Road Infrastructure Improvement for Efficient Utilisation of the Agricultural Potential: A Case Study of Morogoro, Tanzania

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Dissertation Presented for the Degree of
Doctor of Philosophy in Transport Economics
Faculty of Economic and Management Science
Stellenbosch University

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March 2018

Declaration

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February 2018

Abstract

The Morogoro region in Tanzania is endowed with diverse sources of water, fertile land and a good climate, suitable for crop cultivation. Only 29 percent of the arable area, however, is used for agricultural purposes. Inadequate and poor rural transport is partly to blame for the underutilisation of the agricultural potential. Rural transport provides assurance for the supply of the agricultural inputs and facilitates for the delivery of the farm outputs to the markets. Improved rural road infrastructure and transport services stimulate the increase in agricultural production through lowering of the transport price of farm inputs and outputs. Little is known, however, about the extent of agricultural production improvement following the road improvement. The conventional road economic evaluation tools such as Highway Development and Management (HDM-4) and Roads Economic Decision (RED) do not address this issue. These tools concentrate on the direct road user cost savings. Due to the low volume of traffic on rural roads, these savings are not substantial. However, rural road improvement and improved accessibility may result in a substantial impact on price and production of agricultural products. This research illustrates the impact of the road condition and trip distance on the transport price and transport cost of agricultural products. The research also establishes the relationship between transport price and agricultural production. Using the data collected from transport operators and road agencies, statistical relationships between transport price, trip distance and transport cost were established. The results show that transport price per ton-km decreases as the trip distance increases, reflecting factors such as economies of distance. However, the very high transport price over short distances can be attributed to the poor condition of rural roads and low vehicle utilisation. Transport price decreases with transport cost, indicating a competitive transport market. Longer distance trips are expected following rural road improvement, resulting in higher vehicle utilisation. Competition within the transport market is also expected to increase. Furthermore, the Tanzania National Panel Survey (NPS) data of 2012/13 was used to establish the relationship between transport price, access to the market and crop yield. Reduction of the transport price shows a positive impact on crop yield with an elasticity of -0.291. It was also found that farmers who have access to the bigger markets are associated with higher crop yield. When comparing agricultural benefits and road user cost savings for the low volume rural road, the results show that agricultural benefits were roughly three times higher than the road user cost savings. Finally, the research developed a low volume rural road economic appraisal

framework which takes into account agricultural benefits, the effect of the trip distance as well as the effect of transport price.

Opsomming

Die Morogoro-streek in Tanzanië het verskeie waterbronne, vrugbare grond en 'n goeie klimaat wat geskik is vir gewasverbouing. Slegs 29 persent van die bewerkingsarea word egter vir landboudoeleindes gebruik. Onvoldoende en swak landelike vervoer is deels te blameer vir die onderbenutting van die landboupotensiaal. Landelike vervoer is behulpsaam met die voorsiening van landbou-insette en fasiliteer die lewering van plaasuitsette na die markte. Verbeterde landelike padinfrastruktuur en vervoerdienste stimuleer die toename in landbouproduksie, deur die verlaging van die vervoerkoste van plaasinsette en -uitsette. Min is egter bekend oor die mate van verbetering van landbouproduksie as gevolg van die padverbetering. Die konvensionele pad-ekonomiese evalueringsinstrumente soos die "Highway Development and Management" (HDM-4) en die "Roads Economic Decision" (RED) programme, bespreek nie hierdie probleem aan nie. Hierdie instrumente konsentreer op die kostebesparings vir direkte padgebruikers. As gevolg van die lae volume verkeer op landelike paaie, is hierdie besparings minimaal. Landelike padverbetering en verbeterde toeganklikheid kan egter 'n wesenlike impak op die prys en produksie van landbouprodukte tot gevolg hê. Hierdie navorsing illustreer die impak van die padtoestand en reisafstand op die vervoerkoste en vervoerprys van landbouprodukte. Die navorsing bepaal ook die verhouding tussen vervoersprys en landbouproduksie. Met behulp van die data wat van vervoerders en padagentskappe versamel is, is statistiese verhoudings tussen vervoerprys, reisafstand en vervoerkoste vasgestel. Die resultate toon dat die vervoerprys per ton-km afneem namate die reisafstand toeneem, wat faktore soos afstandsekonomieë weerspieël. Die baie hoë vervoerkoste oor kort afstande kan egter toegeskryf word aan die swak toestand van landelike paaie en lae voertuigbenutting. Vervoerprys daal met vervoerkoste, wat 'n mededingende vervoermark aandui. Langer vervoerroetes word verwag as gevolg van landelike padverbetering, wat lei tot hoër voertuigbenutting. Mededinging binne die vervoermark sal na verwagting ook toeneem. Verder is die Tanzanië Nasionale Paneelopname (NPS) se data van 2012/13 gebruik om die verhouding tussen vervoerprys, toegang tot die mark en oesopbrengs vas te stel. Vermindering van die vervoerprys het 'n positiewe uitwerking op die opbrengs met 'n elastisiteit van -0.291. Daar is ook bevind dat boere wat toegang tot die groter markte het, met hoër oesopbrengste geassosieer word. By die vergelyking van landbouvoordele en kostebesparings vir padgebruikers vir die lae volume landelike paaie, toon die resultate dat die voordele vir die landbou ongeveer drie keer hoër is as die koste van die padgebruiker. Ten slotte het die navorsing 'n lae volume landelike

ekonomiese evalueringsraamwerk ontwikkel wat landbouvoordele, die uitwerking van die reisafstand sowel as die effek van die vervoerprys in ag neem.

Acknowledgements

I would like to acknowledge the following people and institutions for their support to accomplish this dissertation.

- My supervisor, Prof Stephan Krygsman, for his guidance, support and encouragement throughout this PhD journey.
- My co-supervisor, Prof Johanna H Nel, for her assistance, especially with the statistical aspect contained in this dissertation.
- The Graduate School of Economic and Management Science at Stellenbosch University for the scholarship they provided to me.
- Dr Jaco Franken, the manager of the Graduate School of Economic and Management Science for his support in administrative matters.
- My employer, University of Dar es Salaam, for financial assistance during my field work and granting me a study leave to pursue this PhD.
- My wife Aretha, my daughter Noreen and my son Norbert for their encouragement and bear with me for such a long period away from them.
- Lastly but not least, my fellow PhD students for encouraging each other during this period.

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List of Abbreviations

AADT	Annual Average Daily Traffic
AASHTO	American Association of State Highways and Transportation Officials
ADB	African Development Bank
AfDB	African Development Bank
AI	Accessibility Indicator
ARS	Average Rectified Slope
BCR	Benefit-Cost Ratio
CAADP	Comprehensive Africa Agriculture Development Program
CBA	Cost-Benefit Analysis
CEA	Cost-Effectiveness Approach
DFID	Department for International Development
FAO	Food and Agriculture Organisation of The United Nations
FYRR	First Year Rate of Return
GDP	Gross Domestic Product
GNP	Gross National Product
HDM-4	Highway Development and Management
IRI	International Roughness Index
IRR	Internal Rate of Return
ISOHDM	International Study of Highway and Management Tools
ISIC	International Standard Industrial Classification
JICA	Japan International Cooperation Agency
LGTP	Local Government Transport Programme
LIFDCs	Low-Income Food-Deficit Countries
LSMS-ISA	Living Standards Measurement Study – Integrated Surveys on Agriculture
MCA	Multi-Criteria Analysis
MDGs	Millennium Development Goals
MKUKUTA	Mpango wa Pili wa Kukuza Uchumi na Kuondoa Umaskini Tanzania
MT	Motorised Transport
NMT	Non-Motorised Transport
NPS	National Panel Survey
NPV	Net Present Value
NTP	National Transport Policy

OECD	Organisation for Economic Co-Operation and Development
OLS	Ordinary Least Square
PIARC	World Roads Association
PMO-RALG	Prime Minister's Office Regional Administration and Local Government
PRSP	National Poverty Reduction Strategy Paper
PSR	Present Serviceability Rating
RAP	Rural Accessibility Planning
RDS	Rural Development Strategy
RED	Roads Economic Decision
SADC	Southern African Development Community
SAGCOT	Southern Agricultural Growth Corridor of Tanzania
SHEMP	Smallholder Enterprise Development and Marketing Programme – Access Road Component
SSA	Sub-Saharan Africa
TANROADS	Tanzania National Road Agency
Tsh	Tanzania Shilling
TZS	Tanzania Shilling
UNFPA	United Nations Population Fund
UNICEF	United Nations Children's Emergency Fund
USAID	United States Agency for International Development
USD	United States Dollar
VOC	Vehicle Operating Cost
WEF	World Economic Forum

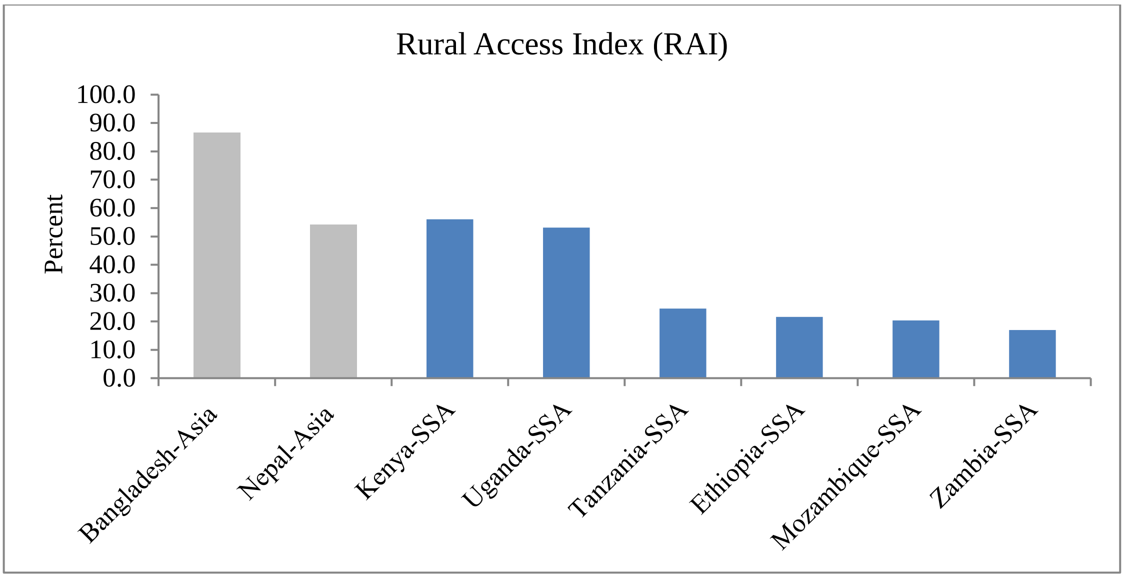
Chapter 1 : Introduction

"Efficient transport is the life-blood of economic modernisation. It is essential to improve agricultural productivity and enable farmers to bring their products to markets. Intensive agricultural production is especially dependent upon access to vehicles at affordable prices. Unfortunately, most agricultural production in Africa still is generated along a vast network of footpaths, tracks and community roads where the most common mode of transport is the legs, heads and backs of women. Indeed, the largest part of a household's time expenditure is for domestic transport. This situation places farmers in a double cost/price squeeze—between high farm-gate costs for inputs and low farm-gate costs for output. Finding ways to provide effective and efficient infrastructure (roads, potable water and electricity) in Sub Saharan Africa (SSA), underpins all other efforts to reduce poverty, improve health and education, and secure peace and prosperity" (Borlaug and Dowswell, 2002 as cited in Banjo, Gordon & Riverson, 2012).

1.1. Background

Sub-Saharan Africa (SSA), the low-income region, is the least endowed sub-continent in terms of infrastructures stock (Bond, 2016). The sub-continent has limited access to good transportation, electricity and telecommunication infrastructures, among other things, (Torero & Chowdhury, 2005; Bond, 2016). The results, particularly in rural communities, are high poverty levels among the population, isolation, and low economic development of these areas. In various parts of the world the quality of the road network is improving, but sub-Saharan Africa is still lagging this trend (Gajigo & Lukoma, 2011; Bond, 2016). Data availability on the condition of the road infrastructure is limited, however, the advancement in digital technology allows for better assessment of the accessibility of transport infrastructure (World Bank, 2016a). Using the Rural Access Index[1] (RAI), Figure 1.1 shows that the level of transport infrastructure accessibility in most African countries is low compared to the countries in other regions (Limi, Ahmed, Anderson, Diehl, Maiyo, Peralta-Quiros & Rao, 2016; World Bank, 2016a).

[1] Rural Access Index (RAI) is the global indicator used to measure transport sector development. Originally RAI was defined as the proportion of people who have access to an all-season road within the walking distance of two kilometres. The new RAI is defined as the proportion of the rural population who live within two kilometres of the nearest road in good condition (i.e. paved road in good or fair condition or unpaved road in good condition).



Source: Iimi *et al.*, 2016; World Bank, 2016a: SSA-Sub-Saharan Africa

Figure 1.1: Rural access index, comparison of sub-Saharan Africa and Asia

Button (2010) argued that one of the major bottlenecks for socio-economic development and national integration in many developing countries is inadequate transport infrastructure. Good transport infrastructure allows for low transportation costs, which stimulate the production of goods and services that use public investment[2] as a significant input factor. It provides access to the wider market and permits exploitation of resources in a broad range of activities, such as agriculture. Employment during the construction and operation phase emerges as the indirect effect of transport infrastructure provision. Transport infrastructure construction has multiplier effects that stem from the requirement of construction materials and associated services (Button, 2010). Transport may also provide the initial impetus for other economic sectors such as fuel supply and garage services (Button, 2010).

Sub-Saharan Africa is at a disadvantage regarding the availability of rural transport infrastructure, the efficiency of agricultural transport, and the marketing[3] and costs of transport (Hine, 2014). Better rural transport is an important factor in reducing the poverty and isolation of the rural population (Hine, 2014). Evidence shows that access to transport infrastructure is an important factor in determining the rural household level of poverty (Torero & Chowdhury, 2005). Generally, transport links the producers and markets, and provides access to social and administrative services.

[2] Public investment - the money that a government spends on public services such as building roads

[3] Marketing - activities associated with the selling of the farm outputs

There is potential for the improvement of agricultural sector in most of sub-Saharan Africa (World Bank, 2013a; Limi, You, Wood-Sichra & Humphrey, 2015). The fertile land, water availability and weather conditions are suitable for a variety of crop cultivation in most of the sub-Saharan Africa countries (World Bank, 2013a). Agriculture is the main economic activity of a large percentage of the rural population in sub-Saharan Africa (World Bank, 2013a). However, to a large extent, the rural population is engaged in small-scale and subsistence farming (Limi *et al.*, 2015). The development of the agricultural sector to facilitate economic growth in sub-Saharan Africa is still low (Limi *et al.*, 2015). Several reasons have been suggested for the low agricultural production and under-utilisation of the potential in the agricultural sector. In Tanzania, as in many other countries, these reasons include (Ramonyai & Konstant, 2006; United Republic of Tanzania, 2016a):

(i) technological constraints, poor technology development and technology transfer;
(ii) limited research in the area;
(iii) poor infrastructure, which includes roads infrastructure;
(iv) poor marketing and pricing policies, e.g. little profit to farmers and inadequate market information;
(v) gender inequality, whereby males are less engaged in agricultural activities; and
(vi) macroeconomics, i.e. excessive taxes, unrealistic budgets, credit not being readily available, and a lack of incentives for innovation.

Furthermore, the marketing problems facing farmers in Tanzania are transport-related, as revealed by the national sample census of agriculture of 2007/08 (Tanzania National Bureau of Statistics, 2012a). The listed key problems facing farmers are (Tanzania National Bureau of Statistics, 2012a):

(i) prices on the open market too low (67%);
(ii) transport prices too high (5%);
(iii) marketplace too far (4.4%); and
(iv) lack of transport (3%).

Therefore, it can be argued that improving transport infrastructure and services to the areas with agricultural potential areas may assist in reducing farmers' problems, better utilisation of agricultural potential and subsequently reduce rural poverty. It is expected that good transport infrastructure and services will improve access to the market through lowered transport costs and prices, increased transport service frequency and availability of different modes of transport, and reduced travel time.

However, funding for transport sector improvement is inadequate (*National Transport Policy-Draft*, 2011). Governments are facing problems in allocating the scarce resources for different uses, with the aim of maximizing social and economic benefits (*National Transport Policy-Draft*, 2011; African Development Bank Group, 2013; World Bank, 2016b). Conventional tools such as cost-benefit analysis serve as an aid in the decision–making process when allocating resources for road investment (*National Transport Policy-Draft*, 2011). These tools, normally, rely on the direct benefits of road users (i.e. saving in vehicle operating cost, saving in travel time and saving in accident cost) which is highly influenced by the number of vehicles using or expected to use the improved road. In rural areas, where the volumes of traffic are low, there are often very few economic benefits to justify the planned road improvement (Schutte, 2005; Transport Research Laboratory, 2005). A tool such as Multi Criteria Analysis (MCA) can be used to incorporate other benefits of road investment, however, MCA can be subjective in decision-making (Lebo & Schelling, 2001a; OECD, 2011). Hine (2014) also pointed out that in most African countries the planning process for the government-funded road projects is very weak and the decisions are made in an ad-hoc manner. Gachassin, Najman & Raballand (2010) added that in most African countries it is a custom to make road investment decisions based on political influence and not for economic reasons. As a result, the limited resources may be spent on the projects which have a relatively low economic impact to the society.

This research, therefore, focuses on improving road appraisal techniques which will include the potential for agricultural sector development. It is expected that the techniques will lead to a more informed and objective decision-making process as well as providing a more economic justification of road infrastructure investment in rural areas. In turn, this is expected to stimulate investment in well-thought rural road projects and consequently better utilisation of agricultural potential. The research will also quantify the benefits that may emanate from efficient utilisation of local agricultural potential as a result of road improvement. In this research, efficient utilisation of agricultural potential refers to the most valuable possible crop production. Road improvement refers to the provision of a higher standard or better quality road condition, which can be achieved through improved routine and periodic maintenance, spot improvement, reconstruction and road upgrading.

1.2. The importance and potential for the development of the agricultural sector

The huge agricultural development potential in sub-Saharan Africa is essential for the development of the region (Gajigo & Lukoma, 2011). The development impact that the sector can bring is difficult to over-emphasise (Gajigo & Lukoma, 2011). Agriculture is important for many sub-Saharan African countries, as it accounts for between 30 to 40 percent of their gross domestic product (GDP) (World Bank, 2013a). More than 70 percent of the population live in rural areas where agriculture is their main economic activity (World Bank, 2013a), and the sector employs roughly 65 to 70 percent of the labour force in most African countries (World Bank, 2013a). The continent has the largest share, 45 percent of the global total, of suitable land for agricultural expansion, with abundant cheap labour and untapped water resources (World Bank, 2013a). The minimum wage rate is in the range of two to three times lower compared to some Asian countries (World Bank, 2013a). Little land in the continent is under irrigation, of the cultivated land in Africa, 95 percent is rain-fed (World Bank, 2013a). Usage of modern farm inputs has remained low and stagnant. The agricultural production increase is largely influenced by the increase in the area under cultivation, and the productivity or yield (i.e. quantity of harvested crops per unit area of the land cultivated) remained low (World Bank, 2013a).

The growth in productivity of the agricultural sector in Africa is the "critical step in the process of economic transformation and growth" for many countries (Gajigo & Lukoma, 2011). The recognition of the contribution of the agricultural sector to development led the heads of state and governments of African countries, at the 2003 African Union (AU) summit, to adopt the Comprehensive Africa Agriculture Development Program (CAADP) to combat hunger and poverty. The CAADP, as an integral part of the New Partnership for Africa's Development (NEPAD), is the policy framework for agricultural transformation, wealth creation, food security and nutrition, economic growth and prosperity ("NEPAD", n.d.). The aims of the CAADP are to activate the transformation of agricultural systems and stimulate increased and sustainable agricultural performance in African countries ("NEPAD", n.d.; Gajigo & Lukoma, 2011). The importance of increasing agricultural productivity in Africa is also emphasised by the information provided by the Food and Agriculture Organisation of the United Nations (FAO). They emphasise that (Gajigo & Lukoma, 2011; FAO, 2016):

- one-third of the sub-Saharan African population is undernourished;

- thirty-seven (37) African countries are classified as low-income food-deficit countries (LIFDCs), which means that the net food trade in these countries has been negative for several years; and
- climate change and drought in some of the grain-producing regions, sales of corn for biofuels production and the projected increase in Africa population further necessitate agricultural productivity growth.

Improving agricultural productivity may help in reducing Africa's problems, ensuring food security, combating hunger and poverty, and increasing economic competitiveness (Gajigo & Lukoma, 2011).

1.3. Tanzania agricultural sector

Tanzania, one of the poorest countries in the world, has huge potential for growth in its agricultural sector (Limi *et al.*, 2015). The country is endowed with fertile land for agricultural activities and a good climate for a variety of crops, with diverse water sources for irrigation. It is estimated that 44 million hectares of the land are suitable for agricultural activities, however, only 24 percent is under cultivation (United Republic of Tanzania, 2016b). There are estimated 29.4 million hectares potential for irrigation, with 7.1 million hectares regarded as high to medium potential (United Republic of Tanzania, 2016a,b), of which only 1.6 percent of the total potential area for irrigation is actually under irrigation (United Republic of Tanzania, 2016a). The use of agricultural inputs such as fertiliser is low. For instance, Tanzania uses about 8 -10 kg/ha of fertiliser compared to an average of 16 kg/ha for Southern African Development Community (SADC) countries and an average of 279 kg/ha in China (United Republic of Tanzania, 2016a).

The national economy depends heavily on the agricultural sector, which contributes roughly 27 percent to the national GDP (Tanzania National Bureau of Statistics, 2014a). The agricultural sector is dominated by small scale farmers (United Republic of Tanzania, 2016b) and employs roughly 65 percent of the country's labour force (CIA World Factbook, 2017).

The potential for agricultural growth in Tanzania has led to some initiatives which are expected to stimulate the growth in the agricultural sector. Phase 2 of the Local Government Transport Programme (LGTP) initiated by the Tanzanian Prime Minister's Office Regional Administration and Local Government (PMO-RALG) is aimed at improving the condition of roads leading to areas of high agricultural potential (African Development Bank Group, 2013). International development partners have also seen the potential of investing in the agricultural sector in order to achieve the general goals of economic growth and reducing poverty levels in rural areas. Through its "Feed the Future" initiative, the United States Agency for International Development (USAID) focuses its investments in Tanzania under the umbrella of the Southern Agricultural Growth Corridor of Tanzania (SAGCOT). The programme, which was initiated at the World Economic Forum (WEF) Africa Summit 2010, focuses on increasing annual crop yield. Other plans for the programme include improved irrigation and improved access to the market through the construction of rural roads (USAID, 2016). The idea of improving access to markets through road improvement aligns with the marketing problems reported by the farmers in the 2007/08 Tanzania national sample census of agriculture (Tanzania National Bureau of Statistics, 2012a).

1.4. Tanzania economic overview

Tanzania, a low-income country, is classified among the least developed countries of the world (World Bank, 2017a). According to the results of the National Household Budget Survey conducted in 2011/12 by the Tanzania Bureau of Statistics, 28.2 percent of the population live below the poverty line (Tanzania National Bureau of Statistics, 2014b). Table 1.1 shows the total GDP, per capita GDP and the annual average growth rate of GDP (Tanzania National Bureau of Statistics, 2014a).

Table 1.1: Gross domestic product at market price

	2009	**2010**	**2011**	**2012**	**2013**
GDP (in TZS. billion)	28 213	32 293	37 533	44 718	53 175
GDP growth rates (%)	6.0	7.0	6.4	6.9	7.0
Per Capita GDP (in TZS. million)	693	770	869	1 025	1 186

Source: Tanzania National Bureau of Statistics (2014a)

The economic activities in the country are classified into 15 different categories according to International Standard Industrial Classification (ISIC) Revision 3. Table 1.2 reveals the share of GDP (in 2013) by economic activity aggregated into four categories (Tanzania National Bureau of Statistics, 2014a).

Table 1.2: Share of GDP at basic current price, 2013

Economic activity	**Percent (%)**
Agriculture, Hunting and Forestry	26.5
Fishing	1.5
Industry and Construction	24.0
Services	47.9

Source: Tanzania National Bureau of Statistics (2014a)

With 70.4 percent of the national population living in rural areas (Tanzania National Bureau of Statistics, 2014c), where agriculture is the main economic activity and contributes roughly 27 percent to the national GDP, it is clear that agricultural sector growth, especially for small-scale farmers in rural areas, is essential for the country's economic development and to ensure food security for Tanzania and Africa from a global perspective.

1.5. National transport policy: road infrastructure and transport service

The national transport policy of Tanzania is contained in the formal National Transport Policy (NTP) document of 2003 (*National Transport Policy*, 2003). Efforts have been made to update the document; however, the released revised national transport policy of 2011 is still in draft phase (*National Transport Policy-Draft*, 2011).

The NTP of 2003 characterises the transport sector as one of high cost and low quality. Several reasons for this have been mentioned, including the large infrastructure maintenance and rehabilitation backlog, inadequate institutional arrangements, inadequate capacity, and the low level of enforcement on safety issues (*National Transport Policy*, 2003). Inadequate maintenance and rehabilitation, which lead to poor road conditions, together with other factors, result in high transport costs and prices, unsafe and infrequent transport services. Despite some progress made since the release of NTP of 2003, the revised (draft) NTP of 2011 still characterised the transport sector, among other things, as one of high costs and prices, low quality of services together with huge infrastructure maintenance backlog and rehabilitation needs. The level of transport investment is insufficient, and the institutional arrangement is outdated (*National Transport Policy-Draft*, 2011).

Rural transport is generally characterised by poor infrastructure, associated with high transport costs and charges. Non-motorised transport (NMT), including walking and head-loading, is one of the main modes of transport (*National Transport Policy*, 2003, *National Transport Policy-Draft*, 2011). This situation reduces rural economic activities efficiency and marketing, thereby fuelling further rural poverty. The low demand for motorised transport in rural areas is due to its low affordability. Some village dwellers, including farmers, are not using motorised transport because they cannot afford the fares and tariffs charged. Because of this low demand, motorised transport is often not even available in rural areas (*National Transport Policy*, 2003).

Maintenance for rural roads infrastructure has been irregular and mostly limited to spot improvement, performed with inadequate resources, which yields only short-term results

(*National Transport Policy*, 2003). The limited available financial resources mainly focus on the improvement of national roads and pay less attention to district roads (*National Transport Policy*, 2003).

In planning and prioritisation for the improvement of the transport sector, the NTP (draft) of 2011 envisages that cost-benefit analysis (CBA) to be used as a main tool to evaluate the planned investment. In a situation where social and environmental issues need to be addressed the NTP of 2011 proposed the use of multi criteria analysis (MCA) (*National Transport Policy-Draft*, 2011).

1.6. Tanzania road network

According to the Tanzania Ministry of Works (2011), the road network in Tanzania is classified into two major classes based on administrative and functional aspects: national roads and district roads. National roads are further divided into two classes: class A (trunk roads) and class B (regional roads). The national roads are managed by the Tanzania National Road Agency (TANROADS). District roads are subdivided into three classes: class C (collector roads), class D (feeder roads) and class E (community roads). The district roads are managed by the Prime Minister's Office, Regional Administration and Local Government (PMO-RALG). Since the classification has changed over the years, in this dissertation, the terms district roads and collector roads are used interchangeably. The terms urban roads and feeder roads are also used interchangeably.

Table 1.3 provides a summary of the road network in Tanzania. The network comprises a total of 91 928 km, out of which 33 891 km are trunk and regional roads and 58 037 km are collector, feeder and urban roads. Only one percent of the collector, feeder and urban roads, and 18 percent of trunk and regional roads are paved (African Development Bank Group, 2013; TANROADS, 2016). In comparison to Kenya and Uganda, by the year 2011 the quality of the road network in Tanzania was still lagging behind. There were only 7 km of paved roads per 1 000 sq.km of land in Tanzania, compared to 82 km and 19.7 km for Uganda and Kenya respectively (Morisset & Wane, 2012). Again, out of 223 countries, Tanzania was ranked at position 55 compared to position 32 of Kenya in terms of the total road network the country has (CIA World Factbook, 2017). This data shows that given the big area of the country, 947 300 km^2 (World Bank, 2017b), the spatial density of road network in Tanzania is low, i.e. 9.7 km per 100 sq.km.

Much is still to be done to improve the road network in Tanzania. Due to the limited funds, careful selection of the roads to be improved needs to be exercised in order to ensure fair disbursement of the available funds and the return on investment.

Table 1.3: Summary of Tanzania road network

Road class	**Paved (km)**	**%**	**Unpaved (km)**	**%**	**Total (km)**
Trunk and regional roads	5 970	18	27 921	82	33 891
Collector, feeder and urban	756	1	57 281	99	58 037
Total	**6 726**		**85 202**		**91 928**

Source: TANROADS, 2016 and African Development Bank Group, 2013

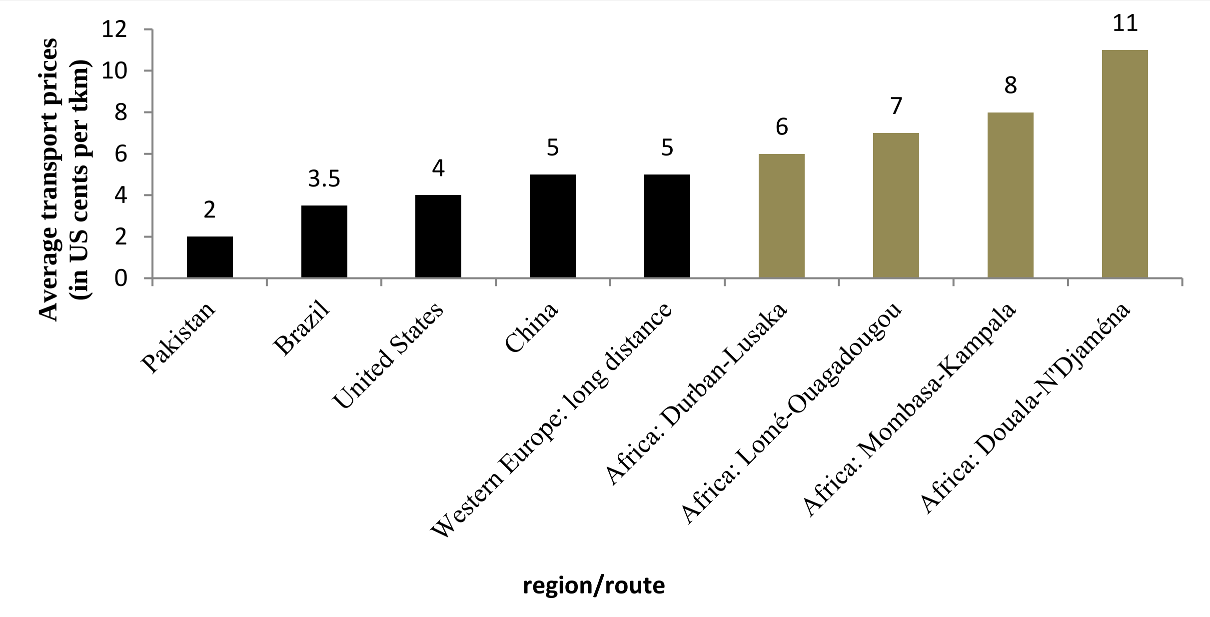
In Tanzania, the main source of funds for road maintenance is from the government through road and fuel toll; that is fuel levy, transit charges, overloading fees and abnormal overloading. The Roads Fund Board is the government agency responsible for ensuring that the money is collected and distributed to the implementing agencies. Generally, the national roads receive a bigger portion of the fund. For instance, in the year 2015/2016, a budget of Tsh 867 billion was approved of which 62 percent was allocated to TANROADS, 30 percent to PMO-RALG, 7 percent to Ministry of Works and one percent to Roads Fund Board ("Roads Fund Board", 2015).

1.7. Transport price, transport cost and trip distance

Transport prices (fares and tariffs) are the rates charged by a transport company or operator to the end user. Normally the transport price comprises of transport cost and a profit margin. Transport costs are the costs a transport operator incurs when transporting cargo or passengers, including vehicle operating costs and other costs such as licensing and insurance and payments at checkpoints. The vehicle operating costs (VOCs), which account for the biggest part of the transport cost, include various variable and fixed costs incurred by a transport operator to operate a given vehicle, notably maintenance labour, tyres and spare parts, fuel and lubricants, crew cost and capital costs (Hine, 2014; Teravaninthorn & Raballand, 2009).

To understand the difference between transport prices and costs, the distinction between the two needs to be clarified. Transport price includes the sum of the transport cost and a profit margin. Therefore, lowering transport cost is expected to lower transport price. However, this is only the case in a competitive market. The situation is different in a strongly regulated and uncompetitive market. There is no direct relationship between the transport price and transport cost. For example, in a situation where cartels limit competition and have monopolised the transport market, there is no clear impact of transport price reduction following transport cost reduction (Teravaninthorn & Raballand, 2009).

Several studies have found that transport prices are high in sub-Saharan Africa compared with other regions in the world. Sub-Saharan Africa has suffered from high transport prices for years. In the late 90's Hine, Ebden and Swan (1997) conducted a study to compare freight transport operations in Tanzania, Indonesia and Pakistan, the results showed that the overall transport tariffs (per ton-km) in Tanzania are three to five times higher than those in Pakistan and two to four times higher than those in Indonesia. Ten years later, as shown in Figure 1.2, Teravaninthorn and Raballand (2009) noted that transport prices are particularly high in sub-Saharan Africa in comparison with other regions. In 2015, Atkin & Donaldson (2015) found that the price of transporting goods within the country, is four to five times higher in Ethiopia and Nigeria compared to the United States of America.



Source: Teravaninthorn & Raballand (2009)

Figure 1.2: Transport prices comparison across different regions

In their study conducted in East Africa, Eberhard-Ruiz & Calabrese (2017) showed that transit delays is one of the key contributors to the high transport prices in the region. The excessive number of roadblocks, weighbridges and slow customs clearance at the border crossing point, congestion in urban centres and borders and inadequate road infrastructure contribute to transit delays and thus high transport prices. Factors such as empty running return trucks (outbound transport price from Mombasa to Kampala is twice as high compared to the inbound transport price) and old and inefficient fleets (most of the imported trucks are used) are also contributing to high transport prices. In West Africa, Nathan Associates Inc. (2012) pointed out more or less the same factors as those identified in East Africa, with some additional regulatory policies which hamper efficiency and competition in the trucking industry. Policies such as freight sharing rules (i.e. allocating a specific share of transit goods to coastal and landlocked country) and queuing systems (i.e. allocating goods in the first in - first out) limit competition in the transport market. They also indicated that low vehicle utilisation due to delays at roadblocks and checkpoint, delays due to duplication of paperwork at the border, overcapacity in the truck fleet, and the use of old and inefficient trucks with high downtime for repair contribute to high transport prices in West Africa.

High transport prices in sub-Saharan Africa have an impact on all economic sectors in the region. They hamper trade between African countries, and render African goods and services less competitive at global level (Gajigo & Lukoma, 2011; Bond, 2016). The price premium they add to distribution costs makes African products more expensive (Gajigo & Lukoma, 2011).

Despite relatively high transport prices, transport costs in Africa are not excessively high in comparison with other regions (Table 1.4). Fixed vehicle operating costs are lower because of the lower capital associated with old trucks and lower wages, but variable vehicle operating costs in Africa are high due to (Teravaninthorn & Raballand, 2009):

(i) high fuel costs;
(ii) aged trucks, which lead to higher fuel consumption and maintenance costs; and
(iii) poor road conditions, which also lead to higher maintenance and fuel costs.

The lower fixed costs to some extent offset the higher variable costs (Teravaninthorn & Raballand, 2009).

Table 1.4: Transport costs comparison between Africa and Europe

	Central Africa	**East Africa**	**France**	**Spain**	**Germany**	**Poland**
Transport costs per vehicle-kilometre (US$)	1.87	1.33	1.59	1.52	1.71	2.18

Source: Teravaninthorn & Raballand, 2009

There is a possibility, however, of lowering the transport costs and prices in sub-Saharan Africa. As reported by Eberhard-Ruiz & Calabrese (2017), on the Mombasa-Kampala route, the transport price declined by 30 percent for the period between 2013 and 2016 mainly due to the reduction of the price of fuel.

The above discussion on transport costs and prices are mainly for long and international routes with fixed trip distance. The findings can apply in rural-urban trips within a country, however, in transporting agricultural products of small-scale farmers in the rural areas further analysis is needed. The transport chain of agricultural products from the farm to the urban market generally involved more than one stage of transport segments (Lançon, Sautier & Anh, 2014; Njenga, Wahome & Hine, 2014; Afolabi, IA & Oyetubo, 2016). The structure of the transport chain differs with location and type of commodity, however, it can be summarised into the following three stages (Lançon *et al.*, 2014; Njenga *et al.*, 2014):

(i) the primary stage from the farm to the village collection point, the key players in transport are the farmers;
(ii) intermediate stage from the village collection point to the district collection point or intermediate markets, key players in transport are farmers, wholesalers, traders and transporters; and
(iii) third stage from the district collection point to the urban market, key players in transport are wholesalers, traders and transporters.

Each of these stages is characterised by different road conditions, trip distances and transport prices (Lançon *et al.*, 2014; Njenga *et al.*, 2014). Furthermore, Lançon *et al* (2014) point out that, in rural areas, an improved rural road that connects to the main transit road across the district allows the wholesalers to come directly with their trucks into producing areas. This situation will change the overall structure of the transport chain of agricultural products and reduce the number of breaking point or stages and, therefore, leading to increased trip distance. Headicar (2009) also pointed out that transport improvement results in a spatial restructuring of the business operations due to the possibility of greater mobility, leading to increased average length of freight haul. Again, Pienaar (2013); Hine (2014) and Lançon *et al.* (2014) assert that long distance trips are characterised with lower unit transport prices (i.e. price *per kilometre*) compared to short distance trips due to factors such as economy of distance.

This research, therefore, explores the effects of road condition and trip distance on transport price and transport cost of agricultural products in the study area.

1.8. Infrastructure and agriculture

Infrastructure that impact agricultural productivity, include (Gajigo & Lukoma, 2011):

(i) road networks;
(ii) irrigation technology;
(iii) post-harvest storage technology;
(iv) telecommunications; and
(v) electricity.

These infrastructures are the major determinants of agricultural development (Platteau, 1996; Gajigo & Lukoma, 2011). Together with other factors such as human capital, credit markets, extension services, fertilises, land, irrigation and agricultural research, reliable infrastructures increase output both per capita and per unit of land (Gajigo & Lukoma, 2011; Limi *et al.*, 2015). Road infrastructure is a necessary factor in production: it reduces transaction costs in input and output markets, and facilitates market integration between sub-regions (Gajigo & Lukoma, 2011; Limi *et al.*, 2015).

This research mainly focuses on the impact of road network infrastructure on the agricultural sector. In their article "Agricultural mechanisation and the evolution of farming systems in sub-Saharan Africa", Pingali *et al*. (1987), as cited in Platteau (1996) concluded that "*adequate transport links to product markets tend to stimulate farmers to increase their marketable surplus, to use land more intensively, and to adopt more efficient techniques and modern inputs*". It links farmers to both input and output markets. An adequate and efficient road network provides farmers with better margins by reducing the price of agricultural inputs, and allows better access to the agricultural output markets (Gajigo & Lukoma, 2011; Limi *et al.*, 2015).

Unfortunately, a large part of sub-Saharan Africa is characterised by poor transport, which adversely affects the movement of agricultural inputs and outputs to and from the rural areas. Poor transport causes delays and reduces the quantities of agricultural resources that can be delivered to and from the farm (Richards, 1985; Riverson *et al*., 1991; Beynon, 1992; as cited in Platteau, 1996; Hine, 2014).

Poor and inadequate road networks also affect the credit accessibility to the farmers (Hine, Riverson & Kwakye, 1983; Gajigo & Lukoma, 2011). Considering the low population density of most African countries, the inadequate road network leads to "higher financial intermediation cost since long distances increase administrative cost of lending, monitoring and loan recovery"(Gajigo & Lukoma, 2011). Two reasons were associated to this: (i) physical measurement of the field/farm (a necessary part of the finance application process) was difficult due to remoteness; and (ii) the difficulty and higher cost of making follow-up trips for the loan progress (Hine *et al.*, 1983).

1.9. Rural road project appraisal

According to Adler (1987), "project appraisal is the process whereby a public agency or private enterprise determines whether a project meets the country's economic and social objectives and whether it meets these objectives efficiently". Project appraisal is the process during which an envisaged project is thoroughly assessed and measured if it can be implemented given the available resources and capacity, whether it can meet the targeted objectives and what social, economic and environmental impact it will have on the country or region. Generally, road project appraisal includes the analysis and assessment of economic, social, financial, institutional, technical, and environmental issues related to a planned intervention (Lebo & Schelling, 2001a).

The purpose of conducting an economic appraisal of road projects, commonly known as cost-benefit analysis (CBA), is to select the investment with the highest economic return (Kerali, 2003; World Bank, 2016b). Economic appraisal essentially involves the comparison of cost streams between alternatives, normally referred as do-minimum or without-projects, and one or more of the do-something or with-project alternatives. The project investment cost is determined by the construction and maintenance cost of the planned intervention or road improvement. The costs of road construction include earthworks costs, pavement construction costs and drainage structures construction costs. The maintenance costs include the costs of repairing road defects such as cracks, potholes and reduce road roughness. The return on investment, or benefits, are in the form of road user cost saving; that is, savings in VOC, savings in travel time and savings in accident costs (Kerali, 2003; OECD, 2011; World Bank, 2016b). In principle, economic appraisal deals with the benefits and costs of the investment, which can be quantified in monetary terms (Transport Research Laboratory, 2004). Normally, in economic evaluation, decisions are made based on common economic indicators such as net present value (NPV), the benefit-cost ratio (BCR), internal rate of return (IRR) of the road project and first year rate of return (Transport Research Laboratory, 2004; OECD, 2011; NWS Government, 2016; World Bank, 2016b).

The economic benefits of road investment can be assessed according to either a producer surplus or a consumer surplus approach. In a situation where the benefits from cost savings for transport users are accrued to the *road users* as a reduction in transport costs, the measured benefits are considered as an increase in *consumer surplus* (Lebo & Schelling, 2001a; Hine, 2014). Alternatively, if the transport cost reductions lower the producers' input and output costs, and result in higher net income to producers, then the measured benefits are considered as an increase in *producer surplus* (Lebo & Schelling, 2001a; Hine, 2014). Consumer surplus is well-suited to conditions where the normal traffic or expected growth in traffic is substantial (Carnemark, Biderman & Bovet, 1976; Archondo-Callao, 2004; Kerali, Odoki & Stannard, 2006; Hine, 2014). In rural areas, where the traffic volume is low and agriculture is the main economic activity, the recommended approach of evaluating road investment benefits is by forecasting the increase in the agricultural production, i.e. the producer surplus approach (Thagesen, 1996). One of the biggest challenge, however, is to predict the agricultural production increase following the transport infrastructure investment (Hine, 2014).

The producer surplus approach was relatively popular during the 1960s and 1970s. Although it is still in use, the approach lost its popularity in favour of the development of economic evaluation tools such as the Highway Development and Management model (HDM-4) and the Roads Economic Decision model (RED). These economic evaluation tools are more commonly used today (Hine, 2014).

HDM-4 and RED are tools developed to assist in the decision-making process for the development and maintenance of roads. Both HDM-4 and RED combine technical and economic appraisals of road projects and employ the consumer surplus approach during the analysis. RED, which comprises a series of spreadsheets, has been customised to fit the evaluation of low-volume roads, while the HDM-4 software is best suited to higher traffic volumes (Lebo & Schelling, 2001a; Archondo-Callao, 2004; Kerali *et al.*, 2006; Hine, 2014). These tools use conventional cost-benefit analysis in assessing and ranking road projects by measuring the saving in VOC, saving in accident cost and saving in time cost following the improvement. Other benefits, such as social and environmental effects, can be included in the analysis, but these benefits are computed exogenously.

In rural areas, the social benefits due to road investment can be substantial (Kerali, 2003; Lucas & Jones, 2012). Socio-economic evaluation, which aims to address wider regional development, is used to assess social benefits. These benefits, such as improved access to education and health facilities and/or improved access to markets, are often difficult to quantify (Kerali, 2003; Transport Research Laboratory, 2004) and for this reason, they are seldom included in economic evaluations (Kerali, 2003; Transport Research Laboratory, 2004) or poorly addressed in road the appraisal process compared to the associated economic benefits (Lucas & Jones, 2012). Approaches such as multi-criteria analysis (MCA) and the cost-effectiveness approach (CEA), together with extended cost benefit analysis (CBA) methods, can be used in the rural road appraisal process (Lebo & Schelling, 2001a; *National Transport Policy-Draft*, 2011). These methods are used to estimate, to some extent, the social benefits of rural road investment.

1.10. Research rationale

Agriculture is one of the major economic activities in most sub-Saharan Africa countries, including Tanzania (World Bank, 2013a; Tanzania National Bureau of Statistics, 2014a). The improvement of the agricultural sector is important for national economic growth, poverty reduction and ensuring food security (World Bank, 2013a). The sector is, however, dominated by small-scale farmers engaged in subsistence farming in most rural areas (OECD/FAO, 2016; United Republic of Tanzania, 2016b). In Tanzania, programmes such as Southern Agricultural Growth Corridor of Tanzania (SAGCOT) have been initiated to improve the agriculture sector (USAID, 2016), however, additional effort is required in addressing the problems that hinder the growth of small-scale farmers within the country. As pointed out in the *National Transport Policy* (2003), *Local Government Transport Programme (LGTP) Phase 1* (2007), *National Transport Policy-Draft* (2011); African Development Bank Group (2013) and PMO-RALG, Tanzania Ministry of Works and JICA (2014) poor rural transport infrastructure and services, among other problems, hamper access to agricultural inputs and markets. This situation leads to low agricultural production (African Development Bank Group, 2013).

However, resources for road improvement are always scarce and rural roads often receive even less attention and budget allocation due to the low traffic volumes they carry (African Development Bank Group, 2013; Hine, 2014). A large percentage of road funds are allocated to primary and secondary roads, which leave tertiary roads with insufficient funds (African Development Bank Group, 2013; Hine, 2014). Phase one of the Local Government Transport Programme (LGTP I), from 2007 to 2012, pointed out that the deficiency of an appropriate road investment decision-making tool is partly the reason for neglecting local transport infrastructure (*Local Government Transport Programme (LGTP) Phase 1*, 2007). Most of the benefits of rural investment are difficult to quantify and therefore cannot be evaluated using the conventional road economic appraisal tools (*Local Government Transport Programme (LGTP) Phase 1*, 2007).

The results of this research will provide a framework for the economic evaluation of rural roads to supplement the existing road investment decision-making tools. The findings may allow for more attention and more resource allocation to rural roads infrastructure investment, which in turn may facilitate the achievement of the overall goals of improving agricultural production, reducing rural poverty and national economic growth.

1.11. Problem statement

In Tanzania, the potential for agricultural sector improvement is not being fully exploited. Among the factors that contribute to the underutilisation of the agricultural potential are poor rural road infrastructure and poor transport services, which hamper market and rural areas accessibility (*National Transport Policy*, 2003, *Local Government Transport Programme (LGTP) Phase 1*, 2007, *National Transport Policy-Draft*, 2011; African Development Bank Group, 2013; Hine, 2014; PMO-RALG *et al.*, 2014; United Republic of Tanzania, 2016a). Poor rural accessibility is associated with high transport costs and prices of agricultural inputs, as well as limiting the access of the rural population to the wider markets (Dorosh, Wang, You & Schmidt, 2010; Kiprono & Matsumoto, 2014; Limi *et al.*, 2015). Poor rural accessibility subsequently impacts the agricultural sector adversely.

Several reasons may be associated with the poor rural road infrastructure, including deficiencies in the road appraisal tools, used in decision-making for the allocation of resources to improve these roads (*Local Government Transport Programme (LGTP) Phase 1*, 2007). Conventional road management and appraisal tools do not fully address the benefit of improved accessibility, especially in the rural areas. These tools concentrate on the direct road user cost savings, that is, savings in VOC, time and accident costs. Road investment, however, has wider economic benefits such as improved reliability, accessibility, efficiency and social inclusion (OECD, 2002; NWS Government, 2016). In the case of rural areas, where the main economic activity is agriculture, rural accessibility improvement following the road investment may result in substantial impacts on price and production of agricultural products. These expected wider agricultural benefits are not captured by the conventional road economic appraisal tools (Kopp, 2016).

1.12. Research aim and objectives

The aim of this research is to establish the relationship between agricultural production, transport price and transport cost. This established relationship will be used to develop a rural road appraisal framework which accounts for wider agricultural benefits, to allow for a more informed decision in allocating resources for investment in the rural road infrastructure.

In order to achieve the research aim, the following four specific objectives divided into two groups will be addressed:

With regard to transport prices, transport costs, road condition and trip distance:

(i) to determine the transport costs and transport prices of agricultural products, and measure the impact of road condition and trip distance on these costs and prices; and

(ii) to establish the relationship between transport price, transport cost and trip distance, which will allow for the estimation of the change in transport price due to the change in transport cost and trip distance following a road improvements.

With regard to rural and market accessibility and agricultural production:

(iii) to establish the relationship between transport price and agricultural production; and

(iv) to establish the potential increase in agricultural production (wider agricultural benefits) following the improvements of rural and market accessibility and reduced transport prices.

1.13. Structure of the thesis

The research is divided into seven chapters, and this section provides a brief description of each[4].

Chapter 1: Introduction – The introduction chapter provides the background of the research and the overview of road infrastructure and the agricultural sector. The chapter also discusses the importance of the research, research problem as well as research aim and objectives.

Chapter 2: Literature review and conceptual framework – The literature and previous work are discussed in this chapter. It reviews the available appraisal methods and discusses their advantages and disadvantages under different circumstances. The chapter describes how the road network is related to economic growth, as well as different ways of measuring the

[4] Note that Chapters 4, 5 and 6 are also presented as separate articles as a result, there are some overlaps between them, particularly in their introductions, data and literature reviews.

economic benefits of road investment. The chapter concludes with a conceptual framework of the research based on the existing body of knowledge.

Chapter 3: Study area and methodology – The method used in collecting and analysing the data is discussed in this chapter. It also provides the approach used to select the study area and details of the selected area.

Chapter 4: The impact of rural road conditions on the transport price of agricultural products – The insight of how rural road conditions can affect the agricultural sector is discussed in this chapter. It provides information on prevailing transport prices and costs, and discusses the factors that affect these prices and costs within the study area. It investigates the effects of distance and road surface type on transport price. The chapter also examines the relationship between transport prices, transport costs and trip distances. It further provides details on the expected changes in the trip patterns of freight vehicles following rural road improvement. It also considers some of the drawbacks of conventional road appraisal tools. This chapter focuses on achieving the first and second specific research objectives.

Chapter 5: The role of road infrastructure in agricultural production – The aim of this chapter is to establish the relationship between the road network, crop production and crop productivity. The impact of the level of rural/market accessibility, as measured by transport prices on agricultural productivity, is analysed. The chapter analyses the possible increase in crop yields after road improvement. This chapter focuses on achieving the third and fourth specific research objectives.

Chapter 6: Low-volume rural roads appraisal: the agricultural benefits context – The focus in this chapter is establishing a low-volume rural road appraisal framework based on the results of Chapters 4 and 5. Details of how the proposed framework incorporates the wider benefits, which are usually not captured by conventional appraisal approaches, are illustrated. The chapter sets the technical construction and maintenance standards required for the improvement of rural roads. The effects of changes in trip patterns and the vehicle utilisation of freight vehicles following road improvement are included when estimating wider agricultural benefits.

Chapter 7: Conclusion and recommendations – Conclusions are provided and discussed in this chapter based on the analysed data and obtained results. Recommendations for future research are provided as well.

Chapter 2 : Literature Review and Conceptual Framework

2.1. General - economic growth and transport

Economic growth depends on the increase in input factors, such as capital and labour, and improved productivity of these input factors (Banister & Berechman, 2003; New Zealand Government, 2014). Economic growth from a transport improvement perspective can be defined as "the continuous increase in economic activity in the impacted area that can be attributed to this investment" (Banister & Berechman, 2003).

Transport investment is an expensive undertaking, and as such it is important to assess the developmental impact and returns an investment will bring in a country (Stifel, Minten & Koru, 2016; Berg, Deichmann, Liu & Selod, 2017). Project appraisal techniques are often used to assess the impact of transport investment on economic development (Button, 2010). These economic appraisal techniques have mostly been applied in the developed world. While their use in developing countries is increasing, they require extensive adaptation to suit the local situation (Button, 2010).

Better transport and economic growth, in aggregate terms, seem to be correlated (New Zealand Government, 2014). The issue arising from the link between transport infrastructure investment and economic growth is whether there is implied causality (Banerjee, Duflo & Qian, 2012; Banister, 2012; Ali, Barra, Berg, Damania, Nash & Russ, 2015). That is whether transport investment spurs economic activities and growth or transport infrastructures are placed in areas with high economic activities (Pradhan & Bagchi, 2013; New Zealand Government, 2014; Ali *et al.*, 2015; Stifel *et al.*, 2016). Banister (2012) and New Zealand Government (2014), however, assert that transport investment in areas where the level of the transport system at the onset is poorly-developed, is likely to have a greater impact on economic growth compared to investment in areas with well-developed transport system. In sub-Saharan Africa, therefore, where the level of road network density and road network quality is low compared to other regions, the potential for economic growth following the improvement of transport infrastructure is expected to be large (Ali *et al.*, 2015).

Theoretically, improvement in transport may enhance economic growth (Deng, 2013). Transport provision or investment and economic growth can be linked directly or indirectly. The direct effects stem from the saving in transport cost, saving in travel time, improved safety and reduced environmental effects (NZ Transport Agency, 2016). The supply of transport services at low cost is conjectured to have a positive impact on economic growth by stimulating the production of goods and services that use public investment as a significant input factor (Button, 2010). The indirect effects of transport investment stem as a result of the response of the society to the direct effects (New Zealand Government, 2014); these include increased productivity and output, improved competition between spatial markets through improved accessibility, economy of scale through agglomeration of some economic activities and resources and transfer of technology and knowledge through connecting people and places and allowing for more interaction between economic actors (Lakshmanan, 2007; Deng, 2013; Pradhan & Bagchi, 2013; Farhadi, 2015; NZ Transport Agency, 2016). The reduced transport costs and prices and improved accessibility directly lower the cost of input factors (Deng, 2013) and permits access to wider markets and subsequently facilitate trade (Berg *et al.*, 2017). There are also multiplier effects emanating from the money spent during the construction and operation of the infrastructure facility from the required construction materials and services (Button, 2010; Pradhan & Bagchi, 2013). However, in developing countries, where the expertise such as engineers and planners and even construction equipment are imported from the developed world and are tied to development aid, this multiplier effect is less substantial in its contribution to the economic growth of the country (Button, 2010).

The impact of transport can be assessed from a microeconomic and a macroeconomic perspective. On a microeconomic level, the assessment of transport is linked to producers, consumers and production cost. Macroeconomic-level assessment is linked to the output levels, employment and income within a national economy (Rodrigue & Notteboom, 2013). In both cases the impact is assessed based on the following aspects (Rodrigue & Notteboom, 2013):

i. network: setting routes that enable new or existing interactions between economic entities;
ii. performance: an improvement in the cost and time attributes for passenger and freight movement;
iii. reliability: an improvement in time performance, notably in terms of punctuality, as well as in reduced loss or damage;
iv. market size: access to a wider market base, where economies of scale in production, distribution and consumption can be improved; and

v. productivity: an increase in productivity due to access to a larger and more diverse base of inputs (raw materials, parts, energy and labour) and broader markets for outputs (both intermediate and finished goods).

Several studies have been conducted which link transport improvement and economic development. Queiroz and Gautam (1992) link the influence of road transportation on economic development in a number of ways. They pointed out that poor accessibility limits the factor mobility[5], and defers the movement of human and material resources to areas where they can be more productive. Using data of the year 1988 for 98 different countries, Queiroz and Gautam (1992) related per capita Gross National Product (GNP) and the road density (in km of paved road/million population). In their regression analysis, they established the equation, *GNP/capita = 1.39 x road density*, meaning that there exists $1.39 of per capita GNP for each per capita millimetre of paved road in a country. The rationale of this equation is that investment in road infrastructure facilitates the economic growth by increasing productivity in other economic activities. In China, Banerjee *et al.* (2012) found that being closer to the transport network have a positive effect on per capita GDP with an elasticity of -0.07, i.e. one percent reduction in the distance from the transport infrastructure is associated with 0.07 percent increase in per capital GDP. Ali *et al.* (2015) assert that reducing transport costs increases GDP; using a case study of Nigeria they estimated that a 10 percent decrease in transport cost increases GDP by 5.4 percent. In Ghana, Jedwab and Moradi (2016) show that better access to transport infrastructure has a short and long-term positive impact on the level of economic activity. Farhadi (2015), using the data for 18 OECD countries for a period between 1870 and 2009, found that investment in transport infrastructure has a positive impact on labour productivity, 10 percent increase in the share of transport infrastructure spending increases the labour productivity by 0.14 percent.

In general, transport investment supports economic growth through reduced transport costs and improved accessibility and reliability, which allows for reduced production and distribution costs of goods and services, more interaction between economic activities, market expansion, and more competitive markets (Lakshmanan, 2007; Deng, 2013; NZ Transport Agency, 2016; Berg *et al.*, 2017).

[5] Factor mobility - ability to move factors of production such as labour and capital

2.2. Rural transport and economy

The long-standing developmental objective in many developing countries has been poverty reduction (Banjo *et al.*, 2012). The improved agricultural production and productivity is the key to achieving this developmental objective (World Bank, 2013a), with the broader agenda being to ensure that the rural population are provided with a minimum basket of goods and services, including transport infrastructure (Banjo *et al.*, 2012). Despite the increase in the investment in the rural infrastructure since the mid-1990s, rural transport has remained poor, probably because of the extremely low levels at the onset (Banjo *et al.*, 2012). This has remained a constraint to increase agricultural productivity, rural growth and thus the alleviation of rural poverty (Banjo *et al.*, 2012).

Sub-Saharan Africa is facing several difficulties regarding the availability of rural transport infrastructure and transport services (Taiwo & Kumi, 2013; Hine, 2014), the efficiency of transporting agricultural products and marketing, as well as the high cost of transport (Hine, 2014). The low level of investment and maintenance in transport infrastructure, together with institutional structure deficiencies, lead to poor quality of the rural transport infrastructure (Hine, 2014). Better rural transport, however, is crucial for reducing poverty and isolation, increasing social welfare, and promoting economic growth (Porter, 2013; Hine, 2014).

Poor rural transport restricts the opportunity to trade *within* the rural areas and *outside* to the wider market, raises production and distribution costs, and reduces the profit margin on produce sales (Carruthers, Krishnamani & Siobhan, 2009). Inefficient rural transport lowers agricultural production yields below their potential level, and impedes the rural population from moving out of subsistence farming into income-generating farming (Hine, 2014).

In a large part of rural areas, motorised transport is limited; walking and head-loading (a means of transport up to 30 times more expensive than trucks) are the typical ways of transport (Hine, 2014). In most cases, the rural motorised transport service (when available) is infrequent, overcrowded, unreliable and unsafe (Hine, 2014). To ensure access and the mobility of rural dwellers in reaching social and economic services, both the transport infrastructure and the transport service need to be examined (Banjo *et al.*, 2012).

Rural transport provision allows for improved mobility rate and availability of different modes of transport, reduced walking distance to social services and roads, and lower transport fares and tariffs (Hine, 2014). High transport costs and infrequent transport services cause low mobility, constrained movement of goods and passengers, and poor development of resources (Hine, 2014). It also reduces interaction with markets and services (Kiprono & Matsumoto, 2014). Due to the lack of an affordable alternative, a huge personal effort is spent on transport. The outcomes are usually adverse effects on health and education, agricultural development, social interaction, and poverty (Hine, 2014).

Dorosh *et.al.* (2010) argued that investment in rural transport can increase the income of a nation through the effects of agricultural activities. Improved rural transport facilitates the delivery of farm outputs to the market, improves access to extension services and improves access to farm inputs such as fertilisers and seeds (Dorosh *et al.*, 2010; Airey, 2014; Limi *et al.*, 2015; Stifel *et al.*, 2016). The overall outcome is increased agricultural production and productivity (Banjo *et al.*, 2012). Reliable rural transport services linking farmers to the markets is a prerequisite for reaping the returns of increased agricultural output in rural areas (Njenga *et al.*, 2014).

In most cases, however, road authorities improve road infrastructure only once traffic volumes reach a certain threshold (Njenga *et al.*, 2014). For rural roads where traffic volumes are low, there are inadequate analyses of the costs and benefits involved, and insufficient understanding of how a seasonally impassable road adversely affects agriculture marketing and the social demands of rural societies (Njenga *et al.*, 2014).

In sub-Saharan Africa, the majority of farmers in rural areas are smallholder farmers (Banjo *et al.*, 2012; Limi *et al.*, 2015). It is estimated that 85 percent are farming on less than two hectares (Banjo *et al.*, 2012). Njenga *et al.* (2014) and Lançon *et al.* (2014) explain the transport chain of agricultural products of small-scale farmers from the farms to the bigger market. They pointed out that the structure of the agricultural product transport chain involves more than one stage of the transport segment and differs with location and type of commodity. In general the transport chain can be divided into the following three segments (Lançon *et al.*, 2014; Njenga *et al.*, 2014):

i. Primary transport segment: the segment from the farm to village consolidation/collection point, typically at the junction of the roads used by motor vehicles. The key actors at this segment are the farmers, who mostly use household-based means of transport such as head-loading, animal carts, bicycles and sometimes motorcycles.

ii. Intermediate transport segment: the segment from the village collection point to the intermediate traders' markets or district collection point. The key actors at this segment are the farmers who also act as traders, wholesalers and transporters.
iii. The last segment: the segment used to transport the agricultural produce to the terminal delivery through regional and trunk roads for national and international markets. The key actors at this segment are transporters, wholesalers and traders.

The three segments are characterised by different road conditions, trip distances and transport prices. The primary transport segment, referred to as the "first mile", is of major concern as this is typically in very poor condition (Njenga *et al.*, 2014). This, combined with the low volume of produce transported by individual farmers, makes the first mile the most inefficient segment in terms of travel speed, transport costs and transport prices (Lançon *et al.*, 2014; Njenga *et al.*, 2014). Perishable crops can be seriously affected by delaying the delivery to the processing industry or market as a result of highly deteriorated or impassable roads associated with unreliable transport services (Ahmed & Hossain, 1990; Mkenda & Campenhout, 2011; OECD, 2013; Taiwo & Kumi, 2013; Hine, 2014). This situation can have a significant adverse impact on farmers' income in rural areas (World Bank, 2013b). Findings by the Food and Agriculture Organisation of the United Nations (FAO) and World Bank study "Africa's Sleeping Giant" (as cited in Banjo *et al.*, 2012) suggest that with regard to rural transport, the focus should be at the extreme lower end of the road network in order to improve the access and mobility of the smallholder farmers. Better analysis and understanding of the agricultural production process, as well as how agricultural products reach the market, could be a step towards improving the rural transport infrastructure and services (Njenga *et al.*, 2014).

The prosperity of the agricultural sector depends on the technology used in the sector, such as irrigation, use of farm inputs such as fertilisers and improved seeds and transfer of knowledge from extension officers etc. (Banjo *et al.*, 2012). Improvement in the rural roads infrastructure is one way to facilitate technology penetration in the agricultural sector, i.e. through the provision of extension services (education or guidance given to farmers by an agricultural expert in order to improve their productivity) and accessibility of farm inputs (Ahmed & Hossain, 1990; Banjo *et al.*, 2012). The mobility of agricultural experts (extension officers) is constrained by poor transport infrastructure (Ahmed & Hossain, 1990) and these workers are poorly motivated to work in less accessible areas (Hine, 2014). On the hand, improved rural road infrastructure and transport services also facilitate the farmers' access to extension services located further from their homes/farms, e.g. the district centre (Airey, 2014; Hine, 2014). Poor rural road infrastructure and high transport charges affect the availability of farm inputs, and subsequently adversely impact agricultural production (Ahmed & Hossain, 1990; Hine, 2014). Hine (2014) pointed out that improved road infrastructure not only facilitates agricultural extension services, but also facilitates access to credit. Aside from spurring agricultural growth, appropriate rural investment ensures food security and complements efforts to cater for food emergencies (Banjo *et al.*, 2012).

Poor rural transport infrastructure and services hamper agricultural productivity and growth, due to longer travel times and higher transport prices of farm inputs and outputs (World Bank, 2013b; Hine, 2014). Poor rural transport increases marketing costs (World Bank, 2013b; Hine, 2014) and with the exception of the rise in mobile phone use, it also limits information flow (Hine, 2014). Poor rural transport leads to low prices of agricultural outputs and high agricultural input prices (Mu & Van De Walle, 2011; Banjo *et al.*, 2012; Kiprono & Matsumoto, 2014). In the study conducted in Bangladesh, Ahmed and Hossain (1990) found that the price of fertiliser was 14 percent lower and the price of rice was 5.7 percent higher in developed villages (i.e. villages with better access to transport, markets and other infrastructure) compared to underdeveloped villages. They also found that in developed villages the use of fertiliser was higher by 92 percent, use of improved seeds was higher by 71 percent and irrigation of farmland was 105 percent more. The development of infrastructure resulted in an efficient use of technology which was estimated to increase the agricultural production by 32 percent (Ahmed & Hossain, 1990). In the study conducted in East Africa, Limi *et al.* (2015) found that 10 percent reduction in transport cost could increase crop production by more than 10 percent, and 10 percent reduction in the distance to the nearest road could increase crop production by 0.5 percent. Khandker, Bakht & Koolwal (2009) also found that providing better transport infrastructure resulted in 2 percent increase in crop prices, 22 percent increase in crops production and a reduction in fertiliser prices. In a study conducted in Morocco by the World Bank (1996) to assess the impact of improved rural roads, it was found that the yield of main crops was increased by 31percent, usage of fertiliser was doubled and contact with the extension centre was increased from less than once per year to more than four times per year.

In areas with poor infrastructure, there is no incentive to invest in the agricultural sector because of the low profitability of farm activities, with poorly integrated and unstable markets (Banjo *et al.*, 2012). Therefore the focus of improving rural transport infrastructure should be to ensure that smallholder farmers are reachable and that they can access the market.

In summary improvement in rural transport infrastructure and transport services can improve the agricultural sector through the following:

Reduction of production costs and increased agricultural yield: improved access to inputs

(i) Lowered agricultural inputs prices: improved transport reduces prices of transporting agricultural inputs from the markets to the farms which leads to lower input prices, and thus stimulate more use of inputs and, subsequently, increased agricultural productivity (Carnemark *et al.*, 1976; Ahmed & Hossain, 1990; Banjo *et al.*, 2012; Kiprono & Matsumoto, 2014; Limi *et al.*, 2015).

(ii) Reliable access to agricultural inputs: Improved transport allows for timely availability of inputs which permit for efficient farming (Mkenda & Campenhout, 2011; Njenga *et al.*, 2014).

(iii) Improved access to extension services: improved transport allows for easy access to extension workers and services which facilitates increased productivity (Ahmed & Hossain, 1990; Hine, 2014).

Increased prices of farmers' produces: improved access to market

(iv) Increased farm-gate prices: with fixed urban market prices, reduction of transport costs (part of marketing/distribution costs) which is passed on to the farmers will increase farm-gate prices (Carnemark *et al.*, 1976; Hine & Ellis, 2001; Mkenda & Campenhout, 2011; Banjo *et al.*, 2012; Hine, 2014).

(v) Reliable output flow of farm produces: this reduces the necessity of holding a high level of stock in urban markets, associated with increased inventory costs which tend to depress the farm-gate prices. It also increases competition in agricultural marketing (Hine, 2014).

(vi) Reduced spoilage: improved transport allow for timely delivery of perishable crops to the market and reduced risk of spoilage which encourages farmers to cultivate high-value perishable crops (World Bank, 1996, 2013b; Airey, 2014).

The overall effect is increased profit to the farmers due to low production costs and high producers' prices, which in turn stimulates more investment in the agricultural sector and, therefore, increased agricultural productivity and production (Dorward & Chirwa, 2011; Banjo *et al.*, 2012).

The economic returns on transport infrastructure investments, however, depend on the appropriate infrastructure investment, agricultural productivity, the marketing system, and the resource endowments of the specific area, which include climate and weather conditions (Banjo *et al.*, 2012). Farm structure may also influence the returns on a rural transport investment: aspects such as the type and amount of production, the farm's size and its commercial orientation, and the existence of marketing groups[6], which allows for the possibility of achieving economies of scale through assembling larger loads with lower unit transport price (Banjo *et al.*, 2012).

2.3. Transport cost, transport price and trip distance

Section 2.3 describes the difference between transport cost and transport price, and provides descriptions of the factors affecting them.

2.3.1. Overview

Transport price and transport cost (see Figure 4.1) can be defined as follows (Teravaninthorn & Raballand, 2009; Hine, 2014):

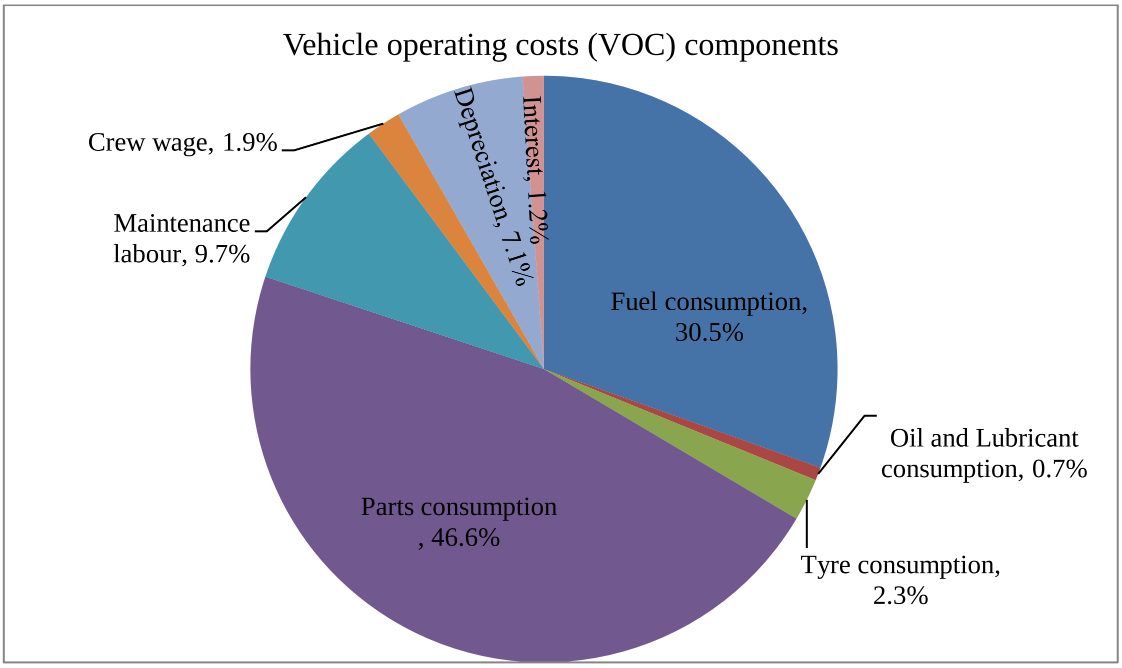
- *Transport price* (fares and tariffs) is the rate charged by a transport company or operator to the end user. Normally the transport price comprises of transport cost plus the profit margin. The transport price may also be referred to as the transport charge.
- *Transport cost* is the cost a transport operator incurs when transporting cargo or passengers. Transport cost comprises of vehicle operating costs (see below) and other associated costs such as insurance and licensing.

Vehicle operating costs (VOCs) include various variable and fixed costs incurred by the transport operator to own and operate and maintain a given vehicle, including maintenance labour, parts consumption, tyre consumption, fuel consumption, oil and lubricants consumption, crew wages, capital costs (i.e. depreciation and interest) and overheads cost (i.e. license and insurance etc.) (Bennett & Greenwood, 2001; OECD, 2002; Tan, Thoresen & Lloyd, 2011; Chatti & Zaabar, 2012). Figure 2.1 provides an example of the percentage share of VOC components on the total VOC for a medium truck travelling on a gravel road.

According to Teravaninthorn and Raballand (2009), VOC plus overheads equal transport cost. However, Bennett and Greenwood (2001) do not differentiate between transport cost

[6] Marketing group can be referred to as selling of farm output as well as buying of farm inputs as a group of farmers

and VOC; they include overhead costs in VOC. In this research, therefore, transport cost and VOC are used interchangeably. However, the term *transport cost* referred in this research should not be confused with term *total transport cost* which includes road construction and maintenance costs as well as road users cost (i.e. VOC, accident cost and travel time cost) (Kerali, 2003).



Source: Author

Figure 2.1: Percentage share of VOC components to the total VOC: Output results from the calibrated RED model for a medium truck traversing on rolling terrain on a gravel road

There are several factors that may affect transport costs and prices at a given locality. These include, but are not limited to, the following (Teravaninthorn & Raballand, 2009; Hine, 2014):

- Load and distance: Longer-distance and bigger loads have lower average unit prices.
- Mode of transport/vehicle type: small modes of transport such as intermediate means of transport (IMT) [7] have a comparative advantage and lower prices for smaller loads and short-distance trips. Large buses and big trucks have the advantage for heavier loads and longer-distance trips.

[7] Intermediate means of transport (IMTs) refers to the means of transport such as bicycles, tricycles, motorcycles and animal carts. These IMTs reduce human drudgery without necessary incur high cost associated with the use of a motor vehicle

- Road condition: The vertical and horizontal alignment, type and surface roughness of the road affect transport costs through their effects on speed, fuel consumption, and vehicle maintenance and repair costs.
- Return cargo: If cargo on the return trip (backload) is assured, the unit freight charge is lower.

Poor road condition causes high vehicle operating costs: increases fuel consumption; increases maintenance costs, reduces the life of tyres, reduces vehicle utilisation due to low vehicle speed and reduces the life of the vehicle due to high wear and tear (Bennett & Greenwood, 2001). Road investments which improve road condition reduce transport costs for vehicles transporting cargo and passengers (Hide, Abaynayaka, Sayer & Wyatt, 1975; Watanatada, Dhareshwar & Rezende-Lima, 1987; Bennett & Greenwood, 2001; Archondo-Callao, 2004; Chatti & Zaabar, 2012), and facilitate transport services. However, the effect of improved roads on transport prices needs further analysis. In the past, it was presumed that an investment in road infrastructure would result in a lower transport price. However, in some areas, for instance in West and Central Africa, no clear impact on transport prices was evident (Teravaninthorn & Raballand, 2009).

The transport price may be influenced by the transport cost, transport market regulations, and competition (Teravaninthorn & Raballand, 2009; Nathan Associates Inc., 2012; Eberhard-Ruiz & Calabrese, 2017). The strong regulated and un-liberalised transport market is associated with strong entry barriers, where transport operators are not free to enter the trucking industry and, therefore, limiting competition in the transport market. In the case where cartels monopolise the transport market, they can set higher transport prices without restriction. In oligopolistic or monopolistic markets, which characterise some transport operations (in West Africa for instance), the transport price often has little relation to the transport cost. Transport cost reductions would have very little impact on transport prices because of the strongly regulated transport market (Teravaninthorn & Raballand, 2009). Cartels are responsible for the large difference between costs and prices, leading to large profits at the relatively low quality. Policies such as freight sharing rules (i.e. allocating a specific share of transit goods to specific transport operator) and queuing systems (i.e. allocating goods in the first in-first out) also limit competition in the sector with no incentive to improve the efficiency in the transport market (Teravaninthorn & Raballand, 2009; Nathan Associates Inc., 2012). In a competitive and deregulated transport market, however, transport prices are determined by the market forces (Teravaninthorn & Raballand, 2009; Nathan

Associates Inc., 2012). In East and South Africa, for instance, the transportation sector is more competitive, with a more mature market (Teravaninthorn & Raballand, 2009; Eberhard-Ruiz & Calabrese, 2017). The deregulated transport market delivers advantages in terms of prices and efficiency of services. In East and Southern Africa, measures that would reduce transport costs are likely to reduce transport prices as well.

2.3.2. Influence of road condition on vehicle operating cost components

Understanding the vehicle operating cost in relation to road condition is important for proper planning and investing in road infrastructure (Chatti & Zaabar, 2012). Vehicle operating cost components can be related to road conditions as well as vehicle speed (Bennett & Greenwood, 2001; Chatti & Zaabar, 2012). In order to calculate VOC in response to the changes in road conditions, VOC is expressed as cost per unit distance (Tan *et al.*, 2011). Highway Development and Management (HDM-4) and Roads Economic Decision (RED) models use these relationships to calculate the vehicle operating costs saving following a road improvement.

Road condition is defined by the vertical and horizontal alignment, road roughness, surface type, road width and sight distance (Thagesen, 1996; Bennett & Greenwood, 2001). The condition of the road affect vehicle speed and subsequently vehicle operating cost (Bennett & Greenwood, 2001). In this section, the discussion is focused on the effect of road roughness (as a measure of road condition) on vehicle operating costs.

Surface or road roughness is a common measure of the road condition and it is widely used as an indicator to describe ride quality or the level of service offered by the road (Mclean & Foley, 1998; Archondo-Callao, 2004; Kerali *et al.*, 2006; Tan *et al.*, 2011; Du, Liu, Wu & Jiang, 2014). Road surface roughness is the measure of irregularity of road and increases with the pavement life due to the effect of traffic loading and environmental related factors (Mclean & Foley, 1998; Chatti & Zaabar, 2012). Several measures can be used to measure road roughness, including present serviceability rating (PSR) and international roughness index (IRI) (Tan *et al.*, 2011). The present serviceability rating was developed by the American Association of State Highways and Transportation Officials (AASHTO). PSR make use of the observers who ride on a road and rate the road on the basis of qualitative scale, ranging from 0-very poor to 5-very good (Tan *et al.*, 2011). IRI developed by the World Bank is a well-recognised standard measure of road roughness (Du *et al.*, 2014). IRI is an index that characterises the longitudinal profile of the wheel path (Mclean & Foley, 1998;

Tan *et al.*, 2011; Du *et al.*, 2014). It is based on the average rectified slope (ARS), that is the accumulated vehicle suspension motion (in m or mm) divided by the distance travelled by the vehicle during measurement (in m or km), and therefore it is expressed in units such as m/km or mm/m (Tan *et al.*, 2011). The advantage of IRI over PSR is the ability of transferring it across different locations (Du *et al.*, 2014). Road roughness, measured in IRI, has been used by several studies and researchers to quantify the relationship between road condition and vehicle operating cost (Mclean & Foley, 1998; Bennett & Greenwood, 2001; Tan *et al.*, 2011; Chatti & Zaabar, 2012).

Vehicle capital cost *per veh-km* is affected by a vehicle's level of utilisation and its service life (Bennett & Greenwood, 2001). Rough roads shorten a vehicle's service life due to high wear and tear, and reduce vehicle utilisation due to low vehicle speed. The result is fewer kilometres travelled by the vehicle during its economic life. With poor road conditions, higher capital cost *per veh-km* will be noticeable.

For instance, in calculating the depreciation components in HDM-4, Bennett (1996c) as cited in Bennett & Greenwood (2001) started by assuming that the vehicle residual value is proportional to the road roughness, a vehicle operated on a rougher road will have low residual value due to more wear and tear. Bennett (1996c) as cited in Bennett & Greenwood (2001) developed the following expression, Equation 2.1, for calculating the vehicle residual value:

$$VRV = max[a_0, a_1 - max(0, (RI - a_2))], \qquad (2.1)$$

where:

- VRV = vehicle residual value in percentage;
- a_0 = minimum vehicle residual value in percent (default value = 2);
- a_1 = maximum vehicle residual value in percent (default value =15);
- a_2 = average road roughness *in IRI m/km*, below which the maximum residual value arise (default value =5); and
- RI = road roughness in IRI m/km.

Using the default values in Equation 2.1, it can be interpreted that the vehicle residual value *in percent*, of a vehicle operated on the road with an average roughness IRI 5 m/km or lower will be 15 percent, and for higher roughness the minimum vehicle residual value will be 2 percent (Bennett & Greenwood, 2001, 2003).

The depreciation cost *per 1000 km*, as a fraction of the replacement vehicle price, less tyre price, is given by the following expression, Equation 2.2 (Bennett & Greenwood, 2001):

$$DEP = 1000(\frac{1-0.01\times VRV}{LIFEKM}), \quad (2.2)$$

where:

- DEP = depreciation cost *per 1000 km*, in fraction of the replacement vehicle price less tyres price (Note: The price of tyres is not included because tyre consumption is modelled differently);
- VRV = vehicle residual value in percentage; and
- $LIFEKM$ = optimal life time vehicle utilisation in km.

Note: LIFEKM is also affected by road roughness, and is given by the following expression, Equation 2.3 (Bennett & Greenwood, 2001):

$$LIFEKM = \frac{LIFEKM0\times LIFEKMPCT}{100}, \quad (2.3)$$

where:

- $LIFEKM$ = optimal life time vehicle utilisation in km;
- $LIFEKM0$ = average vehicle service life in km (user defined); and
- $LIFEKMPCT$ = optimal lifetime kilometreage as percentage of baseline life.

The LIFEKMPCT is given by the following expression, Equation 2.4 (Bennett & Greenwood, 2001):

$$LIFEKMPCT = \min(100, \frac{100}{1+\exp\left(a_0\times RI_{adj}^{a_1}\right)}), \quad (2.4)$$

where:

- $LIFEKMPCT$ = optimal lifetime kilometreage as percentage of baseline life;
- RI_{adj} = adjusted road roughness in IRI m/km; and
- a_0 and a_1= regression coefficients (default values for all vehicles, a_0=-65.8553, a_1=-1.9194).

Therefore, the depreciation cost *per 1000 km* is given by Equation 2.5 (Bennett & Greenwood, 2001):

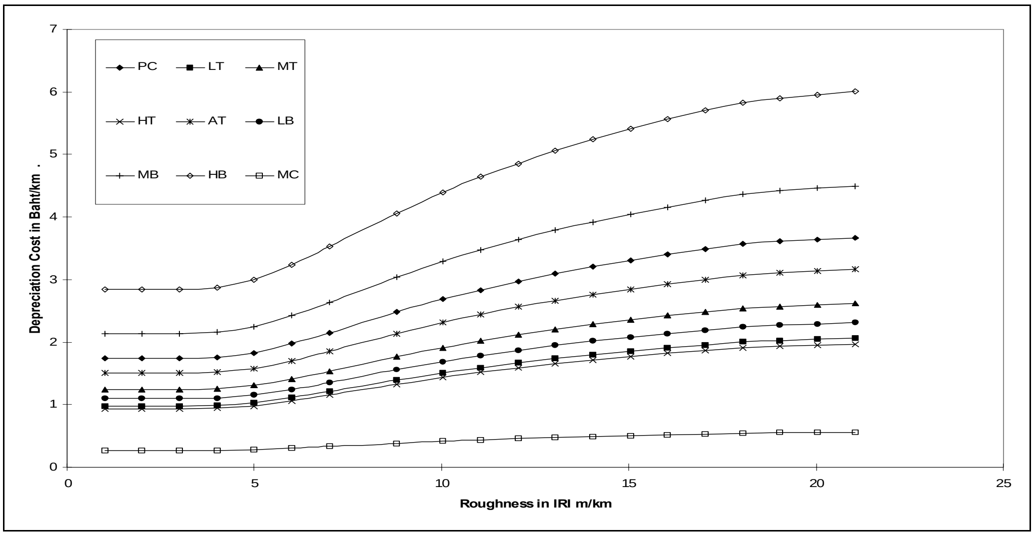
$$DEPCST = DEP \times NVPLT, \quad (2.5)$$

where:

- $DEPCST$ = depreciation cost in cost *per 1000* km;

- *DEP* = depreciation cost *per 1000 km*, in fraction of the replacement vehicle price less tyres price; and
- *NVPLT* = replacement vehicle price, less tyres.

Using Equation 2.5, the graphs in Figure 2.2 were plotted to illustrate the effect of road roughness on depreciation cost (in Thailand currency, Baht/km) for nine different vehicle types, showing that vehicle depreciation increases with the increase in road roughness with higher impact on heavy buses and lower impact on motorcycles (Bennett & Greenwood, 2001). Using Equation 2.1 to 2.5 it can be shown that the low residual value and shorter vehicle life due to poor road conditions (rougher road with higher IRI value) lead to higher depreciation costs.



Source: Bennett & Greenwood (2001, 2003), PC: Passenger Car, LT: Light Truck, MT: Medium Truck, HT: Heavy Truck, AT: Articulated Truck, LB: Light Bus, MB: Medium Bus, HB: Heavy Bus, MC: Motorcycle. 1USD =33.06 Baht, 2017

Figure 2.2: Effect of road roughness (IRI) on capital cost (Baht/km) for different vehicle types: deprecation component

Overhead cost *per veh-km* is affected by vehicle speed and utilisation. The cost *per veh-km* is obtained by dividing the annual overhead cost (i.e. fixed cost per year) by the vehicle working time and vehicle speed, Equation 2.6 (Bennett & Greenwood, 2001):

$$OC = \frac{1000 \times AO \times (100 - PP)}{100 \times S \times HRWK}, \qquad (2.6)$$

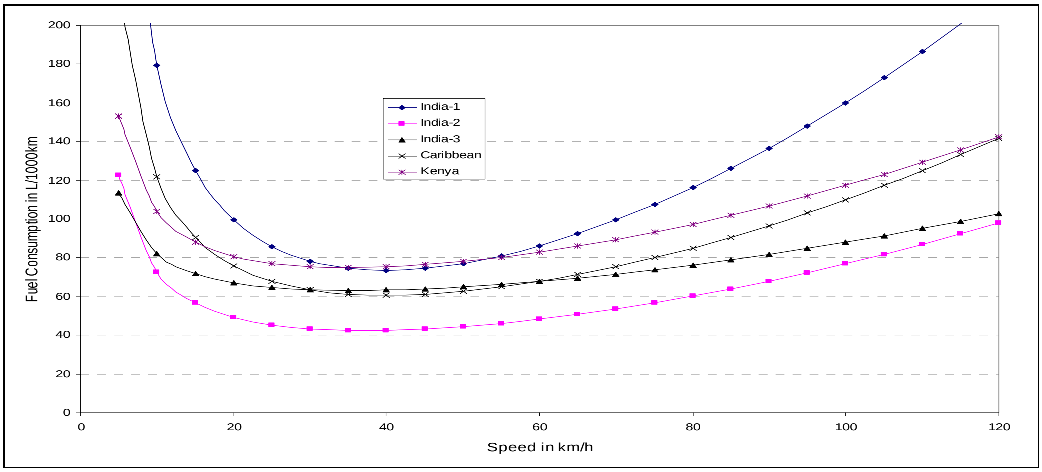
where:

- *OC*= overhead cost per 1000 veh-km;
- *AO* = annual overhead cost in cost/year;
- *PP* = percentage of vehicle used in private trips;

- *HRWK* = annual working time in hours; and
- *S* = average vehicle speed in km/hr.

Higher speed and higher vehicle utilisation result in lower overhead cost *per veh-km*. Vehicle speed also affects crew wage. Crew wage *per veh-km* is obtained by dividing the unit cost (i.e. cost per hour) by the vehicle speed (Bennett & Greenwood, 2001). Poor road conditions with low vehicle speed result in higher crew wages *per veh-km.*

Fuel consumption contributes 20-40 percent of the total vehicle operating cost (HTC 1999 as cited in Bennett & Greenwood, 2001). Bennett and Greenwood (2001) reported results of the relationship between fuel consumption and vehicle speed from different studies. This relationship has a U-shape, with high fuel consumption at lower and higher speeds (Figure 2.3). They also reported the development of mechanistic models[8] which refine these empirical models and relate fuel consumption to the forces opposing vehicle motion such as rolling resistance and aerodynamic forces. Mechanistic models are more flexible and can be applied to different conditions. Due to their advantage over the empirical models, the HDM-4 model adopted mechanistic models for use (Bennett & Greenwood, 2003). Despite the effect of speed on fuel consumption, Chatti and Zaabar (2012) measure the direct effect of road roughness at a constant speed and found that fuel consumption increases with the increase in road roughness. Mclean *et al.* (1998) also reported the results from a number of studies which show that at constant speed fuel consumption increases with the increase in road roughness. This is due to the increase in rolling resistance as road roughness increases.



Source: Bennett and Greenwood (2001)

Figure 2.3: Effect of vehicle speed on fuel consumption: Empirical model results

[8] Mechanistic models are those that correspond to the understanding of the vehicle mechanism and make use of laws of physics, etc. to predict the fuel consumption in relation to the forces opposing the vehicle motion. As oppose to empirical models which are based on direct observation and measurement and extensive data records, mechanistic models are more flexible and therefore can be applied/transferred to different location.

Oil and lubricants consumption constitute only a small percentage of the total VOC. Claffey (1971) as cited in Bennett and Greenwood (2001) found that vehicle speed, as well as the frequency of stop-and-go, affect engine oil consumption. Watanatada *et al.* (1987a) and CRRI (1982) (as cited in Bennett and Greenwood, 2001) related engine oil consumption to road conditions such as roughness, rise and fall, and road width. Pienaar (1984) as cited in Bennett and Greenwood (2001) suggested a method of calculating engine oil consumption as a function of engine speed and fuel consumption, as well as the distance between oil changes recommended by the vehicle manufacturers. For the case of other lubricants, Bennett and Greenwood (2001) reported that their consumptions were very small, and these are therefore not considered in economic evaluation models such as HDM-4. However, for the completeness reason Watanatada *et al.* (1987) provided equations for different vehicles which relate consumption of these lubricants with road roughness.

Tyres are continuously consumed as a vehicle travels. Ellis & Hine (1998) reported that tyre consumption can comprise up to 25 percent of the total VOC for trucks. Tyre consumption increases with an increase in pavement roughness (Bennett & Greenwood, 2003; Tan *et al.*, 2011; Chatti & Zaabar, 2012). Road alignment, particularly horizontal curvature, and vehicle acceleration and deceleration also increase tyre consumption (Bennett & Greenwood, 2001; Tan *et al.*, 2011).

Parts consumption and maintenance labour (maintenance and repair costs) are functions of pavement roughness and vehicle age. The maintenance practices of the vehicle owner and/or operators also play a significant role in these costs. These costs make up a bigger portion of savings in VOC following road improvement – up to 80 percent for some projects (Bennett & Greenwood, 2001). In HDM-4, parts consumption is modelled as a fraction of a new vehicle’s price; the fraction increases with an increase in pavement roughness as well as in vehicle age. Chatti & Zaabar (2012) also found that repair and maintenance costs increase with road roughness, and these cost increase with the increase in speed and are more pronounced in smaller vehicles than in articulated trucks. Maintenance labour is a function of parts consumption and pavement roughness (Bennett & Greenwood, 2001).

2.3.3. Effect of trip length on vehicle operating cost and transport price

Trip length can influence VOC, particularly fixed cost, through vehicle utilisation. Improved road alignment[9] leads to shorter routes, which may change vehicle utilisation. Schutte (1994)

[9] Road alignment refers to the route of the road comprising a series of horizontal and vertical curves

as cited in Bennett and Greenwood (2001) argued that the reduced trip length would have a lower impact on VOC, because vehicles do not travel exclusively on shortened links; they also travel on other routes on the road network. Generally, a shortening of the trip length occurring on one link has indeed left other links on the road network unchanged. Therefore, the savings from reduced trip length will be substantially lower. Yet Hine *et al.* (1997) and Hine (2014) show that changes in trip length can significantly affect transport price, with lower transport price *per kilometre* over longer trip distance.

The transport chain of agricultural products to the urban/bigger markets can roughly be divided into three transport segments i.e. primary transport segment, intermediate transport segment and the last transport segment (see also Section 2.2) (Lançon *et al.*, 2014; Njenga *et al.*, 2014). Lançon *et al.*(2014) pointed out that improvement of rural road which connect to the main road allows for the wholesalers from urban areas/bigger markets (or good roads several kilometre away to come with their trucks directly into more remote areas i.e. agricultural producing areas. This situation changes the structure of the transport chain of agricultural products by reducing the number of transport segments or breaking point, which in turn leading to increased trip distance. Headicar (2009) also pointed out that transport improvement derives not much in terms of the increase in the volume of freight or number of journeys being made, but rather, in the increase of the average length of freight haul or journey. This is due to the spatial restructuring of business operations and personal life due to greater mobility provided by the improved transport infrastructure (Headicar, 2009).

As pointed out by Hine *et al.* (1997) and Hine (2014) that changes in trip length significantly affect transport price, this research will further explore this effect in the context of transporting agricultural products in the study area.

2.4. Road project appraisal

According to Adler (1987), project appraisal "is the process whereby a public agency or private enterprise determines whether a project meets the country's economic and social objectives and whether it meets these objectives efficiently". It provides a detailed and comprehensive review of project related aspects and lays the foundation for project implementation after approval and its evaluation after completion (Adler, 1987). The envisaged project is thoroughly assessed and measured if it can be implemented given the available resources and capacity, whether it can meet the targeted objectives and what social, economic and environmental impact it will have on the country or region. The appraisal process is multi-disciplinary, which involves the analysis and assessment of the following aspects (Adler, 1987; Botes & Pienaar, 2001; Lebo & Schelling, 2001a):

(i) **Economic evaluation** considers the project's total economic cost and the economic benefits to the directly involved community. It considers the quantifiable costs and benefits of the project's implementation.

(ii) **Socio-economic evaluation** aims to address wider regional developments and socio-economic benefits such as income distribution or healthcare improvement. It is recommended that this evaluation should be done for proposed investment programmes as opposed to project investments. The evaluation should be performed on the short-listed projects from the results of an economic evaluation.

(iii) **Financial evaluation** takes into account the timing of the project and future financial commitments, such as subsidies, financial charges and maintenance. It also determines the required funding and the project's financial viability to produce the expected return on investment. It focuses on the cost and revenue of the enterprise responsible for the project.

(iv) **Environmental assessment** looks at the impact of the project on the environment.

(v) **Technical evaluation** assesses the technical feasibility of the engineering and design features of the project, such as capacity, design standards and maintenance standards.

(vi) **Institution appraisal** focuses on the managing organisation and the staff involved in the project's construction and operation.

2.4.1. Economic evaluation

In this research, the focus is on economic evaluation, commonly known as cost-benefit analysis (CBA). "The basic purpose of the economic appraisal of a project is to measure its economic costs and benefits from the point of view of the country as a whole to determine whether the net benefits are at least as great as those obtainable from other marginal investment opportunities" (Adler, 1987). The road economic appraisal assess whether the benefits from the road investment are at least equal to the benefits that could be obtained if the money were invested in other projects. Kerali (2003) argued that in most cases the decision to invest in the road has already been made. The issue is then to determine what type of road should be built, the level of investment required and the expected economic returns.

The purpose of road economic appraisal is to objectively select and rank the projects to be implemented, in order to maximise the return on investments (Kerali, 2003).

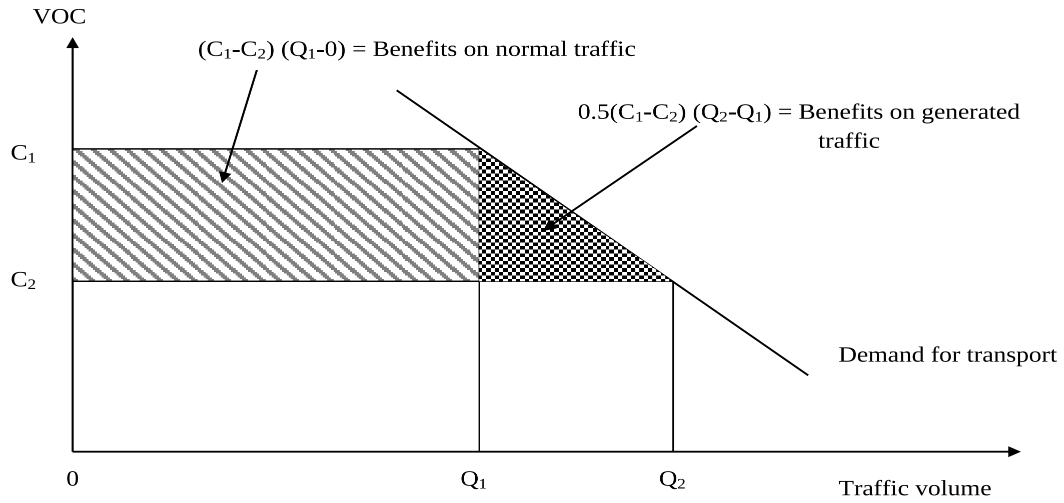
For economic analysis to be conducted, at least two alternatives of road construction should be considered: the "without-project" alternative (or do-minimum alternative) and the "with-project" alternative (or do-something alternative) (Kerali, 2003; OECD, 2011). The without-project option represents the current situation, normally with little or no investment, and in most cases means the continuation of the existing road standard. Usually, the without-project alternative comprises high maintenance and road user costs (Kerali, 2003; NWS Government, 2016). The with-project alternative seeks to reduce road maintenance and road user costs, but has high investment costs. It usually provides better or higher road standards through new construction, reconstruction, upgrading, etc. (Kerali, 2003). The project is said to be viable if the savings in maintenance and road user costs are high enough to offset the investment cost. These benefits are measured using common economic indicators such as net present value (NPV), internal rate of return (IRR), and benefit-cost ratio (BCR) (Transport Research Laboratory, 2004; OECD, 2011; NWS Government, 2016; World Bank, 2016b).

The economic benefits of road investment can be measured either with the consumer surplus approach or the producer surplus approach (Beenhakker & Lago, 1983). In a situation where the benefits from cost savings for transport users accrue to the road users as a reduction in transport costs, the measured benefits can be considered to be an increase in *consumer surplus* (Lebo & Schelling, 2001a; Hine, 2014). Alternatively, if the transport cost reduction lowers the producers' input and output costs, and results in higher net income for producers, then the measured benefits are considered to be an increase in *producer surplus* (Lebo & Schelling, 2001a; Hine, 2014).

2.4.1.1. Consumer surplus approach versus producer surplus approach

In the consumer surplus approach, the economic evaluation is focused on the life-cycle cost of infrastructure, and road user costs and benefits (i.e. VOC, travel time and accidents) (Lebo & Schelling, 2001a; OECD, 2011). The consumer surplus approach is widely used in road investment (Hine, 2014) because it is relatively easy to implement and the benefits are easily identified. Models such as Highway Development and Management (HDM-4) and Roads Economic Decision (RED) use the consumer surplus approach to quantify benefits to consumers. The investment cost is determined by the initial construction costs and continuing maintenance costs throughout the life of the facility (e.g. road infrastructure) (Kerali, 2003;

NWS Government, 2016). The benefits are determined by the saving in road user costs over the economic life of the facility as a result of improvements to the facility (Kerali, 2003). The approach measures the benefits to the consumers of the road. Engineering design standards such as the number of lanes, the construction materials and quantity to be used, and the expected traffic volume provide the basis for economic appraisal (Kerali, 2003). The approach is well-suited to conditions where the normal traffic or expected growth in traffic is substantial (Carnemark *et al.*, 1976). In consumer surplus approach, the savings from the individual vehicles, multiplied by the number of vehicles, provides the total VOC savings, which is the value that is used as the benefit in consumer surplus approach (Thagesen, 1996; Robinson & Thagesen, 2004). Figure 2.4 illustrates the VOC savings in the consumer surplus approach. The VOC with and without road improvement are estimated, i.e. C_1-without road improvement and C_2-with road improvement. The difference between C_1 and C_2 provides the saving per vehicle, for each vehicle type. The total savings for normal traffic, i.e. traffic that would use the road regardless of the condition, are calculated by multiplying the saving per vehicle and the volume of normal traffic, Q_1. The total savings for generated traffic i.e. additional traffic occurring due to lower VOC brought by road improvement are calculated as half the savings per vehicle multiplied by the volume of generated traffic, i.e. Q_2 minus Q_1 (Thagesen, 1996; Robinson & Thagesen, 2004).



Source: Thagesen (1996)

Figure 2.4: VOC savings in consumer surplus approach

In rural areas, where the traffic volume is low, the consumer surplus approach is not suitable (Lebo & Schelling, 2001b). The VOC savings in low volume rural roads are not substantial enough to economically justify the undertaking of rural roads projects (Schutte, 2005). The expected benefits in such situations, however, are not reflected in the savings in road user costs, but rather in the accessibility provided by the road (World Bank, 2005). The benefits that occur through investment in a rural road with a low level of traffic can best be estimated with the producer surplus approach (Carnemark *et al.*, 1976; Thagesen, 1996; Lebo & Schelling, 2001b). Contrary to the consumer surplus approach, the producer surplus approach aims at assessing the "impact of transport investment on local agricultural productivity and output" (Lebo & Schelling, 2001b). As noted by Lebo & Schelling (2001b), the assessment is quite complex "where interventions are expected to open up new areas and adequate production data may be difficult to compile". Transport cost reductions, passed on to farmers, lead to increased farm-gate prices and lower agricultural input prices (Carnemark *et al.*, 1976; UNCHS-HABITAT, 1985). The outcome is increased producer income, which stimulates agricultural production and productivity in the area of influence (i.e. the area impacted by the implementation of the road project) (Carnemark *et al.*, 1976; UNCHS-HABITAT, 1985). Table 2.1 summarises the difference between consumer surplus approach and producer surplus approach.

Table 2.1: The difference between consumer surplus approach and producer surplus approach

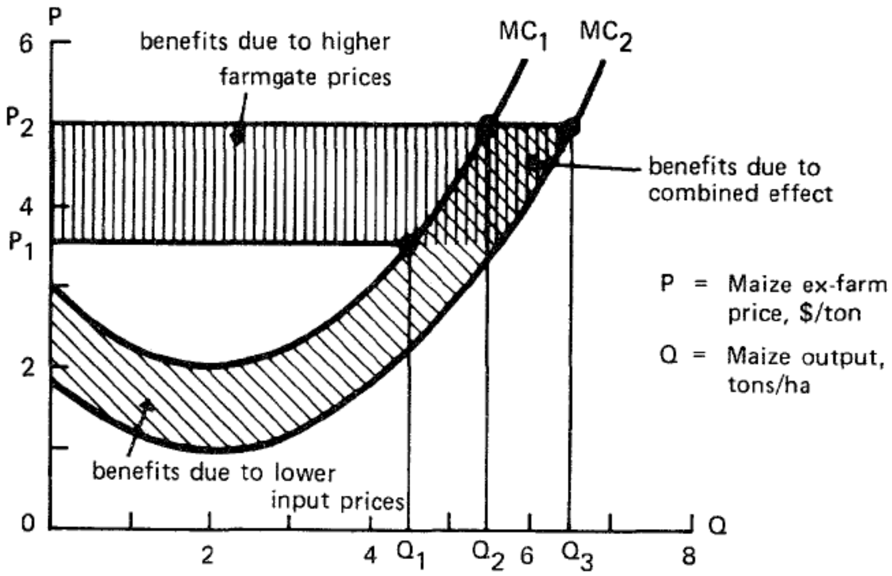
	Consumer surplus	**Producer surplus**
Traffic	Suitable for more than 50 vehicles per day	- Suitable for less than 50 vehicles per day - Cannot handle the benefits from non-agricultural traffic
Major benefits	VOC saving, time saving, accident saving (consumer benefits)	- Crop production increase and the net income increase for the producers (Producer benefits) - Benefits accrue to producers only if the transport cost reduction is passed on to farmers in the form of reduced transport price
Usage	Widely used	Not widely used
Assessment of benefits	Relatively easy to identify and quantify	Can be complex and data intensive
Remarks	- The producer surplus approach and consumer surplus approach will not lead to the same results, using the consumer surplus approach in economic evaluation of low-volume roads may underestimate the real road investment benefits - The two methods can be used together, however, to avoid double counting of the benefits, the measured VOC saving and time saving of agricultural traffic (i.e. vehicle used to transport agricultural products) should not be added to the measured agricultural benefits (i.e. crop production increase).	

Source: Author, based on Carnemark *et al.* (1976); Beenhakker and Lago (1983); Lebo and Schelling (2001a,b)

Figure 2.5 illustrates the producer surplus approach with an example of maize production in a given year. In the without-project, the quantity of crop (maize) produced was Q_1 and was sold at farm-gate price P_1. In the with-project scenario, several changes may arise (Carnemark *et al.*, 1976):

(i) A saving in transport costs is passed directly to the producer in terms of increased farm-gate prices from P_1 to P_2. Maize production increases from Q_1 to Q_2 along the marginal cost curve MC_1 (i.e. the curve which shows the increase in production cost associated with a unit increase in quantity produced).

(ii) A saving in transport costs results in a decrease in production costs (lower agricultural input prices) at any level of output, causing a shift from MC_1 to MC_2. At a new farm-gate price, P_2 (production) increases from Q_2 to Q_3.



Source: Carnemark *et al.* (1976), P = Price and Q = Quantity

Figure 2.5: Changes in maize production following road improvement

These changes are expected to occur simultaneously because road improvement is expected to lower the transport costs both to and from the farm. Production would increase from Q_1 to Q_3, and the total benefits at farm level associated with the road investment would be equal to the shaded area (i.e. incremental producer surplus) in Figure 2.5. Therefore, for each crop, the benefits should be calculated as for the case of maize given above, and for all crops the benefits should be summed year by year to obtain the total project benefits (Carnemark *et al.*, 1976).

The incremental producer surplus (i.e. agricultural benefits) is calculated as follows (Carnemark *et al.*, 1976):

(i) **With-project scenario (after project implementation):**

$Revenue_{\,after} = P_2 \times Q_3;$

$Variable\ cost_{\,after} = Area\ under\ MC_2\ curve;\ and$

Producer surplus $_{after}$ = Revenue $_{after}$ – Variable cost $_{after}$.

(ii) **Without-project scenario (before project implementation):**

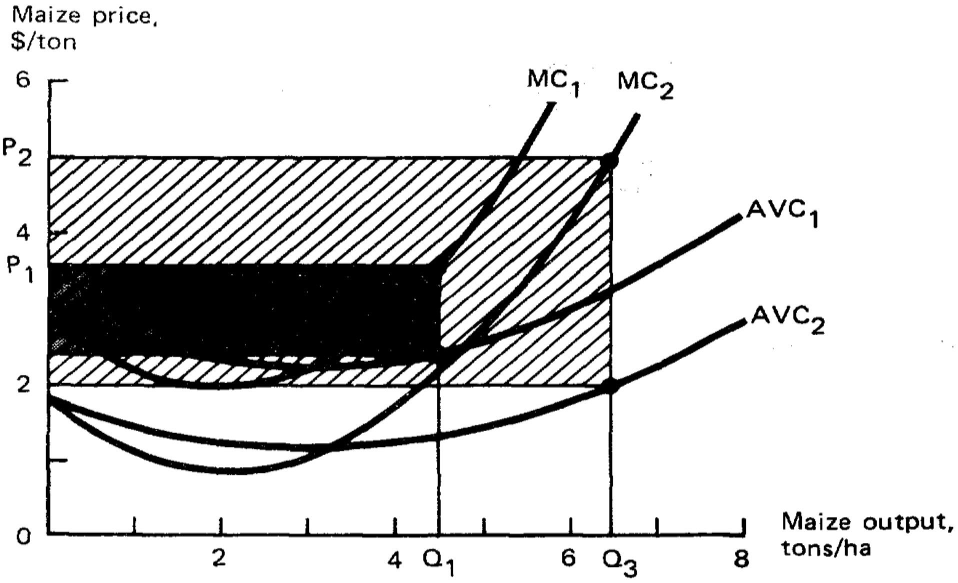
Revenue $_{before}$ = P_1 x Q_1;

Variable cost $_{before}$ = Area under MC_1 curve;

Producer surplus $_{before}$ = Revenue $_{before}$ – Variable cost $_{before}$; and

Incremental producer surplus = Producer surplus $_{after}$ – Producer surplus $_{before}$.

Furthermore, Carnemark *et al.* (1976) assert that to avoid defining the marginal cost curves (MC_1 and MC_2), the average variable production cost (*AVC*) (i.e. variable cost per unit of output produced), which is relatively easy to determine, is used in practice (see Figure 2.6). Instead of calculating the area under the *MC* curves, *AVC* is multiplied by the quantity produced to obtain the total variable production cost. Therefore, in the equations above, the area under MC_2 is replaced by AVC_2 x Q_3 and the area under MC_1 by AVC_1 x Q_1 (Carnemark *et al.*, 1976).



Source: Carnemark *et al.* (1976), P = Price and Q = Quantity

Figure 2.6: Changes in maize production following road improvement: use of average variable cost

2.4.1.2. Issues with consumer surplus and producer surplus approaches

The transport cost saving (which stimulate the agricultural production increase) considered in the producer surplus approach is only the saving from agricultural traffic (i.e. vehicles used to transport agricultural products). The producer surplus approach cannot handle the benefits from non-agricultural traffic (passengers and general traffic). To include the benefits from non-agricultural traffic in the analysis, the consumer surplus approach should be applied, and the benefits added to the agricultural benefits (Carnemark *et al.*, 1976; UNCHS-HABITAT, 1985). However, Lebo and Schelling (2001b) suggested that in such a situation, the VOC saving from agricultural traffic should not be included in the economic analysis, otherwise the benefits will be double-counted.

In a situation where the transport cost savings as a result of road improvement do not accrue to the farmers, either due to a non-competitive transport service or governmental control, there may be little developmental impact in the area of influence, as the producers will not be able to respond (i.e. increase production) to the incentive brought about by road investment (Carnemark *et al.*, 1976). In this situation, the benefits can be in the form of the timely delivery of the produce and reduced spoilage. However, the developmental impact will not be as big as it would be if the transport savings were passed on to the producers (Carnemark *et al.*, 1976).

Therefore, in order to assess how much of the transport cost saving is accrued to the famers, a clear relationship between transport cost and transport price needs to be established. This relationship can then be used to assess how much of the transport cost saving is passed on to the farmers (in form of reduced transport tariffs) after road improvement.

Transport by itself can bring about the expected economic growth only if all other necessary components for economic growth (such as access to material, labour and equipment) are available (Weisbrod & Weisbrod, 1997). In some situations, transport facility investments alone may not be enough to bring economic growth and development to the region, but in coordination with other non-transport related investments, it can bring a significant contribution to the economic growth and development (Weisbrod & Weisbrod, 1997). More specifically, rural road investment alone may not be enough to stimulate the development of the area of influence: other bottlenecks such as fertilisers, seeds, irrigation, extension services and credit may be of equal importance. In such situations, the feasibility of roads investment should be determined in conjunction with other complementary investments to address these bottlenecks (Carnemark *et al.*, 1976). Just as it is difficult to predict these developmental impacts beforehand, it is also challenging to isolate the after-effects of road improvement from the other investments (UNCHS-HABITAT, 1985). There must be a way of controlling for the effects of complementary investments, such as by treating their effects as benefits in the without-projects scenario.

Both the consumer surplus and producer surplus approaches are unsuitable for measuring socio-economic benefits such as an improvement in health and education in the area of road influence. These benefits can be substantial in rural areas (Kerali, 2003; Transport Research Laboratory, 2004). Approaches such as multi-criteria analysis (MCA) and the cost-effectiveness approach (CEA), together with extended cost-benefit analysis (CBA) methods, can be used in the rural road appraisal process (Lebo & Schelling, 2001a). These methods are used to estimate, to some extent, the social benefits of rural road investment.

2.4.2. Results from previous studies

Looking at the effects of transport price on crop prices, previous studies have revealed that the percentage of transport charges embedded in agricultural product prices varies with the type of commodity, the efficiency of the transport sector, the related marketing sector, and trip distance. A study conducted in Ghana by Hine, Riverson and Kwakye (1983) (as cited in Hine & Ellis, 2001) showed that transport charges accounted for 3-5 percent of the final market wholesale price for maize, yam and plantain over a distance of 120 to 200 km. Another study carried by the Ministry of Transport in Ghana showed that transport charges accounted for 11 percent of the maize price over a distance of 420 km, and 25 percent of the tomato price over a distance of 360 km (Ellis & Hine, 1998). In Zaire, Rizet and Tshimanga (1988) (as cited in Hine and Ellis, 2001) showed that transport charges account for 15 to 20 percent of the total difference in the price of cassava between Kinshasa and the village markets 260 to 600 km away. Ahmed and Rustagi (1987) found that African farmers received only 30 to 60 percent of the final market price of their produce, compared to 75 to 90 percent received by Asian farmers.

Previous studies have also shown that improved roads and accessibility improvement impact the agricultural sector positively, together with other social and economic activities of the rural population. Table 2.2 provides a summary of the results from some previous studies and rural road projects.

Table 2.2: Summary results of some previous studies and rural road projects

Study	Reference	Results obtained
A case study example in the World Bank working paper no 241, titled “The economic analysis of rural road projects”, 1979	Carnemark *et al.* (1976)	35 km road improvement from earth to all-weather gravel road with an area of influence considered to be 10 km on each side of the road. The maize production, on average, increased by about 133% (from 7 719 tonnes to 18 050 tonnes) with major changes occurring from year five after road improvement. Farm-gate price increased by $2.0 per tonne.

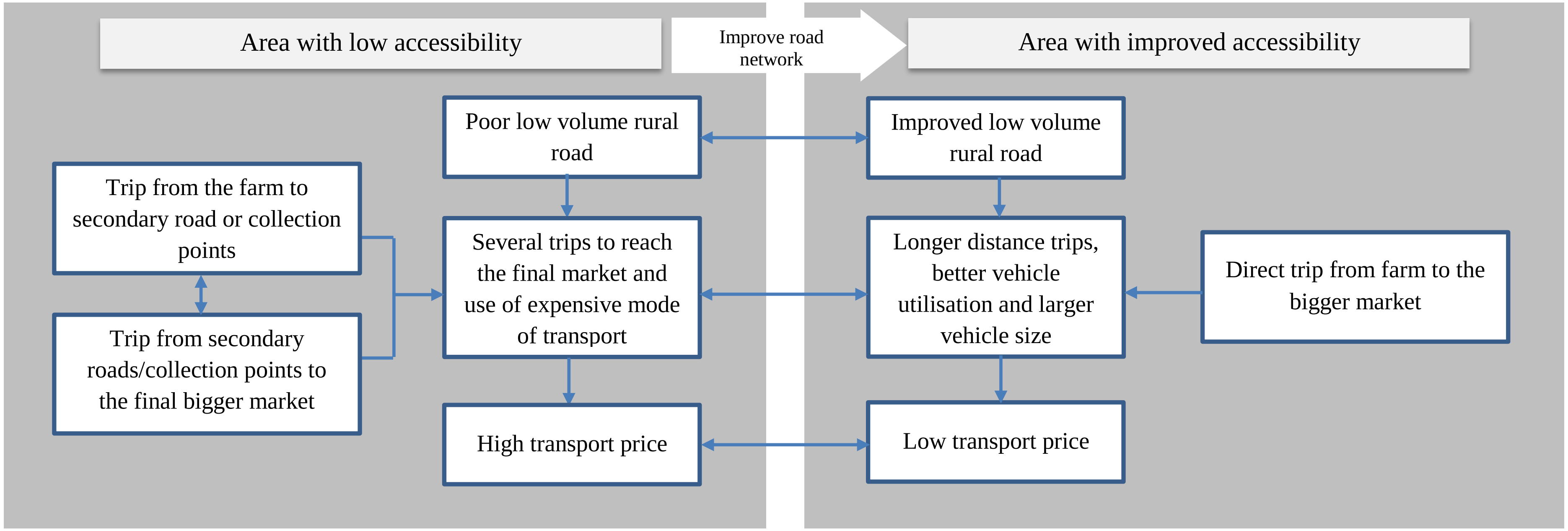
Bhutan rural access project: Economic Analysis, 1999	Lebo & Schelling (2001a)	The NPV at a 12% discount rate showed transport benefits (non-agricultural traffic) equal to \$3 476, net agricultural benefits equal to \$56, net education benefits equal to \$1 699 and net health benefits equal to \$113. Road investment and maintenance cost equal to \$3 817. The project's economic rate of return equalled 15.1%.
Bangladesh rural infrastructure impact study, 1999 and Bangladesh rural infrastructure strategy study, 1996.	Lebo & Schelling (2001a)	The transport price on a smooth asphalt road was \$0.20 while on rough earth road it was \$0.50 (more than double). A change in the means of transport from head porterage to both NMT and motor vehicles. Buses also started to appear. Traffic growth exceeded 100% in the first year after project completion.
Rural roads component of economic restructuring project: India - Andhra Pradesh, 2000	Lebo & Schelling (2001a)	In an accessible area (i.e. an area connected to all-weather road) household income per year was \$700. In an unconnected area household income per year was \$275.
Project appraisal document on a proposed credit to Bhutan for a rural access project, 1999	Lebo & Schelling (2001a)	In an accessible area (up to 0.5 days walk to the nearest road) school children enrolment was 73% for boys and 42% for girls. In an inaccessible area (1-3 days walk to nearest road) school children enrolment was 64% for boys and 22% for girls.
Market access improvement in Zambia (SHEMP), 2007	Andreski (2007)	The result achieved by SHEMP (Smallholder Enterprise Development and Marketing Programme – access road component) programme to improve the market access roads in Zambia showed that between the year 2002 and 2007, the maize price went up from Zambian kwacha 20 000 to Zambian kwacha 30 000. (Exchange rate, 2017:1USD = 9865 Zambian Kwacha)
Crop production and road connectivity in sub-Saharan Africa: A Spatial Analysis, 2010	Dorosh *et al.* (2010)	A 1% reduction in travel time to the nearest city would increase crop production by between 1.6 and 4.8%, depending on the population of the nearest city and the type of technology employed in crop production.
Developmental impact of rural of rural infrastructure in Bangladesh	(Ahmed & Hossain, 1990)	In villages with better infrastructure, the price of fertiliser was 14% lower while the price of rice was 5.7% higher. The use of fertiliser was higher by 92%, use of improved seeds was higher by 71% and irrigation of farmland was 105% more. The development of infrastructure resulted in an efficient use of technology which was estimated to increase the agricultural production by 32%.
Agricultural production and transport infrastructure in East Africa	(Limi *et al.*, 2015)	The study found that 10% reduction in transport price and waiting time cost could increase crop production by more than 10%. They also found that distance to the nearest road has a relatively smaller impact, 10% reduction in distance to the nearest road could increase crop production by 0.5%.
The poverty impact of rural roads: Evidence from Bangladesh	(Khandker *et al.*, 2009)	The study found that providing better transport infrastructure resulted in 2% increase in crop prices, 22% increase in crops production and reduction in fertiliser price. School children enrolment increased by 22% and 29% for boys and girls respectively.
Kingdom of Morocco impact evaluation report: socioeconomic influence of rural roads	(World Bank, 1996)	The study was conducted in the Kingdom of Morocco where rural gravel roads or un-engineered tracks were improved to paved standard. The assessment after road improvement, (compared to before) revealed that yield of main crops increased by 31%, use of fertiliser was doubled and contact with extension centre increased from less than once per year to more than four times per year. The net agricultural value added per unit area cultivated increased by up to 46% in project areas. Traffic volume also increased significantly after road improvement.

2.5. Conceptual framework

Road investments can be well-motivated in high-traffic areas, where the benefits from road user savings are evident (Carnemark *et al.*, 1976; Schutte, 2005; Njenga *et al.*, 2014). However, literature shows that there is potential for wider benefits that may emanate from improving the road infrastructure and accessibility in low-traffic areas (Carnemark *et al.*, 1976; Ahmed & Hossain, 1990; Lebo & Schelling, 2001a; Dorosh *et al.*, 2010; Kiprono & Matsumoto, 2014; Limi *et al.*, 2015). In rural areas with agricultural potential, it is expected that an improvement of the low-volume rural roads will unlock this potential, which may lead to an expansion in agricultural production and productivity (Banjo *et al.*, 2012). The challenge is how these wider agricultural benefits are evaluated ex-ante and included in the road economic evaluation (Hine, 2014). The expected change in transport price and trip distance, to some extent, may explain the expected wider agricultural benefits following the low-volume rural road improvement.

As described in Figure 2.7, the improvement of low-volume rural road infrastructure may result in relatively long trip distances and increased vehicle utilisation, together with the use of relatively larger sizes of vehicle (see Headicar, 2009; Lançon *et al.*, 2014). The improved low-volume rural road may allow vehicles from urban centres (bigger markets) to reach the more remote areas (Lançon *et al.*, 2014). As discussed in Section 2.3.2 better roads lead to lower vehicle operating costs through higher operating speed, less wear and tear, longer service life and better vehicle utilisation (Bennett & Greenwood, 2001). The reduction in vehicle operating costs together with the changes in trip patterns and vehicle types will lead to a significant reduction in the transport price (Hine *et al.*, 1997; Hine, 2014).

Figure 2.8 shows that improved rural accessibility and a reduction in transport prices may enable improved access to the market and access to agricultural inputs (see Dorosh *et al.*, 2010; Airey, 2014; Hine, 2014; Kiprono & Matsumoto, 2014; Limi *et al.*, 2015; Stifel *et al.*, 2016). It may also lower agricultural production costs and increase agricultural product prices (see Carnemark *et al.*, 1976; Ahmed & Hossain, 1990; Hine & Ellis, 2001; Mkenda & Campenhout, 2011; Banjo *et al.*, 2012; Hine, 2014; Kiprono & Matsumoto, 2014; Limi *et al.*, 2016). A reliable supply of inputs, easy access to extension services, and reduced agricultural input prices lead to lower agricultural production costs and higher agricultural yields (Carnemark *et al.*, 1976; Ahmed & Hossain, 1990; Mkenda & Campenhout, 2011; Banjo *et al.*, 2012; Hine, 2014; Kiprono & Matsumoto, 2014; Njenga *et al.*, 2014; Limi *et al.*, 2015). On the other hand, reliable agricultural output delivery, a reduction in agricultural output distribution costs, and reduced losses due to spoilage lead to higher farm-prices for the agricultural outputs (Carnemark *et al.*, 1976; World Bank, 1996, 2013b; Hine & Ellis, 2001; Mkenda & Campenhout, 2011; Banjo *et al.*, 2012; Airey, 2014; Hine, 2014; Njenga *et al.*, 2014). Lower production costs and higher output prices result in higher producer net profit and stimulate more investment in the agricultural sector (Dorward & Chirwa, 2011; Banjo *et al.*, 2012). The ultimate result is increased production in the agricultural sector, which leads to more demand for transport services. This increased demand for transport services, in turn, stimulates more investment in transport infrastructure and services (Rodrigue, 2006; Rodrigue & Notteboom, 2017).



Source: Author.

Figure 2.7: Reduction in transport price as a result of improved road infrastructure and accessibility.

Note: Accessibility referred to the ease of reaching goods, services and destinations. In transport, variables such as transport costs and prices, distances and travel time are generally used to measure accessibility (Scheurer & Curtis, 2007; Litman, 2016). In this case reduced transport price and a more direct trip are regarded as indicators of improved accessibility.

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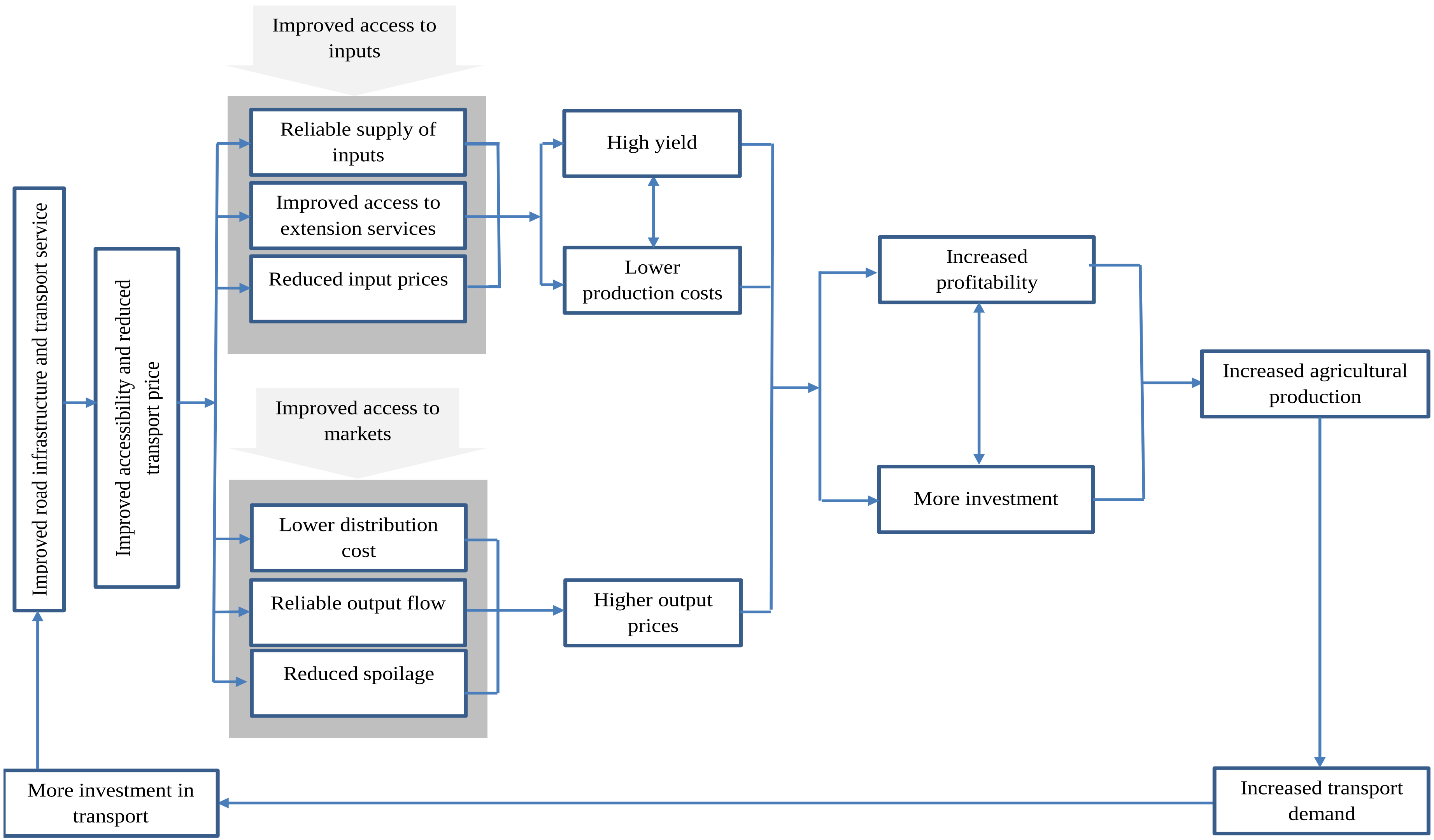


Source: Author

Figure 2.8: Increased agricultural production as a result of reduction in transport price and improved accessibility

2.6. Conclusion

The existing literature has revealed that road conditions significantly affect transport costs. Transport costs, competition and regulation in the transport market, trip distance and cargo volumes are factors that affect the transport price. The relationship between transport cost and road conditions is well-documented. However, little is known about the relationship between transport price, transport cost and road conditions.

A reduction in transport cost following a road improvement may lead to higher farm-gate prices and low agricultural input prices, which may stimulate an increase in agricultural production. The effect is only realised if such a reduction in transport cost is passed on to farmers as reduced transport tariffs for delivering agricultural products to the market, as well as transporting agricultural inputs to the rural areas. The literature revealed that in some areas transport cost reduction is reflected in transport tariffs, however, in oligopolistic and monopolistic transport markets, transport cost reduction has often little relationship with the reduction in transport tariffs. The literature provides the theory on how the improved road infrastructure and transport service may lead to agricultural production increase, however, the extent of agricultural development and quantification of the crop production increase is not well documented.

Several studies have reported that there is potential for an increase in agricultural production as well as an improvement of other social and economic activities in rural areas following a road improvement. However, there are few examples showing an agricultural production increase in a rural area that can be credited to a road improvement. This is most likely due to the complexity of such an analysis, and deficiency of evaluation tools to undertake it as well as limited data.

Chapter 3 : Study Area and Methodology

This chapter provides details on how the study area was selected as well as the description of the study area. It also provides the methodology for data collection and analyses employed in this research.

3.1. Study area

Information from the National Sample Census of Agriculture of the year 2007/2008 (Tanzania National Bureau of Statistics, 2012a) was used as the basis for the selection of the study area. The census was conducted by the Tanzania National Bureau of Statistics (NBS) in collaboration with several other ministries with the aim of collecting information about crop production, crop marketing, crop storage, livestock production and fish farming (Tanzania National Bureau of Statistics, 2012a). The farmers' responses during the census were used as selection criteria. During the census, the farmers reported different crop marketing problems. These problems hinder the farmers from selling their crops and indirectly affect crop production. Two of the reported problems were used as criteria for selecting the study area. The first criterion was the percentage of agricultural households which reported *transport price too high*. The second criterion was the percentage of agricultural households which reported *lack of transport*. The average of the reported percentage was calculated for all (21 regions of the Tanzania mainland) (see Table 3.1) and denoted as the *average*. The Mara region showed the highest average percentage (6.50%), followed by the Morogoro region (5.70%). Considering the financial constraints, selecting a study area too far from Dar es Salaam would have had significant cost implications to the researcher during the data collection phase. Mara is 1 370 km from Dar es Salaam, while Morogoro is 192 km away. Morogoro was therefore chosen as the study area.

Morogoro, Figure 3.1, is the second largest region in Tanzania and occupies a total area of 73 039 square kilometres, with 2 240 square kilometres of water bodies. The region occupies approximately 7.7 percent of the total area of Tanzania mainland and the region's topography comprises mountainous, flat and valley areas. It has one hundred forty three rivers originating from the mountainous areas. The major rivers include the Kilombero, Ruaha, Ruvu, Wami, Ngerengere, Mkindo and Mkondoa. The region's largest mountains are the Uruguru, Ukaguru, Nguru, Udizungwa and the Mahenge hills.

Table 3.1: Study area selection matrix

Sn	Region	Percentage of agricultural households reported marketing problems		
		Transport price too high (%)	Lack of transport (%)	Average (%)
1	Dar es Salaam	8.30	3.00	5.65
2	**Morogoro**	**6.93**	**4.47**	**5.70**
3	Dodoma	5.00	2.00	3.50
4	Pwani	2.20	0.90	1.55
5	Iringa	5.00	1.40	3.20
6	Tanga	2.00	3.00	2.50
7	Arusha	2.60	4.30	3.45
8	Singida	3.00	4.00	3.50
9	**Mara**	**8.00**	**5.00**	**6.50**
10	Shinyanga	5.00	4.00	4.50
11	Rukwa	6.14	3.30	4.72
12	Mtwara	2.07	1.84	1.96
13	Manyara	3.00	3.00	3.00
14	Kilimanjaro	2.30	1.00	1.65
15	Tabora	3.30	2.20	2.75
16	Mbeya	5.30	*	2.65
17	Ruvuma	5.00	1.00	3.00
18	Lindi	*	1.00	0.50
19	Kagera	4.50	4.00	4.25
20	Kigoma	2.30	3.60	2.95
21	Mwanza	2.14	1.77	1.96

Source: Tanzania National Bureau of Statistics (2012a) and author's calculations
* Missing data

Morogoro experiences tropical wet and dry weather, with an average monthly temperature of 18^{0}C in the highland areas and 30^{0}C in the lowland and flat areas. The region also experiences two distinct rainy seasons per year: the long rainy season from February to May, and the short rainy season from October to December. The total annual precipitation received in the region ranges between 600 and 1 200 mm. Highland areas experience higher rainfall in comparison to lowland and flat areas.

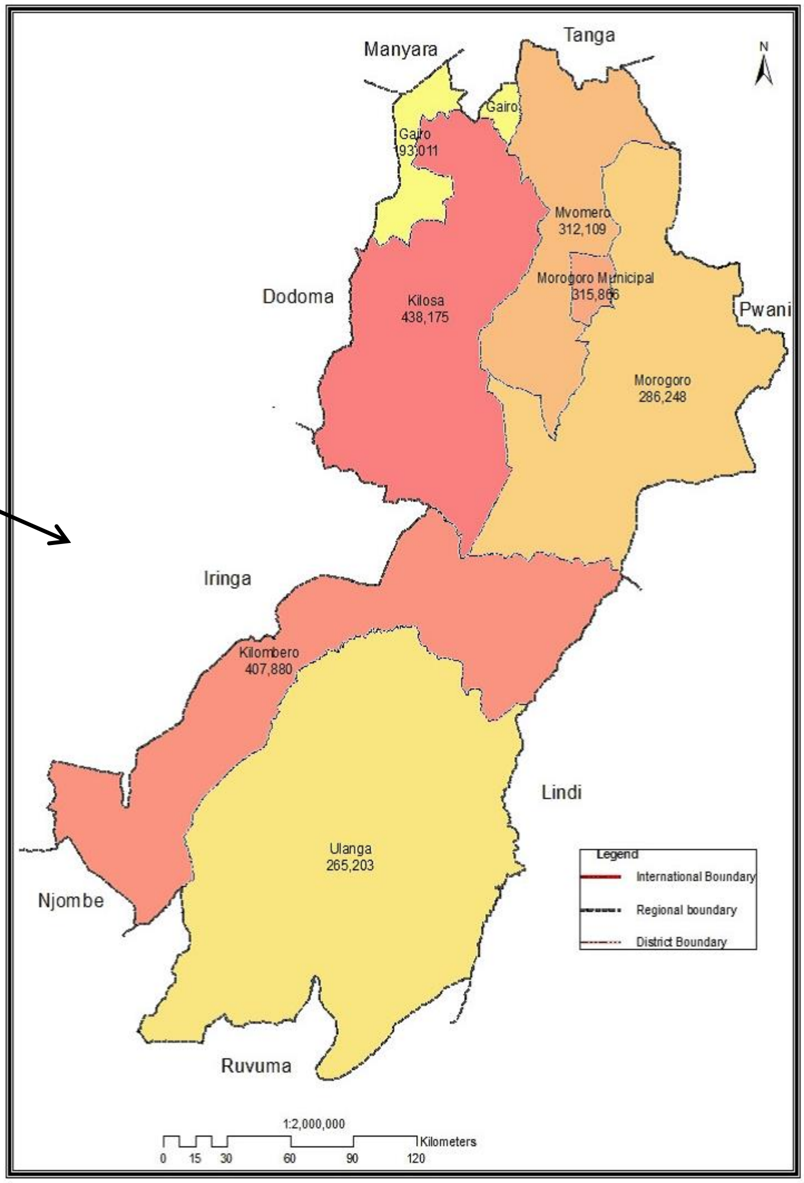
Administratively, Morogoro is divided into six district councils and one municipal council (Figure 3.1). The district councils include Morogoro, Mvomero, Kilosa, Kilombero, Ulanga and Gairo (Table 3.2). Each district is divided into divisions and each division into wards. Wards are further divided into villages and hamlets. The Morogoro municipal council is divided into divisions, wards and streets. Most of the region is characterised as rural, except for the Morogoro municipal council.

Table 3.2: Morogoro region administrative areas

Sn	District	Divisions	Wards	Villages	Streets/hamlets
1	Morogoro Municipal	1	29	-	272
2	Morogoro	6	29	146	716
3	Mvomero	4	23	115	631
4	Kilosa	7	35	118	762
5	Kilombero	5	23	97	412
6	Ulanga	7	31	91	378
7	Gairo	2	11	36	278

Source: Morogoro Regional Commissioner's Office, (2013)

Map of Tanzania showing regions



Source: Collected from Morogoro Regional Commissioner's Office, 2014

Figure 3.1: Map of Morogoro showing districts and population distribution

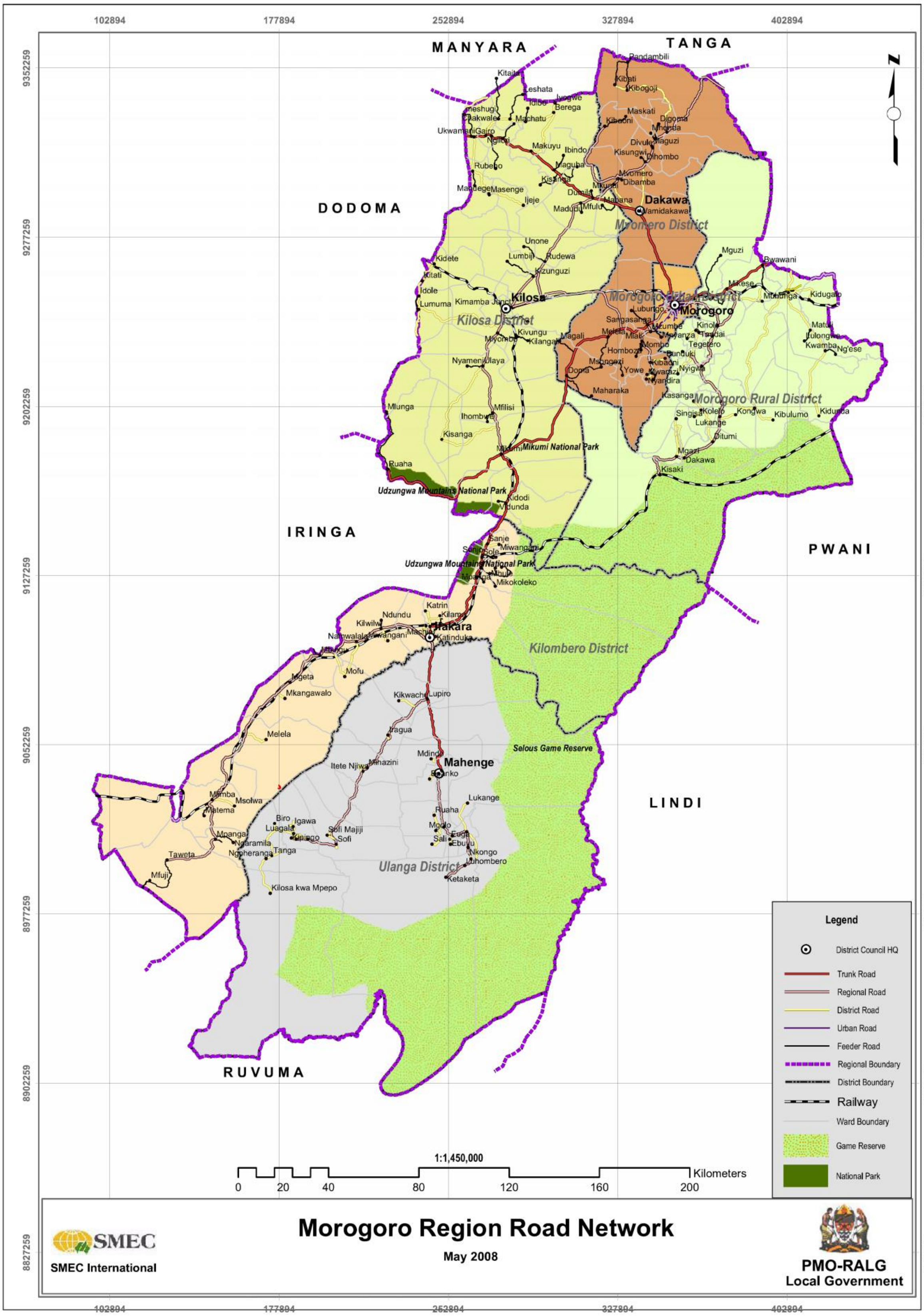
The region has a total arable land area of 2 226 396 hectares, of which only 654 801 hectares are utilised (about 29 percent) for crop cultivation. The region has several sources of water, with a total potential area for irrigation of 1 510 874 hectares, however, only 28 919 hectares (about 2 percent) of the potential area is irrigated. The economy of the region depends mainly on agricultural activities, and the sector contributes about 80 percent of the region's income (Morogoro Regional Commissioner's Office, 2013).

The road network of Morogoro comprises a total of 6 512 km, out of which 1 894 km are trunk and regional roads and 4 618 km are collector, feeder and urban roads (Table 3.3 and Figure 3.2). Roughly 29 percent of trunk and regional roads are paved, and only about one percent of collector, feeder and urban roads are paved. Looking at the spatial road density, there is only 8.3 km of paved road per 1 000 sq.km and total road density of 8.9 km per 100 sq. km.

Table 3.3: Morogoro region road network

Road class	**Paved (km)**	**%**	**Unpaved (km)**	**%**	**Total (km)**
Trunk and Regional roads	544	28.7	1 350.1	71.3	1 894.1
Collector/Feeder/Urban	59.9	1	4 557.9	99	4 617.8
Total	**603.9**		**5 908**		**6 511. 9**

Source: Author computation, data collected from TANROADS-Regional Office and Morogoro Regional Commissioner's Office, 2014.



Source: Collected from Morogoro Regional Commissioner's Office, 2014

Figure 3.2 : Map of Morogoro region showing the road network

3.2. Data collection methods

This section describes the methods used to collect the required data. The process involved desk and field work. During the field work, interviews were conducted with different stakeholders to gather the required information.

3.2.1. Interview survey

Dar es Salaam serves as the main market for the crops from Morogoro and other regions within Tanzania. A survey was done in Dar es Salaam and Morogoro between the months of June and September in 2014 to obtain information about freight charges, crop production and prices, and the road network. During the survey, three types of questionnaires were administered (see sample questionnaires in Table A.1.1 - A1.3 in Appendix 1):

(i) a transporter's questionnaire;
(ii) a road authority official's questionnaire; and
(iii) an agricultural official's questionnaire.

Primary data were collected from the transporters' interviews. The survey adapted the approach of Teravaninthorn & Raballand (2009), where transporters were interviewed to obtain the freight charges and cargo weights of agricultural products. Information about trip origins and destinations was also recorded. In Dar es Salaam, interviews were conducted at the marketplace during the unloading of the agricultural products. Agricultural products are transported from different places of the country, however, only transport operators involved in transporting agricultural products from Morogoro were selected for interviewing. The survey was done at six different markets in Dar es Salaam. Roughly, one interview was conducted per day, and some days no transport operator from Morogoro was encountered. In Morogoro, interviews were conducted at parking areas and loading points in three different districts and Morogoro Municipality. However, there were no designated parking/loading areas for these transport operators. Therefore, the surveyor asked local people where to meet transport operators. Wherever the driver and/or his assistant(s) were encountered (parking or loading); the interview was conducted in face-to-face sessions and the questionnaire was completed on the day of the interview. A total of 15 truck operators (medium trucks) were interviewed and information for 51 different trips was obtained. The obtained information for 51 different trips covers the wide range of agricultural trips in Morogoro region.

Vehicle size do exhibit some economy of scale (Pienaar, 2013). Furthermore, trip distances and pavement surface type impact differently on the different truck types, resulting in different freight charges. To eliminate the impact of vehicle type on freight charges, a default truck consisting of two axles and six tyres, with a loading capacity of 10 tonnes (medium truck), was specified to determine the freight charges. The medium truck is the most commonly used vehicle for transporting agricultural products within the study area.

Secondary data were collected during the interviews with the road authority officials and agricultural officials. Road authority officials were interviewed to obtain information on the road network, including road length, surface type, the condition of the road, traffic data and to obtain maps. Road construction and maintenance cost, vehicle characteristics and vehicle unit economic cost were also obtained from the road authorities officials.

Agricultural officials were interviewed to obtain information about the agricultural sector such as commonly cultivated crops, crop prices, crop yields and the area of cultivated land.

In the case of road authority and agricultural officials, interviews were conducted in six different district councils of the Morogoro region, Morogoro Municipality, the Tanzania National Roads Agency (TANROADS) Morogoro regional office, and the Morogoro regional commissioner's office. Data from these institutions represent the information for the whole Morogoro region. After several visits to these institutions, permission to conduct the interviews was granted. The officer-in-charge was interviewed, with the questionnaire serving as a guideline for the required information. Due to the nature of the required information, the questionnaire could not be completed on the day of the interview. Most of the required information was to be retrieved from the databases and official documents. Therefore, in addition to the questionnaire, these officials provided documents such as government reports and electronic copies of the databases that contained the required information. These data were collected at a later stage.

In total, 32 interviews were conducted, 15 with transporters, 8 with agricultural officials and 9 with road authorities officials (Table 3.4).

Table 3.4: Matrix showing number of interviews conducted

	Transporters (Truck operators)	**Agricultural Officials**	**Road Authorities officials**	**Total**
Dar es Salaam city	9			**9**
Kilosa district	2	1	1	**4**
Gairo district	1	1	1	**3**
Kilombero district	2	1	1	**4**
Ulanga district		1	1	**2**

Morogoro rural district		1	1	**2**
Movomero district		1	1	**2**
Morogoro Municipality	1	1	1	**3**
Morogoro regional commissioner's office		1	1	**2**
TANROADS–regional office			1	**1**
Total	**15**	**8**	**9**	**32**

3.2.2. National Panel Survey (NPS)

This research also used secondary data from the 2012/13 Tanzania National Panel Survey (NPS) to analyse the impact of the level of rural accessibility on agricultural production and productivity. The survey data was obtained from the World Bank database and is part of the Living Standards Measurement Study – Integrated Surveys on Agriculture (LSMS-ISA)[10]. LSMS-ISA is an ongoing research initiative within the development research group of the World Bank, with the goal of promoting and improving the collection of household-level data in developing countries (Tanzania National Bureau of Statistics, 2014d).

The data from the 2012 population and housing census indicated a total of 9 276 997 households in Tanzania. Out of this, 66.7 percent are in rural areas and 33.3 percent in urban areas (Tanzania National Bureau of Statistics, 2015a). During the 2012/13 NPS, a total of 5 015 households were used as the representative sample of the population. Field work for the 2012/13 NPS was conducted between October 2012 and November 2013 (Tanzania National Bureau of Statistics, 2014d).

This research used the third round of the panel survey (2012/13) conducted in the country to collect different household information, including agricultural production, non-farming income-generating activities, consumption expenditure, and other socio-economic characteristics. The first round of NPS was undertaken in 2008/09 and the second round in 2010/11.

The NPS included four types of instruments for data collection: (i) a household questionnaire; (ii) an agricultural questionnaire; (iii) a livestock/fisheries questionnaire; and (iv) a community questionnaire[11]. Each questionnaire was divided into different sections. For this research, most of the required information (such as household agricultural production, sales,

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[10] The Living Standards Measurement Study – Integrated Surveys on Agriculture (LSMS-ISA) is a project which supports governments in seven sub-Saharan African countries to generate nationally representative household panel data, with a strong focus on agriculture and rural development.

[11] The full questionnaires can be obtained at *www.worldbank.org/lsms*

types of crop cultivated and transportation charges) was obtained from the agricultural questionnaire. In the agricultural questionnaire, each section was divided into two parts, denoted as A and B. Part A provides the information for the long rainy season, and part B for the short rainy season. In this research, only the information for the long rainy season was used in the analysis, as there were too little data on the short rainy season.

3.3. Data analysis methods

The research aim was to establish the relationship between agricultural production, transport price and transport cost. This established relationship was used to develop a rural road appraisal framework that accounts for wider agricultural benefits. To achieve the research aim, the research addressed four specific objectives, which were divided into two groups:

With regard to transport prices, transport costs, road condition and trip distance:

(i) to determine the transport costs and transport prices of agricultural products, and measure the impact of road condition and trip distance on these costs and prices; and

(ii) to establish the relationship between transport price, transport cost and trip distance, which will allow for the estimation of the change in transport price due to the change in transport cost and trip distance following the road improvements.

With regard to rural/market accessibility and agricultural production:

(iii) to establish the relationship between transport price and agricultural production; and

(iv) to establish the potential increase in agricultural production (the wider agricultural benefits) following the improvements of rural/market accessibility and reduced transport prices.

The following sections describe the analysis methods used to address these objectives.

3.3.1. Transport price and transport cost, trip distance and road condition

The information gathered during the interview survey was used to calculate the transport prices and costs of the transporters. The transport price for each of the 51 trips obtained during the interviews, expressed per tonne-kilometre, was calculated using Equation 3.1:

$$Transport\ price\ (per\ ton - km)\ = freight\ charge\ per\ trip\ /(trip\ distance\ \times cargo\ weight), \quad (3.1)$$

where:

- *transport price* (in Tanzanian shilling per ton-kilometre (Tsh/ton-km)): The price that the transport provider is charging per tonne carried for every kilometre travelled*;*

- *freight charge per trip* (in Tanzanian shilling (Tsh)): The price that the transport provider is charging per trip for the specific commodity*;*
- *cargo weight* (in tonnes): The load transported*;* and
- *Trip distance* (in kilometre (km)): The distance from the start to the end of the journey.

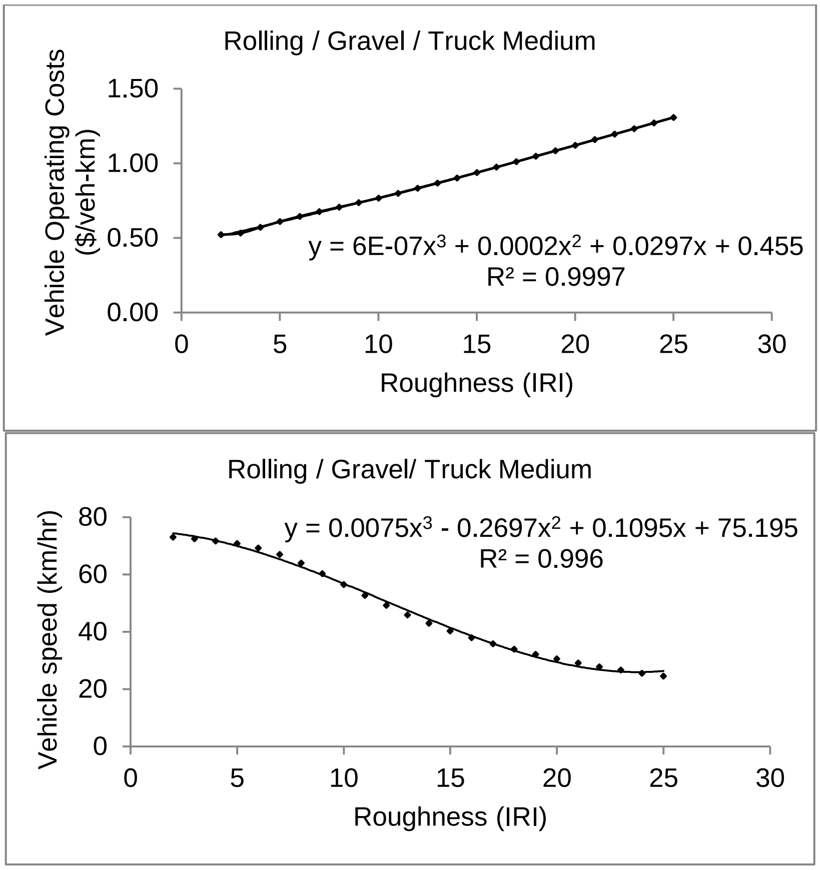
Freight charges and cargo weights were obtained from the information gathered from the transporters' interviews. Trip distances, depending on the origin and destination of the journey, were obtained from the information gathered from the road authority officials.

Road surface type, paved or unpaved, used as a measure of the condition of the road, was used to establish the relationship with transport price. Using the information gathered from the road authority officials, the length of paved and unpaved sections was determined for each trip, and the percentage of the trip distance that the truck traverses on paved sections of the road was specified and used to classify paved and unpaved trips. For each trip, this percentage was recorded as the percentage-paved. To determine the impact of the road surface type on transport price, a scatter plot of transport price versus percentage-paved was plotted and a trendline fitted.

To establish the impact of trip distance on transport price, the trip distance regardless of the surface type was determined. The calculated transport price for each trip was plotted against the trip distance and a trendline was fitted.

The combined effect of road condition and trip distance on transport price was finally analysed. In this case, however, the surface type was not used as a measure of road condition as the surface type alone does not provide enough explanation of the road condition. Surface type does not provide details on surface roughness and other pavement and traffic characteristics. The vehicle operating cost (VOC) was used instead, as there is a well-established relationship between VOC and road condition (Hide *et al.*, 1975; Watanatada *et al.*, 1987; Bennett & Greenwood, 2001; Archondo-Callao, 2004). VOC comprises of fixed and variable costs, and the condition of the road, among other factors, affects these costs. As discussed in Section 2.3.2, poor road conditions limit vehicle utilisation through low vehicle speed. Vehicle capital cost and other fixed costs depend on the level of vehicle utilisation. With low vehicle utilisation, these costs, measured per-kilometre, will be high. Road conditions also affect fuel consumption through vehicle speed. Poor-quality roads increase the need for vehicle parts replacement, as well as maintenance labour.

Road economic evaluation models such as Highway Development and Management (HDM-4) and Roads Economic Decision (RED) are capable of modelling the VOC, given the road condition together with other pavement and traffic characteristics. Figure 3.3, derived from HDM-4 VOC values, provides a graphical representation of the effect of road roughness, measured by IRI, on vehicle operating cost and speed. VOC increases as road roughness increases, while the vehicle speed decreases with an increase in road roughness.



Source: RED - HDM-4 VOC, Calibrated using Tanzania data

Figure 3.3: Effect of road roughness on VOC and vehicle speed

Vehicle operating costs for each of the 51 trips were calculated using HDM-4. Data from the road authority officials, such as road roughness, road length, traffic volumes, vehicle characteristics and economic unit costs, were used as the input data for the HDM-4 model. As discussed in Section 1.7, VOC form the biggest portion of transport cost. However, in a model such as HDM-4 and RED there is no difference between VOC and transport cost (Bennett & Greenwood, 2001). Therefore, the obtained/modelled VOC (or transport costs) were used to establish the relationship between transport price, trip distance and transport cost. Ordinary least squares (OLS) regression was used to establish this relationship, with transport price as dependent variable and transport cost and trip distance as independent variables.

3.3.2. Rural/market accessibility and agricultural production

The NPS data was used to assess the impact of rural/market accessibility on crop production. Accessibility can be defined as the ease of reaching goods, services and destinations. In transport, variables such as transport costs and prices, distances and travel time are generally used to measure accessibility (Scheurer & Curtis, 2007; Litman, 2016). The transport prices farmers reported paying when transporting their crop, the distance from the farm to the road, and the distance to the markets were used to measure the level of rural/market accessibility. Crop yield, defined as the quantity of harvested crops per unit area of the land cultivated, was used to measure crop production.

Several descriptive statistics were performed, and ordinary least squares (OLS) regression was used to establish the empirical relationship between transport price, distance to the market and crop yield. The established empirical model follows a similar approach as that employed by Limi *et al.*(2015), where agricultural production was linked to agricultural inputs and transport accessibility. In this research other variables which affect crop yield were also included in the model. The list below presents a brief description of the independent variables used in the analysis:

(i) **Agricultural inputs** such as inorganic fertiliser and improved seeds are not manufactured in the rural areas, and have to be transported from the area of production to the rural areas. The transport service and associated transport cost during the transportation of the agricultural inputs may, in one way or another, affect the usage of the inputs and eventually the crop yield.

(ii) **Crop market prices** act as an incentive/disincentive to the farmers in relation to the crop yield. Higher crop prices may motivate the farmer to produce more and vice versa. The cost associated with transporting the crops to the market will impact the market price.

(iii) The **distance from the farm to the road** was used to measure the influence of road infrastructure availability on crop yield.

(iv) The **distance the crops were transported to the market for selling** was used to measure the influence of the distance travelled by farmers to sell their crops on crop yield.

(v) The **distance from the farm to the local market** was used to measure the influence of local market vicinity on crop yield.

(vi) **Transport price** was included in the variable list in order to measure its direct effect on crop yield.

Equation 3.2 presents the empirical model used in the analysis:

Crop yield = f(Quantity of input per unit land, market crop price, transport price, distance from the farm to the road, distance from the farm to the local market, distance crop transported to the market for selling). (3.2)

Different crops have a range of expected harvest per unit of land cultivated. In order to control for the effect of the different crop types, dummy variables for different crops were created.

One of the assumptions of the classical linear regression model is that the model is linear in the parameters. Logarithmic transformation of the variables is one way to convert a non-linear model into a linear (in the parameter) model. The variables are log-transformed if they are not linear, i.e. the dependent variable is not a linear function of independent variables or in other words, the rate of change of dependent variable (Y) with respect to independent variable (X) i.e. slope, is not constant (Gujarati & Porter, 2010). In the model, therefore, all the variables were log-transformed, except the dummy variables. The conversion satisfies the condition that the model is linear in parameters and reduces the skewness and the data is approximately normally distributed. The final empirical model is presented in Equation 3.3.

$$ln(Y) = \beta_1 + \beta_2 ln(X_2) + \cdots \beta_n \, ln(X_n) + \alpha_1 D_1 + \cdots \alpha_k D_k + \mu, \qquad (3.3)$$

where:

- Y = Crop yield;
- $X_{2}, X_{3}, \ldots, X_n$ = Factors that may affect crop yield;
- $\beta_{2}, \beta_{3}, \ldots, \beta_n$ = Coefficients;
- $\alpha_{1}, \alpha_{2}, \ldots, \alpha_k$ = Dummy variables coefficients;
- $D_{1}, D_{2}, \ldots, D_k$ = Dummy variables for different types of crops; and
- μ = Error term.

The model coefficients, say β_2 for example, measure the elasticity of Y with respect to X_2 holding the effects of other independent variables constant, that is, it measures the percentage change in Y for a percentage change in X_2 holding the effect of other X variables constant (Gujarati & Porter, 2010).

3.3.3. The rural road appraisal framework, the influence of road network condition and connectivity, transport price and wider agricultural benefits

The relationship between transport price, transport cost and trip distance (Section 3.3.1) and the relationship between rural accessibility and agricultural production (Section 3.3.2) were used to assess the expected wider agricultural benefits following the rural road improvements. The intervention measures required to improve rural roads' infrastructure conditions were determined following the review of the construction and maintenance standards. It was expected that improved rural road infrastructure and connectivity would result in higher vehicle utilisation and lower transport prices, which would subsequently affect the agricultural production. Large vehicles from urban areas would be able to reach more remote areas after road improvement resulting in longer trip distances and increased vehicle utilisation. Based on these expected changes, three scenarios of rural road appraisal were assessed:

(i) an economic appraisal of a low-volume rural road was conducted without including the expected wider agricultural benefits and improved connectivity effect (no change in trip pattern and distances);

(ii) an economic appraisal of a low-volume rural road was conducted, including the expected wider agricultural benefits but without the effect of improved connectivity (no change in trip pattern and distances); and

(iii) finally an economic appraisal was conducted including the expected wider agricultural benefits and the effect of improved connectivity (change in trip pattern and distances).

The results from the three scenarios were compared to assess the effect of rural road network connectivity and the wider agricultural benefits during the economic evaluation of a low-volume rural road investment.

The research used the field-collected data during the interviews and NPS data during the analysis phase. The required data to be used in the analysis were extracted from government reports and databases together with completed questionnaires, and presented along with data analyses and discussions in Chapter 4 to 6. Chapters 4 and 5 present descriptive and regression analyses and various relationships between the variables. Chapter 6 combines the results from Chapter 4 and Chapter 5 together with HDM-4 model results to develop a rural road appraisal framework.

Chapter 4 : The Impact of Rural Road Conditions on Transport Price of Agricultural Products[12]

4.1. Introduction

Transport networks link producers to markets and provide access to social and administrative services. An effective transport system supports economic growth through reduction in travel time, reduction in accident cost and transport cost savings (Button, 2010). The indirect effects of transport investments may ultimately include lower prices for commodities and increased productivity. Rural transport networks and transport operations are particularly important for rural development and the agricultural sector, as it provides access to farm inputs (fertilisers, herbicides/pesticides and improved seeds) and outputs (agricultural produce), as well as other socio-economic activities for the rural population. The improved accessibility, in turn, may lead to increased production of agricultural products.

Agricultural development is a critical step in the process of economic transformation and growth for many African countries (Gajigo & Lukoma, 2011). The agricultural sector accounts for between 30 to 40 percent of the gross domestic product (GDP) (World Bank, 2013a) and employs roughly 65 to 70 percent of the labour force in most African countries (Platteau, 1996; World Bank, 2013a). Agriculture is also the main economic activity for the rural population in these developing countries, including Tanzania (Hine, 2014). In Tanzania, the sector generally contributes 27 percent to the national GDP (Tanzania National Bureau of Statistics, 2014a) and is responsible for about two-thirds of the country's total exports (Tanzania National Bureau of Statistics, 2012a). The sector employs approximately 65 percent of the national population (CIA World Factbook, 2017). Supporting agricultural development may lead to an increase in the crop yield and area cultivated, which should ultimately stimulate economic growth[13] in Africa. Investing and expanding the rural road network in order to reduce transport costs are often endorsed as a popular policy tool to support rural agricultural development.

[12] A shorter version of this chapter was presented at 2017 Transportation Research Board (TRB) annual meeting:
Reference: Fungo, E. & Krygsman, S. 2017. Impact of Rural Road Condition on Transport Price of Agricultural Products. In Washington D.C. *Proceedings of the 96th Transportation Research Board Annual Meeting*.

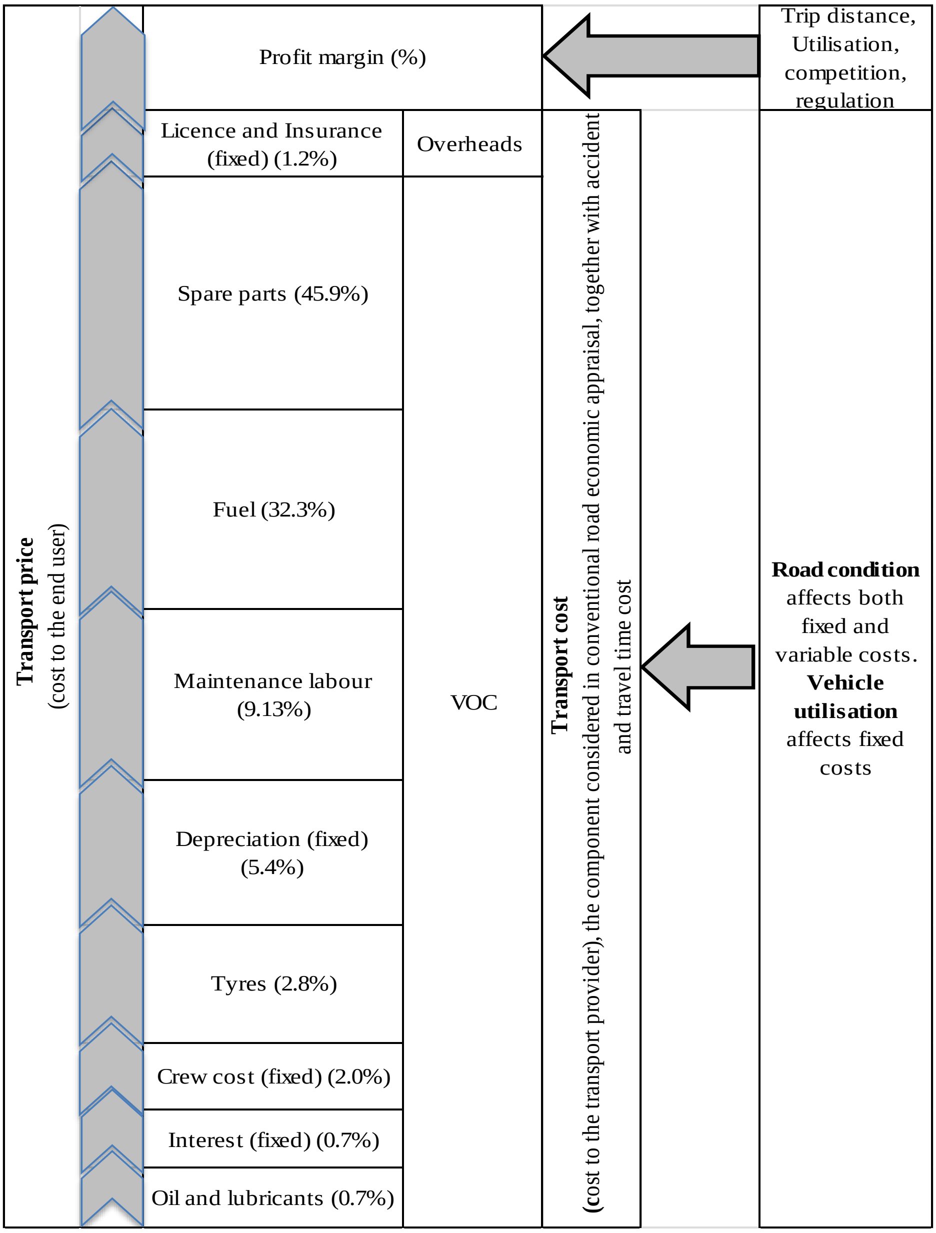
[13] Economic growth of country is normally indicated by an increase in the country's GDP, the monetary value of final goods and services, those that are bought by the final user, produced in a country in a given period of time. Economic development of county is generally indicated by the increase in citizens' quality of life by considering personal factors such as literacy rate and poverty rates. A country's economic growth often leads to a country's economic development.

Conventional road economic evaluation tools such as the Highway Development and Management tool (HDM-4) and the Roads Economic Decision tool (RED) are used to capture the economic benefit of rural road improvement projects. These tools measure the savings of the proposed alternative over a default or base scenario. Savings are made up of, among other factors, reduced vehicle operating costs, shorter travel time and lower accident costs, i.e. the direct benefits. A rural road improvement project is beneficial if these savings exceed the costs of construction and maintenance of the new alternative (Kerali, 2003). The approach followed is often referred to as the consumer surplus approach, as the savings accrue to the road user or the "consumer" of the road. Producers of agricultural commodities, which include farmers, are assumed to benefit from the lower costs of transport through the lower tariffs or transport prices.

Transport prices, fares or tariffs, are the rates charged by a transport company or operator to the end user. Normally transport prices comprise of several transport cost components, as well as a profit margin (Figure 4.1). Transport costs are all the costs a transport operator incurs when transporting cargo or passengers, and includes vehicle operating costs (VOC) and overhead costs (Teravaninthorn & Raballand, 2009; Hine, 2014). Bennett and Greenwood (2001) do not differentiate between transport cost and VOC; they include overhead costs in VOC. In this research, therefore, the terms transport cost and VOC are used interchangeably. However, the term *transport cost* referred to in this research should not be confused with term *total transport cost* which includes road construction and maintenance costs as well as road user costs (i.e. VOC, accident cost and travel time cost).

Upgrading and improving rural roads should lead to lower vehicle operating costs, as road conditions have a direct and strong impact on transport costs (Kerali, 2003; Archondo-Callao, 2004). Not surprisingly, a considerable amount of research has been done to establish the relationship between road improvement and transport cost reduction (Kerali *et al.*, 2006). Less research has been done on the exact relationship between road conditions and transport price (Hine & Chilver, 1991).

The agricultural community, among others, is expected to benefit from the reduction of transport price which will accrue to them in the form of an increased price of farm produce (i.e. through reduced distribution costs) and reduced production cost (i.e. through lowering the price of agricultural input). In turn, this may allow for an increased net income to the farmers and an increased crop production; this situation is expected to improve the well-being of the agricultural community. Should transport prices not reflect transport costs after a road improvement, the economic evaluation may overestimate the benefits to the agriculture community, and thus also the economic developmental benefits.



Source: Author. The percent in brackets are the cost for medium truck traversing on rolling terrain on a gravel road obtained from the calibrated HDM-4 model. These percent varies with road condition, vehicle utilisation and vehicle type

Figure 4.1: Components of transport price and transport cost and the factors impacting on these components

Even if transport prices decrease as the transport costs decrease after an improvement, only relying on the vehicle operating costs savings for the specific road segment may underestimate the benefits. Improved road conditions in rural areas often allow for longer trip distances and thus better vehicle utilisation, and this may also lead to the use of higher capacity vehicles (capable of carrying larger loads) (see Headicar, 2009; Lançon *et al.*, 2014).

Both of these outcomes have significant impacts on transport prices but are not always included in the economic analysis. They potentially lower the transport price, as they impact on the distribution (i.e. cost per km) of the fixed vehicle cost component.

Given the potential impact of transport prices on agricultural development, the effect of a road improvement on transport prices and transport services should be explored (Hine & Chilver, 1991; Hine, 2014). An assessment of the changes in transport price following road improvement will raise awareness about the magnitude of the possible wider benefits. These wider benefits are not always directly captured by conventional road appraisal methods, which focus mainly on VOC savings associated with a specific vehicle fleet and for a specific road segment.

The aim of this chapter is to determine the transport costs and transport prices of agricultural products, and measure the impact of road condition and trip distance on these costs and prices. The relationship between transport price, transport cost and trip distance is explored in a study conducted in Morogoro region, Tanzania. Road surface type (paved or unpaved) and the International Roughness Index (IRI)[14], together with other road characteristics, were used as measures of the road condition.

4.2. Literature review

Road condition is defined by the vertical and horizontal alignment, road roughness, surface type, road width and sight distance (Thagesen, 1996; Bennett & Greenwood, 2001). Road condition, particularly road roughness, influences fixed and variable vehicle costs. Variable vehicle operating costs are directly related to the usage of the vehicle. With poor road conditions, fuel and lubricant consumption increases; maintenance and repair costs increase; tyre consumption increases and labour costs increase (Ellis & Hine, 1998; Bennett & Greenwood, 2001; Chatti & Zaabar, 2012). Fixed costs are also indirectly affected through low vehicle utilisation due to low speed and short service life, as the capital and other fixed cost are calculated per time period (Ellis & Hine, 1998; Bennett & Greenwood, 2001).

[14] International Roughness Index (IRI) is an index used to measure the road surface roughness. Road surface roughness is the measure of irregularity of road surface. The IRI mathematically summarises the longitudinal surface profile of the road in a wheel path, representing the vibrations induced in a car by the road roughness. The common recommended units are meter per kilometre (m/km) or millimetre per metre (mm/m), i.e. cumulative displacement of an axle in relation to the vehicle body *in meter* or *in millimetre* divided by the distance travelled *in kilometre* or *in meter*. Good roads have lower IRI value, i.e. are smoother, compare to poor roads.

While the relationship between the road condition and transport cost is well-documented (Hide *et al.*, 1975; Watanatada *et al.*, 1987; Bennett & Greenwood, 2001; Archondo-Callao, 2004; Tan *et al.*, 2011; Chatti & Zaabar, 2012), less is known about the relationship between road condition, transport costs and ultimately transport prices. Road improvement typically decreases road roughness and improves other road characteristics, which subsequently reduces the VOC and other road user costs, such as time costs and accident costs, for vehicles transporting freight or passengers. These costs are typically included in the economic evaluation of a road improvement. Road user costs after improvement are deducted from road user costs before the improvement. The difference constitutes the saving in road user costs due to the improvement. These savings accrue to the road users, i.e. transport operators. What is unknown is whether a similar decrease can be noticed in the transport price which will benefit the farmers or producers. Generally, it is assumed that the reduction of transport cost will result in the reduction of transport price, which will increase agricultural output, ultimately stimulating economic growth. This, however, is not always the case and in some areas no clear impact on transport price was evident following a reduction in transport cost (Teravaninthorn & Raballand, 2009). In their study, Teravaninthorn & Raballand (2009) tried to explain why, in some areas, the reduction in transport costs did not lead directly to lower transport prices. They pointed out that in west and central Africa, for instance, a reduction in transport costs as a result of corridor rehabilitation or lowered fuel price would lead to zero reduction in transport prices due to a strongly regulated transport market. In east and southern Africa, however, a reduction in transport costs due to corridor rehabilitation, lowered fuel expenses and reduced border-crossing time lead to lower transport prices due to a more competitive transport market in the region (Teravaninthorn & Raballand, 2009).

During road appraisal, the economic benefits of a road improvement are determined by comparing different cost streams for the planned road project (do-something) against the without-project (do-minimum) alternative (Thagesen, 1996; Kerali, 2003; OECD, 2011). In economic evaluation, the considered cost streams are road user costs (transport costs, travel time and accident costs) and road agency costs (road construction and maintenance costs), as well as socio-economic and environmental effects (Kerali, 2003; OECD, 2011; World Bank, 2016b). A transport price reduction is not considered in economic evaluation, as this benefit is assumed to be already captured by the VOC savings and including the transport price would lead to double counting. The transport price, however, may be affected by the actual transport cost, the regulatory and competitive structure of the transport market, and other factors, as shown in Figure 4.1. In oligopolistic or monopolistic transportation markets, especially in rural areas, transport prices frequently have very little relation with the transport costs. Therefore there is a need to scrutinise network and corridor operation and regulation to better understand the relationship between road condition, transport prices and transport costs (Teravaninthorn & Raballand, 2009). Rural road improvement projects intended to support economic development should also consider transport price reduction, as opposed to assuming that road improvement projects will benefit the agricultural sector unconditionally.

Previous studies have revealed diverse effects of road condition on transport costs and transport prices. Ellis & Hine (1998) illustrated the effect of road condition on transport cost and price using data from Zambia and Tanzania. The researchers indicated that in Zambia, the transport price was twice as much per passenger-kilometre on a poor-quality earth road than on a good-quality gravel road. They also reported on a survey conducted in Tanzania, which showed that a 50 percent increase in road roughness (measured by IRI) over a 50 km distance would increase truck charges by 16 percent and pick-up (light-duty truck) charges by almost 100 percent. It was also found that there were large variations in the transport price on the poor-quality road between the wet and the dry season. A study conducted in Nigeria by Akangbe, Oloruntoba, Achem and Komolafe (2013) indicated that poor road condition and seasonality were the reasons for the high transport prices of the agricultural produce.

Apart from the effect of road condition on transport price, in 1990s, Hine *et al.* (1997) found that the overall transport tariff (measured per ton-km) in Tanzania were three to five times higher than in Pakistan, and two to four times higher than in Indonesia. Atkin & Donaldson (2015) also found that the price of transport goods within a country is four to five times higher in Ethiopia and Nigeria compared to the United States of America. The high transport prices in Africa can be attributed to several factors, including empty-running trucks (on return trip), old fleets, low vehicle utilisation, high-speed and heavily-loaded trucks (which leads to high consumption of fuel and parts), high capital cost (purchase price) due to less competition in parts and vehicle supply, high fuel prices, transit delays, low competition in the transport market as well as paying less attention to the routine maintenance of trucks (Hine *et al.*, 1997; Nathan Associates Inc., 2012; Eberhard-Ruiz & Calabrese, 2017).

In general, the literature reveals that road condition does impact on transport costs, with better-condition roads leading to reduced vehicle operating costs. However, very little is known about the impact of road condition on transport prices, and its subsequent impact on the prices and production of agricultural products. As Figure 4.1 suggests, transport price is a function of transport cost, and any impact on transport cost should be reflected in the transport price, although this exact relationship has not been verified. Examining transport prices may provide a better understanding of its impact on agricultural development.

4.3. Study area

This chapter presents research conducted in the Morogoro region, the second-largest region in Tanzania. The region, as much of the rest of the country, is endowed with diverse sources of water, fertile land and a good climate suitable for a variety of crop cultivation. In the Morogoro region, however, only about 29 percent of the arable land is productively used for agricultural purposes (Morogoro Regional Commissioner's Office, 2013). Inadequate transport is partly to blame for the underutilisation of this agricultural potential. Amongst other constraints are technological or research-related issues, poor marketing and pricing policies (Ramonyai & Konstant, 2006). In Morogoro, the problems facing farmers, as reported in the Tanzania National Sample Census of Agriculture of 2007/2008, are (Tanzania National Bureau of Statistics, 2012b) are:

(i) low prices at the open market (65.2%);
(ii) marketplace too far (7.5%);
(iii) transport price too high (6.9%); and
(iv) lack of transport (4.5%).

Improved transport services and road networks may address, to some extent, these problems.

The road network of Morogoro comprises a total of 6 512 km, out of which 1 894 km are trunk and regional roads and 4 618 km are collector, feeder and urban roads. Roughly 29 percent of trunk and regional roads are paved, and only about one percent of collector, feeder and urban roads are paved. Looking at the spatial road density, there is only 8.3 km of paved road per 1 000 sq.km and total road network density of 8.9 km per 100 sq. km. Rural roads and transport are generally characterised by poor infrastructure, high transport costs and prices as well as low-quality transport services (*National Transport Policy*, 2003; African Development Bank Group, 2013). As noted by the *National Transport Policy* (2003), it is important to improve the rural roads network and transport, as poor road transport reduces agricultural marketing and the efficiency with which rural activities can be undertaken. Furthermore, it discourages investments and growth of agricultural potential areas, which increases rural poverty (*National Transport Policy*, 2003; African Development Bank Group, 2013).

4.4. Data collection and surveys

Dar es Salaam serves as the main market for the crops from Morogoro and other regions within Tanzania. A survey was done in Dar es Salaam and in the Morogoro region between the months of June and September in 2014 to obtain information about freight charges and the road network. During the survey, two types of questionnaires were administered (Table A.1.1 - A1.2 in Appendix 1):

(i) a transporter's questionnaire; and

(ii) a road authority official's questionnaire.

Transporters were interviewed to obtain the freight charges and cargo weights of agricultural products. Fifteen interviews were conducted with medium-truck operators: nine in Dar es Salaam and six in Morogoro. Out of the fifteen interviews conducted, freight charges and cargo weights for 51 different routes were collected (Table A2.1 – A2.3 in Appendix 2).

In Dar es Salaam, interviews were conducted at the marketplace during the unloading of agricultural products. Agricultural products are transported from different places of the country, however, only transport operators involved in transporting agricultural products from Morogoro were selected for interviews. The survey was done at six different markets in Dar es Salaam. Roughly, one interview was conducted per day, and some days no transport operator from Morogoro was encountered. In Morogoro, interviews were conducted at parking areas and loading points in three different districts and Morogoro Municipality. However, there were no designated parking/loading areas for these transport operators. Therefore, the surveyor asked local people where to meet transport operators. Wherever the driver and/or his assistant(s) were encountered (parking or loading); the interview was conducted in face-to-face sessions and the questionnaire was completed on the day of the interview. The obtained information for the 51 different trips covers the wide range of agricultural trips in Morogoro region.

The vehicle size exhibits some economy of scale (Pienaar, 2013). Trip distances and the pavement surface type also impact differently on the different truck types, resulting in different freight charges. To eliminate the impact of vehicle type and size on freight charge, a default truck, two axles, six tyres and a loading capacity of 10 tonnes (medium truck), was specified during the interview to determine the freight charges. The medium truck is the most commonly used vehicle for transporting agricultural products within the study area.

Road authority officials were interviewed to obtain information on the road network, including road length, surface type, the condition of the road, traffic data and to obtain maps. Interviews were conducted in six different district councils of the Morogoro region, Morogoro Municipality, the Tanzania National Roads Agency (TANROADS) Morogoro regional office, and the Morogoro regional commissioner's office. Data from these institutions represent the information for the whole Morogoro region. After several visits to these institutions, permission to conduct the interviews was granted. The officer-in-charge was interviewed, with the questionnaire serving as a guideline for the required information. Due to the nature of the required information, the questionnaire could not be completed on the day of the interview. Most of the required information was to be retrieved from the databases and official documents. Therefore, in addition to the questionnaire, these officials provided documents such as government reports and electronic copies of the databases that contained the required information. These data were collected at a later stage. Tables A2.1 – A2.3 in Appendix 2 show trip length, surface type and the general road condition, all extracted from the reports provided by the road authority officials. Vehicle characteristics and vehicle unit economic costs were also obtained from the reports provided by the road authority officials (Table A2.4 in Appendix 2). In total, 24 interviews were conducted with different stakeholders (Table 4.1).

Table 4.1: Number of interviews conducted

Interview station	**Transporters**	**Road authority officials**	**Total**
Dar es Salaam city	9		**9**
Kilosa district	2	1	**3**
Gairo district	1	1	**2**
Kilombero district	2	1	**3**
Ulanga district	NA	1	**1**
Morogoro rural district	NA	1	**1**
Movomero district	NA	1	**1**
Morogoro Municipality	1	1	**2**
Morogoro regional commissioner's office	na	1	**1**
TANROADS–regional office	na	1	**1**
Total	**15**	**9**	**24**

NA = Not available, na = Not applicable

4.5. Transport price, trip distance and surface type

Several factors may impact the transport price or the price charged by the transporters (see Figure 4.1). This section considers three variables:

(i) road surface type (as a measure of road condition);

(ii) trip distance; and

(iii) type of vehicle.

Using the information in Tables A2.1 – A2.3 in Appendix 2, the transport prices, per ton-km, were calculated using Equation 4.1:

$$Transport\ price\ (per\ ton-km)\ = freight\ charge\ per\ trip\ /(trip\ distance\ \times cargo\ weight), \quad (4.1)$$

where:

- *transport price* (in Tanzanian shilling per tonne-kilometre (Tsh/ton-km)): The price that the transport provider is charging per tonne carried for every kilometre travelled;
- *freight charge per trip* (in Tanzanian shilling (Tsh)): The price that the transport provider is charging per trip;
- *cargo weight* (in tonnes): The load transported; and
- *trip distance* (in kilometre (km)): The distance from the start to the end of the journey.

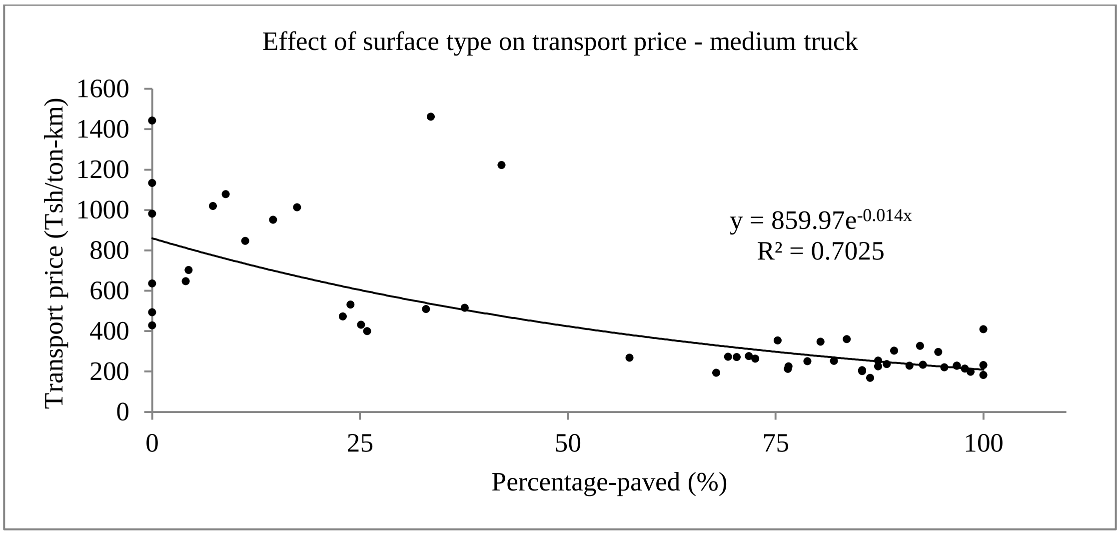
4.5.1. Effect of the road surface type on the transport price

For each section of the road, the surface was categorised as either paved or unpaved. Almost all the trips were undertaken on both paved and unpaved sections of the road to reach the designated destination. Trips lengths ranged from 10 to 600 km. The length of paved and unpaved sections was determined for each trip, and the percentage of the trip distance that the truck traverses on paved sections of the road was specified and used to classify paved or unpaved trips. For each trip, this percentage was recorded as percentage-paved. To determine the effect of road surface type on transport price, a scatter plot of transport price versus percentage-paved was plotted and a trendline fitted (Figure 4.2).

Figure 4.2 shows that the transport price decreases as the percentage-paved increases. The figure also illustrates the large variation in transport price for trips with a small percentage-paved component. This implies that various factors affect transport price for mostly unpaved rural roads. The equation of the fitted line, Figure 4.2, captures the relationship between transport price and percentage-paved. Taking the slopes of the fitted trend line,

$$dy/dx = -12.04e^{-0.014x},$$

at intervals of five percent increases in percentage-paved (the horizontal axis), the results show that the transport price decreases at a diminishing rate. On average, assuming straight-line curves, for trips with a less than 50 percentage-paved component, the transport price decreases by 8.7 Tsh/ton-km for every one percent increase in percentage-paved. For trips with more than 50 percentage-paved, the transport price decreases by 4.3 Tsh/ton-km for every one percent increase in percentage-paved. These results imply that for the same increase in percentage-paved, the impact of paving the road on transport price would be higher on trips which initially comprise of shorter paved sections, compared with the impact on trips which initially comprise longer paved sections. Furthermore, the average transport price on less paved trips (less than 50 percent paved) was 625 Tsh/ton-km, while the transport price on more paved trips (more than 50 percent paved) was 309 Tsh/ton-km. These results show that the transport price is roughly twice as high on less paved trips.



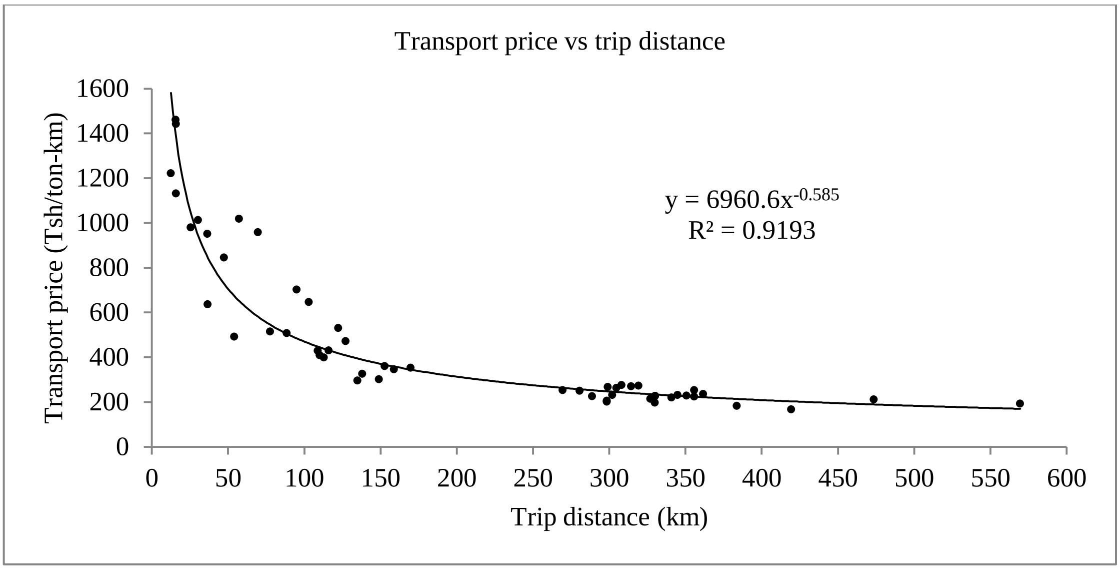
Source: Author

Figure 4.2: Effect of surface type on transport price

4.5.2. Effect of distance on transport price

The relationship between trip distance and transport price was also investigated. Road surface type was ignored at this time. Transport price, as determined by Equation 4.1, was plotted against trip distance (Figure 4.3).

Figure 4.3 shows that the transport price, per ton-km, decreases as the trip distance increases. The transport price is very high over short-distance trips (10 – 50 km), which are the typical rural trips. High transport prices over short distances may be attributed to poor road conditions in rural areas, and probably also to less competition among transport operators. In rural areas, many transport providers are reluctant to operate on very poor roads, and those who are willing, typically charge higher prices to compensate for the cost incurred and lower vehicle utilisation (Hine & Ellis, 2001; Taiwo & Kumi, 2013; Njenga *et al.*, 2014).



Source: Author

Figure 4.3: Effect of trip distance on transport price

The lower transport price *per ton-km* over long-distance trips may be attributed to the fact that over long distance trips the transport market is more competitive. Again, transporters are willing to charge less (per ton-km) over long distance trips due to their more productive utilisation of vehicles and staff. Factors such as economy of distance play an important role in lowering the transport price over long distance trips (Pienaar, 2013; Lançon *et al.*, 2014). The decrease in the transport price may also be explained by the fact that the vehicles travel on higher-quality (higher percentage-paved) roads over long-distance trips (i.e. the bigger part of the trip is traversed on paved road).

The mathematical equation of the fitted trend line, Figure 4.3, shows the relationship between transport price and trip distance. Transport price decreases at a decreasing rate with an increase in trip distance. The transport price decreases dramatically for trip distances shorter than 50 km. Looking at the slope of the fitted trend line equation,

$$dy/dx = -4071.951x^{-1.585},$$

on average, assume straight line curves, the transport price decreases by 36 Tsh/ton-km per kilometre increase for these short-distance trips. Over longer distances, the transport price continues to decrease, but at a more modest rate. For trip distances between 50 and 150 km, the average rate of transport price decrease is 3.5 Tsh/ton-km per kilometre increase, and for trip distances between 150 and 600 km, the average rate of transport price decrease is 0.5 Tsh/ton-km per kilometre increase. These results imply that, over shorter-distance trips, an increase in trip distance has a higher impact on the reduction of transport price than an increase in trip distance over longer-distance trips.

4.6. Transport price, transport cost and road condition

Road surface type and trip distance affect transport price, as illustrated in the preceding sections. The relationship between transport price and road surface type (Figure 4.2), however, does not consider the other road condition characteristics such as road alignment and surface roughness. To include their effect, this section considers the relationship between transport price and surface roughness, together with other pavement and traffic characteristics over different trip distances. Surface roughness, measured by the International Roughness Index (IRI), is a common measure of the road condition and it is widely used as an indicator of the level of service offered by the road (Archondo-Callao, 2004; Kerali *et al.*, 2006; Tan *et al.*, 2011; Chatti & Zaabar, 2012). This relationship can be used to assess how any road investment will affect the transport price, as well as its subsequent impact on agricultural products prices and production.

Models such as HDM-4 and RED provide a methodology for estimating VOC based on surface roughness, together with other pavement and traffic characteristics. There is a strong relationship between surface roughness together with other pavement characteristics and VOC (see Figure 3.3 in Chapter 3). For instance, Figure 3.3 shows that an increase in road roughness, measured in IRI, from 5 to 10 will increase the VOC by 26 percent, i.e. from $0.61/veh-km to $0.77/veh-km. Therefore, instead of using surface roughness, transport cost (defined here as VOC) was used in the analysis. HDM-4 and RED models were used to determine the VOC for 51 trips, based on the road network information, traffic volumes and vehicle characteristics of the study area (Table A2.4 in Appendix 2). As mentioned before, a 10-tonne truck (medium truck) was used in the analysis.

Information from 51 trips was used to develop a regression model with transport cost and trip distance as independent variables, and transport price as dependent variable (Table 4.3). A dummy variable was included in the regression model to control for two different road surface types: (i) less than 50 percent of trips distance is paved; and (ii) more than 50 percent of the trip distance is paved.

The classical linear regression model assumes that the variance of error remains constant or the homoscedasticity condition. The regression model was checked for homoscedasticity using the Breusch-Pagan test. The regression results of the Breusch-Pagan test were statistically insignificant (Table A2.5 in Appendix 2), suggesting that the homoscedasticity condition is satisfied. Also, one of the assumptions of the classical linear regression model is that there is no perfect or near perfect multicollinearity, that is, there are no exact linear relationships among the independent variables. The variance inflection factors (VIF) of the regression model, Table 4.2, were computed (Table A2.6 in Appendix 2). The results indicated low VIF values, below 3. These results suggest that the regression model, Table 4.2, does not exhibit multicollinearity.

Table 4.2 : Regression results: transport price, transport cost and trip distance

Dependent variable: ln(Transport price)	*Coefficients*	*P-values*	*Significant F*	*Adjusted R square*
Intercept	6.618	0.000	0.000	0.996
ln(trip distance)	-0.462	0.000		
ln(transport cost)	0.528	0.000		
D1 (% paved <50%)	0.189	0.000		

The regression model is statistically significant with an adjusted R-square value of 0.996 and all coefficients are statistically significant with the expected signs. The model results show that, when holding other variables constant, on average, a one percent increase in trip distance lowers the average transport price by 0.462 percent. The results also show that holding other variables constant, on average, a one percent decrease in transport cost lowers the transport price by 0.528 percent. These results concur with the results of Teravaninthorn & Raballand (2009), who found that in east Africa, a reduction of 15 percent in transport cost will lead to a 7-10 percent reduction in transport price. The dummy variable coefficient shows that holding other variables constant, the transport price for a trip with less than 50 percent of its distance traversed on a paved road (referred to here as *unpaved trip*) is approximately 19 percent higher than the transport price for a trip with more than 50 percent of its distance is on a paved road (referred to here as *paved trip*).

The regression equations (Equation 4.2 - 4.3) were used to estimate transport prices, for *paved* and *unpaved* trips for different transport costs and trip distances:

Less than 50 percent paved (unpaved trips):

$$ln(Transport\ price) = 6.618 + 0.189 - 0.462\ ln(Trip\ distance) + 0.528 ln(Transport\ cost), \quad (4.2)$$

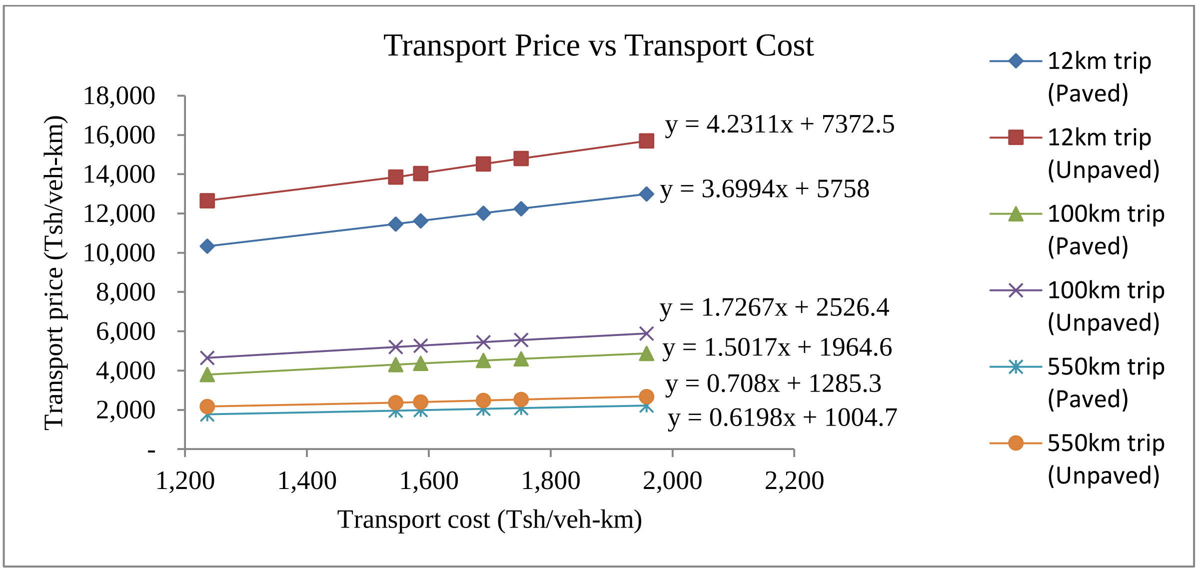
More than 50 percent paved (paved trips):

$$ln(Transport\ price) = 6.618 - 0.462\ ln(Trip\ distance) + 0.528 ln(Transport\ cost), \quad (4.3)$$

where the units are measured as follow:

- *Transport price* (Tsh/veh-km);
- *Distance* (km); and
- *Transport cost* (Tsh/veh-km).

Using Equations 4.2 and 4.3, the relationships between transport prices and transport costs for *paved* trips and *unpaved* trips were plotted for three different distances (Figure 4.4). The equations in Figure 4.4 indicate that for *unpaved* trips transport prices exceed transport cost by up to 9 times over short-distance trips (12 km). This difference between cost and price decreases as the trip distance increases, to about 1.5 times over long-distance trips (550 km). For *paved* trips, the difference between transport price and transport cost is a bit lower compared to the difference on *unpaved* trips. On *paved* trips, the results show a difference of up to 7 times over short distance trips (12 km) to about 1.2 times over long distance trips (550km). The large difference on short distance *unpaved* trips may be attributed to the poor condition of rural roads and limited competition in the transport market. On *paved* trips the transport may be more competitive, that's why the difference is somehow low. Another reason for the big difference between transport price and cost over short distance trips may be vehicle utilisation. In modelling the VOC, the vehicle utilisation used in the RED and HDM-4 models was kept constant regardless of the trip distance. However, overall vehicle utilisation may be significantly lower for short distance trips than long distance trips, which will have a different impact on transport costs.



Source: Author

Figure 4.4: Relationship between transport price and transport cost

Table 4.3 to 4.5 and Figure 4.5 show that transport operators over short distance trips make a huge profit. However, this profit, to some extent, may be lower if proper vehicle utilisation was used in modelling transport cost. In HDM-4, one may use the constant life method or optimal life method. In constant life method, the vehicle life *utilisation in km* is specified by the user and is assumed constant regardless of the road condition and operating speed (Bennett & Greenwood, 2001). In optimal life method, vehicle life *utilisation in km* varies with road condition i.e. the vehicle utilisation decrease with the increase in road roughness (see Equations 2.3 and 2.4). However, the HDM-4 user has to define a *base* average vehicle life utilisation, and the optimal utilisation is taken as either 100 percent or less of the user defined utilisation, depending on the roughness of the road the vehicle is traversing (Bennett & Greenwood, 2001). Normally, the user defined vehicle utilisation is assumed to be the same regardless of the trip distances.

Table 4.3: Distribution of transport price, transport cost and profit margin: 12 km trip

12 km unpaved trip					**12 km paved trip**				
Price* (Tsh/veh-km) (A)	***Cost (Tsh/veh-km) (B)***	***Cost (%) (B/A*100)***	***Profit margin (Tsh/veh-km) (C=A-B)***	***Profit margin (%) (C/A*100)***	***Price* (Tsh/veh-km) (A)***	***Cost (Tsh/veh-km) (B)***	***Cost (%) (B/A*100)***	***Profit margin (Tsh/veh-km) (C=A-B)***	***Profit margin (%) (C/A*100)***
12456	1200	10	11256	90	10168	1200	12	8968	88
13147	1400	11	11747	89	10883	1400	13	9483	87
14107	1600	11	12507	89	11678	1600	14	10078	86
15012	1800	12	13212	88	12427	1800	14	10627	86
15871	2000	13	13871	87	13138	2000	15	11138	85
Average		**11**		**89**			**14**		**86**

*Calculated using Equation 4.2 and 4.3

Table 4.4: Distribution of transport price, transport cost and profit margin: 100 km trip

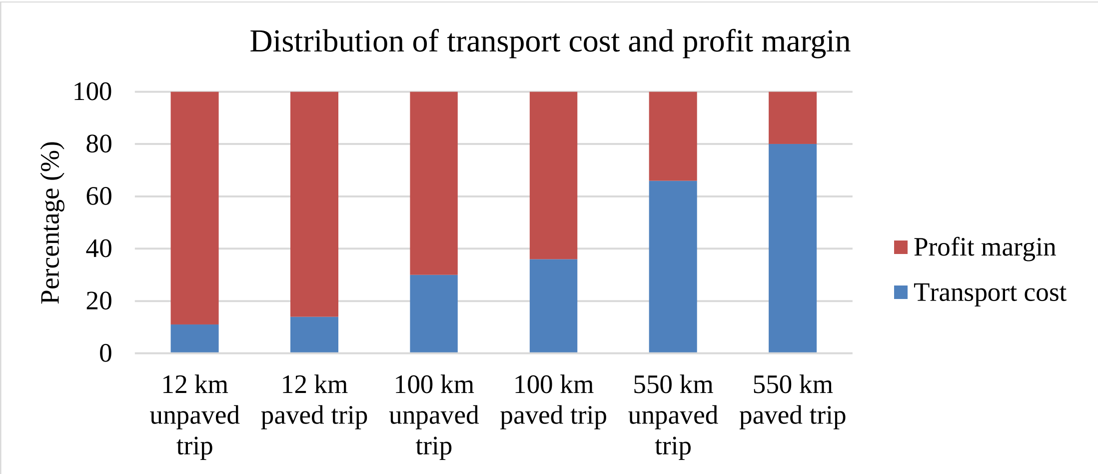
100 km unpaved trip					**100 km paved trip**				
Price* (Tsh/veh-km) (A)	***Cost (Tsh/veh-km) (B)***	***Cost (%) (B/A*100)***	***Profit margin (Tsh/veh-km) (C=A-B)***	***Profit margin (%) (C/A*100)***	***Price* (Tsh/veh-km) (A)***	***Cost (Tsh/veh-km) (B)***	***Cost (%) (B/A*100)***	***Profit margin (Tsh/veh-km) (C=A-B)***	***Profit margin (%) (C/A*100)***
4577	1200	26	3377	74	3736	1200	32	2536	68
4936	1400	28	3536	72	4086	1400	34	2686	66
5297	1600	30	3697	70	4385	1600	36	2785	64
5637	1800	32	3837	68	4666	1800	39	2866	61
5959	2000	34	3959	66	4933	2000	41	2933	59
Average		**30**		**70**			**36**		**64**

*Calculated using Equation 4.2 and 4.3

Table 4.5: Distribution of transport price, transport cost and profit margin: 550 km trip

550 km unpaved trip					550 km paved trip				
Price (Tsh/veh-km) (A)*	*Cost (Tsh/veh-km) (B)*	*Cost (%) (B/A*100)*	*Profit margin (Tsh/veh-km) (C=A-B)*	*Profit margin (%) (C/A*100)*	*Price* (Tsh/veh-km) (A)*	*Cost (Tsh/veh-km) (B)*	*Cost (%) (B/A*100)*	*Profit margin (Tsh/veh-km) (C=A-B)*	*Profit margin (%) (C/A*100)*
2139	1200	56	939	44	1746	1200	69	546	31
2246	1400	62	846	38	1859	1400	75	459	25
2410	1600	66	810	34	1995	1600	80	395	20
2564	1800	70	764	30	2123	1800	85	323	15
2711	2000	74	711	26	2244	2000	89	244	11
Average		**66**		**34**			**80**		**20**

*Calculated using Equation 4.2 and 4.3



Source: Author

Figure 4.5: Distribution of transport cost and profit margin over different trip distances: unpaved and paved trips

An improvement to a low volume road is expected to allow for a competitive market and higher vehicle utilisation. Vehicles from urban areas will be able to reach a more remote area; this situation will lead to longer distance trips (Lançon *et al.*, 2014) and, therefore, increased vehicle utilisation. The new direct trip from urban areas also increases competition on an improved road which may result in a replacement of village trucks or farm tractors which are often less utilised on short and expensive rural trips. The improved road attracts more transport operators leading to increased competition. The overall impact of improving low volume roads is a significant reduction of transport price on these short distance rural trips. This can be illustrated by the equations in Figure 4.4 which show that for the same reduction in transport cost due to road improvement, the reduction in transport price is higher for short-distance trips than long-distance trips. A one unit reduction in transport cost will result in a 4.2 unit reduction in transport price over short-distance *unpaved* trips (12 km), while for long-distance *unpaved* trips (550 km) the same will result in a 0.7 unit reduction in transport price.

4.7. Conclusion

This chapter illustrated the relationship between transport price and transport cost, and how these factors are influenced by trip distance and road condition.

The transport price (per ton-km) decreases with an increase in percentage-paved. It also decreases with an increase in trip distance, with very high transport prices over short-distance trips. Short-distance trips, generally less than 50 km *unpaved* trips, referred to as the 'first mile' (Njenga *et al.*, 2014) are typically rural trips. The very high transport prices for these rural trips may be attributed to, among other factors, the poor road condition, less competition in the transport market and low vehicle utilisation. For short-distance *paved* trips, the transport price is relatively low compared to the transport price for short distance *unpaved* trips. This may be attributed to a relatively more competitive transport market, however, the vehicle utilisation may still be low for these short distance *paved* trips.

Transport price does indeed decreases with a decrease in transport cost. The decrease in transport price, however, is complicated, as it is also affected by the trip distance as well as by the transport market regulatory and competition regime. Rural road improvement lowers transport cost as well as transport price which is an indication of a competitive transport market (see Teravaninthorn & Raballand, 2009). Following rural road improvement, larger freight vehicles from the urban areas will be able to reach more remote areas due to the improved road condition. This will have an impact on the trip length and hence on vehicle utilisation beyond the improved section. This situation is not adequately addressed by the existing tools such as HDM-4 and RED. This new direct trip from urban areas will replace village trucks or farm tractor, which are often less utilised on short and expensive rural trips, on poor low-volume rural roads to take the farm produce to a collecting point (alongside a relatively better road). The process allows for higher utilisation of the trucks and subsequently benefits from the factor such as economy of distance (Pienaar & Vogt, 2009; Lançon *et al.*, 2014). These longer distance trips therefore not only enjoy the benefits of the lower vehicle operating costs of the improved section, but they also benefit from the improved vehicle utilisation associated with longer trips.

Over short-distance trips, the difference between transport price and transport cost is relatively higher than over long-distance trips. This can be attributed to the fact that short-distance trips on unpaved rural roads are served by fewer operators, and the market is often less competitive. The impact of transport cost reduction on transport price reduction is higher over these short-distance trips than over long-distance trips. This implies that a road improvement over short distances will not only lower the transport price and cost, but may also lead to an increase in market competition. Relatively good roads attract more operators and potentially longer trip distances, which explains the higher reduction of transport price.

The benefits of increased transport market competition and increased vehicle utilisation due to longer trips (beyond the improved section) are not captured by the conventional road appraisal approaches. These tools mainly focus on the reduction of the direct road user costs for the improved section of the road. As a result, conventional tools may potentially underestimate the benefits of investing in rural roads. It is concluded in this chapter that road economic appraisal tools should consider factors such as transport price, trip distances and vehicle utilisation, and competition in the transport market in order to capture the wider benefits of improved rural roads. The use of established relationship between transport price, transport cost and trip distance to some extent, will address this issue. This is further illustrated in Chapter 6, however, Box 4.1 provides a hypothetical example of what is expected following the improvement of a low volume rural road.

Box 4.1: Example of the expected benefits of improving low-volume rural road

Assume 12 km of poor low-volume unpaved road to be improved. The segment is linked to an 88 km good unpaved road going to the urban centre. Transportation of agricultural products to the urban centre (big market) is done in two stages, first trip, 12 km and second trip, 88 km. The improvement of the 12 km segment of low-volume rural road reduces the transport cost from Ths 1 800/veh-km to Tsh 1 300veh-km. This will lead to a reduction of transport price (using Equation 4.2) from Tsh 15 012/veh-km to Tsh 12 642/veh-km. Looking at these values, it shows that the transport cost is lowered by Tsh 500/veh-km but the transport price is lowered by Tsh 2 370/ veh-km. This huge drop in transport price, far above the reduced transport cost, implies that the transport operators were making a huge profit, but after road improvement, the transport market becomes more competitive and that's why there is a significant reduction of transport price.

On the second trip, 88 km, no improvement is to be done and assume the transport cost in this trip is Ths 1 300/veh-km. Using Equation 4.2 the price on the second trip is Tsh 5 036/veh-km. Therefore, the total transport price *per vehicle* travel to the urban market before road improvement is *15 012* X *12 + 5 036* X *88 = Tsh 623 312*, and after road improvement it will be *12 642* X *12 + 5 036* X *88 = Tsh 594 872*. However, due to the improvement of the 12 km section of the road, the vehicle from the urban centre will be able to traverse in this section. Therefore, instead of having two-stage trip, the agricultural products will be transported directly to the urban centre on a one-stage trip. Using the transport cost of Ths 1 300/veh-km, the transport price for this one-stage trip (i.e. 100 km trip) will be Tsh 4 747/veh-km. Therefore, the transport price to the urban centre *per vehicle* will be *4 747* X *100 = Tsh 474 700*. So, the effect of the change in trip pattern lowers the transport price *per vehicle* further (one-stage trip from village to urban centre) from Tsh 594 872 to Tsh 474 700.

The above shows the only transport cost reduction is Tsh 500/veh-km, and for a 12 km section, the transport cost savings will Tsh 6 000/vehicle. This is the benefit considered in the conventional economic appraisal approaches (time and accident costs savings not included). However, the reduction in transport price taking into consideration the change in trip distance and transport market competition is Tsh 148 612/vehicle (i.e. Tsh *623 312 – 474 700)*. This transport price reduction is 25 times higher than the reduction in transport cost. Meaning that the benefits of investing in a low-volume rural road are expected to be 25 times higher than what would have been reported if the conventional road appraisal approach is used.

Chapter 5 : The Role of Road Infrastructure in Agricultural Production[15]

5.1. Introduction

The African Development Bank has recognised that investment in infrastructure such as transport, power supply and telecommunication is important for supporting economic growth, reducing poverty and achieving the Millennium Development Goals (MDGs) (Kandiero, 2009). At a macro level, infrastructure investment allows for better private sector activities through lowering production cost, opening up new markets for goods and services, and supporting trade (Kandiero, 2009). Road infrastructure improvements, for example, can be expected to increase the income of the producers and lower their production cost through the reduced transportation cost of goods and services (Kiprono & Matsumoto, 2014).

Despite the importance of infrastructure for economic growth in African countries, investment in infrastructure such as transport, power supply and telecommunication by the public sector is only 2 – 3 percent of Gross Domestic Product (GDP) (Kandiero, 2009). Compare this to East Asian countries, for instance, during the period of 1996 – 2005 infrastructure investment in China was, on average, 7.78 percent of its GDP (Davis, 2008). Poor transport infrastructure, high transport cost and missing links in the transport network pose a challenge for market integration and intra-African trade (Kandiero, 2009). The level of transport infrastructure development in Sub Saharan African countries is still low; only 30 percent of the rural population have access to all-weather roads (Kandiero, 2009). Transport prices are estimated to be twice as high as those of South and East Asia (Kandiero, 2009).

Road infrastructure is the backbone of many rural and urban transport systems. In rural areas, among the strategies often adapted to stimulate agricultural development is the provision of proper and adequate transport. Crossley *et al.* (2009) state that transport is a basic component of the agricultural sector; it provides assurance for the supply of the agricultural inputs and facilitates the delivery of the farm outputs to the market. Transport can also be a decisive factor for the success or failure of agricultural activities. Improvement of the rural roads and transport services are essential to ensure price reduction of agricultural inputs, improvement of market access for agricultural produce, and improvement of access to agricultural

[15] Short version of this chapter was presented at 2017 Southern African Transport Conference (SATC) and the paper was nominated for the best paper of the year:
Reference: Fungo, E., Krygsman, S. & Nel, H. 2017. The Role of Road Infrastructure in Agricultural Production. In Pretoria *Proceedings of the 36th Southern African Transport Conference* .94-108.

extension services (OECD, 2013; Taiwo & Kumi, 2013; Hine, 2014). Improved road infrastructure and transport services allow for lower transport costs and prices and subsequently increased agricultural production (Banjo *et al.*, 2012). There is a need to improve the connectivity between the collection points, markets and agro-industries through an improved and well-maintained road network (Chakwizira, Nhemachena & Mashiri, 2010). Oyatoye (1994) as cited in Kassali *et al.* (2012) found that, in Nigeria, an improvement in the quality of the roads allows farmers to realise lower marketing costs and receive a better price for their agricultural produce. It will also improve the access to the wider market and reduce losses and delays in moving the farm produce (Ikejiofor & Ali, 2014). If the agricultural produce reaches the market in time, in good quality and at low transport price, the situation will attract more money for the producers (Ikejiofor & Ali, 2014).

Improved transportation allows for the diffusion of new technology and techniques (Banjo *et al.*, 2012). It also provides benefits outside the agricultural sector, such as better access to social amenities and public facilities, increased mobility and reduced isolation (Ikejiofor & Ali, 2014).

Although improved road infrastructure and transport services are necessary, they are not the only factors to ensure agriculture development and sustainable poverty reduction in rural areas (Chakwizira *et al.*, 2010). Road infrastructure investment should preferably complement other rural development programmes such as improvement in irrigation systems, post-harvest storage technology, provision of extension services and financial support.

Despite the popularity of road infrastructure investment, little is known about the extent of agricultural production improvement following improvement in transport infrastructure and transport service. This chapter, therefore, focuses on investigating and empirically quantifying the impact of improved accessibility on the agricultural production of Tanzanian smallholder farmers. The objective of the chapter is to establish the relationship between the transport price of agricultural products and the agricultural production of smallholder farmers. The chapter also establishes the potential crop production increase that can be realised if transport prices are reduced.

5.2. Overview of Tanzania agricultural sector and the road network

The agricultural sector is important for economic growth. In Tanzania, this sector contributes roughly 27 percent to the national GDP and reported a growth rate of 2.6 percent in the fourth quarter of the year 2015 (Tanzania National Bureau of Statistics, 2015b). The agricultural sector also accounts for more than two-thirds of the total exports of the country (Tanzania National Bureau of Statistics, 2012a) and employs more than 65 percent of the national population (CIA World Factbook, 2017).

As is the case for other African countries, agricultural development in Tanzania holds significant potential for development. Tanzania has a total of 396 500 sq. km (roughly 40 million hectares) of arable land (World Bank, n.d.). It has 29.4 million hectares with potential for irrigation; however, only about 1.1 percent is irrigated (Tanzania-CountrySTAT, 2012). However, in order to realise this potential, the agricultural sector requires a paradigm shift and a move from subsistence farming to income-generation farming (Girvan, 2007).

In Tanzania, rural roads and transport services are generally characterised by poor infrastructure, high transport cost and charges as well as low-quality service (*National Transport Policy*, 2003; African Development Bank Group, 2013). The country has a total road network of 91 928 km (Table 5.1). The network comprises of trunk, regional, collector, feeder and urban roads. To a large extent, the country’s road network is unpaved: only 18 percent of trunk and regional roads are paved, with roughly one percent of the local roads paved (African Development Bank Group, 2013; TANROADS, 2016). Looking at the spatial road network density, there is only 9.6 km of road network per 100 sq.km of land in Tanzania and 7 km of paved roads per 1 000 sq.km of the land.

Table 5.1: Tanzania road network

Road class	**Paved**		**Unpaved**		**Total**
	km	**%**	**km**	**%**	**km**
Trunk and regional roads	5 970	18	27 921	82	33 891
Collector/feeder/urban	756	1	57 281	99	58 037
Total	**6 726**		**85 202**		**91 928**

Source: TANROADS and PMO-RALG (2013)

5.3. Literature review: the relationship between road infrastructure and the agricultural sector

Road conditions are an important factor in determining transport costs and prices. Hine and Ellis (2001) used data from Zambia in comparing transport price to road roughness. Transport price was twice as high on a poor-quality earth road in comparison to transport price on a good-quality gravel road. A survey conducted in Tanzania found that, over a 50 km section of road, an increase in roughness of 50 percent would increase truck charges by 16 percent and increase pickup (light duty truck) charges by 100 percent (Ninnin, 1997 as cited in Hine &

Ellis, 2001). The situation becomes worse during the wet season. In Madagascar for example, the passenger fare for taxis, commonly known as "taxis-brousses", is 70 percent higher on poor-quality roads during the wet season than during the dry season (Ninnin, 1997 as cited in Hine & Ellis, 2001).

Several studies suggest that one of the significant constraints for agricultural development in rural areas is the poor condition of rural infrastructure. In their study done in the Mhlonto local municipality in South Africa, Chakwizira *et al.* (2010) point out that one of the key constraints to sustainable agricultural and rural development is the poor state of the basic rural infrastructures, including transport and irrigation infrastructure. The poor road condition also affects the transport price of agricultural products. Ikejiofor and Ali (2014) conducted a study in Nigeria and concluded that poor road condition is one of the prominent causes that impede the marketing of agricultural products. Another study conducted in Nigeria by Akangbe *et al.* (2013) indicated that over 70 percent of the study's participants confirmed that the poor road condition and road seasonality were the reasons for the high transport prices of agricultural produce. In the same study, road conditions and the remoteness of the area were mentioned as reasons which deny farmers access to the various agriculture-related goods and services. Roughly 78 percent of the respondents were reported not to have access to markets, agricultural extension services, agricultural inputs, agricultural credit and the usage of modern farming techniques and equipment (Akangbe *et al.*, 2013). Yaro, Okon and Bisong (2014) argued that in an area where accessibility was good, the access to farm inputs was 5.9 percent more than in an area with poor accessibility. Another study, conducted by Kiprono and Matsumoto (2014) using longitudinal data from 2004 to 2012 in Kenya, indicated an increase in the use of maize hybrid seeds, chemical fertilisers and maize productivity in areas with better road access.

Hine *et al*. (1983) conducted a study in Ghana and found no evidence to suggest that villages with less accessibility suffer any disadvantage in obtaining agricultural inputs. However, they pointed out that poor accessibility may adversely affect agriculture through the inability to obtain finance. Two related reasons explained the inability to obtain loans i.e. (i) physical measurement of the field/farm (a necessary part of the finance application process) was difficulty due to remoteness; and (ii) the difficulty and higher cost of making follow-up trips for the loan progress. Hine *et al.* (1983) also indicate that villages located further from major markets experienced lower farm-gate prices[16] due to higher transport charges.

Tracey-White (2005) pointed out that improved road and transport services provide several advantages for rural populations, such as:

- better access to collection centres and markets of agricultural produce within and outside the village;
- reduced transportation time spent by family members;
- rapid and timely delivery of commodities;
- reduced spoilage and losses of crops, especially perishable crops, during transportation;
- reduced vehicle operating costs; and
- provision of better and more cost-effective access to social services, such as schools and health facilities.

Hine & Ellis (2001) argued that if the transport cost is equivalent to 30 percent of the farm-gate price, a 20 percent reduction in the transport cost fully passed to the farmers will result in a 6 percent increase in farm-gate price, and thus increased income to the farmers. They also point out that if the agricultural production elasticity is +1 (i.e. one percent increase in farm-gate price leads to one percent increase in agricultural production), normally ranges from 0 to 1.5, then agricultural outputs are estimated to rise by 6 percent. The results of a study conducted by Dorosh *et al.* (2010) on crop production and road connectivity in Sub-Saharan Africa indicated that a one percent reduction in travel time to the nearest city would increase crop production by between 1.6 and 4.8 percent, depending on the population of the nearest city and the type of technology employed in crop production. Their study's regression results also suggested that there was a much greater concentration of production in regions surrounding large cities than in regions surrounding smaller cities.

In Zambia, between the year 2002 and 2007, the SHEMP (Smallholder Enterprise Development and Marketing Programme – Access Road Component) initiative, a programme to improve market accessibility through road improvement, showed a positive impact on crop production and sales. The SHEMP programme used labour-based construction technology to improve market-access roads. In a four-year period, the maize purchase volume went up from

[16] The farm-gate price is the price of the product available at the farm, excluding any separately billed transport or delivery charge

600 bags to 62 490 bags. The maize price went up from Zambian kwacha[17] 20 000 to Zambian kwacha 30 000, and transporters experienced a 50 percent reduction on the replacements of spare parts (Andreski, 2007). Yaro *et al.* (2014) found that in an accessible area, farm produce attracts 16.8 percent more demand in comparison to inaccessible areas. They also found that employment opportunities in the agricultural sector increased by 15.5 percent.

The literature reveals that the condition of the road affects transport cost of vehicles transporting goods and passengers as well as the price charged by the transport operators (Hine & Ellis, 2001; Tracey-White, 2005; Andreski, 2007). Transport costs and prices, and the level of accessibility of a rural area, also play a significant role in the development of agricultural sector (Andreski, 2007; Chakwizira *et al.*, 2010; Dorosh *et al.*, 2010; Akangbe *et al.*, 2013; Ikejiofor & Ali, 2014; Kiprono & Matsumoto, 2014). However, there is no enough empirical evidence on the impacts of a reduction in transport costs on crop production.

5.4. Data

Data from the National Panel Survey (NPS) of 2012/2013 were analysed. This section provides the details of the data and describes the data extraction and manipulation process.

5.4.1. National Panel Survey (NPS)

The National Panel Survey (NPS) was conducted in Tanzania with the main purpose of providing data to be used by the government and other stakeholders in measuring the progress of the MKUKUTA II[18] poverty reduction strategy, as well as assessing the impact of other national policy initiatives. MKUKUTA II, implemented from 2010 to 2015, is the continuation of MKUKUTA I, which ran from 2005 to 2010. These initiatives were government commitments to accelerate economic growth and fight poverty in Tanzania. As it was for its predecessor, MKUKUTA II is the government's strategy to meet the Millennium Development Goals (MDGs) and other national development goals. The focus of MKUKUTA II includes economic growth and the reduction of poverty, improved quality of life and social well-being, good governance and accountability (*National Strategy for Growth and Reduction of Poverty*, 2010; Tanzania National Bureau of Statistics, 2014d).

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[17] (Exchange rate, 2017:1USD = 9865 Zambian Kwacha)

[18] Mpango wa pili wa Kukuza Uchumi na Kuondoa Umaskini Tanzania (MKUKUTA II) is a Swahili acronym for the National Strategy for Growth and Reduction of Poverty.

This research uses the Tanzania National Panel Survey data for 2012/13 collected by the Tanzania National Bureau of Statistics (NBS) (Tanzania National Bureau of Statistics, 2014d). The survey data were obtained from the World Bank database and are part of the Living Standards Measurement Study-Integrated Surveys on Agriculture (LSMS-ISA)[19] (World Bank, n.d.). LSMS-ISA is an ongoing research initiative within the Development Research Group of the World Bank, with the goal of promoting and improving the collection of household-level data in developing countries around the world (Tanzania National Bureau of Statistics, 2014d).

Data from the 2012 population and housing census indicated a total of 9 276 997 households in Tanzania. Of these 66.7 percent are located in rural areas and 33.3 percent in urban areas (Tanzania National Bureau of Statistics, 2015a). For the 2012/13 NPS, a total of 5 015 households were used as the representative sample of the population. Field work for the 2012/13 NPS was conducted between October 2012 and November 2013 (Tanzania National Bureau of Statistics, 2014d).

The NPS for 2012/13 was the third round of the panel survey conducted within the county. The first round was undertaken in 2008/2009 and the second round in 2010/2011. The survey collects household information including agricultural production, non-farming income-generating activities, consumption expenditures and other socioeconomic characteristics. The survey design and implementation were done by the NPS technical committee. The committee comprises representatives from different ministries, government agencies and development partners[20], including the Ministry of Agriculture, Food Security and Cooperatives, the Ministry of Finance, the Millennium Challenge Account – Tanzania, the World Bank, the DFID, UNICEF, UNFPA, and JICA (Tanzania National Bureau of Statistics, 2014d).

The National Panel Survey included four types of instruments for data collection: a household questionnaire, an agricultural questionnaire, a livestock/fishery questionnaire and a community questionnaire[21]. Each questionnaire was divided into different sections. For the purpose of this research, most of the required information (such as household agricultural

[19] The Living Standards Measurement Study – Integrated Surveys on Agriculture (LSMS - ISA) is a project that supports governments in seven Sub-Saharan African countries to generate nationally representative household panel data, with a strong focus on agriculture and rural development.

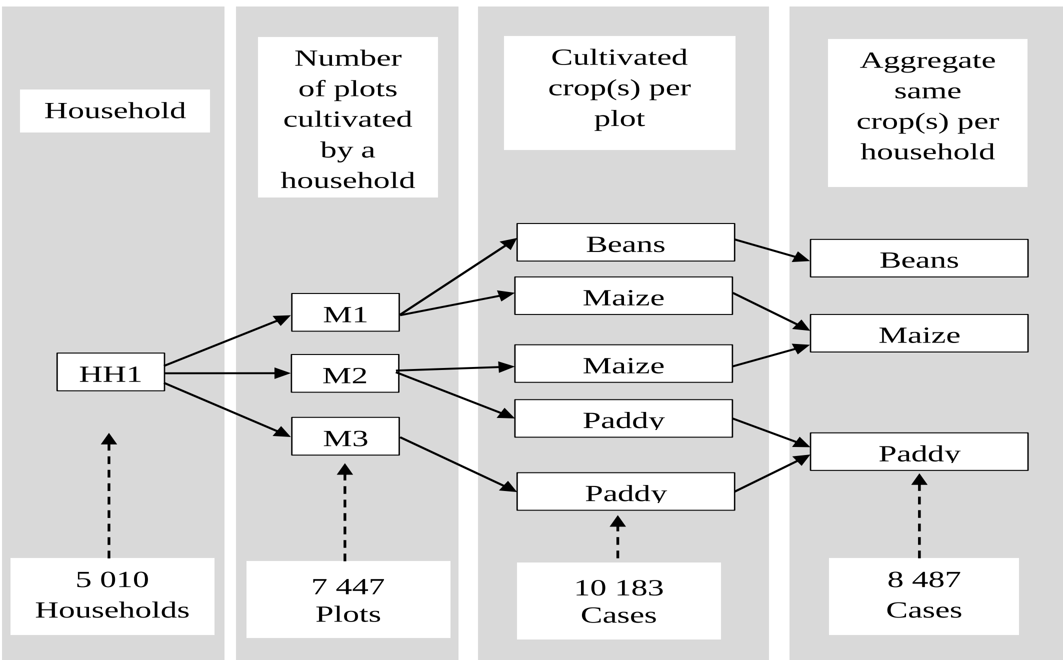
[20] Funding for the survey was provided by a grant from the European Commission, and additional funding was provided by the World Bank through the Living Standards Measurement Study - Integrated Surveys on Agriculture (LSMS-ISA) program (Tanzania National Bureau of Statistics, 2014d)

[21] The full questionnaires can be obtained at www.worldbank.org/lsms.

production, sales, types of crops cultivated, and transportation charges) was obtained from the agriculture questionnaire. Table A3.1 in Appendix 3 summarises the information collected with the agricultural questionnaire. Tanzania experiences two agricultural seasons, long rainy season and short rainy season. In the agricultural questionnaire, each section was thus divided into two parts, denoted as A and B. Part A provides the information for the long rainy season and part B for the short rainy season. However, only the information for the long rainy season was used in the analysis, as there were fewer data for the short rainy season.

5.4.2. Data merging and aggregating

This section describes merging and aggregating of NPS data, to reform and structuring the data in a format that analysis can be carried out. The required information was obtained from the agricultural questionnaire. The data set comprised of 15 different files (Table A3.1 in Appendix 3) with agricultural information. The merging of the files and aggregation of the data were done for each household, as presented in Figure 5.1. The process involved identifying the number of plots cultivated by each household and the types of crops planted on each plot. A household can plant the same crop on more than one plot. It can also plant multiple crops on the same plot. The crops from different plots were aggregated to get the total amount of cultivated crops per household. The final data set is comprised of 5 010 households and 8 487 cases. More details about data merging and aggregating are provided in Appendix 3.



Source: Author

Figure 5.1: Merging and aggregation process

5.4.3. Variables used in the analysis

The following six points and Table 5.2 provide the descriptions of the computations used to derive additional required variables to be used in the statistical analysis:

(i) The quantities of organic fertiliser, first-type inorganic fertiliser, second-type inorganic fertiliser, pesticides/herbicides, and seeds were aggregated to obtain *the total quantity of all the agricultural inputs* used by the household for a specific crop.

(ii) The *quantity of inputs per acre* was obtained by dividing the total quantity of the agricultural inputs by the area harvested.

(iii) The *unit crop price* was obtained by dividing the total value of sales by the quantity sold.

(iv) The transport price was reported as the amount paid to transport the crops to the market. A market can be a physical local market or any other market or place where farmers sell their crops to individual buyers or institutions. The *transport price per ton-trip* was obtained by dividing the amount paid to transport crops to the market by the quantity sold.

(v) Transport price per ton-trip was divided by the distance the crops were transported to the market to obtain the *transport price per ton-km*.

(vi) *Crop yield* was obtained by dividing the quantity harvested by the area harvested.

Table 5.2: Computed variables

Sn	Additional variables computation
1	*Total quantity of inputs (kg) = [quantity of organic fertiliser used] + [quantity of first and second type inorganic fertiliser used] + [quantity of herbicides/pesticides used] + [quantity of seeds used]*
2	*Quantity of inputs per acre (kg/acre) = [Total quantity of inputs] / [area harvested]*
3	*Crop price (Tsh/kg) = [total value of sales] / [quantity sold]*
4	*Transport price (Tsh/ton-trip) = [amount paid to transport crop] / [quantity sold] x [1000]*
5	*Transport price (Tsh/ton-km) = [Transport price (Tsh/ton-trip)] / [distance crop transported to the market (for selling)]*
6	*Crop yield i.e. crop production per unit of land cultivated (kg/acre) = [quantity harvested] / [area harvested]*

Note: 1 hectare = 2.47 acres

Table 5.3 provides list of all the variables used in the analysis, including the computed variables.

Table 5.3: Summary of variables used in the analysis

Sn	Variable	Units	Description/file name*
1	*Crop name*		Descriptive, regression / All files
2	*Plot size/area*	Acre	Descriptive / AG_SEC_2A
3	*Main crop cultivated on a plot*		Descriptive / AG_SEC_3A
4	*Soil quality*		Descriptive / AG_SEC_3A
5	*Distance from the plot to the local market*	Kilometre	Regression / AG_SEC_3A
6	*Distance from the plot to the road*	Kilometre	Regression / AG_SEC_3A
7	*Whether plot was irrigated or not*		Descriptive / AG_SEC_3A
8	*Quantity of organic fertiliser used per plot*	Kilogram	Expression 1 / AG_SEC_3A
9	*Usage of organic fertiliser*		Descriptive / AG_SEC_3A
10	*Quantity of first inorganic fertiliser used per plot*	Kilogram	Expression 1 / AG_SEC_3A
11	*Usage of inorganic fertiliser*		Descriptive / AG_SEC_3A
12	*Quantity of second inorganic fertiliser used per plot*	Kilogram	Expression 1 / AG_SEC_3A
13	*Usage of inorganic fertiliser*		Descriptive / AG_SEC_3A
14	*Quantity of pesticides/herbicides used per plot*	Kilogram	Expression 1 / AG_SEC_3A
15	*Usage of pesticides/herbicides*		Descriptive / AG_SEC_3A
16	*How much of the plot area was planted*		Descriptive / AG_SEC_4A
17	*Whether crops were intercropped on not*		Descriptive / AG_SEC_4A
18	*Amount of seeds used*	Kilogram	Expression 1 / AG_SEC_4A
19	*Whether seeds used were improved seeds or not*		Descriptive / AG_SEC_4A
20	*Areas harvested*	Acres	Expression 2,6 / AG_SEC_4A
21	*Quantity harvested*	Kilogram	Expression 6 / AG_SEC_4A
22	*Total value of sale*	Tsh	Expression 3 / AG_SEC_5A
23	*Quantity sold*	Kilogram	Expression 3,4 / AG_SEC_5A
24	*If sold crops were transported or not*		Descriptive / AG_SEC_5A
25	*Distance crop transported to the market (for selling)*	Kilometre	Expression 5 / AG_SEC_5A
26	*Means of transport*		Descriptive / AG_SEC_5A
27	*Amount paid during transporting crops*	Tsh	Expression 4 / AG_SEC_5A
28	*Regional name*		Spatial distribution / AG_SEC_A
29	*Quantity of inputs per acre*	kg/acre	Regression / Computed
30	*Crop price*	Tsh/kg	Regression / Computed
31	*Crop yield*	kg/acre	Regression / Computed
32	*Transport price per ton per trip*	Tsh/ton-trip	Regression / Computed
33	*Transport price per ton per kilometre*	Tsh/ton-km	Descriptive / Computed

*Description provides the information about where the variable was used and the file name provide the name of the file from which the variable was obtained. **Expression** indicates that the variable was used to compute another variable given in Table 5.3, **descriptive** indicates that the variable was used in descriptive analysis, **regression** indicates that the variable was used in the regression analysis and **spatial distribution** means that the variable was used in describing the spatial distribution of the sample.

5.5. Analysis and results

This section provides analysis performed in this research, assumptions made during the analysis, the results that were obtained, and discussion.

5.5.1. Descriptive statistics at plot level

Some descriptive statistics at plot level were computed before aggregating the data, as the aggregated files do not contain crop information per plot but only crop information at a household level. After omitting the missing cases, the descriptive statistics described in Table 5.4 and 5.5 indicate that 83 percent of the plots were cultivated. Organic fertiliser was used on 11.8 percent of cultivated plots, first-type inorganic fertiliser on 11.2 percent of cultivated plots, second-type inorganic fertiliser on 36.8 percent of cultivated plots and herbicides/pesticides on 9.9 percent of cultivated plots. Improved seeds were used on 13.1 percent of cultivated plots, traditional seeds on 76 percent of cultivated plots and recycled improved seeds were used on 10.9 percent of cultivated plots. These results suggest that the usage of these agricultural inputs is not very high among the farmers. Roughly half of the cultivated plots contained multiple crops (50.9 percent of cultivated plots were reported to be intercropped). The data also suggest that the type of cultivation was typical rain-fed, as only 1.9 percent of cultivated plots were reported to be irrigated. Generally, soil quality was fairly good as 45.4 percent of the plots were reported to have good quality soil, 48.4 percent average quality soil and 6.2 percent poor quality soil. The results indicate that a large percentage of the farmers are smallholders. Roughly 80 percent of farm plots are less than 3 acres in size, with an average plot size of 2.9 acres (1.17 ha). Again, 38.1 percent of the plots were reported to be partially cultivated, that is, only part of the plot was planted.

Table 5.4: Summary descriptive statistics at plot level, 2012/13 NPS data

	Frequency						
	YES	**Percent**	**NO**	**Percent**	**Sub Total (N value)**	**Missing Data**	**Total**
Plot cultivated?	6183	83.0	1264	17	7 447	1 710	9 157
Use organic fertiliser?	725	11.8	5 441	88.2	6 166	2 991	9 157
Use first-type inorganic fertiliser?	691	11.2	5 477	88.8	6 168	2 989	9 157
Use second-type inorganic fertiliser?	254	36.8	437	63.2	691	8 466	9 157
Use pesticide/herbicide?	608	9.9	5 559	90.1	6 167	2 990	9 157
Plot irrigated?	117	1.9	6 195	98.1	6 312	2 845	9 157
Cultivation intercropped?	2 506	50.9	2 422	49.1	4 928	2 249	7 177
Crop planted entire plot?	3 048	61.9	1 879	38.1	4 927	2 250	7 177

Table 5.5: Summary descriptive statistics at plot level, 2012/13 NPS data

		Frequency	Percent	Cumulative Percent
Soil Quality	Good	2 864	45.4	45.4
	Average	3 053	48.4	93.7
	Bad	397	6.2	100.0
	Sub Total (N Value)	6 314	100.0	
	Missing	2 843		
	Total	9 157		
Types of seeds used	Improved	1 036	13.1	13.1
	Traditional	6 027	76.0	89.0
	Improved, recycled	864	10.9	99.9
	Other	7	0.1	100.0
	Sub Total (N value)	7 934	100.0	
	Missing	2 249		
	Total	10 183		
Plot size	Less than 3 acres	6 005	80.6	
	More than 3 acres	1 442	19.4	
	Sub Total (N value)	7 447	100	
	Missing	1 710		
	Total	9 157		

5.5.2. Descriptive statistics at household level

The aggregated data set provided crop information at household level (see Figure 5.1). The data set provided 64 different types of crops (Table A3.5 in Appendix 3) and a household may cultivate more than one type of crop.

5.5.2.1. Crop selling and transportation

A household may sell part of the harvested crops or not sell at all. Among those who sold their crops, some of the households reported transporting their crops to the markets. The data provided in Table 5.6 indicate that 38 percent of cultivated crops were sold, of which 30.6 percent were reported to be transported to the markets. Of the 30.6 percent who transported their crops to the markets, 62.8 percent reported paying nothing for the transportation of the crops. This may indicate that family labour was used (see Section 5.5.2.3). A further analysis revealed that only 4.3 percent (n = 261) of the total number of harvested crops (n = 6 070) included payment when transported to the market for selling.

Table 5.6: Descriptive statistics: Crop selling and transportation, 2012/13 NPS data

	Frequency						
	YES	**Percent**	**NO**	**Percent**	**Sub Total (N value)**	**Missing Data**	**Total**
Did you sell crops?	2 302	38	3 768	62	6 070	2 417*	8 487
Did you transport crops for selling?	704	30.6	1 598	69.4	2 302	6 185	8 487
Pay for transport service?	261	37.2	443	62.8	704	7 783	8 487

*Not reported

Generally, these results suggest that most of the farmers engage in subsistence farming; only a few sold their crops.

The results in Table 5.7 show that, on average, those who sold crops had significantly bigger farm sizes and higher quantity harvested. However, there was no significant difference in crop yield between the two groups. The results also show that bigger farms were further from the road and from the local market. It is normal to have people reside close to the road (residential areas), and they may have relatively small farms near their homes and bigger farms further from their homes.

Table 5.7: Difference in farm size, crop production and distance variables, 2012/13 NPS data

Variable description		Did you sell crops?		
		YES (N value = 2 302)	**NO (N value = 3 768)**	**P value**
Area harvested (acres)*	Mean	2.5	1.5	0.000
	Median	1.5	1.0	
	Std. Dev	4.7	2.9	
Quantity harvested (kg)*	Mean	906	310	0.000
	Median	400	120	
	Std. Dev	2 006	1 271	
Crop yield (kg/acres)*	Mean	552	445	0.445
	Median	286	160	
	Std. Dev	1 313	8 442	
Distance from the farm to the road (km)	Mean	3.0	2.0	0.000
	Median	1.0	1.0	
	Std. Dev	7.6	5.4	
Distance from the farm to the local market (km)	Mean	12.5	10.2	0.000
	Median	7.3	6.0	
	Std. Dev	15.8	13.8	

*Values for all crops

The results in Table 5.8 show that those who sold but did not transport their crops for selling had a significantly higher crop yield, however, there was no significant difference in the quantity they harvested and the quantity they sold when compared to those who reported transporting their crops to market for selling. The data set, however, did not reveal how the farmer's products reach the market. Therefore, not much can be said about the agricultural production of these farmers in the context of road infrastructure and associated transport prices involved in transporting their crops to the market. The average crop price was significantly higher for those who transported their crops compared to those who did not. Looking at the distance variables, it was also found that there is no significant difference between the average distances from the farm to the road and from the farm to the local market between these two groups of farmers.

Table 5.8: The differences between transported vs non-transported crops, 2012/13 NPS data

Variable description		**Transported crops for selling?**		
		YES (N value =704)	**NO (N value = 1598)**	**P value**
Area harvested (acres)*	Mean	2.7	2.3	0.041
	Median	1.5	1.4	
	Std. Dev	4.0	5.0	
Quantity harvested (kg)*	Mean	883	917	0.747
	Median	397	400	
	Std. Dev	2 549	1 715	
Crop yield (kg/acres)*	Mean	462	592	0.004
	Median	250	300	
	Std. Dev	646	1516	
Quantity sold (kg)*	Mean	565	547	0.729
	Median	212.5	200	
	Std. Dev	1 034	1 372	
Crop price (Tsh/kg)*	Mean	819	696	0.000
	Median	650	500	
	Std. Dev	731	666	
Distance from the farm to the road (km)	Mean	2.7	3.0	0.337
	Median	1.0	1.0	
	Std. Dev	6.3	8.1	
Distance from the farm to the local market (km)	Mean	12.9	12.3	0.400
	Median	8.0	7.0	
	Std. Dev	15.4	15.9	

*Values for all crops

The results in Table 5.9 show that those who paid for transport services, transported their crops to a more distant market for selling, compared with those who did not pay. Those who paid for transport service had farms significantly further from the local market. There was no significant difference for the distance from the farm to the road between these two groups. Those who paid for transport services had a significantly higher crop yield, crop price and quantity sold.

Table 5.9: Differences between those who pay and those who did not pay for transport services, 2012/13 NPS data

Variable description		Did you pay for transport services?		
		YES (N value = 261)	**NO (N value = 443)**	**P value**
Area harvested (acres)*	Mean	2.7	2.8	0.737
	Median	2.0	1.3	
	Std. Dev	3.5	4.3	
Quantity harvested (kg)*	Mean	1 074	769	0.073
	Median	600	300	
	Std. Dev	1 494	2 997	
Crop yield (kg/acres)*	Mean	578	393	0.001
	Median	317	216	
	Std. Dev	770	551	
Quantity sold (kg)*	Mean	820	414	0.000
	Median	440	140	
	Std. Dev	1 267	834	
Crop price (Tsh/kg)*	Mean	909	767	0.017
	Median	660	610	
	Std. Dev	808	676	
Distance from the farm to the road (km)	Mean	3.2	2.3	0.077
	Median	1.0	1.0	
	Std. Dev	6.9	5.8	
Distance from the farm to the local market (km)	Mean	16.4	10.7	0.000
	Median	10.0	7.0	
	Std. Dev	20.4	11.0	
Distance to the market for selling (km)	Mean	22.5	6.9	0.000
	Median	9.0	4.0	
	Std. Dev	49	9.7	

*Values for all crops

5.5.2.2. Farm-gate and market price

Farm-gate price is the price of a product available at the farm, excluding any separately billed transport or delivery charges. Market price, in turn, is the price at which a product is offered at the marketplace. In the 2012/2013 data set, the farm-gate price and market price were not explicitly reported. In this research, however, the reported crop price from the farmers who did not transport their crops for selling was regarded as the farm-gate price, while the market price was considered to be the reported crop price from the farmers who did transport their crops to the markets. The argument is that farmers reported the crop price depending on the place they sell their crops.

Maize and paddy/rice, the most common food crops, were used to analyse the difference between farm-gate price and market price. Table 5.10 provides details on the number of households which cultivated these crops, sold and reported transporting the crops. Of the 581 households which sold maize, only 126 households transported their crops to the markets. In the case of paddy/rice, out of 291 households which sold the crop, only 58 households transported this crop to the market.

Table 5.10: Household crop cultivation, selling and transportation, 2012/13 NPS data

Crop	No. of households that cultivated crops	No. of households which sold the cultivated crops	No. of households not transporting crops to the markets	No. of household transporting crops to the markets	No. of households paying for transport services	No. of households not paying for transport services
Maize	2070	581	455	126	52	74
Paddy/rice	691	291	233	58	24	34

Table 5.11 shows that the mean prices of the transported maize and paddy/rice are higher than the mean prices of non-transported maize and paddy/rice. Although not statistically significant, on average, the price of transported maize was 6 percent more and paddy/rice 19 percent more compared with their corresponding prices when not transported.

Table 5.11: Price of transported versus non-transported crops, 2012/13 NPS data

Variable description		Crop transported?							
		Maize				Paddy			
		YES (N value =126)	NO (N value = 455)	Diff (%)	P value	YES (N value = 58)	NO (N value = 233)	Diff (%)	P value
Crop price (Tsh/kg)	Mean	459	433	6	0.354	858	719	19	0.140
	Median	400	360	11		667	648	2.9	
	Std. Dev	265	321			657	536		
Distance to the market for selling (km)	Mean	12.1	na			20.7	na		
	Median	6.0	na			9.0	na		
	Std. Dev	14.7	na			27.1	na		
Transport price (Tsh/ton-trip)	Mean	11 919	na			11 809	na		
	Median	0.0	na			0.0	na		
	Std. Dev	18 799	na			18 510	na		

(Exchange rate, 2013: 1USD = Ths 1600), na = not applicable

It is expected that the farm-gate price, profit margin, transport price and other logistics cost would add up to the market price. Using the average transport prices per trip and the crop prices (Table 5.11), this relationship was illustrated for maize and paddy/rice. The results in Table 5.12 show that the price of maize at the market was higher by 3.2 percent than the sum of the farm-gate price and transport price. The price of paddy/rice at the market was 17.4 percent higher than the sum of farm-gate price and transport price. These results indicate that farmers are obtaining better crop prices if they transport their crops to the market for selling. Although there are numerical differences between the farm-gate and market price, the results in Table 5.11 and 5.12 should be read with caution because the differences between the two prices are not statistically significant.

Table 5.12: Relationship between farm-gate price, transport price and market price, 2012/13 NPS data

Crop	Farm-gate price (Tsh/kg) (A)	Transport price (Tsh/kg) (B)	Sum (Tsh/kg) (C = A + B)	Market price (Tsh/kg) (D)	Difference (Tsh/kg) (E = D – C)	Difference (%) (E/C*100)
Maize	433	11.919	444.919	459	14.081	3.2
Paddy/rice	719	11.809	730.809	858	127.191	17.4

(Exchange rate, 2013: 1USD = Ths 1600)

5.5.2.3. Mode of transport

Four different modes of transport were reported to be used to transport crops to the market (Table 5.13). The results indicate that, on average, the Non-Motorised Transport (NMT) trips are shorter compared to car trips. NMT includes walking, cycling or the use of animals. The results also show almost all those who reported not paying for transport services use NMT modes. This may indicate that the family members together with animals or bicycles were used, the cases where there is no need for payment.

Table 5.13 also shows that in some instances where hired NMT modes were used, they charge a higher transport price than that of the usage of cars. Cars were more frequently used by the farmers who reported to pay for transport services.

Table 5.13: Mode of transport, distance, payment for transport service, 2012/13 NPS data

Means of transport	**Pay for transport service (N value = 261)**		**Not pay for transport service (%) (N value = 443)**	**Average distance to the market for selling (km) (N value = 704)**
	(%)	Transport price (Tsh/ton-km)		
On Foot	2.3	4 229	28.7	5
Bicycle	21.4	3 353	51.4	8
Animal	17.6	2 806	14.0	6
Car	42.7	2 220	0.5	44
Other	16.0		5.4	
Total	100		100	

(Exchange rate, 2013: 1USD = Ths 1600)

5.5.3. Agriculture and transport service

Considering the effect of transport infrastructure and service on the agricultural sector, four aspects were examined:

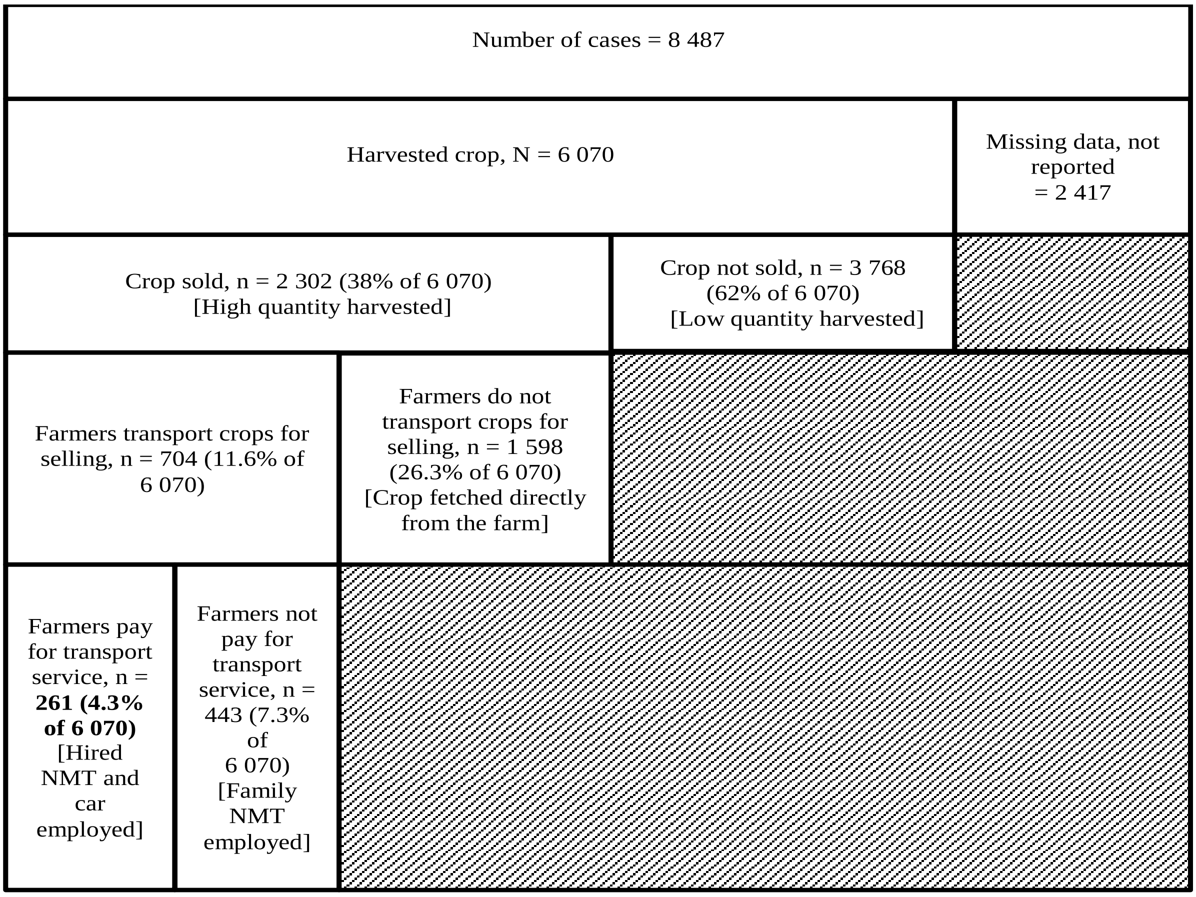
(i) The price of transporting agricultural products.

(ii) The distance from the farm to the road.

(iii) The distance the crop is transported to the market for selling (market for selling can be a physical local market or any other market or a place where farmers sell their crops to individual buyers or institutions).

(iv) The distance from the farm to the local market.

Crop yield, as the dependent variable, was used to determine the relationship between agricultural production and transport services. The analysis included only the farmers who reported transporting their crops to the market and paying for the transport service, which constituted 261 cases, equivalent to 4.3 percent of the total number harvested crops (see Table 5.6 and Figure 5.2).



Source: Author

Figure 5.2: Sub-sample used in the regression analysis

5.5.3.1. Crop yield and transport service

Crop yield can be defined as the quantity of the harvested crops per unit area of the land cultivated. Crop yield may be influenced by, among other things, the usage of the agricultural inputs, the available technology, weather conditions and the soil type. This research examines the relationship between road infrastructure, transport services and crop yield. Ordinary least squares (OLS) regression was used to empirically quantify this relationship.

The OLS model comprises of six independent variables with crop yield as the dependent variable. The list below presents a brief description of the independent variables used in the analysis:

(i) **Agricultural inputs** such as inorganic fertiliser and improved seeds are not manufactured in the rural areas, and have to be transported from the area of production to the rural areas. The transport service and associated transport cost during the transportation of the agricultural inputs may, in one way or another, affect the usage of the inputs and eventually the crop yield.

(ii) **Crop market prices** act as an incentive/disincentive to the farmers in relation to the crop yield. Higher crop prices may motivate the farmer to produce more and vice versa. The cost associated with transporting the crops to the market will impact the market price.

(iii) The **distance from the farm to the road** was used to measure the influence of road infrastructure availability on crop yield.

(iv) The **distance the crops were transported to the market for selling** was used to measure the influence of the distance travelled by farmers to sell their crops on crop yield.

(v) The **distance from the farm to the local market** was used to measure the influence of local market vicinity on crop yield.

(vi) **Transport price** was included in the variable list in order to measure its direct effect on crop yield.

The empirical model is presented in Equation 5.1:

Crop yield = f(Quantity of input per unit land, market crop price, transport price, distance from the farm to the road, distance from the farm to the local market, distance crop transported to the market for selling) (5.1)

Each crop has a range of expected harvest per unit of land cultivated. Tomatoes, for example, have an average yield of 7 ton/ha, while the average yield for green grams is 0.2 ton/ha (values obtained from the 2012/13 NPS data). Combining different types of crops will distort the results. In order to control for the effect of the different crop types, the crops were divided into 14 groups, and 13 dummy variables were created, with vegetable and roots and tubers as base crops (Table 5.14). The groups are: (i) sesame; (ii) tobacco; (iii) cotton; (iv) pigeon peas; (v) cow peas; (vi) chickpeas; (vii) green grams; (viii) sorghum; (ix) maize; (x) beans; (xi) paddy/rice; (xii) groundnuts; (xiii) tomatoes; and (xiv) vegetables and roots and tubers. Table 5.14 provides a list with units of all variables used in the model. All the variables were log-transformed, except dummy variables, to reduce the skewness and to have data approximately normally distributed (see an example of crop yield histograms with a normal curve displayed in Figure A3.1 in Appendix 3). The final empirical model is presented in Equation 5.2:

$$ln(Y) = \beta_1 + \beta_2 ln(X_2) + \cdots \beta_n \, ln(X_n) + \alpha_1 D_1 + \cdots \alpha_k D_k + \mu, \tag{5.2}$$

where:

- Y = Crop yield;
- $X_2, X_3, \ldots, X_n$ = Factors that may affect crop yield;
- $\beta_2, \beta_3, \ldots, \beta_n$ = Coefficients;
- $\alpha_1, \alpha_2, \ldots, \alpha_k$ = Dummy variables coefficients;
- $D_1, D_2, \ldots, D_k$ = Dummy variables for different types of crops; and
- μ = Error term.

Table 5.14: Variables used in the crop yield model

	Variables	**Units**	**Observation* (N)**
Dependent variable	*ln(Crop yield)*	kg/acre	261
Independent variables	*ln(Quantity of input per acre)*	kg/acre	261
	ln(Market crop price)	Tsh/kg	261
	ln(Transport price per trip)	Tsh/ton-trip	261
	ln(Distance from the farm to the road)	km	261
	ln(Distance from the farm to the local market)	km	261
	ln(Distance crop transported to the market for selling)	km	261
	Dummy (Beans)		
	Dummy (Chick Peas)		
	Dummy (Cotton)		
	Dummy (Cow Peas)		
	Dummy (Green Gram)		
	Dummy (Groundnuts)		

Dummy (Maize)
Dummy (Paddy/Rice)
Dummy (Pigeon Peas)
Dummy (Sesame)
Dummy (Sorghum)
Dummy (Tobacco)
Dummy (Tomatoes)

*Only those reported to transport and pay for the transport service are included in the analysis (see Figure 5.2)

Table 5.15 provides the results of the ordinary least squares (OLS) regression. Tests to check for multicollinearity and heteroscedasticity were also performed.

Table 5.15: Crop yield, regression model results

Dependant variable: ln(Crop yield)	***Coefficients***	***P-values***	***Significant F***	***Adjusted R square***
(Constant)	7.559	.000	.000	.435
ln(Transport price-Tsh/ton-trip)	-.291	.000		
ln(Market crop price-Tsh/kg)	.056	.462		
ln(quantity of input per acre)	.080	.008		
ln(Distance from the farm to the road – km)	-.014	.684		
ln(Distance from the farm to the local market – km)	.058	.235		
ln(Distance crop transported to market for selling – km)	.161	.002		
Dummy (Beans)	-.497	.054		
Dummy (Chick Peas)	-1.427	.110		
Dummy (Cotton)	-.431	.072		
Dummy (Cow Peas)	-.171	.791		
Dummy (Green Gram)	-1.876	.000		
Dummy (Groundnuts)	-.596	.040		
Dummy (Maize)	.503	.019		
Dummy (Paddy)	.842	.002		
Dummy (Pigeon Peas)	-.715	.027		
Dummy (Sesame)	-.849	.011		
Dummy (Sorghum)	.308	.635		
Dummy (Tobacco)	-.048	.878		
Dummy (Tomato)	1.285	.001		

Test for multicollinearity

One of the assumptions of the classical linear regression model is that there is no perfect multicollinearity, that is, there are no exact linear relationships among the independent variables. In Model 5.15 (Table 5.15) two approaches were used to test for the multicollinearity of the variables. First, Pearson's correlations between independent variables were computed and examined (Table A3.6 in Appendix 3). The results indicated low correlations between independent variables, with the highest value being 0.592 between log-transport price and log-crop price. Secondly, the variance inflection factors (VIF) were computed (Table A3.7 in Appendix 3). The results indicated low VIF values, below 3, except for the cotton dummy variable, with a value of 3.14. These results suggest that Model 5.15 does not exhibit multicollinearity.

Test for heteroscedasticity

The classical linear regression model assumes the homoscedasticity condition. However, when panel data are used in the analysis, there are higher chances of the "error variance" not being constant, which implies heteroscedasticity. From the results of Model 5.15, the scatter plot of the squared unstandardised residuals versus the unstandardised predicted value (Figure 5.3) indicates that heteroscedasticity may be present in the data. Another three tests, the Breusch-Pagan test, Park test and White's test were performed as well. The Breusch-Pagan test was performed by replacing the dependent variable in Model 5.15 by the square of the unstandardised residuals and regressing with all the independent variables of Model 5.15. The regression results were statistically significant (Table A3.8 in Appendix 3), suggesting that according to the Breusch-Pagan test, heteroscedasticity is present in the data.

The squared unstandardised residuals of Model 5.15 were regressed with the unstandardised predicted values in the Park test (Table A3.9 in Appendix 3). The regression results were not statistically significant, suggesting there is no heteroscedasticity in the data. The White's test was performed by regressing the squared unstandardised residuals of Model 5.15 with the unstandardised predicted values and the squared unstandardised predicted values (Table A3.10 in Appendix 3). The F-test and t-test results were not statistically significant, indicating that there is no heteroscedasticity in the data. The chi-square value of 1.044 with two degrees of freedom ($n*R^2$: 261*0.004 = 1.044) was obtained with the p-value of 0.593, supporting the results that heteroscedasticity is not present in the data. The results from the two tests suggest that homoscedasticity condition is satisfied.

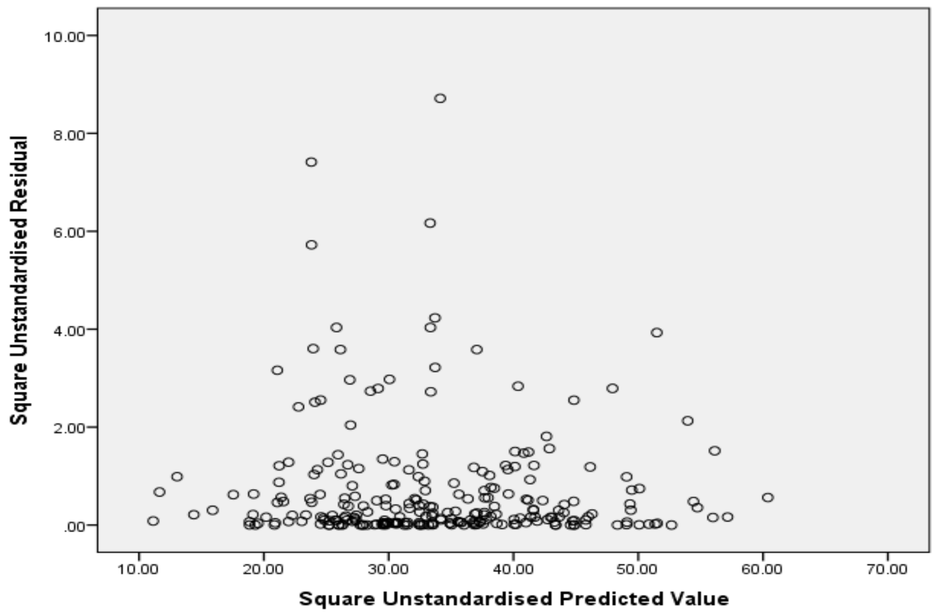


Figure 5.3: Squared unstandardised residues vs unstandardised predicted values

Model interpretation

The results of the model (Table 5.15) are statistically significant with an adjusted R-square value of 0.435, meaning that 44 percent of the variation in crop yield is explained by the linear regression model. The transport price showed a negative relationship with crop yield with an elasticity of -0.291, implying that a one percent reduction in the transport price is associated with an increase in crop yield by 0.291 percent. These results corresponded well with the results suggested by Hine & Ellis (2001) which showed that a 20 percent reduction in transport cost, fully passed on to farmers, will raise the agricultural output by 6 percent, or stated differently, that a one percent reduction in the transport cost will raise the agricultural output by 0.3 percent. Limi *et al.* (2015) using the data from East Africa also found that a one percent reduction of transport price and waiting time cost could increase crop production by more than one percent with higher elasticity for export crops compared to domestic food crops.

The distance that crops are transported to the market for selling showed a positive relationship with crop yield, with an elasticity of 0.161. These results imply that a one percent increase in the distance farmers transport their crops to the market for selling will increase the crop yield by 0.161 percent. This finding is surprising, as one would expect that those who sell to the nearby markets will have fewer market access problems and lower transport charges, both of which may impact positively on crop yield. Two possible reasons may be associated with these results:

(i) Those who sell their crops at more distant (relatively bigger) markets are more exposed and have a higher chance of accessing goods and services which may not be available locally. Such as agricultural inputs, advice from extension officers and people they meet which in turn facilitate the increase in crop yields.

(ii) Selling at more distant markets is associated with a lower unit transport price measured in *per ton-km* (see Figure A3.2 in Appendix 3), as well as a higher crop price. The longer routes have the advantage of economy of distance; the road conditions are relatively good (secondary roads leading to the bigger markets) and the use efficient modes of transport (longer trips use cars as opposed to walking and cycling). Relatively speaking, those who sell at more distant markets are better off in terms of transport price and crop price, which in turn facilitates an increase in crop yield.

The quantity of inputs per acre showed a positive relationship with crop yield, with an elasticity of 0.080. A one percent increase in the quantity of input per acre will increase the crop yield by 0.08 percent. The analysis showed no statistically significant relationship between crop yield and market crop price.

It is expected that if the farm is closer to the road, there are benefits such as lower transport prices and ease of access to the farm, which may be associated with higher crop yield. However, the analysis showed no statistically significant relationship between the distance from the farm to the road and crop yield. This could be due to the fact that most of the tertiary roads near the farms are of poor quality and do not provide sufficient transport services required to lower the transport price. As a result, no significant reduction of transport price which may facilitate increase in crop yield was observed. This was revealed by the low and statistically insignificant correlation between the distance from the farm to the road and the transport price (see Table A3.6 in Appendix 3). Table A3.6 in Appendix 3 provides Pearson's correlation results between all the independent variables used in the analysis.

The distance from the farm to the local market also reveals no statistically significant relationship with crop yield. As discussed, farmers who sell their crops at a more distant market have the advantage of increasing crop yield. The fact that the distance from the farm to the local market was not statistically significant gives a clue that the local market alone is not providing enough goods and services required by the farmers to facilitate the increase in crop yields.

Dummy variables coefficients showed the expected results, with the highest coefficient for tomatoes, 1.285, and lowest for green grams, -1.876. This means that, on average, yield of tomato is approximately 128.5 percent higher than the yield of vegetables and roots and tubers. Again for the case of the green grams the dummy coefficient show that, on average, the yield of green grams, on average, is approximately 187.6 percent less than the yield of vegetables and roots and tubers.

The model results show that the distance from the farm to the local market and the distance to the market for selling have different impacts on crop yield. Therefore, it was interesting to find out at which market crops were sold. Table A3.11 in Appendix 3 provides a list showing to which institution, individual buyers or physical market the farmers reported to sell their crops during the 2012/13 NPS, referred to in this chapter as the market for selling. Furthermore, a one-to-one comparison between the distance from the farm to the market and the distance to the market for selling was done[22] (Table 5.16). Of the 261 cases compared, 75 cases (29%) showed equal distances, implying that these crops were sold at the local market. For the remaining cases, the results showed that 133 crops (43%) were sold at a distance shorter than the distance to the local market and 73 crops (28%) at a distance longer than the distance to the local market.

Table 5.16: One-to-one comparison between the distance from the farm to the local market and distance to the market for selling

	Crops sold at the local market	**Crops sold at a place nearer than the local market**	**Crop sold at place further from the local market**
Number of sold crops	75 (29%)	113 (43%)	73 (28%)

5.5.3.2. Relationships between farm size, crop yield and distance from the farm to the road

The relationships between farm size, crop yield and the distance from the farm to the road were examined. The Pearson's correlation results, Table 5.17, showed a negative correlation between farm size and crop yield, meaning that small-size farms are associated with a high crop yield. The distance from the farm to the road showed a positive correlation with farm size, meaning that small farms are closer to the road compared to bigger farms. Since small farms are associated with a high yield and are closer to the road, it may be concluded that the

[22] (i) The distance from the farm to the local market is the average distance for all the farms cultivated by a household
(ii) The distance to the market for selling does not indicate where the crops are coming from. It was assumed that the crops were coming from the farm as well.

farms that are closer to the road exhibit high yields. Surprisingly, crop yield had a statistically insignificant correlation with the distance from the farm to the road. These results suggest that the high yields seen on small farms are not necessarily because of them being closer to the road. Other factors probably also contributed to the high yields. The size of farm has statistically significant positive correlation with the quantity harvested, meaning that the bigger farms are associated with high quantity of harvests. The bigger farms, however, are associated with low crop yields. Therefore, it can be concluded that the high quantity of harvests seen on the bigger farms are influenced by the size of the farm and not by the high crop yield. This results correspond well with the suggestion by the World Bank (2013a) that in Africa, the agricultural production increase is largely influenced by the increase in the area under cultivation and not productivity or yield.

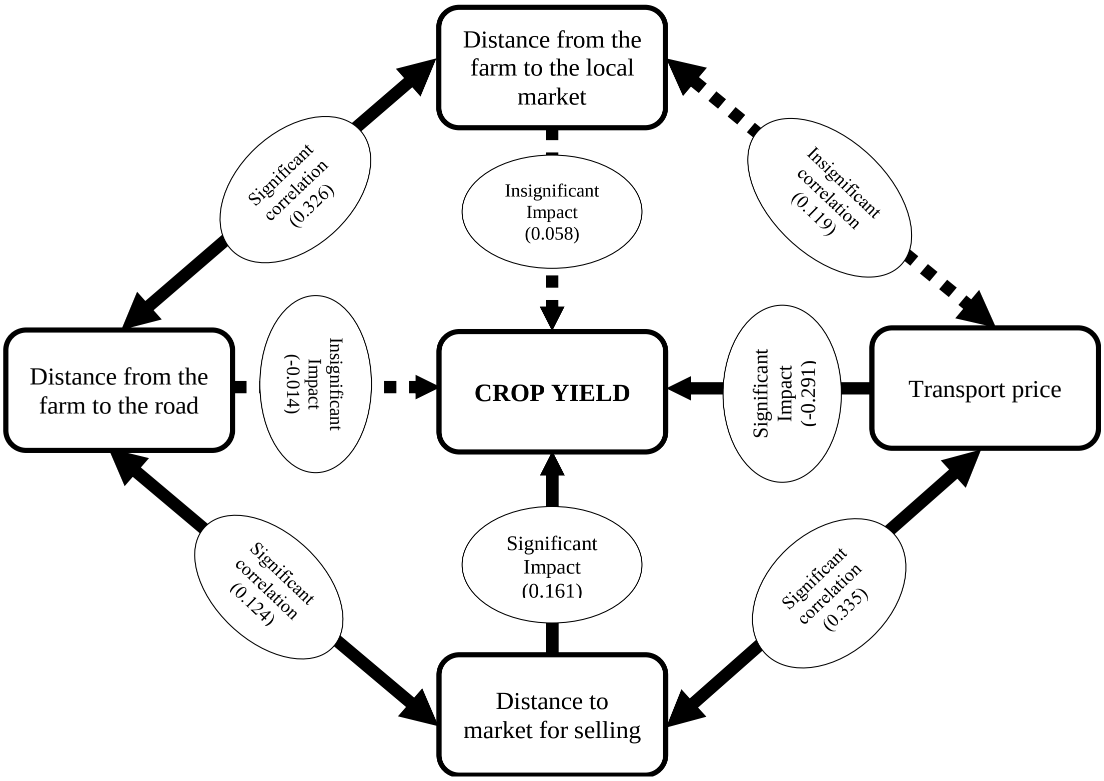
Table 5.17: Relationship between farm size, crop yield and distance from the farm to the road

		Farm size (acres)	Distance from the farm to the road (km)
Crop yield(kg/acre)	Pearson correlation	-.175	-.035
	Sig. (2-tailed)	.005	.570
	N	261	261
Distance from the farm to the road (km)	Pearson correlation	.165	1
	Sig. (2-tailed)	.007	-
	N	261	261
Quantity harvested (kg)	Pearson correlation	0.397	.046
	Sig. (2-tailed)	.000	.459
	N	261	261

5.6. Conclusion and recommendations

Descriptive statistics show that roughly 80 percent of the cultivated plots are less than 3 acres, with an average farm size of 2.9 acres (1.17ha), implying that the agricultural sector is dominated by the smallholder farmers. The dominant farming practice is also subsistence farming, as only 38 percent of the farmers sold their crops. The majority did not produce crops for commercial purposes. Those who sold their crops, on average, produced a higher quantity of harvest. Of the 38 percent who sold their crops, only 31 percent transported their crops to the market for selling. Several modes of transport were used to transport crops to the market, ranging from walking to the use of cars. The average trip distance to the market ranges from 5 – 44 km. NMT modes were used for shorter trips and cars for longer trips.

Using the regression model results (Table 5.15) and the Pearson's correlation results (Table A3.6 in Appendix 3), Figure 5.4 was constructed to summarise the findings of the chapter. The figure shows the relationship between crop yield, transport price and the distance variables.



Source: Author

Figure 5.4 : Relationship between crop yield, road infrastructure and transport service

A reduction in the transport price for transporting agricultural products has a positive impact on the agricultural yield. The elasticity of this impact is -0.291, meaning that a one percent reduction in transport price increases the crop yield by 0.291 percent. This expected change concurs with the results of Hine & Ellis (2001), who suggest that a one percent reduction in transport cost, fully passed to farmers, will increase agricultural output by 0.3 percent. Investing in road infrastructure in order to reduce transport costs and prices would, therefore, benefit the agricultural sector.

This research has also revealed that those farmers who sell their crops at a more distant market have higher crop yield compared to those who sell at a nearby (local) market. This could be due to the fact that those who sell at a distant market have the advantage of accessing goods and services which may not be available locally. They have a higher chance of accessing agricultural inputs and advice from extension officers and people they meet from a more distant market. The fact that the distance from the farm to the local market had an insignificant effect on crop yield gives a clue that the local market does not provide enough goods and services required to facilitate the increase in crop yield. Again, those farmers who sell their crops at a more distant (potentially bigger) market have the advantage of getting higher crop prices and low unit transport prices. The low unit transport price is attributed to the factors such as usage of efficient modes of transport, economy of distance and travelling on better (secondary) roads that leading to the bigger markets. Improving access to the bigger markets could therefore benefit farmers and subsequently increase agricultural production.

Small farms were found to be closer to the road and exhibit higher crop yield. However, being closer to the road was not a direct reason for having higher yields, because there was no significant relationship between crop yield and the distance from the farm to the road. The size of the farm has a significant effect on the quantity harvested: bigger farms are associated with more harvests. Looking at crop yield, however, it was found that bigger farms had lower yields compared to small farms. This means that the higher quantities of harvest seen on the bigger farms are influenced by the size of the farm, and not the high yield. The World Bank (2013a) also suggested similar pattern that in Africa, the agricultural production increase is largely influenced by the increase in the area under cultivation and not productivity or yield.

The established empirical relationship between transport price and crop yield can be used during the road appraisal processes to quantify the expected increase in agricultural yields following the road infrastructure investment. Road infrastructure investment lowers transport cost and hence transport price (see Section 4.6 in Chapter 4). However, in order to improve agricultural yield and production, an improved rural road network must be linked to the secondary roads which provide access to the bigger markets (improve access to bigger market); otherwise, it will not have the necessary impact on the agricultural sector. Improved connectivity allows for competitive transport market and even lower transport prices (see Section 4.6 in Chapter 4).

Chapter 6 : Low-Volume Rural Roads Appraisal: The Context of Agricultural Benefits

6.1. Introduction

Using the conventional economic evaluation approach commonly known as cost-benefit analysis (CBA), and tools such as Highway Development Management (HDM-4) and Road Economic Decision (RED), planned improvements of low-volume rural roads are often found to be economically unviable because of the low traffic volume associated with these roads (Schutte, 2005; Transport Research Laboratory, 2005). These tools mainly concentrate on the benefits due to savings in road user costs (i.e. vehicle operating cost, travel time, and accident cost). Economic development benefits, such as the agricultural surplus, are expected to manifest themselves as generated traffic (Transport Research Laboratory, 2005). However, relying on these road user benefits, a low-volume rural road will often exhibit very little benefits to offset the construction and/or maintenance costs of the planned intervention (Transport Research Laboratory, 2005). Investment in low-volume rural roads, however, may be associated with substantial social and agricultural benefits, which are not captured by the conventional road economic appraisal tools (Kerali, 2003; Lucas & Jones, 2012). Archondo-Callao (2004) suggested that for roads with less than 50 vehicles per day, multi-criteria analysis (MCA) or cost-effectiveness analysis (CEA) should be used in evaluations, as these methods succeed in estimating the social benefits of a rural road investment to some extent. Lebo & Schelling (2001) and OECD (2011), however, pointed out that MCA can be non-transparent, and is often associated with a subjective evaluation. CEA, on the other hand, can be used to rank different planned interventions, but it does not provide sufficient justification on the economic return of the planned intervention. As discussed in Section 1.11, it is clear that the existing tools and techniques are inefficient to conduct an economic evaluation of low-volume rural roads.

It is the aim of this research to narrow the gap by developing a low-volume rural road appraisal framework which accounts for wider agricultural benefits. The framework can be considered as an extension to cost-benefit analysis. However, this framework uses transport *price* to assess the expected benefits rather than transport *cost*, which is commonly used in economic evaluations.

Generally, the improvement of a low-volume rural road and the subsequently improved connectivity is associated with a reduction in transport costs and prices, and a change in the trip distance of freight vehicles (see Section 4.6 and Figure 4.1). Such a road improvement and the improved connectivity may allow longer trip distances (Headicar, 2009; Lançon *et al.*, 2014), higher vehicle utilisation, and increased competition in the transport market. The empirically established relationship between transport price, transport cost and trip distance (discussed in Section 4.6), together with the elasticity of crop yield (discussed in Section 5.5.3.1), are used here to determine the increase in agricultural yields following an improvement to a low-volume rural road.

6.2. A practical illustration of the proposed framework for appraising low-volume rural road

6.2.1. Study area and data

Data from the Kilosa district in the Morogoro region in Tanzania (Figure 3.1) was used to illustrate this approach of appraising low-volume rural roads. The data collected from the study area include information about the road network, and related details such as traffic volumes, vehicle characteristics, the condition of the roads, and maintenance and construction unit costs and standards. Agricultural details such as agricultural products prices, crop yields and cultivated land are also provided. The road network and related information were obtained from the road agencies during interviews. Agricultural details were obtained during interviews with agricultural officers (see Section 3.2.1).

6.2.1.1. Road network, traffic data and road works unit costs

Table A4.6 in Appendix 4 shows the road network of the Kilosa district. The network consists of trunk, regional, collector, urban and feeder roads. Within the district, all road classes except urban roads accommodate an average traffic volume of less than 200 vehicles per day. Different roads of the same class show different traffic volumes; however, for the purpose of conducting the analysis with HDM-4, the traffic volumes in Table A4.7 in Appendix 4 were used for each specific road class. Based on traffic surveys and forecast for some projects conducted in the Tanzania, an annual traffic growth rate of 6.5 percent was adopted for all types of vehicles. Vehicle characteristics and associated economic unit costs used in the analysis are provided in Table A4.8 in Appendix 4. Road works unit costs provided in Table A4.9 in Appendix 4 were assigned to different road classes depending on the intended treatment. A discount rate of 12 percent was used in the economic analysis.

6.2.1.2. Agricultural data

Table A4.10, Appendix 4, provides the agricultural data used in the analysis. Crop prices, crop yields and land distribution (i.e. the distribution showing out of the total land cultivated how much is for each specific crop) for twelve crops cultivated in the Kilosa district are provided. Using the crop production data for ten different crops for a period of 2004 to 2012 (Tanzania National Bureau of Statistics, 2015c), an average annual crop production growth rate of 4.5 percent was determined and used in this analysis (see Appendix 4 for details of determination of crop production growth rate).

6.2.2. Road standards and alternatives used in the analysis

The road network of the Kilosa district in Morogoro was used to illustrate the process of the economic evaluation of low-volume rural roads. The details of the proposed intervention measures implemented to deliver good or fair conditions of rural roads are provided in Table 6.1.

Three guidelines informed the standards for the improvement of roads used in this analysis: (i) the Overseas Road Note 20 (ORN 20); (ii) the Tanzania Road Geometric Design Manual of 2003; and (iii) the Tanzania Pavement and Materials Design Manual of 1999 (Tanzania Ministry of Works, 1999, 2011; Transportation Research Laboratory, 2003a). The principle of maintaining roads to provide basic access was adopted from the ORN 20 (Transportation Research Laboratory, 2003a). Therefore, in setting the improvement standard for unpaved roads, the target was to ensure fair road conditions throughout the year. Unpaved roads in fair condition are sufficient to provide basic access in rural areas (see Figure A4.1 in Appendix 4). The Tanzania Road Geometric Design Manual (Tanzania Ministry of Works, 2011) proposes design standards according to the volume of traffic accommodated by the road. These design standards were used as a guide in deciding the surface type to be employed on different roads. The material types and pavement thicknesses were obtained from the Tanzania Pavement and Materials Design Manual (Tanzania Ministry of Works, 1999). More details about these guidelines are provided in Appendix 4.

Table 6.1: Improvements standards and targeted road conditions

Sn	Road class and condition	Base alternative		Intervention / Alternatives		
		Road works description	Roughness (IRI)	Road works description		Targeted condition all year-round and roughness (IRI)
1	Gravel-Urban roads in fair and poor condition	Grading: Once per year; Regravelling: if gravel thickness <=50mm and at interval of >=3 years; Spot regravelling: if gravel thickness <= 100mm and Maximum material <= 300m3/km/year and at interval >=3 years	IRI 11-20 m/km	Altn1	(Improve maintenance standard): Grading: Every 30 days; Regravelling: if gravel thickness <=50mm and at interval of >=3 years; Spot regravelling: if gravel thickness <= 100mm and Maximum material <= 300m3/km/year and at interval >=1 years	Fair condition, IRI 7 – 9 m/km
				Altn2	(upgrade to paved road): Pavement type: Double surface dressing on granular base; Patching: if potholing >= 1no/km and severely damaged area >=5%; Crack sealing: if wide structural cracking between 10% and 30% or transverse thermal cracks > = 15 no/km; Edge repair: if edge break >= 1 m^2/km; Resealing: if total damaged area > = 30%	Good condition, IRI 2 – 4 m/km
3	Gravel-Regional roads in good condition	Same as base alternative for gravel-urban roads above	IRI 6-15m/km	Altn1	(Improve maintenance standard): Grading: Every 60 days; Regravelling: if gravel thickness <=50mm and at interval of >=3 years; Spot regravelling: if gravel thickness <= 100mm and Maximum material <= 300m3/km/year and at interval >=1 years	Fair condition, IRI 6 – 7 m/km
				Altn2	(Upgrade to paved road): Same as *Altn2* above for gravel-urban roads	Good condition, IRI 2 – 4 m/km
4	Gravel-Regional roads in fair condition	Same as base alternative for gravel-urban roads above	IRI 7-15m/km	Altn1	(Improve maintenance standard): Grading: Every 90 days; Regravelling: if gravel thickness <=50mm and at interval of >=3 years; Spot regravelling: if gravel thickness <= 100mm and Maximum material <= 300m3/km/year and at interval >=3 years	Fair condition, IRI 6 – 9 m/km
				Altn2	(Improve to paved road): Same as *Altn2* above for gravel-urban roads	Good condition, IRI 2 – 4 m/km

5	Gravel-Regional roads in poor condition	Same as base alternative for gravel-urban roads above	IRI 8-16m/km	Altn1	(Improve maintenance standard): Grading: Every 90 days; Regravelling: if gravel thickness <=50mm and at interval of >=2 years; Spot regravelling: if gravel thickness <= 100mm and Maximum material <= 300m3/km/year and at interval >=2 years	Fair condition, IRI 6 – 8 m/km
				Altn2	(Improve to paved road): Same as *Altn2* above for gravel-urban roads	Good condition, IRI 2 – 4 m/km
6	Gravel collector roads in good, fair and poor condition	Same as base alternative for gravel-urban roads above	IRI 7-18m/km	Altn1	(Improve maintenance standard): Grading: Every 90 days; Regravelling: Gravel thickness <=50mm and at interval of >=3 years; Spot regravelling: Gravel thickness <= 100mm and Maximum material <= 300m3/km/year and at interval >=1 years	Fair condition, IRI 6 – 9 m/km
7	Gravel-feeder roads in good condition	Same as base alternative for gravel-urban roads above	IRI 7-11m/km	Altn1	(Improve maintenance standard): Grading: Every 120 days; Regravelling: if gravel thickness <=50mm and at interval of >=3 years; Spot regravelling: if gravel thickness <= 100mm and Maximum material <= 300m3/km/year and at interval >=3 years	Fair condition, IRI 6 – 8 m/km
8	Gravel-feeder roads in fair condition	Same as base alternative for gravel-urban roads above	IRI 7-14m/km	Altn1	(Improve maintenance standard): Grading: Every 180 days; Regravelling: if gravel thickness <=50mm and at interval of >=3 years; Spot regravelling: if gravel thickness <= 100mm and Maximum material <= 300m3/km/year and at interval >=3 years	Fair condition, IRI 6 – 9 m/km
9	Earth-collector roads in good, fair and poor condition	Grading every two years	IRI 12-22m/km	Altn1	(Upgraded to gravel road): Grading: Every 90 days; Regravelling: if gravel thickness <=50mm and at interval of >=3 years; Spot regravelling: if gravel thickness <= 100mm and Maximum material <= 300m3/km/year and at interval >=1 years	Fair condition, IRI 6 – 8 m/km
10	Earth-feeder roads in good, fair and poor condition	Grading every two years	IRI 11-21m/km	Altn1	(Upgraded to gravel road): Grading: Every 180 days; Regravelling: if gravel thickness <=50mm and at interval of >=3 years; Spot regravelling: if gravel thickness <= 100mm and Maximum material <= 300m3/km/year and at interval >=3 years	Fair condition, IRI 6 – 8 m/km

6.2.3. Economic evaluation

This section provides the details of the proposed approach of appraising rural roads that takes into account the effect of trip distance, road connectivity, and wider agricultural benefits. Details of how the expected changes in transport prices and trip distances incorporated in the appraisal process of the low-volume road are also provided. This economic analysis was performed using HDM-4[23] software, with the expected wider agricultural benefits determined exogenously.

Firstly, the entire road network of the study area was analysed following the conventional approach; i.e. without including the effect of the changes in trip distance and agricultural benefits in the analysis. In the second iteration, the analysis included the agricultural benefits, but not the effect of the change in trip distance. Thirdly, both the expected agricultural benefits and the change in the trip distance were included in the analysis.

6.2.3.1. The conventional economic evaluation approach

The Tanzania Ministry of Works (2011) recommends a design life of 15-20 years for district roads (see Section 1.6 and Appendix 4 for details about road classes). In their economic evaluation for upgrading an earth road to a gravel-standard road, Carnemark *et al.* (1976) used a 13-year analysis period, while Beenhakker and Chammari (1979) used a 12-year analysis period. Hine (2014) points out that, normally, rural roads are evaluated over a period of 10-20 years. For this research, therefore, a period of 10 years (from 2016 to 2025) was selected. A ten years analysis period is a bit short, as the economic analysis period can be up to 30 years to allow for a longer return period of the capital invested. However, if the agricultural benefits will be substantial to justify the road improvement for such a short analysis period; certainly that will also be the case for a longer analysis period.

The analysis was firstly done following the conventional approach, which includes measuring the savings in road user costs, i.e. vehicle operating cost (VOC) and travel time. Accident

[23] HDM-4 has been produced by the International Study of Highway and Management Development Tools (ISOHDM) and jointly published by the World Roads Association (PIARC) and the World Bank. The tool combines technical and economic appraisal of road projects for the purpose of preparing investment programme and strategies of road networks. The initiatives of preparing road investment appraisal model stated since 1968 by the World Bank. Extensive researches and studies have been conducted since then, and several models were developed such as Highway Cost Model (HCM), Road Transport Investment Model (RTIM), Highway Design and Maintenance Standard model (HDM), RTIM2, HDM-III, HDM-PC, HDM-Q, HDM Manager, until 2000 where version one of HDM-4 was released. Later on, version two of HDM-4 was released. HDM-4 is widely used; over 100 countries in the world have been using the model in road projects appraisal. HDM-4 is often used by the World Bank as a tool for appraising road projects in developing countries.

cost was not included in the analysis due to lack of data. To simplify the analysis diverted traffic, if at all are present, was not considered.

The expected total increase in agricultural production following the road improvement (see Table 6.7) was roughly 800 tonnes per year. The increase in traffic to carry this load (assuming a 10-tonne capacity) would be equivalent to 80 vehicles. Distributing this traffic throughout a year (365 days) would be equivalent to an additional 0.2 vehicles per day. This is a very small number, and therefore no generated traffic was included in the analysis. The only traffic considered in the analysis was normal traffic; Figure 6.1 shows the annual average daily traffic (AADT) growth for this category using annual traffic growth rate of 6.5 percent.

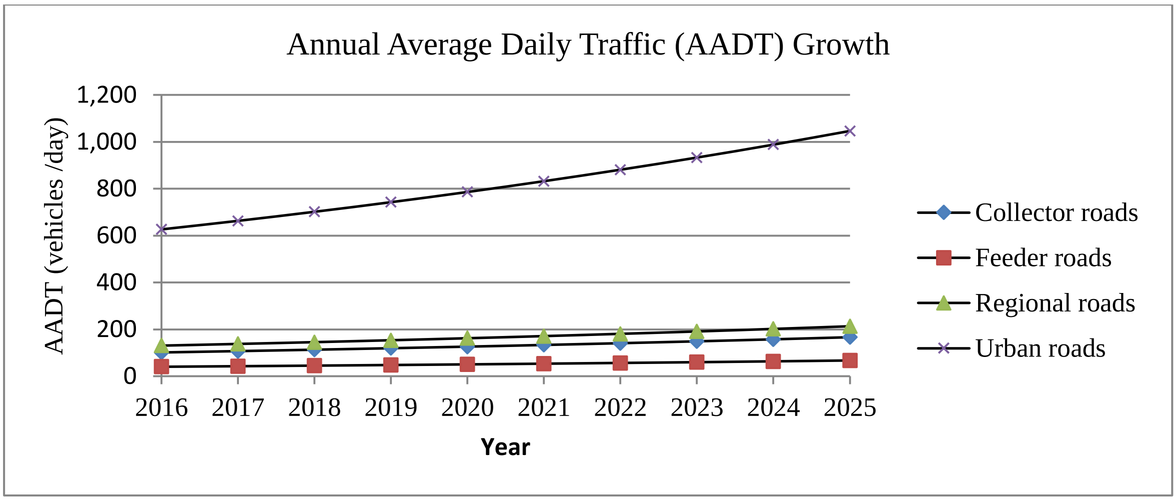


Figure 6.1: Annual Average Daily Traffic (AADT) growth for normal traffic

The HDM-4 results in Table 6.2 show that it is economically viable to pave urban roads because of their high traffic volume (positive NPVs). The results show no economic justification to pave regional roads (negative NPVs), but rather to improve maintenance standards to ensure that roads are in fair condition (IRI, 6 – 9 m/km) all year round. In the case of collector roads, improving the maintenance standards of gravel-surfaced collector roads to ensure fair condition (IRI, 6 – 9 m/km) all year round is economically justifiable (positive NPVs), for roads which were in good and fair conditions. Upgrading earth collector roads to gravel-surfaced roads is economically justifiable (positive NPV), regardless of the existing condition of the road. For earth feeder roads, regardless of the existing condition of the road, upgrading to gravel roads is not economically viable (negative NPVs) because of the low volume of traffic on these roads. Improving maintenance standards to ensure a fair condition of gravel feeder roads was also not economically viable (negative NPVs).

Table 6.2: Kilosa district road network economic analysis: HDM-4 analysis results

Sn	Road class and condition	Length (km)	Traffic volume (AADT) in year 2013	Intervention / alternatives*	Total agency cost (USD millions)	Agency capital cost (USD millions)	Agency recurrent cost (USD millions)	Increase in agency cost (USD millions)	Decrease in user cost (USD millions)	NPV (USD Millions)
1	Gravel-Urban-Fair	12.1	529	Improve maintenance standard	2.244	0.230	2.014	1.755	3.974	2.219
				Improve to paved road	2.745	2.745	0.000	2.256	5.543	3.288
2	Gravel-Urban-Poor	36	529	Improve maintenance standard	6.709	0.716	5.993	5.090	11.264	6.173
				Improve to paved road	8.169	8.166	0.003	6.550	16.000	9.450
3	Gravel-Regional-Good	120	111	Improve maintenance standard	10.380	0.614	9.766	7.719	8.443	0.723
				Improve to paved road	27.220	27.220	0.000	24.559	12.574	-11.985
4	Gravel-Regional-Fair	75.03	111	Change maintenance standard	4.826	0.816	4.010	2.896	3.995	1.099
				Improve to paved road	17.019	17.019	0.000	15.089	7.24	-7.849
5	Gravel-Regional-Poor	48.16	111	Improve maintenance standard	3.202	0.571	2.631	1.919	2.455	0.536
				Improve to paved road	10.924	10.924	0.000	9.638	4.396	-5.242
6	Gravel-Collector-Good	75	96	Improve maintenance standard	4.773	0.226	4.547	3.133	3.161	0.028
7	Gravel-Collector-Fair	76.5	96	Improve maintenance standard	4.969	0.672	4.297	3.036	3.128	0.092

8	Gravel-Collector-Poor	61	96	Improve maintenance standard	4.16	0.823	3.337	2.421	2.217	-0.204
9	Earth-Collector-Good	17	96	Upgraded to gravel road	1.110	0.276	0.834	1.110	1.934	0.824
10	Earth-Collector-Fair	41.9	96	Upgraded to gravel road	2.735	0.679	2.056	2.735	4.901	2.166
11	Earth-Collector-Poor	75.9	96	Upgraded to gravel road	4.790	1.217	3.573	4.79	10.235	5.445
12	Gravel-Feeder-Good	4	34	Improve maintenance standard	0.137	0.018	0.119	0.051	0.017	-0.035
13	Gravel-Feeder-Fair	8.7	34	Improve maintenance standard	0.308	0.055	0.253	0.112	0.045	-0.067
14	Earth-Feeder-Good	44	34	Upgraded to gravel road	1.720	0.680	1.040	1.720	0.446	-1.274
15	Earth-Feeder-Fair	130	34	Upgraded to gravel road	5.082	2.008	3.074	5.082	1.419	-3.664
16	Earth-Feeder-Poor	236.2	34	Upgraded to gravel road	9.234	3.649	5.585	9.234	2.765	-6.469

*See Table 6.1 for base alternatives and details about the alternatives

This analysis of the Kilosa district's road network shows that the improvement of roads with relatively high traffic volumes is economically justified in comparison to roads with relatively low traffic volumes. As illustrated in Figures 6.2 and 6.3, the VOC savings, together with the travel time savings obtained from paving urban roads, are sufficient to offset the investment and recurrent costs incurred by the road agency. But, for the case of feeder roads where traffic volumes are very low, these consumer benefits are not enough to offset the costs required to upgrade and maintain these roads. The decision may be reached, therefore, not to improve these roads, which can adversely impact the agricultural sector.

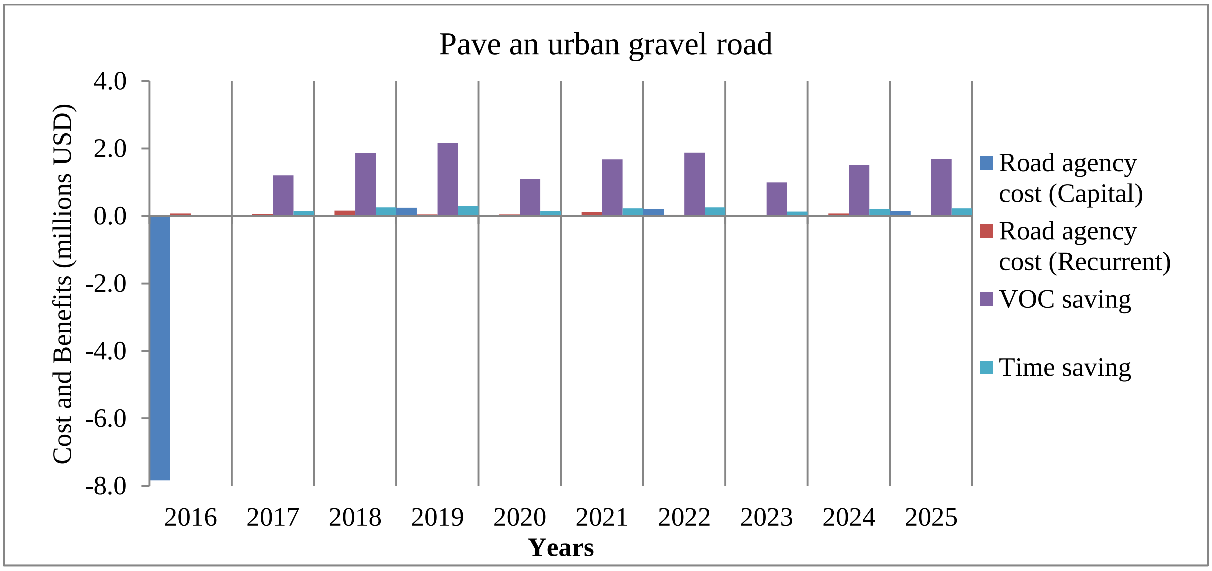


Figure 6.2: Comparison cost and benefits streams: paving an urban gravel road

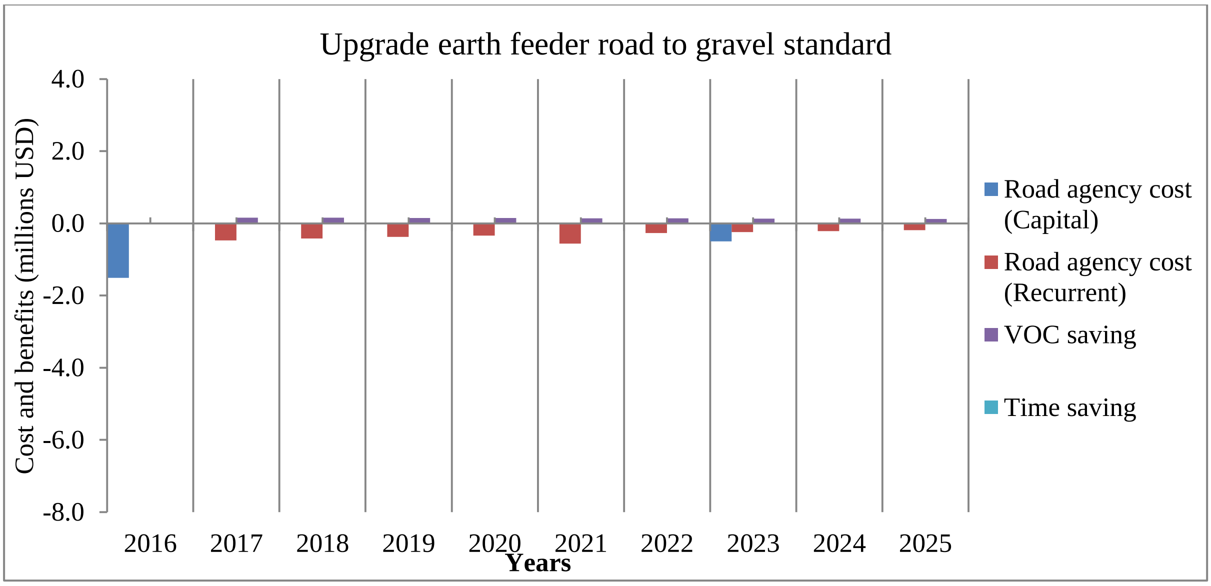


Figure 6.3: Comparison costs and benefits stream: upgrading an earth feeder road to gravel standard

6.2.3.2. Wider agricultural benefits and the distance effect in rural roads economic evaluation

The previous section showed that, when using a conventional economic evaluation approach, improvements of rural roads with low volumes of traffic are not economically viable. This is due to the fact that the conventional economic evaluation approach uses VOC and time savings as the benefits of improving roads i.e. the consumer surplus approach. Yet for roads with a low volume of traffic, these savings are not enough to offset the construction and maintenance costs of a proposed intervention. The wider agricultural benefits i.e. the producers' benefits, however, can be substantial on these roads.

This section uses earth feeder roads to illustrate the proposed approach of including wider agricultural benefits in the appraisal process for a low-volume rural road. The approach makes use of the expected effects of the changes in the trip distance and transport prices following the improvement of the road.

Generally, road improvement lowers transport cost. HDM-4 was used to model transport cost reduction following a road improvement. Using the established relationship between transport price, trip distance and transport cost (described in Section 4.6), Equation 6.1 and 6.2 were used to estimate the reduction in transport price following the changes in transport cost and trip distance.

For unpaved trips (less than 50 percent of the trip distance is on paved road):

$$ln(Transport\ price) = 6.807 - 0.462\ ln(Trip\ distance) + 0.528ln(Transport\ cost), \quad (6.1)$$

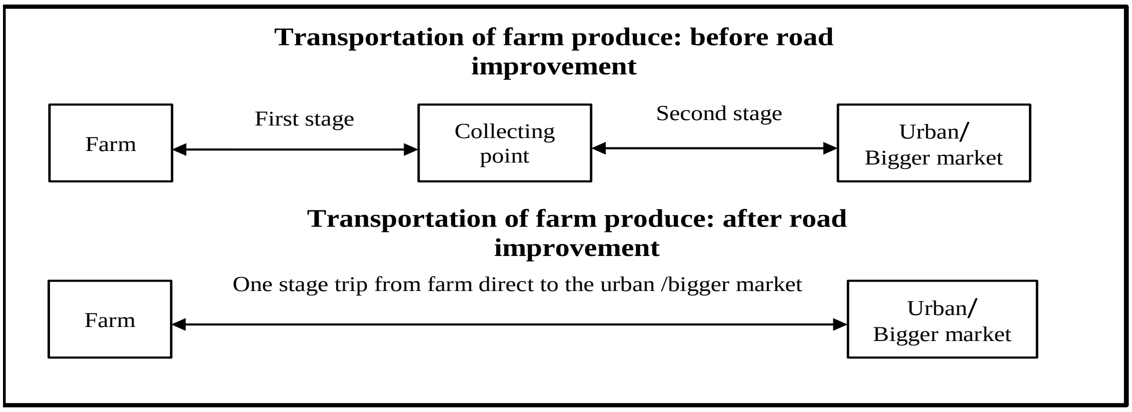
For paved trips (more than 50 percent of the trip distance is on paved road):

$$ln(Transport\ price) = 6.618 - 0.462\ ln(Trip\ distance) + 0.528ln(Transport\ cost), \quad (6.2)$$

where:

- *Transport price* (Tsh/veh-km);
- *Distance* (km); and
- *Transport cost* (Tsh/veh-km).

An improvement of a low-volume rural road that is connected to the secondary road network allows for longer-distance trips and higher vehicle utilisation (described Section 4.6). These changes in trip characteristics have a significant impact on transport prices, and subsequently on agricultural productivity. Figure 6.4 conceptually illustrates the change in a trip pattern following the improvement of a low-volume road. The trip to transport agricultural products from the farm to the urban market, which used to consist of two stages, can be completed in one stage following the rural road improvement.

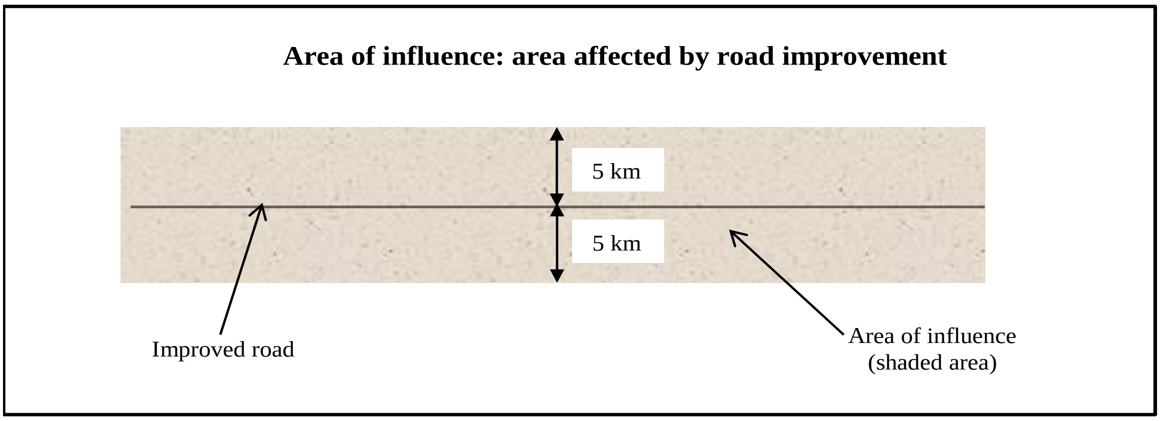


Source: Author

Figure 6.4: Change in trip pattern after road improvement

Normally, it is very difficult to obtain the data on agricultural production increase following the road investment. In Section 5.5.3, however, the relationship between transport price and crop yield was established, showing that a one percent reduction in transport price will increase crop yield by 0.291 percent. This established relationship was used to estimate the increase in crop yield following a road improvement.

Carnemark, Biderman and Bovet (1976) pointed out that different studies have reported different areas of influence i.e. the area affected by a road improvement, and proposed some mathematical approaches that could be used to identify the area of influence. An area of influence may range from a 5 km distance on either side of the improved road to the distance that a person can walk in a day (approximately 32 km on either side of an improved road). In this research, a corridor of 10 kilometres (5 km on either side of an improved road) was adopted as the area affected by the road improvement (Figure 6.5). Of this area, 30.5 percent was considered to be arable land (Tanzania National Bureau of Statistics, 2012a) and 29 percent utilised land (Morogoro Regional Commissioner's Office, 2013). In measuring the effect of road improvement on agricultural production only this utilised area at a distance of 5 km each side of the road was considered.

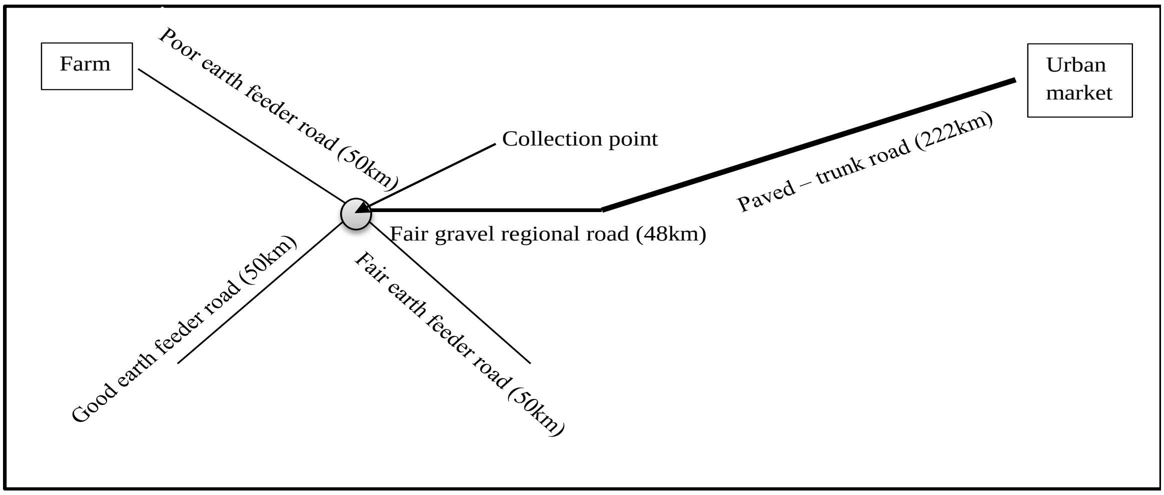


Source: Author

Figure 6.5: The area affected by a road improvement

The effect of rural road improvement was assessed in two phases. In *Phase 1*, it was assumed that trip patterns would not change after the improvement of the rural road. A two-stage trip from the farm to the market was assumed. In *Phase 2*, the change in trip pattern was demonstrated; that is, the improvement of a low-volume road will result in a one-stage trip instead of two-stage trip (Figure 6.4). It should be noted that the latter will happen only if the improved road is connected to secondary roads going to the bigger market.

Figure 6.6 shows a schematic diagram for the three earth feeder roads that are proposed to be improved. The feeder roads were assumed to be in good, fair and poor condition, and connected to a regional gravel road. The two-stage trip considered in *Phase 1* included the first stage of 50 km from the farm to collection point located at a junction between the earth feeder road and the gravel regional road; and the second stage of 270 km, comprising 48 km of gravel regional road and 222 km of paved trunk road. In *Phase 2*, the first and second stages were joined to form one-stage trip of 320 km.



Source: Author

Figure 6.6: Feeder roads connected to secondary road

Lebo and Schelling (2001b) suggest that VOC savings for agricultural traffic (in other words, vehicles used to transport agricultural products) should not be included in the economic analysis in a situation where the agricultural benefits are to be considered, since this will cause the benefits to be double-counted. In this approach, the VOC savings of the truck transporting agricultural products (a medium truck in this case) are therefore not included. However, Lebo and Schelling (2001b) pointed out that the effect of these vehicles on road deterioration should be included in the analysis.

Phase 1: Two-stage trip before and after a rural road improvement

The aim of the project considered in this analysis was to upgrade the earth feeder roads to gravel road standard, and to ensure that the upgraded gravel roads would be in fair condition all year round (see Table 6.1 and Figures A4.2-A4.4 in Appendix 4). The main function of these feeder roads is to provide access, and therefore a high vehicle operating speed is not necessary. However, the improvement of these roads would lead to an increase in vehicle operating speed. Taking the example of upgrading an earth road in poor condition to gravel standard, the average vehicle operating speed of a medium truck would increase from the range of 30-35 km/hr to the range of 70-80 km/hr (Figures 6.7 and 6.8). Assuming there are no vehicle stops, a 50 km journey which took roughly one and half hours before the road improvement would be completed in roughly 40 minutes after the improvement.

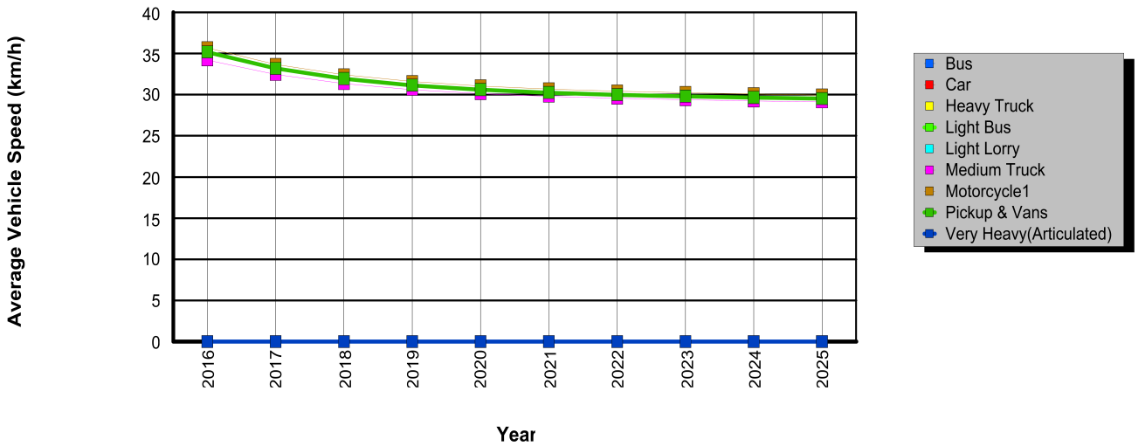


Figure 6.7: Average vehicle operating speed for earth feeder road in poor condition: (IRI 17-21 m/km)

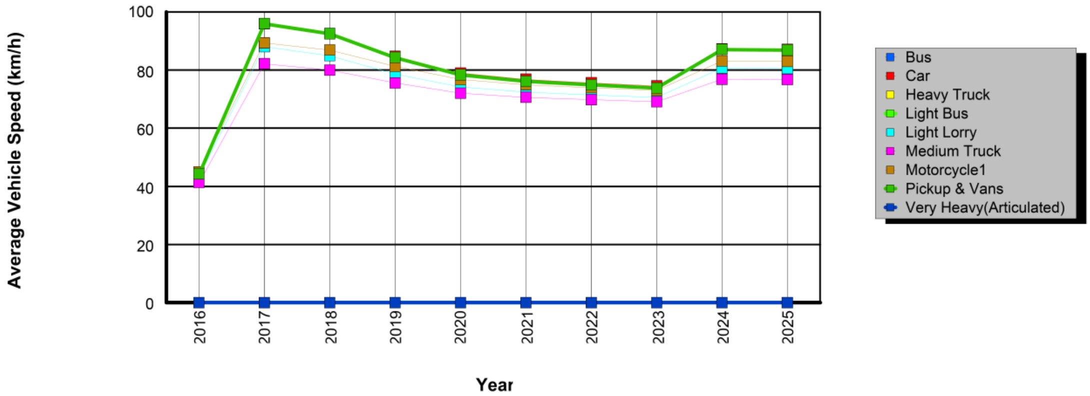


Figure 6.8: Average vehicle operating speed for gravel feeder road in fair condition: (IRI 6-8 m/km)

Table 6.3 provides the results of the expected changes in transport cost, transport price and crop yield after the implementation of the proposed road improvement (see also Table A4.11 and A4.12 in Appendix 4 for more details). Over a ten-year period transport cost from farm to urban market would be reduced on average by 11.1-11.7 percent and transport price reduction would be in the range of 10.3 -10.7 percent. Crop yield, in the area of influence, is expected to increase by 2.99 - 3.11 percent following the road improvement.

Table 6.3: Expected annual changes in transport cost, transport price and crop yield: two-stage trip

Road class and condition	**Transport cost before improvement (Tsh/ton-trip)**	**Transport cost after improvement (Tsh/ton-trip)**	**Transport cost reduction (%)**	**Transport price before improvement (Tsh/ton-trip)**	**Transport price after improvement (Tsh/ton-trip)**	**Transport price reduction (%)**	**Increase in crop yield (%)**
Upgrade Earth-Feeder-Good	39 850	35 355	11.1	102 825	91 877	10.6	3.10
Upgrade Earth -Feeder-Fair	40 197	35 727	11.3	103 562	92 910	10.3	2.99
Upgrade Earth-Feeder-Poor	40 552	35 820	11.7	104 306	93 164	10.7	3.11

In order to include agricultural benefits in the economic analysis, the increase in crop *yield* was converted to the increase in crop *value*. Table 6.4 - 6.6 illustrates the procedures used to calculate the increase in crop value for the twelve different crops cultivated in the Kilosa district. The results, Table 6.4 - 6.6, are increases due to the upgrading of earth feeder road in good, fair and poor condition to gravel standard. The increases in crop values were included in the analysis as agricultural benefits. It was assumed that these benefits would commence beginning of year three i.e. the second year after the completion of the road upgrade.

The crop production pattern in the study area shows an average annual growth of 4.5 percent (see Section 6.2.1.2). It was assumed that the increase in crop production due to the road improvement would also follow the same pattern. Therefore, during the analysis, the agricultural benefits were also increased at a rate of 4.5 percent annually.

Table 6.4: Increase in crop value in year three following the improvement of earth feeder road in good condition to gravel standard: two-stage trip

Crop	Crop yield before improvement (Ton/ha)	Crop yield after improvement (Ton/ha)	Increase in crop yield (Ton/ha)	Cultivated area (ha)	Increase in production (ton)	Crop price (Tsh/ton)	Increase in crop value (Tsh)
	(A)	(B)	(C=B-A)	(D)	(E=CxD)	(F)	(G=ExF)
Maize	2.0	2.062	0.062	1795.4	111.24863	420 000	46724425
Paddy	2.0	2.062	0.062	1337	82.844726	542 000	44901841
Sorghum	1.0	1.031	0.031	87.7	2.7182174	420 000	1141651
Bulrush millet	1.0	1.031	0.031	3.8	0.1183496	420 000	49707
Cassava	6.0	6.186	0.186	109.7	20.390304	315 000	6422946
Sweet potatoes	7.0	7.217	0.217	27.1	5.8876152	315 000	1854598.79
Beans	1.0	1.031	0.031	143	4.431026	1 200 000	5317231
Cotton	1.2	1.227	0.037	4	0.1471669	735 000	108168
Onion	9.0	9.279	0.279	23.4	6.5258974	840 000	5481754
Sesame	1.0	1.031	0.031	164.9	5.1093137	2 520 000	12875471
Tomato	35.0	36.084	1.084	4.2	4.5506258	945 000	4300341
Sunflower	1.7	1.753	0.053	49.4	2.6032469	857 000	2230983
Total				**3749.6**	**246.5751**		**131 409 117**
Total increase in value: USD 77 757							

Exchange rate 1USD = 1 690 TSH

Table 6.5: Increase in crop value in year three following the improvement of earth feeder road in fair condition to gravel standard: two-stage trip

Crop	Crop yield before improvement (Ton/ha)	Crop yield after improvement (Ton/ha)	Increase in crop yield (Ton/ha)	Cultivated area (ha)	Increase in production (ton)	Crop price (Tsh/ton)	Increase in crop value (Tsh)
	(A)	(B)	(C=B-A)	(D)	(E=CxD)	(F)	(G=ExF)
Maize	2.0	2.060	0.060	1795.4	107.472	420 000	45 138 448
Paddy	2.0	2.060	0.060	1337	80.033	542 000	43 377 728
Sorghum	1.0	1.030	0.030	87.7	2.626	420 000	1 102 900
Bulrush millet	1.0	1.030	0.030	3.8	0.114	420 000	48 020
Cassava	6.0	6.180	0.180	109.7	19.698	315 000	6 204 930
Sweet potatoes	7.0	7.210	0.210	27.1	5.688	315 000	1 791 648
Beans	1.0	1.030	0.030	143	4.281	1 200 000	5 136 747
Cotton	1.2	1.226	0.036	4	0.142	735 000	104 496
Onion	9.0	9.269	0.269	23.4	6.304	840 000	5 295 685

Sesame	1.0	1.030	0.030	164.9	4.936	2 520 000	12 438 436
Tomato	35.0	36.048	1.048	4.2	4.396	945 000	4 154 374
Sunflower	1.7	1.751	0.051	49.4	2.515	857 000	2 155 256
Total				**3749.6**	**238.205**		**126 948 668**
Total increase in value: USD 75 118							

Exchange rate 1USD = 1 690 TSH

Table 6.6: Increase in crop value in year three following the improvement of earth feeder road in poor condition to gravel standard: two-stage trip

Crop	Crop yield before improvement (Ton/ha)	Crop yield after improvement (Ton/ha)	Increase in crop yield (Ton/ha)	Cultivated area (ha)	Increase in production (ton)	Crop price (Tsh/ton)	Increase in crop value (Tsh)
	(A)	(B)	(C=B-A)	(D)	(E=CxD)	(F)	(G=ExF)
Maize	2.0	2.062	0.062	1795.4	111.61528	420 000	46878419
Paddy	2.0	2.062	0.062	1337	83.117764	542 000	45049828
Sorghum	1.0	1.031	0.031	87.7	2.727176	420 000	1145414
Bulrush millet	1.0	1.031	0.031	3.8	0.1187397	420 000	49871
Cassava	6.0	6.187	0.187	109.7	20.457506	315 000	6444114
Sweet potatoes	7.0	7.218	0.218	27.1	5.9070195	315 000	1860711
Beans	1.0	1.031	0.031	143	4.4456297	1 200 000	5334756
Cotton	1.2	1.227	0.037	4	0.1476519	735 000	108524
Onion	9.0	9.280	0.280	23.4	6.5474054	840 000	5499821
Sesame	1.0	1.031	0.031	164.9	5.1261529	2 520 000	12917905
Tomato	35.0	36.088	1.088	4.2	4.5656237	945 000	4314514
Sunflower	1.7	1.753	0.053	49.4	2.6118266	857 000	2238335
Total				**3749.6**	**247.3878**		**131 842 213**
Total increase in value: USD 78 013							

Exchange rate 1USD = 1 690 TSH

As was the case in conventional economic analysis, HDM-4 was used to undertake a ten years economic analysis with agricultural benefits determined exogenously. The agricultural benefits were increased at a rate of 4.5 percent annually from year three, i.e. the second year after upgrading the roads. The results in Table 6.7 show that the targeted improvements for the three feeder roads from earth to gravel road standard were not economically viable i.e. they exhibited negative NPVs.

These results show that the benefits due to increased agricultural value, together with the VOC savings and time and cost savings for *non-agricultural traffic*, were not enough to offset the investment and recurrent costs of the proposed interventions. The decision may be reached, therefore, not to improve these roads, which would adversely impact on the agricultural sector.

Table 6.7: HDM-4 analysis result for upgrading earth feeder roads to gravel standard for the entire analysis period: two-stage trip

Sn	Road class and condition	Length (km)	Traffic volume (AADT)	Discounted increase in agricultural value (USD Millions)	Discounted increase in road agency cost	Discounted saving in road user cost (USD Millions)	NPV (USD Millions)	IRR
1	Earth-Feeder-Good	50	34	0.394	1.551	0.399	-0.758	-44.0
2	Earth-Feeder-Fair	50	34	0.381	1.551	0.439	-0.731	-44.3
3	Earth-Feeder-Poor	50	34	0.395	1.551	0.491	-0.665	-40.2

Figures 6.9 - 6.11 show the benefits and costs for the entire analysis period including the VOC and time savings for non-agricultural traffic.

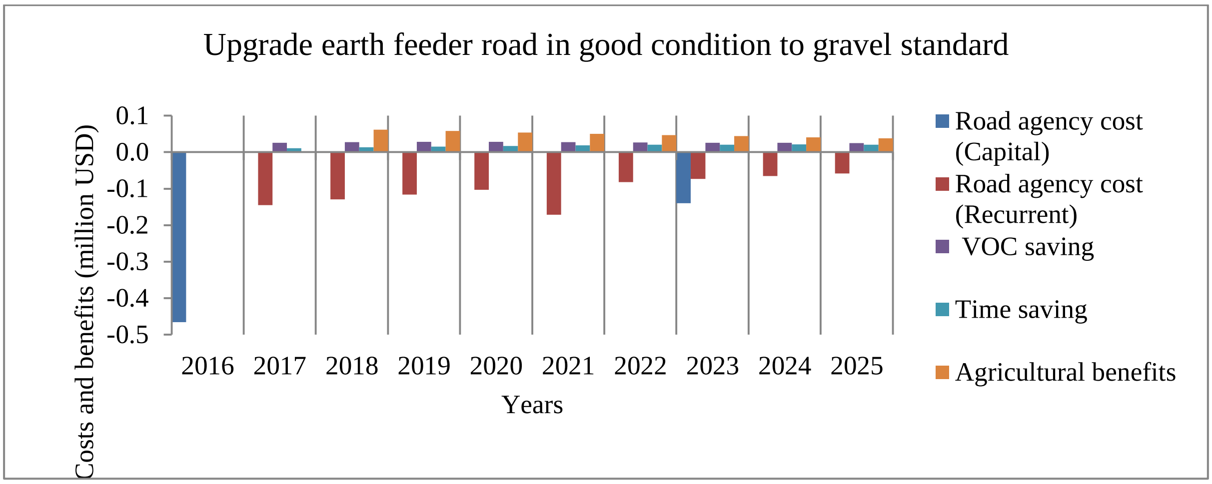


Figure 6.9: Comparison costs and benefits stream for upgrading an earth feeder road in good condition to gravel standard, two-stage trip

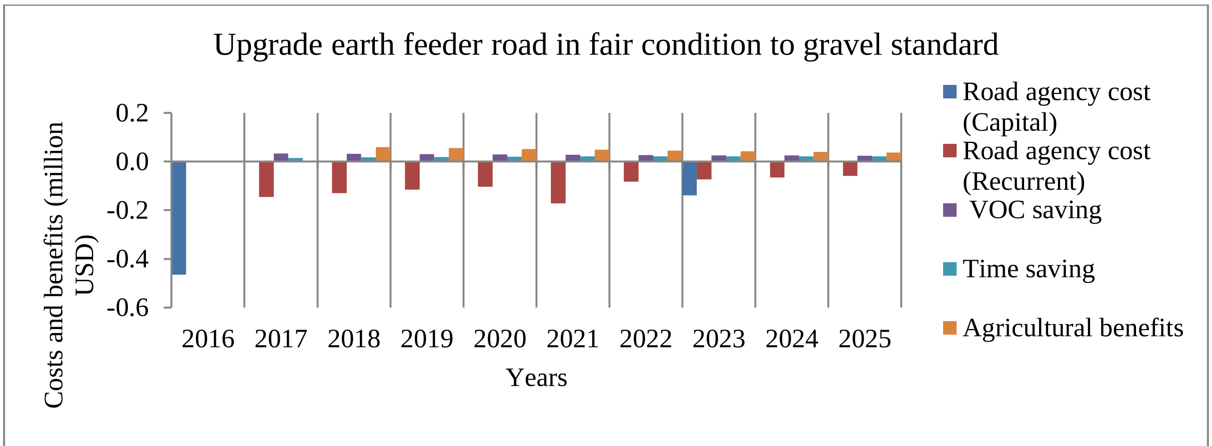


Figure 6.10: Comparison costs and benefits stream for upgrading an earth feeder road in fair condition to gravel standard, two-stage trip

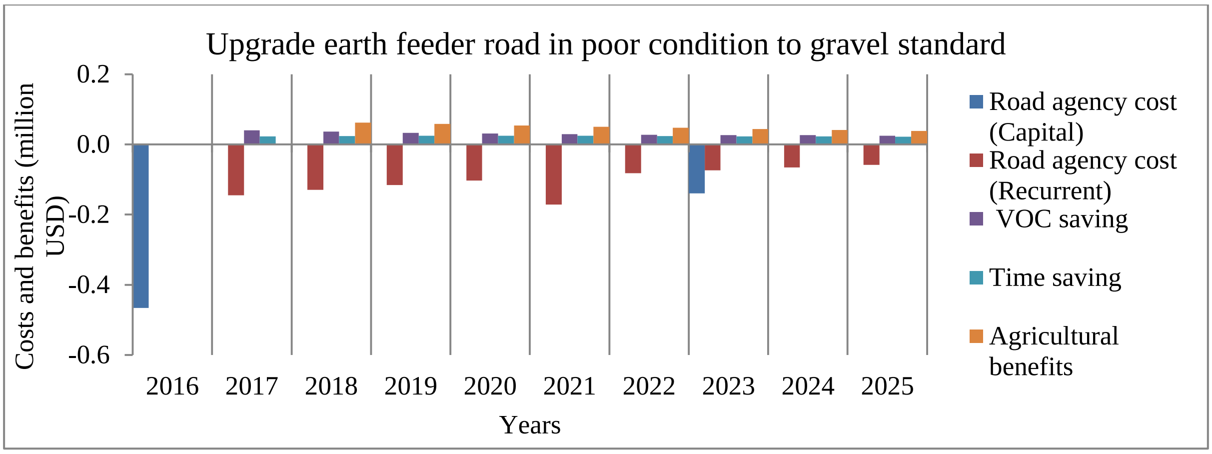


Figure 6.11: Comparison costs and benefits stream for upgrading an earth feeder road in poor condition to gravel standard, two-stage trip

Phase 2: Two-stage trip before and one-stage trip after a rural road improvement

The same targeted improvements as in *Phase 1* were analysed during this phase. However, in this case, it was considered that the improvement of feeder roads would result in longer trip, a one-stage trip of 320 km as opposed to a two-stage trip of 50 km and 270 km. Such a change in trip pattern would have a significant impact on the reduction of transport prices of the agricultural products (see Figure 4.3 and Section 4.6).

The results in Table 6.8 show that, on average, transport cost from the farm to the market would be reduced by 11.1-11.7 percent and transport price reduction would be in the range of 34.4 - 34.9 percent (see also Table A4.9 and A4.11 in Appendix 4 for more details). Crop yield, in the area of influence, is expected to increase by 10.0 - 10.2 percent after the implementation of the proposed road improvement.

Table 6.8: Expected annual changes in transport cost, transport price and crop yield: one-stage trip

Road class and condition	Transport cost before improvement (Tsh/ton-trip)	Transport cost after improvement (Tsh/ton-trip)	Transport cost reduction (%)	Transport price before improvement (Tsh/ton-trip)	Transport price after improvement (Tsh/ton-trip)	Transport price reduction (%)	Increase in crop yield (%)
Earth-Feeder-Good	39 850	35 355	11.1	102 825	67 420	34.4	10.0
Earth-Feeder-Fair	40 197	35 727	11.3	103 562	67 794	34.5	10.1
Earth-Feeder-Poor	40 552	35 820	11.7	104 306	67 887	34.9	10.2

Using the percentage increase in crop *yield*, the increase in crop *value* was determined using the procedures discussed in Phase 1. Table 6.9 - 6.11 provides the increased crop values following the upgrade of an earth feeder road in good, fair and poor condition to gravel standard. These increases in crop values were included in the HDM-4 analysis as agricultural benefits. It was assumed that these benefits would commence beginning of year three i.e. the second year after the completion of road upgrade, and would increase at a rate of 4.5 percent annually (see Section 6.2.1.2).

Table 6.9: Increase in crop value in year three following the improvement of an earth feeder road in good condition to gravel standard: one-stage trip

Crop	**Crop yield before improvement (Ton/ha)**	**Crop yield after improvement (Ton/ha)**	**Increase in crop yield (Ton/ha)**	**Cultivated area (ha)**	**Increase in production (ton)**	**Crop price (Tsh/ton)**	**Increase in crop value (Tsh)**
	(A)	**(B)**	**(C=B-A)**	**(D)**	**(E=CxD)**	**(F)**	**(G=ExF)**
Maize	2.0	2.200	0.200	1795.4	359.7815	420 000	151108234
Paddy	2.0	2.200	0.200	1337	267.9224	542 000	145213942
Sorghum	1.0	1.100	0.100	87.7	8.7908	420 000	3692136
Bulrush millet	1.0	1.100	0.100	3.8	0.3827	420 000	160753
Cassava	6.0	6.601	0.601	109.7	65.9429	315 000	20772005
Sweet potatoes	7.0	7.701	0.701	27.1	19.0407	315 000	5997830
Beans	1.0	1.100	0.100	143	14.3301	1 200 000	17196090
Cotton	1.2	1.310	0.110	4	0.4759	735 000	349817
Onion	9.0	9.902	0.902	23.4	21.1050	840 000	17728161
Sesame	1.0	1.100	0.100	164.9	16.5237	2 520 000	41639669
Tomato	35.0	38.507	3.507	4.2	14.7169	945 000	13907437
Sunflower	1.7	1.870	0.170	49.4	8.4190	857 000	7215067
Total				**3749.6**	**797.432**		**424 981 141**
Total increase in value: USD 251 468							

Exchange rate 1USD = 1 690 TSH

Table 6.10: Increase in crop value in year three following the improvement of an earth feeder road in fair condition to gravel standard: one-stage trip

Crop	**Crop yield before improvement (Ton/ha)**	**Crop yield after improvement (Ton/ha)**	**Increase in crop yield (Ton/ha)**	**Cultivated area (ha)**	**Increase in production (ton)**	**Crop price (Tsh/ton)**	**Increase in crop value (Tsh)**
	(A)	**(B)**	**(C=B-A)**	**(D)**	**(E=CxD)**	**(F)**	**(G=ExF)**
Maize	2.0	2.201	0.201	1795.4	360.892	420 000	151 574 624
Paddy	2.0	2.201	0.201	1337	268.749	542 000	145 662 138
Sorghum	1.0	1.101	0.101	87.7	8.818	420 000	3 703 531
Bulrush millet	1.0	1.101	0.101	3.8	0.384	420 000	161 250
Cassava	6.0	6.603	0.603	109.7	66.146	315 000	20 836 117

Sweet potatoes	7.0	7.704	0.704	27.1	19.099	315 000	6 016 342
Beans	1.0	1.101	0.101	143	14.374	1 200 000	17 249 165
Cotton	1.2	1.310	0.110	4	0.477	735 000	350 897
Onion	9.0	9.905	0.905	23.4	21.170	840 000	17 782 878
Sesame	1.0	1.101	0.101	164.9	16.575	2 520 000	41 768 189
Tomato	35.0	38.518	3.518	4.2	14.762	945 000	13 950 362
Sunflower	1.7	1.871	0.171	49.4	8.445	857 000	7 237 336
Total				**3749.6**	**799.893**		**426 292 828**
Total increase in value: USD 252 244							

Exchange rate 1USD = 1 690 TSH

Table 6.11: Increase in crop value in year three following the improvement of an earth feeder road in poor condition to gravel standard: one-stage trip

Crop	Crop yield before improvement (Ton/ha)	Crop yield after improvement (Ton/ha)	Increase in crop yield (Ton/ha)	Cultivated area (ha)	Increase in production (ton)	Crop price (Tsh/ton)	Increase in crop value (Tsh)
	(A)	**(B)**	**(C=B-A)**	**(D)**	**(E=CxD)**	**(F)**	**(G=ExF)**
Maize	2.0	2.203	0.203	1795.4	364.836	420 000	153231178
Paddy	2.0	2.203	0.203	1337	271.686	542 000	147254076
Sorghum	1.0	1.102	0.102	87.7	8.914	420 000	3744007
Bulrush millet	1.0	1.102	0.102	3.8	0.388	420 000	163012
Cassava	6.0	6.610	0.610	109.7	66.869	315 000	21063834
Sweet potatoes	7.0	7.711	0.711	27.1	19.308	315 000	6082094
Beans	1.0	1.102	0.102	143	14.531	1 200 000	17437681
Cotton	1.2	1.311	0.111	4	0.483	735 000	354732
Onion	9.0	9.914	0.914	23.4	21.401	840 000	17977227
Sesame	1.0	1.102	0.102	164.9	16.756	2 520 000	42224672
Tomato	35.0	38.556	3.556	4.2	14.924	945 000	14102825
Sunflower	1.7	1.873	0.173	49.4	8.537	857 000	7316432
Total				**3749.6**	**808.635**		**430951769**
Total increase in value: USD 255 001							

The results in Table 6.12 show that the proposed upgrade of earth feeder roads to gravel roads is economically viable for all feeder roads, whatever their condition (i.e. they all exhibited positive NPVs). These results show that trip pattern has a significant impact during the economic evaluation of a low-volume rural road. Consideration of the change in trip pattern during the economic evaluation of a low-volume rural road may therefore lead to a decision to invest in these roads, which would in turn have a positive impact on the agricultural sector and rural population.

Figures 6.12 - 6.14 show the comparison of the costs and benefits for the entire analysis period including the VOC and time saving for non-agricultural traffic.

Table 6.12: HDM-4 analysis result for upgrading earth feeder roads to gravel standard for the entire analysis period: one- stage trip

Sn	Road class and condition	Length (km)	Traffic volume (AADT)	Discounted increase in agricultural value (USD Millions)	Discounted increase in road agency cost	Discounted saving in road user cost (USD Millions)	NPV (USD Millions)	IRR
1	Earth-Feeder-Good	50	34	1.274	1.551	0.399	0.122	16.5
2	Earth-Feeder-Fair	50	34	1.278	1.551	0.439	0.166	18.2
3	Earth-Feeder-Poor	50	34	1.292	1.551	0.491	0.232	20.7

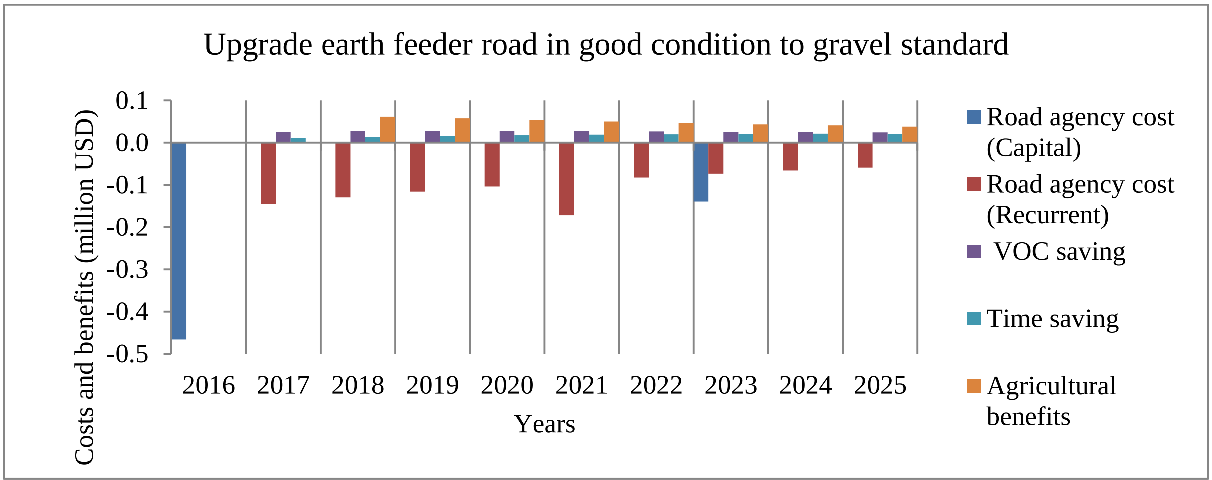


Figure 6.12: Comparison costs and benefits stream for upgrading an earth feeder road in good condition to gravel standard: one-stage trip

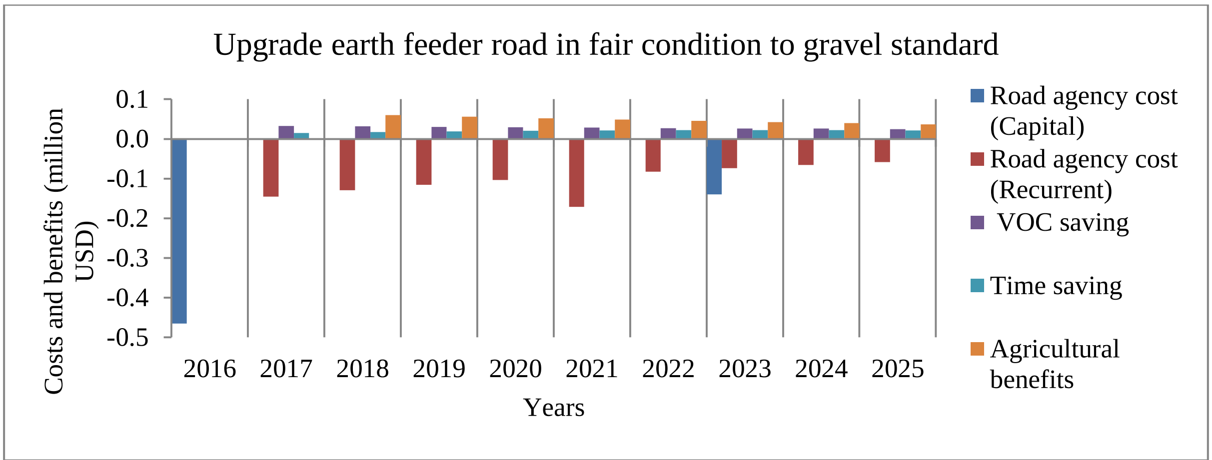


Figure 6.13: Comparison costs and benefits stream for upgrading an earth feeder road in fair condition to gravel standard: one-stage trip

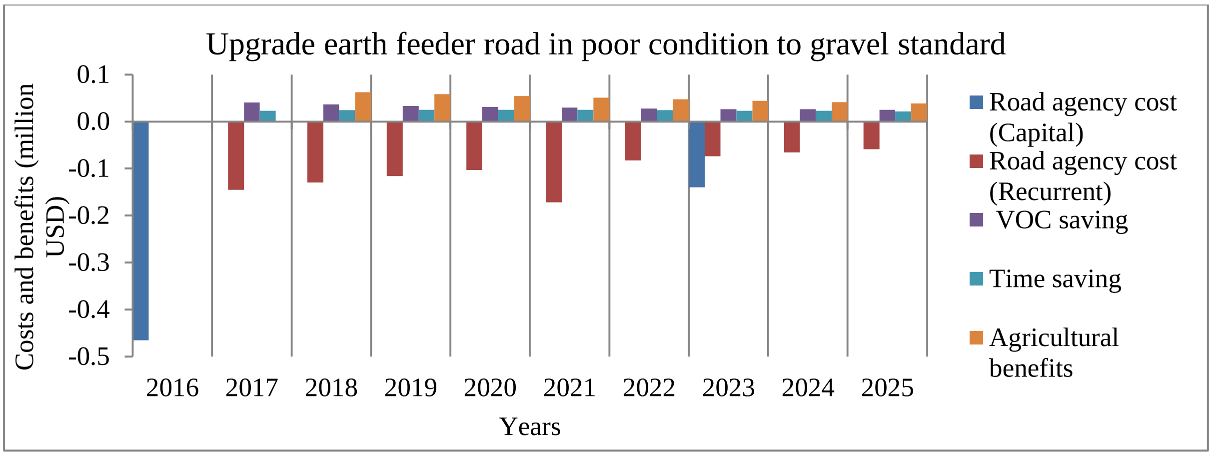
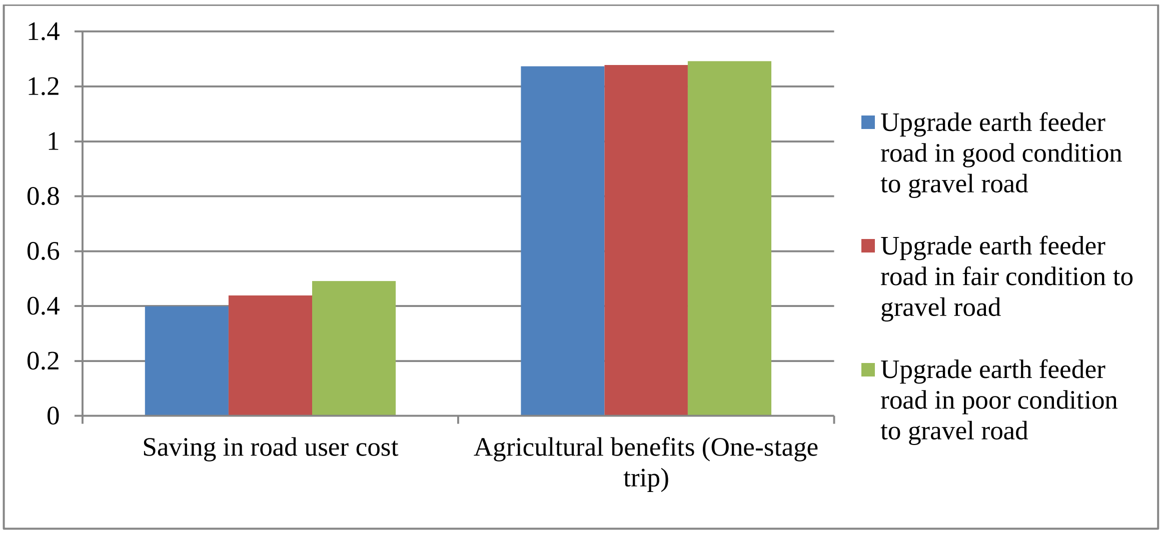


Figure 6.14: Comparison costs and benefits stream for upgrading an earth feeder road in poor condition to gravel standard: one-stage trip

Comparison between road user cost saving and agricultural benefits

The results in Table 6.12 and Figure 6.15 show that for low-volume rural roads, the expected agricultural benefits are roughly three times higher in comparison to the road user savings when the effect of the change in trip pattern is included in the analysis.



Source: Author

Figure 6.15: Comparison between road user cost saving and agricultural benefits: upgrading earth feeder roads to gravel standard

The savings from the individual vehicles multiplied by the number of vehicles gives the total VOC savings and time savings, which is the value that is used as the benefit in the conventional economic analysis. Due to the low volume of traffic on rural roads, these savings are relatively small compare to the investment cost. However, the reduction in transport price for those few vehicles operating on these roads, together with the improved access to urban markets following the road improvement, leads to a substantial increase in crop production. Agricultural benefits emanating from the road improvement are much higher than the saving in road user costs from those few vehicles traversing rural roads. Appraising a low-volume rural road using the savings in road user cost to measure the accrued investment benefits, while ignoring the effect of the change in trip pattern on transport price and the subsequent increase in agricultural production will underestimates the real investment benefits of improving these low-volume rural roads.

6.3. A framework for the economic appraisal of low-volume rural roads

This section describes a framework for the economic appraisal of low-volume rural roads that takes into account agricultural benefits and the effect of trip distance. The framework is a supplement to conventional road appraisal approach, explaining the procedures to undertake in conducting the economic evaluation of low-volume rural roads. Figure 6.16 summarises the procedure, which can be divided into the following six steps.

Step 1: Establish the trip patterns, trip distances and transport prices within the study area

This step entails determining the routes and number of trips used to transport crops from the farms to the big markets. An origin-destination (O-D) survey can be conducted in this regard (see Table A1.2 in Appendix 1 for an example). During the O-D survey, transport price, weight of load and means of transport will also need to be captured. [Step 1 is normally not carried out in the conventional approaches].

Step 2: Determine the transport cost

Using data obtained from road agencies, together with field work (if necessary), gather all the information required to model the transport cost. Record the information about road conditions, road lengths, and traffic data for each stage or trip established in Step 1. Collect information about the unit cost for construction and maintenance, as well as construction and maintenance policies and standards. Record the vehicle fleet characteristics and associated economic and financial costs. Most of these data are available in the road network databases of the district and regional road agency offices. Then use existing tools such as HDM-4 or RED to model the transport cost for each trip established in Step 1. [Step 2 is carried out in the conventional approaches].

Step 3: Establish the relationship between transport price, transport cost and trip distance

Use regression analysis (or another approach) to establish the relationship between transport price, transport cost and trip distance using the transport prices and trip distances obtained in

Step 1, together with the transport cost modelled in Step 2. [Step 3 is not carried out in the conventional approaches].

Step 4: Establish the crop price and crop production pattern of the study area

Crop prices can be obtained by conducting interviews at the marketplace and/or with agricultural officials. Reports of agricultural census or surveys (for example national panel surveys), along with reports from the local agricultural departments, can provide the required information about crop prices and production patterns. Visiting the website or offices of the national bureau of statistics and the ministry responsible for the agricultural sector can also provide information. [Step 4 is not carried out in the conventional approaches].

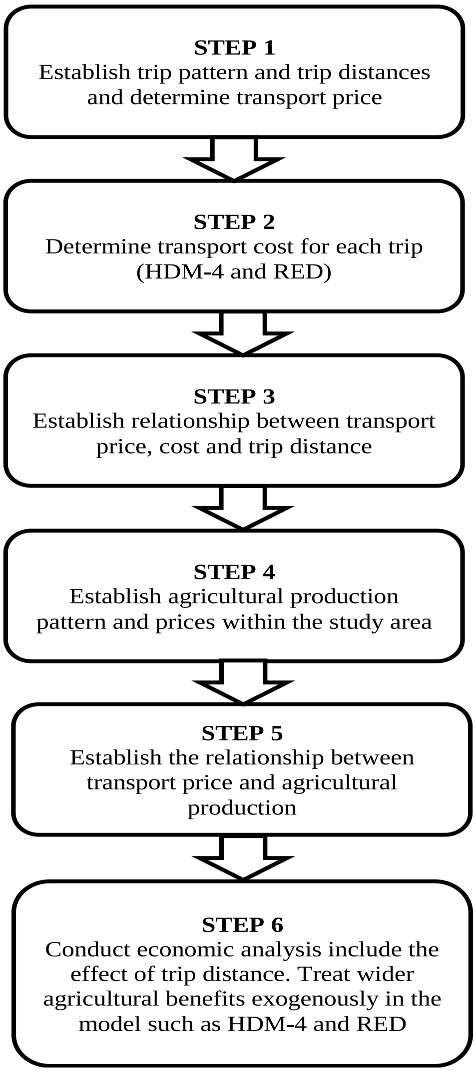
Step 5: Establish the relationship between transport price and crop production

Regression analysis (or another approach) can be used to establish the relationship between transport price and crop production (agricultural yields). The relationship can be established using cross-sectional or longitudinal data, depending on the availability of data. The cross-sectional approach can be used to compare agricultural production between those areas where the transport price is low and those areas where the transport price is high (if both are in the same region). The longitudinal approach can be used to trace the change in agricultural production following a change in transport price in one specific area over a period of time. [Step 5 is not carried out in the conventional approaches].

Step 6: Conduct economic evaluation, including the wider benefit from the agricultural sector and the effect of trip distance

Use the available road economic evaluation tools such as HDM-4 or RED to conduct an economic evaluation, treating the agricultural benefits exogenously. To avoid double-counting, VOC and travel time savings of vehicles transporting agricultural products should not be included. Treat road user cost savings for other vehicles categories normally. In the case of agricultural benefits, the effect of trip distance on transport price and subsequently on crop yields needs to be considered. Based on the O-D survey conducted in Step 1, establish the change in trip pattern that is likely to occur after the improvement of the rural road. There may also be a change in vehicle type, since the vehicles that operate on poor low-volume roads will be replaced by relatively larger vehicles from urban markets. The latter will be able to travel further in the more remote areas due to the improvement of the road, resulting in an increase in vehicle utilisation and trip distance and subsequently the benefits from the factor such as economy of distance.

Thereafter, estimate the reduction in transport price using the relationship established in Step 3 and the expected increase in agricultural yield using the relationship established in Step 4. Calculate the increase in crop value by multiplying the increase in crop production by the crop price. Include the increase in crop value (a wider agricultural benefit) in the analysis to obtain the total benefits of the investment in a low-volume rural road. [Step 6 is carried out in the conventional approaches, with exceptional of including wider agricultural benefits in relation to trip distance].



Source: Author

Figure 6.16: A framework for including agricultural benefits and trip distance effect in the economic appraisal of low-volume roads

The six steps described above will allow for the quantification of the expected increase in crop value following the road improvement. Steps 3 and 5 can be done once and used for several projects in the same area or other areas with similar characteristics.

6.4. Conclusion

The presented framework for the economic evaluation of low-volume rural roads takes into account the expected changes in transport price and trip distance following the road improvement, as well as road connectivity. The framework is a supplement to conventional road appraisal approach, explaining the procedures to undertake in conducting the economic evaluation of low-volume rural roads. The change in transport price is used to estimate the expected increase in agricultural production. This appraisal framework shows that by including the wider agricultural benefits and the effect of the change in trip pattern, i.e. distance, has a significant impact on economic feasibility of low-volume roads. Overlooking these factors may result in underestimating the benefits that a low-volume rural road may hold.

Using data from the Kilosa district in the Morogoro region in Tanzania, it was illustrated that upgrading feeder roads (from earth to gravel standard) that are connected to secondary roads, will lead to, roughly, a 35 percent reduction in the price of transporting agricultural products from the farm to the market. The reduction in transport price may stimulate an increase of, roughly, 10 percent in agricultural production. These agricultural benefits can justify road improvement - a decision which would not have been reached if conventional appraisal approaches had been used that only focus on savings from road users.

In comparing the VOC and time savings to the agricultural benefits emanating from the improved low-volume road, the results show that the agricultural benefits are three times higher than the road user cost savings. The savings from the individual vehicles, multiplied by the number of vehicles, is the total road user cost savings, which is the value that is used as the benefit in conventional economic analysis. Due to the low volume of traffic on rural roads, these consumer savings are not substantial. However, the savings from the individual vehicles on rural roads together with increased vehicle utilisation, as well as a more competitive transport market, lead to a significant reduction in the price charged to transport agricultural products from the farm to the market. Transport price reduction and improved access to urban markets lead to a substantial increase in crop production. This increase, that is the wider agricultural benefit, is much more significant than the total road user cost savings from the few vehicles traversing rural roads. Ignoring the agricultural benefits and concentrating on road user savings alone will underestimate the investment benefits during an economic appraisal of a low-volume rural road.

The 2007/08 National Sample Census of Agriculture in Tanzania reported various market problems such as transport prices are too high; the marketplace is too far; and lack of transport (Tanzania National Bureau of Statistics, 2012b). These problems hinder small-scale farmers from selling their products as well as increasing production. As a result, the agricultural sector in Tanzania is dominated by subsistence farming. Improved rural roads will allow for improved transport services by attracting more transport operators, which would, in turn, allow for lower transport prices and increase market accessibility. This, together with other rural development initiatives, may lead to a paradigm shift from subsistence to income-generating farming, and subsequently achieve the primary goal of reducing rural poverty and ensuring food security.

Chapter 7 : Conclusions and recommendations

7.1. Introduction

In Tanzania, as in many other sub-Saharan African countries, there is huge potential for agricultural development. The agricultural development potential in sub-Saharan Africa is essential for the development of the region (Gajigo & Lukoma, 2011). Agriculture is important for many sub-Saharan African countries, as it accounts for between 30 to 40 percent of their gross domestic product (GDP) (World Bank, 2013a). The sector employs roughly 65 to 70 percent of the labour force in most sub-Saharan African countries (World Bank, 2013a). Poor rural transport infrastructure and transport services are partly to blame for the underutilisation of agricultural potential (*Local Government Transport Programme (LGTP) Phase 1*, 2007, *National Transport Policy-Draft*, 2011; African Development Bank Group, 2013; PMO-RALG *et al.*, 2014). Transport infrastructure and transport services are among the key factors that support the development of the agricultural sector (see Dorosh *et al.*, 2010; Mkenda & Campenhout, 2011; Banjo *et al.*, 2012; OECD, 2013; Taiwo & Kumi, 2013; Hine, 2014; Kiprono & Matsumoto, 2014). In Tanzania, among others, the key problems facing farmers in marketing their products include: prices at the open market being too low (67%); transport prices being too high (5%); the marketplace being too far (4.4%); and lack of transport (3%) (Tanzania National Bureau of Statistics, 2012a). These problems hinder the small scale farmers from selling their crops which also affect crop production. To a large extent, these problems are related to the poor quality of rural transport infrastructure and transport services. Addressing the rural transport issue may reduce these problems and improve agricultural production.

Rural roads are associated with low volume of traffic, due to that, the limited available financial resources mainly focus on the improvement of national roads with high traffic volumes and pay less attention to low volume rural roads (*National Transport Policy*, 2003; African Development Bank Group, 2013). As a result, improvement and maintenance of rural roads infrastructure has been irregular and mostly limited to spot improvement, performed with inadequate resources, which yields only short-term results (*National Transport Policy*, 2003).

One of the reasons for the poor rural road infrastructure is the deficiencies in the appraisal tools used in decision-making for the allocation of resources to improve these roads (*Local Government Transport Programme (LGTP) Phase 1*, 2007). Conventional road appraisal tools do not fully capture the benefit of improved accessibility, especially in the rural areas. Wider agricultural benefits which may accrue as a result of improving low-volume rural roads are not fully captured (Kopp, 2016). Conventional appraisal tools such as HDM-4 and RED concentrate on direct road user benefits (VOC savings, time savings and accident cost savings), which in the case of low-volume rural roads are too small to offset the construction and maintenance costs of these roads (Schutte, 2005; *National Transport Policy-Draft*, 2011). As a result, the improvement of most of these roads seems not economically viable (Schutte, 2005; *National Transport Policy-Draft*, 2011), and when competes for funds with national roads with high traffic volume, less budget is allocated to these roads (*National Transport Policy*, 2003; African Development Bank Group, 2013). This situation keeps these roads in poor condition.

The aim of this research was to establish the relationship between agricultural production, transport price and transport cost. This relationship was used to develop a low-volume rural road appraisal framework which accounts for wider agricultural benefits, in order to allow for more informed decision-making in allocating resources for investment in these roads. To achieve the research aim, the research addressed four specific objectives, divided into two groups:

With regard to transport prices, transport costs, road condition and trip distance:

(i) to determine the transport costs and transport prices of agricultural products, and measure the impact of road condition and trip distance on these costs and prices; and
(ii) to establish the relationship between transport price, transport cost and trip distance, which will allow for the estimation of the change in transport price due to the change in transport cost and trip distance following a road improvement.

With regard to rural and market accessibility and agricultural production:

(iii) to establish the relationship between transport price and agricultural production; and
(iv) to establish the potential increase in agricultural production, (wider agricultural benefits) following the improvement of rural and market accessibility and reduced transport prices.

Objectives (i) and (ii) were addressed in Chapter 4, while Objectives (iii) and (iv) were addressed in Chapter 5. The results of Chapters 4 and 5 were used in Chapter 6 to develop a low-volume rural road appraisal framework. A practical illustration of how the new framework can be used was also presented in Chapter 6.

7.2. Research findings and implications

This section presents the summary of the research findings and their implications.

7.2.1. Transport price, transport cost, road condition and trip distance

The findings presented in this section address Objectives (i) and (ii). Surface type was used as a measure of the road condition, and assessed for its impact on transport price. For each trip, the length of the paved section of the road was denoted as the percentage-paved. The results indicate that the transport price, measured *per ton-km*, decreased with an increase in percentage-paved. These results imply that transport operators charge higher prices on roads with longer unpaved sections.

The research also found that transport price decreases with an increase in trip distance. Transport price is very high over short-distance rural trips which is generally less than 50 km in length and referred to as the 'first mile' (Njenga *et al.*, 2014). The high price of short-distance trips could be due to factors such as poor road condition, limited competition in the transport market and low vehicle utilisation.

Road surface type affects transport price, with higher transport price on less paved trips. Surface type, however, does not consider other road condition characteristics such as road alignment and surface roughness. In order to include their effects as well, the relationship between transport price and surface roughness (measured by the International Roughness Index (IRI)) together with other pavement characteristics was established.

There is a well-established relationship between road condition and vehicle operating cost (VOC) or transport cost (Hide *et al.*, 1975; Watanatada *et al.*, 1987; Bennett & Greenwood, 2001; Archondo-Callao, 2004). Therefore, instead of directly using road roughness together with other road conditions in the establishment of their relationship with transport price, VOC or transport cost was used in this analysis. HDM-4 was used to calculate the VOC for each trip based on the road network characteristics within the study area.

It was found that transport price decreases with transport cost, which is an indication of a competitive transport market (see (Teravaninthorn & Raballand, 2009). The decrease in transport price, however, is complicated by the fact that it is also affected by the trip distance as well as transport market regulation and competition. In deregulated and more competitive transport market measures that would reduce transport costs such as road improvement are expected to reduce transport prices as well. However, in a situation where cartels limit competition and have monopolised the transport market, there is no clear impact of transport price reduction following transport cost reduction (Teravaninthorn & Raballand, 2009).

The research established the empirical relationship between transport price, transport cost and trip distance. This relationship was used to predict the change in transport price following a change in transport cost and trip distance after a road improvement. Using the established relationship, the research found that the difference between the transport price and the transport cost is higher over short-distance trips. The transport price is up to nine times higher than the transport cost over short distances (12 km). This difference decreases as trip distance increases, to roughly 1.5 times higher over long-distance trips (550 km). The big difference between transport price and transport cost over short-distance trips may be attributed to the fact that there is less competition in the transport market for these trips. Another possible reason for the difference is vehicle utilisation. In modelling the VOC, the vehicle utilisation used in the RED and HDM-4 models was kept constant regardless of trip distance. However, overall vehicle utilisation may be significantly lower over short-distance trips compared to long-distance trips, which will have a different impact on transport costs.

The established relationship between transport price, transport cost and trip distance, to some extent, addresses the effect of competition in the transport sector, as well as vehicle utilisation. The impact of lowering transport cost on transport price is higher for short-distance trips than long-distance trips. The results show that a one unit reduction in transport cost will result in a reduction of 4.2 units in transport price over short-distance trips (12 km), while for long-distance trips (550 km) the same will result in a reduction of 0.7 units in transport price. This suggests that the higher reduction in transport prices over short-distance trips is not only due to the reduction in transport cost (because road improvement lowers transport cost), but also due to the increased competition in the transport market, as well as better vehicle utilisation. An improved road will attract more transport operators leading to increased competition.

The improvement of a low-volume rural road may also result in a change in trip pattern. Vehicles from urban centres (bigger markets) can reach more remote areas following the road improvement (see also Lançon *et al.*, 2014). The improvement may also result in the replacement of less-utilised village vehicles, which charge high transport prices for short-distance rural trips. This would result in longer trip distances and higher vehicle utilisation, which would reduce the fixed vehicle operating cost (cost per kilometre travelled).

An improvement of a low-volume rural road which is associated with possible longer trip distances, higher vehicle utilisation and increased competition in the transport sector will result in a significant reduction of the transport price. This reduction is normally not captured using tools such as HDM-4 and RED which only focus on the savings in vehicle operating cost due to the improvement of a specific section of the road.

To assess the benefits of improving a low-volume rural road, the effect on transport price should be included, as opposed to only considering the changes in transport costs. If not, the real investment benefits of rural roads are underestimated.

7.2.2. Rural and market accessibility and agricultural production

The findings presented in this section address Objectives (iii) and (iv). Descriptive statistics from the National Panel Survey (NPS) conducted in 2012/2013 show that roughly 80 percent of the cultivated plots in Tanzania are less than 3 acres in size, with an average farm size of 2.9 acres (1.17 ha). The agricultural sector is dominated by the smallholder farmers and subsistence farming practice, as only 38 percent of farmers sell their crops. The majority do not produce crops for commercial purposes. The NPS showed that those who sold their crops, on average, produced a higher quantity of harvest. Of the 38 percent who sold their crops, only 31 percent transported their crops to the market for selling. Several modes of transport were used to transport crops to the market, ranging from walking to the use of cars. The average trip distances to the market ranged from 5 km to 44 km. non-motorised transport (NMT) modes were used for shorter trips and motorised transport (MT) for longer trips.

The research also found that a reduction in transport price has a positive impact on crop yield. Reducing the transport price by one percent will increase crop yield by 0.291 percent. This expected change concurs with the results of Hine & Ellis (2001), who suggest that a one percent reduction in transport cost, fully passed to farmers, will increase agricultural output by 0.3 percent. Limi *et al.* (2015) also found that a one percent reduction in transport price and waiting time cost could increase agricultural production by more than one percent. Investing in road infrastructure to reduce transport costs and prices would, therefore, benefit the agricultural sector.

Improvement of road infrastructure and transport services and subsequent reduction in transport price are necessary but they are not the only factors to ensure increased crop yield. Road infrastructure improvement is a complement of other factors affecting agricultural production such as improvement in irrigation systems, post-harvest storage technology, provision of extension services and financial support.

The research also revealed that those farmers who sell their crops at the more distant markets have higher crop yields compared to those who sell at nearby (local) markets. There are two possible reasons for this:

(i) Those who sell their crops at more distant (relatively bigger) markets are better exposed and have a higher chance of accessing goods and services which may not be available locally, such as agricultural inputs and advice from extension officers and people they meet. These may facilitate an increase in crop yield.

(ii) Selling at more distant markets is associated with a lower unit transport price measured in *per ton-km*, as well as a higher crop price. The longer routes have the advantage of economy of distance; the road conditions are relatively good (since secondary roads leading to the bigger markets are in better condition) and involve efficient modes of transport (since longer trips use cars as opposed to walking and cycling). Famers who sell at more distant markets are better off in terms of transport price and crop price, which in turn facilitate an increase in crop yield.

It was also found that access to nearby (local) markets has an insignificant impact on crop yield, indicating that the local markets are not providing enough goods and services to facilitate the increase in crop production.

Small farms were found to be closer to the road and also exhibited a higher crop yield. However, being close to the road was not a direct reason for having higher yields, because there was no significant relationship between crop yield and the distance from the farm to the road. The size of the farm has a significant effect on the quantity harvested: bigger farms are associated with larger harvests. Looking at crop yield, however, it was found that bigger farms had lower yields compared to small farms. This means that the higher quantities of harvest seen on bigger farms are influenced by the size of the farm, and not the high yield. This result support the claim by the World Bank (2013a) that in Africa, the agricultural production increase is largely influenced by the increase in the area under cultivation and not productivity or yield.

The established empirical relationship between transport price and crop yield can be used during the road appraisal processes to quantify the expected increase in agricultural yield following a road infrastructure investment. Road infrastructure investment lower transport costs and transport prices. However, in order to improve agricultural production, an improved rural road network must be linked to the secondary roads leading to the bigger markets.

Improving low-volume rural roads and enhancing road network connectivity allows for lower transport prices and facilitates access to bigger markets, which ultimately impact positively on the agricultural sector.

7.2.3. Low-volume rural road economic appraisal framework

The research presented a low-volume rural road economic appraisal framework, Figure 6.16, which is an extension to the conventional cost-benefit analysis. The framework uses transport price to assess the expected benefits rather than transport cost, which is commonly used in economic evaluations. The change in transport price is used to estimate the expected increase in agricultural production. The benefits associated with this increase in agricultural production are treated exogenously and included in a conventional tool such as HDM-4 and RED.

As presented in Section 6.3, the steps of this framework are:

1. Establish the trip patterns, trip distances and transport prices within the study area.
2. Determine the transport cost.
3. Establish the relationship between transport price, transport cost and trip distance.
4. Establish the crop price and production patterns within the study area.
5. Establish the relationship between transport price and crop production.
6. Conduct the economic evaluation including the wider benefits from the agricultural sector and the effect of trip distance.

A practical illustration of the proposed framework for appraising low-volume rural roads, using data from the Kilosa district in the Morogoro region in Tanzania, revealed that upgrading feeder roads (that are connected to the secondary roads) from earth to gravel standard, will lead to a roughly a 35 percent reduction in the price of transporting agricultural products from the farm to the bigger market. This reduction in transport price may lead to an increase of ±10 percent in agricultural production. These agricultural benefits are enough to justify a road upgrade - a decision which would not have been reached if conventional appraisal approaches had been used.

In comparing the VOC and time savings to the agricultural benefits emanating from the improved low-volume road, the results show that the agricultural benefits were roughly three times higher than the road user cost savings. The road user savings from the individual vehicles on rural roads together with increased vehicle utilisation, as well as a more competitive transport market, can lead to a significant reduction in the price charged to transport agricultural products from the farm to the market. Transport price reduction and improved access to urban markets lead to a substantial increase in crop production. This increase, termed the wider agricultural benefit, is much higher than the total road user cost savings from the few vehicles traversing rural roads. During the economic appraisal of low-volume roads, ignoring the agricultural benefits and concentrating on road user savings alone will underestimate the investment benefits.

Improvement of low-volume rural roads will address some of the market problems mentioned in the 2007/08 National Sample Census of Agriculture in Tanzania, such as that transport prices are too high; the marketplace is too far; and lack of transport (Tanzania National Bureau of Statistics, 2012b). The agricultural sector in Tanzania is dominated by subsistence farming and these problems hinder small-scale farmers from selling their products as well as increasing production. Better rural roads and improved transport services will allow for lower transport prices and increase market accessibility. This, together with other rural development initiatives such as irrigation and post-harvest storage technology (as discussed in Torero & Chowdhury, 2005; Gajigo & Lukoma, 2011; Hine, 2014), may lead to a paradigm shift from subsistence to income-generating farming, and subsequently achieve the primary goal of reducing rural poverty and ensuring food security.

7.3. Recommendations for future work

In this research, the analysis used a medium truck as the means of transportation. It is recommended that, in future studies, other types of vehicle and modes of transport that are available in the study areas should also be assessed. This will allow for a more understanding of what changes in vehicle type and mode of transport may occur following the improvement of a low-volume rural road, and how these changes would affect the way agricultural products are transported to market.

The statistical relationship between agricultural yields and transport price included only the farmers who transport their crops and pay for the transport services (only 4.3 percent of data set). This leaves out a large portion of the farmers who cultivated crops but did transport or pay for transport service. National surveys such as Tanzania's National Panel Survey (NPS), which are conducted for the purpose of assessing the economic development of a country, need to be improved so as to provide more detail on transport section. The surveys should collect information not only from farmers but also from the transport operators who are engaged in the agricultural sector. This will provide more information on how agricultural products reach the market even for the farmers who sell but did not transport their crops to the markets themselves. This will allow for the bigger percentage of farmers to be included in the analysis.

Local road network data need to be improved. Making available GPS coordinates from the start to the end of each road link and providing maps showing entire local road networks. This will allow for easy locating of a specific link in the road network and even to link the road network with other datasets.

Africa needs to increase agricultural output and it is important to understand the impact of infrastructure investment such as roads on the agricultural sector. Investment in infrastructure and improvement in agricultural sector should aim at reducing poverty, ensuring food security as well as supporting the economic development of the region.

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Appendix 1

Table A1.1: Road authority official's sample questionnaire

INTERVIEW WITH ROAD AGENCIES OFFICIALS

PART 1

Interviewer details

1. Date of the interview:

2. Name of the interviewer:

Interviewee details

1. Organisation name:

2. Regional:

3. District:

4. Interviewee position in organisation:

5. Name of the interviewee:

PART 2

Please provide the information regarding the following questions. Separate documents containing the information can be provided

1. Provide the details of the road network (pavement and geometry) such as road class, road chainage and length, surface type, carriage and shoulder widths the road terrain (flat, rolling, mountainous) and drainage systems.

2. Provide the information about the condition of the road (distress and roughness) including road roughness, distress type, distress extent and severity and drainage features condition.

3. Provide the information about the traffic volume in the road network including annual average daily traffic (AADT), vehicle category and traffic growth rate.

4. For each vehicle category provides the details of vehicle characteristics and economic unit cost such as no. of wheels, no of axles, axle load, annual utilisation, working hours, vehicle purchase price, maintenance labour cost, crew wages cost, overhead cost and passenger travel time cost.

5. Provide the information about the road routine and periodic maintenance, road upgrade etc. and when was it is done and/or the frequency of activity.

6. Provide the information about road construction and maintenance unit costs, the agency economic cost factor and prevailing discount rate.

Table A1.2: Transporters sample questionnaire

INTERVIEW WITH TRANSPORT OPERATORS

PART 1
Interviewer details

1. Date of the interview:

2. Name of the interviewer:

Interviewee details

1. Organisation name:

2. Type of organisation *(Private owner, company)*:

3. Regional:

4. District:

5. Interviewee position in organisation:

6. Name of the interviewee:

PART 2
Please provide the information regarding the following questions

1. What is the origin and destination of your frequent trips

Trip no.	From			To		
	Region	District	Ward/ village	Region	District	Ward/ village

2. What type of crops do you transport and how much is the loading and charges per trip

Trip no.	Crop type	Cargo weight/load (Tons)	Transport charges (Tsh)

Table A1.3: Agricultural officials sample questionnaire

INTERVIEW WITH AGRICULTURAL OFFICIALS

PART 1
Interviewer details

1. Date of the interview:
2. Name of the interviewer:

Interviewee details

1. Organisation name:
2. Regional:
3. District:
4. Interviewee position in organisation:
5. Name of the interviewee:

PART 2

Please provide the information regarding the following questions. Separate documents containing the information can be provided

1. What are the common types of crops cultivated in the district
2. Provide information about the prices of the crops cultivated in the district
3. Provide information about the harvested quantity of crops cultivated in the district
4. Provide information about crops yield and the potential for increase in crops yield
5. Provide information of the total arable land in the district
6. Provide information about the area utilised for agricultural purposes
7. Provide information of area occupied by each crop cultivated in the district

Appendix 2

Table A2.1: Freight charges for medium trucks, trip distance and general road condition: from ward centre to district centre

Sn	District	Ward	From	To	Road class*	Length of paved section (km)	Condition of paved section	Length of gravel section (km)	Condition of Gravel section	Length of earth section (km)	Condition of earth section	Total Length	Cargo Weight (tons)	Freight charges per trip (Tsh)
1	Gairo	Kibedya	Kibedya	Gairo Town	D+T	5.3	Fair	7.3	Fair			12.6	0.13	2 000
2	Gairo	Chakwale	Chakwale	Gairo Town	D+T	5.3	Fair	10.5	Poor			15.8	0.13	3 000
3	Kilosa	Tindiga	Tindiga	Kilosa Town	F+R	0		15.9	Fair, Poor	0		15.9	10	180 000
4	Gairo	Rubeho	Rubeho	Gairo Town	D	0		16	Fair			16.0	0.13	3 000
5	Kilosa	Kilangali	Kilangali	Kilosa Town	C+R	0		7.2	Poor	18.3	Poor	25.5	10	250 000
6	Gairo	Chakwale	Kitaita	Gairo Town	F+D+T	5.3	Fair	25.1	Fair, Poor			30.4	0.13	4 000
7	Gairo	Idibo	Idibo	Gairo Town	F+D+T	5.3	Fair	31.1	Fair, Poor			36.4	0.13	4 500
8	Kilombero	Mngeta	Namwawala	Ifakara Town	R	0		36.7	Fair, Poor			36.7	0.15	3 500
9	Gairo	Iyongwe	Iyongwe	Gairo Town	D+T	5.3	Fair	42	Fair			47.3	10	400 000
10	Kilombero	Mngeta	Mofu	Ifakara Town	D+R	0		44.7	Fair, Poor	9.5	Fair, Poor	54.2	0.15	4 000
11	Ulanga	Iragua	Iragua	Ifakara Town	T	4.19	Fair	53.08	Poor			57.3	0.12	7 000
12	Ulanga	Mahenge	Mahenge	Ifakara Town	T	6.17	Fair	63.41	Poor			69.6	0.12	8 000
13	Ulanga	Mtimbira	Mtimbira	Ifakara Town	T	4.19	Fair	90.78	Fair, Poor			95.0	0.12	8 000
14	Ulanga	Malinyi	Malinyi	Ifakara Town	R+T	4.19	Fair	98.89	Fair, Poor			103.1	0.12	8 000
15	Kilombero	Mngeta	Chita	Ifakara Town	R	0		109	Fair, Poor			109.0	0.15	7 000

*T=Trunk road, R= Regional road, D= District road, C=Collector road, F= Feeder road

Table A2.2: Freight charges for medium trucks, trip distance and general road condition: from ward centre to Morogoro urban

Sn	District	Ward	From	To	Road class*	Length of paved section (km)	Condition of paved section	Length of gravel section (km)	Condition of Gravel section	Length of earth section (km)	Condition of earth section	Total Length	Cargo Weight (tons)	Freight charges per trip (Tsh)
1	Kilosa	Rudewa	Rudewa	Morogoro	R+T	110.15	Good, Fair	0				110.2	10	450 000
2	Kilosa	Tindiga	Tindiga	Morogoro	F+R+T	29.21	Fair	83.62	Fair, Poor			112.8	10	450 000
3	Kilosa	Zombe	Zombo	Morogoro	R+T	29.21	Good, Fair	86.92	Good, Fair, Poor			116.1	10	500 000
4	Kilosa	Kilangali	Kilangali	Morogoro	C+R+T	29.21	Fair	74.92	Fair, Poor	18.3	Poor	122.4	10	650 000
5	Kilosa	Ulaya	Ulaya	Morogoro	R+T	29.21	Fair	98.01	Good, Fair, Poor			127.2	10	600 000
6	Gairo	Kibedya	Kibedya	Morogoro	D+T	127.7	Good, Fair	7.3	Fair			135.0	10	400 000
7	Gairo	Chakwale	Chakwale	Morogoro	D+T	127.7	Good, Fair	10.5	Poor			138.2	10	450 000
8	Gairo	Rubeho	Rubeho	Morogoro	D+T	133	Good, Fair	16	Fair			149.0	10	450 000
9	Gairo	Chakwale	Kitaita	Morogoro	F+D+T	127.7	Good, Fair	25.1	Fair, Poor			152.8	10	550 000
10	Gairo	Idibo	Idibo	Morogoro	F+D+T	127.7	Good, Fair	31.1	Fair, Poor			158.8	10	550 000
11	Gairo	Iyongwe	Iyongwe	Morogoro	D+T	127.7	Good, Fair	42	Fair			169.7	10	600 000
12	Kilosa	Kimamba	Kimamba	Morogoro	R+T	29.21	Fair	48.41	Good, Fair			77.6	10	400 000

*T=Trunk road, R= Regional road, D= District road, C=Collector road, F= Feeder road

Table A2.3: Freight charges for medium trucks, trip distance and general road condition: from ward/district centre to Dar es Salam

Sn	District	Ward	From	To	Road class*	Length of paved section (km)	Condition of paved section	Length of gravel section (km)	Condition of Gravel section	Length of earth section (km)	Condition of earth section	Total Length	Cargo Weight (tons)	Freight charges per trip (Tsh)
1	Kilosa	Kimamba	Kimamba	Dar es Salaam	R+T	221.21	Good, Fair	48.41	Good, Fair			269.6	10	680 000
2	Kilosa	Kilosa Town	Kilosa	Dar es Salaam	R+T	221.21	Good, Fair	67.72	Good, Fair			288.9	10	650 000
3	Kilosa	Rudewa	Rudewa	Dar es Salaam	R+T	221.21	Good, Fair	59.41	Good, Fair			280.6	10	700 000
4	Mvomero	Turiani	Turiani	Dar es Salaam	R+T	255.04	Good, Fair	43.52	Fair			298.6	10	600 000
5	Mvomero	Turiani	Turiani	Dar es Salaam	R+T	255.04	Good, Fair	43.52	Fair			298.6	0.13	8 000
6	Morogoro rural	Kisaki	Kisaki	Dar es Salaam	R+T	171.88	Good, Fair	127.33	Fair, Poor			299.2	10	800 000
7	Kilosa	Rudewa	Rudewa	Dar es Salaam	R+T	302.15	Good, Fair	0				302.2	10	700 000
8	Kilosa	Tindiga	Tindiga	Dar es Salaam	F+R+T	221.21	Good, Fair	83.62	Fair			304.8	10	800 000
9	Kilosa	Zombo	Zombo	Dar es Salaam	R+T	221.21	Good, Fair	86.92	Good, Fair, poor			308.1	10	850 000
10	Kilosa	Kilangali	Kilangali	Dar es Salaam	C+R+T	221.21	Good, Fair	74.92	Fair ,poor	18.3	Poor	314.4	10	850 000
11	Kilosa	Ulaya	Ulaya	Dar es Salaam	R+T	221.21	Good, Fair	98.01	Good, Fair, Poor			319.2	10	870 000
12	Gairo	Kibedya	Kibedya	Dar es Salaam	D+T	319.7	Good, Fair	7.3	Fair			327.0	10	700 000
13	Gairo	Msingisi	Msingisi	Dar es Salaam	D+T	325	Good, Fair	5	Fair			330.0	10	650 000
14	Gairo	Chakwale	Chakwale	Dar es	D+T	319.7	Good, Fair	10.5	Poor			330.2	10	750 000

				Salaam										
15	Gairo	Rubeho	Rubeho	Dar es Salaam	D+T	325	Good, Fair	16	Fair			341.0	10	750 000
16	Gairo	Chakwale	Kitaita	Dar es Salaam	F+D+T	319.7	Good, Fair	25.1	Fair, Poor			344.8	10	800 000
17	Gairo	Idibo	Idibo	Dar es Salaam	F+D+T	319.7	Good, Fair	31.1	Fair, Poor			350.8	10	800 000
18	Kilosa	Kisanga	Kisanga	Dar es Salaam	D+R+T	310.91	Good, Fair	45	Fair, Good			355.9	10	900 000
19	Kilosa	Kisanga	Kisanga	Dar es Salaam	D+R+T	310.91	Good, Fair	45	Fair, Good			355.9	10	800 000
20	Gairo	Iyongwe	Iyongwe	Dar es Salaam	D+T	319.7	Good, Fair	42	Fair			361.7	10	850 000
21	Kilosa	Malolo/Mikumi	Ruaha Mbuyuni	Dar es Salaam	T	383.79	Good, Fair	0		0		383.8	10	700 000
22	Kilombero	Ifakara	Ifakara	Dar es Salaam	T	362.32	Good, Fair	57.09	Fair, Poor			419.4	10	700 000
23	Kilombero	Mngeta	Mbingu	Dar es Salaam	R+T	362.32	Good, Fair	111.29	Fair, poor			473.6	10	1 000 000
24	Kilombero	Mlimba	Mlimba	Dar es Salaam	R+T	386.58	Good, Fair	182.88	Fair, Poor			569.5	10	1 100 000

*T=Trunk road, R= Regional road, D= District road, C=Collector road, F= Feeder road

Table A2.4: HDM-4 and RED input data

Vehicle Characteristic: Medium Trucks 2 axles & > 3.5 tonnes	**Economic cost (USD): Medium Trucks 2 axles & > 3.5 tonnes**	**General road characteristics: Morogoro region**
Pass Car space equiv. = 1.4	New Vehicle = 68 666	Carriageway width = 5.5 - 6.5 m
No of Wheels = 6	Replacement Tyre = 314	Shoulder width 0 - 1.5 m
No of Axles = 2	Fuel per litre = 0.82	Number of Lanes = 2
Tyre Type = Bias ply	Lubricating oil per litre = 2.35	Flow Direction = Two ways
Base no of recaps = 1.3	Maint labour per hour = 4.49	Terrain = Rolling
Retread cost = 15%	Crew wages per hour = 1.05	Wearing course thickness
Annual utilisation = 100 000 km	Annual overhead = 2096	- AC = 50 mm
Working hours = 3260 hrs	Annual interest = 5 %	- Gravel = 150 mm
Average life = 15 yrs	Passenger work time per hour = 0.46	Pavement Structural number
Private use = 0 %	Passenger non-work time per hour = 0.14	-AC = 2.4
No. Passengers = 0	Cargo per hour = 0	-Gravel = NA
Work related pass trips = 0 %	Financial- Economical Cost Factor = 0.82	Pavement roughness
ESALF = 1.7	Discount rate = 12 %	-AC = 5.0 m/km
Operating Weight = 13.8 tonnes	Exchange Rate: 1 USD = 1 690 Tsh	-Gravel = 6.0 - 15.0 m/km

Table A2.5: Brauch-pagan-test results: Model 4.2

Dependant variable :Square of unstandardised residues	Coefficients	P-values	Significant F	Adjusted R square
Intercept	-0.029	0.257	0.167	0.045
ln(Trip distance)	-0.001	0.119		
ln(Transport cost)	0.005	0.181		
D1 (% paved <50%)	-0.003	0.027		

TableA 2.6: VIF values, test for multicollinearity: Model 4.2

Dependant variable : ln(transport price)	Collinearity Statistics	
	Tolerance	VIF
ln(Trip distance)	0.513	1.949
ln(Transport cost)	0.513	1.949

Appendix 3

Table A3.1: Summary of the agricultural questionnaire, 2012/2013 NPS data

SECTION	SECTION TITLE	SUMMARY DESCRIPTION*
SECTION A:	Household identification / survey staff details	***Household location variables, unique within panel round household identification variables,*** date and time of interview, analytic weights, cluster identification, sampling strata identification, enumerator identification, supervisor identification, and data entry clerk identification.
SECTION 01:	Household roster	Key roster information only, including name, age, sex of household members as well as which member is the key respondent for the agricultural questionnaire.
SECTION 2A/2B:	Plot roster	***Roster of all plots owned or cultivated by the household, including measurement information as calculated by GPS and farmer's estimate ,*** GPS coordinates, weather conditions at measurement, and reason for missing GPS.
SECTION 3A/3B:	Plot details	Detailed information on usage of plot, ***main cultivated crops,*** distance of plot from home, ***distance of plot from market, distance of plot from road*** , decision-makers in household, ***soil quality*** and type with a focus on erosion, ***irrigation*** and sources of irrigation, ownership status of plot, rental value, ***value of agricultural inputs*** , usage patterns of fertilisers and agriculture inputs obtained on credit. Household and hired labour for farming activities is also reported.
SECTION 4A/4B:	Annual crops by plot	Crop planting patterns, ***intercropping, area and quantity of harvested crops, estimated value of harvested crops*** , associated losses, ***crop seeds purchased along with associated values,*** source and ***type of seed*** for all annual crops.
SECTION 5A/5B:	Annual crop production and sales	Questions on ***quantity of crops sold*** , ***value of sales*** , customers crops sold to, ***average distance that crops were transported to for selling*** , ***amount paid to transport crops, means of transport*** , post-harvest losses, how crop residue was handled, method and duration for which crop was stored.
SECTION 6A:	Fruit trees by plot	Number of fruit trees planted on the plot, when these were planted, presence of intercropping, quantity produced, loss before and after harvest, quantity sold, associated value and location sold, method and quantity of crop stored are asked in this section.
SECTION 6B:	Permanent crops by plot	Number of permanent crops planted on the plot, when these were planted, how many were planted in the past 12 months, intercropping activities, quantity produced, losses before and after harvest, quantity sold, associated value and location sold, method and quantity of crop stored are asked in this section.
SECTION 7A/7B:	Fruit crops – production and sales	Quantity of crop sold, associated value and location sold, post production losses and method and quantity of crop stored are included.
SECTION 8:	Input vouchers	Information is asked about amount of inputs redeemed from vouchers, household members that received the vouchers and how the inputs redeemed from vouchers were used by the household.
SECTION 9A/9B/9C:	Outgrower schemes and contract farming	Information on crops, companies, pre-planting agreements, and buyer compliance are recorded for farmers engaging in outgrower schemes and contract farming.
SECTION 10:	Processed agricultural products and agricultural by-products	Information on crops, by-product names and quantity produced, amount of crop used as input, quantity sold, associated prices and buyers and costs incurred due to labour/other inputs are included in this section.
SECTION 11:	Farm implements and machinery	Detailed information on the number of farm implements and machinery used or owned by the household in the past 12 months along with associated value if sold, whether the item was used, reasons for no usage, whether any of these items were rented or borrowed for use in the last twelve months and associated rents paid
SECTION 12A/12B:	Extension	Any extension services or advice that the household received for agricultural or livestock activities in the past 12 months through government extension, NGOs, Cooperative/Farmer's Association, Large Scale Farmers, Radio/television, Publications or Neighbours including what activity advice was sought for, subjective rating for advice received, and price paid for receiving advice.
SECTION NETWORK		Throughout the various sections of the agricultural questionnaire, there are questions that refer to persons outside the household that are involved in the agricultural process. Examples include landlords, suppliers of inputs, harvest purchasers, outgrower partners, etc. The network roster file contains the location and category of each of these persons.

*Bold and italicised are variables used in the analysis.

Data merging and aggregation

Among the 15 agricultural files provide in the NPS data, five different files were merged and variables manipulated and aggregated to put the data in the required format. The process started by merging file AG_SEC_2A and AG_SEC_3A. File AG_SEC_2A contains 5 010 households, 15 variables and 9 157 cases; the required variable in this file was plot size/area. File AG_SEC_3A contains 5 010 households, 178 variables, and 9 157 cases, in this file the required variables were: main crop cultivated on a plot, distance of the plot from the road, distance of the plot from the local market, soil quality, whether plot was irrigated or not, organic fertiliser used per plot, inorganic fertiliser used per plot as well as pesticides/herbicides used per plot. A combination of two variables, i.e. unique household identification (y3_hhid) and plot number (plotnum) were used in merging the two files, i.e. unique household identification and plot number were matched from the two files, and the information from both files was combined into one file. Let’s call the combined file 2A_3A; this file contains 5 010 households, 189 variables and 9 157 cases, and for each plot, the reported cultivated crop was the main crop. File AG_SEC_4A which contains 5 010 households, 40 variables and 10 183 cases was then merged with file 2A_3A. In file AG_SEC_4A the required variables were: how much of the plot area was planted, whether crops were intercropped on not, the amount paid to purchase seeds, whether seeds used were improved seeds or not, areas harvested and quantity harvested. Two variables were used in merging these files, unique household identification (y3_hhid) and plot number (plotnum). Now the merged file, call it file 2A_3A_4A contains 5 010 households, 224 variables, and 10 183 cases. In file 2A_3A, the cultivated crop on a plot was given as the main crop cultivated (ag3a_07_1) and in file AG_SEC_4A the cultivated crop was given as crop name (zaoname), meaning that the reported cultivated crop on file AG_SEC_4A can be either the main crop or other crop planted together with the main crop. In such a situation is where a single household can have two or more crops planted in the same plot, termed as intercropping. Table A3.2 gives an example of an intercropped plot, i.e. household HH1 planted maize and sunflower on the same plot, M1, and household HH2 planted maize and beans on the same plot, M3.

Intercropping poses a challenge, because, if two or more crops were planted in the same plot the data set did not explicitly tell how was the plot divided for each of the planted crops. This makes it difficult to know what portion of the plot was planted with either main crop or other crops.

Table A3.2: Intercropped plots

Household ID	Plot number	Crop
HH 1	M1	Maize (Main crop)
HH 1	M1	Sunflower (other crop)
HH 2	M3	Maize (Main crop)
HH 2	M3	Beans (other crop)

Therefore, it was assumed that the size of the plot which was occupied by the crop is equal to the reported harvested area for that specific crop. The reported area harvested per crop appears to be the same for all crops planted on the same plot and in some cases was equal to the plot size. Take an example of a plot which was 1.5 acres and there were two different types of crops planted on that plot, then an area of 1.5 acres was reported as the areas harvested for the crops type one as well as for crop type two; meaning that the reported areas harvested per crop were somehow bigger than the actual area harvested per crop.

Again, input usage, i.e. fertilisers and herbicides/pesticides, was given per plot in file AG_SEC_3A, but in the case of intercropping, other crops were also planted in the same plot and it was difficult to differentiate between the inputs used for main crop and those used for other crops. Therefore, the inputs usage per plot was assigned for each crop planted on that particular plot. Meaning that, if the fertiliser usage was 100kg per plot and, there are two different crops planted on that plot, each crop was assumed to use 100kg of fertiliser.

On the other side, a household can cultivate the same crop in two or more of its plots. In such a case the crops were aggregated to get the total for a household. The condition used to aggregate crops was if the same crop was planted in different plots and the cultivating household is the same, then the crop information such as area harvested, quantity harvested, etc. from different plots were aggregated to get the total for the household. Aggregating the same crops for the household was done to allow for merging crops cultivation and crops selling information, as the crops selling information was given *per household per crop* and not *per household per crop per plot* as it was given in crops cultivation information. Table A3.3 gives an example of aggregating crop cultivation information for a household. The aggregated file contains 5 010 households and 8 487 cases.

The aggregated file 2A_3A_4A was then merged with file AG_SEC_5A which contains 5 010 households, 48 variables and 8 422 cases. The required variables in file AG_SEC_5A were: quantity sold, the total value of the sale, if sold crops were transported or not, the average distance travelled during crop selling, means of transport and amount paid during transporting crops. File 2A_3A_4A_5A was obtained which contains 5 010 households and 8 487 cases.

Table A3.3: Example of aggregating area harvested

Household ID	Plot number	Crop	Area harvested (acres)
HH 1	M1	Maize	2
HH 1	M2	Maize	2.3
HH 1	M3	Maize	1.9
HH 2	M1	Beans	1.5
HH 2	M2	Beans	2.2
Etc.	Etc.	Etc.	Etc.

Aggregate →

Household ID	Crop	Area harvested (acres)
HH 1	Maize	6.2
HH 2	Beans	3.7

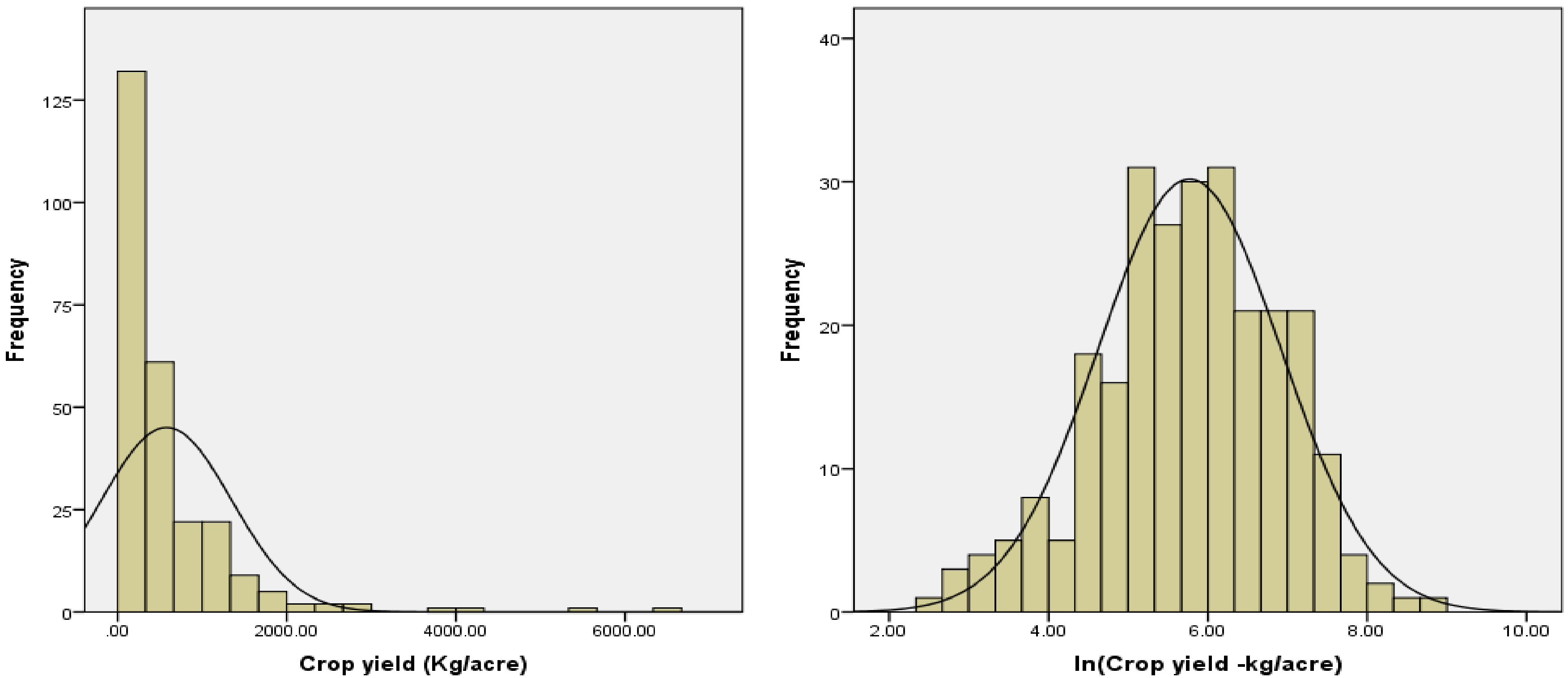
Finally, file 2A_3A_4A_5A was merged with file AG_SEC_A to obtain the spatial distribution of the sample within the country. File AG_SEC_A contain the household information including the region and district where the household is situated. Table A3.4 shows the spatial distribution of households.

Table A3.4: Regional spatial distribution of households

Sn.	Region	Frequency	Percent	Cumulative Percent
1	ARUSHA	155	1.8	21.6
2	DAR ES SALAAM	223	2.6	24.2
3	DODOMA	311	3.7	27.8
4	IRINGA	328	3.9	31.7
5	KAGERA	323	3.8	35.5
6	KASKAZINI PEMBA	73	.9	36.4
7	KASKAZINI UNGUJA	85	1.0	37.4
8	KIGOMA	263	3.1	40.5
9	KILIMANJARO	239	2.8	43.3
10	KUSINI PEMBA	85	1.0	44.3
11	KUSINI UNGUJA	39	.5	44.8
12	LINDI	441	5.2	49.9
13	MANYARA	132	1.6	51.5
14	MARA	119	1.4	52.9
15	MBEYA	390	4.6	57.5
16	MJINI MAGHARIBI	29	.3	57.8
17	MOROGORO	259	3.1	60.9
18	MTWARA	623	7.3	68.2
19	MWANZA	410	4.8	73.1
20	PWANI	132	1.6	74.6
21	RUKWA	216	2.5	77.2
22	RUVUMA	391	4.6	81.8
23	SHINYANGA	596	7.0	88.8
24	SINGIDA	177	2.1	90.9
25	TABORA	555	6.5	97.4
26	TANGA	219	2.6	100.0
	Total	**8 487**	**100.0**	

Table A3.5: List of crops

SN	CROP(SWAHILI)	CROP(ENGLISH)	Frequency	Valid Percent	Cumulative Percent
	MISSING		2249	26.5	26.5
1	ALIZETI	SUNFLOWER	196	2.3	28.8
2	BAMIA	OKRA	14	.2	29.0
3	BILINGANYA	EGG PLANT	8	.1	29.1
4	CHAINESE	SPINACH	3	.0	29.1
5	CHOROKO	GREEN GRAM	81	1.0	30.1
6	DENGU	CHICK PEAS	24	.3	30.3
7	FIGIRI	OTHER	1	.0	30.4
8	FIWI	OTHER	16	.2	30.5
9	HOHO	GREEN PEPPER	2	.0	30.6
10	KABICHI	CABBAGE	7	.1	30.7
11	KAHAWA	COFFEE	1	.0	30.7
12	KARANGA	GROUNDNUTS	433	5.1	35.8
13	KAROTI	CARROT	3	.0	35.8
14	KIENYEJI	OTHER	1	.0	35.8
15	KUNDE	COWPEAS	225	2.7	38.5
16	KUNDE NENE	COWPEAS	2	.0	38.5
17	KUNDE ZA ASILI	COWPEAS	1	.0	38.5
18	MABOGA	PUMPKINS	53	.6	39.1
19	MAGIMBI	COCOYAMS	107	1.3	40.4
20	MAHARAGE	BEANS	676	8.0	48.4
21	MAHINDI	MAIZE	2070	24.4	72.8
22	MAJANI YA KUNDE	COWPEAS LEAVES	1	.0	72.8
23	MAJANI YA MABOGA	PUMPKINS LEAVES	3	.0	72.8
24	MANJANO	OTHER	1	.0	72.8
25	MATEMBELE	OTHER	13	.2	73.0
26	MBAAZI	PIGEON PEAS	214	2.5	75.6
27	MBAAZI NDEFU	PIGEON PEAS	1	.0	75.6
28	MCHICHA	AMARANTHS	20	.2	75.8
29	MIHOGO	CASSAVA	34	.4	76.2
30	MKUNDE	COWPEAS	1	.0	76.2
31	MNAVU	OTHER	2	.0	76.3
32	MPUNGA	PADDY	691	8.1	84.4
33	MTAMA	SORGHUM	283	3.3	87.7
34	MWANI	OTHER	7	.1	87.8
35	NAMANGAYA	OTHER	1	.0	87.8
36	NGANO	WHEAT	20	.2	88.1
37	NGOGWE	OTHER	2	.0	88.1
38	NGWARA	OTHER	4	.0	88.1
39	NJEGERE	FIELD PEAS	7	.1	88.2
40	NJUGU MAWE	BAMBARANUTS	68	.8	89.0
41	NYANYA	TOMATO	42	.5	89.5
42	NYANYA CHUNGU	OTHER	4	.0	89.5
43	PAMBA	COTTON	151	1.8	91.3
44	PARETO	PYRETHRUM	13	.2	91.5
45	PILIPILI	PEPPER	2	.0	91.5
46	SELENA	OTHER	1	.0	91.5
47	SOYA	SOYABEANS	11	.1	91.6
48	SPINACHI	SPINACH	7	.1	91.7
49	SUKUMA WIKI	SPINACH	5	.0	91.8
50	TANGO	CUCUMBER	8	.1	91.9
51	TIKITI MAJI	WATERMELON	8	.0	91.9
52	TUMBAKU	TOBACCO	62	.7	92.6
53	TUNGULE	OTHER	4	.0	92.7
54	UFUTA	SESAME	109	1.3	93.9
55	ULEZI	FINGER MILLET	25	.3	94.2
56	UPUPU	OTHER	1	.0	94.3
57	UWELE	BULRUSH MILLET	65	.8	95.0
58	VIAZI MVIRINGO	IRISH POTATOES	42	.5	95.5
59	VIAZI VIKUU	YAMS	23	.3	95.8
60	VIAZI VITAMU	SWEET POTATOES	339	4.0	99.8
61	VITUNGUU MAJI	ONIONS	16	.2	100.0
62	VITUNGUU SAUMU	GARLIC	1	.0	100.0
63	ZA ASILI	OTHER	1	.0	100.0
64	ZA KUTAMBAA	OTHER	1	.0	100.0
	Total		8487	100.0	



(a) Before log-transformation (b) After log-transformation

Figure A3.1: Crop yield histogram with normal curve displayed before and after log-transformation

Table A3.6: Pearson's correlation: Crop yield and transport service, Model 5.15

Correlations							
		ln(Transport price-Tsh/ton-trip)	ln(Crop price-Tsh/kg)	ln(Quantity of input per acre)	ln(Distance from the farm to the road - km)	ln(Distance from the farm to the local market - km)	ln(Distance crop transported to the market for selling - km)
ln(Transport price-Tsh/ton-trip)	Pearson Correlation	1	.592**	-.159*	.108	.119	.335**
	Sig. (2-tailed)		.000	.010	.082	.054	.000
	N	261	261	261	261	261	261
ln(Crop price-Tsh/kg)	Pearson Correlation	.592**	1	-.218**	.153*	.120	.097
	Sig. (2-tailed)	.000		.000	.013	.054	.117
	N	261	261	261	261	261	261
ln(Quantity of input per acre)	Pearson Correlation	-.159*	-.218**	1	-.196**	-.079	.009
	Sig. (2-tailed)	.010	.000		.001	.205	.888
	N	261	261	261	261	261	261
ln(Distance from the farm to the road - km)	Pearson Correlation	.108	.153*	-.196**	1	.326**	.124*
	Sig. (2-tailed)	.082	.013	.001		.000	.045
	N	261	261	261	261	261	261
ln(Distance from the farm to the local market - km)	Pearson Correlation	.119	.120	-.079	.326**	1	.143*
	Sig. (2-tailed)	.054	.054	.205	.000		.020
	N	261	261	261	261	261	261
ln(Distance crop transported to the market for selling - km)	Pearson Correlation	.335**	.097	.009	.124*	.143*	1
	Sig. (2-tailed)	.000	.117	.888	.045	.020	
	N	261	261	261	261	261	261

Table A3.7: VIF results, Model 5.15

Dependent Variable: ln(Crop yield -kg/acre)	Collinearity Statistics	
	Tolerance	VIF
(Constant)		
ln(Transport price-Tsh/ton-km)	.364	2.744
ln(Crop price-Tsh/kg)	.398	2.510
ln(Quantity of input per acre)	.669	1.495
ln(Distance from the farm to the road - km)	.832	1.202
ln(Distance from the farm to the local market - km)	.824	1.213
ln(Distance crop transported to the market for selling - km)	.349	2.867
Dummy (Beans)	.542	1.845
Dummy (Chick Peas)	.952	1.050
Dummy (Cotton)	.318	3.143
Dummy (Cow Peas)	.905	1.105
Dummy (Green Gram)	.805	1.243
Dummy (Groundnuts)	.564	1.773
Dummy (Maize)	.400	2.502
Dummy (Paddy)	.487	2.055
Dummy (Pegion Peas)	.686	1.458
Dummy (Sesame)	.558	1.792
Dummy (Sorghum)	.901	1.110
Dummy (Tobacco)	.381	2.623
Dummy (Tomato)	.795	1.258

Table A3.8: Breusch-Pagan test results, Model 5.15

Dependent variable: Square Unstandardised Residual	**Unstandardised Coefficients**	**P values**	**Significant F**	**R- square**
(Constant)	1.151	.085	.000	.184
ln(Crop price-Tsh/kg)	-.070	.473		
ln(Transport price-Tsh/ton-trip)	.026	.748		
ln(Quantity of input per acre)	-.021	.595		
ln(Distance from the farm to the road - km)	-.019	.671		
ln(Distance from the farm to the local market - km)	.030	.638		
ln(Distance crop transported to the market for selling - km)	.096	.152		
Dummy (Beans)	-.762	.023		
Dummy (Chick Peas)	-1.240	.282		
Dummy (Cotton)	-.480	.121		
Dummy (Cow Peas)	2.223	.008		
Dummy (Green Gram)	-.744	.238		
Dummy (Groundnuts)	.564	.134		
Dummy (Maize)	-.808	.004		
Dummy (Paddy)	-.815	.019		
Dummy (Pegion Peas)	-.535	.200		
Dummy (Sesame)	-.357	.404		
Dummy (Sorghum)	-.617	.462		
Dummy (Tobacco)	-.698	.086		
Dummy (Tomato)	.131	.785		

Table A3.9: Park test results, Model 5.15

Dependant variable: Square Unstandardised Residual	**Unstandardised Coefficients**	**P- values**	**Significant F**	**R-square**
(Constant)	1.190	.030	.356	.003
Unstandardised Predicted Value	-.087	.356		

Table A3.10: White's test results, Model 5.15

Dependant Variable: Square Unstandardised Residual	Unstandardised Coefficients	P- values	Significant F	R-square
(Constant)	-.265	.956	.606	.004
Unstandardised Predicted Value	.287	.298		
Square Unstandardised Predicted Value	-.033	.697		

Figure A3.2: Relationship between transport price and distance to the market

TableA3.11: List of markets for selling crops, 2012/13 NPS data

			Distance crop transported to the market for selling		
	Market for selling	**Frequency**	**Mean**	**Median**	**Std.Dev**
1	Relative	4	14.8	16.0	9.3
2	Neighbour	7	22.0	4.0	29.4
3	Friend	3	15.7	6.0	16.7
4	Market	52	16.8	10.0	17.0
5	Open market	19	8.7	8.0	6.4
6	Cooperative union	34	5.8	3.5	7.3
7	Farmers party	9	6.7	5.0	4.8
8	Private business person	88	34.4	12.0	73.2
9	Business contact	16	22.0	22.5	13.9
10	Abattoir/factory	4	76.2	2.0	149.2
11	Grocery/local merchant	11	37.4	13.0	43.1
12	NGO	2	6.0	6.0	2.8
13	Other	7	16.7	12.0	15.7
14	Missing data	5			
	TOTAL	**261**			

Appendix 4

Calculation of crop production growth rate

Table A4.1 show the annual crop production. Table A4.2 shows the growth factor for each crop (i.e. production in ***n+1*** divide by production in year ***n***). Then a geometric mean

i.e. $\sqrt[8]{product\ of\ factors}$,

was calculated to find the average for all years for each crop. Finally the annual average growth rate, 4.5 percent, was obtained.

Table A4.1 annual crop production from 2004 to 2012

Year	Crop production (000 tonnes)									
	Maize	***Paddy***	***Wheat***	***Cassava***	***Beans***	***Sweet potatoes***	***Onions***	***Tomato***	***Sunflower***	***Cotton***
2004	4286	1030	66	2470	603	1245	232	527	30	149
2005	3857	957	69	2643	742	1220	236	543	30	166
2006	5191	1148	77	3335	919	1704	258	652	31	376
2007	5485	1209	83	3550	993	1721	247	597	30	130
2008	5759	1390	87	3763	1065	1755	252	625	31	201
2009	5846	1460	85	4215	1180	1667	253	611	30	141
2010	6252	1614	86	4299	845	1700	256	623	32	142
2011	6523	1679	88	4385	871	1734	261	642	36	146
2012	6914	1746	91	4692	906	1838	274	676	39	158

Source: Tanzania National Bureau of Statistics (2015c)

Table A4.2: Growth factors for different crops and annual crop production growth rate

	Factors(production in year n+1/ production in year n)									
Years range	***Mai ze***	***Pad dy***	***Whe at***	***Cassa va***	***Bea ns***	***Sweet potatoes***	***Onio ns***	***Tomat oes***	***Sunflow ers***	***Cott on***
2004 to 2005	0.90	0.93	1.05	1.07	1.23	0.98	1.02	1.03	1.00	1.11
2005 to 2006	1.35	1.20	1.12	1.26	1.24	1.40	1.09	1.20	1.03	2.27
2006 to 2007	1.06	1.05	1.08	1.06	1.08	1.01	0.96	0.92	0.97	0.35
2007 to 2008	1.05	1.15	1.05	1.06	1.07	1.02	1.02	1.05	1.03	1.55
2008 to 2009	1.02	1.05	0.98	1.12	1.11	0.95	1.00	0.98	0.97	0.70
2009 to 2010	1.07	1.11	1.01	1.02	0.72	1.02	1.01	1.02	1.07	1.01
2010 to 2011	1.04	1.04	1.02	1.02	1.03	1.02	1.02	1.03	1.13	1.03
2011 to 2012	1.06	1.04	1.03	1.07	1.04	1.06	1.05	1.05	1.08	1.08
Geometric mean of factors	1.06	1.07	1.04	1.08	1.05	1.05	1.02	1.03	1.03	1.01
Annual growth rate in % = (geometric mean of factor - 1)x100	6.16	6.82	4.10	8.35	5.22	4.99	2.10	3.16	3.33	0.74
Average annual growth rate	**4.50**									

Construction and maintenance standards

In managing the road network, the condition of the road need to be assessed and a decision made as to where, when and what type of intervention is required. To ensure consistency within the road administration the pre-define rules are set to identify the stage and circumstance to intervene in order to stop or reduce the rate of further road deterioration. These pre-defined rules are known as standards and intervention levels. In principle, these standards and intervention levels should be derived as part of the maintenance policy. Standard and intervention levels ensure that funds are spent efficiently and each part of the road network gets its fair share of the budget (Transportation Research Laboratory, 2003b). Standards are set in order to achieve a certain level of service to be provided by the road and to ensure optimal resource allocation during road infrastructure maintenance and improvement.

Overseas Road Note 20 (Transportation Research Laboratory, 2003a) point out that standard should be set considering the function and usage of the roads, when the traffic level is low and roads are less important it is possible to overlook certain sites and yet still to provide a suitable level of service to the road users. Considering the expected level of service and type of road, the offered service can be sufficient under one of the following standards (Transportation Research Laboratory, 2003a):

(i) Full standard: whereby the road provides safe, reliable, quick and comfortable year-round travel. The standard is suitable for primary and secondary roads as well as tertiary, feeder and access roads of more than 50 km[24] in length and equivalent daily traffic above 100[25].

(ii) Basic access: whereby the road provides safe and reliable year-round access for the typical vehicle (medium truck). This standard is suitable for tertiary, feeder and access roads less than 50 km in length with equivalent daily traffic below 100[2].

(iii) Partial access: whereby the road provides a minimum level of service at very low cost and access may not be year-round and may not suit all types of vehicle. The standard is suitable for tertiary, feeder and access roads that are in poor condition and not prioritised for improvement. The standard is also suitable for unclassified roads.

[24] The length can be changed based on the local condition
[25] The traffic volume can be changed based on the local condition

Roads have two basic functions (i) to provide mobility between centres; and (ii) to provide access to land and properties adjoining the road. For roads which the main function is to provide mobility, such as through and long distance traffic, high vehicle speed and uninterrupted traffic flow are desirable. For roads which the main function is to provide access, the high vehicle speed is not necessary and for the safety reasons not desirable. Therefore, the function of the road within the road network has a significant impact on the design standard to be adopted. Functional classification of the road affects features of the road such as the carriageway width, road alignment, traffic control measures and frequency of access (Tanzania Ministry of Works, 2011).

In Tanzania, road classification is based partly on function aspect and partly on administrative aspect. The road network is classified in accordance with the Road Act of 2007 as national roads and district roads. National roads are further classified as class A, trunk roads and class B, regional roads while district roads are further classified as class C, collector roads, class D, feeder roads and class E, community roads. Road class A and B are the highest classes, they cater for long distance trips and their major function is to provide mobility. Road class A and class B are managed by the Tanzania National Roads Authority (TANROADS). Road class C, D and E mainly cater for short trip distances and feed the higher class roads. These low class roads are managed by Prime Minister's Office Regional Administration and Local Government (PMO-RALG) (Tanzania Ministry of Works, 2011; TANROADS, 2016).

Tanzania road geometric design manual illustrates eight different design classes to be adopted for the design of different road class (Tanzania Ministry of Works, 2011). Table A4.3 provide the cross section dimension and surface type for each design class. The paved surface should be used for roads in the design class DC1 – DC5, design class DC6 may be gravel or paved while for the design class DC7 – DC8 gravel or earth road should be adopted.

Table A4.3: Road design classes, surface type and cross section dimension

Design class	**Surface**	**Carriageway**			**Shoulder width (m)**	**Median width (m)**
		Width (m)	Lane width (m)	No. of lanes		
DC1	Paved	2 x 7	3.5	4	2 x 2.5	9 – 12
DC2		7.5	3.75	2	2 x 2.0	-
DC3		7.0	3.5	2	2 x 2.0	-
DC4		6.5	3.25	2	2 x 1.5	-
DC5		6.5	3.25	2	2 x 1.0	-
DC6	Gravel or paved	6.0	3.0	2	2 x 1.0	-
DC7	Gravel	5.5	2.75	2	2 x 1.0	-
DC8	Earth of gravel	4.0	4.0	1	2 x 1.0	-

Source: Tanzania Ministry of Works (2011)

Table A4.4 illustrate the linkage between the design class and road functional class. The design class DC1 can be adopted for the road class A and /or B if the traffic volume on these is more than 8 000 vehicle per day. Design class DC8 can be adopted for road class D and/or E if the traffic volume on these roads is less than 20 vehicles per day. The linkage is important to ensure that the road is providing satisfactory service throughout its design life without the requirement of major improvement. In Tanzania a design life of 20 – 30 years is adopted for national roads and 15 – 20 years is recommended for district roads.

Traffic volume during the expected lifespan of the road is used as a guide to decide which design class is suitable for which road class. For the new road, however, design class DC4 is considered as the minimum standard to be adopted for trunk roads regardless of the traffic level and for regional roads, the design class DC5 is considered as the minimum standard. In any case, however, the design class to be adopted should be justified economically. Therefore, the final decision of the design class to be used will depend on the once-off construction costs, maintenance costs and road user costs. These costs are related to the volume and composition of traffic, travel time, accident and vehicle operating costs (Tanzania Ministry of Works, 2011).

Table A4.4: Linkage between design class and road class

Design class	**AADT (veh/day)**	**Functional class**				
		A	**B**	**C**	**D**	**E**
DC1	> 8 000	x	x			
DC2	4 000 – 8 000	x	x			
DC3	1 000 – 4 000	x	x			
DC4	400 – 1000	x	x	x		
DC5	200 – 400		x	x		
DC6	50 – 200			x	x	
DC7	20 – 50			x	x	x
DC8	< 20				x	x

Source: Tanzania road geometric manual of 2011

The Tanzania pavement and materials design manual provides guidance in pavement type to adopt and material to be used for road construction and maintenance (Tanzania Ministry of Works, 1999). The pavement structure mainly depends on traffic loading and climatic conditions. The loading is measured by cumulative number of standard axles, E80, during the design life and climate is specified as dry, moderated or wet. For a paved road, an asphalt concrete or surface treatment can be used as a surfacing material. The base material from granular material to bituminous material can be used. Rigid pavement could be employed as well, however, due to high investment cost their use is limited to heavily trafficked roads. Gravel roads are desirable for lower class roads. They consist of a gravel wearing course that meets the specified material requirements. Typically, 100 – 150 mm gravel wearing course is used for gravel roads in Tanzania (Tanzania Ministry of Works, 1999).

Tanzania developed a computer-based road maintenance management system (RMMS) called ‘Road Mentor’. The Road Mentor is the core of the road information system. The system produces annual maintenance programme. The information from Road Mentor can be exported to HDM-4 and used for strategic, programme and project analysis (Katala & Toole, 2000).

The Road Mentor data collection manual of 2005, a tool used for data collection for the implementation of the Road Maintenance Management System (RMMS) provides the required intervention measures to improve the road network based on the general existing condition of the road. Table A4.5 describe the condition of the roads and the required intervention measure for gravel roads. For each specific general condition of the road, the value of international roughness index (IRI) is provided and the level of the required intervention specified. IRI is the worldwide common index used to describe the road condition.

Table A4.5: Roads overall condition and required intervention measures for gravel roads

Overall condition	Description	Intervention
Very good	Shape condition of the surface in the ‘as built condition. IRI less than 4 m/km	Routine Maintenance
Good	Positive camber or crossfall with no ponding of water, with low frequency of defects of low severity. The camber or crossfall will usually be greater than 4%. IRI 4 – 6 m/km	Light grading capable of maintaining surface condition.
Fair	Camber or crossfall at minimum required to shed water. Insignificant ponding of water with low frequency of defects with medium severity, or medium frequency of defects with low severity, IRI 6 – 9 m/km	Light grading capable of restoring surface condition unless extensive potholing and concave shape exists, otherwise heavy grading required to restore surface condition.
Poor	Camber or crossfall insufficient to shed water and water ponding in ruts or areas of concave shape up to 150 mm deep. Medium frequency of defects with low severity or high frequency of defects with medium severity, IRI 9 – 15 m/km	Reprocessing suitable under most conditions, otherwise light or heavy reshaping required
Very poor	Substantial loss of camber or crossfall and water ponding in ruts or areas of concave shape in excess of 150 –300 mm. High frequency of defects with high severity, IRI greater than 15m/km	Light or heavy reshaping essential to restore shape

Source: Data Collection Manual Road Mentor Version 5 (2005)

Figure A4.1 provides the pictures taken during the field work showing the five different general road condition described in Table A4.3. The describe conditions on pictures is based on visual assessment.

Gravel road in very good condition

Gravel road in good condition

Gravel road in fair condition

Gravel road in poor condition

Gravel road in very poor condition

Figure A4.1: Pictures showing different condition of unpaved roads

Data used in analysis

Table A4.6: Kilosa road network

Sn	Road class and surface type	Condition	Total length (km)
1	Truck road – Paved	Good	162.9
		Fair	146.2
		Poor	16
2	Regional road - Paved	Good	44.91
		Fair	0
		Poor	0
3	Regional road – Gravel	Good	120
		Fair	75.03
		Poor	48.16
4	Collector road - Gravel	Good	75
		Fair	76.5
		Poor	61
5	Collector road - Earth	Good	17
		Fair	41.9
		Poor	75.9
6	Urban road - Gravel	Good	0
		Fair	12.1
		Poor	36
7	Feeder road - Gravel	Good	4
		Fair	8.7
		Poor	0
8	Feeder road - Earth	Good	44
		Fair	130
		Poor	236.2

Table A4.7: Traffic volume for different road class

Traffic volumes (AADT) in year 2013				
Vehicle category	**Urban roads**	**Regional roads**	**Collector roads**	**Feeder roads**
Bus	30	9	7	0
Car	69	20	16	4
Heavy truck	39	11	9	0
Light bus	33	10	8	0
Light lorry	30	9	7	2
Medium truck	36	10	8	2
Motorcycles	200	15	20	20
Pick up & vans	82	24	19	6
Very heavy truck (articulated)	10	3	2	0
Total	**529**	**111**	**96**	**34**

Source: TANROADS and PMO-RALG and author computation

Table A4.8: Vehicle characteristic and economic unit cost

Vehicle Classification	**Motor Cycle**	**Car**	**Pickups and vans**	**Light Bus ≤ 25 seats**	**Bus >25 (Seats)**	**Light truck ≤ 3.5 Tons**	**Medium truck Two - Axles > 3.5 Ton**	**Heavy truck (3-4 Axles) Truck > 10 Tons**	**Very heavy truck (articulated)**
Number of Axles	2	2	2	2	2	2	2	3	5
Number of Tyres	2	4	4	4	6	6	6	10	18
Passenger car space equivalent	0.5	1	1	1	1.6	1	1.4	1.6	1.8
Number of Passengers	1	4	5	15	50	0	0	0	0
Passenger working time value per hour ($)	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46
Passenger non-working time value per hour ($)	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14
Average Annual Kilometre	10000	25000	40000	94000	120000	60000	100000	120000	120000
Working Hours/ Year	200	590	1250	1050	2720	1050	3260	3660	3660
Average Vehicle Life (Yrs)	5	15	15	15	15	15	15	15	15
Operating weight (tons)	0.2	1.2	2.3	2.5	16.7	2.3	13.8	26	45
New vehicle Economic price($)	795	19986	28668	44788	326047	38969	68666	81434	174730
Fuel price per litre ($)	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82
Oil price per litre ($)	2.35	2.35	2.35	2.35	2.35	2.35	2.35	2.35	2.35
Maintenance labour per hour ($)	4.49	4.49	4.49	4.49	4.49	4.49	4.49	4.49	4.49
Crew wage per hours($)	0	0	0.94	1.5	1.5	0.94	1.05	1.05	1.44
Annual overhead ($)	100	508	1304	580	3462	707	2096	3316	3974

Source: Updated TANROADS VOC, Exchange rate, 2014: USD 1 = TSH 1 690

Table A4.9: Road works unit costs

Unpaved roads		
Treatment Type/Road work	**Economic cost (USD)**	**Financial cost (USD)**
Grading	2033.02/km	2479.29/Km
Spot gravelling	17.47/ m^3	21.30/ m^3
Regravelling	12.86/ m^3	15.68/ m^3
Upgrade earth road to gravel road standard	11 641/km	14 196.34/km
Upgrade gravel road to paved standard	226 834.32/km	276 627.22/km
Paved roads		
Patching	7.03/ m^2	8.57/ m^2
Crack sealing	1.27/ m^2	1.55/ m^2
Edge repair	13.2/ m^2	16.1/ m^2
Resealing	3.33/ m^2	4.06/ m^2

Source: TANROADS and PMO-RALG , Exchange rate, 2014: USD 1 = TSH 1 690

Table A4.10: Crop yield, crop price and cultivated land

<table>
<tr><th>Crop</th><th>Crop group</th><th>% of Arable land out of total land</th><th>% utilisation of Arable land</th><th>% occupied by crop group</th><th>% occupied by crop out of crop group</th><th>Crop yield (tons/ha)</th><th>Crop price (Tsh/ton)</th></tr>
<tr><td>Maize</td><td rowspan="4">cereal</td><td rowspan="13">30.5</td><td rowspan="13">29</td><td rowspan="4">85.2</td><td>47</td><td>2.0</td><td>420000</td></tr>
<tr><td>Paddy</td><td>35</td><td>2.0</td><td>542000</td></tr>
<tr><td>Sorghum</td><td>2</td><td>1.0</td><td>420000</td></tr>
<tr><td>Bulrush millet</td><td>0.1</td><td>1.0</td><td>420000</td></tr>
<tr><td>Cassava</td><td rowspan="2">Roots and Tubers</td><td rowspan="2">3.5</td><td>69.9</td><td>6.0</td><td>315000</td></tr>
<tr><td>Sweet potatoes</td><td>17.3</td><td>7.0</td><td>315000</td></tr>
<tr><td>Beans</td><td>Pulse</td><td>4.9</td><td>65.1</td><td>1.0</td><td>1200000</td></tr>
<tr><td>Cotton</td><td>Cash crop</td><td>0.1</td><td>89</td><td>1.2</td><td>735000</td></tr>
<tr><td>Onion</td><td rowspan="2">Fruits and vegetable</td><td rowspan="2">1.2</td><td>43.5</td><td>9.0</td><td>840000</td></tr>
<tr><td>Tomato</td><td>7.8</td><td>35.0</td><td>945000</td></tr>
<tr><td>Sunflower</td><td rowspan="2">Oil seed and Nuts seeds</td><td rowspan="2">5.3</td><td>20.8</td><td>1.7</td><td>857000</td></tr>
<tr><td>Sesame</td><td>69.4</td><td>1.0</td><td>2520000</td></tr>
</table>

Source: Source: PMO-RALG and National Bureau of Statistics, 2012a

Graphical representation of road roughness before and after road improvement

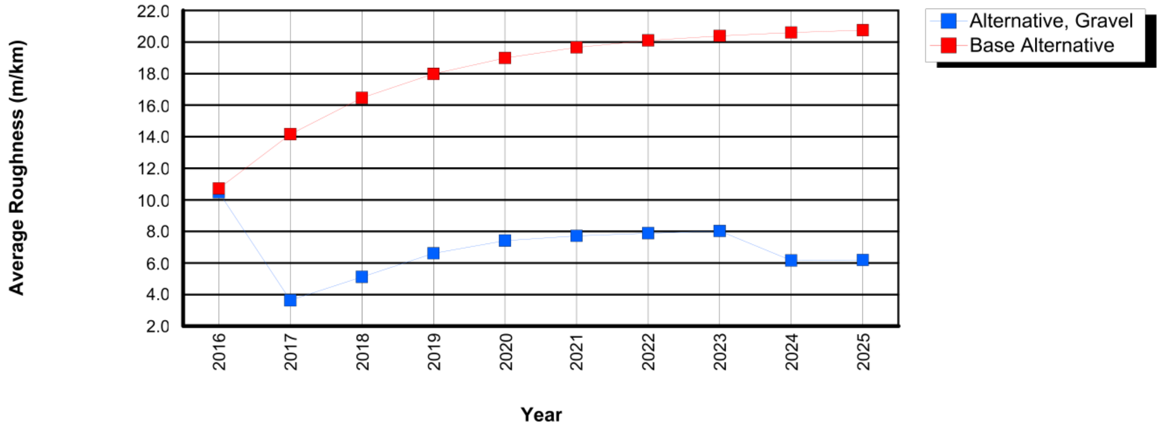


Figure A4.2: Graph showing the road roughness before and after improvement: earth feeder road in good condition

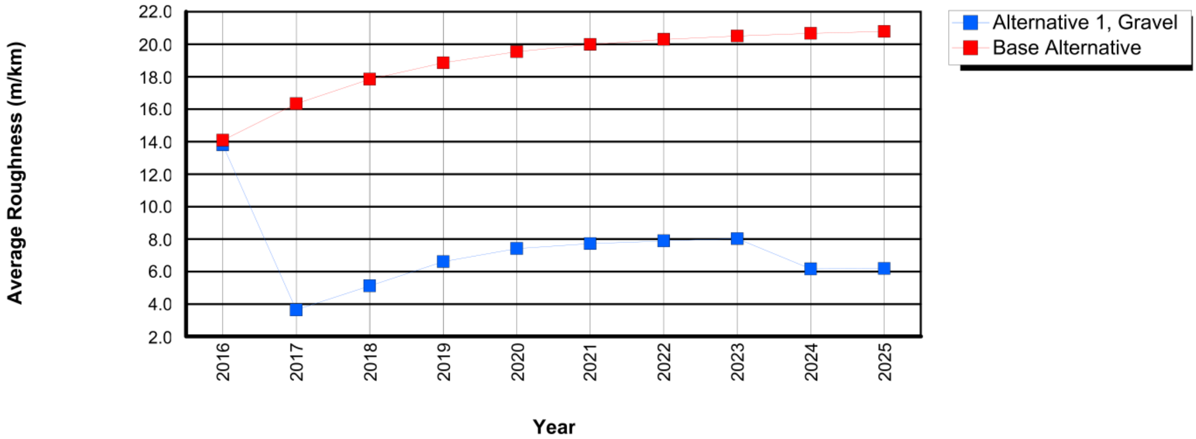


Figure A4.3: Graph showing the road roughness before and after improvement: earth feeder road in fair condition

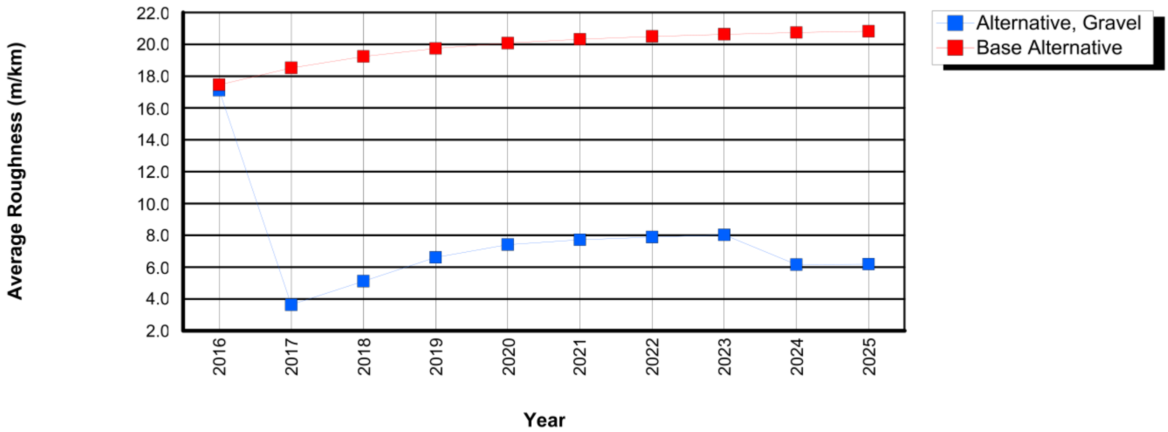


Figure A4.4: Graph showing the road roughness before and after improvement: earth feeder road in poor condition

Table A4.11 Transport cost and transport price before road improvement

Road condition and class	Stage one	Stage 2			Total trip length	Stage 1	Stage 2	Stage 1	Stage 2	Stage 1	Stage 2	Stage 1	Stage 2	Total trip cost and price (Two stage)	
	Length (km)	Length Unpaved (km)	Length paved(km)	sub total length (km)	Total length (km)	Cost (Tsh/veh-km) (HDM-4)	Cost (Tsh/veh-km) (HDM-4)	Price (Tsh/veh-km) (Eqn 6.1)	Price (Tsh/veh-km) (Eqn 6.2)	Cost (Tsh/ton-trip)	Cost (Tsh/ton-trip)	Price (Tsh/ton-trip)	Price (Tsh/ton-trip)	Cost (Tsh/ton-trip)	Price (Tsh/ton-trip)
	(A)	(B)	(C)	(D=B+C)	(E=A+D)	(F)	(G)	(H)	(I)	(J=F*A/10)	(K=G*D/10)	(L=H*A/10)	(M=I*D/10)	(N=J+K)	(O=L+M)
Earth feeder road in good condition	50	48	222	270	320	2 043	1 099	8 301.64	2 274.18	10216.05	29 634.34	41 508.18	61 316.35	**39 850**	**102 825**
Earth feeder road in fair condition	50	48	222	270	320	2 113	1 099	8 449.11	2 274.18	10562.5	29 634.34	42 245.56	61 316.35	**40 197**	**103 562**
Earth feeder road in poor condition	50	48	222	270	320	2 183	1 099	8 597.84	2 274.18	10917.4	29 634.34	42 989.18	61 316.35	**40 552**	**104 306**

Table A4.12 Transport cost and transport price after road improvement (two-stage trip)

Road condition and class	Stage 1	Stage 2			Total trip length	Stage 1	Stage 2	Stage 1	Stage 2	Stage 1	Stage 2	Stage 1	Stage 2	Total trip cost and price (Two stage)	
	Length (km)	Length Unpaved (km)	Length paved(km)	sub total length (km)	Total length (km)	Cost (HDM-4)(Tsh/veh-km)	Cost (HDM-4)(Tsh/veh-km)	Price (Eqn 6.1)(Tsh/veh-km)	Price (Eqn 6.2)(Tsh/veh-km)	Cost (Tsh/ton-trip)	Cost (Tsh/ton-trip)	Price (Tsh/ton-trip)	Price (Tsh/ton-trip)	Cost (Tsh/ton-trip)	Price (Tsh/ton-trip)
	(A)	(B)	(C)	(D=B+C)	(E=A+D)	(F)	(G)	(H)	(I)	(J=F*A/10)	(K=G*D/10)	(L=H*A/10)	(M=I*D/10)	(N=J+K)	(O=L+M)
Earth feeder road in good condition	50	48	222	270	320	1 144	1 099	6 112.14	2 274.18	5720.65	29 634.34	30 560.71	61 316.35	**35 355**	**91 877**
Earth feeder road in fair condition	50	48	222	270	320	1 218	1 099	6 318.77	2 274.18	6092.45	29 634.34	31 593.84	61 316.35	**35 727**	**92 910**
Earth feeder road in poor condition	50	48	222	270	320	1 237	1 099	6 369.49	2 274.18	6185.4	29 634.34	31 847.43	61 316.35	**35 820**	**93 164**

Table A4.13 Transport cost and transport price after road improvement (one-stage trip)

Road condition and class	Stage 1	Stage 2 length			Total trip length	Stage 1	Satge 2	One stage trip (1 & 2 combined to longer trip)	One stage	Total trip cost and price (One stage trip)	
	Length (km)	Length Unpaved (km)	Length paved(km)	sub total length (km)	Total length (km)	Cost (HDM-4) (Tsh/veh-km)	Cost (HDM-4) (Tsh/veh-km)	Weighted Average Cost (Tsh/veh-km)	Price (Eqn 6.2) (Tsh/veh-km)	Cost (Tsh/ton-trip)	Price (Tsh/ton-trip)
	(A)	(B)	(C)	(D=B+C)	(E=A+D)	(F)	(G)	(H=(F*A/E)+(G*D/E))	(I)	(J=H*E/10)	(K=J*E/10)
Earth feeder road in good condition	50	48	222	270	320	1 144	1 099	1 106	2 109.38	**35 355**	**67 420**
Earth feeder road in fair condition	50	48	222	270	320	1 218	1 099	1 118	2 121.07	**35 727**	**67 793**
Earth feeder road in poor condition	50	48	222	270	320	1 237	1 099	1 121	2 123.98	**35 820**	**67 887**