensive computerization of Weighbridges/posts including installation of video cameras. -Discusses costs vs benefits of the computerized system -Highlights drivers responses to the improvement	-Does not mention the type of weighbridges & facility layout at the check posts

	AUTHOR, YEAR	TITLE	STRENGTHS	GAPS
3.	Taylor et.al. (2000)	Weight Limit Enforcement In the US	-Highlights the Impact of enforcement -Shows relationship between pavement life and overloading	-Does not define what low or high level enforcement entail
Previous Studies in Africa				
1.	Pinard, M.I. (2011).	Emerging Good Practice in Overload Control in Eastern and Southern Africa	-Highlights challenges and benefits of privatization in South Africa. -Gives effective design criteria for weighbridges Namibia, facilities provided at different weighbridges -Highlights weighbridge operations in Zambia and benefits of ALC	-Does not discuss the role of enforcement in reduction overloading in Namibia
Previous Studies in Kenya				
1.	Anyango, G.J. (2011)	Addressing the persistent delays at the weighbridges	-It discusses challenges facing weighbridge operations in Kenya which was useful to this study.	-It does not give the impacts of on-going improvements at various weighbridges in Kenya
2.	European Union (2006).	Best Options Study “Assessing the current ALC in Kenya”	-Assesses the ALC programme in Kenya -Reviews the legal and	-It does not discuss the role of enforcement in

	AUTHOR, YEAR	TITLE	STRENGTHS	GAPS
		Recommendations	institutional framework -Provides different options for short-term and long-term strategies in ALC in Kenya.	the success of the best options proposed.
3.	Ogege, S. (2011)	Improving Axle Load Control- Current and Future Interventions	-Discusses on-going and planned developments which were useful to this study	-Does not provide strategy for increased public awareness and training
Policy, Regulations & Legal Framework				
1.	EAC Vehicle Load Control Bill, 2012	East African Community (2012)	-Recommendations on overload control in East African states are highlighted and were important to this study	-It does not provide for how to arrive at the fees to be paid in place of fines -Effect of the increased axle load limit on pavement designs in Kenya is not covered.
2.	Integrated National Transport Policy, 2009	Ministry of Transport (2009)	-It discusses the application of revenue from Government control systems such as ALC.	-Not clear on where fines from ALC should be paid into.
3.	Traffic Act Cap 403/ Traffic Amendment	Ministry of Transport & Infrastructure (2013)	-It provides regulations for ALC-axle load limits, fines and axle load allowance.	-Does not clearly define who a loader is. -Does not put

	AUTHOR, YEAR	TITLE	STRENGTHS	GAPS
	Act 2013		These were relevant to this study.	restrictions on entrance into the transportation industry making it sometimes difficult to know the owner.

Source: Author (2015)

CHAPTER 3

3.0 Methodology

In order to achieve specific objectives of the study the research thesis consists of a structured exercise including Planning, Design and Operations.

3.1 Planning

The starting point to understanding the planning of the weighbridge station was a desk study involving review of any existing related literature from various sources:

(i) Internet materials related to the research-

This involved search for previous studies and research abroad, in Africa and in Kenya. Three cases were considered from abroad: weight limit enforcement in the US, Weighing-in-motion experiment in France and a cost benefit study of computerized inter-state check posts in India. Three case studies were identified in Africa that is, Progressive Overload control in Namibia, Process Related Load Control Program in Zambia and Privatization of Weighbridge Operations in South Africa. Previous studies in Kenya that were assessed were Best options Study “Assessing current ALC” Recommendations, Addressing the persistent delays at the weighbridges and Improving Axle Load Control- Current and Future Interventions.

The above studies were reviewed in relation to the assessment of operations at Gilgil weighbridge station and their applicability.

(ii) Related Policy, Regulations and Legal framework

Traffic (Amendment) Act of 2013 covers most of the regulations and legal framework for Axle Load Control in Kenya and formed the main part of this review. Integrated Transport Policy, 2009 was also reviewed. The East African Community passed a bill, the EAC Load Control Bill, 2012 which was also discussed and reviewed in this study.

(iii) Library Books and Reports

The reports and books reviewed were from the Kenya National Highways Authority Archives and include Sub-Saharan Africa Transport Policy Program, Working Paper No. 90, Truck Overloading

Study in Developing Countries and The East African Trade and Transport Facilitation Project Report. The reports also included those discussing the existing facilities at Gilgil and the planned improvements for the weighbridge station. They assisted in assessing the Planning for the weighbridge station.

Interviews, which is discussed under design and operations also assisted in assessing the Planning for the weighbridge station.

3.2 Operations

In order to assess the operations of the weighbridge station, similar parameters were used and included reconnaissance, interviews, review of reports and traffic surveys.

3.2.1 Reconnaissance

A reconnaissance site visit was conducted to familiarize with the existing conditions through observation at the weighbridge station understudy. The reconnaissance contributed largely to the formulation of the problem statement which was based on the existing condition in design and operations at the weighbridge station.

3.2.2 Interviews

The study involved interviews with various stakeholders who included:

1. Manager, Axle Load Control Unit- Kenya National Highways Authority.
2. Management Consultants at the Gilgil Weighbridge- The weighbridge manager, 1 system administrator, 1 weighbridge operator, and 2 clerks were interviewed.
3. Truck Drivers- 100No were interviewed
4. Chief Inspector of Police in charge of the police officers at Gilgil weighbridge station.

Questionnaires were used to conduct the interviews. Appendix 1 contains a sample questionnaire that was used to interview drivers. Information that was sought from the other interviewees is as listed:

Axle Load Control Unit- KeNHA

- What is Institutional framework at Gilgil Weighbridge?
- What is the Source of funding for Gilgil Weighbridge Operations?
- How is the new East Africa axle overload control act affecting KeNHA ALC?
- What are the planned improvements at Gilgil Weighbridge Station
- According to your Assessment, what are some of the legal gaps in the existing axle load control laws?
- How does KeNHA monitor the operations and performance of the management consultants at the weighbridge station?

Management Consultants of the Weighbridge Station

- What are the initiatives undertaken since your arrival?
- What are some of the challenges faced in the various sections of operation?
- Are you satisfied with your partnership with the Police? If not, why?
- What are the machines, facilities and equipment under your management at the station?
- How can the operations at the weighbridge be improved further?
- Do you have a training program? If yes, what does it entail, frequency?

Chief Inspector Police

- What is the prosecution procedure at the weighbridge station?
- What are the challenges faced by Police Officers at the station?
- How frequently are the Police Officers transferred from the station?
- Are the Police Officers trained in Axle Load Control? If yes, then by who and how frequent?

3.2.3 Traffic Surveys

In order to determine the capacities of the facilities to be provided at the weighbridges, the truck traffic was very important, hence the need to conduct the traffic surveys. This formed the basis of assessing the planning and design of the weighbridge station. The key data that was collected under this survey were:

- Waiting time- The time a vehicle enters the queue at the weighbridge shall be recorded. A computer print-out from the weighbridge operator shall indicate the time the first axle was weighed, among other information. Waiting time shall then be computed.
- Service time- Time from weighing of the first axle to the time the last axle is weighed. This shall also be obtained from the computer print-out.
- Hourly traffic- Heavy Goods vehicle traffic shall be recorded on an hourly basis while indicating direction. This will enable hourly traffic distribution and peak hourly flows to be determined.
- Origin and destination of the vehicles and goods carried.
- Axle load weights- Since the study is being conducted at the static weighbridge, the management consultants shall be requested to assist with this data in the form of a computer print-out.
- Parking Surveys- shall be conducted to establish the parking turn over. Parking turn over refers to the total number of trucks parked every one hour. There are trucks parked within the holding area and those that park outside the holding area but near the station at the exit. This shall be used to assess the efficiency of the existing parking facilities.
- Prosecution summary/ court fines for the period of the study.

This data was collected during a 24-hour 7-day period and involved 5 technicians (3 technicians on 12-hour day shift (7am-7pm) and 2 technicians on 12-hour night shift (7pm-7am)). They worked under the supervision of the researcher. One technician recorded the diverted traffic into the weighbridge and issued questionnaires to the drivers for their responses. The second technician in either shift recorded the un-diverted traffic only for vehicles greater than 7 tonnes. The diverted traffic recorded and their arrival times were matched with the computer printout by the weighbridge operator in order to determine queuing times and to confirm if all the vehicles that were diverted into the weighbridge were actually weighed.

The researcher administered the questionnaires to the other interviewees allowing opportunity for further discussions beyond the questions provided in their questionnaires. He also provided the Manager of the weighbridge with the facilities and equipment form to be filled. This was reviewed

further to confirm that what was included was indeed available at the weighbridge and also confirmed their status and condition.

3.2.4 Further Desk Review and Analysis

Desk review continued after all the data had been collected and data analysis was carried out in order to assess the adequacy of the facilities provided and the operations at the Gilgil Weighbridge Station.

CHAPTER 4

4.0 Research Findings, Analysis and Discussions

4.1 Results and Analysis from Interviews

Table 4.1 gives a summary of findings from various stakeholders who were interviewed as part of this research. The findings showed the structure of management of the weighbridges after privatization and the improvement in compliance since privatization of the weighbridges. The source of funding for weighbridge operations was also established as the Road Maintenance Levy Fund among other findings.

Table 4.1: Research findings from Interviews

Research query	Finding
Eng. Muita Ngatia- Axle Load Control Unit Manager-Kenya National Highways Authority	
Institutional Framework at Gilgil Weighbridge station	<ul style="list-style-type: none"> • Management Consultant’s team headed by Weighbridge Manager reporting to KeNHA ALC unit • Traffic Police headed by Chief Inspector reporting to Traffic Commandant
Source of Funding for Weighbridge Operations	<ul style="list-style-type: none"> • Roads Maintenance Levy Fund from Kenya Roads Board
How EAC Axle Overload Control Act (2013) affects KeNHA ALC	<ul style="list-style-type: none"> • Led to amendments to traffic act in June 2013 which included revised axle load limits, 5% operational allowance on axle load, reduction of weighbridge stations and introduction of 7 axles
Planned Improvements at Gilgil Weighbridge station	<ul style="list-style-type: none"> • Most of the planned improvements have been completed and include installation of High Speed Weigh-in-motion system, CCTV Cameras, Public Display Units, rehabilitating the holding bay. • Pending activity was rehabilitation of entrances and exits.
Any legal gaps in the existing axle Load control laws	<ul style="list-style-type: none"> • Overloading fines (legal notice no.65-2008) not commensurate with cost of road damage. • A loader is not clearly defined for clarity during prosecution of an overloading offender.

Research query	Finding
How KeNHA monitors operations and performance of Management Consultants	<ul style="list-style-type: none"> • Impromptu independent monitoring, monthly site visits and reporting.
Mr. Isaac Mugo- Weighbridge Manager	
Initiatives undertaken by the Management Consultants since arrival	<ul style="list-style-type: none"> • Reduction of Axle and Gross Vehicle weight (GVW) Overload • from average highs of 70% and 30% respectively to current levels of 35% and 2% respectively. • Supervision of on-going improvements at the weighbridge station • Elimination of unauthorized personnel who contribute to malpractices at the station • Improved cleanliness of the station and improved efficiency of weighbridge operators
Is there a training programme	<ul style="list-style-type: none"> • Yes, the head office conducts bi-annual training for the staff on overloading dangers, road maintenance, roles of various stakeholders, new legislations and their relevance.
Are you satisfied with your Partnership with the traffic police	<ul style="list-style-type: none"> • Yes, however; the separate reporting structure sometimes results into friction
Are the major facilities at the Station adequate	<ul style="list-style-type: none"> • No. Screening lane, backup weighbridge readers are inadequate
Mr. Wilson Njogu- Chief Inspector Police	
Is the traffic police the main source of malpractices at the station	<ul style="list-style-type: none"> • Not true and there are no malpractices at the weighbridge under the watch of the traffic police
How frequently are the Traffic Police transferred from the station	<ul style="list-style-type: none"> • On a quarterly basis
Is there a training program for the Police on axle load control	<ul style="list-style-type: none"> • Yes, SGS (the Management Consultants) conducts a bi-annual Training at the traffic police headquarters on axle load control, role of the police and other stakeholders, new related legislations
Are there challenges faced by the traffic police at the station	<ul style="list-style-type: none"> • None at the moment. The officers are trained, staffing capacity is adequate and there is good working relationship with SGS.

Research query	Finding
Drivers-100 drivers	
Main causes of overloading transporters	<ul style="list-style-type: none"> • To make more money • Poor enforcement of laws
What are the prevailing challenges at the Weighbridge station	<ul style="list-style-type: none"> • Service time is too long • Corruption
Best way of curbing overloading	<ul style="list-style-type: none"> • Increase amount of fines • Replace traffic police with special type of weighbridge police
How do you rate the efficiency of the weighbridge	Very Good- 0 Good- 11 Average- 59 Bad- 25 Very Bad-5
Have you ever been prosecuted at the weighbridge	Yes- 47 No- 53

Source: Author (2014)

4.2 Waiting/ Queuing Time Analysis

Waiting time is the time a vehicle takes from joining the queue to the time its first axles are weighed. Table 4.2 shows the average queuing times for the station during data collection which was after the installation of the High speed weigh-in-motion system.

The average queuing time for the month of July 2014 as obtained from Kenya National Highways Authority, the month immediately before HSWIM system came into operation, of *13.47 minutes* was recorded. From the data collected in this research after installation of the HSWIM weighbridge as presented in Table 4.2, the average queuing time reduced to 9.12 minutes for the week ending October 11th 2014. A seasonality factor of 1 was applied to give an average of 9.12 minutes for the month of October. The recorded times are still far above the recommended maximum times for a Type 1 Traffic Control Centre (TCC1) of 4 minutes for which Gilgil Weighbridge station is modeled to be in order to perform efficiently.

Table 4.2: Average Queuing Times

Days of the week	Average Queuing Times after Installation of HSWIM Weighbridge (Author, 2014)
Sunday Oct. 05 th 2014	3.68
Monday Oct. 6 th 2014	6.54
Tuesday Oct. 7 th 2014	9.67
Wednesday Oct. 8 th 2014	15.74
Thursday Oct. 9 th 2014	13.33
Friday Oct. 10 th 2014	10.21
Saturday Oct. 11 th 2014	4.64
Average	9.12

4.3 Service Time Analysis

Service time is the time taken from weighing the first axle to the last axle of a given vehicle. This data is not usually analyzed at the weighbridge station as it is not considered as critical as the queuing time.

Table 4.3 shows the recorded average service times as part of this research.

Table 4.3: Average Service Times

Day of the week	Average Service Time (minutes) after Installation of Multi-deck Weighbridge (Author, July 2014)
Sunday Oct. 05 th 2014	1.54
Monday Oct. 6 th 2014	1.51
Tuesday Oct. 7 th 2014	1.49
Wednesday Oct. 8 th 2014	1.26
Thursday Oct. 9 th 2014	1.34
Friday Oct. 10 th 2014	1.48

Day of the week	Average Service Time (minutes) after Installation of Multi-deck Weighbridge (Author, July 2014)
Saturday Oct. 11 th 2014	1.46
Average	1.44

Average service time of *1.44 minutes* was recorded during the research period with a multi-deck weighbridge in use. This was still indicative of low efficiency of Gilgil station as a TCC1 Facility considering that a maximum service time of *0.8 minutes* is required for an efficient operation of a TCC1 Facility (SATPP, 2010).

4.4 Weighbridge Capacity Analysis

Axle load analysis was done to determine the Design Weighbridge Traffic (DWT) volume for optimum operation. The Design Weighbridge Traffic volume is determined as follows;

$$DWT = Peak \% \text{ overloading} * peak \text{ daily volume factor} * peak \text{ hour factor} * ADT$$

Where:

DWT=Design weighbridge traffic volume.

Peak % overloading=% of truck volume expected to be screened off into the axle load station for further weighing.

Peak daily volume factor = $\left(\frac{peak \text{ day volume}}{off \text{ peak volume}} + 1\right) * 0.5$: - determined from the diurnal variation.

Peak hourly volume factor = $\left(\frac{peak \text{ hour volume}}{off \text{ peak volume}} + 1\right) * 0.5$: - determined from the hourly variation in traffic volume.

Average Daily Traffic = Arithmetic average of the daily traffic volume.

4.4.1 Average Daily Truck Traffic

Table 4.4 and Figure 4.1 give the Average Daily Traffic (ADT) volumes for trucks (Medium and heavy goods vehicles) at the Gilgil Weighbridge Station.

Table 4.4: Average Daily Truck Traffic (2014)

Vehicle Type	Daily Volume
Medium Goods Vehicles (2 axles > 7 tonnes)	33
Heavy Goods Vehicles (3 & 4 axles)	96
Heavy Goods Vehicles (5, 6, & 7 axles)	1910
ADT	2039

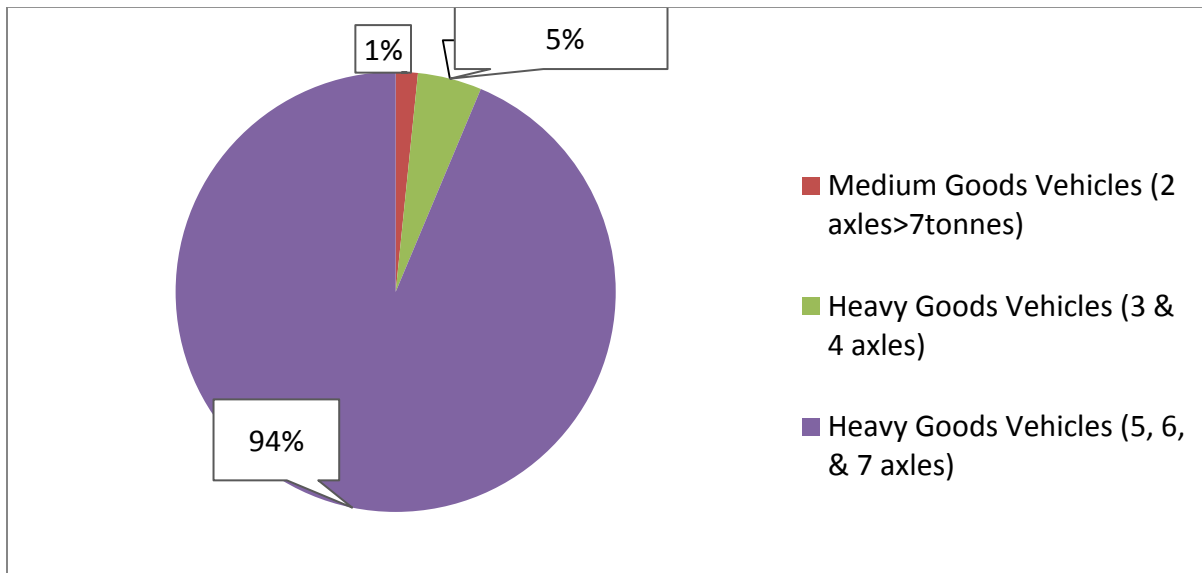


Figure 4.1: Traffic Volume Composition at Gilgil

Before installation of the screening lane and the High Speed Weigh-in-motion system, all these trucks were expected to be diverted into the station for weighing. However, at the time of the study, only the trucks that were potentially overloaded (within 10% of the limits) after passing through the HSWIM machine were diverted into the station for confirmatory weighing at the static multi-deck weighbridge.

4.4.2 Daily Traffic Variation

The daily variation in traffic volumes were analyzed, the results shown in Figure 4.2. The truck traffic was highest on Wednesday and remained until Friday before falling to off peak days. From Figure 4.2, the peak daily factor for Gilgil Weighbridge Station was determined using the following formula.

$$\begin{aligned} \text{Peak daily volume factor} &= \left(\frac{\text{peak day volume}}{\text{off peak volume}} + 1 \right) * 0.5 \\ &= \left(\frac{2594}{1576} + 1 \right) * 0.5 = 1.32 \end{aligned}$$

From the analysis, the adopted peak daily volume factor was **1.32** for Gilgil weighbridge station. Bell et.al. (2001) noted that peak daily volume factors of up to 2.5 indicate acceptable levels of daily traffic variations while values greater than 2.5 (peak day traffic more than four times the off peak day traffic) show an imbalanced system that may require policy actions to address.

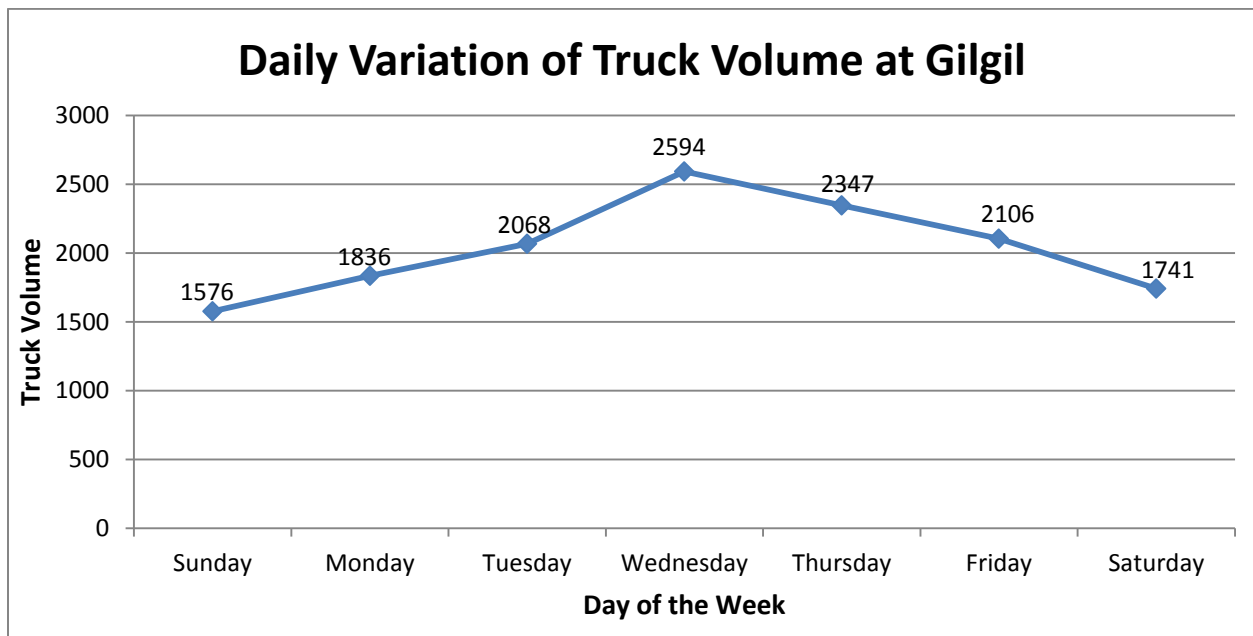


Figure 4.2: Daily Variation OF Truck Volume (2014)

4.4.3 Peak Hour Traffic Volume

Essentially, any traffic facility is designed to accommodate the peak hour demand. Further analysis was therefore done to consider the demand on the axle load station during the peak traffic time. This involved analysis of hourly variation of traffic volumes, the results of which are given in Figure 4.2.

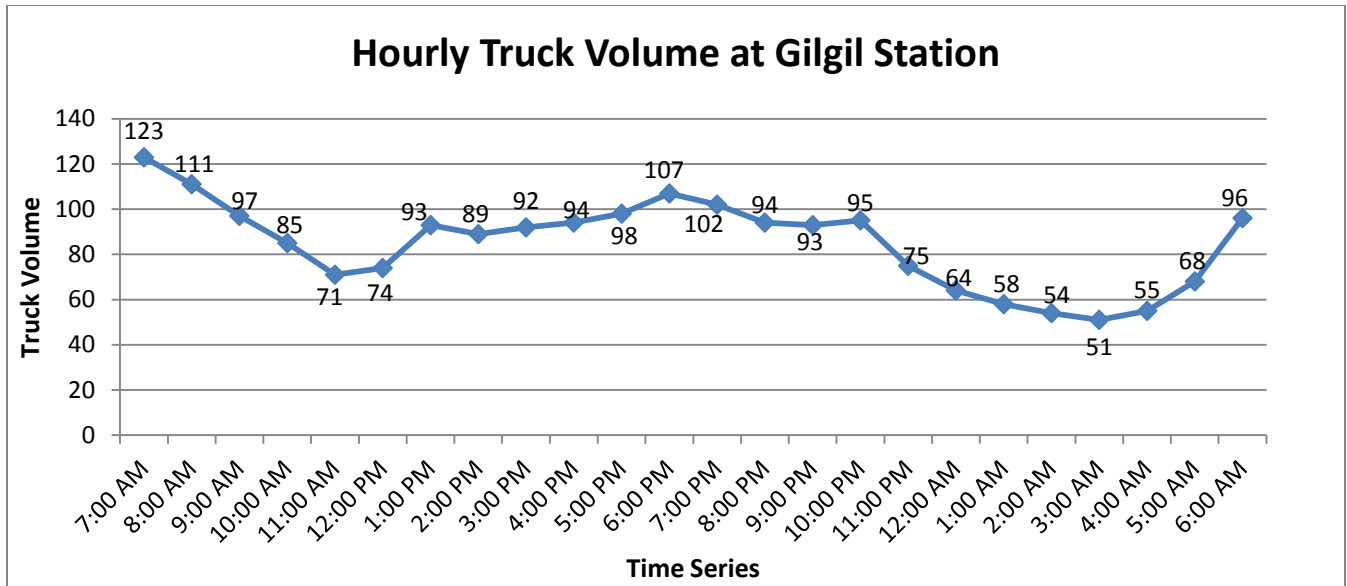


Figure 4.3: Hourly truck volume at Gilgil Weighbridge Station (2014)

From analysis of peak time truck traffic, the peak hour volume factor was determined as follows;

$$\begin{aligned}
 \text{Peak hourly volume factor} &= \left(\frac{\text{peak hour volume}}{\text{off peak volume}} + 1 \right) * 0.5 \\
 &= \left(\frac{123}{51} + 1 \right) * 0.5 = 1.71
 \end{aligned}$$

The adopted peak hour volume factor was therefore **1.71** and represented acceptable level of variation in hourly traffic. Peak hourly volume factors have higher allowances due to the night factor and values up to 10 have been found acceptable in many transport systems (Bell et al. 2001).

4.4.4 Percentage Overloading

The approach is based on the criteria that only trucks that appear are overloaded will be diverted into the Weighbridge station. Overloaded traffic comprises the following categories of trucks;

- Cautioned/warned: Trucks that have exceeded the axle load limits but are within the allowable 5% limit.
- Redistribution of loads: Trucks that have exceeded the axle load limits and have also exceeded the 5% allowance but are within the Gross Vehicle Weight limits
- Charged: Trucks that have exceeded the Gross Vehicle Weight Limits.

The adopted percentage for overloaded trucks was determined by comparing the peak percentage overloading for the duration considered. Summary of the peak percentage overloading is presented in Table 4.5.

Table 4.5: Peak percentage overloading

Year	Peak Month	Peak Percentage Overloading
2012	July	79.84%
2013	April	63.74%
2014	October	38.20%

Source: Kenya National Highways Authority, 2014

The Weighbridge station should be designed to perform optimally during the peak hour of operation. Therefore, the peak percentage overloading over the previous 3 years of 79.84% should be adopted. However, the peak overloading recorded in 2012 and 2013 occurred before amendments were made to the traffic act which allowed 5% operational allowance on axle overloads and increased axle load limits. Since then the overloads declined sharply and the October 2014 peak overloading of 38.2% is thus adopted for determining the Design weighbridge traffic.

4.4.5 Projected Weighbridge Truck Traffic

The projection in Table 4.6 and Figure 4.4 was based on average annual growth rate of 2.1% determined from historical truck traffic records from Kenya National Highways Authority. The study assumed that the adopted peak hour factors were constant. Compound growth rate formula was used to project traffic as shown:

$$\text{Future ADT} = \text{Current ADT} \times (1 + r)^n, \text{ where,}$$

ADT= Average Daily Truck Traffic

‘r’= Annual growth rate

‘n’= number of years from the current year.

The same formula was used to project the design weighbridge traffic.

Table 4.6: Projected Weighbridge Truck Traffic

Year	Average Daily Truck Traffic (ADT)	Design W/bridge Traffic = ADT \times 1.71 \times 1.32 \times 38.2%	Trucks weighed/ h =DWT/24 (veh/h)
2015	2039	1758	73
2020	2263	1952	81
2025	2510	2165	90
2030	2785	2401	100
2035	3090	2665	111

Source: Author (2014)

From Table 4.6 and Figure 4.4, the 2015 truck ADT of 2039 already exceeded the required maximum system daily tuck traffic of 2000 for a TCC1 Facility. The design weighbridge traffic required weighing of 73 veh/h which was above the weighing capacity of 50 veh/h. In 20 years, the hourly weighing requirement would be 111, which is more than twice the weighing capacity.

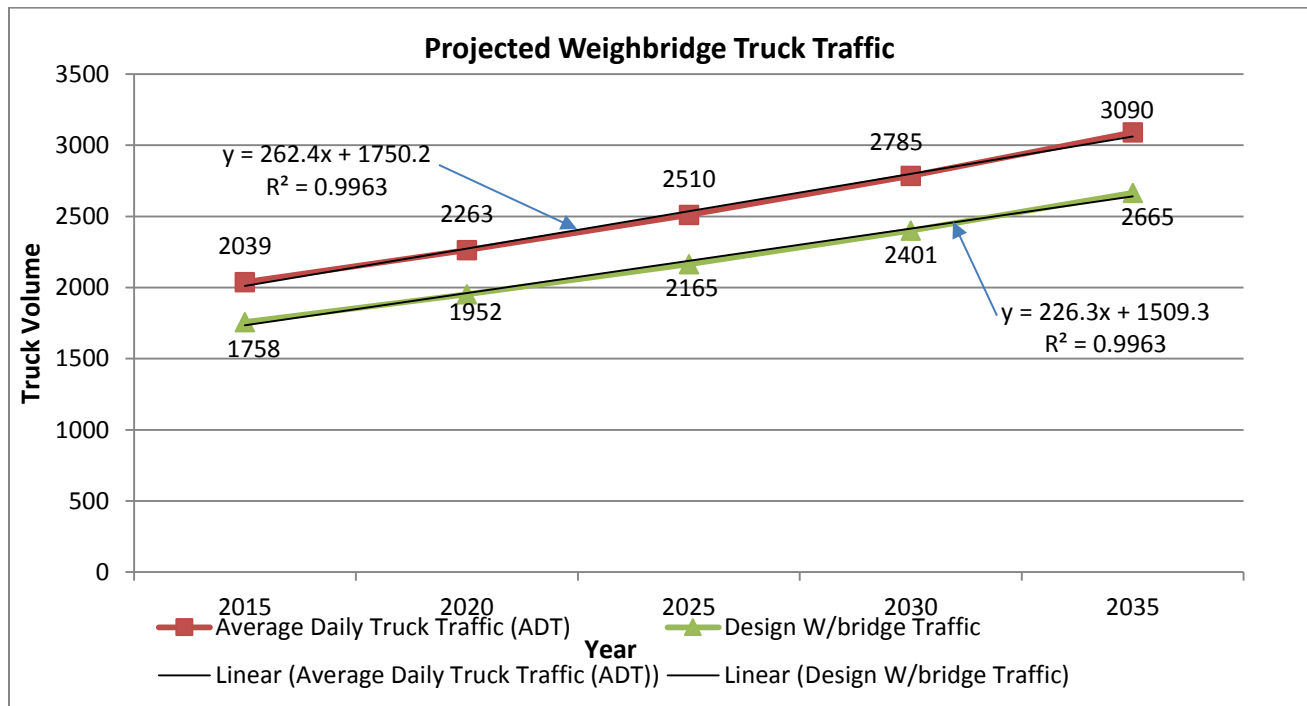


Figure 4.4: Projected Weighbridge Truck Traffic

The capacity of a weighbridge station relates directly to the extent of congestion that will be tolerated especially during peak hours of operation and forms a major component of the planning

stage of a weighbridge station. For Gilgil weighbridge station, the analysis showed that the current truck traffic far exceeded the capacity. The peak hour traffic volume, queue times, service times, all exceeded their acceptable levels.

4.4.6 Parking Demand Analysis

Parking survey was done to be able to establish the parking turnover. The objective was to determine the optimum capacity of the holding area. Trucks were parked either within the holding area (for offenders) or immediately after the exit for those that had been weighed and were resting/ broken down although there was no designated external parking. Summary of the analyzed parking turnover is presented in Tale 4.7.

Table 4.7: Average Parking Turnover

Time Beginning	Vehicles parked (Holding area)	Vehicles parked (External Parking)
6.00am	16	22
7:00am	18	26
8:00am	18	28
9:00am	17	28
10:00am	14	31
11:00am	11	33
12:00pm	12	37
1:00pm	12	42
2:00pm	17	41
3:00pm	17	39
4:00pm	18	36
5:00pm	18	34
6:00pm	16	30
Average Hourly Parking	16	33
Peak Hourly Parking	18	42

From Table 4.7, the average parking turnover is 16 in the holding area and 33 outside the holding area. The ALCS had nothing to do with the trucks parked outside the holding area. However, if these trucks were to continue parking outside the station, then its efficiency was expected to be compromised.

From the survey, the parking capacity within the holding area for a typical 6-axle truck was 22, which was slightly more than the peak hourly parking. It was expected that more compliance would be achieved with continued automation of the station leading to reduced overloaded vehicles. As a result, the current holding area capacity is adequate to handle current and future truck traffic.

For a comprehensive planning of a weighbridge facility, any external parking near the facility requires to be incorporated in the plans as parking would most likely be used by the trucks.

4.5 Measures of Queuing System Performance

4.5.1 Simulation for M/M/1 Model

At Gilgil Weighbridge Station, the system has one server and the queue discipline is first come, first served. This represents the M/M/1 model. From earlier analysis:

Average Daily Truck Volume= 2039

Average Service Time= 1.44 minutes

Average hourly truck volume = $2039/24 = 85\text{veh/h}$

i) **Arrival Rate, λ** = $85/60 = 1.42\text{ veh/min}$

ii) **Service Rate, μ** = $1/\text{Service time} = 1/1.44\text{minutes}$
 $= 0.69\text{veh/min}$

iii) **Length of the Queue, L_q** = $5\lambda^2 / \mu (\mu - \lambda)$
 $= 5 \times 1.42 \times 1.42 / 0.69(0.69 - 1.42)$
 $= 10.65$
 $= 11\text{ vehicles in queue}$

iv) **The Average time in line, W_q** = average queuing time= 9.12 minutes

v) **Average time in the system, W** = $W_q + 1/\mu$
 $= 9.12 + 1.44$
 $= 10.56\text{ minutes}$

vi) System Utilization, $\rho = (\lambda/s\mu)*100\%$
$$=(1.42/1 \times 0.69)*100\%$$
$$= 205.8\%$$

System utilization measures the extent to which the weighing machines are busy rather than idle. The higher the percentage utilization, the greater the length of the waiting line and the average waiting time. Values of 100% and above are indicative of an overutilized system whose waiting costs are quite high and performance low. This is largely due to the high arrival rates compared to the service rates.

For system utilization to reduce to a maximum of 100% with the single weighing system, the service rate μ has to reduce significantly since the arrival rate cannot be changed.

Therefore for system utilization $\rho = 100\%$, service rate $\mu =$ arrival rate $\lambda = 1.42 \text{ veh/min}$

Service time $= 1/1.42 = 0.70 \text{ minutes}$

For an optimum 80% system utilization,

Service rate μ should be $= (100/80)*1.42/1$
 $= 1.775 \text{ veh/min}$

Service time $1/\mu$ should be $= 0.56 \text{ minutes}$

Probability of 0 Vehicles in Queue, $P_0 = 1 - (\lambda/\mu)$
 $= 1 - (1.42/1.775)$
 $= 0.2$

As the system utilization decreases with arrival rate constant, the service rate increases.

vii) Simulation of future scenarios for M/M/1 model

Table 4.8 gives a summary of the main parameters for system performance for 2015 and their projections in 2035 based on a system with one server.

Table 4.8: Projected system performance for an M/M/1 model

	Parameter	Year 2015	Year 2035
1.	Arrival Rate, λ (ADT/24x60)	2039/24x60= 1.42 veh/min	3090/24x60= 2.15 veh/min
2.	Service Rate, μ (1/Service Time)	1/1.44min = 0.69 veh/min	Assume = 0.69 veh/min
3.	System Utilization, $\rho = (\lambda/s\mu)*100\%$	205.8% %=> over-utilized system, high Waiting costs	311.6%
4.	Length of Queue, $Lq = 5\lambda^2 / \mu (\mu - \lambda)$	11 vehicles	23 Vehicles
5.	Average Time in Line, $Wq =$ average queuing minutes	9.12 minutes	19.2 minutes

Table 4.8 shows that the projected arrival rate would rise to 2.15 veh/min and assuming a constant service rate of 0.69 veh/min, the projected system utilization would increase to 311.6%. It would then be impractical to operate such a system with one server and additional server (s) would be necessary to address the potential congestion levels at the station.

4.5.2 Simulation for M/M/2 Model

An M/M/2 model utilizes two servers to serve one queue. This is not the scenario at Gilgil weighbridge station but it was important to analyze the effect of increasing the number of servers for the queue.

Average Daily Truck Volume= 2039

Average Service Time = 1.44 minutes

Average hourly truck volume= 2039/24 = 85

From earlier calculations, **Arrival Rate, $\lambda = 1.42$ veh/minute**

For the Service time, an assumption is made that the new server would have the same service time as the existing. Therefore, service time for each server = 1.44 minutes

Service Rate, $\mu = 1/1.44 = 0.69$ veh/minute

i) Length of Queue, $Lq = 5\lambda^2/m\mu (\mu - \lambda)$, where m is the number of servers

$$= 5 \times 1.42 \times 1.42 / (2 \times 0.69 (0.69 - 1.42))$$

$$= 5.3, \text{ say } 6 \text{ trucks}$$

ii) Average Queuing Time, $Wq =$ current queuing time/m = 9.12 min/2

$$= 4.56 \text{ minutes}$$

iii) Average Time in the System, $W = W_q + 1/\mu$
$$= 4.56 + 1.44$$
$$= 6 \text{ minutes}$$

iv) System Utilization, $\rho = (\lambda/m\mu) * 100\%$
$$= (1.42/2 * 0.69) * 100\%$$
$$= 102.9\%$$

From the calculations, it is clear that increasing the number of servers for one queue to two reduces the queuing time, average time in the system and the system utilization. However, the system utilization is still above 100% at 102.9%. It can be deduced that even with an investment in an additional server, there is still need to have a lower service time which translates to higher service rate.

Consider Gilgil weighbridge station as an M/M/2 system with a reduced service time from 1.44 minutes to 1.0 minute:

The service rate, $\mu = 1.0 \text{ veh/minute}$

Average time in system, $W = 4.56 + 1.0 = 5.56 \text{ minutes}$

The system utilization, $\rho = (1.42/2 * 1.0) * 100\%$
$$= 71.0\%$$

As shown, a reduction in service time from 1.44 minutes to 1 minute (by 27 seconds) results into a 71% utilization which is reasonable as it creates a system stability and allows for a maintenance schedule that would then be based on the daily idle times. It should be noted that any reduction in service time by 5 second or more would result into a system utilization of less than 100% on an M/M/2 model. Figure 4.5 shows the simulation for a two-server station at a service rate of 1 veh/min from 2020 to 2035 and based on current levels of compliance. 100% utilization would be attained in the middle of 2033 but with the targetted increased compliance/ reduced overloading of HGVs, a two-server system would be adequate to serve Gilgil weighbridge station for the next twenty years.

In order to project the system utilization, the projected weighbridge truck traffic (see Table 4.6) was used to compute the arrival rates over the projected period. The corresponding system utilizations were determined using the formula in section 4.5.2 (ii) and represented graphically in Figure 4.5.

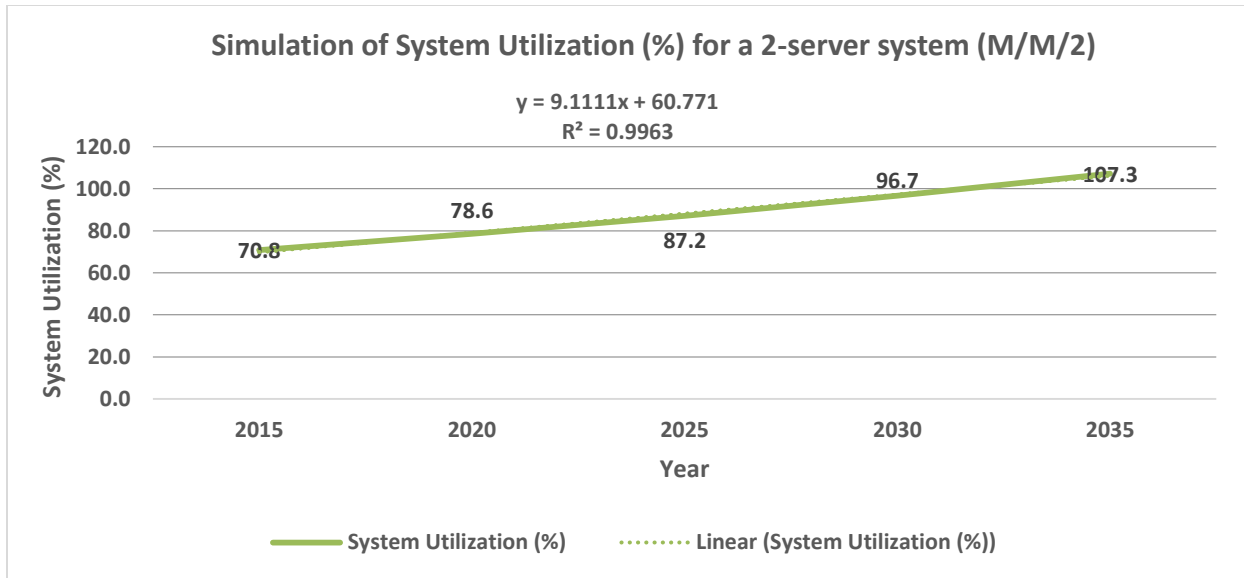


Figure 4.5: Projected Gilgil Weighbridge Station utilization

4.6 Weighbridge Station Design

The design of a weighbridge station affects its performance and efficiency. This study established that one server at Gilgil station was inadequate to handle the truck traffic at the time of study and the weighbridge layout made it difficult to increase number of servers. All weighbridge types have specific layouts set out to maximize flow of traffic and efficiency of the weighbridge station. While Gilgil Weighbridge Station was planned as a Type 1 Traffic Control Centre (TCC 1), the layout that is in place is only a partial TCC 1 layout. The result was interference in flow of traffic even for through traffic and possibility for trucks to avoid weighing and re-weighing even after being diverted into the station.

An effective weighbridge layout should allow for uninterrupted flow of traffic (see Figure 4.6) while maximizing controls within the weighbridge station and to ensure that once diverted into the station, a truck cannot avoid weighing and re-weighing. An inadequate layout like the one at Gilgil station, creates room for manipulation of the system by unscrupulous personnel/ truck drivers.

Figure 4.6 represents a proposed layout for one side of Gilgil station which was to be duplicated on the opposing side since the main road was a two-way traffic road.

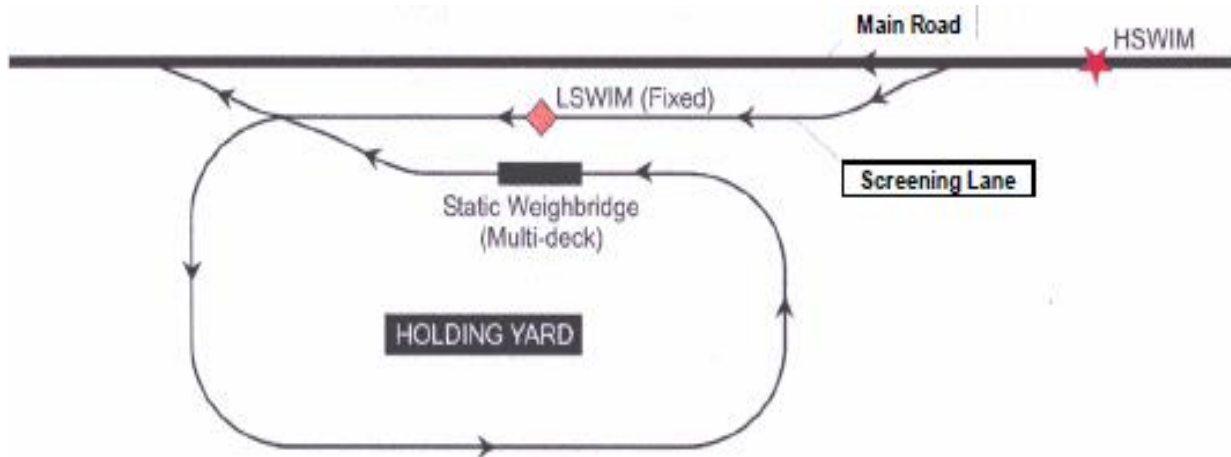


Figure 4.6: Typical layout for a TCC1 facility for one- way traffic

Source: SATPP, Working Paper number 90 (2010)

Another important aspect of design is pavement design. The screening lane was designed with a concrete surfacing and was performing well. However, the entrances and exits had gravel surfacing which was not able to withstand the HGV loads. An assessment of the proposed pavement design (50mm AC surfacing) for the entrances and exits showed that this would be inadequate to handle the HGV loads and their turning movements which would result in premature failure.

4.7 Assessment of Weighbridge Improvements

During the course of this research, a number of improvements were on-going at the weighbridge and the time of data collection, the following were already in use:

- Privatization of weighbridge management. This had led to improved operation, efficiency, and cleanliness of the weighbridge even though the levels of efficiency are still low.
- 120m long screening lane for trucks which improved control by segregating truck traffic from other traffic
- High Speed Weigh-in-motion System reduced congestion by only diverting trucks that overloaded/ near the limits into the weighbridge. However, the levels are still very high as was shown in the analysis of queue and service times.
- Construction of the holding bay. The existing holding bay was expanded and the new one was meeting the current demand as shown in the parking demand analysis.

- Installation of CCTV Cameras. These had been installed at the station to curb malpractices, although they only relayed feeds to the office of the weighbridge manager and the feeds could not be relayed to KeNHA headquarters in real time.
- Fencing. The weighbridge station was fenced and access to it was controlled. This has eliminated a lot of idlers at the station who used to increase probability of corruption at the station.

While the improvements have considerably improved performance of the weighbridge station, the current level is still inefficient in terms of queue and service times and ability to handle the incoming truck traffic.

4.8 Gilgil Weighbridge Station Planning

Planning of a weighbridge station requires consideration of various elements such as siting, HGV traffic and types of weighbridges required and their maintenance and operation complexity, amenities within and surrounding the station and waste management.

4.8.1 Siting of Gilgil Station

Siting of a weighbridge station is dependent on the traffic volume on the route and class of the road. For Gilgil Station which is located along the busiest route in Kenya (Northern Corridor Road), the station had a segregated 120m screening lane which facilitated through traffic flow at the station. This was adequate at the time but the length of the screening lane could be increased in future.

4.8.2 Selection of weighbridges

The type of weighbridges at a weighbridge station are also determined by the truck traffic levels along the route. The single axle weighbridges that were still in use at Gilgil weighbridge station are unsuitable for a station with over 2000 veh/day. However, improvements were made by installation of a multi-deck weighbridge which was the recommended weighbridge type.

4.8.3 Weighbridges Maintenance

Critical to the performance of any facility is the maintenance framework for the facility as breakdowns are unavoidable. One of the major challenges at Gilgil Weighbridge station is poor

response to breakdowns. While a new multi-deck weighbridge was installed to improve operations by reducing service times, it had frequently broken down at the time of the study. During such breakdowns, trucks were diverted to the alternative single axle weighbridge which resulted into longer service times and interfered with traffic flow for through traffic.

At Gilgil weighbridge station, it took more than a day to respond to a breakdown of a weighbridge resulting in congestion at the station. For any weighbridge station to perform well, it should have a clear communication channel for any breakdowns and a stipulated response mechanism so that unnecessary inefficiencies associated with delayed responses are eliminated.

4.8.4 Station amenities and waste management

Gilgil station was equipped with sanitary facilities within the station for the staff and drivers, water points for drinking water and a kitchen for staff. However, there was no rest or eating area planned for contrary to planning requirements. This led to mushrooming of haphazard developments around the station and extensive use of the unplanned and undeveloped external parking just after the station. Parking demand analysis showed a peak hourly parking of 42 vehicles at the external parking with the vehicles parking on the shoulders and ditch.

In addition to the facilities within a station, proper planning requires provision of other amenities to cater for drivers, travelers and the staff at the station such as rest and eating area, external parking and washrooms.

Upon privatization of the weighbridge station management in 2013, waste management became the responsibility of the weighbridge contractors and a performance deliverable in their contract. At the time of the study, the waste management within the station was adequate with no littering and drains cleaned. The main challenge was managing wastes from the nearby kiosks, hawkers and the external parking area as they eventually impacted on the station's drainage condition.

Proper waste management at a weighbridge station involves not just the station but any surrounding facilities that impacts on the cleanliness of the station.

4.9 Stakeholder Participation

For the challenge of overloading on Kenyan roads to be effectively addressed, involvement of stakeholders such as the public, importers, transporters, drivers, roads authorities and management contractors, is very important. Since 2013, there had been increased awareness in Kenya about overloading, weighbridge stations and related malpractices through stories in the media, although the level of awareness was still low.

In an ideal situation, increasing the capacity of weighbridges would not be envisaged because it was an indicator of high levels of non-compliance which translated to overloading and deterioration of the roads. Consultative meetings, workshops, billboards and television adverts focusing on dangers of overloading, role of each stakeholder, purpose of weighbridge stations such as Gilgil, would go a long way in improving compliance to Axle Load requirements. An example of such initiatives was the one launched by KeNHA Axle Load Control Unit in 2015 to urge transporters to join associations within which they could self-regulate at their points of origin with their own weighbridges. This was intended to improve compliance.

CHAPTER 5

5.0 Conclusion and Recommendations

5.1 Conclusion

- This research established *guidelines for operations of a weighbridge station*. These included understanding the weighbridge weighing and screening capacities based on peak hourly traffic, queue times, service times, parking demand, weighbridge types and layouts, weighbridge maintenance framework and stakeholder participation.
- *Challenges* affected Gilgil Weighbridge station were identified and included inadequate capacity and amenities, long queue and service times, high external parking demand, poor lighting, short circuiting effects of rain and poor maintenance framework. These challenges resulted into the congestion and inefficiency that was frequently witnessed at the station.
- The *planned improvements* at the station were substantially complete at the time of the data collection. Installation of a High Speed Weigh-in-motion weighbridge, screening lane, new multi-deck weighbridge, holding bay and CCTV Cameras were some of the improvements. They collectively improved operations at Gilgil weighbridge station considerably by reducing queue and service times even though the levels were still below the desired levels and channelizing truck traffic.
- The weighbridge station layout, station amenities, external parking inadequacies, condition of entrances and exits, waste management and management of surrounding development were identified as *outstanding design and operations concerns* for this weighbridge station.

5.2 Recommendations

- i) *Review of Gilgil Weighbridge Station layout* with a view to improving flow and control of vehicles at the station through re-arrangement of facilities.
- ii) *Implementation of Axle Load Control Information Monitoring System* with the capability of transmitting the live weighing data and images from the weighbridges to a central system to enhance transparency at the weighbridges.
- iii) Establish a proper *maintenance framework* for the station's facilities especially the weighbridges with clear communication channels and prompt response times to breakdowns
- iv) Promotion of *self-regulation* by Transporters through accredited Transporters Associations especially at points of Origin in order to improve compliance.
- v) *Rehabilitation* of the entrance, exit and external parking adjacent to the station to improve efficiency through improved movement in and around the station.
- vi) Improvement of lighting especially at the entrance to station and points of diversion into the screening lane
- vii) *Enhance Stakeholder Participation* in order to create more awareness on the dangers of overloading and the responsibility of the public, importers, transporters, drivers, roads authorities and management contractors. This can be done through consultative meetings, workshops, billboards and television adverts.
- viii) Movement, over time, to the development and use of a special section of the Kenya Police as a *HGV Traffic Police Force* under the control of Authority responsible for Axle Load Control, for the purpose of axle load enforcement and heavy vehicle safety enforcement with clear command structures.

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APPENDICES

APPENDIX 1: HGV DRIVERS QUESTIONNAIRE

Date:.....

Location.....

Name of Respondent:.....

Tel:.....

Nationality:.....

Sex:.....

Occupation/Designation:.....

(a) Do you think some transporters overload?

- (i) Yes
- (ii) No

(b) Do you think there is adequate awareness on overloading in Kenya?

- (i) Yes
- (ii) No

(c) Do you think there are prevailing challenges at the Gilgil weigh bridge?

- (i) Yes
- (ii) No

(d) Do you think there is an improvement in Weighbridge Operation?

- (i) Yes
- (ii) No

(e) Do you think the introduction of High Speed Weigh in motion system has improved efficiency at the Weighbridge

- (i) Yes
- (ii) No

(f) Are you satisfied with the service at the weighbridge station?

- (i) Yes
- (ii) No

(g) Have you ever been prosecuted before?

(i) Yes

(ii) No

(h) Are you a regular user of the Weighbridge?

(i) Yes





(ii) No





(i) Have you ever been affected by weighbridge breakdown at the weighbridge station?

(i) Yes

(ii) No

APPENDIX 4: Vehicle Count Summary

VEHICLE COUNT FORM			
VICTOR ODIWUOR ODULA F56/82445/2012 UNIVERSITY OF NAIROBI Sheet No... 01		MSC. CIVIL ENGINEERING THESIS: AN ASSMENT OF OPERATIONS OF WEIGHBRIDGES IN KENYA: CASE OF GILGIL WEIGHBRIDGE STATION	
	Day: Sunday-Saturday	Date: 05th Oct 2014- 11th Oct. 2014	
Time Period	MGV 2AXLES>7Tonnes 	HGVs 3-4 AXLES 	HGVs 5-6 AXLES ARTICULATED TRUCKS.  
6.01am-7.00am	7	14	651
7.01am-8.00am	21	14	826
8.01am-9.00am	14	42	721
9.01am-10.00am	13	34	632
10.01am-11.00am	7	63	525
11.01am-12.00pm	22	29	446
12.01pm-1.00pm	6	34	478
1.01pm- 2.00pm	21	56	574
2.01pm-3.00pm	13	60	550
3.01pm- 4.00pm	20	41	583
4.01pm- 5.00pm	14	49	595
5.01pm- 6.00pm	21	42	623

VEHICLE COUNT FORM			
VICTOR ODIWUOR ODULA F56/82445/2012 UNIVERSITY OF NAIROBI Sheet No... 02		MSC. CIVIL ENGINEERING THESIS: AN ASSMENT OF OPERATIONS OF WEIGHBRIDGES IN KENYA: CASE OF GILGIL WEIGHBRIDGE STATION	
	Day: Sunday-Saturday	Date: 05th Oct 2014- 11th Oct. 2014	
Time Period	MGV 2AXLES>7Tonnes 	HGV 3-4 Axles 	HGVs 5-6 AXLES ARTICULATED TRUCKS.  
6.01pm-7.00pm	14	35	700
7.01pm-8.00pm	14	21	679
8.01pm-9.00pm	7	35	616
9.01pm-10.00pm	7	28	616
10.01pm-11.00pm	2	22	641
11.01pm-12.00am	0	14	511
12.01am-1.00am	0	8	440
1.01am- 2.00am	0	1	405
2.01am-3.00am	0	2	376
3.01am- 4.00am	1	6	350
4.01am- 5.00am	0	8	377
5.01am- 6.00am	7	14	455
Sub-Total	231	672	13,370
Total	14,273		

APPENDIX 5: Parking Survey Summary

PARKING SURVEY FORM			
VICTOR ODIWUOR ODULA F56/82445/2012 UNIVERSITY OF NAIROBI Sheet No... 01		MSC. CIVIL ENGINEERING THESIS: AN ASSMENT OF OPERATIONS OF WEIGHBRIDGES IN KENYA: CASE OF GILGIL WEIGHBRIDGE STATION	
Day: Sunday-Saturday		Date: 05th Oct. 2014- 11th Oct. 2014	
Time Period	Average Vehicles Parked	Time Period	Vehicles Parked
6.01am-7.00am	18	12.01pm-1.00pm	12
7.01am-8.00am	18	1.01pm- 2.00pm	12
8.01am-9.00am	18	2.01pm-3.00pm	17
9.01am-10.00am	17	3.01pm- 4.00pm	17
10.01am-11.00am	14	4.01pm- 5.00pm	18
11.01am-12.00pm	11	5.01pm- 6.00pm	16
Peak Hourly Parking			18
Total Vehicles Parked			192
Average Hourly Parking			16