REPUBLIC OF KENYA

MINISTRY OF ROADS AND TRANSPORT

RDM 1.2

Road Design Manual

Volume 1: Geometric Design

Part 2: Traffic Surveys

2025

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Foreword

This manual was developed by the Ministry pursuant to The Fourth Schedule of the Constitution which assigns to the National Government the functions and powers of setting standards for the construction and maintenance of all public roads including those under the County Governments.

It is part of a series of manuals that replace the first generation of road manuals developed in the first and second decades after independence. This second generation of the road manuals were developed to cover the entire road project cycle covering planning, appraisal, design, contracts, construction, maintenance, operations and monitoring. The series incorporates best practices, climate change considerations, and recent technologies to enable the provision of road infrastructure that is safe, secure, and efficient.

Under the Kenya Vision 2030 long term plan, infrastructure expansion and modernisation are some of the foundations for the realisation of economic, social and political transformation of Kenya into a rapidly industrialising middle-income country. The plan envisages an integrated, safe and efficient transport and communication infrastructure network consisting of roads, railways, ports, airports, waterways, and telecommunications infrastructure.

The strategies to be pursued under the Vision 2030 plan to improve infrastructure services and to maximise the economic and social impacts of infrastructure development and management include: Strengthening of the institutional framework for infrastructure development and maintenance; Raising efficiency and quality of infrastructure projects; Enhancing local content of identified infrastructure projects to minimise import content; Benchmarking infrastructure facilities and services provision with globally acceptable performance standards; and, Implementing infrastructure projects that will stimulate demand in hitherto marginalised areas.

The first three 5-year Medium Term Plans (MTP) under the Vision 2030 from 2008 to 2022 targeted construction of 1,950 km, 5,500 km and 10,000 km of new paved roads under MTP I, II and III, respectively, totalling 17,450 km. This was a massive infrastructure development program intended to double the paved road network in 10 years compared to 8,600 km developed from independence in 1963 to 2008.

Implementation of MTP I to III resulted in the construction of 14,000 km of paved roads, which extended the paved road coverage to Arid and Semi-Arid regions, that had been previously neglected. However, some key milestones of the Vision 2030 goals have not been realised. This has been due to internal and external challenges. External challenges included: climate change – prolonged droughts; the emergence of COVID-19 pandemic; global supply chain disruptions; exchange rate volatility; and rising interest rates in the leading economies.

The internal challenges included: inadequate road maintenance equipment; pavement overloading by heavy goods vehicles; huge maintenance backlog of the road network; low contracting and supervision capacity particularly in the Counties; poor quality control and assurance of works; congestion in urban areas; encroachment on road reserves; high costs and delays in payments of land acquisition; lack of harmonisation of cross-border transport regulation and operational procedures; rapid urbanisation; increased traffic volume with exponential growth of motorcycle traffic; high cost/delays in relocation of utilities and services along and across road reserves; inadequate funding of projects and programs; and, delay or default in payments for goods, services and works.

The implementation of MTP III came to an end on 30th June 2023, ushering in the implementation of the Fourth Medium Term Plan (MTP IV), which has been aligned to the aspirations of the Kenya Vision 2030 and the Kenya Kwanza Government’s Bottom-Up Economic Transformation Agenda (BETA) planning approach and its key priorities.

BETA is the Government's transformation agenda geared towards economic turnaround through a value chain approach. BETA has targeted sectors with the highest impact to drive economic recovery and growth. This will be achieved through bringing down the cost of living; eradicating hunger; creating jobs; expanding the tax base; improving foreign exchange balances; and inclusive growth. BETA ensures rational resource allocation by eliminating wastage of resources occasioned by duplication, overlaps, fragmentation and ineffective coordination in the implementation of programmes and projects.

The Fourth Medium Term Plan key priorities are clustered under five key sectors, namely: Finance and Production; Infrastructure; Social; Environment and Natural Resources; and Governance and Public Administration. The infrastructure sector seeks to: enhance transport connectivity by constructing 6,000 km of new roads, maintaining rural and urban roads, rail, air and seaport facilities and services; expand communication and broadcasting systems; and promote the development of energy generation and distribution by increasing investments in green energy (geothermal, wind, solar and hydro). The infrastructure gap is expected to be bridged by promoting economic participation of the private sector through public private partnerships in the financing, construction, development, operation, and maintenance of infrastructure.

The plan entails a shift of focus to fundamentals in project planning and implementation which include: respect for technical input, regulations and standard practices; adherence to project life cycle i.e., planning, feasibility studies and design before procurement of works; public and stakeholder consultation; procurement within budgetary ceilings; shifting focus during project implementation from the finished product 'black top' to the construction of the foundation; building local capacity particularly MSMEs by ensuring prompt payments; and capacity building at all levels to enable internalisation of policies and processes.

The first generation of the road manuals were used for 35 to 45 years. It is my sincere hope that the second generation of the road standards which have been developed in alignment with the Government's strategy will provide guidance in solving most of the above challenges and those expected to emerge in the next 50 years. Implementation of the manuals will enable achievement of the Government aspirations which include inclusive growth; creation of sustainable employment; building of MSMEs; climate change adaptation and realisation of the UN SDGs; enhanced efficiency in management of infrastructure and transport system; and, laying the foundation for the next national long-term plan at the end of the Vision 2030.

On behalf of the Government of Kenya, I would wish to thank the European Union for financing the development of the first drafts of the manuals in 2009 and the African Development Bank for the financial support in the review and updating of the manuals. I would also like to thank the members of the National Steering Committee and the Technical Task Force for their input. The Technical Administrators, and the Kenya National Highways Authority (KeNHA) for the procurement and able administration of the consultancy Contract. I also thank the Consultant, TRL Limited for their role in providing technical expertise that was essential for the success of the manuals updating exercise. I also wish to express my deepest appreciation to our stakeholders and all those who have contributed to this process and the staff of the Ministry for their continued input.

Hon. Davis K. Chirchir, E.G.H
Cabinet Secretary, Ministry of Roads and Transport

Preface

This **Part 2** of the **Geometric Design Manual: Volume 1** sets out standardised methodologies for traffic data gathering, handling, and reporting for sustainable management of the road network in Kenya.

The context of the road design process, its philosophy and principles are discussed in the complete set of the road design manuals developed under this series. The use of each Part of the RDM and the relationship between the Volumes and Parts and the design process are covered. **Volume 1: Part 2** of the RDM is particularly useful for carrying out traffic surveys and studies to ensure that sufficient and appropriate data is available to carry out necessary planning, design, implementation, and management of the road infrastructure.

As much as possible, the traffic engineer should attempt to meet all criteria presented in the Manual. However, the Manual should not be considered a standard which must be met regardless of impacts. This Manual presents most of the information normally required in the carrying out traffic surveys for road design and related purposes; however, it is impossible to address every data requirement which may be encountered. Therefore, the traffic engineer must exercise good judgment on the scope of individual projects and, frequently, he/she must be innovative in their approach to roadway design. This may require, for example, additional research on newer and innovative methodologies and technologies when undertaking ground field surveys, and in the analysis of data, documentation, and archiving.

Eng. Joseph M. Mbugua, CBS
Principal Secretary, State Department for Roads

Document Management

Document Status

This document has the status of a Manual. Users shall apply the contents there-in to fully satisfy the requirements set out. The content of the manual is based on current practice in Kenya and latest practices in the road sector, both regionally and internationally.

Sources of the Document

Copies of the document can be obtained from:
The Principal Secretary, State Department for Roads, Ministry of Roads and Transport, Works Building, Ngong Road, P.O. Box 30260 - 00100, NAIROBI Email: ps@road.go.ke

A secured PDF copy maybe downloaded from: www.roads.go.ke/downloads

Notification of Errors and Requests for Amendments

While all care and consideration has been applied in the compilation of this document, the Ministry accepts no responsibility for failure in any way related to the application of this manual or any reference documents cited in it.

Requests for edits and corrections can be freely sent to the following address:
The Principal Secretary, State Department for Roads, Ministry of Roads and Transport, Works Building, Ngong Road, P.O. Box 30260 - 00100, NAIROBI Email: ps@road.go.ke

Amendments Request Form:

Request No.	Name	Organisation	Chapter	Page	Section/ Clause	Ref. to: Figure/ Table/	Type of Request	Request

Type of request: General – G; Editorial – E; Technical - T

Amendments to Date:

Amendment No.	Description	Amendment Effective Date	Amendment Approved by:

Acknowledgements

This Manual was prepared by the Ministry of Roads and Transport, State Department for Roads, with the kind assistance of the African Development Bank.

A National Steering Committee was set up and chaired by the Permanent Secretary, Ministry of Roads and Transport, with the following membership: Principal Secretary for Devolution, Office of the Deputy President; Chief Executive Officer, Inter-Governmental Relations Technical Committee; Chief Executive Officer, Council of Governors; Managing Director and Council Secretary, Kenya Bureau of Standards; Director, National Transport and Safety Authority; Director General, Kenya Roads Board; Director General, Kenya Wildlife Services; Chief Executive Officer, Engineers Board of Kenya; Director General, Kenya Rural Roads Authority; Director General, Kenya Urban Roads Authority; President, Institution of Engineers Kenya; Director Policy, Strategy and Compliance; Kenya National Highways Authority; Chief Engineer, Roads Division, State Department for Roads; Chief Engineer, Materials Testing and Research Division, State Department for Roads.

The technical work was undertaken under the guidance of a Technical Task Force, chaired by Eng. David Maganda, with the following gazetted members: Francis Gichaga (Prof.) (Eng.), Andrew Gitonga (Eng.), Timothy Nyomboi (Dr.) (Eng.), Rosemary Kungu (Eng.), Charles Obuon (Eng.), Sylvester Abuodha (Prof.) (Eng.), Samuel Kathindai (Eng.), Nicholas Musuni (Eng.), Charles Muriuki (Eng.), Tom Opiyo (Eng.), John Maina (Eng.), Fidelis Sakwa (Eng.), Daniel Cherono (Eng.), Maurice Ndeda (Eng.), Theo Uwamba (Eng.).

The Consultant for the review and updating of the manuals and specification for road and Bridge Construction was TRL Limited (UK), in partnership with Consulting Engineers Group Ltd, India and Norken International Limited, Kenya. The Consultant’s team composed of the Team Leader, Charles T. Bopoto (Eng.), Geometric Design Lead Expert, John Rolt (Dr.), Author, Nancy Abira (Eng.) and Project Manager, Warsame Mohamed.

Technical Administration was provided by James Kung’u (Eng.), Joachim Mbarua (Eng.) and Stephen K. Kogi (Eng.), assisted by the project secretariat Esther E.O. Amimo (Eng.), Monicah Wangare (Eng.) and Catherine K. Ndinda (Eng.)

Project coordination was provided by the KeNHA team led by Kungu Ndungu (Eng.) and J. N. Gatitu (Eng.), supported by Victoria Okumu (Dr.), (Eng.), Isaiah Onsongo (Eng.), Clarence Karot (Eng.), Howard Ashihundu (Eng.), Naomi Njoki Nthiga (Eng.), Shiphrah Mibey (Eng.), Mateelong Moses (Eng.) and Rose Rahabwanjohi (Eng.).

Abbreviations

ADT	Average Daily Traffic
AADT	Annual Average Daily Traffic
AASHTO	The American Association of State Highway and Transportation Officials
EF	Equivalence Factor
ESA(L)	Equivalent Standard Axle (Load)
GDP	Gross Domestic Product
GIS	Geographical Information System
GNI	Gross National Income
HCM	Highway Capacity Manual
HGV	Heavy Goods Vehicle
HSM	Highway Safety Manual
km	Kilometre
kN	Kilo Newton
KRB	Kenya Roads Board
LGV	Light Goods Vehicle
m	Metre
MC	Motorcycle
MESA	Millions Equivalent Standard Axle Load
MGV	Medium Goods Vehicle
MT	Motorised Traffic
NMT	Non-Motorised Traffic
NTSA	National Transport and Safety Authority
PC	Pedal Cycle
PCU	Passenger Car Units
RICS	Road Inventory Condition Survey
SF	Seasonal Factor
VEF	Vehicle Equivalence Factor
vph	Vehicles Per Hour

Glossary of Terms

AADT	The average 24-hour volume at a given location over a full 365-day year; the number of vehicles passing in a site in a year divided by 365 days (366 days in a leap year).
ADT	The average 24-hour volume at a given location over a defined time period less than one year; a common application is to measure ADT for each month of the year.
Authority	A government organisation that is responsible for a specific area or function and with vested power or right to make decisions or enforce regulation. In Kenya, these include Ministries, Departments and Agencies (MDA) at national and county levels.
Commercial Vehicles	These are the main type of vehicles that damage the pavement. They consist of buses and omni-buses.
Free Flow	A condition of traffic where a vehicle's speed is not influenced by anything other than the roadway geometry
Normal Traffic	Traffic that would pass along the existing road or track even if no new road improvement were provided. This increases naturally by virtue of normal social and economic growth
Pavement Design Traffic	This is the sum of the cumulative equivalent standard axles for all vehicle classes considered for the pavement design of a particular road. It is the commercial vehicle loading over the design life of a pavement.
Road Agency	An Agency with responsibility for driver licencing, and includes an Agency that carries out those functions as a delegate or agent of the Road Agency, or an Agency that supports the functions of an individual with statutory responsibility for driver licensing.
Road Heirarchy	This is an asset management system of classifying all the roads and streets in a given area, according to their function.
Road Safety Audit	A road safety audit is defined as a formal and independent technical check of a road scheme design and construction, to identify any unsafe features or potential hazards and to provide recommendations for rectifying them during all stages, from planning to early operation
Survey Supervisor	The survey supervisor is appointed by the Traffic Engineer to represent the engineer during field work. His/her main role is to direct, plan, coordinate, and oversee staff who conduct field work. A survey supervisor is responsible for the quantity and quality of field output accomplished by survey parties.
Seasonal Factor (SF)	Seasonal factors (SF) are used to normalise traffic counts undertaken at any time of the year to more representative flow values of the annual traffic. The SF is the ratio of the average ADT in the specific month and the actual AADT. The correction is obtained by dividing the traffic count by the SF. The SF depends on the month of the year, the type of vehicle and region of the country.
The 85th Percentile Speed	Stationing is used to establish a reference in highway and building construction. This base line or reference can then be used to locate features along and adjacent to the base line.
Weigh-In Motion (WIM) Systems	WIM systems are used for measurement of axle loads and provide continuous traffic data without interrupting the traffic flow. When combined with other sensors, WIM can provide traffic volumes, axle weights for various vehicle classifications, and vehicle speeds.

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1 Introduction

1.1 General

This manual was prepared by the Ministry of Roads and Transport as part of a series of manuals that cover the entire project cycle. The series incorporate best practices, climate change considerations, and recent technologies thereby enabling the provision of road infrastructure that is safe, secure, and resilient.

The Kenya road manual series is as follows:

Project Cycle Stage	Manual: Volume or Part/Chapter	Code
A. General	**Procedures and Standards Manual**	PSM
	1. General	
	2. Policies	
	3. Procedures Guidance	
	4. Codes of Practice	
	5. Guidelines	
	6. Product/Testing Standards	
B. Planning	**Network and Project Planning Manual**	NPM
	1. Road Classification	
	2. Route/Corridor Planning	
	3. Route/Corridor Planning	
	4. Highway Capacity	
	5. Project Planning	
C. Appraisal	**Project Appraisal Manual**	PAM
	1. Environmental Impact Assessment and Audit	
	2. Social Impact Assessment	
	3. Traffic Impact Assessment	
	4. Road Safety Audits	
	5. Project Appraisal	
	6. Feasibility Studies	
D. Design	**Road Design Manual**	RDM
	1. Geometric Design	
	2. Hydrology and Drainage Design	
	3. Materials and Pavement Design for New Roads	
	4. Bridges and Retaining Structures Design	
	5. Pavement Maintenance, Rehabilitation and Overlay Design	
	6. Traffic Control Facilities and Communication Systems Design	
	7. Road Lighting Design	
E. Contracts	**Works and Services Contracts Manual**	WSCM
	1. Forms of contracts	
	2. Standard Specification for Road and Bridge Construction	
	3. Bills of Quantities	
	4. Standard/Typical Drawings	
F. Construction	**Road Construction Manual**	RCM
	1. Construction Management	
	2. Project Management	
	3. Site Supervision	
	4. Quality Assurance	
	5. Quality Control	

This table continues onto the next page...

Project Cycle Stage	Manual: Volume or Part/Chapter	Code
G. Maintenance	**Road Asset Management Manual**	**RAAM**
	1. Maintenance Management	
	2. General Maintenance	
	3. Pavement Maintenance	
	4. Bridges and Structures Maintenance	
H. Operations	**Road Operation Manual**	**ROM**
	1. Traffic Management	
	2. Vehicle Load Control	
	3. Emergency Services	
	4. Tolling	
I. Monitoring & Evaluation	**Road Design Manual**	**MEM**
	1. Performance Monitoring Manual	
	2. Technical Audits	
	3. Poverty, Gender Equality and Social Inclusion Monitoring	

Table 1.1 shows how this part (2 – Traffic Surveys) fits within Volume 1 – Geometric Design, and the wider Road Design Manual structure.

Table 1.1 Road Design Manual Coding Structure

Vol.	Manual Title	Part Name	Code
1	**Road Design Manual: Vol. 1** Geometric Design	**Part 1** - Topographic Survey	RDM 1.1
		Part 2 – Traffic Surveys	RDM 1.2
		Part 3 – Geometric Design of Highways, Rural and Urban Roads	RDM 1.3
2	**Road Design Manual: Vol. 2** Hydrology & Drainage Design	**Part 1** – Hydrological Surveys	RDM 2.1
		Part 2 – Drainage Design	RDM 2.2
3	**Road Design Manual: Vol. 3** Materials & Pavement Design for New Roads	**Part 1** – Ground Investigations and Material Prospecting	RDM 3.1
		Part 2 – Materials Field and Laboratory Testing	RDM 3.2
		Part 3 – Pavement Foundation and Materials Design	RDM 3.3
		Part 4 – Flexible Pavement Design	RDM 3.4
		Part 5 – Rigid Pavement Design	RDM 3.5
4	**Road Design Manual: Vol. 4** Bridges & Retaining Structures Design	**Part 1** – Geotechnical Investigation and Design	RDM 4.1
		Part 2 – Bridge and Culvert Design	RDM 4.2
		Part 3 – Retaining Structures Design	RDM 4.3
		Part 4 – Reinforced Fill Structures Design	RDM 4.4
		Part 5 – Bridges and Structures Condition Survey	RDM 4.5
		Part 6 – Bridge Maintenance Design	RDM 4.6
5	**Road Design Manual: Vol. 5** Pavement Maintenance, Rehabilitation & Overlay Design	**Part 1** – Pavement Condition Survey	RDM 5.1
		Part 2 – Pavement Maintenance, Rehabilitation and Overlay Design	RDM 5.2
6	**Road Design Manual: Vol. 6** Traffic Control Facilities & Communication Systems Design	**Part 1** – Road Marking	RDM 6.1
		Part 2 – Traffic Signs	RDM 6.2
		Part 3 – Traffic Signals and Communication System	RDM 6.3
		Part 4 – Other Traffic Control Devices	RDM 6.4
7	**Road Design Manual: Vol. 7** Road Lighting Design	**Part 1** – Grid-connected Road Lighting	RDM 7.1
		Part 2 – Solar Road Lighting	RDM 7.2

This manual must be applied sensibly and flexibly in conjunction with the skill and judgement of the designer. Compliance with the guidance given in the manual does not relieve designers of the responsibility for establishing that their design is suitable, appropriate, safe, and adequate for the purpose stated in the project requirements.

1.2 Objective of this Part

This Traffic Survey Manual sets out standardised methods for data gathering, handling, and reporting for sustainable management of the road network in Kenya.

The main purpose of carrying out traffic surveys and studies is to ensure that sufficient and appropriate data is available to undertake necessary planning, design, implementation, and management of the road infrastructure, which is aimed at meeting the prevailing traffic flow, future traffic growth and axle loading without considerable deterioration in the level of service.

Design of roads depends on reliable data on the number, composition, and behaviour of traffic. If sufficient data from surveys is not provided, the deficiency in the facility design would be costly in the long-term. The data obtained from these surveys therefore help in geometric, structural, and pavement design, planning of road network, traffic regulation, control and road safety.

It is intended that this Manual will facilitate appropriate and sustainable decisions to be taken by the road agencies on whether a new road is required under the prevailing traffic conditions. This Manual will also enable road agencies to ascertain the timing of the required improvements, such as capacity expansion, structural upgrading or pavement strengthening.

Road agencies have the following key functions as far as the use of this Manual is concerned:

i. Collecting and collating data related to the use of highways, rural and urban roads as necessary for efficient forward planning under the Kenya Roads Act and other relevant policy documents.

ii. Monitoring and evaluating the use of highways, rural, and urban roads.

iii. Planning the development and maintenance of all roads; and

iv. Preparing the road works programmes for all roads.

1.3 Scope of this Part

This document provides engineers with a good understanding of the range of techniques and approaches needed for traffic studies, axle load surveys and methods of future traffic projections with regard to upgrading, rehabilitation, reconstructions and maintenance of roads. This Manual does not cover transport planning. However, several aspects are transferable to planning contingent on the technical judgement of the traffic engineer.

This Manual details the methods of undertaking various traffic surveys, and initial analysis of the data. How the output data from traffic surveys is applied in the various manuals within the series is covered under Table 1.1. While the Manual is written for the left-hand rule of the road, it is still applicable for right-hand rule, although it will require that the diagrams be transposed, and the accompanying text interpreted accordingly.

This Manual does not replace the relevant textbooks, nor is it a substitute for sound engineering knowledge, experience, and judgment. Standards are indicated which should be adhered to under normal conditions, while abnormal conditions should be given special consideration in consultation with the **Chief Engineer, Roads**.

Table 1.2 Application of Survey Data Output in Various Manuals

Chapter	Survey Type	Application of Data Output
3: Classified Volume Counts	Midblock volume counts	**Roadway capacity analyses** **Vol 1: Part 3** – Geometric Design of Highways, Rural, and Urban Roads
	Intersection volume counts	**Intersection Design; Swept Path Analysis; and Intersection Capacity Analysis** **Vol 1: Part 3** – Geometric Design of Highways, Rural, and Urban Roads
	NMT (section and intersection) volume counts	**Intersection Design and NMT facilities design** **Vol 1: Part 3** – Geometric Design of Highways, Rural, and Urban Roads
	Pedestrian acceptable gap, Pedestrian group study and NMT related surveys	**Pedestrian facilities design and Safe systems design** **Vol 1: Part 3** – Geometric Design of Highways, Rural, and Urban Roads
4: Origin Destination Surveys	Roadside interviews License plate surveys Household surveys	**Network Performance Analyses and Traffic Distribution Analyses** **Vol 1: Part 3** – Geometric Design of Highways, Rural, and Urban Roads
5: Future Traffic Estimation	Estimation of ADT and AADT and Economic analyses	**Vol 1: Part 3** – Geometric Design of Highways, Rural, and Urban Roads **Vol 3: Part 4** – Flexible Pavement Design **Vol 3: Part 5** – Rigid Pavement Design **Vol 5: Part 2** – Pavement Maintenance, Rehabilitation and Overlay Design **Vol 6: Part 3** – Traffic Signals and Communication System
6: Traffic Speed and Delay Surveys	Spot Speed Surveys	**Vol 1: Part 3** – Geometric Design of Highways, Rural, and Urban Roads
	Network Speed and Delay Surveys	**Road traffic and network performance analyses and Road investment appraisal.** **Vol 1: Part 3** – Geometric Design of Highways, Rural, and Urban Roads **Project Appraisal Manual:** Road Safety Audits
	Intersection Delay Surveys	**Intersection capacity and performance** **Vol 1: Part 3 –** Geometric Design of Highways, Rural, and Urban Roads **Project Appraisal Manual:** Road Safety Audits
7: Axle Load Surveys	Axle Load Surveys	**Pavement loading analysis.** **Vol 3: Part 4** – Flexible Pavement Design **Vol 5: Part 2** – Pavement Maintenance, Rehabilitation and Overlay Design
8: Parking Surveys	Parking inventory Parking Cccupancy Parking Turnover Surveys	**Urban Roadway Design and Capacity Analyses** **Vol 1: Part 3** – Geometric Design of Highways, Rural, and Urban Roads
9: Collation of Crash Data	Crash Data Recording and Analysis	**Safety systems design and Treatment of hazardous sections.** **Vol 1: Part 3** – Geometric Design of Highways, Rural, and Urban Roads **Project Appraisal Manual:** Road Safety Audits

1.4 Organisation of the Manual

This Manual is structured into three distinct sections as listed below.

Chapter 1: Introduction. This chapter gives a broad background on the concept of traffic data collection. It also discusses the purpose and scope of this Manual.

Section 1: Chapter 2: Traffic Survey Planning. Section 2.1 of this chapter discusses general issues concerning traffic surveys. Section 2.2 and 2.3 cover the common aspects and fundamental considerations that a traffic engineer should employ when planning and implementing a traffic survey program.

Section 2: Chapters 3-9. These chapters each describe particular surveys. The common aspects covered in each chapter include methods of measurement, sampling and error checking, survey duration, timing and frequency, data analysis, and output. Additional scope has been included in specific chapters based on conditions and requirements of each type of survey.

Section 3: Appendices. This part details the instructions and survey forms for supervisors and surveyors.

2 Traffic Survey Planning

2.1 General

2.1.1 Road Classification System

Roads have two basic, but possibly conflicting functions: to move traffic smoothly and without interruption, and to provide access. The function of any specific road is a balance between these two functions as is defined by the road hierarchy (see **Road Design Manual Vol 1**, **Part 1.3: Geometric Design Manual**).

The concept of road hierarchy is fundamental to safe and efficient traffic operations. Therefore, it is important in any study of the traffic network to describe the road links in terms of their classification within the hierarchy.

2.1.2 Vehicle Classification System

Adoption of a particular vehicle classification depends on the type of survey. For example, in a road capacity review, divisions may be according to vehicle occupancy; for a road damage study, they may be by vehicle weight; for traffic signals studies they may be according to their passenger car unit values; and for economic analysis the classification may be by their operating characteristics.

Each vehicle class must be distinguished from the other by a unique characteristic which can be seen easily in a moving traffic stream. The traffic engineer should provide a sketch or photograph of vehicle types to the field survey staff.

The vehicle classification system that shall be used for traffic studies is shown in the Table 2.1 below. For a particular survey, partial classes may be surveyed, or the classes may be broken down further based on the objective of the survey.

Table 2.1 Vehicle Classification

Vehicle Category	Vehicle Class	Code	Description Based on Unique Characteristics and Traffic Act (Cap 403)	Class by Axle Configuration
Passenger Vehicles	Pedal Cycle	PC	Non-motorised bicycle or tricycle.	
	Motorcycle	MC	Self-propelled vehicle with less than 3 wheels.	
	Three wheelers & Tuk-tuks	MR	Self-propelled vehicle with three wheels.	
	Cars, Jeeps, SUV, Pick-up	C	Passenger motor vehicle with seating capacity of not more than nine persons including the driver.	
	Microbus	MCB	Two axle rigid chassis passenger motor vehicle with seating capacity of 10 to 14 persons including the driver.	2-Axle Rigid
	Minibus	MB	Two axle rigid chassis passenger motor vehicle with seating capacity of 15 to 25 persons including the driver.	2-Axle Rigid
	Bus	B	Two axle rigid chassis passenger motor vehicle with seating capacity of 26 to 53 persons including the driver.	2-Axle Rigid
	Omnibus	OB	Three or four axle passenger motor vehicles with seating capacity of more than 53 persons including driver.	3 or 4-Axle rigid or articulated
Goods Vehicles	Light Goods Vehicle	LGV	Two axle rigid chassis goods vehicle of gross vehicle weight not exceeding 3,500 kg.	2-Axle Rigid
	Medium Goods Vehicle	MGV	Two axle rigid chassis goods vehicle or tractor of gross vehicle weight of 3,500 kg to 8,500 kg.	2-Axle Rigid
	Heavy Goods Vehicle	HGV	3 or 4 axle rigid chassis goods vehicle or tractor with gross vehicle weight greater than 8,500 kg.	3 or 4-axle Rigid
	Articulated Heavy Goods Vehicle	AHGV	Articulated goods vehicle having 3 or more axles of gross vehicle weight exceeding 8,500 kg.	3 or more -Axles Articulated

2.1.3 Traffic Variation and Sampling

Traffic variations are usually cyclical, and may be hourly, daily, or seasonal. Appropriate days and times of survey depend on the survey objective (such as, whether average values or peak values are required).

Surveys should not be conducted when traffic flow is affected by abnormal conditions, such as traffic incidents, roadworks, public holidays, public processions, and inclement weather conditions (particularly heavy rain). If the survey cannot be postponed, influence of the disruption should be noted and accounted for during analysis.

The aim of any survey should be to collect only as much data as is required to give an estimate at the desired level of accuracy. Variations in sample size and the sampling methods is indicated for each type of survey in the subsequent chapters.

2.2 Fieldwork Preparation

2.2.1 Liaison with Authorities

The traffic engineer should obtain a letter of introduction and/or permission letter to undertake surveys from the Agency commissioning the study. It is recommended that permission should be given formally in the form of a letter with the relevant agencies' letterhead. Surveyors must always have with them a copy of this letter during field work.

It may be necessary to obtain permission from more than one Government authority or agency, and from the property owner(s) if the survey equipment will be set up on private land.

Sometimes, the permitting process can be onerous. Use of video technology may be problematic in locations where privacy is a concern and may not be permissible. The traffic engineer must then reflect and account for change of survey locations or change of survey methods.

The approval of the police may be required for some activities on the road, and their presence necessary for some types of survey. However, as much as possible, the police must be made aware that there should be no unusual police presence which could affect the traffic characteristics being measured during the survey.

2.2.2 Choice of Survey Equipment

All traffic surveys require use of some equipment. The survey supervisor must specify and include a list of equipment needed when giving survey instructions. The survey supervisor must ensure that the surveyors are adequately trained to operate the equipment.

The choice of survey equipment defines the methodology of the survey. Matching a specific technology or equipment to a survey type requires considering the following factors:

a. Cost of equipment.

b. Availability and ease of use of equipment including vendor support and tail-end support in data transcription and analysis.

c. The physical characteristics of the site.

d. The traffic characteristics (e.g. motorised, non- motorised traffic, operating speeds of traffic, tendency of NMT to move in groups, anticipated peak demands etc.).

e. Whether only axle loads, or counts are required, or also speeds, user behaviour, vehicle categories, or demographic data is required; and

f. Need for obtaining permits or other forms of permission.

The survey supervisor must ensure survey equipment is charged, calibrated, and functioning properly before the survey team leaves for site. Hardware needs to be routinely tested to make sure it is working. To minimise vandalism, or the police removing survey equipment from the road or roadside, hardware should be conspicuously branded with the organisation's name or logo.

Watches are used extensively in traffic surveys. It is recommended that, digital chronometer watches which can display hour, minute, and second simultaneously be used for all timing tasks. Stopwatches are not recommended as they are prone to operator error.

With time, some traffic survey equipment such as inductive loops and pneumatic tubes can change sensitivity thereby becoming less prone to non-detections (under-counting) or false-positive detections (over-counting). Periodic recalibration of equipment through validation surveys should be carried out. It is the responsibility of the equipment owner to undertake calibration.

Equipment installation can be one of the most challenging steps in the data collection process. Obtaining necessary permits and installing the equipment on site must be undertaken prior to the actual survey. It is recommended that the survey supervisor provides to the surveyor team a check list of the installation procedure. Periodic checking during the survey to ensure the equipment is working properly is important.

2.2.3 Training of Surveyors

Staff training is important for both automated and manual surveys. For automatic surveys, focus should be on making sure the equipment is working properly and on downloading data from the equipment. For manual surveys, depending on the type of study, survey staff must be adequately trained on the overall purpose of the study, early detection of risks and errors of survey, how to conduct interviews, etc. The training of survey supervisors may be different from that of traffic surveyors or enumerators.

Training must cover the intended use of the data as it will inform the method of data collection along with the location and duration of the surveys. The traffic engineer should provide these details. However, the traffic surveyors, especially if from the local area, may know a better approach (cheaper, faster, or more accurate) to meet the specific objective of the survey.

During training, it is important for the survey supervisor to evaluate the capacity of each surveyor for conducting the survey. It may be necessary to exclude traffic surveyors who are not reliable or who cannot demonstrate effective capability to follow the survey protocol. The exact equipment and material that will be used during the actual survey should be used for training.

2.2.4 Safety and Security Considerations

Safety during traffic surveys is of utmost importance. During surveys, the traffic engineer must ensure that:

1. All staff on site are wearing reflective vests (full reflective pants/shirts if working at night).
2. The survey utilises traffic cones to delineate work area when setting up hardware on the road.
3. Traffic police are available to slow down traffic if necessary and use flashing lights on the work vehicle.
4. The work vehicle is parked off the road when setting up survey equipment.
5. If possible, the surveyors should avoid setting up equipment on the road during peak traffic times and avoid unnecessary risks (e.g. standing in the middle of the road waiting for vehicles to pass).

Surveys can be extensive lasting several weeks; therefore, the site conditions should be amiable for both day and night surveys. The survey supervisor must ensure that:

1. The site is flat with a clear view of the road and traffic with adequate shelter for surveyors and tents should be provided if there are no houses nearby.
2. There is access to toilet facilities, water, and food.
3. There should be provision of chairs, umbrellas, water, and light refreshments. It is mandatory for a first aid box to be always available on site.
4. The site is away from crash-prone (hazardous) locations and free from criminals particularly at night. Armed police should be part of the survey team if operating at night.
5. There is adequate lighting even in the night. Where there are no streetlights particularly in rural areas, rechargeable lamps and/or generators will be necessary.

2.2.5 Pilot Surveys

Pilot surveys are full field tests of a survey method, preferably at the location of the actual survey itself. Though they are sometimes omitted for reasons of economy, experience has shown that pilot surveys are a vital part of ensuring acceptable data quality. They can also help in determining the survey sample size and survey duration, thus ensuring the most effective use of available time and resources. If the pilot survey is well planned, and proves to be successful, the survey data may become part of the main data set.

2.3 Data Handling

2.3.1 Processing and Error Checking

Processing and analysing the survey data should begin as soon as possible, for potential errors to be identified and corrected. This initial analysis can also inform sampling criteria.

Some vendors of survey equipment provide custom software that imports the output files from their products into a spreadsheet. This approach can help avoid mistakes from manually copying between data files. Alternatively, road agencies or engineering firms with in-house programming expertise can develop their own software to compile survey data. This may make it possible to automate certain calculations and graphics production.

Data is prone to errors during transcription from one format to another. When collecting data using manual methods, phones or tablets with custom software can be used for inputting data to reduce such errors. If possible, data transcribers should be stationed near surveyors.

The data must be periodically reviewed and sense-checked by the traffic engineer. Some of the initial checks that can be undertaken during the survey exercise include:

- For classified counts, summary statistics should reflect typical volumes on roads of similar conditions or align with historical data.
- Volume counts should align with typical peak hours and typical directional flow. For example, high pedestrian volumes going towards the city during the morning peak.
- Operating speeds should align with traffic volumes, vehicle type and the road function/ design.
- Axle loads should align with the directional flow of Heavy Goods Vehicle (HGV) traffic.

It is necessary to keep checking the available data storage capacity especially if traffic volume is high otherwise one may lose the initial data if the storage is full before completion of the survey.

2.3.2 Data Analysis

The data analysis seeks to draw conclusions relevant to the study objectives from the characteristics and trends established during the survey. Statistical techniques can be used to indicate, for example, whether there is a relationship between variables under examination or whether a significant difference has resulted from a particular road treatment.

The traffic engineer must ensure that from the onset, the survey is designed to yield data that can be used to test and quantify a particular hypothesis. The use of control survey data may be a powerful tool in this analytical process.

Expansion factors can be used during the analysis to expand or convert survey data under conditions different from the survey. The types of adjustments that can be applied include:

1. Temporal adjustments: used to estimate data results at a different time, or for a longer period, than was undertaken. A common application is to expand a short-term to an estimate of annual data.
2. Environmental adjustments: used to estimate what the survey results would have been under different conditions such as speed or parking data collected under rainy weather converted to fair weather day.
3. Land use and facility type adjustments: used to account for differences in volumes attributable to differences in the surroundings of a survey site, compared to a continuously surveyed control site.

3 Classified Volume Counts

3.1 General

Classified volume counts fall into two categories — road segment data and intersection data.

- Road segment data usually consists of collecting vehicle and NMT volumes, speeds, and vehicle classifications. Collecting this data is typically done either manually or by using pneumatic tube counters or radar detectors.
- Intersection data usually consists of crossing movements, turning movements and vehicle classifications.

In both categories, motorised, pedestrian and cyclist counts can be undertaken. In general, classified volume counts at a network level may consist of:

1. A modest number of permanent, continuously operating, data collection sites (Section 2.1); and
2. Short-duration (about one week or less) data collection stations.

Permanent data collection sites provide knowledge of seasonal and day-of-the-week trends, while short-duration monitoring provides the geographic coverage needed to understand traffic characteristics on individual roadways as well as on specific roadway segments.

This section of the Manual only deals with the methodology of conducting traffic volume counts. The application of the data in geometric and safety design is covered under the following manuals: **RDM Vol 1: Part 3** – Geometric Design of Highways, Rural, and Urban Roads, **Vol 4: Part 1** – Bridge and Culvert Design and PAM 4: Road Safety Audit Manual.

3.2 Vehicle Classification and Configuration

The vehicle classification system recommended for traffic studies in Kenya is as shown in Table 2.1. Whereas these vehicle classes can be adopted as the general classification for traffic surveys, it is imperative to note that traffic counting, and classification is a dynamic process and is project based. The classes are also expected to change slightly with time.

For automated counts, the survey equipment must first be calibrated in accordance with the required vehicle classification.

3.3 Selection of Census Stations

The location and distribution of the counting stations influences the consistency of the data collected. It forms the basis for comparison with historical data on the network.

Data obtained from permanent census locations (see Section 7.2) facilitate comparison with data collected over limited periods. This is important in forecasting of traffic for the design year selected. As much as is practicable, count locations should correspond to the permanent count stations.

The road hierarchy and functional class influence the selection of census locations. The counting sites should be uniformly distributed along the road section to give a good representation of the flow characteristics.

Turning movement counts at major intersections are usually useful as one survey station can effectively cover several road links.

Local knowledge should be used to pick appropriate locations for conducting the NMT traffic counts to ensure a true reflection of the traffic using the road. Pedestrian counts for sizing a rural facility should not be undertaken too close to towns and villages. For urban facilities, the counts should be undertaken within the built-up areas and at locations with peak demand.

If the objective of NMT counts is to corelate the data output with MT characteristic, then the screen line should be adjacent to or within the MT influence area. If the data is required for design of NMT crossing facilities, the counts stations should be located at an intersection or midblock where NMT users tend to cross.

Key Considerations for Classified Volume Counts

- Are all intersection turning movements at an intersection accounted for?
- Do the major traffic movements make sense?
- Are there allowable movements at an intersection with no traffic volume recorded in the TMC?
- Is the orientation of the raw TMC data (north, south, east, west) consistent with how the data is being used in the traffic forecasts? If overall traffic and/or classification counts are collected upstream of a TMC, do the counts generally balance?
- Do truck percentages along the mainline and ramps generally balance?
- If counts are collected manually, are there sudden surges in 15-minute period volumes suggesting inattentiveness?
- Are there indications of data corruption or count equipment failure such as very high or very low counts relative to prior or next period that cannot be explained?
- Depending on the location of the study and time of year the data is collected, do seasonal factors need to be applied to the traffic volumes prior to starting the forecasts?

3.4 Methods of Measurement

The methods fall into two categories: manual and automatic. While there is no distinct difference in the two methods, the type to be adopted should be selected based on the magnitude of the survey, the type of flow, the type of network, quality of data required and economic considerations.

3.4.1 Manual Methods of Collection

Manual methods are the most common and involve assigning an enumerator by the roadside to record traffic as it passes. There are several applications that can be customised to allow entering traffic data into phones or tablets. Also, some applications allow image capture of the road section or intersection.

These methods are simple to use but are prone to errors with increasing traffic flow. This can be improved by changing the observation team of enumerators or by rotating them at intervals.

While expensive in terms of manpower, sometimes, manual methods may be necessary when accurate turning movements at an intersection is required.

During survey, traffic count surveyors should not be very close to axle load survey team or roadside interviewing team to avoid distraction.

3.4.2 Automatic Methods of Collection

Automatic methods adopt two approaches, either observation or sensing methods. Automatic observation is either by video cameras or radar traffic classifiers while automatic sensing methods include use of pneumatic tubes or inductive tubes installed on the road.

Automatic traffic counters such as pneumatic tubes use mechanical means to measure the volume of traffic moving past a survey point. They record data continuously over a long period of time at a relatively low operational cost. The long-term data collection reduces the sampling errors caused by fluctuation in traffic flow.

Pneumatic tubes designed for bicyclists are generally smaller, to minimise the bump as cyclists ride over them, they are also more sensitive, to better detect bicyclists. They can be used on bicycle-specific facilities or in mixed traffic.

Pneumatic tubes work by having two tubes run across the road and connected at one end to a data logger. The other end of the tube is sealed. When a pair of wheels hit the tube, air pressure in the tube activates the data logger which records the time of the event. The time of event relates to the speed of the vehicle while the amount of pressure exerted relates to the weight of the vehicle.

While pneumatic tubes are the standard method of data collection based on cost and data accuracy, some of the inherent weaknesses that must be considered by the traffic engineer include:

i. Once installed, they degrade rapidly under heavy traffic flow and when the road surfacing quality is poor. They are difficult to repair, and the surveyor may not know if something has gone physically wrong until it is retrieved. It is recommended to have a surveyor periodically check the tubes during the survey.
ii. Pneumatic tubes are incapable of completing turning movement counts due to the complex setup needed to measure movements and the inability to map a specific vehicle to a specific movement.
iii. When used on a single 2-way carriageway, the vehicle direction is established based on which tube is crossed first. This has the drawback that if two vehicles cross the tubes at the same time then the direction cannot be accurately determined.
iv. Should two cars be very close together when they cross the tubes, the system may see them as one multi-axle vehicle.

On roads with high HGV traffic or with unpaved surfacing, thicker tubes should be used. Specialised bicycle-specific counters are thinner. Tubes more than 18 metres are not recommended as the air pulses may not be strong enough to register in the counter. 15-metre-long tubes are standard. On two-tube installation, the two tubes should be of the same length. Manual counting is necessary to periodically check the accuracy of automatic counters.

At busy intersections, it may be cost effective to collect turning movement counts with video instead of combined manual turning movement counts and segment counts. Video data collected over a 48-hour period, for instance, can improve the level of service calculations based on averaging peak hour data, as well as identifying anomalies. It can also provide data for accurate traffic control warrant analyses and traffic signal timing.

3.5 Midblock Volume Counts

3.5.1 Duration and Timing of Counts

The type and quality of data determines the duration of counts. Ideally, counts are conducted over 12, 16 or 24 hours continuously for at least seven consecutive days per station.

When full overnight counts for seven days are not practical for security or any other reason, a partial count is admissible. In such cases, the duration should preferably be 16 hours, or at least 12 hours, each day, with at least two 24-hour counts, on one weekday and one weekend day. The partial day counts are then grossed up to 24-hour counts as described in Section 3.5.2.

If a 7-day count is not feasible or not required, then the survey should run for at least 3 weekdays and either Saturday or Sunday. Such reduction in duration must be approved by the traffic engineer.

If possible, 7 days counts should be repeated at least twice a year, once during the peak season and another during the off-peak season.

Periods of extreme unusual traffic flow should be avoided, for example election days, annual festivals, and public holidays (if they are rare). However, when an abnormal but regular situation occurs more than an average of once per month, such as when traffic volumes increase on the week of payment of salaries or wages, then it should be included in the counting period and the estimate of AADT adjusted accordingly.

Seasonal factors such as school calendars, harvest periods etc should also be considered and repeat counts undertaken at different times of the year, to normalise such data. Such data can also be obtained from permanent counters (see Section 7.2).

The flow of traffic is normally unusual during an axle load survey, particularly when the operators of goods vehicles suspect that there might be arrests for overloading. If there are any indications that traffic flow might be affected, the traffic counts should be conducted before an axle load survey.

In situations where traffic counts are undertaken prior to axle load surveys, the counts can provide a basis for estimating the required sample size for the axle load survey.

The data recording form for midblock traffic counts is included under Appendix 3.1.

3.5.2 Variation in Traffic Flow and Adjustments

Traffic flow on the road network changes considerably at each point in time. Some of the key variations are:

i. Hourly pattern: traffic flow variation throughout the day and night;

ii. Daily pattern: The day-to-day variation throughout the week; and

iii. Monthly and yearly pattern: The season-to-season variation throughout the year.

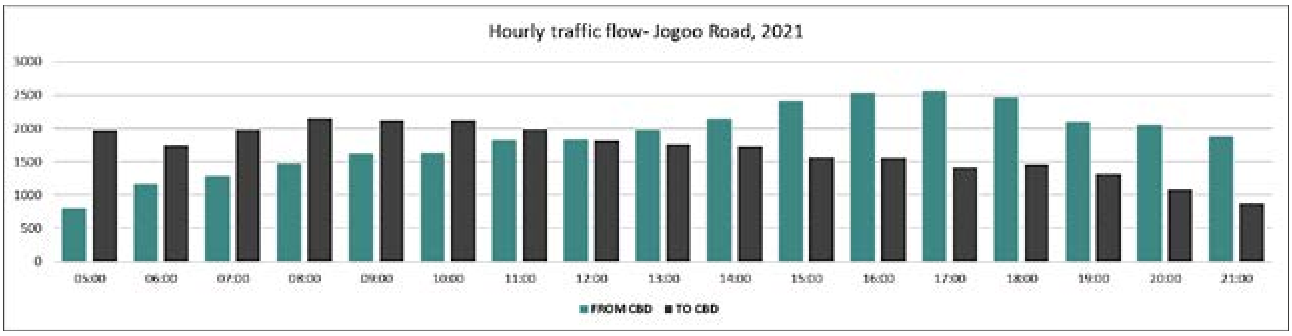
Hourly Flows

Typical hourly patterns of traffic flow, particularly in urban areas, generally show several distinguishable peaks. Peak in the morning followed by a lean flow until another peak in the afternoon, and a peak in the late evening. The peak in the morning is often sharper- such that traffic reaches the peak over a short duration and immediately drops to its lowest point. The afternoon and evening peaks on the other hand are characterised by a generally wider peak. The peaks are reached and dispersed over a longer period than the morning peak.

In urban satellite towns of the city, the morning peak may be too early, and evening peak may be too late in comparison to the traffic nearer the city. There may also be no considerable peak in the afternoon.

The traffic engineer must be cognisant of the directional distribution on dual carriageways and the variation in the traffic composition. See Figure 3.1.

Figure 3.1 Typical Hourly Traffic Flow, ADT, Jogoo Road, Nairobi 2021



Daily Flows

The traffic volume generally varies throughout the week. The traffic during working days (Monday to Friday) may not vary substantially, but the traffic volume during weekends is likely to differ from working days on different type of roads and in different directions.

In the major urban centres and on major corridors leaving from the city, weekend traffic can be considerably high.

Monthly and Yearly Flows

The monthly and yearly pattern normally reflects the seasonal variation of traffic flow. The pattern may vary for passenger cars and goods vehicles. In Kenya, the patterns may also be influenced by the school calendar especially on urban corridors.

Seasonal factors (SF) are used to normalise traffic counts undertaken at any time of the year and to make the counts more representative of annual average traffic flows. The SF values are the ratios of the Average Daily Traffic (ADT) in the specific month and the actual Annual Average Daily Traffic (AADT). The correction is obtained by dividing the traffic count by the SF. The SF depends on the month of the year, the type of vehicle and region of the country.

$$\text{Seasonal factor (SF)} = \frac{\text{Traffic volume count for a specific month}}{\text{Average traffic volume count for 12 months}}$$

Equation 3.1

SF should be obtained from the Chief Engineer (Roads). These factors are to be updated periodically. In the absence of long duration data, data obtained from the virtual weigh stations (See Section 7.2) can be used.

3.5.3 Data Analysis and Output

The general measures of vehicular traffic on a road are:

Average Daily Traffic (ADT)

This is the most commonly used measure of traffic in traffic engineering analysis. Theoretically, this is the volume of traffic moving in both directions on a road on an average traffic day of the year for 24 hours.

ADTs can be calculated from any sample of repeated daily counts of traffic volumes, with duration as short as one week. Because that short-duration count may be subject to seasonal fluctuation or other sources of bias, ADTs are often annualised by applying adjustment factors. The resulting volume being the annual average daily traffic (AADT).

Annual Average Daily Traffic (AADT)

The average 24-hour volume at a given location over a full 365-day year; the number of vehicles passing in a site in a year divided by 365 days (366 days in a leap year).

Both these terms are stated in terms of vehicles per day (veh/day). Daily volumes are generally not differentiated by direction or lane but are totals for an entire designated road location. They can be readily established when continuous counts are available. When only periodic counts are undertaken, the ADT and AADT can be estimated by applying relevant factors to account for season, month, and day of week.

The data obtained from traffic counts must be corrected and adjusted to give the best estimate for the traffic volume used for engineering design of roads. The following sub sections outline the processes for converting field data obtained from the traffic counts into standard formats.

Conversion of a Partial Day's Count into a Full Day's Traffic Count

The average daily traffic (ADT), based on a 7-day traffic count, is obtained by summing the five (5) full 24-hour weekdays counts and two (2) full 24-hour weekend days, and then dividing by seven. However, in some cases, a full day may not be available, and the dataset may only be available for either 12 hours or 16 hours.

A partial-day count is converted to a full-day count by grossing up the partial count using the 24-hour traffic count and taking the ratio of traffic in the same counting period to the full 24-hour count. For instance, a 12-hour survey from 06.00 to 18.00 can be scaled up to a full 24-hour day count as follows:

$$\text{Full 24-hour count} = \frac{\text{Partial 12-hour count (06.00 to 18.00) x (Full 24- hour count)}}{\text{Count from 06:00 to 18:00 hours in the 24-hour survey}}$$

Equation 3.2

To enhance accuracy, traffic counts from the same periods of the day should be used in the numerator and denominator of this equation. For example, a traffic count for the period between 06.00 hours to 18.00 hours must be scaled up by the traffic in this same period during the 24-hour count, as opposed to any other 12-hour period.

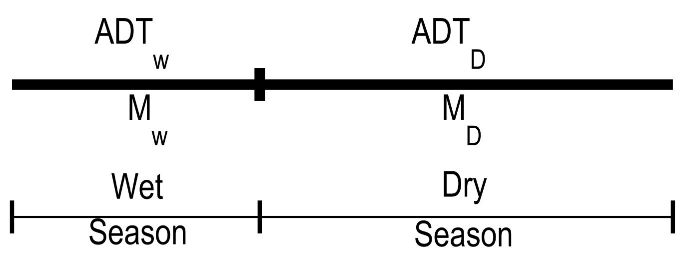
Partial weekend traffic counts need to be grossed up based on a weekend 24-hour count, given that traffic flows over the weekends vary significantly from the weekday flows, especially for commercial vehicle traffic.

Correction for Annual Variation Using Seasonal Factors

Seasonal Factors are used to correct for annual variation of traffic.

Where SFs are not available, AADT may be estimated based on weighted ADT from seasonal counts, for example, ADT in dry and wet seasons and the duration of the wet and dry seasons, as illustrated in Figure 3.2. Also, where accurate data is not available, traffic data from virtual weigh stations or tolled roads may be used in SF estimation.

Figure 3.2 Traffic count adjustment in relation to seasonal characteristics



The weighted average of the traffic count in relation to the seasonal characteristics of the region in which the counts were undertaken is obtained as follows:

$$AADT \approx Weighted\ ADT = \frac{(ADTW * MW)}{12} + \frac{(ADTW * MW)}{12}$$

Equation 3.3

Where,

$ADTW$ = Average daily traffic count in wet season

$ADTD$ = Average daily traffic count in dry season

MW = Number of months comprising the wet season

MD = Number of months comprising the dry season

3.5.4 Determining the Design Hour Volume

Although AADT is important, it is typically not used for capacity design because it does not reflect the variations of traffic. Therefore, the design for capacity of most roadways is based on the design hourly volume (DHV). The design hour should be one that is 'not exceeded very often or by much'(AASHTO, 2001).

Design hour volume for rural roads is the 30th highest hourly volume within a year (abbreviated as 30HV). i.e. the hourly volume that is exceeded by 29 hourly volumes during designated year. It is derived from AADT by multiplying the annual average daily traffic by a factor, K.

The K factor is the proportion of AADT occurring during the 30th peak hour flow. This means that if the 365 peak hour volumes of the year at a given location are listed in descending order, the 30th peak hour is the 30th on the list and represents a volume that is exceeded 29 hours of the year.

For rural roads, the 30th peak hour may have a significantly lower volume than the worst hour of the year, as critical peaks may occur only infrequently. In such cases it is not economically feasible to invest large amounts of capital in providing additional capacity or higher road class that will be used in only 29 hours of the year.

In urban cases, where traffic is frequently at capacity levels during the daily commuter peaks, the 30th peak hour is often not substantially different from the highest peak hour of the year. It is normal to design for the 100th highest hourly flow on urban roads.

K factors are based upon local or regional characteristics at existing locations. The values as shown in Table 3.1 are illustrative, and specific data on these characteristics should be available for the project road from the local highway authorities.

Table 3.1 General Ranges for K Factors

Facility Type	Normal Range of Values | K-Factor
Rural	0.15 – 0.25
Semi-urban	0.12 – 0.15
Urban	0.07 – 0.12

Source: Traffic Engineering, by Roess, Prassas & MacShane

On two-lane two-way roads, the Design Hourly Volume (DHV) is usually the total volume for both directions. For roads with more than two lanes or where a two-lane road is to be widened in future, the volume in each direction must be known. This is referred to as the 'directional design hour volume' (DDHV), and is found using the following relationship:

$$DDHV = AADT * K * D$$

Equation 3.4

Where,

K = proportion of daily traffic occurring during the peak hour

D = proportion of peak hour traffic traveling in the peak direction of flow

During peak hours on multi-lane roads, the volume in the peak direction can vary from 55 to 70 percent of the total flow depending on the origins and destinations of the traffic. The directional split may be greater on a highly recreational route or on road carrying commute traffic. The design must therefore consider the proportion of traffic in one direction to ensure an adequate design is undertaken. The heavier flow is the design criterion.

Example

A divided rural multi-lane highway is required to cope with an AADT of 40,000 vehicles per day. A 100 kph design speed is chosen with standard lanes of 3.5m wide and there are no obstructions within 1.83m of any travelled edge. The traffic is assumed to be composed entirely of private cars and the driver population is ideal.

The peak hour factor is 0.9 and the directional factor, D, is estimated at 0.6. The highway is to be designed to cope with the thirtieth hourly volume during the year. Calculate the service flow.

Solution

Directional design hour volume, $DDHV$:

$$DDHV = AADT * K * D$$

= 40,000 * 0.15* 0.6
= 3,600 vph

We can now calculate the service flow, knowing the hourly volume and the peak hour factor:

$$SF = V \div PHF$$

= 3,600 ÷ 0.9
= 4,000 vph

3.6 Intersection Turning Volumes

Intersection turning volume surveys counts the number of vehicles and type of movement of vehicles through an intersection. This data is used in making decisions regarding the geometric design of the roadway, sign and signal installation, signal timing, pavement marking, traffic circulation patterns, capacity analysis, parking and loading zones, and vehicle classification.

The methodology of survey is similar to carrying out traffic counts at midblock. As a vehicle enters the intersection, the turning movement and vehicle type should be recorded.

Additional information that should be recorded include:

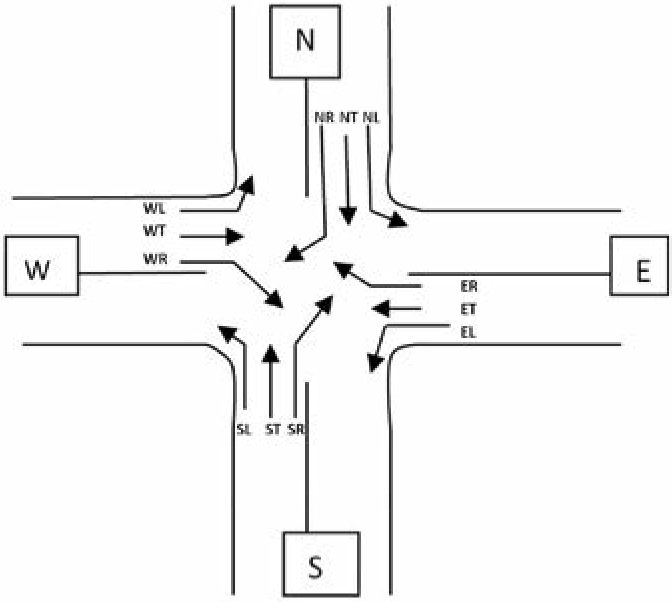
- The movements being observed by each recorder;
- The orientation of the intersection (i.e. indicate where north is);
- The type and locations of traffic control signs;
- Any adjacent commercial or residential developments, including structures, parking lots, etc.; and
- Any traffic incident (collision, congestion, etc) during the survey that causes a disruption to traffic.

If an event occurs during the survey that causes a major detour of traffic, it may warrant repeating the counts on a different day. However, the data may still be useful if more than half of the study period and the peak periods were captured while normal traffic conditions were present, before and after the event.

3.6.1 Typical Turning Movements

Turning movement counts capture all movements that vehicles make through an intersection. Typically, as a vehicle approaches an intersection it can turn right, go straight, or turn left. A standard intersection (see Figure 3.3) is made up of four legs (two roads crossing), which means that there are twelve possible movements vehicles can make through a standard intersection.

Figure 3.3 Typical Movements Through an Intersection



Key:
NL – From the north turning left
NT – From the north going straight through
NR – From the north turning right
EL – From the east turning left
ET – From the east going straight through
ER – From the east turning right
SL – From the south turning left
ST – From the south going straight through
SR – From the south turning right.
WL – From the west turning left
WT – From the west going straight through
WR – From the west turning right

3.6.2 Duration and Timing of Intersection Counts

Turning movement counts should be undertaken for a consecutive 24-hour period, usually from 12:00 AM to 12:00AM. However, a 16-hour count may be sufficient if it is not possible to conduct manual counting during night-time.

It is important that both AM and PM peak periods are captured during the counts, and therefore, the counting period must be predetermined.

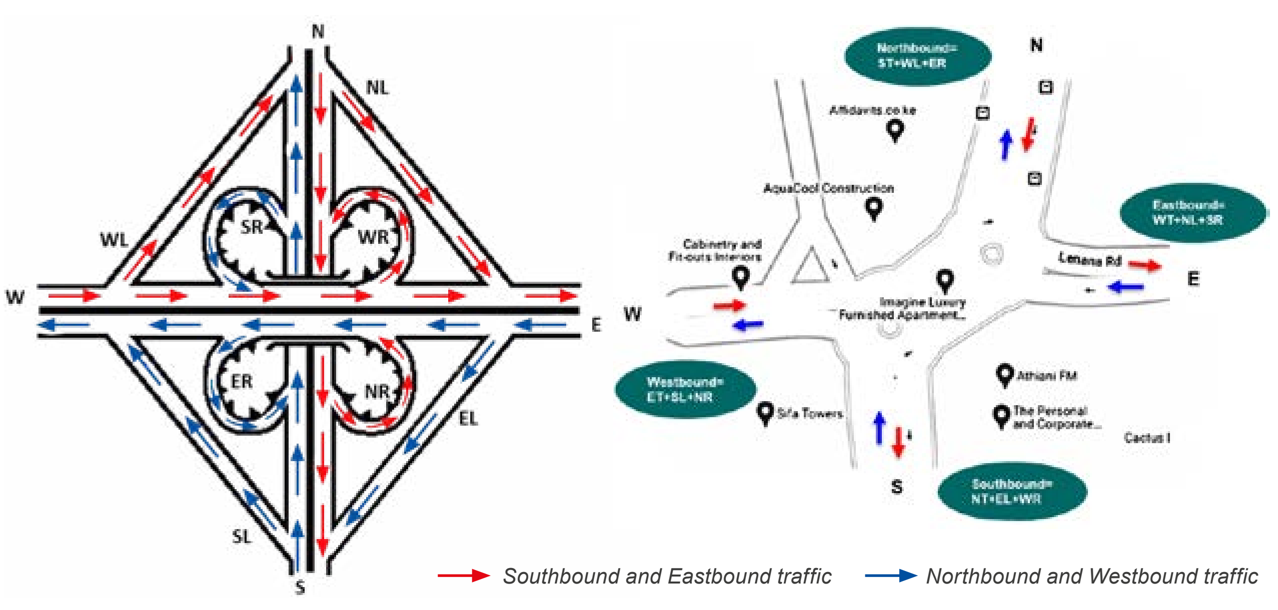
Turning movement counts should be conducted on a non-holiday weekday. Preferred days are Tuesdays, Wednesdays, and Thursdays. Surveys on Monday, Fridays and weekends should only be carried based on engineering judgement such as if there is a large weekend-traffic generator within the proximity of the intersection.

3.6.3 Counts at Interchanges and Roundabouts

The procedure for turning movement counts at interchanges and roundabouts are the same as at-grade intersections. However, coordination among surveyors is required to ensure that all movements are captured, and double counting is avoided.

As much as possible, the traffic engineer should summarise interchange movements into the 12 basic movements (See Figure 3.4). If the configuration is too complex, such as a U-turn and or there is an access to a commercial/ residential area on one of the ramps, then multiple consecutive turning movement counts at different locations on the interchange should be carried out.

Figure 3.4 Turning Movements at a Cloverleaf Interchange (Left) and Traffic Circle (Right)



The turning movements through roundabouts and traffic circles are more difficult to track than the turning movements through a standard intersection, particularly those with higher volumes of traffic. Each vehicle needs to be tracked from its point of entry into the roundabout all the way to its point of exit. For example, if a vehicle enters a roundabout from the north leg and exits the roundabout or intersection on the east leg, the movement is a NL (from the north turning left) movement.

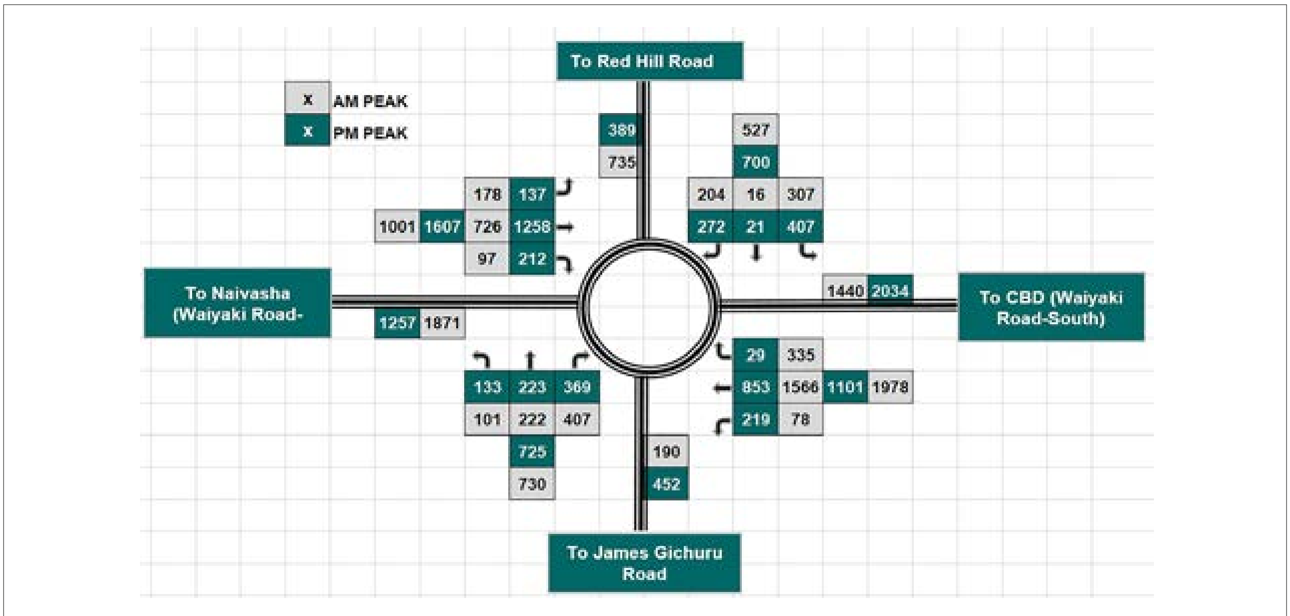
Video counting with cameras fixed at vantage positions should be used to capture traffic if the surveyors cannot maintain a line of sight through the roundabout.

The data recording form for intersection movement counts is under Appendix 3.2.

3.6.4 Data Analysis and Output

For ease of analysis, the turning movement flow matrices are usually prepared by type of vehicle or road user. Different matrices are also prepared for different times of the day to separate peak hours from off-peak hour flows.

Figure 3.5 Representation Showing Traffic Flows at an Intersection



3.7 NMT Volume Counts

Conducting non-motorised traffic counts present unique challenges in comparison to motorised vehicle counting. As compared to motorised counts, there are fewer standard practices for collecting NMT counts and there is minimal historical data available for assessing trends.

Some of the key challenges of NMT counts that the traffic engineer should consider in planning NMT counts include:

- Non-motorised volumes are much more sensitive to environmental conditions such as precipitation, temperature, darkness, etc. than are motorised vehicle volumes.
- Pedestrians and bicyclists are more challenging to detect than motor vehicles, because they are smaller, move in less regular patterns, and are not confined to fixed lanes, as are vehicles.
- Counting technologies used for non-motorised counting are different from those commonly used for motorised vehicle counting, and new technologies are emerging. Even when counting technologies are similar (e.g. pneumatic tubes, inductive loops), the counting errors associated with these technologies can be different for non-motorised users.

NMT volume counts can either be at an intersection (signalised or unsignalised) or midblock location (along the footpaths, designated and undesignated level crossings), underpasses, or overpasses.

The count duration will depend on the counting methodology. A counting duration of 4 to 7 days is sufficient. Generally, NMT counts are conducted during daytime, but night counts can be carried out depending on the objective of the study.

A person who passes by a point more than once should be counted each time they pass by the point.

Along road sections, an observer stationed on each side of the road should count bicycles in the normal flow direction, and all pedestrians and handcarts on the same side of the road irrespective of their direction.

At intersections, pedestrians, cyclists, and handcarts that cross each intersection arm should be counted irrespective of the direction of travel.

The data recording form for NMT counts is included under Appendix 3.3 (section counts) and Appendix 3.4 (intersection counts).

3.7.1 NMT Types

Depending on the environment and purpose of the study the NMT counts should capture the following NMT types:

- Adult pedestrians;
- Children pedestrians;
- Older pedestrians;
- Pedestrians with impairments;
- Pedestrians carrying load;
- Pregnant women;
- Cyclists; and
- Handcart users.

3.7.2 Pedestrian Crossing Observation

Pedestrian crossing observation yields the following information on pedestrians:

1. Road crossing time which is important in computing the mean walking speeds and the availability of adequate gaps in the traffic stream.
2. Crossing behaviour of individual or group crossing, this indicates availability of crossing facilities and perception of risk by pedestrians.
3. Pedestrian crossing trajectory, either right angle or diagonal depending on the availability of crossing gaps and vehicle speeds.
4. Availability and quality of pedestrian crossing facilities.
5. Information on pedestrians' attributes such as age, gender, etc. that may be used for comparative social analyses.

3.7.2.1 Acceptable Gap

Most pedestrians will accept a gap of 4-6 seconds at normal urban vehicle speeds to cross two lanes of traffic and shorter gaps at slow vehicle approach speeds.

Two methods, data logger or manual method, can be used to estimate the degree of difficulty of crossing for pedestrians. The method selected should be compatible with the complexity of the situation.

By the data logger method, using measurements of headway, flow and speed recorded during traffic counts and spot speed surveys, the data can be analysed to provide the following information:

- A table of the average time taken for a gap (greater than specified value) to occur between vehicles;
- A count profile of the vehicle flow throughout the day; and
- A distribution of vehicle speeds throughout the day.

By the manual method, applying a sampling criterion for pedestrians, the surveyor records the time the sampled pedestrian arrives at the crossing point, the length of time taken waiting for a gap to cross and the crossing time. If it is a dual carriageway, the time waiting in the median is also recorded. The form for this study is shown in Appendix 3.5.

The manual method should be supplemented by qualitative data. Using engineering judgement, the surveyor should assess on a descriptive form and record either 'Impossible to cross safely' to 'No difficulty in crossing within a second or two'. Based on the level of detail of data required, the traffic engineer can increase the categories for the descriptive responses.

Additional information should also be included such as if the pedestrian attempts to cross halfway and goes back, or if the pedestrian experiences any hindrances such as carrying load, assisted walking, holding a child etc.

3.7.2.2 Pedestrian Group Size Study

The purpose of this survey is to determine adequate gap time required for the 85th percentile group size of pedestrians to cross a street of specified width at a given time. The form for this study is shown in Appendix 3.6.

3.7.3 Data Analysis and Output

1. The NMT volume count study is used to determine the volume of pedestrians crossing the streets at signalised or non-signalised intersections. This study is used predominantly for minimum pedestrian volume warrant for signals installation.

2. To compute the 85th percentile pedestrian group size, the cumulative total number of groups of pedestrians crossing together is computed and then multiplied by 0.85.

3. Gap acceptance for pedestrians is computed as the average waiting time taken by all sampled pedestrians to cross the road. On a dual carriageway, acceptable gap should be calculated for each traffic stream.

4. The speed of crossing by an individual pedestrian is computed as:

$$V = \frac{\text{Width of the road}}{\text{Time taken to cross the road (less waiting time)}}$$

Equation 3.5

5. Individual speeds of sampled pedestrians are aggregated to compute the average walking speed. If there is a raised median 1.2m wide or greater, then the width of the road equals the exposed walking distance from curb to median.

NOTE: *The normal pedestrian traffic walking speed is 1.1m/s. Large variance from this would indicate possible deficiency with the existing road layout and safety features. This analysis can be supplemented by attribute data of the sampled pedestrians*

4 Origin and Destination Surveys

4.1 General

Origin-Destination (O-D) surveys are carried out to establish the nature of travel patterns in and around the area of enquiry and would normally be undertaken as part of a regional planning exercise and for an individual road project. These surveys, which can be quite labour-intensive, serve several useful purposes, including providing quantitative assessment of the amount of traffic likely to be affected by the proposal, the consequent impacts on various elements of the road system and commodity flows.

4.2 Need Identification

This is the first step in planning an O-D survey. It involves the identification of the issues related to the impact of the road project and to develop an understanding of the needs of road users during the survey period. The survey should aim at minimising delays and various pro-active measures, such as use of variable message signs to communicate with motorists in advance of the survey location are encouraged.

4.3 Methods of Survey

Data collected from O-D surveys is used to analyse the effect of proposals for change (e.g. a new traffic management scheme, or a new road) on travel through a study area.

Such a survey is intended to capture at minimum the following information:

- Travel mode, vehicle type and occupancy.
- Trip purpose and frequency.
- Number and purpose of the regular trips made by the same vehicle over a given period.
- Origin and destination of trips and route preference.
- Commodity type carried by vehicle.
- Potential diverted traffic.
- Preferred stopover locations.
- Common O-D pairs, depicted by desire line diagrams.
- Household characteristics of the trip making family.

The O-D data may be used in the following areas:

i. To determine the amount of by-passable traffic that enters a town,
ii. To develop trip generation and trip distribution models in transport planning process,
iii. To assess the adequacy of parking facilities by forecasting future parking needs,
iv. To determine the adequacy of the highway system and to plan for new facilities based on current and future land use changes.

The most common techniques employed in O-D survey are:

4.3.1 Road-side Interview Survey

Trained personnel are stationed at points where site distances, gradients and roadway widths are suitable., Traffic police will normally control traffic at the interview stations. The data can be manually recorded on individual sheets/ cards or entered on tablets or phones using a customised software. The latter is more accurate and particularly suitable with limited personnel.

4.3.2 Registration Number Plate Survey

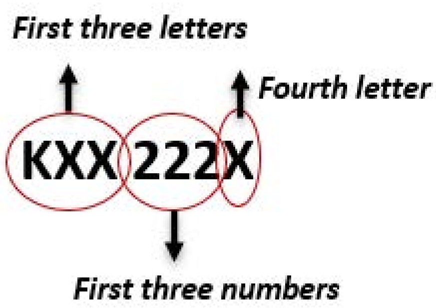
This method obtains less information, but it is easier to implement and is suitable for determining existing patterns of movement in small study areas. However, computerisation of the registration-matching process is essential. This survey matches the number plates and category of vehicles which enter and exit a defined study area via alternative routes to accumulate an O-D matrix.

Surveyors record a sample of the registration numbers and category of vehicles inbound and outbound to the study area, together with the time of observation and class of vehicle, if required. Two (2) or more surveyors are required at each observation point, one or more for each direction of traffic flow. Additional surveyors can be located at intermediate points inside the study area to provide more information on routing, travel time and possibly stops.

To reduce bias, the registration numbers can be used to select sample size, such as selecting all vehicles where the first number is an even number. Vehicle colour may also be used but the traffic engineer must first establish that it will not introduce any bias. And if the latter is adopted, the simultaneous volume count must also be classified by colour (as well as vehicle type) for expansion purposes.

To reduce errors during recording, the whole registration number should be recorded. If not practicable, then the first THREE letters and first TWO numbers should be recorded as shown in Figure 4.1.

Figure 4.1 Kenya Vehicle Registration Format



It is likely that about 10% of the numbers might not be matched due to recording errors, particularly where entry and exit flows are heavy. In such situations, manual recording may be impractical and CCTV or other video recording techniques should be considered.

NOTE: Since the survey begins and ends at the same time at all locations, some vehicles will be recorded exiting that will not have been captured at entry, and vice versa. This data should be removed from the dataset by estimating the average travel time from one cordon line to the other.

4.3.3 Household Survey

Household interviews may be conducted by telephone calls (or calls over internet) or by an interviewer visiting households and conducting a one-on-one interview. Household surveys are useful in collecting information on individual travellers and households' socio-demographics and trip characteristics such as trip purpose, frequency, origin and destination, and mode of travel.

Figure 4.2 Household Surveys

Household surveys are time and resource intensive and to reduce bias and errors, the interviewers should be equipped with a handheld GPS to record the survey. This logged data should be periodically checked by the supervisor to mitigate biases if any in the distribution of sampled homes.

4.4 Sampling and Survey Bias

It is not usually possible to interview each motorist, road user or household without causing undue delay or employing an excessive number of interviewers. For this reason, only a proportion of the population should be surveyed. The required sample size can be estimated from the following formula:

$$SS = [\hat{p}\,(1-\hat{p})] * \left(\frac{z}{E}\right)^2$$

Equation 4.1

Where,

SS = Sample size, or the number of responses required to ensure that the data is significantly representative of the vehicular population under study.

$\hat{p}$ = Sample proportion, or the sample as a percentage of the estimated vehicular flow.

z = z-value (statistic) corresponding to the level of confidence required (for instance, 1.96 at the 95% confidence level)

E = Margin of error required, or a measure of the variation within the data: the smaller this value is the more uniform the data is.

Table 4.1 Levels of Confidence and Associated Z-values

Level of Confidence (certainty)	z–value
90%	1.65
95%	1.96
99%	2.57

The survey duration depends on the sample size needed, however, as a general guide, for a single project corridor, at least 250 respondents is a sufficient sample size. The respondents must be spread uniformly over the entire project road length.

This manual recommends on average a survey duration of three (3) weekdays and one (1) weekend day, which should cover main market days or typical vehicle movements. For a roadside interview, the sample size should be at least 25% of drivers passing the interview location and care need to be exercised to ensure that this 25% is representative of the total traffic by way of random selection of vehicles.

As much as possible, the selection of the sample size should be free from bias that might impact the accuracy of the output. Some of the common biases the traffic engineer should be aware of include:

1. Non-coverage bias: This is present when a sampling plan does not include all subsets of a study population. Examples of such bias include a sampling frame that excludes persons under age 16, specific motorists of vehicle categories or days of the week.
2. Non-response bias: This can be present when a portion of the study population that possesses certain traits does not respond to a survey, causing the responses collected to be significantly different from those that would have been collected from the full population. Motorists stopped for roadside interviews may agree or refuse to participate. Efforts should be made to minimise non-response, for example by offering incentives for roadside interviews or by returning to a selected household several times to carry out an interview if on the first or second visit no one is home.
3. Self-selection bias: Survey responses almost always include some level of self-selection bias, which happens when individuals voluntarily choose to respond, or not respond, to a survey questionnaire. Using a sampling method (rather than inviting any interested participants) and making efforts to reduce non-response bias helps to minimise self-selection bias.

4.5 NMT Surveys

4.5.1 NMT Route Choice Analysis

Roadside interviews of bicyclists or of any other NMT vehicles, along a number of routes can provide information on trip origin – destination pairs, and trip purposes. This kind of survey need not cover the entire city but is best while considering a specific neighbourhood. This technique provides rather indicative than definitive data on route preference.

For pedestrians, it is generally assumed that their trips are shorter and more dispersed both in time and space, a route preference study is therefore less meaningful. Tracking of arbitrarily selected pedestrians using handheld GPS units within a given area would provide good information of common barriers causing detours to pedestrians, predominant road crossing spots, and commonly traversed paths. These would be determined from downloads of GPS tracks at the end of the survey period that could be as short as 1 hour to 12 hours. The GPS tracks are then overlaid onto the area map to visualise the exact route taken by the pedestrian.

The main weakness of these methods is that they can only tell the existing route choice but fail to indicate the likelihood of route shift if a change occurs in any socio-economic factors.

4.5.2 User Perception Surveys

This is closely related to NMT route choice analysis; however, user perception surveys are specifically intended to provide insight into shortcomings prior to or after construction of a project. The effectiveness of NMT infrastructure can be directly measured by asking users whether they have changed their behaviour as a result of the treatment.

Most important is to identify whether:

a. Users would otherwise have travelled by a different mode of transport for their journey (that is, car, public transport); or
b. They are making all-new walking trips directly as a result of the project.

The recommended method for identifying user perceptions is to conduct an intercept survey after construction. This survey should be conducted at relatively busy times (to maximise sample sizes) and seek to interview, as a general guide, around 100 NMT users (sampled based on the type and use of the facility).

Survey times should, as much as feasible, be representative of the user mix – for example, a weekday morning to capture commuting walking and weekend morning to capture recreational trips.

4.5.3 Attitudinal Surveys

Attitudinal surveys are meant to capture the social characteristics of NMT including:

- Age.
- Gender.
- Fare differences and fare competitions for various modes (e.g. boda-boda & motorcycles).
- Income/ poverty levels of NMT users.
- Trip frequencies.
- Comfort of NMT modes.
- Competition between the NMT modes and the MT modes.
- Pedestrian- motorist interaction.
- Perceptions of safety and security.

4.6 Survey Questionnaire

The survey questionnaire should be designed to meet the data needs and must consider aspects of safety of surveyors and for motorists to answer satisfactorily during roadside interviews. A sample of the O-D Survey questionnaires (for roadside interviews and license plate) is shown in Appendix 4.1 and 4.2.

For the household survey, the questionnaire should be short and define essential elements without harming data quality. The survey questionnaire question will vary based on the data needed. However, the key components of the survey are included under Appendix 4.3. The traffic engineer should only include questions in the household interview form if:

1. It is relevant to the models being developed or refined or to other anticipated analytical efforts.
2. It is expected to be a valid measure of the variables e.g., when using asset ownership to measure wealth, the traffic engineer must define the specific household assets that are good indicators.
3. It can be coded meaningfully.
4. The surveyor and respondent agree unanimously on the meaning of the question.
5. The response categories exhaust all meaningful answers.
6. The categories are meaningful and understandable.
7. The benefits of having the survey question outweighs costs in terms of survey length, respondent burden and risk of non-response.
8. The information gained from the survey is more useful than information that would be gained elsewhere (not from the survey). Such as information that may be available from public records.

It is good practice to carry out a pilot run of the questionnaire on a small sample of respondents to test length and to ensure that questions are interpreted as intended.

4.7 Site Selection and Surveyor Training

The survey locations should be selected considering optimum location to collect data and convenience for the survey staff. It is a common practice to identify safe zones such as bus stops, sidewalks, medians, and traffic islands for interviewers. Access needs to be provided to motorists without creating vehicle delays.

Ideally, O-D surveys should be done in conjunction with traffic volume counts, but at a location where stopping traffic will not interfere with the counts. Axle load surveys could also be undertaken alongside these other surveys or be lagged slightly so that vehicle flow patterns can be used to plan the axle load exercise.

Under O-D studies it is necessary to define external cordon lines which are imaginary boundaries of the study area. To counter-check the accuracy of the survey data, it may be necessary to have screen-lines, which are imaginary lines dividing the study area into smaller parts. The screen lines can capture stopping vehicles and duration of stops.

Training for surveyors is very important to improve the quality of data collected. Ideally, the traffic engineer should train the supervisors who in turn train the surveyors.

The training should cover aspects of:

- Project background and extent, objectives of the survey.
- Safety and security, including where to stand, how to approach a vehicle, proper conduct, and safe interaction with respondents.
- General information on the task: responsibilities and expectations, survey organisation and logistics, confidentiality of information collected and restocking of survey forms.
- Questionnaire administration, enumerator recruitment and supervision process (only for supervisors).
- Review of the questionnaire: concepts and definitions used, clarity of questions, how to enter responses, etc.
- Procedures to follow in administering the questionnaire.
- Practical work/pre-testing questionnaire.

4.8 Data Analysis and Output

Data analysis for OD and household surveys is mostly done using spreadsheets due to the voluminous data. Other programs such as the Statistical Package for Social Sciences (SPSS) could be utilised. The program choice depends on the complexity of the analysis, information sought from the analysis and availability of resources to the analyst.

The data is presented as maps, tables, charts, or as qualitative analysis. Such data can also be combined with georeferenced data/ information for clarity of presentation.

The attitudinal surveys would result in various analyses. The following are the most desirable data presentation for NMT social characteristic surveys:

- Challenges faced by NMT users.
- NMT mode-income correlations.
- NMT infrastructure condition.
- Operating conditions experienced by NMT modes.
- NMT trip distributions and route choice.

5 Traffic Growth Estimation

5.1 General

For most design purposes, an estimate of the traffic in the design year is required. Design parameters are based on traffic forecasts for the design year. However, traffic forecasting is an uncertain process, and the accuracy depends on the accuracy of the baseline data.

A traffic engineer may make use of time series analysis or econometric methods to estimate reasonable growth factors depending on the availability of historical traffic volume counts, macroeconomic data and any such data that may help in estimating economic development within the project's area of influence in the future.

Time series analysis: Historical data is analysed to establish any definite trend after which the engineer could employ the use of ordinary least squares regression to estimate best fit curve that could take any of the following forms.

$$T_f = T_0 (1 + r)^t$$

Equation 5.1

$$T_f = a + \beta t$$

Equation 5.2

$$T_f = a + \beta t$$

Equation 5.3

Where,

T_f = Is the future traffic volume,

T = Is the time variable (years after the base year),

a, β, c, k are parameters to be determined from the time series data. This however, requires sufficient data spanning several years, say 10 years.

In the engineering practice in Kenya, a traffic engineer determines one or two applicable compound growth rates for the design period of the road. The selection of the appropriate compound growth rates can be one of the problematic steps in determination of design traffic. Too high a rate will overestimate design traffic while too low rates will result in underestimation of design traffic. It is accepted that generally, in the first ten years of construction or rehabilitation, the traffic growth is usually above 5% and reducing to between 1-4 per cent thereafter.

The traditional compound traffic growth rate approach to determine the design traffic growth rate and then the cumulative growth factor for pavement and cross section design can significantly overestimate the design traffic if the compound growth rate is not carefully selected and adjusted for the design life of the pavement. This over estimation of design traffic may lead the pavement engineer to select a pavement type with a high capital cost and overdesign the pavement thickness resulting in the unnecessary expensive pavement.

The demerit with the linear growth rate model is that it can only be expressed as the change in the total traffic volume at a particular time. It can be expressed as a percentage of the total traffic for a particular year, but the percentage will change depending on what year is selected. The linear growth rate is not transferable between different roads. An advantage of the linear growth model is that it is independent of the initial traffic estimate at the time of opening unlike the compound growth model, which generates a different growth rate depending on what is chosen as the initial year.

Econometric method: Past planning data on selected economic indicators such as Gross National Income (GNI), population, industrial output, agricultural farm output, vehicle registration, or fuel consumption can be obtained from the relevant government agencies alongside historic traffic volume counts and used in econometric analysis to project future traffic growth rates. A regression equation with a basic functional form as given in Equation 5.4 can be fitted into the data.

$$Log_e T = a + \beta Log_e\,(GNI)$$

Equation 5.4

Where,

T = Baseline traffic volume

a = Constant

β = Coefficient of elasticity (elasticity)

GNI = Gross National Income

Beta (β) in the above equation is a measure of elasticity of traffic with respect to GNI. If for instance, it assumes a value of say 0.02, it would imply that for every 1% increase in GNI there would be a growth of 2% in traffic. Therefore, if the GNI is expected to rise by 3% in the future, the traffic growth rate will be 6%.

Prior to undertaking traffic projection, the following aspects should be considered by the traffic engineer:

- ✓ Available traffic forecasts from other studies: Were previous traffic forecasts developed for a study in or near the project study area? If so, previous methods and assumptions should be reviewed, and the study team should determine if any of the information can be used. If a previous study in or near the project study area with traffic forecasts is not used in the development of the new traffic forecasts, explanations should be provided as to why these were not used or deemed appropriate. All available data and studies used to develop traffic forecasts should be documented.
- ✓ Horizon year (s): The traffic engineer should ensure the base year, opening year and forecast horizon year is carefully selected to prevent under- or over-forecasting of traffic.
  a. Base year: the year when traffic counts and other traffic operational data (e.g., O-D, travel time, and delays) are collected or available.
  b. Opening year: the year when a project upon completion is open to public traffic.
  c. Interim Year: a year between the opening year and the forecast horizon year (design year), typically ten (10) years after the opening year.
  d. Design year: the year for which a roadway is designed.
- ✓ Documentation requirements: At a minimum, documentations should address assumptions adopted in the approach. Generally, forecasting methodology and techniques, supporting data sources, and forecasting analysis results in tabular and graphic format to illustrate projected growth rates and traffic volumes for the study corridor. If a demand model is applied, documentation on the model validation approach and results should be included as part of reporting.

***NOTE:** Declining traffic growth assumes traffic growth tapers off due to land use approaching built-out conditions or traffic demand approaching or exceeding roadway capacity. A declining traffic growth trend can be replicated using logit or other fitting equation as a function of roadway capacity. A declining traffic growth trend should be considered to replace linear or exponential traffic growth when roadway capacity and land use constraints are observed to affect traffic demand and travel behaviour. When a trend analysis produces minimal or negative traffic growth rates, a minimum traffic growth rate of 0.2 percent annually should be applied. Traffic growth rate calculations should be documented to describe the selected trend.*

5.2 Types of Traffic

When forecasting motorised traffic growth, it is usual to separate the traffic into the following three categories:

- Normal traffic.
- Diverted traffic.
- Generated traffic.

5.2.1 Traffic Categories

5.2.1.1 Normal Traffic

This is the future traffic that would travel on the existing road even if it were not improved. The projection for normal traffic is usually done by extrapolating time series data on traffic levels and assuming the growth rate will remain constant in absolute terms—a fixed number of vehicles per year (a linear interpolation), or constant in relative terms, that is, a fixed percentage increase.

Growth can also be related linearly to the anticipated Gross National Income (GNI). This is preferable because it explicitly considers changes in overall economic activity. If data on GNI is not available traffic forecasts should then be based on time series data.

It is only safe to extrapolate forward for as many years as reliable traffic data exists from the past, and for as many years forward that the same general economic conditions are expected to continue.

Fuel sales data could be used as a proxy to estimate a country-wide growth in vehicle traffic. It is usually prudent to counter-check how realistic the future forecasts are regardless of the forecasting method used. There are fluctuations arising from ever changing global fuel prices and vehicle import restrictions could impact severely on the future traffic growth rates particularly in developing countries such as Kenya.

5.2.1.2 Diverted Traffic

This is the traffic currently travelling along other itineraries, but which is likely to divert onto the improved/new road because of more comfort, convenience or time and cost savings, but still travels between the same origin and destination.

The origin destination survey is carried out to provide data for the traffic diversions likely to occur and the assignment of the diverted traffic is normally done by an all-or-nothing method in which it is assumed that all the vehicle that would save time or money by diverting would do so, and that vehicles that would lose time or increase costs would not transfer. And all the perceived costs should be included.

Diverted traffic is normally projected to grow at the same rate as traffic on the road from which it is diverting from.

5.2.1.3 Generated Traffic

Road development attracts generated traffic, which consists of *(a)* converted traffic (change in mode) and *(b)* induced traffic (increased total motor vehicle travel due to increased accessibility of the area).

Converted traffic is a direct consequence of large reductions in Vehicle Operating Costs [VOC] and corresponds to an underlying transport demand (due to the prevalent poor road/traffic conditions, travel remains unattractive).

Induced traffic includes traffic resulting from change in land use such as increased industrial or residential intensity due to the availability of cheaper transport. In practice, it is difficult to estimate the induced volume of traffic likely to be generated by a specific transport investment and this component is often underestimated. Each project must therefore be examined individually in the light of information about demand elasticities and similar experiences within the region of country concerned.

The generated traffic should be forecasted using the demand relationships (It is difficult to forecast accurately and can be easily overestimated). The price elasticity of demand for transport is the responsiveness of traffic to a change in transport costs, following a road investment. Distinction is made between passenger traffic, agricultural and non-agricultural freight traffic. The price elasticity of demand for transport should be based on door-to-door travel costs estimated following origin and destination surveys.

Generated traffic is likely to be significant in cases where the road investment brings about large reductions in transport costs and journey times. For small improvement within an already developed highway system, or involving short lengths of rural road, generated traffic will be small and can normally be ignored. For major projects such as those involving addition of extra lanes, or several major intersections, demand modelling software can be a powerful tool in understanding the potential traffic impacts.

5.2.1.4 Price Elasticity of Demand

Demand curves from economic theory can be used to estimate generated traffic, based the interaction between price and demand for travel as defined by price elasticity of demand—the responsiveness of traffic to change in transport costs arising from an investment in a road infrastructure. It is defined as the proportionate percentage change in travel demand to the percentage change in travel cost.

Literature on price elasticity of demand from several studies in least developed and emerging economies estimate typical values falling within a range of (-0.6) to (-2.0) with an average value of approximately (-1.0). This implies that a 1% reduction in transport costs results in a 1% increase in traffic.

In contrast, elasticity of demand for freight is much lower, varying from (-0.1) to (-0.5). Further, available evidence gives a general indication that price elasticity of demand for passenger is also lower, varying from (-0.1) to (-0.5) and largely depends on the proportion of transport costs in the commodity price.

5.2.2 Methods of Motorised Traffic Forecasting

Table 5.1 summarises the methods for estimating the traffic growth. These methods will not all give robust and reliable figures. Therefore, the traffic engineer must employ some degree of judgement about the quality of the data to obtain the best traffic growth estimate.

Table 5.1 Methods of Estimating Traffic Growth

Method	Description
Local historic precedent	In some cases, annual traffic data (collected for a number of years) for nearby roads may be available. The traffic data can be used to compute the traffic growth rate. The historical growth rates are often the best indicator of traffic growth on the road especially in the short term. The data to be considered should be nearby roads and as much as possible, be roads of similar function and hierarchy.
Economic growth estimation	Traffic growth is closely related to the growth of the economy measured in terms of Gross Domestic Product (GDP). Economic growth rates can be obtained from government plans and government estimated growth figures. The growth rate of traffic should preferably be based on regional growth estimates because there can be large regional differences.
Vehicle registry	The Government of Kenya maintains a registry of the number of vehicles registered annually. The annual traffic growth rate can therefore be estimated from the vehicle registries. However, since a good proportion of registered vehicles remain in Nairobi and Mombasa, the rate of growth in other peripheral areas is expected to be lower. The vehicle registry should be computed with and without motorcycles due to the rapid growth in the volume of motorcycles.
Weighbridges	The annual number of trucks weighed at static weighbridges, or weigh in motion stations, offer a good method to estimate the growth rate related to various truck categories. With good enforcement of truck weighing, this can be a good source of reliable data.
Population trends	In the long term, more macro-economic factors such as GDP growth and population growth are often the dominant factors. Population trends (national and local) can also provide useful information about possible traffic growth.
Fuel consumption trends	The Government's Customs Department maintains records of fuel imports. Fuel imports are related to demand, which is in turn is partly related to traffic growth rate. However, it should be noted that some of the fuel is used in industrial plants, agricultural equipment, and generators.

Note: *Some of the forecasting approaches might be sensitive to change in Government policies, for example, ban on particular vehicle type, re-routing of traffic etc. will influence the traffic growth trends. The traffic engineer must account for such factors as necessary in the estimation.*

Three traffic growth rates should be determined: low; medium and high. These three rates should be used to assess the impact on the designed facilities as one of them adopted. Based on prevailing factors, different growth rates may be used for different vehicle classifications.

Depending on the nature of any road development project, the forecasting approaches in use are:

i. Simple growth factoring of the existing flows, with total traffic assignment to a single road, normally used where there is no alternative competing roads or modes.
ii. The use of diversion curves in an 'either/or' situation, usually applicable in analysis of small towns with limited transport network.
iii. Complex computer-based models.

5.2.2.1 Forecasting with Traffic Demand Models

Increasingly, traffic demand forecasting models are becoming essential tools for roadway and facilities design. By modelling a traffic system, we can both understand aggregated phenomena arising from complex interactions and predict the behaviour of the traffic system in the near or far future.

The project data typically required as input into traffic demand models include roadway conditions, traffic counts, traffic controls such as signal timing plans, delays and queue lengths, operational speeds, and crash data.

Consideration should be given to the scope, location, and the nature of the project when selecting a model to be used for project traffic forecasting. The traffic engineer should verify that the latest version of the model is obtained and conduct a review of the base year validation and forecast year projections within the project study area.

All models used for project traffic forecasting must be approved by the relevant road authority that commissioned the study and determined to be suitable for forecasting traffic for the project. The main categories of computer-based models that could be used in road feasibility and for assessing project alternatives include:

- The classic four-stage model for transport demand analysis predicts the travel demand that is likely to materialise under some given set of assumptions. They largely reflect population and transport system characteristics.
- Land-use/transport interaction models which forecast changes in both travel demand and land-use patterns in response in changes in accessibility provided by the transport system (less popular with analysts and focus mainly on urban studies).
- Traffic assignment models that mainly focus on the supply side of the transport system, that is, how the predicted travel demand impacts on the proposed network; traffic forecasts are an input variable to these models.
- Junction simulation models which are used in optimisation of individual junction designs. Future traffic forecasts are key input variable in such analysis.

For rural roads or inter-urban highways, the forecasting analysis is less complex, usually relying on macroeconomic forecasts. On the other hand, urban road projects require more complex transport demand modelling.

5.3 Forecasting Non–motorised Traffic

Precise forecasting of NMT traffic flow is crucial for identifying the potential use of NMT infrastructure and improving NMT users’ safety and comfort. Most approaches and methods of traffic projection have traditionally excluded NMT activity.

Importantly, NMT traffic flows are characterised by their sensitivity to environmental conditions (e.g. weather situations and topography) and are more dynamic, hence challenging to forecast. Forecasting of NMT demand is important in the design of facilities such as:

a. Cycle paths, footpaths, or shared paths, including 'missing links' in an existing path network;

b. Unsignalised road crossings such as pedestrian refuges, zebra crossings;

c. Grade separated infrastructure; and/or

d. Signalised road crossings, including mid-block operated signals and NMT crossings at signalised intersections.

5.3.1 Methods of NMT Forecasting

Forecasting approaches vary widely in the amount of data and level of effort required. The type, specificity, and reliability of data also vary between different forecasting approaches.

Simple forecasting techniques such as factoring and comparison methods can be useful for simple NMT facilities design, however, more labour-intensive modelling tools can provide fine-grained analysis on future demand, network connectivity, collision rates etc.

While traffic forecasting is inherently uncertain, this is particularly true for NMT demand forecasting where:

- Existing data on pedestrians and cyclists' activity is limited, and often of variable quality;
- NMT activity, particularly in areas of predominantly recreational activity, is highly sensitive to weather and seasonal factors; and/or
- There is a wide variety of sociodemographic, land use and transport network-related variables which affect NMT activity; not all of these are readily measurable.

The three forecasting tools generally used for NMT traffic at road segment or corridor level include:

i. Factoring.

ii. Comparison methods.

iii. Demand modelling.

5.3.1.1 Factoring

With this method, NMT counts are obtained prior to construction, and these are factored up using indicative diversion rates from other completed projects to provide an estimate of the post-construction demand. This method is carried out in three steps:

1. Obtaining counts: of existing NMT users at the site(s) as described in Section 3.7.
2. Estimating the split between transport and recreation trips expected on the proposed facility: The trip purpose split is required to estimate the diversion rates.

   Generally, NMT trips can be divided into:

   i. Transport such walking to work, education, church, shopping, hospital etc.

   ii. Recreation trips; those where walking or cycling itself is the purpose.

   On major roads in Kenya, it is expected that most of trips will be transport related with more recreation trips in lower hierarchy roads and within/near parks.

   If the trip involves multiple purposes (for example, walking for both exercise and for a transport purpose, such as shopping, or a trip to a market), the trip should be treated as having a transport purpose. During weekdays, transport trips are more than during weekends.

   In the absence of existing data to define the distribution of the NMT trips by purpose, the traffic engineer may make assumption on the distribution based on local knowledge. However, as NMT database for a city, town or area is further developed, the data should be used for computation of the distribution factors.
3. Factoring up the observed demand using diversion rate factors.

   Diversion rates are the proportion of users after construction that are estimated to have changed their behaviour as a result of the project and can be considered as *(a)* pre-existing, *(b)* mode diversion and *(c)* induced.

   In most projects, the majority of NMT users are likely to be pre-existing – they may, however, be attracted to use the project in preference to other, more circuitous, or unattractive, pre-existing routes. The proportion diverting from motorised modes (private vehicle or public transport) will depend on *(a)* the proportion of transport versus recreation demand (higher levels of transport demand will lead to higher diversion), and *(b)* the relative attractiveness of the motorised modes. Construction of a 4 metre NMT lane from Upperhill to Nairobi CBD could have considerable modal diversion.

Indicative diversion rates should be based on intercept surveys in Kenya. From one project to another, the values should be corrected for:

1. Proportion of public transport use;
2. Scale of the project; and
3. Amenity of the NMT facility.

Table 5.2 shows typical range of diversion values that can be used as a guide, however, applicable values for Kenya should be derived from intercept surveys of NMT traffic on existing roads.

Table 5.2 Typical Diversion Rates, Adopted from Australia, 2021

Method	Description	
Diversion	**Transport**	**Recreation**
Pre-existing	60-88%	65-90%
Mode shift from car	3-10%	1-5%
Mode shift from PT	5-20%	0%
Induced	0%	10-30%

NOTE: 1. *If an NMT corridor is improved, a proportion of pre-existing traffic can be diverted to the new route.* ***2.*** *Proportion of mode shift from car will depend on the land-use and socio-economic factors of the project area. Mode shift from public transport for reaction trips is generally negligible.*

Example:

A new pedestrian crossing is proposed along Gitanga Road. Pedestrian counts within 50 metre of the location over two weekdays found an average weekday crossing demand of 500 pedestrians. Crossing demand on a single weekend day was observed to be 200 pedestrians.

Average day demand is: $$D_{ADT} = \frac{(500 * 5) + (2 * 200)}{7} = 415$$

The location, Gitanga road is assumed to be fairly residential, however the road is key commute route during the weekdays. Assuming the traffic split on weekdays is 65% transport, and 70% recreational on weekends.

The weighted purpose split is:

Average weekday demand: $$D_{ADT-W} = \frac{(500 * 5)}{(500 * 5) + (2 * 200)} = 0.86$$

Average weekend demand: $$D_{ADT-E} = 1\text{-}0.86 = 0.14$$

Average transport split: $$D_{ADT-T} = (0.86 * 0.65) + (0.14 * 0.3) = 0.60\ (60\%)$$

Average recreational split: $$D_{ADT-R} = (0.86 * 0.35) + (0.14 * 0.7) = 0.40\ (40\%)$$

Determining the projection factor from the diversion rates:

Assuming the diversion rates for pre-existing traffic is 80% for both transport and reactive purpose trips:

$$\text{Projection factor} = \frac{1}{(D_{ADT-T} * 0.8) + (D_{ADT-T} * 0.8)} = \frac{1}{(0.6 * 0.8) + (0.4 * 0.8)} = 1.25$$

Demand forecast = 1.25 * 415 = 519

5.3.1.3 Comparison Methods

This method relies on the availability of a reliable database. Using this approach, the traffic engineer can forecast the possible NMT demand at one location using historical volumes from one or more similar sites.

5.3.1.3 Direct Demand Models

Direct demand models are generally based on different versions of regression modelling as a function of measured characteristics of the adjacent environment. They can be simple in development and application since they are generally based on available data. However, in defining the variables, and fitting the regression models, the traffic engineer must be cognisant of the different characteristics and behaviour of the various types of NMT.

5.4 Scale of Forecasting

The scale of forecasting analyses for both MT and NMT is determined by the following factors:

- the nature of the project area (urban or rural): larger, more expensive projects present greater risks of wasted expenditure, should the project underperform and, in any case, would be expected to have more resources available to fund more sophisticated demand forecasting methods that the scale of expenditure warrants:
- The size and variety of alternative choices (roads and other transport modes) and prevailing modal split.
- Availability of data and resources: sophisticated approaches require significant time and financial resources, which may not be available or warranted.
- The forecasting approach adopted.

In situations where information is missing or outdated, new surveys would have to be undertaken to provide the necessary information required or to merely update the past data. This underscores the fact that estimation of required resources for forecasting must be based on a good understanding of the completeness of existing data sources.

5.5 Accuracy of Traffic Forecasts

However good the method of estimation adopted, baseline traffic flow measurements and traffic growth rates are prone to error. Accuracy of traffic flow forecasts is largely dependent on the accuracy and appropriateness of the base traffic count data.

Traffic count data are normally subject to errors arising from data sampling, measurement techniques used, and human errors either during the field surveys or at processing stage. Additionally, the forecasting process itself introduces some errors just as any other predictive model would, as the models rely on several assumptions that cannot be proven beforehand.

Forecasting approaches are sensitive to change in government policies such as increases in tax, ban on vehicles, rerouting of traffic on the network etc.

Future traffic estimates must then always be treated as only that, estimates. Any analyses based on traffic forecasts should be subject to sensitivity tests. The tests should cover a range around the estimated traffic forecasts to ensure that any pavement design or economic evaluation decisions are robust against inaccuracies in traffic forecasts.

6 Traffic Speed and Delay Surveys

6.1 General

Speed is a critical traffic metric as it relates to safety, time, comfort, convenience, and economics. Accurate traffic speed data is essential for road safety measures, pedestrian protection, and traffic management.

6.2 Spot Speed Surveys

The speed of vehicles can be measured instantaneously (spot speed) or averaged over distance or time. The spot speed of a vehicle varies as the vehicle accelerates or brakes. Spot speed data is used to:

- Determine observance of, and suitability of, existing speed limits.
- Establish suitable new speed limits.
- Determine a suitable design speed for geometric design of the highway.
- Provide information for use in road safety and enforcement programmes.
- Assist the location of certain traffic signs.
- Determine speed-flow relationships and traffic densities.

Spot speeds should be undertaken in free flow conditions. The exception is if speed measurements are to be taken for other reasons e.g. in connection with changes to an existing feature that naturally impacts the free flow of traffic.

Free flow is the condition of traffic where a vehicle's speed is not influenced by anything other than the roadway geometry and driver's decision making. Thus, it is the natural speed that drivers adopt when not impeded by any other traffic. Some of the conditions that exist in a free flow state are:

1. There is a minimum 5 second gap between vehicles.
2. An appropriate distance is required for a vehicle to reach a steady speed that is not influenced by start-up or slow-down speeds caused by any traffic control devices.
3. There should be no influence caused by:
   - Slow vehicles such as trucks or buses.
   - Enforcement or the perception of enforcement, construction or lane closures, inclement weather, or special event traffic.
   - Locations where the road geometry can cause vehicles to slow down and speed up such as at isolated sharp bends, gradients, and road narrowing.

Two situations where entirely free flow conditions may not be required include:

1. Improvements to an existing junction (see Section 6.4 of this manual).
2. In urban environments such as residential streets where persistent parking is typical, it would not be possible to undertake speed measurements in entirely free-flow conditions. In this situation, the persistent parking can be considered a deliberate design feature that naturally impacts the free flow of traffic.

Spot speed measurements should be taken in dry weather conditions.

6.2.1 Speed Measurement Frequency

Spot speed measurements should consist of a minimum of two individual speed measurement periods, undertaken on different days of the week, and at different times of the day.

The two individual measurement periods should be in different months and at least one month apart. If not feasible, a neutral month should be selected. A neutral month is a month that is not impacted by seasonal variation in traffic flows. This manual suggests using February, March, June, July, September, and October as neutral months based on the typical Kenyan school calendar.

On two-way roads, the individual measurements should be undertaken for each direction of flow.

Spot speed measurements should be undertaken outside peak traffic flow periods. Non-peak periods depend on location and road function. On urban arterial corridors such in Nairobi, Mombasa, Kisumu, and Nakuru, these are between 5-7 a.m., 10-12 p.m., 2-4 p.m. and 8-10 p.m. In smaller towns and rural roads, these are usually between 9-12 p.m. and 2-5 p.m. The non-peak hours can be reviewed on a case-by-case basis to account for traffic patterns and site-specific circumstances e.g. if a school, church, mosque is nearby that opens/closes at a particular time.

Speed measurements should not be carried out during a local event that can result in traffic flows and speeds that are not typical. This also includes situations where traffic is diverted along the study route due to road works occurring on other parts of the network.

Speed measurements should not be undertaken during weekends or on national holidays. On busy roads, measurements are usually conducted on a Tuesday, Wednesday, or Thursday.

Speeds should be measured at locations where the prevailing speeds are representative of the entire speed zone section. If speeds vary on a given route, more than one speed zone section will be required. Where there is a difference in the 85th percentile speeds derived from the individual speed measurements periods, the higher value shall be used in the subsequent design.

6.2.2 Sampling

Target population for spot speed measurement is all vehicles in the traffic-stream in free flow conditions.

On busy roads, this should be only passenger cars. Increasingly, research has shown motorcycles operating speeds to be high and these could also be included as part of the survey. Slower moving vehicles, such as goods vehicles can substantially slow the calculated mean speed.

On low volume roads, slower moving vehicles speeds can be measured. To reduce their impact on the calculation of 85th percentile speed, a correction factor should be applied.

The sample size for spot speed surveys should be such that the distribution of speed data follows a normal distribution curve. The minimum N (where N is the number of vehicles surveyed) must be 30 for a normal distribution.

However, as a general guide, a sample size of 200 vehicles is considered sufficient of busy roads. On very low volume roads, the time periods can be adjusted to increase the likelihood of observing up to 100 vehicles.

Minimum sample size should be calculated by the following equation:

$$N = \frac{v^2\, S^2\, (2 + u^2)}{2d^2}$$

Equation 6.1

Where,

N = Minimum sample size.

v = Normal deviate corresponding to the desired confidence level.

S = Standard deviation of the sample.

u = Normal deviate corresponding to the percentile being estimated.

d = Permitted error in the estimate.

The sample standard deviation of spot speeds is the only variant directly affected by vehicular speeds. The other three variables are selected at the traffic engineer's discretion based on purpose and accuracy of survey.

6.2.3 Methods of Measurement

Spot speed measurements can be undertaken using either manual or automatic methods. A variety of manual and automated methods of speed measurement are available, including:

1. Handheld radar speedometers (manual).
2. Pneumatic tubes or inductive loops (automated).

6.2.3.1 Manual Speed Measurement Methods

Radar speedometers operate on the Doppler principle. These devices typically powered by an automobile battery and give direct readings of vehicle speeds with an accuracy of ± 3 km/h.

The operating instructions for the radar unit should provide factors for calibration, optimum distance of survey, and optimum angle of survey.

As many of the vehicles that pass during a particular survey period should be recorded. A minimum of two surveyors should be used to reduce errors and allow for more vehicles to be recorded.

If the vehicle flow is high and speed of all vehicles in free flow cannot be measured, a sampling method should be used. For example, the sampling could be that the speed of every 6th vehicle in the stream is recorded (Refer to Section 6.2.2 for sample size).

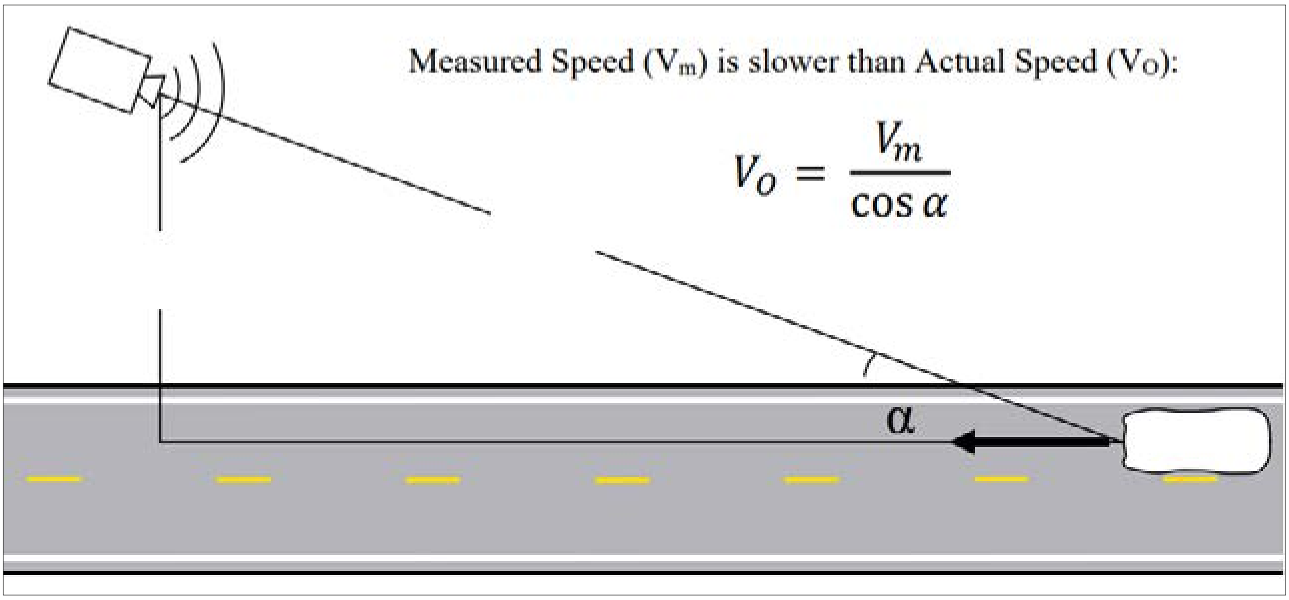
Figure 6.1 Radar Speed Meters

On dual carriageways, surveys should be completed for specific lanes at a time to reduce the risk of vehicles being missed when trying to measure vehicle speeds across multiple lanes at the same time. The results from individual lane surveys can then be added together.

Speed measurement should be done in an unobtrusive, undetectable manner to obtain a sample of normal traffic speeds. Surveyors, and their equipment (such as a vehicle) should obviously not be in a position that could influence the speed or flow of vehicles. Appearance of enforcement will alter the speed of vehicles and free flow conditions will not exist.

Basic equipment training, understanding of the cosine effect, and knowledge of which cars to survey are required.

Figure 6.2 Cosine Effect



__NOTE:__ The cosine effect shows that the speed measured by the radar (or other device), Vm, can be an inaccurate measurement of the vehicle's actual speed, Vo, depending on the angle, α, between the radar's line of sight and the vehicle's direction of travel. The difference between Vm and Vo can be minimised by reducing the perpendicular distance, d, between the radar and the vehicle's direction of travel. The readings should be simply corrected depending on vehicle lane. Automatic correction is possible with modern equipment.

The recording form is shown in Appendix 6.1.

6.2.3.2 Automatic Speed Measurement Methods.

Automated speed measurements can reduce the risk of errors by providing greater volumes of data and reducing the risk of the results being artificially skewed (for example caused by the presence of a surveyor inadvertently influencing driver behaviour). However, equipment such as inductive loops and pneumatic tubes cannot always fully distinguish between different vehicle types because the classification is based on axle spacing

Pneumatic tubes or other roadway automated equipment should only be used by trained personnel able to determine which vehicles are in free flow. The surveyor must also eliminate from the data the recordings of non-free flow vehicles and following vehicles in a platoon.

Vehicle speed measurement equipment should be checked for accuracy prior to a survey and be recalibrated annually.

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6.2.4 Data Analysis and Output

Results may be presented numerically or graphically. The most common graphical outputs are histograms and cumulative distributions of speeds which allow the extremes of the speed range to be seen. This is illustrated under Figure 6.3 and Figure 6.4.

Numerical results can be mean speeds; the range of speeds; the proportion of vehicles above or below a certain speed (for road safety and enforcement).

The 85th percentile is commonly used to describe speeds. This excludes extremely fast drivers (and gross measuring errors) and gives an estimate of what most drivers consider a top limit.

Where speed measurements have been taken either partially or entirely in wet weather conditions, the following values should be added to each individual speed recorded in wet weather[1].

1. 8 kph for class A and B roads.
2. 4 kph for class C and below.

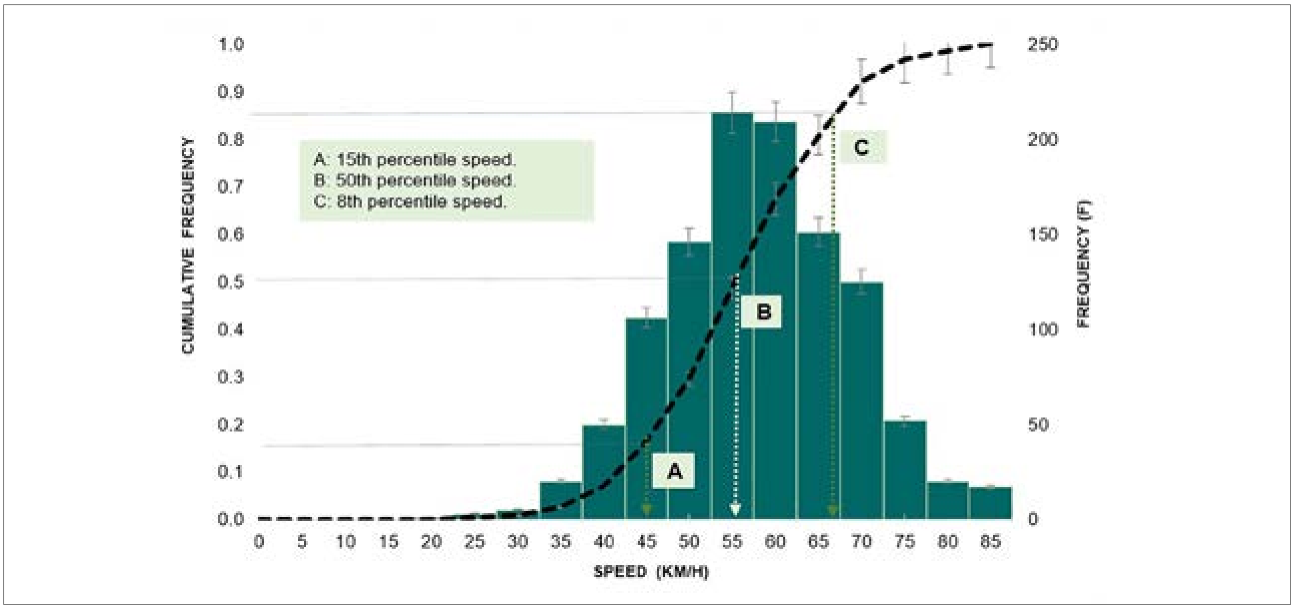
Wet weather conditions include periods after rainfall when the road surface is still wet.

Table 6.1 Example of Frequency Distribution (for Spot Speed Data)

Class Boundary (km/h)			Frequency		
Lower Bound	Upper Bound	Bin Mid (md)	Frequency (f)	Relative Frequency	Cumulative Frequency
20	25	22.5	0	0.00	0.0
25	30	27.5	4	0.02	0.0
30	35	32.5	7	0.03	0.0
35	40	37.5	9	0.04	0.1
40	45	42.5	14	0.06	0.1
45	50	47.5	11	0.05	0.2
50	55	52.5	23	0.10	0.3
55	60	57.5	55	0.24	0.5
60	65	62.5	61	0.27	0.8
65	70	67.5	21	0.09	0.9
70	75	72.5	13	0.06	0.9
75	80	77.5	8	0.03	1.0
80	85	82.5	3	0.01	1.0
85	90	87.5	1	0.00	1.0
		Total	230		

[1] *CA 185: https://www.standardsforhighways.co.uk/tses/attachments/8995b012-dac8-4ee3-a8a8-03da2e5c2ae4*

Figure 6.3 Graphical Output-spot Speed Results (Jogoo Road, Nairobi, 2021)



It is usually assumed that the distribution of speeds is a normal distribution. Hence, the equations relating to a normal distribution can be used to calculate the 85th percentile from the mean and standard deviation. The equations are as shown below but modern equipment should be capable of automatically calculating this.

$$p85 = m + s$$

Equation 6.2

Where,

$p85$ = The 85th percentile speed.

m = The mean of the measured vehicle speeds.

s = standard deviation of the measured vehicle speeds.

$$m = \frac{\sum v}{n}$$

Equation 6.3

Where,

$\sum v$ = The sum of all measured vehicle speeds.

n = The number of measured vehicle speeds.

$$s = \sqrt{\frac{\sum (v - m)^2}{n - 1}}$$

Equation 6.4

6.2.5 Traffic Signal Installations

When the design parameters for traffic signal installations are to be determined based on speed measurement, spot speed measurements of all motor vehicle types should be used. Measurements on the approach to the proposed installation should be based on the following rules:

1. Between 150 and 200 metres back from the existing/proposed stop line but as close to 160 metres as is practicable.
2. Where there are no parked vehicles within 100 metres of the measurement point.
3. When flows are between 20% to 40% of the maximum capacity of the junction.
4. Only during a green phase where no queues are present.

6.3 Network Speeds and Delay Surveys

Average network travel times and journey speeds are a measure of road traffic performance. They provide an indication of existing road link and network performance and help to identify specific congestion spots. They are important as an input to traffic models and road investment appraisals.

The basic method of measurement of network speeds and delays is the floating car method. Other techniques which can be adapted to the survey include moving-vehicle method, ANPR, videos and use of GPS.

Floating car technique provides a direct and accurate measurement of travel times and delays, and personal experience of the causes of delays (surveyors can directly observe the cause and period of delay). However, it requires large outlay of resources for a comprehensive network coverage.

The floating car method only surveys cars. Other vehicle types can be surveyed by following a selected vehicle. However, it may be difficult to choose random vehicles to follow when the route of the vehicle is not known in advance.

The surveyors should be cognisant of safety, especially at high speeds or in heavy traffic.

For a comprehensive study of a traffic network, surveyed links should include all the main road network, and various minor roads. When floating car technique is carried out for monitoring `before and after' surveys, specific turning movements which represent ‘typical’ movements through the site must be identified and included.

6.3.1 Methods of Measurement

The survey car is driven along a pre-determined route, at the typical speed of other cars. Surveyors in the car record the time at pre-determined timing points and the duration and cause of all stops and delays. In addition, the distance between the timing points is measured. Using a GPS, the location at the start and end and at each major intersection is recorded.

Pilot surveys should cover all survey links, at the same times of day as the full survey. This is to familiarise survey staff with the method and routes and to test the number of survey cars needed.

Practice should also establish the driving style required to 'float' or maintain one's position in the traffic stream, i.e. for the survey car to overtake the same number of vehicles that overtook it along the length of the route. The driver should not allow his driving style to change in response to the pressures of the survey.

To account for different traffic conditions throughout the day, each survey run should be related to a particular period. Typically, these periods are morning and afternoon peaks, daytime off-peak, evening peak. A minimum of three runs is recommended for each period.

Maximum route length capable of being covered in one run can be estimated from the duration of each period being studied, the number of runs required and typical assumed speeds. For example, in a 2-hour period requiring 4 runs, the maximum route travel time would be 30 minutes; allowing (say) 10 minutes for turnaround and unexpected problems leaving 20 minutes travel time; route length at an assumed 15 km/h would be 5 km.

The traffic engineer should identify the best route choice to cover the network in an efficient way. The survey links and nodes should be identified and shown on a network map, including one-way streets, and banned turns.

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Traffic Speed & Delay Surveys

In planning the survey, the traffic engineer should make the following considerations:

- Most links are usually 2-way and must then be surveyed in both directions.
- Circular routes are easier to operate; furthermore, U-turning vehicles can create problems of safety and delay, and it may be easier to have two vehicles circulating in opposite directions.
- If more than one survey car is needed, it is better to use short routes with one car per route (per direction) than longer routes with more than one car per route.
- For before and after studies, the routes chosen for the before study must be repeated exactly after planned changes have been implemented.

If the average of runs within a period is needed for some special purpose, the dispatcher should send off every car (in that period) at equal intervals. The dispatching interval should be greater than the longest circuit time in the pilot survey at the most congested time.

Recording form is shown in Appendix 6.2.

***NOTE:** Transit vehicle and truck tracking techniques can also be used for network delay surveys. However, they require active cooperation between the agencies with the operators. Public agencies wishing to track commercial vehicles must demonstrate to the vehicle fleet owner that the owner will receive some direct benefit in return for the expense of transcribing and sharing the vehicle tracking information.*

6.3.2 Data Analysis and Output

Data are usually presented by link (separately by direction), either as travel time or speed, and can then be aggregated for journeys or routes.

Data from individual runs should be presented individually as they represent conditions at different times of day. Simple averages can be calculated, but they may produce biased results, as more runs are made when speeds are high and delays few.

Travel times for each link or route can be compared by time of day and may be compared with the corresponding traffic flow by time of day.

6.4 Intersection Delay Surveys

Most delays in an urban area arise at intersections or accesses. Intersection delay is therefore a measure of intersection performance, usually presented in the form of average delay per vehicle. The data can be used to compare various intersections and indicate those most in need of improvement (either in design or control) or to compare the before and after delay following improvement.

Intersection delay study is used to evaluate the performance of intersections in allowing traffic to enter and pass through, or to enter and turn onto another route.

These kinds of surveys are generally carried out at roundabouts and priority/signalised intersections and involve measuring the queue lengths and delay times of vehicles incident on the junction. Traffic simulation software such as ARCADY and PICADY could assist in such analysis and are strongly recommended by this Manual.

6.4.1 Methods of Measurement

Two alternative survey techniques can be used; queue length (counting the number of stationary queueing vehicles at fixed time intervals) and queue delay (timing sampled individual vehicles passing through an intersection).

When comparing delay survey results (for example, in a before and after study), it is essential that the same survey method has been used.

Table 6.2 Comparison of Survey Techniques for Intersection Delays

Queue Length	Queue Delay
✓ Provides only total and average delay and cannot distinguish between delays for different turning movements.	✓ Distribution of delay can be calculated.
✓ Does not take account of delays other than on junction approaches.	✓ Delay can be estimated separately by turning movement.
✓ Relies on a clear determination of the number of stopped vehicles. Where the queue is 'rolling' as at roundabouts - the method is not reliable.	✓ Delays can be divided between the junction approach and the shared junction area.
	✓ The cause of delay to each sample vehicle can be recorded (for example, junction controls, pedestrians, other stopped vehicle).

6.4.1.1 Queue Length

Using the form (see Appendix 6.3), the number of stopped vehicles queueing on an approach to the junction are counted at fixed intervals, usually 15 or 30 seconds, although other intervals can be selected. Only vehicles that are stopped completely should be counted, vehicles which 'roll-through' the stop should not be counted.

For signalised intersections, the sampling interval should be selected so that it will not be a multiple of the traffic signal cycle length. For example, if cycles conform to a cycle length of 45, 60, 75, 90, 105, 120, 135, or 150-seconds, a 23-second interval between samples can be used.

For roundabouts or unsignalised intersections, the traffic engineer should select an appropriate interval.

At sites where the whole queue cannot be counted by one surveyor, or where vehicle classification is required, the approach must be sub-divided. The distance between the stop line and a point at least 10 metres beyond the back of the longest queue is divided into a number of `boxes' such that each box is small enough for a surveyor to be able to maintain a continuous count of the number of stopped vehicles in it. The front wheels determine the box the vehicle is in, except that the first and last boxes should include all vehicles in front of or behind the box, respectively (see Figure 6.4).

A sketch plan should be prepared, showing for every approach:

- The number of approach lanes, and any special fixed features (for example, bus stops, major accesses).
- Junction controls and signs. For signalised junctions, measure cycle time based on the average values over 5 cycles and note whether left turn on red is allowed.
- Whether delay is related to traffic movements on any other approach (for example, at roundabouts, and for opposed right turn vehicles at signals).
- The longest queue normally observed during the peak period.

If queues extend back to the next major junction upstream, then instead, `floating car method' or registration plate matching survey should be used.

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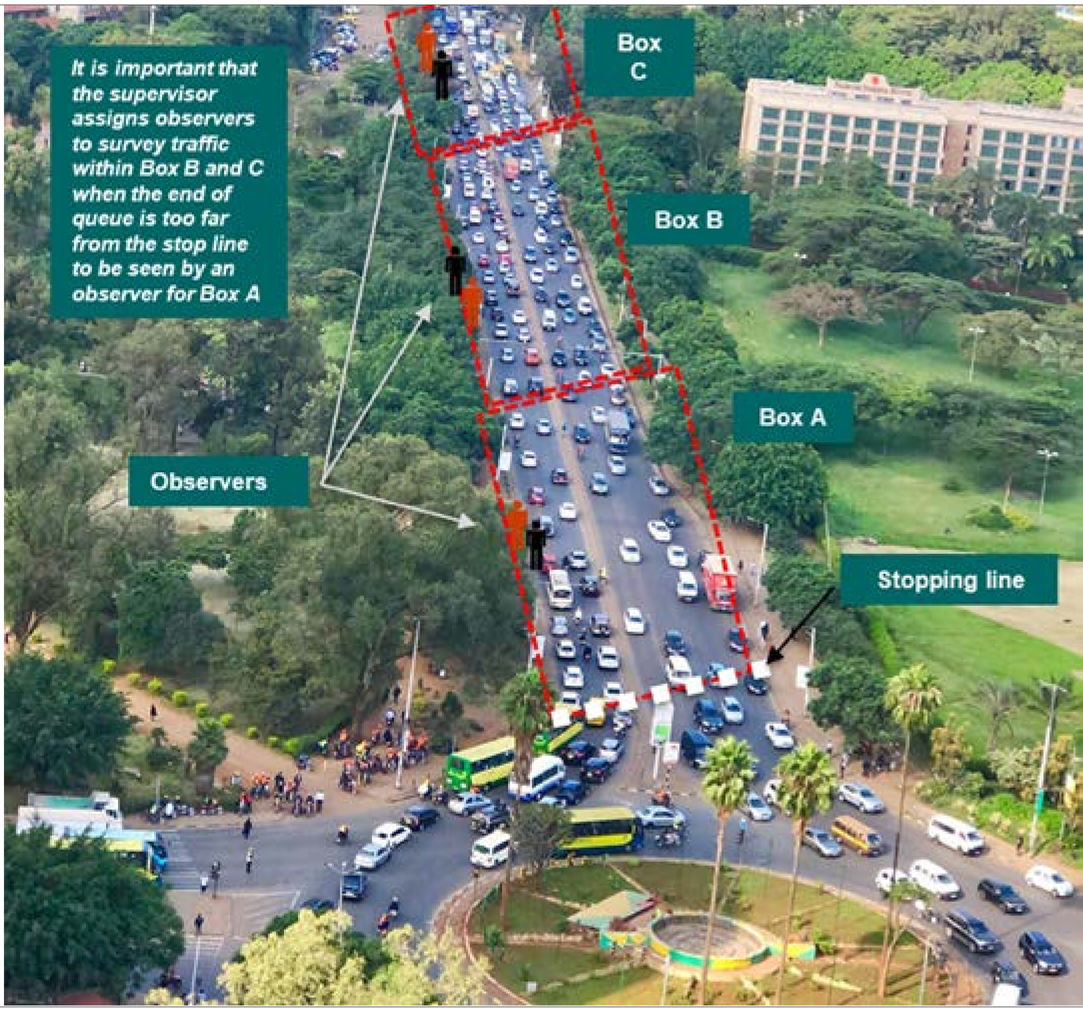
Figure 6.4 Delay Measurement by Stopped Vehicle Method



The traffic must not be classified into more than three vehicle classes. The Traffic engineer should determine the vehicle classes based on passenger car unit and impediment to flow. Similar vehicle classes should be adopted for queue delay survey. Non-motorised vehicles are not usually included.

An observation interval of between 10 and 30 seconds should be chosen (preferably an exact factor of 60 seconds) but must not be an exact factor of any regular signal cycle time occurring during the survey. The observation interval remains fixed throughout the survey and is the same for all approaches. Duration is usually 5 or 10 minutes to survey the entire intersection, which allows the different approaches to be surveyed in rotation. (All approaches must be surveyed simultaneously if delays on them are related.)

NOTE: *the sampling time is the time between each observation. While observation time is the time taken to survey each approach to the intersection.*

Video staggered along the carriageway can also be used to monitor queue lengths. This requires regular monitoring. Video is useful for queues exceeding 120 meters.

The field observation requires at least two observers. The first observer counts and records the number of vehicles stopped on the approach for each sampling interval. A stopwatch can be used to provide the observer with the proper intervals for counting the stopped vehicles. A vehicle is counted more than once in the delay determination if it is stopped during more than one sampling time.

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The second observer performs a separate tabulation of the approach volume for each period by classifying the vehicles as either stopped or not stopping. This period is also applicable for the evaluation of delays to pedestrian traffic at an intersection or any other location.

Alternatively, by accumulating the amount of time spent by each vehicle in the queue and counting all vehicles (moving and stationary), a true measurement of delay can be achieved.

6.4.1.2 Queue Delay

This involves recording vehicle arrival times and departure times at the intersection. Manual observation techniques are often used for queue delay surveys.

If possible, an elevated location should be established from where a surveyor can see all the approaches to the intersection. Individual vehicles are timed between fixed timing points on each approach. Vehicles are identified as either 'delayed' or 'not delayed' and average travel times between the timing points determined for each category.

The total and average delay is derived from the difference in travel times between the two sets (refer to form in Appendix 6.4).

For each approach, three points must be identified which are visible to the surveyor. The finish timing point can be either the exit from the junction, as defined in the travel time survey, or the stop line.

The start timing point must be at least 10 metres beyond the longest anticipated queue and related to a fixed, easily identifiable object. The sampling point should be at least 20 metres in advance of the start point. A pilot survey should be used to test the procedure during the most congested time of the proposed survey period.

6.4.2 Data Analysis and Output

The output from queue length and delay surveys are essential to calibrate and validate traffic models and provide evidence of congestion and delays.

For queue length surveys, total delay should be presented for each approach and for each time studied. Total for all approaches may be given provided the data were all collected at the same time.

$$\text{Total delay (vehicle hours)} = \text{Total number of queuing vehicles} * \text{Fixed time interval (hours)}$$

$$\text{Average delay} = \frac{\text{Total delay}}{\text{Traffic volume}}$$

Equation 6.5

For queue delay surveys, the calculations can be separated by vehicle class, turning movement, or period. Average un-delayed travel time is calculated from the travel times of those vehicles identified as un-delayed.

Individual delay time for delayed vehicles is calculated by subtracting the average un-delayed time for that class, from the sample vehicle travel time.

1. $\text{Mean delay} = \frac{\sum \text{Individual vehicle delays}}{\text{No. of sampled delayed vehicles}}$

2. $\text{Total delay} = \text{mean delay} * \text{traffic volume}$

Equation 6.6

7 Axle Load Surveys

7.1 General

Traffic contributes to the failure of pavements due to the magnitude of individual axle loads and the number of loading repetitions by these axle loads. For pavement design and maintenance purposes it is imperative to consider both the cumulative number of vehicles expected to use the road and the axle loads of these vehicles.

For every road design for a new facility, or for improvement of an existing one, the axle load distribution over a sample of typical vehicles using the road (or expected to use the road) must be measured. Axle load surveys therefore provide essential information that is required for both cost-effective pavement design and preservation of existing roads.

It is recommended that an axle load survey be carried out since basing designs on legal axle load limits is not valid given the widespread problem of overloading and due to the unknown proportion of vehicles that may be only partially loaded. There may also be significant differences between axle loads of vehicles using different classes of roads. This Manual, therefore, strongly recommends that for any road design, an axle load survey of heavy vehicles be undertaken in the area where the road will be constructed and/or on the study road to determine the damaging effect of traffic in terms of standard axles.

Cars and other two axle vehicles exert insignificant loading on pavements thus there is no use to weigh them. Axle load surveys weigh only commercial vehicles (goods vehicles and large buses)

This Manual only deals with the methodology of conducting axle load surveys. The analysis of the data and computation of design traffic is covered under **RDM Volume 3, Part 4: Flexible Pavement Design**.

7.2 Permanent Census Points

Firstly, the choice of traffic census points should as much as practicable correspond to the permanent traffic data stations. These permanent stations allow comparison of traffic counts collected over limited periods to historical traffic data.

Several weigh bridges have been established, these stations use weigh-in-motion to provide continuous traffic data and are designed for multi-lane bi-directional free flow measurement with integrated ICT Network. They are distributed on the national highway network as per Table 7.1 .

Table 7.1 Locations of VWS on the Kenya Network

Locations of VWS			
1	Mukumu; Kisumu – Kakamega	12	Kamulu
2	Mwatate; Voi – Taveta	13	Malili; Mombasa – Nairobi
3	Malaba; Webuye – Malaba	14	Kaloleni
4	Southern Bypass 1	15	Kaloleni
5	Makutano; Kitale – Marich Pass	16	Ahero
6	Southern Bypass 2	17	Emali; Emali – Oloitoktok
7	Ngeria *(before Bypass interchange)*; Eldoret – Nakuru	18	Eldoret
8	Yatta	19	Kibwezi; Kibwezi – Kitui
9	Eldama Ravine; Kampi Ya Moto – Eldama Ravine – Kamwosor	20	Mayoni
10	Sagana	21	Madogo; Madogo – Garissa – Nuno & Madogo – Hola
11	Kajiado; Athi River – Namanga	22	Laisamis

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Axle Load Surveys

Figure 7.1 Virtual Weigh Station Along Southern Bypass Road

There are also nine permanent weigh bridges on the Kenyan road network that can provide continuous axle load data. The locations are as follows:

Table 7.2 Locations of Permanent Weighbridges on the Kenya Network

Location		Type
1.	**Mariakani** (Along **A109**)	High speed WIM and multi deck scales
2.	**Mtwapa** (Along **B8**)	Static
3.	**Athi River** (Along **A104**)	High speed WIM and multi deck scales
4.	**Gilgil** (Along **A104**)	High speed WIM and multi deck scales
5.	**Webuye** (Along **A104**)	High speed WIM and multi deck scales
6.	**Rongo** (Along **A1**)	Static
7.	**Juja** (Along **A2**)	Static
8.	**Busia** (Along **B1**)	Static
9.	**Isinya** (Along **A104**)	Static

Secondly, selection of locations for traffic survey and axle load data relies on the segmentation of the road corridor into homogeneous sections. As an initial guide, the traffic engineer can adopt the road segmentation as per the most current Road Inventory and Condition Survey (RICS).

7.3 Vehicle Classes for Axle Load Analysis

Goods vehicles of gross vehicle weight exceeding 3,500kg and passenger vehicles of seating capacity of 26 persons or more should be considered for axle load survey and analysis (the vehicles classification for the full range of vehicle fleet in Kenya is as tabulated in Table 2.1). Table 7.3 reflects only the vehicle classes to be considered for axle load surveys.

Table 7.3 Vehicle Classification for Axle Load Surveys

Vehicle Class	Code	Description based on Road Design Manual and the Traffic Act (Cap 403)	Class by Axle Configuration
Bus	**B**	Two axle rigid chassis passenger motor vehicle with seating capacity of 26 to 53 persons including the driver.	2-Axle Rigid
Omnibus	**OB**	Three or four axle passenger motor vehicles with seating capacity of more than 53 persons including driver	3 or 4-Axle rigid or articulated
Light Goods Vehicle	**LGV**	Two axle rigid chassis goods vehicle of gross vehicle weight not exceeding 3,500 kg.	2-Axle Rigid
Medium Goods Vehicle	**MGV**	Two axle rigid chassis goods vehicle or tractor with gross vehicle weight of 3,500 kg to 8,500 kg.	2-Axle Rigid
Heavy Goods Vehicle	**HGV**	3 or 4 axle rigid chassis goods vehicle or tractor with gross vehicle weight greater than 8,500 kg.	3 or 4-Axle Rigid
Heavy Goods Vehicle	**AHGV**	Articulated goods vehicle having 3 or more axles of gross vehicle weight exceeding 8,500 kg.	3 or more Axles Articulated

7.4 Choice of Weighing Equipment

Vehicle weighing systems for the distribution of axle loads can either be *(a)* static weighing stations, *(b)* static portable scales, or *(c)* using weigh-in-motion (WIM). The choice of equipment depends on duration of survey, safety, and resource considerations.

As a first consideration, the traffic engineer should obtain data from a fixed weighbridge if one exists near the study road or if there is a virtual weigh-in motion station along the study corridor (see Section 2.1). If not, or in case additional data is required, then a portable static weigh pad should be used to measure the axle loads.

Static scales have high accuracy, with a typical precision of 3 to 5 percent, but they suffer the risk of safety, delays, and avoidance by motorists. Avoidance of weigh stations by trucks, which either take alternative routes or avoid driving while the weigh station is in operation, can be exacerbated by the delays and the high visibility of the static weighing operation.

It is recommended that portable static scales be regularly and accurately calibrated by the manufacturer using calibrations provided by an accredited facility.

Other versions of WIM are in portable form and have increasingly become popular. However, they are less accurate and therefore, they should not be used for obtaining axle load data for design purposes. Research evidence indicates that portable WIM scales underestimate the weights for steering axles (which are lighter) and overestimate the drive and trailer axle weights (which are heavier).

7.5 Sample Size of Axle Load Surveys

Accuracy of the survey increases with the number of vehicles weighed. As much as possible, all vehicles should be weighed. However, this may not be practicable especially when using static portable pads by the roadside.

The number of vehicles that can be weighed depend on; *(a)* volume and flow of vehicles, *(b)* speed of weighing and *(c)* site layout. Safety is paramount and should be considered above everything else. In case the weighing is causing queuing and a long tailback of vehicles, the survey should be suspended until normal conditions prevail.

Traffic counts should be conducted prior to inform the volumes. The traffic volumes can be used to determine the sample size of the axle load survey. Without prior traffic counts, the sample size should be determined within the first hours of survey.

On busier roads, the surveyor should target to weigh at least 10% of the commercial vehicles. The number of vehicles weighed can be reduced by weighing a smaller number of empty vehicles. This is because, like buses, the load distribution of empty vehicles is constant. However, the empty vehicles should still be interviewed, and their details recorded for the rest of survey as other vehicles.

To eliminate bias in sampling, the surveyor should select the vehicle to be weighed in rotation, for example, every third or fourth commercial vehicle.

Buses and omnibuses have high axle loads and should be weighed as part of the survey. It is acknowledged though that the load distribution is fairly constant for similar sized buses, and they can make frequent trips. It is sufficient to weigh only a small number of buses. The surveyor should target to weigh at least 5% of the buses comprising empty, partially full and full buses should be sufficient.

The variation in directional load distribution can be large on some roads. Design should be based on the direction with the higher axle loading to avoid risk of premature pavement failure. It is therefore critical the direction of each vehicle weighed is clearly recorded.

The survey entry form is in Appendix 7.1.

7.6 Duration of Axle Load Surveys

The duration of the survey should be the same as the duration recommended for traffic counts. If possible, axle load survey should be conducted continuously for 24 hours over the entire week (7 days).

If night surveys are not practicable, the survey time can be reduced. However, the survey durations should be at least 12 or 16 hours. Surveys less than seven days are not recommended.

If the traffic engineer observes considerable avoidance by motorists (this is highly likely for overloaded vehicles), then the survey duration can be modified. The survey can be undertaken over fourteen days for each half day or spread over a full month. This may not be always a possible alternative due to resource constraints.

Days of abnormal traffic flows should be avoided, for example, public holidays. Much care needs to be taken especially in rural areas with marked seasonal variation in traffic flows. Surveys could be repeated at different times of the year and results weighted according to the duration of the ‘seasons’ to enhance accuracy.

7.7 Survey Location and Site Layout

The survey site should be located on a clear stretch of road with good visibility in both directions. It is advisable to site the weighing equipment at a hill crest so long as the approaches on both sides have adequate visibility, since heavy vehicles will naturally slow down at such places due to gradient.

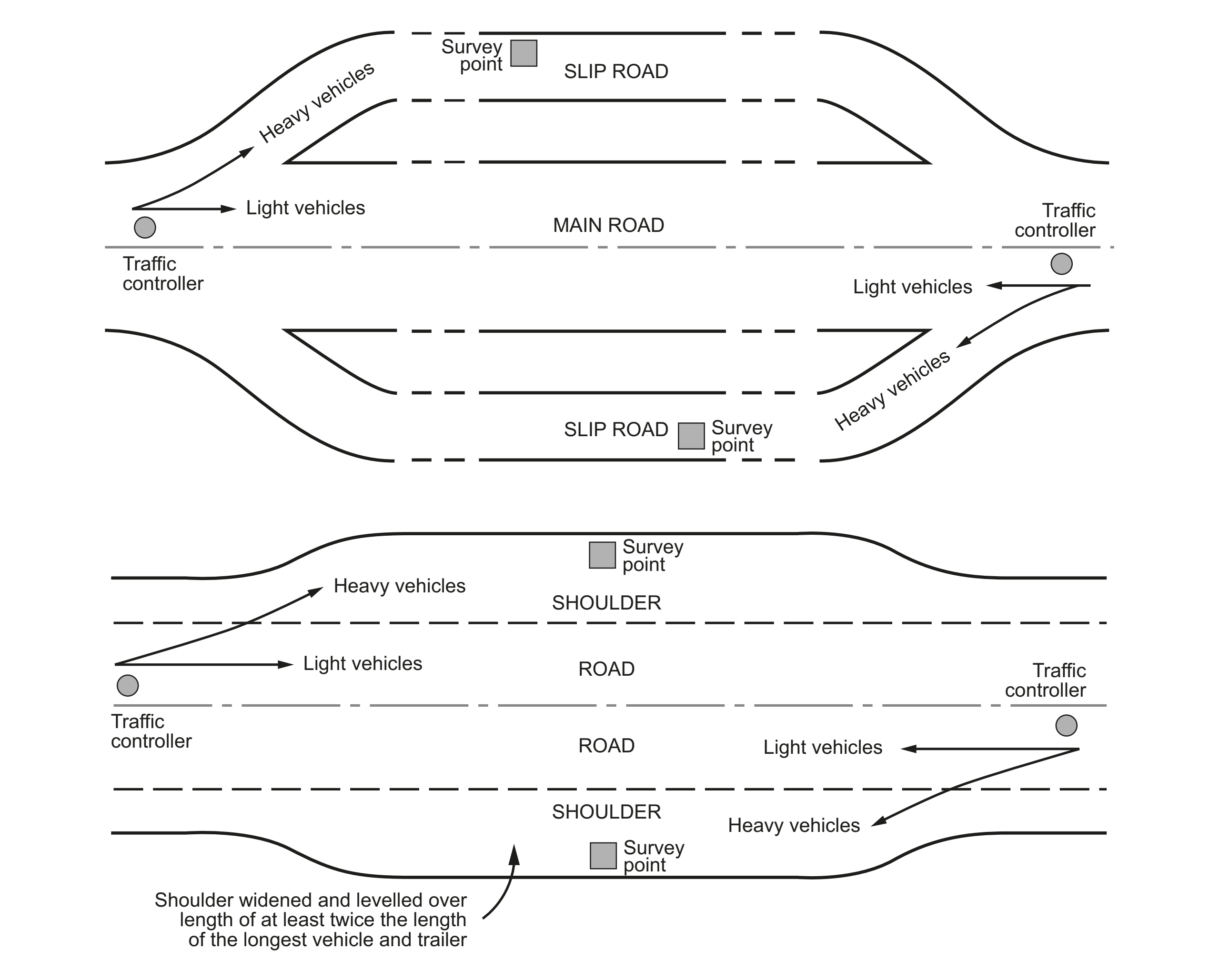
The survey team should be positioned away from road intersections. If queues form as a result of the weighing process, the operation should be stopped until normal traffic flows prevail.

Advanced warning signs need to be sited on the approaches to weighing site to inform drivers of the axle load survey and accord vehicles time to break safely and to stop. During the survey, traffic controllers should stand at the middle of the road about 30 meters on either side of the weighing pads where they are clearly visible to the oncoming traffic. They should instruct the truck driver on how to approach the weigh bridge at a slow speed.

The driver questionnaire can be used to conduct origin destination survey and to obtain additional information such as: age of vehicle, average annual mileage, commodity carried, which may be used for economic analysis such as vehicle operating costs (VOC) and the road user operating costs.

Case 1: For medium to high traffic flows, two sets of weigh pads should be used. They should be set in each direction- not exactly opposite but within the same road section. The pads can either be set on the slip roads if present or on the hard shoulder (see Figure 7.2).

Figure 7.2 Layout for Medium-High Traffic Flow on Slip Road *(Top)* & Hard Shoulder *(Bottom)*



Case 2: If only one set of weigh pads are available, then alternate weighing should be used. Vehicles travelling in one direction can be weighed for a set period, and the pads then moved to the opposite direction. The traffic engineer can alternate the directions on separate days to account for hourly fluctuations of traffic during the day. Similar to case 1, the pads need not to be set directly opposite each other but must be within the same road section.

Case 3: For low traffic volumes, vehicles travelling in both directions can be weighed using only one set of weigh pads. The measurements in both directions can either be done simultaneously on a slip road or hard shoulder if the trucks crossing are unlikely to cause hazard. If not, then as case 2, vehicles in one direction can be weighed for a set period and then the weigh pads moved to the opposite direction (see Figure 7.3).

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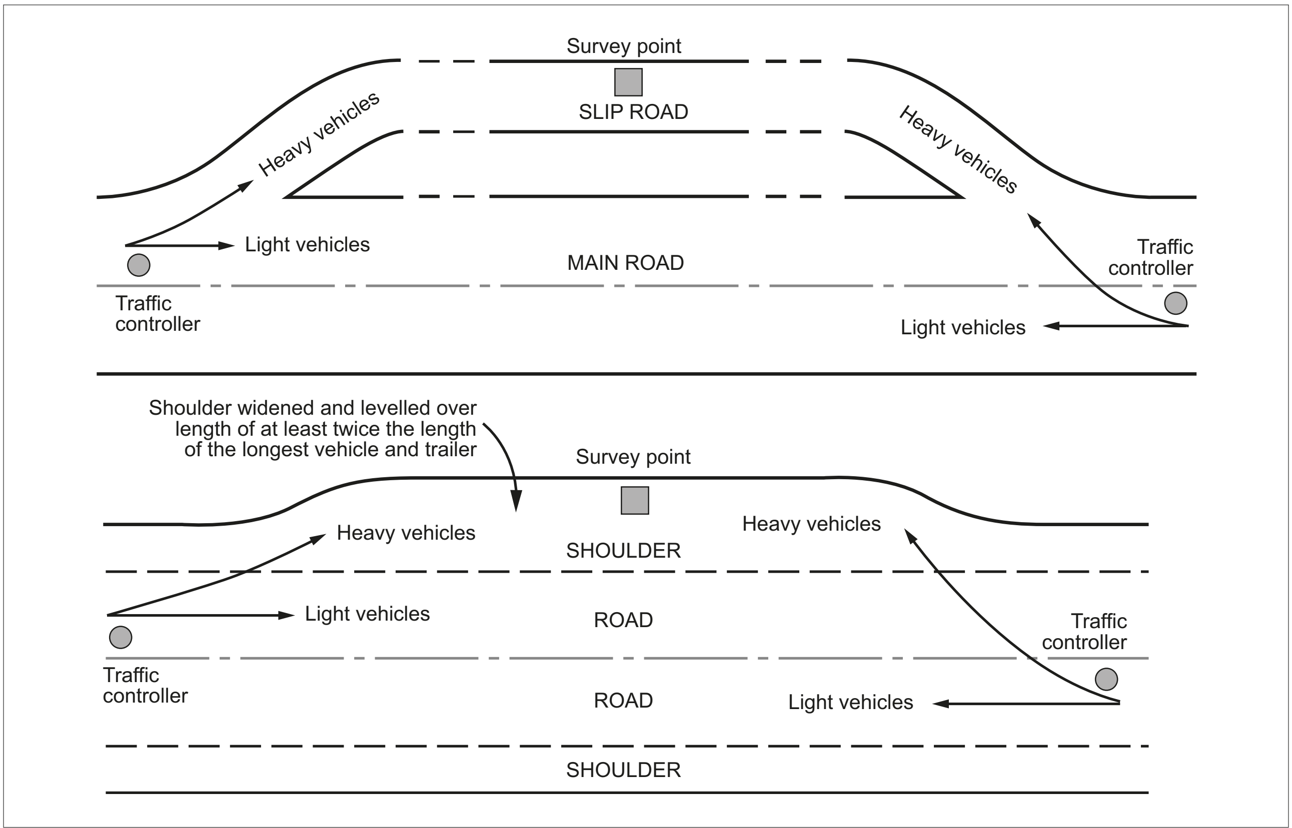
Axle Load Surveys

Figure 7.3 Layout for Low Traffic Flow, on Slip *(Top)* Road and Hard Shoulder *(Bottom)*



7.8 Sizing and Positioning of Weigh Pads

The weigh pads need to be placed or positioned on a firm levelled ground.

If only one weigh pad is being used, then a level platform ought to be provided to support all wheels on one side of the vehicle that are part of the same suspension unit. This ensures that the wheel being weighed is at level longitudinally with others in the unit. This does not prevent a slight transverse tilt from one side of the vehicle due to the camber effect, but the errors introduced in this case by the small tilt are quite insignificant.

Evidence from research show that raising an individual wheel by say 20 mm could result in errors in the axle load in excess of 10%. The transverse tilt should be eliminated by placing a dummy weigh pad and platform to support the opposite wheels of the axle being weighed. This has the effect of keeping the axle at level and prevents any errors introduced by the camber effect of the road. Errors arising from longitudinal tilt are usually negligible provided the site is sufficiently levelled.

For vehicles with multiple axle configurations such as tandems and tridems, weighing need to be undertaken for each individual line of wheel loading.

The size of weigh pads does not matter particularly when heavy articulated trucks with large tyres are being weighed. It is the width of the pads that are critical. The pads must be wider than a set of twin tyres, which are usually about 45 to 55cm wide. If the entire base of each wheel is not resting on the weigh pad, then the loading of the vehicle is concentrated only on part of each tyre. This could present danger to the survey staff as a tyre blow-out could easily occur more so if the tyres are worn out.

The capacity of one set of weigh pad should be at least 40,000kg; each capable of weighing 20,000kg of wheel load separately.

Figure 7.4 Vehicle's Front and Rear Wheels Adequately Accommodated by the Weigh Pad

7.9 Data Analysis and Output

Analysis of axle load survey data is comprehensively covered in **RDM 3.3**, section 2.5.

8 On-street Parking Surveys

8.1 General

This section covers parking surveys undertaken for roadway design. Parking survey is intended to quantify parking patterns by collecting data on the existing parking capacity and demand. The survey data can be used to determine lengths of stay, capacity, and usage of available parking spaces.

8.2 Methods of Measurement for Parking Surveys

Parking surveys are mostly undertaken by manual methods. Three types of surveys should be carried out:

1. Parking inventory survey.
2. Parking occupancy survey.
3. Parking turnover survey.

8.2.1 Parking Inventory Survey

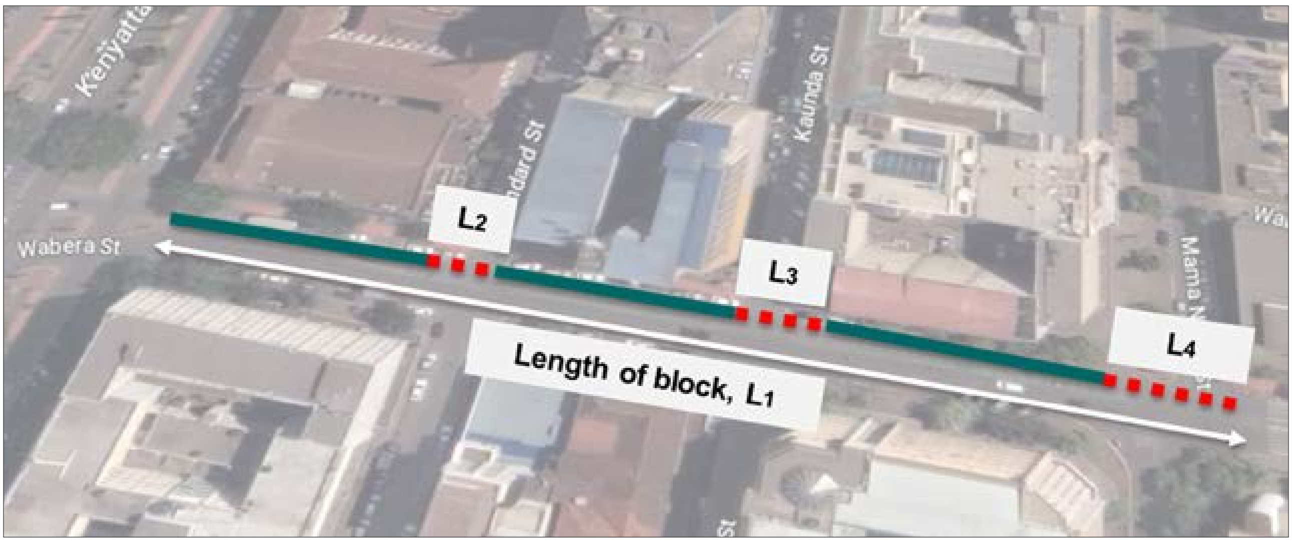
As a first consideration, the traffic engineer should establish if there is an existing parking inventory for the road corridor. In the absence of such data, parking inventory should be estimated by either:

- **Marked spaces:** If the parking spaces along the road section are marked, these spaces should be counted manually and tabulated to determine the parking supply.
- **Unmarked spaces:** If unmarked, the traffic engineer should make an estimate of the parking capacity by measuring the length of the road section/corridor and subtracting the sum of lengths of all accesses and no-parking areas from the length of each block face. The resulting length is then divided by the length of a typical parking space as indicated in Table 8.1.

Table 8.1 Typical Parking Spaces for Cars

Typical Parking	Space Requirement	
	Width (m)	**Length** (m)
Parallel parking	2.4	6
Angled parking	2.4 to 2.7	5.4

Figure 8.1 Estimation of Available Length for Parking



The parking inventory on an unmarked road is therefore estimated as:

$$L_0 = \frac{(L_1 - L_2 - L_3 - L_4)}{Length\ of\ a\ typical\ parking\ space}$$

Equation 8.1

Where,

L_1 is the length of block, L_2, L_3 and L_4 are length of the accesses and no parking areas.

Places which are illegal to park, and where drivers are unlikely to park should be identified and marked differently in the survey. Examples of this include:

i. Private property
ii. Where parking would contravene roadway restrictions such as yellow lines
iii. Where parking would obstruct an access; where the width of the road is too narrow to allow parked cars and passing traffic.
iv. Parking spaces restricted to private use, disabled parking, taxi parking or high-occupancy vehicle parking.
v. Where the width of the road is likely to lead to parking partially or fully on the walkway, or passing traffic to mount the kerb to pass, with the potential to obstruct the walkway for pedestrians.

NOTE: *Parking spaces that primarily serve as waiting bays for public service vehicles (PSVs) should also be indicated.*

8.2.2 Parking Occupancy Survey

The survey should take the form of a beat survey where a parking surveyor walks a planned route at regular intervals (every 1 hour), recording the number of parked vehicles.

The parking surveyor should record the number of vehicles parked legally, double parked vehicles, those blocking other vehicles in lots, and any large trucks blocking more than one space. To accurately capture demand, the number of bicycles parked should be counted as well.

If multiple parking surveyors are participating in data collection, if practicable, they should start and end at the same location, preferably near a shop outlet or a well-defined access road. See Figure 8.2 for illustration.

Figure 8.2 Survey Layout for Two Surveyors Starting at Same Location

The length of block assigned to each surveyor should be such that it can be completed within the hour of shift. Typically, a 2 km length of block can be surveyed in one hour but this should be established from a pilot survey.

The surveyors should count and record the type of vehicles parked. The classification adopted for the survey should be agreed upon by the traffic engineer based on the need(s) of the survey. Typical car equivalence values that can be used to convert the vehicles into car space are as shown in the table below:

Table 8.2 Conversion Factors to Car Space Unit

Vehicle type	Equivalence factor for car space unit
Bicycle	0.1
Two-wheeler/ three-wheeler	0.3
Car	1.0
Minibus	1.5
LGV	2.0
MGV	3.0
Omnibus	3.9
HGV	4.0

8.2.3 Parking Turnover Surveys

Turnover surveys are undertaken in a similar way to occupancy surveys. However, for turnover surveys, the surveyor also records the license plate of the vehicle. Bicycles and any unregistered vehicles are not recorded.

Since the surveyor is required to record more detail than in occupancy surveys, survey length covered in every one-hour shift is generally reduced, typically to 1 km.

The survey is undertaken hourly, during which the vehicle types, licence plates and the type of parking for each vehicle is recorded.

8.3 Survey Duration and Frequency

Two weekday surveys (Monday to Thursday) and one weekend survey on a Saturday or Sunday are required. This is adequate to capture the peak parking demand.

During the survey, there should be no known special event occurring or inclement weather that may impact parking demand.

Occupancy and turn over surveys should be undertaken between 6:00 AM – 8:00 PM on weekdays. During weekends, the duration can be shorter between 9:00 AM – 8:00 PM. However, this is based on engineering judgement.

Occupancy and turnover surveys should be carried out every hour of the survey duration: such that between 6:00 AM – 8:00 PM, there should be fourteen runs. If the traffic flow is low and number of parked vehicles noticeably fewer, the traffic engineer can reduce the duration to four one-hour runs. The runs should be when the parking demand is most high.

8.4 Extent of Surveys

The occupancy and turnover surveys should be carried out within 200 m walking distance from the extent of the corridor. This includes all available public highway areas where one can legally park a vehicle within a 200m walking distance from the proposed road section.

Note: this area is NOT a circle with a 200m radius but a 200 m walking distance as measured along all roads up to a point 200 m from the extent of the road section under survey.

Figure 8.3 Parking Survey Extents

8.5 Data Analysis and Output

Parking data is best analysed in a spreadsheet where the traffic engineer should summarise the data collected. The occupancy and duration results should be kept separate, at least initially, by location, time of day and day of week. Graphics and displays on map(s) can be helpful in presenting the results.

8.5.1 Parking Occupancy

This is calculated as vehicles parked during a given time divided by the total number of spaces.

Generally, 85-90 per cent occupancy is considered the highest acceptable target since someone looking for a space will not find an empty one easily.

Occupancies above 100% are possible when vehicles park illegally or in unofficial spaces. That is, if illegally parked vehicles were included in the survey and in the calculation of parking streets, the sum of number of vehicles parked and number of free spaces may be greater than the total number of parking spaces recorded in the inventory.

8.5.2 Parking Duration

This is the length of time a vehicle remains in each parking space. It can be estimated from the license plate information. It is calculated in two stages; first by calculating the duration for each vehicle observed, and then taking an average duration for all spaces by parking area and period.

Duration data can be used to understand parking behaviour and redefine the use of existing spaces more efficiently.

8.5.3 Parking Turnover

This is the inverse of duration; turnover describes the number of vehicles that can use a space in a given period of time. For example, in a designated space with an average duration of 15 minutes, 4 different vehicles can park every hour.

9 Collation of Crash Data

9.1 General

Crash data is a critical component of safety data, and it's a key input in designing safe infrastructure in accordance with **RDM Volume 1**, **Part 3: Geometric Design of Highway, Rural and Urban Road**s and **Volume 4, Bridges and Retaining Structures Design**.

Crash data supplemented by other safety data such as road inventory and condition survey, traffic flow and speed data are useful in undertaking proactive safety actions by:

- Ensuring the safest road design scheme is selected for construction.
- Checking that the proposed road infrastructure or feature is designed and built to minimise the occurrence of road safety problems.

The methodology of undertaking such diagnosis is covered under the **PAM 4: Road Safety Audit Manual**.

9.2 Methodology of Collating Crash Data

The primary source of crash data in Kenya is the national crash database managed by NTSA. Alternatively, crash data can also be obtained from police crash reports. If the data available is in hard copy, the traffic engineer should plan prior for resources required to digitise the data.

At minimum, crash data useful for road design must provide information on crash frequency, crash severity, number of injuries by severity type (i.e. fatal, serious, minor, etc.). Other important information includes:

- Crash identification number.
- Information about the crash site (e.g. an accurate location).
- Events that resulted in the crash (e.g. the crash type).
- Information on those involved (gender, age, road user type, whether alcohol was involved, use of seatbelts, etc.).
- Weather and lighting conditions.
- Vehicles involved.
- Time of day, day of week, and date.
- Cause code (in accordance with Kenya Traffic Police P41 form).

9.2.1 Defining Crash Location

At best, crash location should be defined as an individual site (such as an intersection or bend in the road), or a short midblock section within the road corridor under study.

From police data, crash locations and other crash attributes can sometimes be poorly or inaccurately defined. In built-up areas, it is common practice for police crash reports to refer to a junction or a landmark. However, in rural areas, junctions or landmarks may be few and far between.

The traffic engineer must define a cut-off point, such as between crashes that occur at an intersection and crashes that are considered 'mid-block'. However, if the data records are poor, it may be necessary to look beyond these defined boundaries when analysing crash data.

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Collation of Crash Data

9.2.2 Defining a Time Period

Typically, a three- to five-year period is adequate to provide a large enough sample of data, whilst minimising the chance of changes to the road network.

When retrieving the data, it is important to use whole years to avoid cyclic or seasonal variations in the crash and traffic data. It is also important to be aware of any changes in database definitions that may have occurred in that time.

9.2.3 Training of Enumerators

To reduce data losses, the enumerator should be trained to transcript the data in a format compatible with the analysis tool.

The enumerators must be trained on proper conduct and the supervisor should always be available to oversee the exercise.

Recording of fatal and serious injury crash types must be prioritised. However, the enumerators may also record data on minor injury crashes as they may be indicative of a potential fatal or serious injury crash in the future.

9.3 Data Correction and Cleaning

Once the data is in a digital database format, it should be reviewed for unusual data. Some source of unusual data can also be as a result of error during transcription. Potential errors in crash data collated from police crash reports include:

- Multiple records of the same crash occurrence. The traffic engineer should check such records against date, location, and casualties etc. There can be cases when one record is entered more than once with a different value on one attribute for example, hour of crash.
- Mis-recording of crash attributes, e.g., name of road/location, time, date, and parties involved. Incorrect records increase the difficulty in establishing the crash location.
- Missing information and incomplete record of some attributes. For example, type of crash recorded as fatal, but no record of the casualties.
- Use of general names to describe roads/ corridors, crash locations and parties involved. For example, crash location recorded as Next to supermarket, parties involved as Nissan and Lorry.
- The level of effort used to clean data should be commensurate with the end use of the data. For example, correcting for parties involved may be unnecessary if the dataset required is to compute crash frequencies.

After an incorrect data entry is identified, it can be omitted or cleaned. If the incorrect records are few, they can be omitted from the database. However, if they can influence the analysis, then the incorrect entries should be replaced with the correct attribute values.

9.4 Data Analysis and Output

At the most basic level, using data from a crash data system, the presentation of crash locations on a map can provide information on crash clusters. In the absence of a crash data system, measurements such as crash frequency, crash rate and crash severity should be presented either in tabular or graphical format.

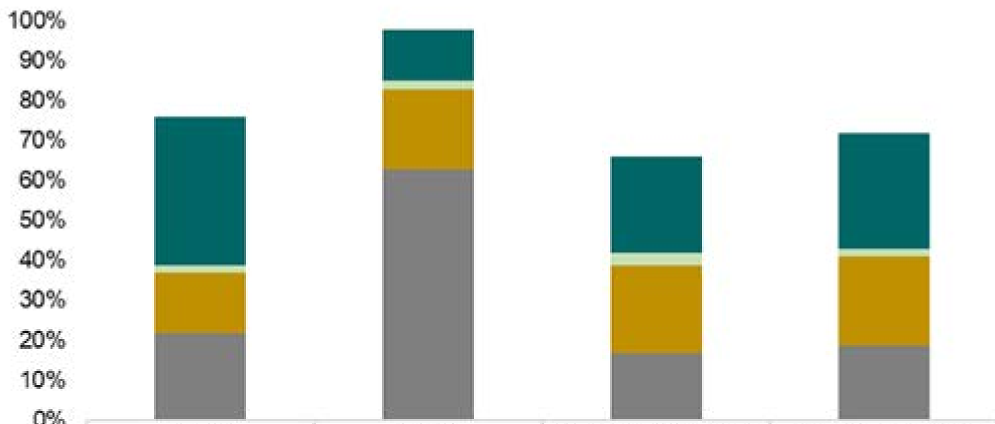
The analysis should isolate the following crashes.

- Single vehicle crashes.
- Crashes of vehicles driving in the same direction on the road section.
- Crashes of oncoming vehicles on the road section.
- Crashes of vehicles entering a junction from the same direction.
- Crashes of vehicles entering a junction from opposite directions.
- Crashes of vehicles entering a junction from neighbouring lanes.
- Crashes of vehicles and pedestrians.
- Crashes with standing or parked vehicles.
- Crashes with cyclists.
- Crashes of motorcycles.

Given the proportion of motorcycle fatal and serious injuries in Kenya; provision can be made to record details of such crashes separately (not included with other vehicles).

An effective way to identify groupings of certain crash types or other common factors at a location is to present the data as a frequency diagram, a factor matrix, or a collision diagram of the different crash types.

Figure 9.1 Frequency Diagram Showing Distribution of Parties Involved



	A104	A109	KeNHA Roadway	National Network
Pedestrian	37%	13%	24%	29%
Pedal cycle	2%	2%	3%	2%
Motor cycle	15%	20%	22%	22%
HGV	22%	63%	17%	19%

HGV Motor cycle Pedal cycle Pedestrian

9.4.1 Frequency Diagrams

A simple frequency histogram or diagram can be used to show the distribution. Crash type variables can be used to describe the type of the crashes in terms of parties involved, collision and vehicle/ pedestrian manoeuvre just before the crash.

This method is adequate for an initial assessment, but due to its simplicity, it should not be done as an alternative to a factor matrix or collision diagram.

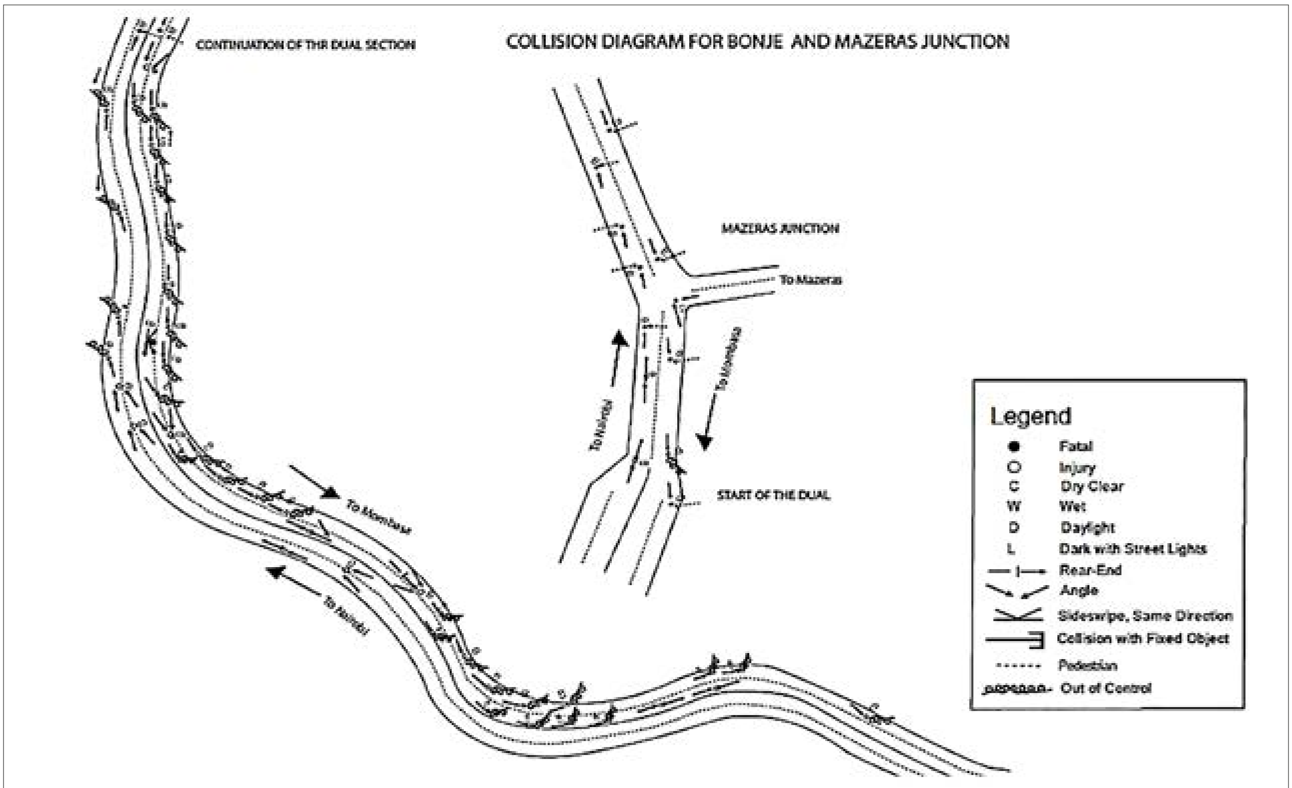
9.4.2 Factor Matrix

A factor matrix takes the frequency table approach one step further and considers additional factors such as the crash severity, year of the crash, direction of travel, type of road users, collision type, surface and lighting conditions, time of day, and day of week.

9.4.3 Collision Diagrams

A collision diagram is an illustrative presentation of the crashes that have occurred at a location. Crashes are pinpointed on a diagram of the intersection or road section, showing the crash type (through standard symbols), the direction of travel, and other relevant information (e.g., the date, time of day, weather, and lighting conditions). Several software packages allow the automatic creation of these diagrams.

Figure 9.2 Collision Diagram Developed for Mazeras, Bonje Road Section on A8 Corridor.



10 Appendices

Appendix 3.1 Classified Traffic Count Form

CLASSIFIED SECTION COUNTS FORM					
Consultant/ Institution:		Project Name:			
Date:		Day:		Day/Night:	
Direction From:		Direction to:		Station Name:	
Enumerator Name:		Phone Number:		Supervisor Name:	

Hour	Motorcy-cle	Tuk-tuk	Cars	Pick-up, Vans, Jeep, SUV	Micro-bus (10-14 seater)	Minibus (15-25)	Bus (26-53)	Omni bus (>53)	Light Trucks (<3.5 tonnes load) unladen	Medium Trucks (2 axles, 3.5-7.5 tonnes load) unladen	Heavy Trucks (3 & 4 axles, 7.5-12 tonnes load) unladen	Articu-lated and Draw-back Trucks (5-7 axles)	Others (Tractors, etc)
5:00-6:00 AM													
6:00-7:00 AM													
7:00-8:00 AM													
5:00-6:00 PM													
TOTAL													

Appendix 3.2 Intersection Traffic Counts Form

CLASSIFIED INTERSECTION COUNTS FORM					
Consultant/ Institution:			Project Name:		
Date:		Day:		Day/Night:	
Direction From:		Direction to:		Station Name:	
Enumerator Name:		Phone Number:		Supervisor Name:	

Hour	Bus (26-53)			Omni bus (>53)			Light Trucks (<3.5 tonnes load) unladen			Medium Trucks (2 axles, 3.5-7.5 tonnes load) unladen			Heavy Trucks (3 & 4 axles, 7.5-12 tonnes load) unladen			Articulated and Draw-back Trucks (5-7 axles)		
	↰	↑	↱	↰	↑	↱	↰	↑	↱	↰	↑	↱	↰	↑	↱	↰	↑	↱
5:00-6:00 AM																		
6:00-7:00 AM																		
7:00-8:00 AM																		
5:00-6:00 PM																		
TOTAL																		

Appendix 3.3 NMT Section Count Form

NMT CLASSIFIED SECTION COUNTS FORM					
Consultant/ Institution:			Project Name:		
Date:		Day:		Day/Night:	
Direction From:		Direction to:		Station Name:	
Enumerator Name:		Phone Number:		Supervisor Name:	

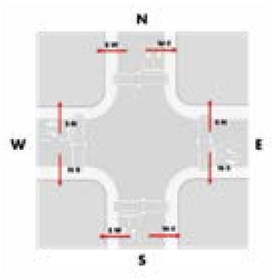
Hour	Pedestrians		Remarks	Bicyclists		Remarks	Handcart		Remarks
	Male	Female		Male	Female		Standard size	Non-standard size	
5:00-6:00 AM									
6:00-7:00 AM									
7:00-8:00 AM									
5:00-6:00 PM									
TOTAL									

NOTES:

1. Record pedestrians, bicyclists and handcart pullers walking or cycling in either direction on the sidewalk.

2. Under remarks, indicate aspects such as carrying load, older pedestrians, with child, handcart impeding flow or any other that align to objectives of the survey.

Appendix 3.4 NMT Intersection Counts Form

NMT CLASSIFIED SECTION COUNTS FORM						
	Consultant/Institution:			Project Name:		
	Date:		Roadway Width *(m)*:		Station Name & ID:	
	Movement *(N/S/E/W)*:		Median Width *(m)*:		Phone Number:	
	Direction From:		Weather:		Enumerator Name:	
	Direction To:					

Hour	Pedestrians								Bicyclists								Handcarts							
	North Leg		South Leg		West Leg		East Leg		North Leg		South Leg		West Leg		East Leg		North Leg		South Leg		West Leg		East Leg	
	E-W	W-E	E-W	W-E	S-N	N-S	S-N	N-S	E-W	W-E	E-W	W-E	S-N	N-S	S-N	N-S	E-W	W-E	E-W	W-E	S-N	N-S	S-N	N-S
5:00-6:00 AM																								
6:00-7:00 AM																								
7:00-8:00 AM																								
5:00-6:00 PM																								
TOTAL																								

Appendix 3.5 Acceptable Gap Survey Form

ACCEPTABLE GAP FOR CROSSING SURVEY FORM					
Consultant/ Institution:			Project Name:		
Date:		Number of Lanes:		Carriageway *(single/dual)*:	
Width of Road *(m)*:		Width of Median:		Station Name & ID:	
Enumerator Name:		Phone Number:		Supervisor Name:	

SN No	Direction of Crossing	Waiting Time 1 *(min: sec)*	Crossing Time 1 *(min: sec)*	Waiting Time 2 on median *(min: sec)*	Crossing Time 2 *(min: sec)*	Remarks
1						
2						
3						
4						
5						
6						
7						
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9						
10						
11						
12						
13						
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15						
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17						
18						
19						
20						

NOTES:
1. Under remarks, record pedestrian behaviour and characteristics. Indicate if pedestrian was running, carrying luggage, old, disabled, with child, etc.

1 2 3 4 5 6 7 8 9 10 Appendices

Appendix 3.6 Pedestrian Group Study Survey Form

PEDESTRIAN GROUP STUDY SURVEY FORM					
Consultant/ Institution:			Project Name:		
Date:		Sheet No:		Carriageway *(single/dual)*:	
Time: From:		Time: To:		Raised Median *(Y/N)*:	
Width of Road *(m)*:		Width of Median:		Station Name & ID:	
Enumerator Name:		Phone Number:		Supervisor Name:	

Group size	Number of Groups		No. of rows *(n)*	Cumulative Total	Computations	Remarks
	Tally	Total				
5 or less						
6 – 10						
11 – 15						
16 – 20						
21 – 25						
26 – 30						
31 – 35						
36 – 40						
41 – 45						
46 – 50						
Total Number of Groups						
Calculation of adequate gap time *(g)* in seconds						
$G = W / 3.5 + 3 + (N - 1)2$						
Where W = Width of roadway in metre						
3.5 = Assumed walking speed in metre/second						
3 = Perception and reaction time in seconds						
$(N - 1)2$ = Pedestrian clearance time						
N = Number of rows in 85th percentile group size						
2 = Time interval between rows in seconds						

Appendix 4.1 Roadside Interview Survey Form

ORIGIN DESTINATION SURVEY FORM					
Consultant/ Institution:			Project Name:		
Date:		Day:		Sheet No:	
Direction From:		Direction To:		Station Name & ID:	
Enumerator Name:		Phone Number:		Supervisor Name:	

SN No	Vehicle Reg No.	Vehicle classification	Axle type	Origin *(from)*	Destination *(to)*	Frequency of trip	Commodity/goods carried	Remarks/ notes
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								

NOTES:
Additional columns can be added based on the objective of the survey. For example, motorists could be asked on perception of quality.

1
2
3
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Appendices

Appendix 4.2 License Plate Survey Form

LICENSE PLATE SURVEY FORM					
Consultant/ Institution:			**Project Name:**		
Date:		**Day:**		**Sheet No:**	
Location *(GPS Coordinates)*:					
Direction From:		**Direction To:**		**Station Name & ID:**	
Enumerator Name:		**Phone Number:**		**Supervisor Name:**	

SN No.	Vehicle Reg No.	Vehicle Classification	Axle Type	Time Stamp *(hr/min)*	Remarks/notes
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					

Appendix 4.3 Household Survey Form

HOUSEHOLD SURVEY FORM					
Consultant/ Institution:				Project Name:	
Date:		Day:		Questionaire No.:	
GPS code:		County/ Subcounty:		Household Code:	
Respondent Name:		Phone Number:		Supervisor Name:	

Section 1: Confidentiality and Consent

Greetings. I am (insert name and show identification) conducting household survey on behalf of (show authorisation letter) on the proposed (project name). I will ask you a set of questions to (insert objectives of survey).

The information obtained will be used (insert use of information). During the interview, you may seek clarification if you do not understand.

Your answers are completely confidential and shall only be used for purposes of this survey. It is important that you answer all questions as accurately as possible.

The interview will take about (insert approximate duration), and I will appreciate your help in responding to these questions.

Would you be willing to participate?

Signature of the interviewee ________________ **Date:** ________

(Indicating that an informed consent has been given verbally by the respondent)

Section 2: Instructions to Enumerators

This questionnaire will be administered to the male/female head of the household (children must not be interviewed without the consent of parents/guardians). If the person you meet is not the head of the household, please clearly note on the interview form, thank him or her and discontinue the interview.

Please record the answers as given to you. All questions should be answered; questionnaires with unanswered questions will be rejected. Multiple answers will only be allowed for questions which accept multiple answers.

A household comprises (insert what is a household for purposes of each survey).

Name and signature of the enumerator ________________ **Date:** ________

(Indicating that enumerator understands the instructions)

Section 3: Transportation

Member No: ________________ *(1) Head of household, (2) Spouse (3) Child (4) Other*

Name of household member: ________________

Do you own any vehicle? Yes ____ No ____

If yes, indicate type of vehicle ________________ *(1) Bicycle (2) Motorcycle (3) Tuk-tuk (4) Personal Car*

Give a Summary of your trips in the last **(insert days)** Days *(Note: Going is one Trip, coming back home is another trip)*

Appendix 4.3 Household Survey Form *(continued)*

Section 3: Transportation *(continued)*

	Origin *(from)*	Destination *(to)*	Trip Purpose 1: Work 2: Home 3: Market 4: Farm 5: School 6: Hospital 7: Recreational 8: Other	Mode of Transport 1: Walking 2: Matatu/Bus 3: Motorcycle 4: Tuk-tuk 5: Taxi 6: Private car - driver 7: Private car - passenger 8: Other	Frequency in a week
Trip 1					
Trip 2					
Trip 3					
Trip 4					
Trip 5					
Trip 6					
Trip 7					
Trip 8					
Trip 9					

Section 4: Remarks of the Enumerator

NOTES:
Depending on the objectives of the survey, other household characteristics can also be captured including:
1. Demographic data of the household
2. Income stream assessment
3. Asset profile etc

Appendix 6.1 Spot Speed Survey Form

SPOT SPEED SURVEY FORM					
Consultant/ Institution:			Project Name:		
Date:		Weather:		Sheet No:	
Day:		Direction From:		Station Name & ID:	
Time:		Direction To:		Roadway Name:	
Enumerator Name:		Phone Number:		Supervisor Name:	

SN No	Vehicle Classification	Time stamp *(hr: min)*	Speed *(km/h)*	Notes/ Delays	SN No	Vehicle Classification	Time stamp *(hr: min)*	Speed *(km/h)*	Notes/ Delays
1					23				
2					24				
3					25				
4					26				
5					27				
6					28				
7					29				
8					30				
9					31				
10					32				
11					33				
12					34				
13					35				
14					36				
15					37				
16					38				
17					39				
18					40				
19					41				
20					42				
21					43				
22					44				

REASONS FOR DELAY:
S: Signals, J: Other junctions, P: Pedestrians, B: Bus or paratransit, K: Parked or loading, N: Not delayed, X: Part of platoon – not a free speed, R: Roadworks – Diversion, A: Accident – Breakdown, F: Floods – Weather Extremes

Appendix 6.2 Network Delay Survey Form

FLOATING CAR SURVEY FORM					
Consultant/ Institution:			Project Name:		
Date:		Vehicle ID:		Sheet No:	
Time From:		Direction From:		Driver Name:	
Time To:		Direction To:		Route Name:	
Enumerator Name:		Phone Number:		Supervisor Name:	

Location name	Link name & ID	Node name & ID	GPS coordinates		Odometer reading	Time *(hr: min)*	Delay *(Yes/No)*	Remarks
			X	Y				

NOTES:
Readings of odometer, GPs recording, and time should be taken at the approach and at the exit of every node.

Appendix 6.3 Queue Length Survey Form

QUEUE LENGTH SURVEY FORM				
Consultant/ Institution:			Project Name:	
Date:		Sheet No:		Sketch
Day:		Enumerator Name:		
Direction From:		Route Name & ID:		
Direction To:		Supervisor Name:		
Sampling Time *(sec)*:		Phone Number:		
Weather:				

SN No.	Start Time	Stop Time	Vehicle Type			Notes
	hr: min: sec	*hr: min: sec*	Cars / Minibus / LGV	Bus / Omnibus	MGV / HGV	
1						
2						
3						
4						
5						
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Appendix 6.4 Queue Delay Survey Form

<table>
<tr><th colspan="5">QUEUE DELAY SURVEY FORM</th></tr>
<tr><td>Consultant/ Institution:</td><td colspan="2"></td><td>Project Name:</td><td></td></tr>
<tr><td>Date:</td><td></td><td>Sheet No:</td><td></td><td>Sketch</td></tr>
<tr><td>Day:</td><td></td><td>Enumerator Name:</td><td></td><td rowspan="5"></td></tr>
<tr><td>Direction From:</td><td></td><td>Route Name & ID:</td><td></td></tr>
<tr><td>Direction To:</td><td></td><td>Supervisor Name:</td><td></td></tr>
<tr><td>Sampling Time (sec):</td><td></td><td>Phone Number:</td><td></td></tr>
<tr><td>Weather:</td><td></td><td></td><td></td></tr>
</table>

SN No.	Time at Sampling Point *(hr: min: sec)*	Time at Entry Point *(hr: min: sec)*	Time at Entry Point *(hr: min: sec)*	Vehicle Classification	Delay	
					Delayed	Not Delayed
1						
2						
3						
4						
5						
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7						
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18						
19						
20						

Appendix 7.1 Axle Load Survey Form

AXLE LOAD SURVEY FORM

Consultant/Institution:			Project Name:		
Date:		Day:		Sheet No:	
Direction From:		Enumerator Name:		Station Name & ID:	
Direction To:		Phone Number:		Supervisor Name:	

SN No.	Vehicle Reg No.	Vehicle Classification	Axle Configuration	Loading 1. Unladen (goods) 2. Half laden 3. Fully laden 4. Empty (passengers) 5. Half full 6. Full	Wheel Loads (Tonnes)							Comments
					1	2	3	4	5	6	7	
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												

Appendix 8.1 Parking Inventory Survey Form

PARKING INVENTORY SURVEY FORM					
Consultant/Institution:		Project Name:		Carriageway Type *(single/dual)*:	
Date:		Day:		Sheet No:	
Direction From:		Enumerator Name:		Route Name & ID:	
Direction To:		Phone Number:		Supervisor Name:	

SN No.	Category		Number of Spaces Available		Vehicle Type							Total
			Parallel	Angle	Bicycle	Motorcy-cle	Tuk-tuk	Car	LGV	Bus	MGV/HGV	
1	Marked parking spaces											
2	Unmarked parking spaces											
3	**Restricted Parking**	Private use										
		Disabled parking										
		Taxi parking										
		Public transport bays										
4	Private parking											
5	Illegal parking spaces (specify)											
		Total										

Appendix 8.2 Parking Occupancy Survey Form

PARKING OCCUPANCY SURVEY FORM					
Consultant/ Institution:			Project Name:		
Date:		Direction From:		Carriageway:	
Day:		Direction To:		Enumerator Name:	
Time From:		Route Name & ID:		Phone Number:	
Time To:		Weather:		Supervisor Name:	

SN No.	Parking Description		Type of Vehicle						Total
			Motor-cycle	Tuk-tuk	Car	LGV	Bus	MGV/ HGV	
1	Legally Parked								
2	Parked on restricted area	Parked on yellow line/no parking							
		Private use							
		disabled parking							
		Taxi parking							
		Public transport bays							
3	Parked fully on footpath or mounted on kerb blocking footpath								
4	Double parked								
5	Vehicles blocking more than one space								
6	Bicycles								
Total									
New Arrivals									
Departures									

Appendix 8.3 Parking Turnover Survey Form

PARKING TURNOVER SURVEY FORM					
Consultant/ Institution:			Project Name:		
Date:		Direction From:		Carriageway:	
Day:		Direction To:		Enumerator Name:	
Time From:		Station Name & ID:		Phone Number:	
Time To:		Weather:		Supervisor Name:	

SN No.	Vehicle Type	Vehicle Reg. No.	Type of Parking		Remarks
			Parallel	Angle	
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
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18					
19					
20					

NOTES:

1. *Turnover will be computed every hour. The supervisor must ensure every surveyor completes the survey in good time to allow for time to walk back to the start of the location with the same hour. This time should be determined during the pilot survey.*

2. *During recording, the surveyor must record all parked vehicles. Under the column 'Remarks', the surveyor should indicate the following whenever applicable:*

Parking supply

Vehicles parked:

i. *On private property*
ii. *Where parking would contravene roadway restrictions such as yellow lines*
iii. *Where parking would obstruct an access; where the width of the road is too narrow to allow parked cars and passing traffic.*
iv. *Parking spaces restricted to private use, disabled parking, taxi parking or high-occupancy vehicle parking.*
v. *Where the width of the road is likely to lead to parking partially or fully on the walkway, or passing traffic to mount the kerb to pass, with the potential to obstruct the walkway for pedestrians.*

Parking demand

Vehicles:

i. *Parked legally,*
ii. *Double parked vehicles,*
iii. *Those blocking other vehicles in lots, and any large trucks blocking more than one space.*
iv. *Number of bicycles parked as well.*

Appendix 9.1 Crash Data Recording

PARKING INVENTORY SURVEY FORM					
Consultant/Institution:		Project Name:		Carriageway Type *(single/dual)*:	
Date:		Day:		Sheet No:	
Direction From:		Enumerator Name:		Route Name & ID:	
Direction To:		Phone Number:		Supervisor Name:	

SN No.	Date/ Year	Time	Road Name	Road Section	Specific Crash Location	Parties Involved				Cause Code	Severity of Crash	No. of Casualities			Comments
		24 hrs				1	2	3	4			Fatal	Serious	Slight	
1															
2															
3															
4															
5															
6															
7															
8															
9															

NOTES:
M1: *Motorcycles,* ***M2***: *Cars,* ***M3***: *Pickups, 4x4,* ***M4***: *Minibus,* ***M5***: *Bus,* ***M6*** *- Omnibus,* ***M7***: *LGV,* ***M8***: *MGV,* ***M9***: *HGV,* ***N1:*** *Pedestrians,* ***N2***: *Pedal cyclists,* ***N3***: *Hand carts.*

Published by TRL

TRL
THE FUTURE
OF TRANSPORT

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