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SYSTEM DYNAMICS APPROACH TO URBAN PUBLIC TRANSPORT ECONOMIC SUSTAINABILITY: STRATEGY TO REDUCE OVERALL IMPACT OF URBAN TRANSPORT PARTIAL DEREGULATION IN HARARE CITY.

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ABSTRACT

Public transportation plays a key role to socio-economic development of any nation. This service enhances people's livelihood framework by facilitating mobility and accessibility to services. Moreover, there is clear global evidence that a well performing public transport is an important enabler of sustained economic prosperity. Rapid urbanization in developing countries has resulted in transport facilities and infrastructure failing to cope with demand resulting in congestion, movement delays, high travel costs and the likes. This prompts implementation of non-comprehensive strategies such as partial deregulation of transportation systems that caused further deterioration in economic sustainability. An economically sustainable transport system advocates for mobility, resource, and operational efficiency. This research focuses on developing a bus investment conceptual framework of a public transport system that improves mobility, resource, and operational efficiency to aid in sustaining of public transportation system for an unforeseeable future. With this in mind, a Harare bus investment system has been created as a policy framework model to evaluate its economic sustainability. This will help develop a long-term economically sustainable public transportation and reduce the overall impact of the earlier liberalisation of the transportation sector.

Key words: Public transportation, system dynamic, partial deregulation, economic sustainability, bus investment.

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CHAPTER 1

1.0 INTRODUCTION

1.1 Background

Public transport plays an important role in fulfilling the travel needs of people in cities of developing world. It plays a key role in the socio-economic development of any nation and enhances people's livelihood framework by facilitating mobility and accessibility to services (Nyarirangwe & Mbara, 2007). Transport networks must be able to support the economic growth, growing populations and diverse expectations of urban activity. There is clear global evidence that a comprehensive and well performing transport system is an important enabler of sustained economic prosperity. A large volume of traffic flow does not only cause traffic congestion, it also resulted huge losses in terms of productivity and will affect the ability of cities to compete globally. Usually there is a tendency of cities building more roads to overcome this problem. However, cost that includes financial, social, and environmental responsibility will increase with increase of urbanisation hence transportation sustainability is compromised (UNEP) retrieved 10/22/2013, from http://www.unep.org/transport/. Furthermore, there is carbon dioxide emission and non-renewable energy consumption, which is a major threat to future generation. Economically sustainable transportation should advocate for resource, operational and mobility efficiency, as well as local economic development.

Provision of right technological options and investments on infrastructure, complemented with appropriate policies and regulatory framework achieves overall benefits of transport sector to human well being. An efficient and clean public passenger transport system has low specific energy consumption and emission per passenger/km travelled as specified by Holden, Linnerud, & Banister, (2013). Public transport (buses, light rail, metros, and trains) uses less space for transporting goods and services as opposed to private vehicles creating an optimal land use management for social and economic activities while protecting the environment. More importantly, it provides equitable transport services to a large segment of the population especially the underserved population (United Nations Environment Programme, (UNEP) retrieved 10/22/2013, from http://www.unep.org/transport/.

Improvements in public transport sector in developing world provide an opportunity for poverty alleviation and enhance economic growth with environmental co-benefits. Many studies on improvement of passenger transport sustainability were carried out from application of system dynamics in policy making to assessment of partnerships in transport system case studies with Dirgahayani & Nakamura (2012) analysing successful application of multi-level government coordination (vertical coordination) and local stakeholder coordination (horizontal coordination) partnerships in two case studies. The analysis results of these partnership policies points out that successfulness was due to their historically conducive backgrounds. This opens other avenues to try application of other types of partnerships other than vertical and horizontal co ordinations. In analysis of the initial effects of introduction of commuter omnibuses service in Harare after the partial deregulation Maunder & Mbara, (1995) looked at proponents and opponents of deregulation. Proponents of deregulation or free competition seek the complete relaxation of controls, arguing that this induces an increase in diversity of the provision of market-oriented services best suited to meet demand characteristics. Whilst opponents of deregulation seek varying levels of control and government involvement believing market forces may led to increasing imperfection and imbalances in the provision of services. In addition, opponents of deregulation believe that this leads to wasteful use of scarce resources with environment disbenefits. Obtained results showed that sudden impact was an improvement in waiting time but there was an increase in transport fleet of 118% between January-September 1994. This trend continued until this day where about 10,000-commuter omnibuses are in operation and service provision has deteriorated than it was prior to deregulation due to increase rate of vehicles that has outgrown utilities capacity causing congestion. This congestion has caused an increase in operational costs and because of high operational costs; commuter operators illegally doubling the fares during the peak period.

Thus, a sound sustainable urban public transportation policy is needed to improve on the chaotic transportation system created by the liberalisation of the transportation sector during the Economic Structural Adjustment Programme (ESAP) era. This is case of Harare (Zimbabwe) urban public transportation system.

1.2 Case Background

1.2.1 Transportation history of Harare city

This section presents a brief overview on the transportation history to give an insight to the transportation system in the area under study. Public transportation here is considered as either buses, minibuses known as commuter omnibuses or shared taxis. Cycling plays, a limited role accounting for only less than 3% of total trips in Harare and minibuses serve 90% of the market currently (UN-Habitat, 2013). Pre-independence in 1980, the United Transport Group operated stage carriage services in urban areas of Zimbabwe under a franchise agreement between the local authority and the bus company. The company had exclusive rights to operate within an area of 26 km radius and was to operate at a certain level of profitability where in case of not meeting the target the difference would require payment of subsidy by local authority. The system was rigid with long waiting and commuting time.

Post independence, the Government regarded urban public transport services as a key sector of the economy and pursued a policy targeted at redressing the socio-economic imbalance by acquiring 51% of the stage bus company, which changed to Zimbabwe United Passenger Company (ZUPCO). Participation of the government improved operational performance and service levels. This participation by government was to help and influence acquisition of new fleet and boost expansion of the company. However, beginning of the 1990s the financial viability of ZUPCO Harare division deteriorated constraining its ability to renew and expand its fleet to keep abreast with demand. In 1990, the government embarked on an Economic Structural Adjustment Programme (ESAP) whose thrust aimed at economy liberalisation through removal of certain controls and regulations inhibiting competition. It is against this backdrop of liberalisation that urban public transport got liberated or partially deregulated in August 1993 and saw introduction of privately operated commuter omnibuses to compete with ZUPCO. Despite liberalisation of the sector quality control, continue to be enacted by the government with fare determination being solely the government's responsibility (Mbara & Maunder, 1996). Deregulation aims to improve production and delivery of infrastructure through market force and competition (World Bank, 1994). Though, there was instant positive impact of waiting time and queue reduction due to 'a hail and ride service' provided by commuter omnibuses, long term effects had some negative impact both socially and economically on the urban public transport in the city under study.

1.2.2 Stage bus collapse

Commuter omnibus legalisation aimed at supplementation of service provided by the stage bus company but due to their hail a ride service operation customers preferred the commuter omnibuses to ZUPCO. Deterioration of financial viability of ZUPCO, low ridership together with the removal of subsidies meant low productivity and high operational costs that pushed ZUPCO out of market and eventually collapsed. The stage bus operated on a time table were passengers would wait until time for departure.

1.2.3 Urbanisation

Since Zimbabwe is still a developing country, urbanisation is at its peak with Harare city habouring the largest population percentage compared to all provinces and has an annual growth rate of 1.1%. Harare population has increased from 1 458 204 – 2 123 132, between 1992 and 2012 with a highest percentage of 16% in all provinces and 47% of all urban population shown by figure 1.1 below. Due to the increase in population and carrying capacity of commuter omnibuses, the public transport sector had to increase to keep abreast with demand. This increase resulted in un-proportionality between the fleet and utilities development with City of Harare Strategic Plan (2012-2025) pointing out that the growth has strained the infrastructure. Urbanization brings about irreversible changes in our production and consumption patterns. How we plan, manage, and live in this expanding city determines, largely, the pace of global warming. (Harare City Strategic Plan, 2012-2025).

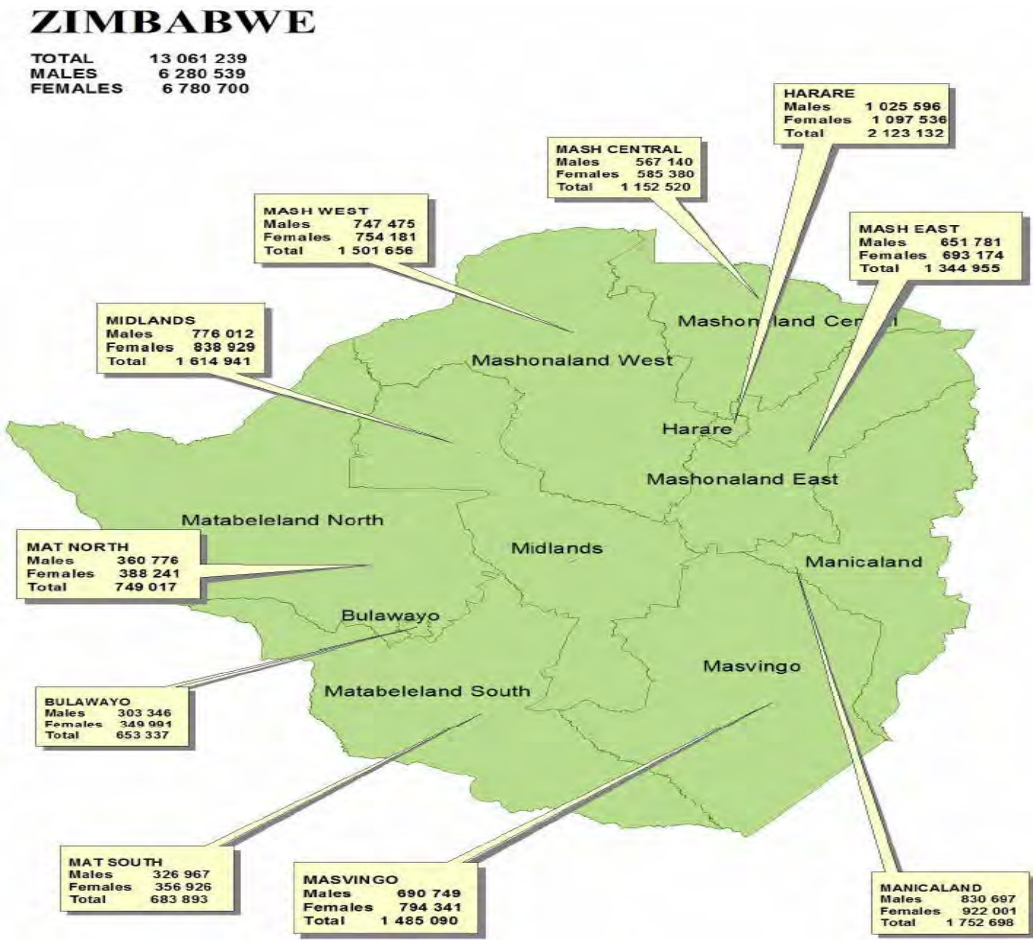


Figure 1.1Zimbabwe Provincial Population distribution, Source: CSO Zimbabwe

1.2.4 Congestion and fare variation

The collapse of the stage bus, population increase and commuter omnibus carrying capacity have lead to increase of commuter omnibuses until saturation point with almost ten thousand vehicles plying the routes of Harare city in order to keep abreast with demand. A holding bay out of the city centre had to be constructed as means of controlling public transport which have gotten out of hand to an extent of having 60% of the commuter omnibuses operating illegally (Chideme, 2013). In addition, land use pattern of the city shown by figure 1.2 below plays a major part in congestion and fare irregularities. Workers have to be in certain places at certain times thus, there is a high demand at certain times, which causes congestion and operators double the gazetted fare during this high demand period, the government is failing to control and manage this. This makes travelling back and forth to work places unsustainable as the commuters has to fork out more on transportation cost than on personal development.

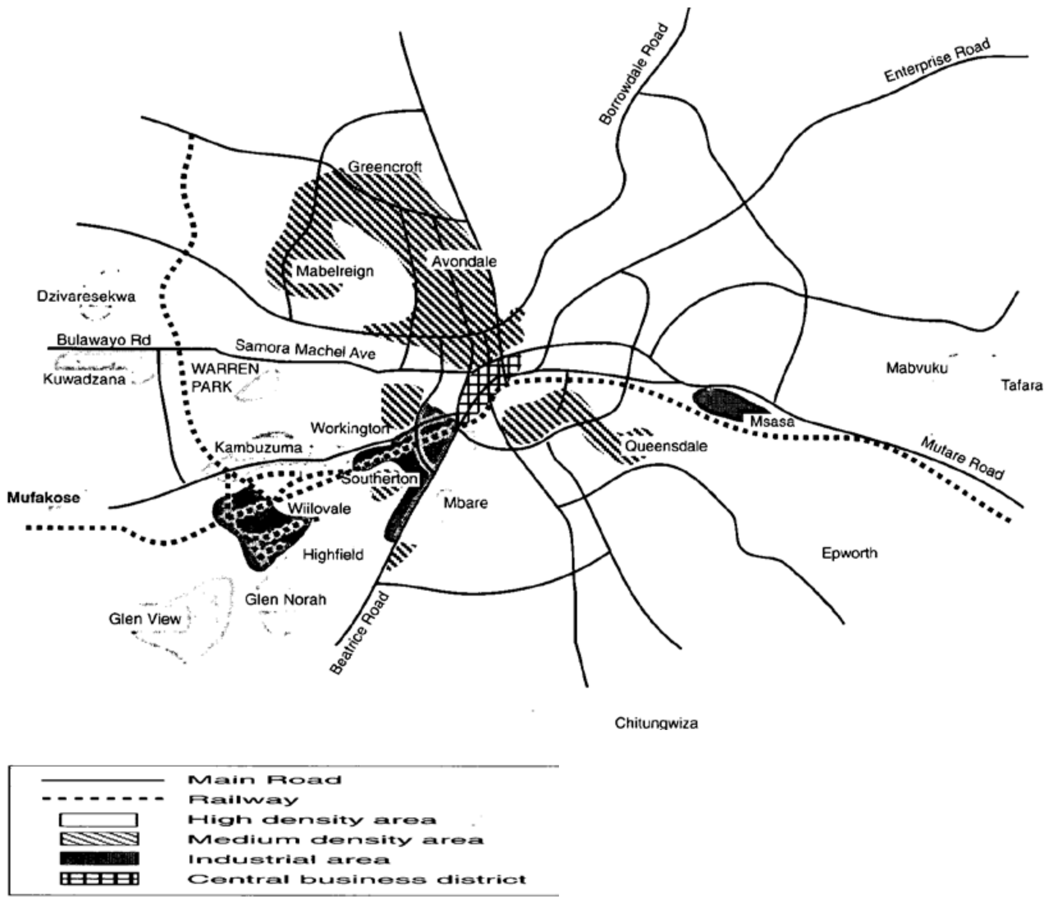


Figure 1.2 City land use pattern extract from Maunder and Mbara (1996).

1.2.5 Utility capacity and deterioration

Mahachi (2012) in unveiling of the City of Harare Strategic Plan (2012-2025) pointed out that population growth has strained the infrastructure. A population of about 2 million residents is being served by infrastructure designed for 300 000 people as a result of high volume of traffic flow road networks wear off quickly and potholes patching is the current maintenance being done only to be exposed during the rainy season. This is costly and a risk to the community at large as the roads will be prone to accidents. The city leaders also claim that though the population has increased the utilities were not growing at the same rate as the population hence there is serious supply deficiency.

1.3 Theoretical Background

1.3.1 Sustainability

Sustainability is equity and harmony extended into the future, a careful journey without an endpoint, a continuous striving for harmonious co-evolution of economic, social and environmental goals (Voula & Pedersen, 1998). It integrates economics, social and environmental issues. It has economic development at its core. Low (2003) define it as a set of nested boxes with economic, society and environment all imbedded in each other meaning that what goes on in economy and society is subject to natural environment, which supplies the inputs and absorbs the waste. In addition, what goes on in economy is the subject to the fairness integrity and stability of society. Beuhler & Pucher (2011) alluded that in practice, emphasis has been on environmental sustainability, neglecting financial has been an important omission. For example, transport systems around the world suffer from low productivity because it is perishable hence it requires subsidies and for those that are privatised in most cases experience high operational costs and are not affordable to the poor. No amount of excellent social and environmental performance will prolong the life of a business that is not economically sustainable hence for the system to be sustainable it has to, economically sustain its operations. Improving economic sustainability would realise the potential environment and social benefits of public transport.

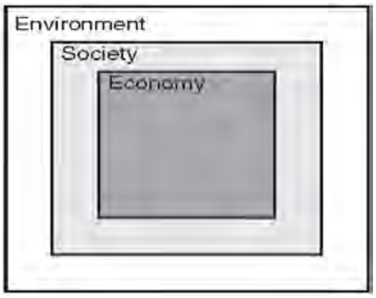


Figure1.3 Sustainability as a set of nested boxes extract from Low 2003

1.3.2 Economic sustainability

Though not regarded as correct, the general definition of economic sustainability adopted for this research is that it is the ability of an economy to support a defined level of economic production indefinitely. In this particular research, the set level of economic production is an affordable price/km (fare), bankruptcy and profitability of the system. Economic sustainability is also, the use of various strategies for employing existing resources optimally so that business continues to function over a number of years while consistently returning a profit as well as involving efficient usage of different organisational assets to allow continued functioning profitability for a longer period. The idea is to aid in identifying areas of operation in which resources are not being utilised in the most efficient manner and take steps to correct the situation. For example, in this case use of smaller carrying capacity vehicles would mean duplication of duties, which derives operational costs higher, and push the price (fare) up in order for the company to make profit. In line with microeconomic theory, the law of demand states that transport service decreases when service price increases hence the business will not last (Rodrigue, 2013). In addition, if there is no re-investment in fleet renewal, vehicle efficiency decreases with age and fuel consumption increases, which will affect profitability and may lead to bankruptcy and collapse. A business to be sustainable it has to economically sustain its operations to prolong its life.

1.3.3 Concept of sustainable transport

The concept of sustainable transport is based on the notion of sustainable development and there is a multitude of definitions (Kristle & Reddy Sudhakara, 2011). The researcher defined sustainable transport system as the one in which fuel consumption, vehicle emission, safety, congestion, social and economic access are of such levels that they can be sustained into the indefinite future without causing irreparable harm to future generations of the world from Richardson (1999). Economic sustainability of transport derived from the defined economic sustainability has to ensure continuous supply of transport service at a profit and affordable price in order to pull demand and maintain stability for an unforeseeable future.

1.4 Research Gap

Motivated by real problem, a review of previous studies within the area shows those researchers focused on how policy change has affected affordability, service level and operational cost and activities of the transport system. Before liberalisation, the system was characterised by long waiting time and rigidness. After liberalisation, it is characterised by unreliability, un-affordability, and congestion. Liberalisation was to provide economic growth through competition, which would not take place due to price control by the government. This was shown through analyses of sudden impact of commuter omnibus introduction in Harare Mbara & Maunder (1995); activity patterns in transport policies for the urban poor in Harare and challenges and options for coping with demand for urban passenger transport in Zimbabwe (Mbara, 2002; 2006). Mbara and Nyarirangwe (2007) also did an assessment of the public transport service modal choice, affordability and perceptions coming up with effects, impacts and brought out what the real situation is like without providing a real solution to the problem. Having focused on the ‘how’ part it only provides the ‘ends’ not the ‘means’ to solve the problem hence this research will focus on the ‘means/mechanism’ of solving the persistent transportation problem in Harare city.

1.5 Problem definition

Prior to liberalisation of the transport sector urban public transport was affordable even though it was rigid and characterised by long waiting time. It operated at a certain profitability and subsidies were payable if profits not met. Post liberalisation is characterised by variable fare, unreliable passenger transport, congestion and high non-renewable energy consumption caused by lower carrying capacity vehicles which requires more vehicles to meet demand as well as high utility deterioration. Economically this is unsustainable as economic sustainability is when resources are efficiently used, and distributed to maximise the benefits and minimise external costs of mobility (UN-Habitat, 2013). Furthermore, a calling for the re-introduction of Zimbabwe Passenger Company (ZUPCO) buses by the public (The Herald 26 April 2013), and call for private operators to combine and buy large volume transport (The Herald 12 June 2014). In addition another columnist of the same paper on 13 March 2014 argued that use of 100 seater buses would mean 1000 passengers could be ferried by 10 buses than 63 commuter omnibuses, which would lower congestion. Based on this fact, the statement of problem of this thesis is failure of liberalisation policy to improve economic performance and create a platform that can economically sustain the transport system and keep pace with urban population growth and mobility needs within the city of Harare.

1.5.1 Research Question

How can an economically sustainable model of public transport be developed to improve/address the chaotic operations of the current system in Harare City?

1.6 Aim

The purpose of this research is to develop a conceptual model of Harare city transport system that identifies policy levers and conceptual framework to debottleneck urban public transportation for promoting long-term economical sustainability. An economically sustainable system is the one that is resource and operationally efficient, profitable to service providers and affordable to passengers and have an environment conducive and viable for investment. This will reduce the overall impact of the earlier liberalisation of the transportation sector.

1.7 Research significance/ benefits

If the research is successful, it will provide an alternative solution to the policy makers that can be applied to re-regulate and optimize the urban public transportation system and establish profitability over a long term. A profitable business is much more likely to remain stable and continue to operate from one year to another which guarantees the transport system's future that continues to contribute to the financial welfare of the owners, employees and community through affordable fares. Furthermore, re-investment in fleet maintenance and renewal would be a possibility without fear of bankruptcy and creating a platform conducive for economies of scale that will enable forward movement in attainment of MGDs. Theoretically; the research will show that economic sustainability is the root enabler of environmental sustainability through reduction of fossil fuel consumption and congestion. In addition, economy is the heart of sustainability that cannot be achieved through an excellent social and environmental performance.

1.8 Scope of study

In this research, focus is on economic sustainability of public transport to improve efficiency, affordability and congestion within the metropolitan city of Harare in Zimbabwe. Economic sustainability performance indicators such as profitability, efficient use of resources, and affordability shall be used.

1.9 Outline of thesis

This research has six chapters organised as follows: Chapter 1 introduces theoretical and the problem background, statement, aim and objectives, research question and justification. Chapter 2 is dedicated to literature review of previous studies in public transportation, and Chapter 3 presents methodology. Chapter 4 contains results presentation of the system that includes system boundary, relationships, behaviour and validation. Chapter 5 is for scenario experimentation of different policy frameworks. Chapter 6 concludes and gives recommendation of future work.

CHAPTER 2

2.0 LITERATURE REVIEW

2.1 Definition of terms and concepts

2.1.1 Deregulation

Deregulation is the removal of controls imposed by governments on the operation of markets to take away barriers to entry (transport economies). According to Menaz (2006) deregulation is the removal of regulations, often in order to adjust competition policy. It is often taken to mean privatisation, however, though sometimes related these terms do not have same meaning. A quote from OECD, (1997) by Menard & Ghertman (2009) defines deregulation as the complete or partial elimination of regulation in a sector with intent of improving economic performance, citing Kim and Prescott (2005) saying that deregulation can bring programmability of managerial behaviour and higher ambiguity in cause-effect relationship. Partial deregulation can take many forms such as deregulation of market entry or exit or deregulation of price control. It can be partial or complete, slow or fast (Menard & Ghertman, 2009). The researcher went on to say that it is a term that gained widespread currency in the period 1970-2000 seen as a process by which governments remove, reduce or simplify restrictions on business and individuals with the intent of encouraging the efficient operation of markets. It occurs when there is a significant decrease or elimination of government regulation over an industry, market or economy. A stated rationale of deregulation is that fewer and simpler regulations will lead to a raised level of competitiveness, therefore higher productivity, more efficiency and lower prices overall. Proponents of deregulation or free competition seek the complete relaxation of controls, arguing that this induces an increase in diversity of the provision of market-oriented services best suited to meet demand characteristics (Maunder & Mbara, 1995).

2.1.2 Partial deregulation/ Liberalisation

Partial deregulation from Menard and Ghertman (2009) means that the process of deregulation is not completed. It might not be completed because regulators chose to open up to competition only part of the regulated sector. They might for example allow market entry but still regulate the retail price. This definition might not be correct but due to its similarity to the case under study, it is the adopted for this research. Partial deregulation has negative impact on firm efficiency.

2.1.3 Urban public transportation

Public transport refers to formal (regulated) motorised urban surface transport available to members of the public (Un-Habitat, 2013). It is very crucial for the movement of goods and people which marks the backbone of the economy and sustainable development (Mudzengerere & Madiro, 2013). According to Maunder and Pearce public transport in countries of developing world are characterised by rapid urbanisation, high growth rates in traffic, congestion, and decreasing regulation of public transport. Because majority of the developing world's inhabitants are dependent, on public transport services the need for efficient, safe and effective public transport is essential to ensure adequate and affordable accessibility for sustainable development (Maunder & Pearce, 1999).

Public transportation plays a more important role in developing countries than industrialised countries because its economic efficiency is vital for large volumes of non-car owners, while its capacity is needed to serve the high-density rapidly growing cities. For these reasons, it is essential that cities of developing world pursue transportation policies that ensure provision of transport service that is attractive in terms of time, cost, accessibility, affordability and profitability whose goal is to raise quality of life in compliance to sustainable mobility. Pardo added to the voice by saying that the crucial role is mainly in urban development of cities of developing countries by providing access for people to education, markets, employment health and other key services, and an enhanced mobility for the poor and vulnerable groups is one of the most important preconditions for achieving Millennium Development Goals. The existing reality, however, is that urban transportation systems in most developing cities are far from ideal. The most visible and frequently mentioned transport problem of a city is its traffic congestion, and it is known that high levels of congestion create significant impact on local and national Gross Domestic Product (GDP). Accessible and affordable public transport service and safe infrastructure for non-motorized transport such as cycling and walking is lacking in most developing country cities. While transport enables the economy to grow, if not well managed, it can also retard growth and the efficient delivery of essential social services. The lack of comprehensive planning of transport systems, without due consideration to social, economic, environmental elements of the city, can result in physical breaks in the fabric of communities and reinforce social exclusion.

In order to return urban places to people and to create more liveable cities, decision makers in these cities urgently need to change the direction of urban transport development toward a more sustainable future. Establishing a sustainable urban transport system requires a comprehensive and integrated approach to policymaking and decision-making, with the aim of developing affordable, economically viable, people-oriented and environment-friendly transport systems

2.1.4 Sustainability

Has no universal definition according to Litman and Burwell (2006), quotes from (Centre for sustainability, 2004) defined it as “the capacity for continuance into the long term future”. (Brundtland report 1987) “as development that meets the needs of the present generation without compromising the ability of the future generations to meet their own needs” and (Themes sustainable development, 2004) as the achievement of continued economic development without detriment to the environmental and natural resources.

2.1.5 Sustainable urban public transportation

Derived from sustainable development from Brundtland report (1987) sustainable public transport can be considered as one that is able to meet today's transportation needs without compromising the ability of future generations to meet their transportation needs. Defined from the context of developing world a sustainable transport system must provide mobility and accessibility to all urban residents in a safe and environmentally friendly mode of transport (Ziestman, Rilett & Kim, 2003). Though not regarded as the most appropriate definition, it will be used for this research.

2.1.6 Partnership

Partnership is a process that evolves from informal and irregular exchanges to institutionalised relationships. It is the most mature form of coordination which engages in higher levels of joint activities, it also is a process which evolves from informal and irregular exchanges to institutionalised relationships with a higher level of dedicated resources or investment and open to communication or information (Dirgahayani and Nakamura, 2012).

2.1.7 System dynamics

System dynamics is a perspective and set of conceptual tools that enables understanding the structure and dynamics of complex systems, a rigorous modelling method that enables building formal computer simulations of complex systems and uses them to design policies that are more effective and organisations (Sterman, 2000). It has the ability to mimic the real scenario and reduce the system into multiple small individual pieces, which enables whole system study.

2.2 Urban public transportation in Zimbabwe

In Zimbabwe, most prominent public transport types are passenger taxi, buses, trains and commuter omnibuses with road more extensive than urban rail service.

Private operators due to partial deregulation provide public transport mainly in commuter omnibus, bus and taxi sectors with commuter omnibus covering about 90% of all demand. Urban transportation is a vital part of economic activity and responds to well-designed economic policies. Much can be accomplished to improve urban life by using basic knowledge of economic incentives.

2.2.1 Pre-partial deregulation

Public transport comprised of metered taxi, pirate (now emergency taxi) and the bus service operated by private enterprise under monopoly granted by the city council. During this period, public transport system was fairly continuous and reliable though not as cheap as can be possible. This was due to the exaggerated high peak-requirements that forced the bus company to service this demand (Jordan, 1983). It was rigid and characterised by long waiting times.

2.2.2 Post partial deregulation

In 1993, the Zimbabwean government implemented Economic Structural Adjustment Program that saw a partial transport deregulation. This era, with government having acquired 51% of the stage bus (ZUPCO) to help and influence acquisition of new fleet and boost expansion the company could not meet the demand (Maunder & Mbara, 1995). The partial deregulation saw an introduction of privately owned commuter omnibuses of an average capacity of 15 passengers to the market to aid ZUPCO and meet demand and price control of the public transport remained solely the responsibility of the government as a way to protect the poor. The commuter omnibuses operated on a hail a ride service on a fixed route just like the shared taxis in developed countries.

Their introduction had a sudden impact of service improvement and increased public fleet (Maunder and Mbara, 1995). In 1996, Maunder and Mbara went a step further by analysing their initial introduction effects to the city. The assessment based on a comparison of factors and case study material 'pre' and 'post' August 1993 unearthed some positives and negatives which showed that the bus company was under threat. The competition, it is alleged, led to deterioration in drivers' behaviour with "drivers speeding to outrace other drivers, overloading of buses and jumping red lights to make as many trips as possible" (Herald Newspaper 1993). However, service frequency improved and passenger-waiting times reduced because of the liberalisation process but there has been a rapid growth in both the number and variety of commuter minibus fleet and the total public transport passenger carrying capability in Harare. The fleet grew by 118 percent between January-September 1994 and by September; commuter omnibuses represented 30 percent of the public transport fleet. Most (83 percent) of the commuter omnibuses operate to and from high population density areas while the remaining 17 percent operate in medium and low-density areas. Following the introduction of commuter omnibuses, the number of routes operated has increased by approximately 10 percent. Despite an improvement in the level of service attributed to commuter omnibuses, it can be argued that the mushrooming of small capacity vehicles results in an overall inefficient use of resources; smaller vehicles being less efficient in terms of cost per passenger carrying capacity than conventional buses. Furthermore, the common finding was that public transportation maintained their fares as they were before liberalisation with fares tending to rise especially during the busiest times of the day and there is congestion at major boarding locations in the city centre appears to have increased, adversely affecting other road users and the environment in general.

Kodero (2005) targeted pro-poor transport policy with the aim of building national capacity for policy dialogue and engagement in influencing transport policies and programmes in the context of poverty reduction in Zimbabwe. Between November 2003 and April 2004, the Zimbabwe Forum for Rural Transport and Development (ZFRTD) reviewed the pro-poor agenda of Zimbabwe transport sector policies and ongoing transport investment programmes. It also examined the inclusion of mobility and access issues within key national development policies. The report’s main conclusion points to the need to create strong dynamic links between transport policies and poverty reduction strategies. The researcher went on to say that, review of transport-related policies and programmes in Zimbabwe revealed absence of a clear demonstration of their contribution to poverty reduction and the finding points to the need not only for better integration of pro-poor concerns into the general transport policy framework, but also ensure transport sector policies firmly anchor in poverty reduction strategies. In addition, while broader stakeholder involvement in transport planning and management is currently taking place, there is scope for enhancing inclusive and participatory approaches. Tackling this challenge entails delivering efficient and effective transport and a host of other social and economic infrastructure and services.

Pro-poor transport policies are policies, initiatives, programs and directives aimed at addressing transport issues confronting rural and urban poor. Below are some of tests or indicators to determine the extent to which transport policies are pro-poor:

- ✓ economic/financial affordability of transport fares and tariffs;
- ✓ Ease or accessibility of transport modes or transport services/facilities
- ✓ Affordable cost of purchasing transport mode e.g. Intermediate Transport Modes (IMTs)
- ✓ Environmental sensitivity and sustainability of transport modes
- ✓ Mobility facilities utilisation rate by the poor.

One limitation to Kodero's research is that he tried to address both urban poor transport and rural transport as a single entity. Transportation requirements is demand driven hence the demands of the urban is very different from the rural demands.

Kodero (2005) points out that development of urban mass transport systems has been on the drawing board for quite some time. Both the Draft National Transport Policy and the Draft Urban Transport Policy point to the fact that an urban mass transport system should be developed at some point in time when justified by demand. Urban mass transport is the subject of local, regional and national policies in different policy fields, such as transportation planning, environmental planning and economic planning. The implication is that coordination across sectors and agencies is necessary in designing a mass transit system proposed in existing (draft) policies. Compatibility problems between the available network and the kind of service 'demanded' by the swelling population of urban poor require financial and technical ingenuity. The researcher believes that potential benefits of developing a multi-modal and integrated urban mass transport system, which is compliant with the 21st Century needs and trends, are enormous and need be built into current measures to revive the economy. Considering the current state of the system and how it is conducting business there is need for regulations first and building of passenger confidence in public transport so as to pull them to use of public transport.

Mbara (2006) looked at challenges and options of coping with urban passenger transport in Zimbabwe. He alluded that the public transport is characterised by inefficiency and unreliability partly because of macro-economic fundamentals, which have increased operational costs. He concluded by saying that there is need for sustainable urban public transport system in the country. Moreover, there is requirement of policy framework and transparent symbiotic partnership between the central and local governments, private sector and civic societies to exist. The current challenges include inter-alia, need for cost reduction, encouragement and development of cheaper modes, integration of land use, positively influencing modal choice of the cheaper mode. In 2007, Mbara and Nyarirangwe wrapped up analysis of the woes of urban transportation in Zimbabwe by assessment of public transport service modal choice, affordability and perceptions in an unpalatable economic environment in Harare urban corridor. In their assessment, they recommended that a holistic approach, starting at national level, becomes very critical and there is need for hard working by the state and its partners to correct the negative international image of the country to boost investor confidence. This is important for the economy to come off its knees. Further, there is need to re-foster partnerships between the various sectors of the economy. Efforts of such partnerships should be directed at inter alia reducing transport costs, creation of a public transport development scheme administered through commercial banks and the Reserve Bank of Zimbabwe, investment in cheaper and high capacity modes as well as research and development. Town planners should also desist from the traditional outward urban sprawl approaches and focus more on land use integration. All these efforts should be guided by the aim of creating a safe, adequate, reliable and affordable public transport system.

Pirie (2013) in the report of Un-Habitat of sustainable urban mobility in Anglophone Sub-Saharan Africa (ASSA), have noted that progressive deregulation of the sector created competition between private operators in an over-supplied market that resulted in non-compliance with safety rules and inefficiencies in fare structure. The current urban transport crisis in ASSA vary across cities but they all have very low urban mobility, have poorly regulated and managed transport space which explains the unreliable transport and chaotic traffic. The researcher went on to point that committing public funds to build more road space and buy newer serviceable vehicles is a familiar but flawed response it addresses symptoms rather than causes. It has resulted in little attention paid to tackling multidimensionality and root cause of a complex transport crisis. Key challenges noted for reform, social policy directed at facilitating transport equity and raising civic consciousness about importance of starting to redress gender, age and ability in transport access and mobility including physical access, treatment, price and safety. Economically minibus taxi fleets needs upgrading substituting them with larger buses would make urban transport in ASSA cities more efficient as these will limit road congestion, reduce cost of mobility, which stands at more than 16% of income, and up to 15-20% of productive time. In addition, it will reduce indirect costs of public health and mitigation of air pollution together with climate change. Another urgent need in these cities is sustained, standardised transport system monitoring and data collection. This remove hampers in analysis and policy recommendations.

Herald Reporter (2013) quoted Mrs Doreen Tirivanhu of the Institute of environmental studies addressing participants at a media workshop of Institute of Environmental Studies calling for investment in public transport system to build an efficient and sustainable transport network to improve flow of traffic and reduce air pollution.

2.3 Sustainable passenger transport

Sustainable passenger transport derived from sustainable development has no clear definition from different environment perspective. In the eye of developed world, it is more on the side of environmental issues hence more researches are about greenhouse gas (GHG) emissions reduction. From the developing worldview, we cannot talk of GHG reduction when the transportation is not available, accessible, and affordable thus focus is on reforming policies to have viable passenger transport with benefits of environmental issues. Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. It requires meeting the basic needs of all and extending to all the opportunity to satisfy their aspirations for a better life (Brundtland, 1987). It has with it two key concept that is the Concept of 'NEEDS', in particular essential needs of the world's poor, to which overriding priority should be given and limitations idea imposed by the state of technology and social organisation on the environment's ability to meet present and future needs. Sustainable passenger transport can be derived from this basic sustainable development idea. ECMT (2004) define sustainable transport as a system that is accessible, safe, environmentally friendly and affordable, quote from (Litman, 2009).

Zietsman, et al (2003) points out that sustainable transportation in developing communities face different problems than typical industrialised cities, hence goals and objectives aspired by developing communities are different from those of industrialised cities. It also follows that performance measurement for sustainable transportation for such cities cannot be the same. In the developing communities context a sustainable transport system must provide mobility and accessibility to all urban residents in a safe and environmentally friendly mode of transport. Awasathi, Chauhan & Omrani (2011) cited that World Bank (1996), Loo (2002) and Schipper (2003) use ‘‘triple bottom line’’ of economic, environmental, and social equity to define sustainability. From this and Brundtland Report the researcher concurred with Black, (1996); Richardson, (2005) that sustainable transportation can be considered as one that is able to meet today’s transportation needs without compromising the ability of future generations to meet their transportation needs. Then provide some examples of sustainable transportation such as energy efficient vehicles, vehicle with clean fuels like biodiesel, electricity, car sharing, and park-and-ride. A further citation of the centre for sustainable transportation (1997) defines sustainable transportation system as one that:

- ✓ Allows the basic access needs of individuals and societies to be met safely and in a manner consistent with human and ecosystem health, and with equity within and between generations.
- ✓ Is affordable, operates efficiently, offers choice of transport mode and supports a vibrant economy.
- ✓ Limits emissions and waste within the planet’s ability to absorb them, minimizes consumption of non-renewable resources, limits consumption of renewable resources to the sustainable yield level, reuses and recycles its components, and minimizes the use of land and the production of noise.

Holden, Linnerud & Banister (2013) went a step further by going back to Brundtland Report (1987) to try to define what sustainable passenger transport framework is. The researcher narrowed the framework to passenger transport mobility only including air transport. Unlike Holden et al, (2013) who just provided a framework of sustainable passenger transport, Zietsman et al (2003) gave features that require strengthening to achieve a sustainable urban transport system. These include mobility, accessibility, affordability, social equity, efficiency, safety, security, convenience, low carbon, comfort, and people- and environment-friendliness and in order to achieve all these elements, there is need for an integrated manner in addressing the various challenges. In general, they said sustainable transport emphasizes the use of public transport, bicycles and walking and discourages the use of individual motorized modes of transport (cars and motorcycles). It also promotes the improvement of institutions, urban development plans, sound policies, appropriate technologies and the development of promotional schemes that persuade users into using sustainable urban transport modes.

2.4 Different approaches to sustainable urban transport

Seen as one of the crucial elements of sustainable development sustainable passenger transport have undergone different reforms in order to achieve a sustainable mobility with many researchers using different approaches such as partnerships and application of different policy assessment tools. Awasthi et al (2011) listed some of the approaches used as:

- ✓ Life cycle analysis (LCA): Originally developed for industrial processes, the use of LCA (Goedkoop, 2000; Guine, 2002) to evaluate the environmental impact of transport system is growing.
- ✓ Cost-benefit analysis (CBA) and cost-effectiveness analysis (CEA): Applications of cost-benefit analyses for sustainable transportation can be found in El-Diraby, Abdulhai, and Pramod (2005) and Jonsson (2008).
- ✓ Environmental impact assessment (EIA): The aim of this method is to assess the environmental impacts of a new localized pollution source, such as an industry or highway, and its surroundings (Bond, Curran, Kirkpatrick, & Lee, 2001; Fischer, Wood, & Jones, 2002; Jay & Handley, 2001; Wood, 2002). Applied to transport, EIA has been used to study the environmental impact of some practices.
- ✓ Optimization models: A mathematical optimization model consists of an objective function and a set of constraints in the form of a system of equations or inequalities. In the context of sustainable transportation, an optimization model attempts to find an optimal solution under the constraints of the social, economic and environmental objectives. Linear programming is commonly used. An application of dynamic optimization

approach for sustainable urban transport development can be found in Zuidgeest (2005).

- ✓ System dynamics models: System dynamics is used to model complex systems. In system dynamic models, relationships between the system elements are demonstrated through stocks, flows and a feedback mechanism over time. These models can design and evaluate a cause and effect relationship within an integrated sustainable transportation system (Tao & Hung, 2003). Richardson (2005) presents frameworks for sustainability analysis of passenger and freight transport using influence diagrams and root cause analysis.

Due to causal relationships found in this field system dynamics application has taken centre stage in reforms of passenger transport policy. In studying urban congestion in Thuong & Noi (2003) said that economic and urbanization development has caused many negative impacts on people's life such as under-standard and over-used infrastructure, traffic problem, environment pollution, previous studies proposed in many solutions however, traffic congestion was not considered in the relationship with other factors of the whole system. They used system dynamics to identify related causes and effects and find effective negative loops that can be improved to reduce the urban congestion in Hanoi.

Kwan & Blanco (2009) also applied system dynamics as perspective and conceptual tool to enable better understanding of the structure and dynamics of SmartWay transport partnership program. Blanco et al used system dynamic tool to evaluate the success of the program and understand key factors contributing towards the program's success in view of developing recommendations on how to sustain the program. SmartWay Transport Partnership is an innovative collaborative voluntary program between the U.S Environmental protection Agency (EPA) and the freight industry designed to improve energy efficiency and lower greenhouse gas (GHG) emissions. Like Egilmez and Tatari the aim is to reduce GHG emission in freight transport in U.S. Yevdokimov & Mao (2002) added that systemic analysis and system dynamic approach can simultaneously address both positive and normative aspects of transportation's sustainability when they modelled a sustainable transportation system in Canada. Some of the application of system dynamics in transportation include city bus fleet maintenance management by Bivona & Montemaggiore (2005) and modelling of urban travel system by (Raux, 2003).

To round up Egilmez & Tatari (2012) followed through with application of same methodology in policy formulation of reduction of overall impact of transport sector to environment. The focus was mainly on highway passenger transport. The researcher argued that provision of industrial and services via transport services put a strain on the natural functions of the earth, thus compromising the ability of the planet to sustain future generations. Since the growth trend of passenger transport is on the increase, the focus was on formulating sustainable passenger transport policy to reduce the sector's overall impact and trend of growth and green gas emission. The proposed policy is to economise the use of energy and increase use of public transport and number of electric vehicles.

Apart from use of system dynamic in a bid to induce sustainability in transportation, there is notable application or implementation of partnerships. Ang & Marchal (2013) proposed private investment as a way of improving sustainable transport structure. Their argument was that infrastructure is the pillar of economic development in sustainable transport. On the other hand Willoughby, (2013); Dirgahayani and Nakamura, (2012) went a step further by analysing successful partnerships applied in different cities. Willoughby (2013) analysed how much effective was public private partnerships and their substantial contributions to improvement of urban transport and sustainability in developing countries. Results showed strongest impact in Sao Paulo and Seoul where there was serious confrontation of congestion and urban public deterioration.

This led to Holden et al (2013) re-visit Brundtland Report (1987) and define sustainable passenger transport framework. The argument was that focuses of mainstream literature on sustainable transport have changed from the global challenges to social equity and impacts on the environment. They defined the passenger transport framework's main dimensions as safe guarding long-term ecological sustainability, satisfying basic transport needs and promoting intra- and inter-generational equity. Passenger transport policies should aim to achieve these main dimensions, and this covers a sustainable passenger transport at the developing world level since the basis is satisfaction of human basic needs especially the world's poor, which are the main residents of the developing world.

2.4.1 Partnerships

Is a process that evolves from informal and irregular exchanges to institutionalised relationships Is the most mature form of coordination which engages in higher levels of joint activities, and a higher level of dedicated resources or investment and open to communication/information (Dirgahayani and Nakamura, 2012). Partnership arises whenever two or more people co-own and share profits and losses of the business. Everyone contributes to the business be it money, ideas or property though management rights and personal liability vary depending on which type of partnership form the business takes. There are three types of partnerships namely general, limited and limited liability partnership (Findlaw, accessed 02/02/14).

- ✓ A general partnership is a partnership with only general partners who take part in the management of the business and takes responsibility for the liabilities of the business. If one partner is sued, all partners are held liable.
- ✓ Limited partnership has both general partners and limited partners. Limited partners do not participate in day-to-day management or operations of the partnership and bears no liability for debts or actions of partnership, they just mere investors who provides an investment to receive a share of the profits.
- ✓ Limited liability partnership formed with general partners, but all general partners are shielded from liability for the acts of other partners or employees. It is similar to a limited liability company only that it operates under partnership rules.

2.4.2 Overview of system dynamics and its use in transportation studies

System dynamics is a perspective and set of conceptual tools that enables understanding the structure and dynamics of complex systems, a rigorous modelling method that enables building formal computer simulations of complex systems and uses them to design policies that are more effective and organisations (Sterman, 2000). A tool that can be used for modelling complex systems and understanding the pattern and behaviour of different stages over time. It has the ability to mimic the real scenario and reduce the system into multiple small individual pieces, which enables whole system study. Egilmez and Tatari (2012) cited Forrester (1961) definition that it as a computer aided approach to understanding the behaviour of a system over time that have been employed to tackle dynamic problems from various fields of study. It is a strong tool used in modelling complex systems to understand the pattern of behaviour of different stages over time. The traditional approach to systems problems is to understand the behaviour of a system based on the cause and effect relationships among system elements separately. It consists of feedback loops and has the ability to mimic the real scenario and reduce the system into multiple small individual pieces, which enables whole system study (Egilmez & Tatari, 2012). Used as a holistic modelling system dynamics simulation approach have been applied in models such as urban planning (White et al).

2.5 Transport policy strategies

In order to advocate the principles of sustainable transportation and apply them in real cases specific policy strategies have to be introduced a quote from Route and Anderson (1999) by Voukas (2001). There are about fours ways namely demand oriented, supply oriented, policies regarding land use and urban planning and lastly regarding energy efficiency and innovation technology. Supply oriented policy targets at improvement of public transport system in terms of quality, capacity, efficiency, attractive fares and bus priority

From Pardo’s point of view, the dimension of the analysis was from the ‘push and pull’ approach where from the standpoint of ‘where’ people should be in transport (‘where’ should they be ‘pushed’) and from which modes we should pull them. Its emphasis lies in measures that persuade users into using public transport and non-motorised transport and develop policies that improve conditions for the use of these modes. In order to pull people to use of public transport a supply-oriented policy has to be developed first hence a supply-oriented policy is one of the major interests in this study. The aim is improvement of public transport service quality and developing policies that improve the conditions for the use of the public transport. Bus systems have the potential to provide high quality service and great performance, rivalling the capacity of commuter omnibus system, but to achieve full sustainable transportation non-motorised travelling integration is necessary. Since the city is not designed for non-motorised transportation the starting point to obtain sustainable transportation is to improve public transportation usage through creation of quality accessible, affordable and profitable transport system to attract investment. The outcome is that public transport remains the main mode for all citizens while having affordable cost.

2.6 Research position

In conclusion since previous studies have shown that congestion has become a problem, demand has outgrown supply and according Mbara (2006), 83% of is served from high density, (Small) 02/02/2014 extract says that automobiles are most economical at low passenger densities, bus transit at medium densities and rail transit at very high densities. This means that in economies of scale as passenger density increases, it becomes worthwhile at some point to pay one driver to serve many passengers by carrying them in a single vehicle. This will cut on many costs in service duplication and resource utilisation experienced by use of public transport of lower carrying capacity in high and medium densities in the area under study.

Preceding reports on transportation issues of the area under study have highlighted that transportation before partial deregulation was reliable even though not cheap. The post independence liberalisation of the economy brought about an introduction of low carrying capacity commuter omnibuses hence variance in fares and a rise in both direct and indirect costs through congestion and uneconomical use of resources. Mbara and Nyarirangwe (2007) called for overhauling of current transport system and re-fostering of partnerships. Partnerships requires proper integration of parties and from the studied literature the problems are stemming up from causal and effect relationships thus to address the root cause rather than symptoms, a causal and effect tool is a must and due to its complexity sustainable transport pose both as quantitative and qualitative. Furthermore, Pirie (2013) pointed out that committing public funds to build more road space and buy newer serviceable vehicles is a familiar but flawed response, which addresses symptoms rather than causes that has resulted in little attention paid to tackling multidimensionality and root cause of a complex transport crisis.

2.6.1 Choice of method

From the research position, it has been noted that before liberalisation, transportation was characterised by long waiting times and rigidity because of the operating timetable. There was a certain level of profitability in which subsidies were payable if not met hence it was affordable though rigid. As a means to reduce waiting time and rigidity the system was liberalised for market entry and this era saw an introduction of small capacity vehicles whose operation was ‘hail a ride’, which meant a reduction in high volume vehicles and cause congestion due to duplication of duties. Because of liberalisation, there is now inefficiency use of resources through duplication of duties, congestion that increase operational costs, fuel consumption, CO_2 emissions and illegal fare increase to cover operational costs, removal of subsidies due to numerous small vehicle. Thus, problems within the transport system are emanating from policy change that is the partial deregulation of the system. Hence, because of non-linear relationships, complexity, the dynamism of the problem and causal effect relationship exhibited by the problem, system dynamics has been chosen as the method due to its unique characteristics of incorporating delay that distinguish it from traditional management support tools. This will facilitate understanding of the relationship between the behaviour of the system over time and its underlying structure and strategic policies or decision rules.

CHAPTER 3

3.0 METHODOLOGY

3.1 Introduction

There are different types of models namely scenarios, mental and formal models (Hsiao, 2011). Of particular importance are the formal models, which include optimisation, econometrics and simulation. Models are useful in policy making in various ways. They improve understanding of the possible consequences of policy choices, clarifies decision-makers' assumptions and values that helps building of understandable narratives in support of policy proposals as well as providing framework for negotiation.

Policy-making is about trying to affect the future to maintain or improve on the status quo of public wellbeing, thus formal models must provide the possibility to test policies beforehand and accelerate learning (Hsiao, 2011). They should possess characteristics for medium-long term planning as well as these key forms of endogenously representing key variables, comprehensiveness and transparency and properly representing dynamic complexity of the system. To try to clarify transparency Boulanger and Br'echet (2005) added that an interdisciplinary model opens the black box between core variables and impact indicators and incorporate the impact indicators into the model's kernel.

As a methodology proposed for this research, System dynamics makes use of feedback relationships, delay, incorporates non-linearity and provides transparency within a system. The objective to use system dynamics here is to understand the interdependencies existing between the structure of system and its behaviour and the extent to which various policies influence the system's functioning mechanisms. This will provide basis or policy levers for future development.

3.2 Methodology critique

Multi Criteria Decision Making (MCDM) method has one general problem of no solution optimisation of all criteria at the same time therefore solutions are compromised. Evaluation of each choice on set criteria facilitates selection (Awasathi et al, 2005). Simulation models correctly define boundaries, realistically indentify causal relations whilst optimisation models offer a correct objective function definition, and extensively use linearity as well as lack feedback and dynamism. Optimisation models are intrinsically normative not descriptive (Boulanger & Brechet, 2005). On the other hand, econometric models use full rationality of human behaviour and availability of perfect information. They are structural in that they convey causal and counterfactual information used for policy evaluation. Whilst system dynamics capture highly complex, non-linear feedback relationships that exist in the real world and incorporates variable time delays that separates actions from events. Captured by Maunder & Mbara (1995, 1996) in Harare public transport the effect of deregulation could not be evaluated at the onset of the policy due to delay. This gives credibility to system dynamic modelling, which incorporate time delay that can be simulated to understand the future behaviour.

3.2.1 Structure

While the other named methods apply statistical tools to data sets and infer causal relationships between correlated variables, system dynamics develops explicit descriptions of causal relationships within formal feedback structure that allows drawing up of data to calibrate parameter values and results, verifiable model by both common sense and formal mathematics to an operational statement about how the world works. Extract from http://www.decisiondynamics.com (17/05/14).

3.2.2 Behaviour

System dynamics recreates dynamic behaviour rather than solving for steady-state solution. By mimicking the system behaviour, it allows testing of alternative assumptions, decisions and policies within a simulated program environment that provides a dynamic analytical environment that provides a method to anticipate and plan for likely future events extract from http://www.decisiondynamics.com (17/05/14). System dynamics addresses the whole system including economic, social and environmental factors and takes account of interactions across the whole system to generate long-term scenarios to show effects over time. It aids in analysis and understanding how the system functions.

Unlike optimisation, Multi Criteria Decision Making (MCDM) and econometrics methods, system dynamic models focus on endogenous explanation and support multidisciplinary approach with proper representation of dynamic complexity and transparency. Dynamic complexity is the incorporation of major delays in a system between variables. Endogenous key variables can produce the fundamental changes shown in figure 3.1 below. No modelling method other than system dynamics could endogenously generate projections red and blue behaviour given historical data from point, -15 to now (Dangerfield, 2005).

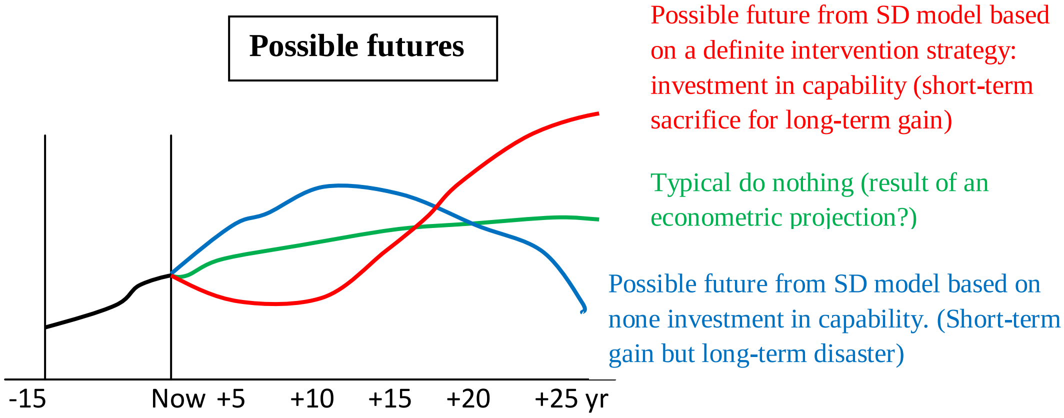


Figure 3.1 Unique System dynamics feature adapted from Dangerfield (2005)

Table 3.1 Methods comparison

Author	Method	Feedback	Non-linear	Delay	Endogenous
Egilmez & Tatari (2012)	System dynamics	Yes	Yes	Yes	Yes
Zuidgeest (2005)	Optimisation	Yes	Yes	No	Yes
Shirzadi et al (2012)	Multi Criteria Decision Making	Yes	Yes	No	Yes
Alam et al (2011)	Econometrics	Yes	Yes	No	Yes

From the above critique system dynamic have an upper hand to other methods as it includes delay not found in other methods. Secondly though it draws model upon broader set of data system dynamics requires far less data for quantifying model parameters and often include critical parameters to understand system behaviour that have not been measured through collection of 'hard' data. With a shortlist of critical data points, analysts can focus limited resources on gathering and verifying only essential data and reduce resource waste in collection of unnecessary data. This is suitable for the problem at hand due to lack of recorded data that can be used.

3.3 Methodology outline

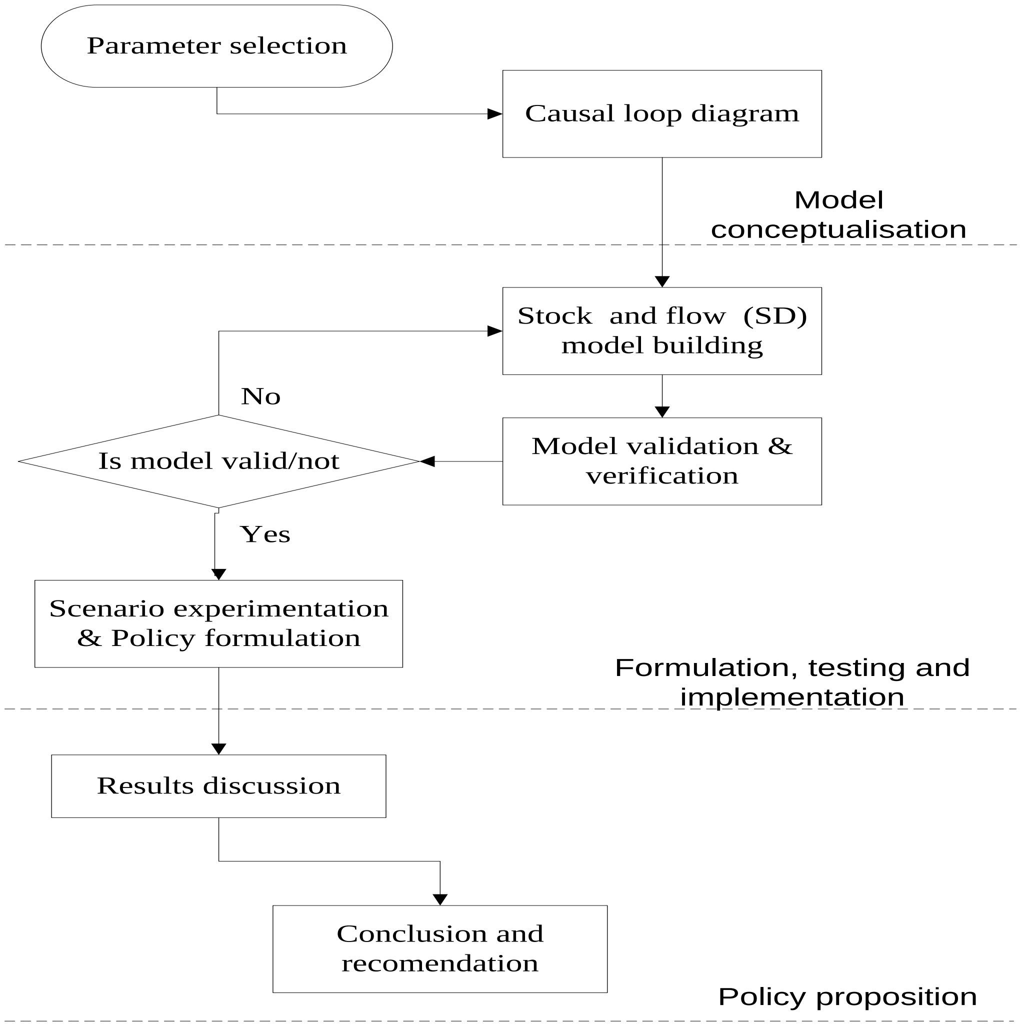


Figure 3.2 Overview of system dynamics methodology

3.4 System conceptualisation

In first series of papers prepared for MIT System Dynamics in Education project Stephanie (1997) examines in depth the steps of conceptualisation. Conceptualisation process involves deciding on model purpose (type of action or behaviour over time that model will analyse), defining model boundary, shape of reference mode and identification of key variables as well as feedback loops of the system (Stephanie, 1997). The researcher stresses that a system dynamics model is built to understand a system of forces that have created a problem and continue to sustain it. Thus, to have a meaningful model, there must be some underlying problem in a system that creates a need for additional knowledge and understanding of the system. Hence, conceptualisation stage goal is to arrive at a rough conceptual model capable of addressing the relevant problem in a system. In conceptualisation, modeller seeks to extract as much relevant information and understanding the system as much as possible.

3.4.1 Parameter selection

This is a process of defining the system boundary parameters; it identifies key variables for causal loop construction. The variables fall into three different variable types namely exogenous, endogenous and auxiliary variables. Endogenous are the important variables hence exogenous variables do not have any influence on the system behaviour. If they do then they must be modelled as endogenous variables.

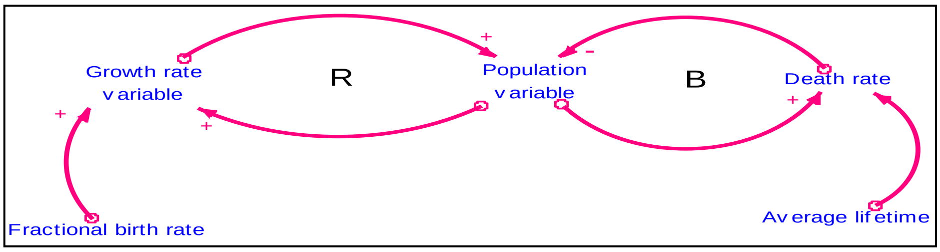
3.4.2 Reference mode

Stephanie (1997) alluded that reference is a plot of the behaviour of key variables of system over time. Reference mode captures mental model and historical data on paper, gives clues to appropriate model structure and can check plausibility once the model is built. It is done to check for some existence of behaviour worth modelling. There are two types namely the historically and the hypothesised reference modes. A hypothesised is used when there is lack of historical data. It consists of simplified curve capturing the key features of the behaviour pattern of the important components of the system. Due to lack of adequate data, in this research hypothesised mode shall be used.

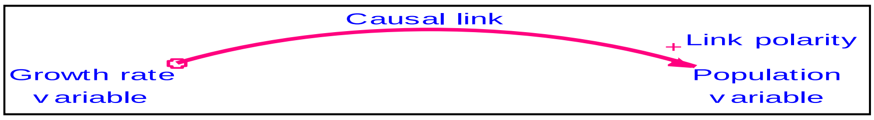
3.4.3 Causal loop diagram

According to Sterman (2000), causal loop diagrams are simple maps showing the causal links among variables with arrows from cause to effect. Variables are related by causal links. Each link is assigned a polarity, either negative (-) or positive (+) to indicate how the dependent variable changes when the independent variable changes. They are an important tool for representing feedback structure of a system. Figure 3.3 below shows an example of causal loop and its important feedback loop. The letters R and B are loop identifiers, which shows whether the loop is a positive (reinforcing) or negative (balancing) feedback respectively.

A positive link means an increase in cause will increase effect to above what it would have been and a cause decrease would decrease effect beyond what it would have been. A negative link means that if a cause increase, the effect decreases below what it would be with a decrease in cause resulting in increase in effect to above what it would have been.



a) Causal loop diagram example



b) Causal link relationship

Figure 3.3 Causal loop diagram, Adopted from Sterman (2000)

3.5 Formulation, testing and implementation

Since causal loop diagrams do not quantify the system entities, this is the conversion stage from causal loop diagrams to level and rate equations or stock and flow diagrams as well as estimation and selection of value parameters. The resultant stock and flow diagram is tested for validity that is instilling confidence into the system model. Model simulation tests the model assumptions and dynamic hypothesis. Implementation of various scenarios follows, to test model's response to different policies and translate the insights into accessible form.

3.5.1 Stocks and flow diagram

Causal loop diagrams' inability to capture the stock and flow structure of a system, which is one of the two central concepts of dynamic systems theory means that a stock and flow diagram has to be constructed. Stock and flow diagrams emphasize the underlying physical structure of the system. They track accumulations of material and information as they move through a system. Stocks include inventories of product and populations to name just but a few. Stocks are state variables or accumulations that characterize the state of the system and generate the information upon which decisions are based, Sterman (2000). They create delays by accumulating the difference between inflow and outflow. Flows are the rates of increase or decrease in stocks, such as births and deaths, investment and depreciation, and receipts and expenditures. Figure 3.3 below shows diagramming notation of stocks and flows. Harare population is the stock and population increase rate and decrease rate are the increase and decrease flows of the population respectively.

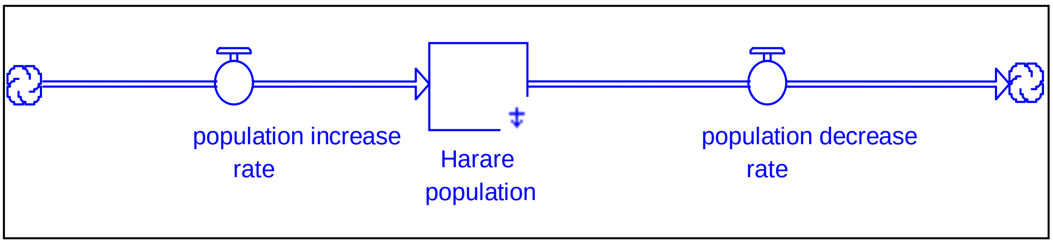


Figure 3.4 Stock and flow diagram

3.5.2 Model verification and validation

Verification and Validation is more than fitting data it seeks clarity of purpose, transparency, theoretically and empirically compelling variable relationships, reasonable behaviour and data consistency. It is done to prove credibility of the model through some rigorous tests. Model validity is classified according to model types that is ‘causal-descriptive’ (“theory-like”, “white-box”) and purely correlational (purely data-driven, “black-box”) models (Barlas, 1996). In purely correlational (black-box) models, what matters is the aggregate output behaviour of the model. Un-availability of causality in structure put emphasis on output behaviour. It has to match the real world within some specified range of accuracy to attain validity. Usually used on forecasting model purposes. On the other hand white box or causal-descriptive models are statements how the real world operates hence generating an accurate behaviour is not sufficient for model validity. What is crucial is validity of the internal structure of model. This must not only reproduce/ predict the behaviour, but also explain how the behaviour generated and possibly suggest ways of changing the existing behaviour. Model validity depends both on a clear specification of system structure and analysis of system behaviour. In this research, a white box approach is the way to go.

3.5.3 Scenario experimentation and simulation

Simulations of various scenarios take centre stage as way to translate the insights of the study so as come up with a better policy

3.6 Evaluation and recommendation

This stage provides the platform for analysis and discussion of the experimentation results. Research outcome is evaluated, recommendations are made and groundwork for future study is laid.

CHAPTER 4

4.0 SIMULATION AND VALIDATION

4.1 Dynamic hypothesis

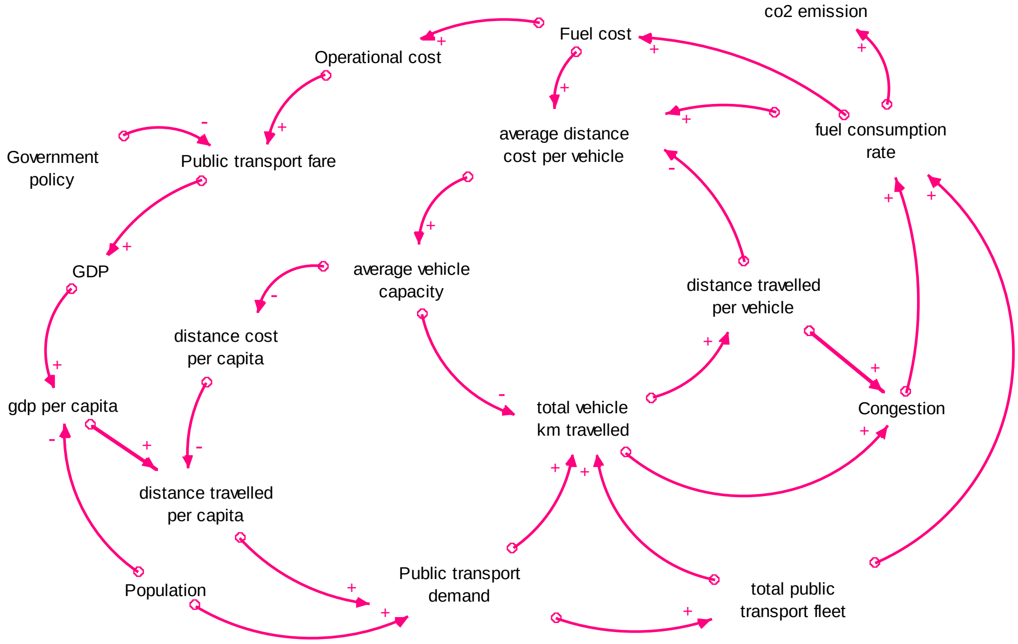


Figure 4.1 Dynamic hypothesis

Figure 4.1 is the hypothesis of the research, which that average vehicle capacity plays a key role in efficient use of resources. The lower the vehicle capacity the higher the distance travelled through more trips, the higher the traffic congestion that leads to high fuel consumption, CO2 emissions and operational costs that in the end push public transport fare.

4.2 System description

The system has three sub-models, which are population and GDP, Investment sub-model and bus operations sub-model. The first sub-model population and GDP give the growth of the variables population and GDP their impact on GDP per capita. Investment model caters for the dynamics of investor attraction, capital investment and return on investment. Lastly, bus operations give the account of behaviour response to investment on of public transport. The system boundary is outlined in variable selection stating which is included and not.

4.2.1 Initial variable value

- Average daily trips = 5
- Earmarked tax = 5%
- The government proposed yield curve of a minimum of 8% interest rate guides minimum attractive rate of return.

4.2.2 Variable types

- Exogenous,

Exogenous means arising from without (Sterman, 2000). These are the controlling variables; they cause a change in behaviour of a system by affecting other variables within the system but are not affected by the variables in the system. They are the independent variables and should be minimised with the system in order to be able to fully analyse system behaviour. An example of exogenous variable in this particular case is population. The growth of the population affects the transport demand but transport demand do not affect population growth.

- Endogenous

The word endogenous means arising from within (Sterman, 2000). An endogenous theory generates the dynamics of a system through interaction of the variables and agents in a model. Specification of how the system is structured and decision rules in the system patterns of behaviours generated by the structure decision rules can be explored. In addition, behaviour changes that might happen are explored through alteration of structure or decision rules Sterman (2000). Endogenous variables are the ones that change state, they are important in analysis of system behaviour as they are affected by other variables within and outside the system. An example of endogenous variable is transport fleet that is affected by demand and affects congestion or fuel consumption.

- Auxiliary

These are variables used to aid the clarity and communication of the system. They consists of constants and functions of stocks. An example is fuel price

4.2.3 Reference mode

The key variable used in reference mode is the public transport fleet. Historically after partial deregulation, there was an introduction of commuter omnibuses in 1993. Population was 1,458,204 during that period. The commuter omnibus (public transport fleet) has since grown to 10000 vehicles by 2013 and population has increased to 2,123,132. From this point of view, it has been noted that there is exponential growth of public transport fleet with the increase in population hence reference model is an exponential growth between 1993 and 2013. Thus, due to lack of numerical data from 1995 to 2012 hypothesised reference mode is estimated from the known facts. Figure 4.2 shows the hypothesised reference mode.

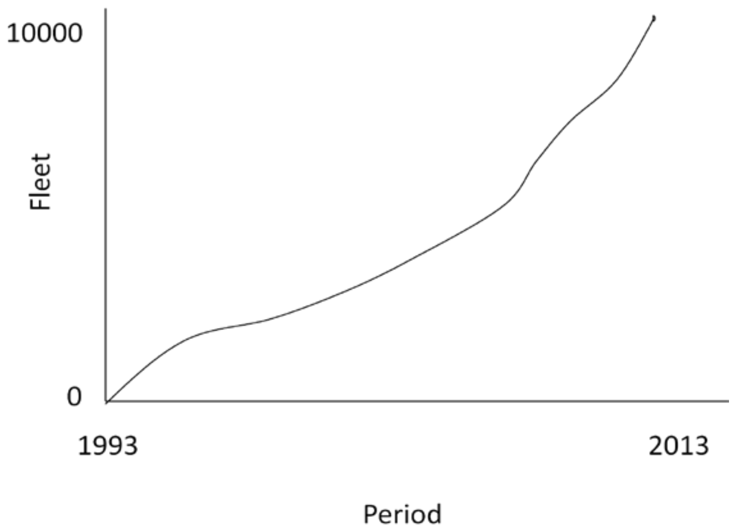


Figure 4.2 Hypothesised reference mode

4.2.4 Parameter Identification/ system boundary

The system focuses on urban public transport not including taxis, walking and bicycles. The idea is to replace low carrying capacity vehicles namely commuter omnibuses with high volume carrying capacity buses. Parameter identification defines the system boundary that will give key variables for causal loop construction. These fall into three different variable types namely exogenous, endogenous and auxiliary variables. Table 4.1 below show the key parameters.

Table 4.1Identified Parameters/ Variables

Parameter	Category	Description	Type	Unit	Affected by
Capital investment funds	Stock	The total amount of money invested	Endogenous	USD	Number of investors
Public transport demand	Convertor	Total number people to be transported	Endogenous	People	Population growth
Profit	Convertor	Amount realised after tax & operational costs	Endogenous	USD	Investor
Rate of return	Flow	Rate of turnover per amount invested	Endogenous	Percent (%)	Interest rate
Revenue	Convertor	Total amount before tax	Endogenous	USD	Public transport capacity
Operational cost	Convertor	Total amount used	Endogenous	USD	Congestion
Public transport fleet	Stock	Total number of vehicles	Endogenous	Buses	Public transport capacity
Bus fare	Convertor	Price per km	Endogenous	USD/ km	Government policy
Public transport capacity	Convertor	Total number of passengers in a bus	Endogenous	Person s/ Bus	Public transport demand
Investors	Stock	Total number of investors	Endogenous	People	Rate of return

Continuation table 4.1

Parameter	Category	Description	Type	Unit	Affected by
Government policy	Convertor	Bus fare control	Exogenous	-	-
Daily trips	convertor	Average number of daily possible trips	Auxiliary	-	Public transport capacity
Population	Stock	Total number of people in Harare city	Exogenous	People	-
Economy	Stock	Gross Domestic Product (GDP) of Harare city	Endogenous	USD	Investment
Congestion	Convertor	Total vehicle km travelled	Endogenous	Km	Public transport capacity
Fuel price	Convertor	Retail price per litre	Auxiliary	USD/ Litre	-
Fuel consumption	Convertor	Total amount of consumed fuel in litres	Endogenous	Litres	Total vehicle km travelled

4.2.5 Assumptions

As noted in the problem background, that the public is calling for change in the transport system and yearning for the heydays, they used to board the timetabled stage bus and ZUPCO it is assumed that they are in consent to the bus investment.

4.3 Causal loop diagram

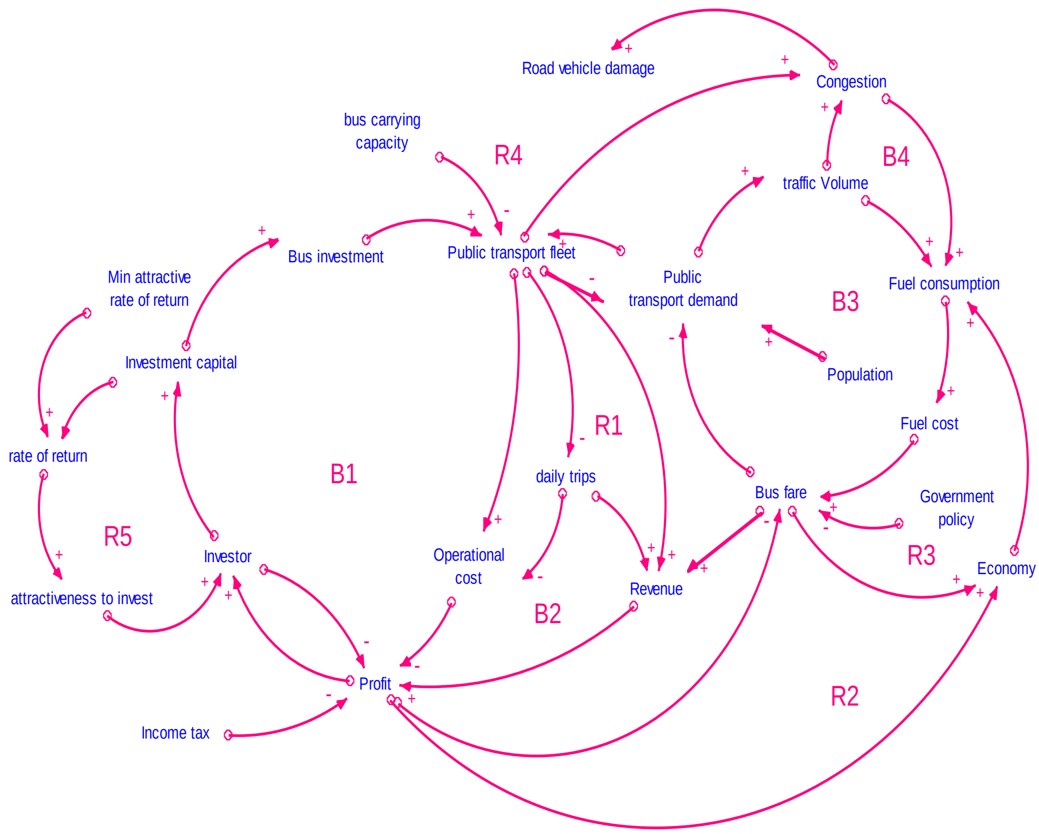


Figure 4.3 Causal loop diagram

4.3.1 Feedback loops

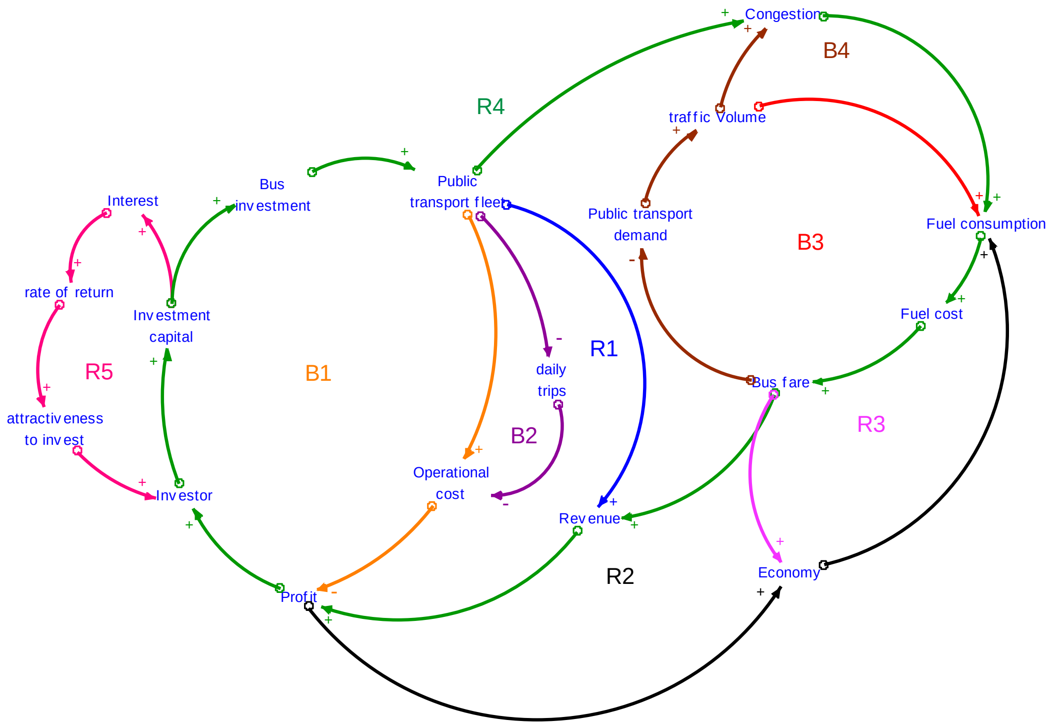


Figure 4.4 Relationship between variables

1. Negative loop B1: Availability of capital funds promotes increase in public transport fleet this will increase operational costs and in turn decrease profit that will affect attractiveness of investing.
2. Negative loop B2: Capital investment promotes increased public transport this would reduce daily trips resulting in an increase in operational cost, which will reduce profit and affect attractiveness of investing.
3. Negative loop B3: Traffic volume increase increases the fuel consumption this increase tends to trigger an increase in bus fare to maintain equilibrium. Meaning that as bus fare increase, demand decrease and this will close the loop.
4. Negative loop B4: Traffic volume increase results in increased congestion and further increase in fuel consumption to beyond what it should have again causing an increase in bus fare. Increasing bus fare reduces public transport demand this will again close the balancing loop.

5. Positive loop R1: Availability of capital funds increases the public transport fleet that would result in increased revenue and profit meaning pulling more investors.
6. Positive loop R2: Bus fare increases revenue and profit which in turn increases the economy. An increase in economy means an extra can be used and results in increased fuel consumption that further pushes for bus fare increase to maintain breakeven.
7. Positive loop R3: an increased fuel consumption pushes for bus fare increase which in turn increase the economy as more will be used for personal consumption and again causing an increase in economy to reinforce fuel consumption.
8. Positive loop R4: Public transport fleet increase increases congestion, which in turn increase fuel consumption and advocates for bus fare increase. An increased bus fare increases revenue and profit, this will attract investors and increase the capital funds amount further reinforces the increase of public transport.
9. Positive loop R5: A better rate of return attracts more investors this causes an increase in capital funds base, which in turn increases return on investment.

4.4 Stock and Flow diagram

4.4.1 Population and GDP sub-model

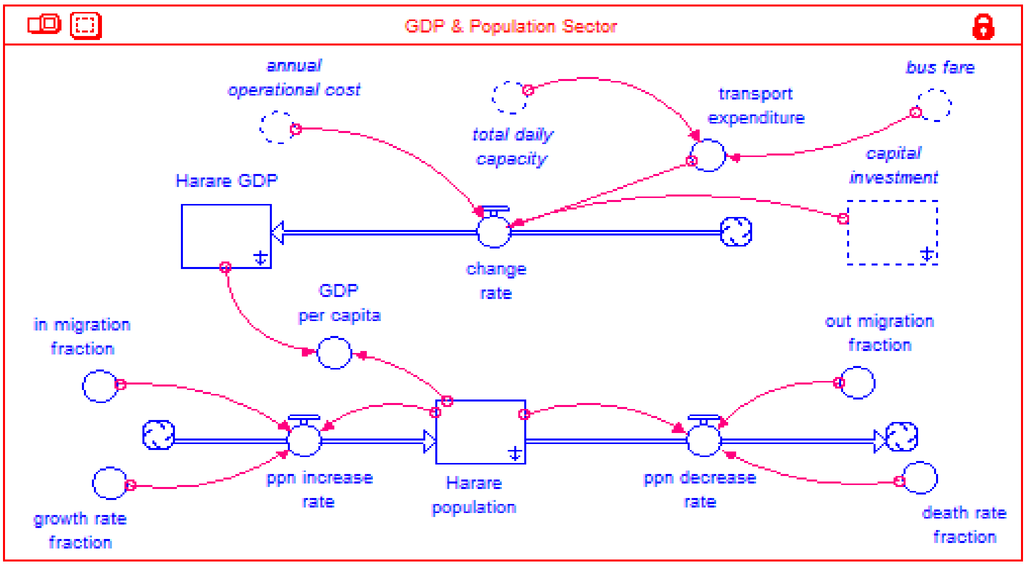


Figure 4.5 population and GDP sub-model

a. Population and GDP sub-model behaviour description

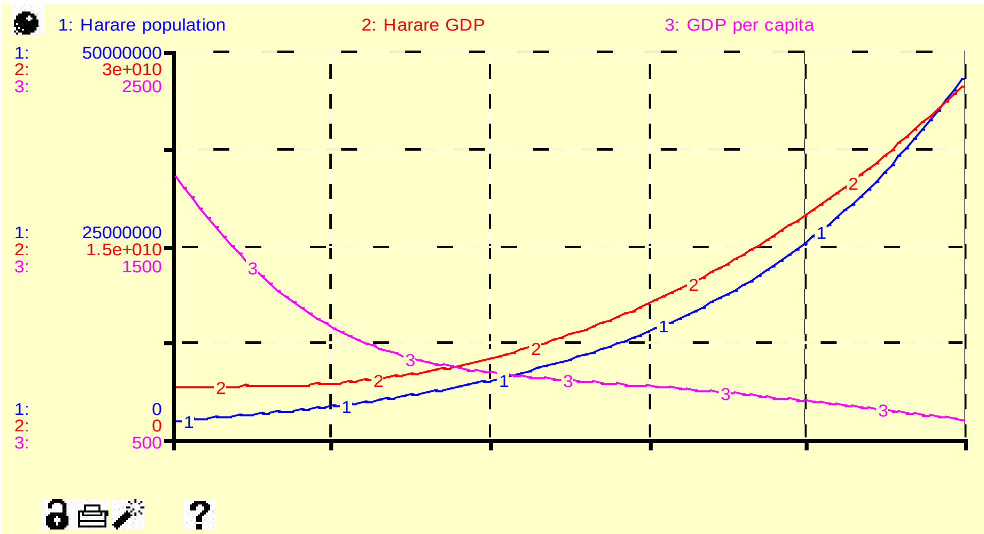


Figure 4.6 Population and GDP behaviour

Demand of public transport is stemming from the population increase. From figure 4.6 above because of high in migration rate of 49% and higher birth rate of 3.3% the behaviour of the city's population is an exponential growth hence this would result in an increased demand of transport be it public or private. GDP of the city has also exponential growth behaviour but at a lower rate than population, this results in a low GDP per capita. A low GDP per capita is a sign to show that majority are poor hence public transport will be cheap mode of transport or people will resort to walking or out migration if they cannot afford the public transport fare. There is an increased demand that would see an increase in public transport. With the capacity of the current public transport, the city would become unliveable in a matter of years hence an investment in high volume capacity vehicle is an ideal solution.

4.4.2 Investment sub-model

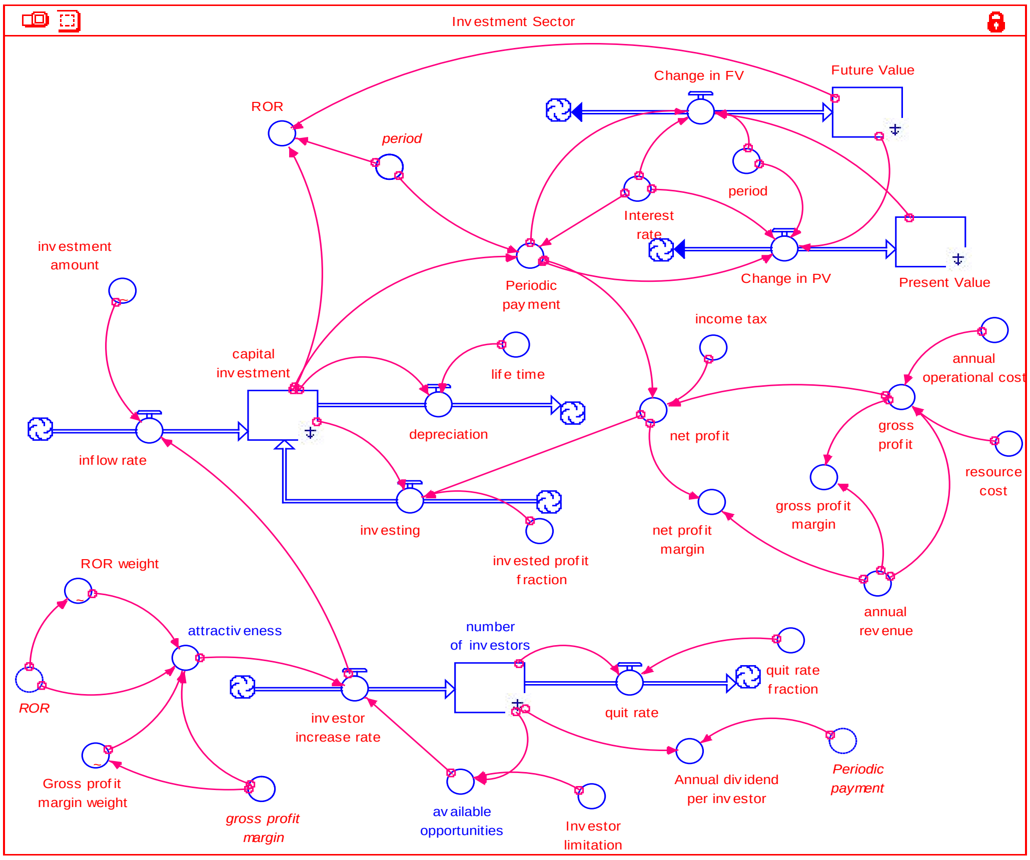


Figure 4.7 Investment sub-model

Investment sub model behaviour description

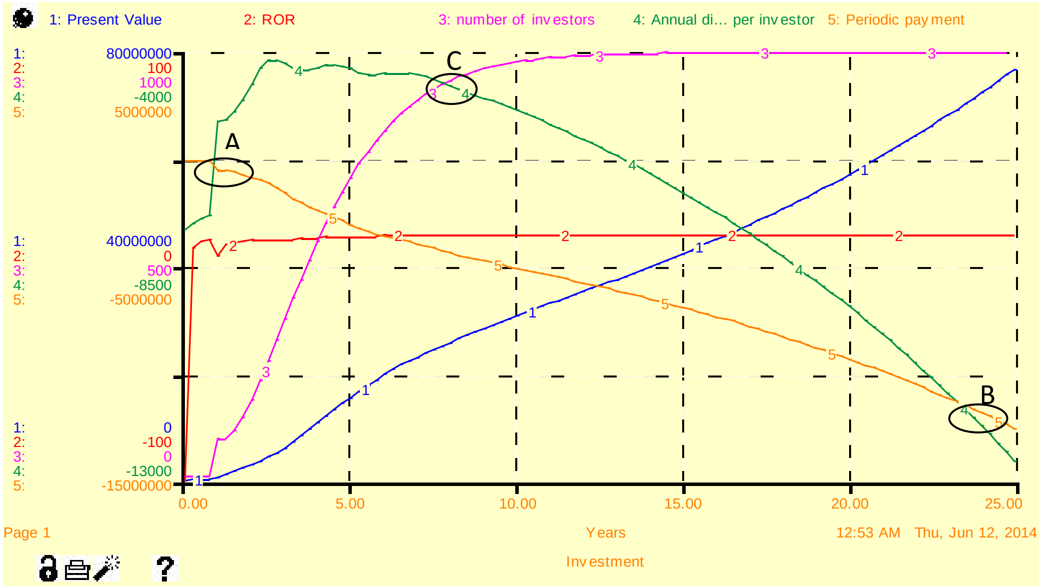


Figure 4.8 Investment behaviour

From the investment sub model limiting the investor has an effect on the output as the behaviour produced is goal seeking. It tries to balance the system, thus when investor increase rate decreases and number of investors become almost constant at point C the payable dividend per investor starts increasing exponentially. In early stages of the because of low rate of return there are no investor increase, then when ROR is above the government proposed yield of 8% investors are attracted and the increase rate increases causing drop in both ROR and per investor dividend. This drop in ROR is due to delay in response to the sudden increase of the number of investors. Point A reflects non-linearity of the system with a shift in dominance of positive feedback to negative feedback, as the dividend per investor decrease with the increase in number of investors. Despite the fact that periodic payment is increasing negative feedback is more dominant than positive feedback.

As the system grows and as the number of investor stabilises the ROR obtaining its maximum value. This stabilisation result in a positive feedback dominance with the increase rate of dividend per investor outgrowing periodic payment as shown on point B. As long as the system is stable, this behaviour will continue until acted upon by another force. Because of this positive feedback both dividend and periodic payment increase exponentially.

4.4.3 Bus operations sub-model

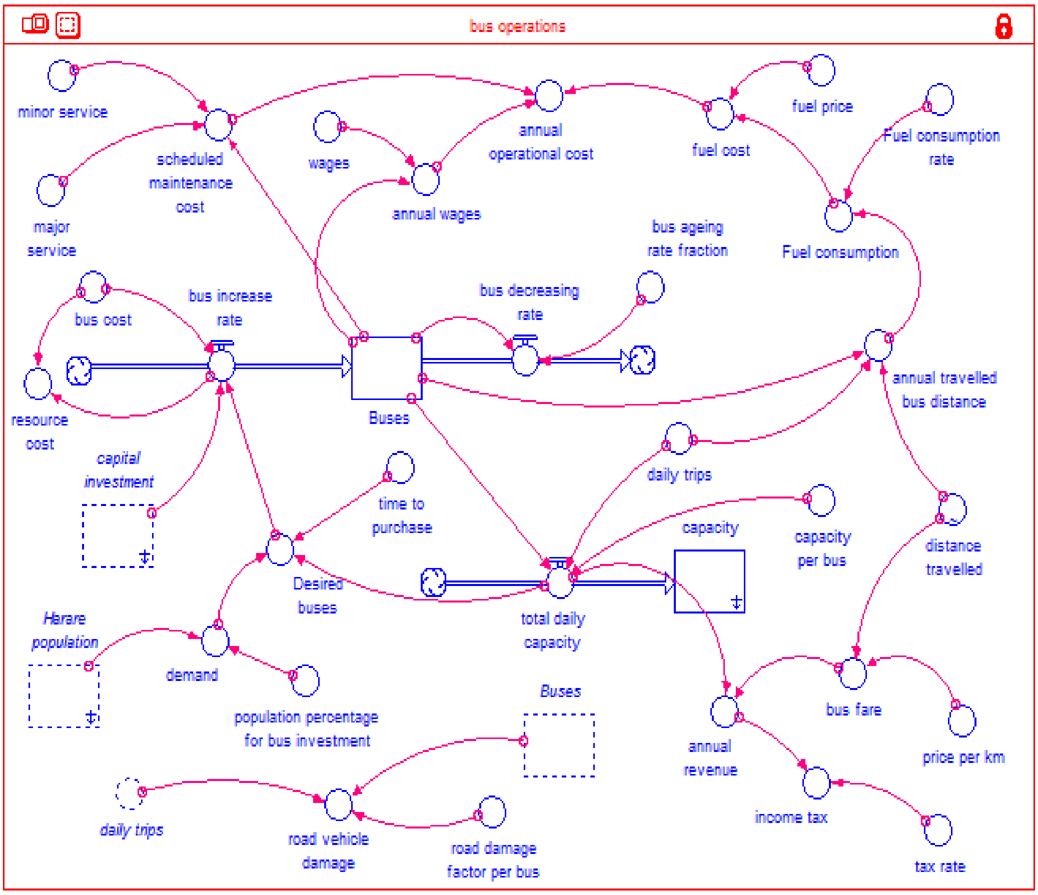


Figure 4.9 Bus operation sub-model

b. Bus operations behaviour description

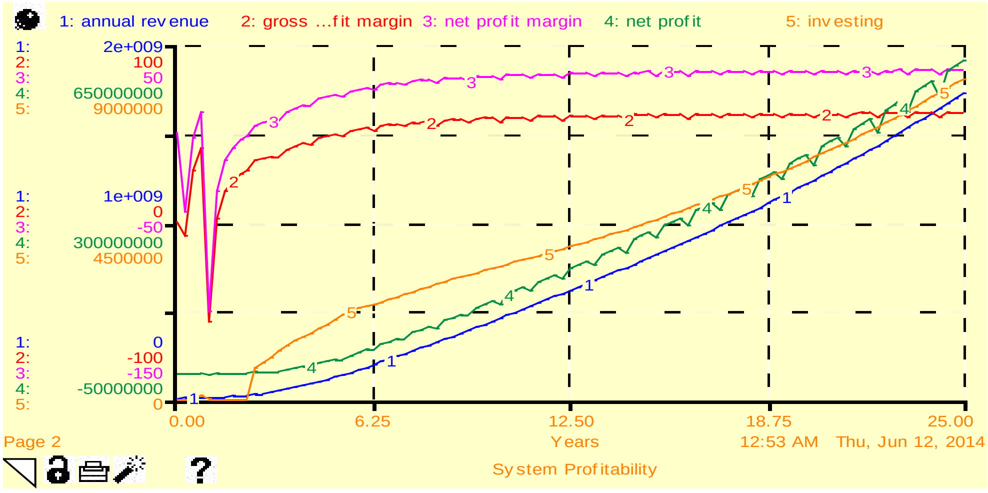


Figure 4.10 Bus operation behaviour (a)

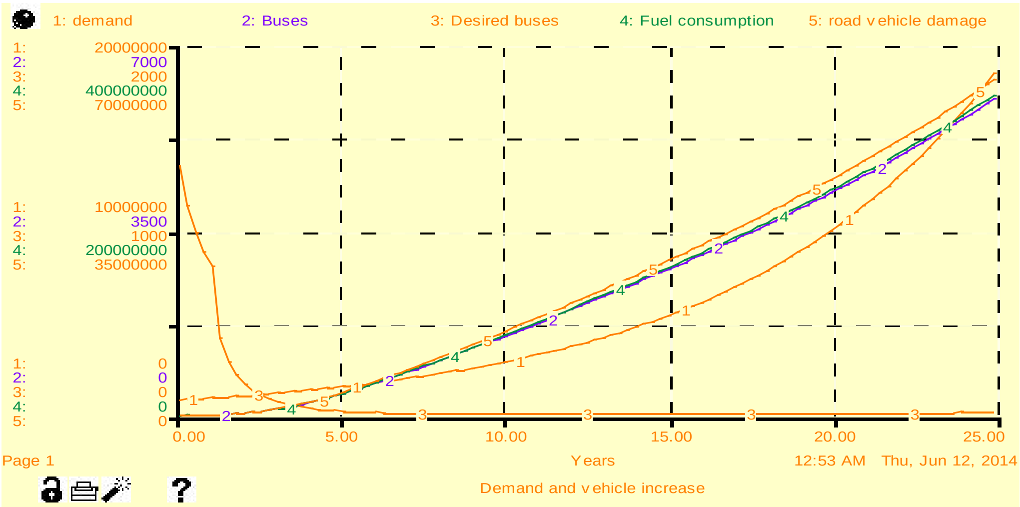


Figure 4.10 Bus operation behaviour (b)

Figure 4.10 (a) shows behaviour of system revenue and profitability to increase of bus fleet and 4.10 (b) shows the behaviour of the impact of demand on fleet increase, road damage, fuel consumption and desired buses. As the demand increase so as the desired number of buses to fulfil the need. An increase in the number of vehicles results in a growth in fuel consumption, road damage caused by the vehicles, revenue as well as profit. An exponential increase in the number of buses provokes an exponential decrease in number of the desired buses as the two balance each other. The desired buses behaviour is negative goal seeking hence as it approaches equilibrium the reduction rate decreases and this stabilises the system as shown by the gross profit margin that also approaches equilibrium. This is shown by the graphs of the two, which become almost like straight lines with little variation in the output. The behaviour of net and gross profit margin is positive goal seeking to achieve an optimal operating efficiency of the system. Achieving system optimal efficiency results in an exponential increase of the net profit and revenue generated by the system.

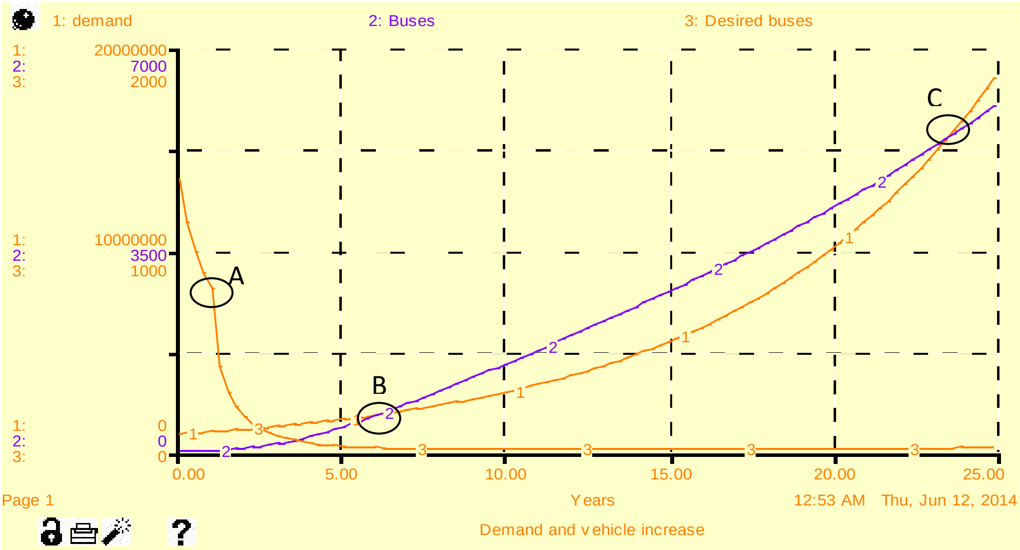


Figure 4.11 Reaction to investor increase

Point A signifies a change in decrease rate speed as the number of investors increase. As the number of investors increase buses increase at a faster rate than that of demand causing a balance in supply and demand shown by point B. At point C there is shift in balance of the supply-demand to dominance of demand hence the desired number of buses start to increase with the increase in demand.

4.5 Verification

Verification is testing of conformity or model's logic accuracy and error checking of the simulation program by checking formulation, equations and variable unit parameter. Its purpose is to check whether the model runs properly without formulation error. Figure 4.12 below shows model verification test on formulation and unit parameter checking.

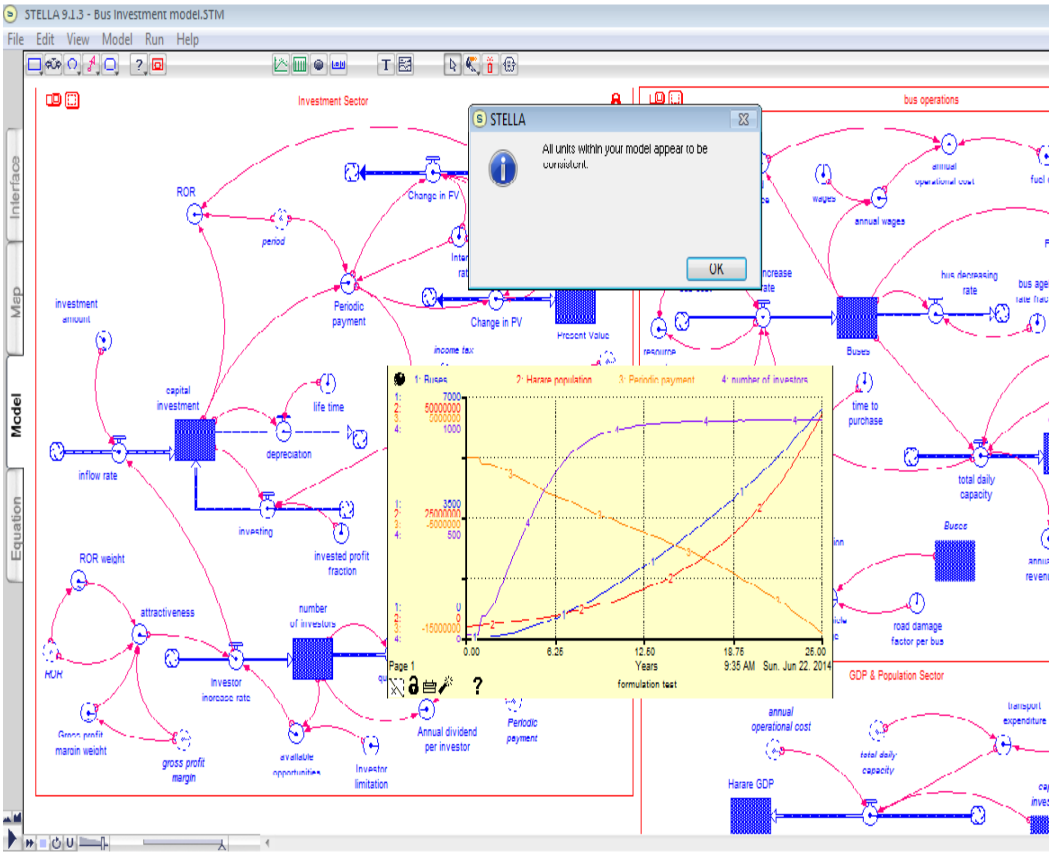


Figure 4.12 Formulation and error checking

4.6 Validation

Since, system dynamics has a weakness of misleading if relationships are incorrectly formulated, acceptability of intended use of the model whether it mimics the real world is done through validation. Validation is a process of establishing confidence in the soundness and usefulness of a model (Forrester 1973, Forrester and Senge 1978). It is an iterative process, which involves

structural validity – behavioural validity – structural validity. Structural validity includes checking for dimensional consistency, parameter verification, boundary adequacy, structure verification and extreme condition testing. Behavioural validity assesses how the solution derived from the simulation model compares against the performance of the real system. This includes trend comparison, comparing means and comparing amplitude to name a few (Qudrat-Ullah, 2012).
Due to unavailability of concrete data and difference in carrying capacity of the public transport between model and real data or historical data fleet increase was used as the endogenous validation variable.

4.6.1 Structural validation

Forrester & Senge (1978) give examples of direct structure test such as, Structure and parameter verification tests, direct extreme-conditions test and dimensional consistency. Structure verification test means comparing the structure of the model against the structure of the real system (Forrester & Senge, 1978). Dimensional consistency test entails dimensional analysis of model equations. Direct extreme condition testing involves evaluating the model equations under extreme conditions and assessing the plausibility of the resulting values against knowledge or anticipation of what would happen under similar condition in real life (Barlas, 1994). Unit consistent and physical check of the model to determine whether it is performing the according to concept was done.

a. Mimicry

The model should be able to mimic the behaviour of the real world. Figure 4.12 shows model simulation result with average number daily trips, of note is the negative profit for the first two years. Break even was achieved on the second year running. This is an accepted common knowledge that a business does not breakeven at very beginning. Points A and B show the positive profit and time period respectively.

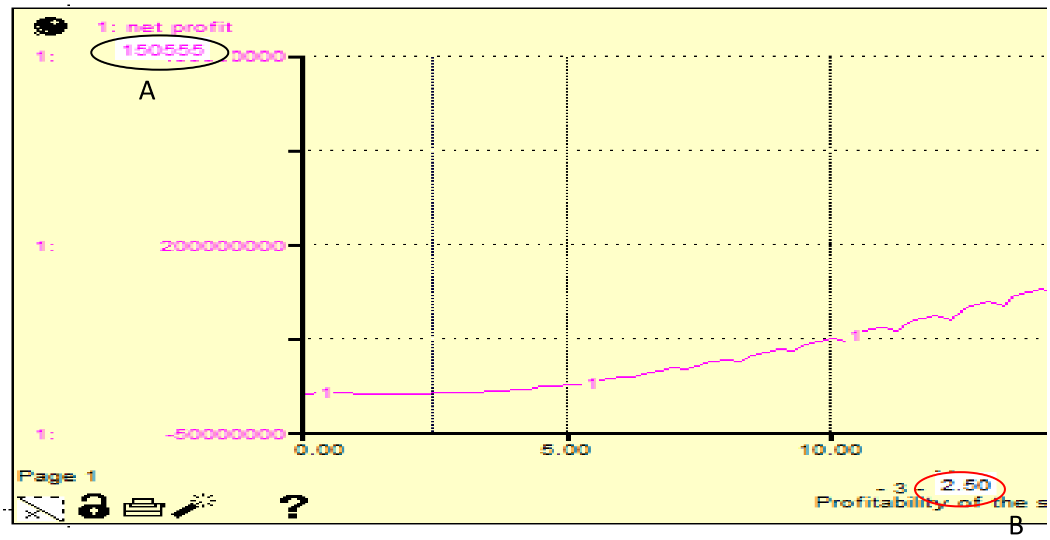


Figure 4.13 Mimicry behaviour

b. Boundary adequacy test

Boundary adequacy test is part of validation test that is designed for limiting the boundary of the model. Conducted by consideration of main objective of the model boundary adequacy test is done simultaneously in model building. Variables within the system are tested for significant effect on model purpose, if none is found then the non-effect variables must not be included in the model.

c. Parameter tests

Model parameter test is done for verification of relationship status between two variables to follow the initial logic of the system. Below figure 4.15 shows the resultant behaviour relationship of the desired buses to the increase in stock of buses. Logically as the buses increase, the desired buses should decrease until achievement of equilibrium. From the result, it has been shown that the model follows the logic.

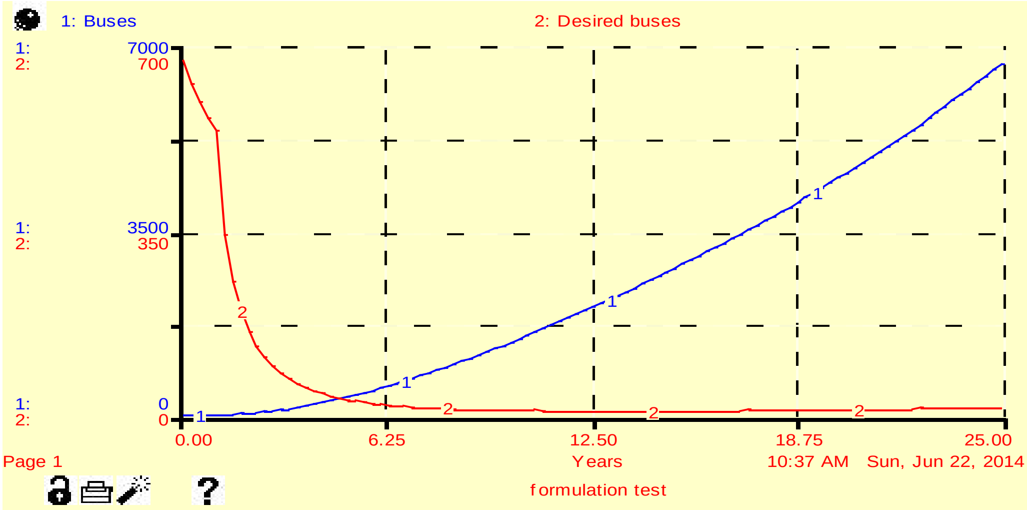
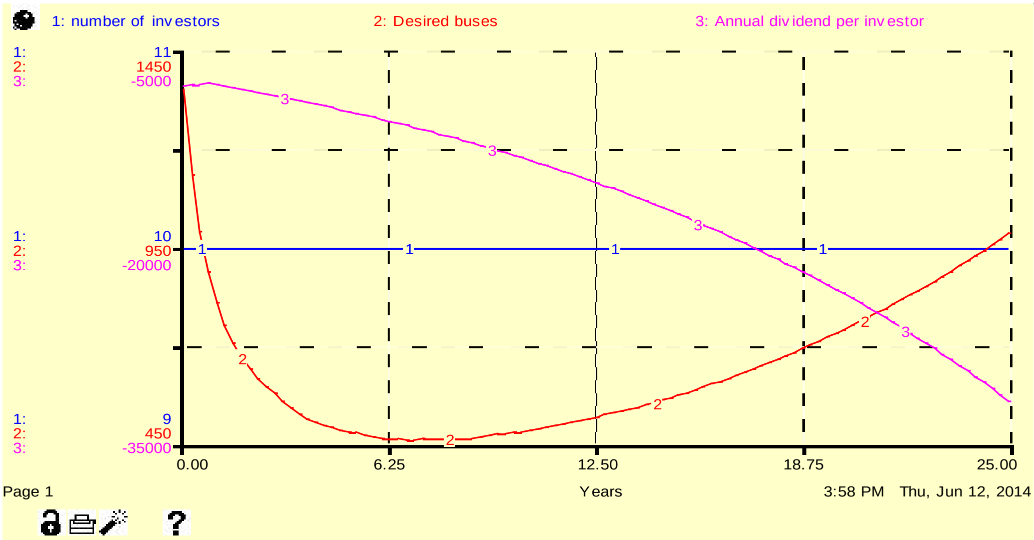


Figure 4.14 Parameter test behaviour

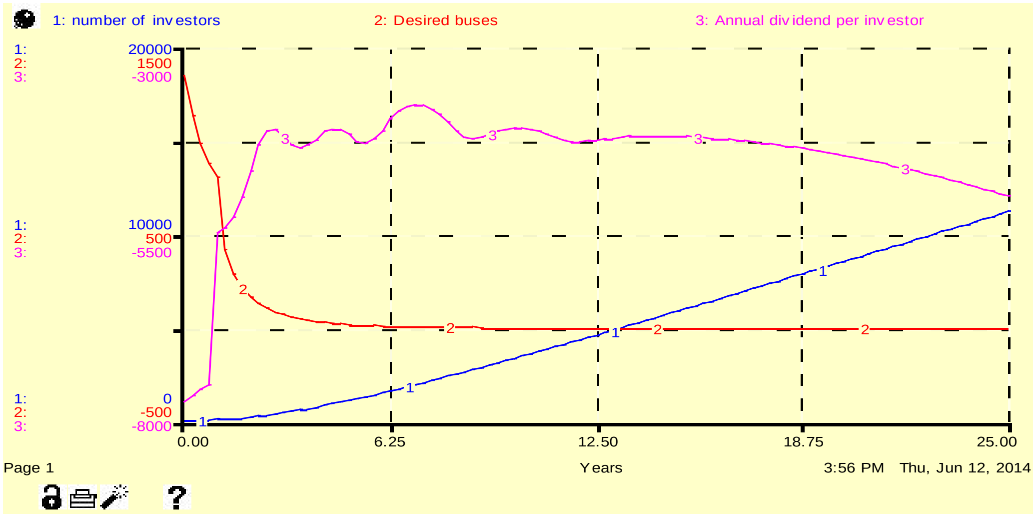
4.6.2 Structure-oriented behaviour test

a) Extreme conditions behaviour testing

Extreme conditions tests are designed to measure the model's ability using extreme conditions. Smallest and largest possible values are assigned to a selected variable for testing. In this particular case, the number of investors is maintained at a smallest constant and unlimited for the largest possible value respectively.



i. Smallest extreme condition



ii. Largest extreme condition

Figure 4.15 Extreme condition behaviour (i & ii)

Maintaining number of investor at the initial number of five results in low bus increase rate because of fewer funds available for fleet procurement, which is only possible after certain percentage re-investment, that will be done upon realisation of positive profit. Demand outgrows supply hence the desired buses behaviour shifts from goal seeking to exponential growth. In-spite of system profitability demand overcomes supply. Dividend per investor increase exponentially as profit increases. On the other hand, an unlimited number of investors mean more procurement funds, goal seeking rate increases and achieves equilibrium at a shorter period with supply equalling demand. Desired buses become zero and fluctuate between 0 – 1 as population increase.

4.6.3 Behaviour validity

Model behaviour tests evaluates adequacy of model structure through analysis of behaviour generated by the structure. It includes behaviour reproduction, behaviour prediction, behaviour anomaly, family member, surprise behaviour, extreme policy, boundary-adequacy (behaviour) and behaviour sensitivity (Forrester & Senge, 1978). Due to lack of data, more emphasis was put on structural validity tests as a way of validating the model. Figure 4.16 below shows the public transport fleet behaviour. The behaviour produced is an exponential growth same as the hypothesised reference mode.

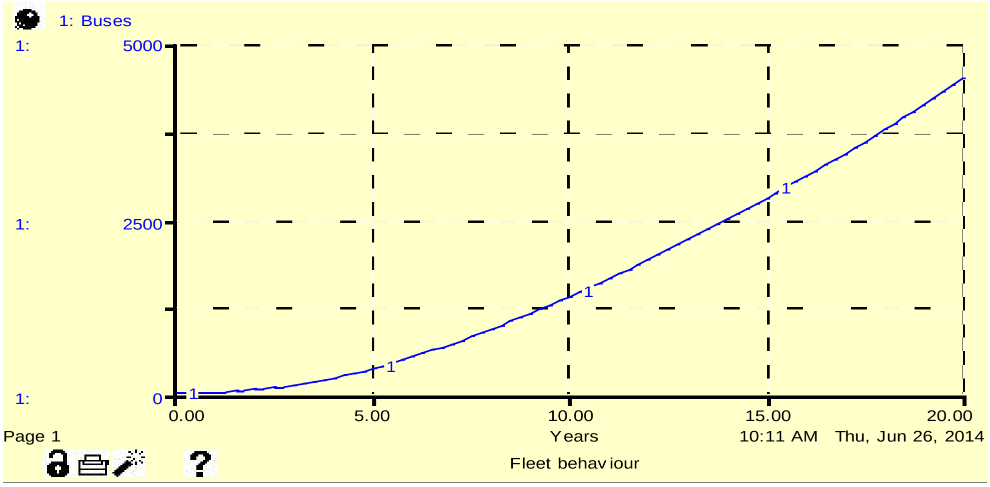


Figure 4.16 Fleet behaviour

Public transport fleet behaviour is compared to hypothesised reference mode. Since the model produced the same behaviour of the hypothesised reference and other tests done proving to be in line with the expected structure of the model then it can be inferred that the model is valid

CHAPTER 5

5.0 POLICY SCENARIO EXPERIMENTATION

5.1 Policy scenario creation and experimentation

As the number of investors grew the profits will decrease due to a large base of dividends, when profit decreases there is a pressure to increase the revenue source to balance the operations and keep investors happy which leads to one thing, fare increase. An increase in fare will see a decrease in the number passengers and further reduce revenue and profits, this will lower investor confidence and some may withdraw as result capital investment funds will fall. As the fare, increase continues the patronage will also plummet and business may end up unable to sustain its operations and become bankruptcy, in the end it may fold down or close shop. Thus, there is need for trade off between expected profit and the number of investors to maintain profits and fare stability that will guarantee a continued operational sustainability.

5.2 Scenarios Logic

5.2.1 Earmarked taxes

Earmarked tax considered in this case is a percentage value used to reduce the fuel prices for the bus system. Instead of paying the normal price per litre, the public transport of the bus system would pay a cut price less the earmarked tax value.

5.2.2 Daily trips

Apart from the given daily trips, these can be changed to possible minimum daily trips and maximum possible daily trips that are combined with ear-marked tax.

5.2.3 Subsidies

Apart from earmarked tax and daily trips, the government can introduce subsidies to cushion the operating costs of the bus system. The subsidy amount in this case is an agreement between the government and the bus system hence there is no specific value to simulate and get a result. Whenever a certain level of the agreed profitability is not met the agreed amount of subsidies will be payable. This is one of the qualitative approaches within the system.

5.2.4 Investor incentives

Furthermore, the government can offer incentives to investors such reduced duty on importation of goods and spare parts of public transportation to boost the attractiveness of the system.

5.3 Scenarios performance

a) Model performance

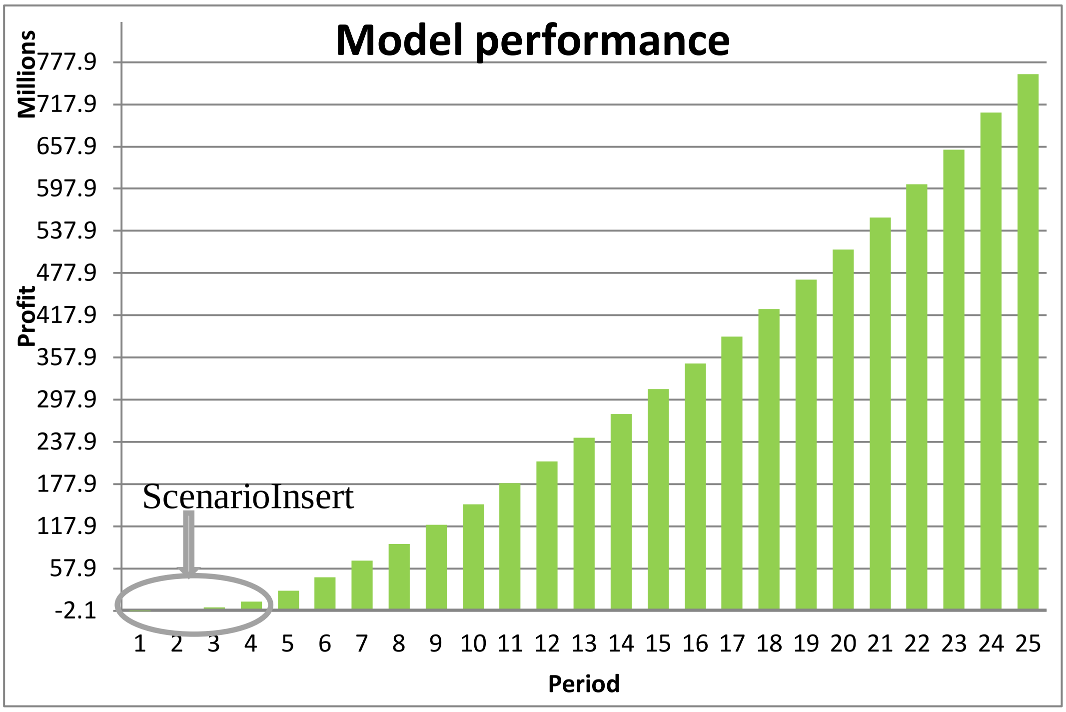


Figure 5.1 System profit growth

Average daily trip is taken as the normal scenario performance. Minimum and maximum possible trips are simulated to get the behaviour response of the system. Since the first part of period are not clearly visible the part is represented as scenario insert of different possible policy scenarios.

5.3.1 Scenario 1 Minimum daily trips

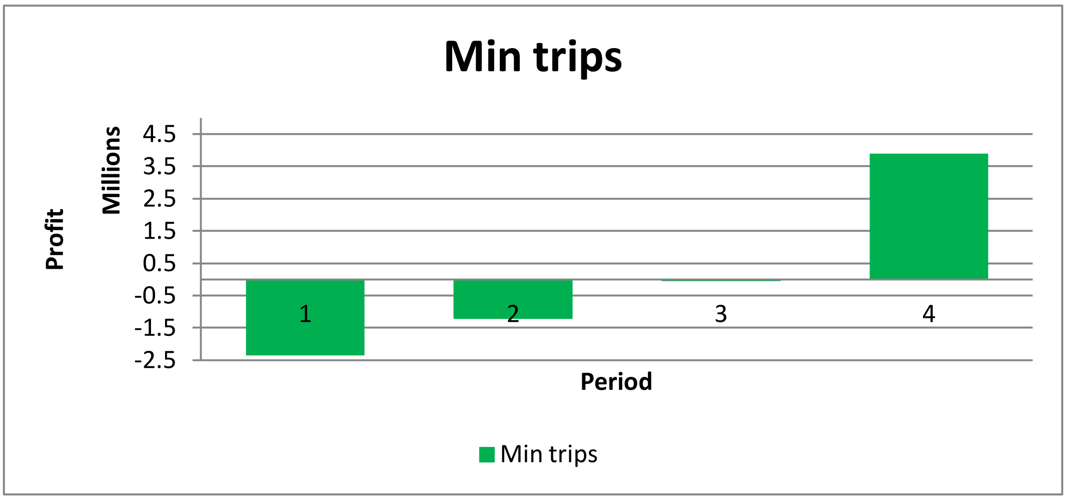


Figure 5.2 Minimum possible daily trips profit scenario

Profit is realised after 3 years of operation, which would require heavy subsdising.

5.3.2 Scenario 2 Minimum daily trips + earmarked tax

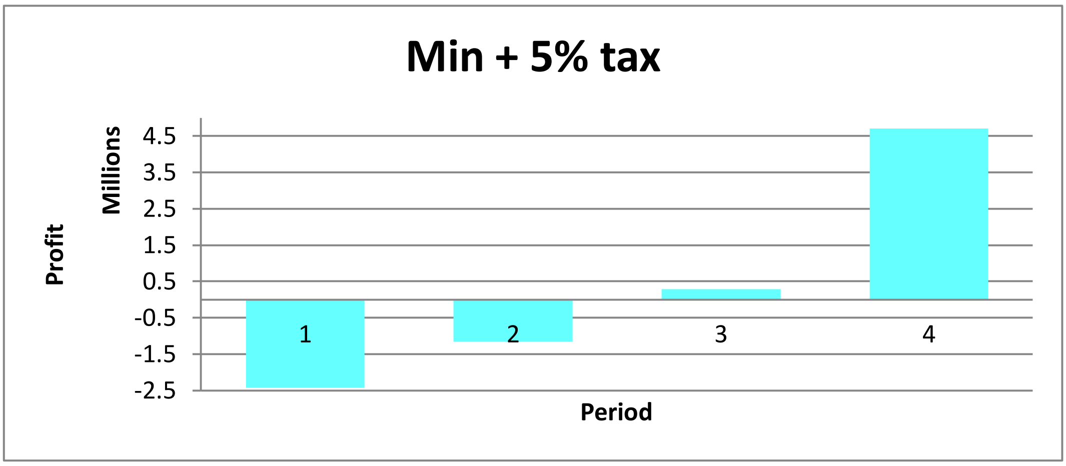


Figure 5.3 Minimum daily trips + 5% tax scenario

Figure 5.3 shows simulation of minimum daily trips with earmarked tax. In the first and second years profit is negative but at increasing rate.

5.3.3 Scenario 3 Average daily trips

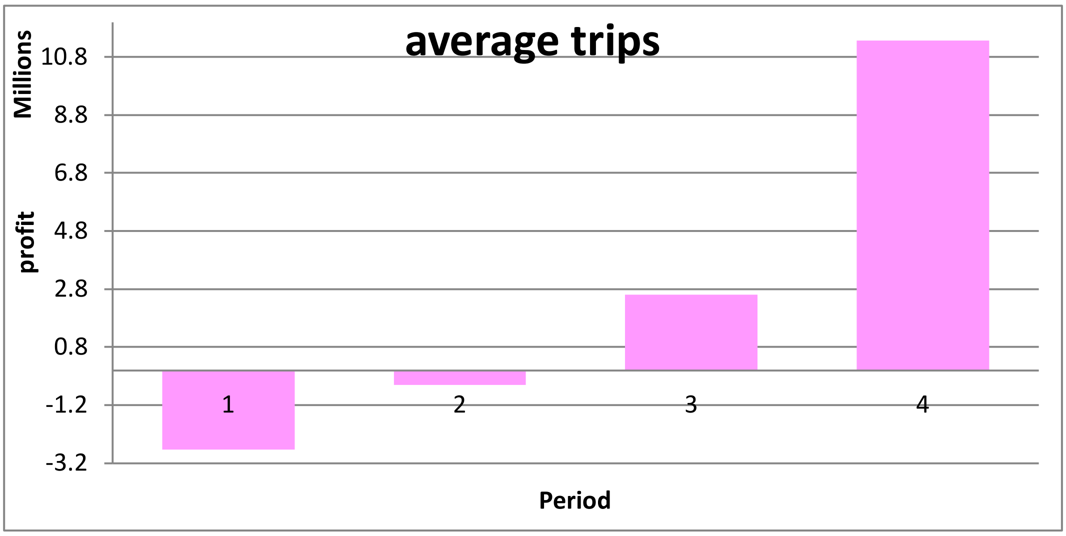


Figure 5.4 Average daily trips scenario

In scenario 3 positive profit is realised in second year running with smaller value in the second year than that recorded in minimum daily trips.

5.3.4 Scenario 4 Average daily trips + earmarked tax

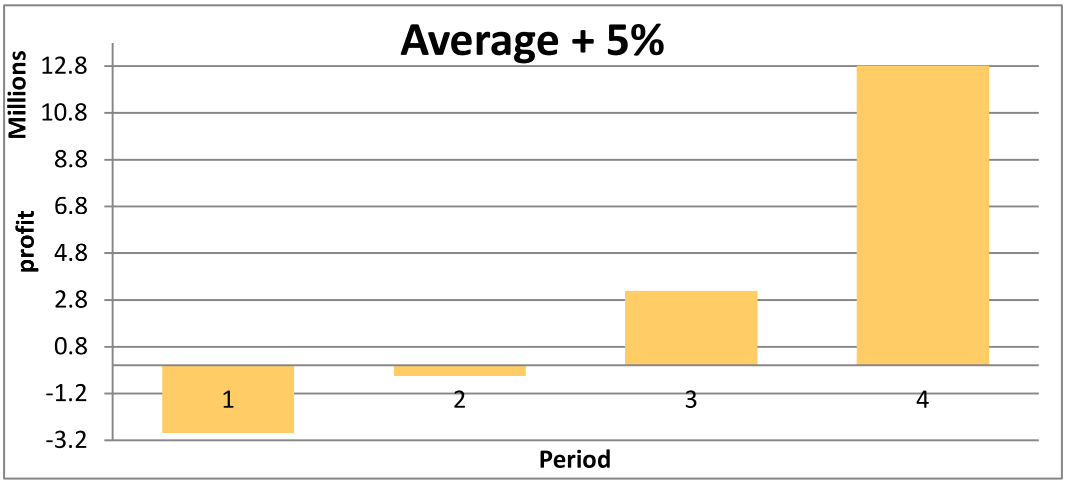


Figure 5.5 Average daily trips + 5% tax scenario

Like in the previous simulation, the scenario the first and second years produced negative profit for average trips + earmarked tax and recorded positive profit in the third year running with some differences in the value.

5.3.5 Scenario 5 Maximum daily trips

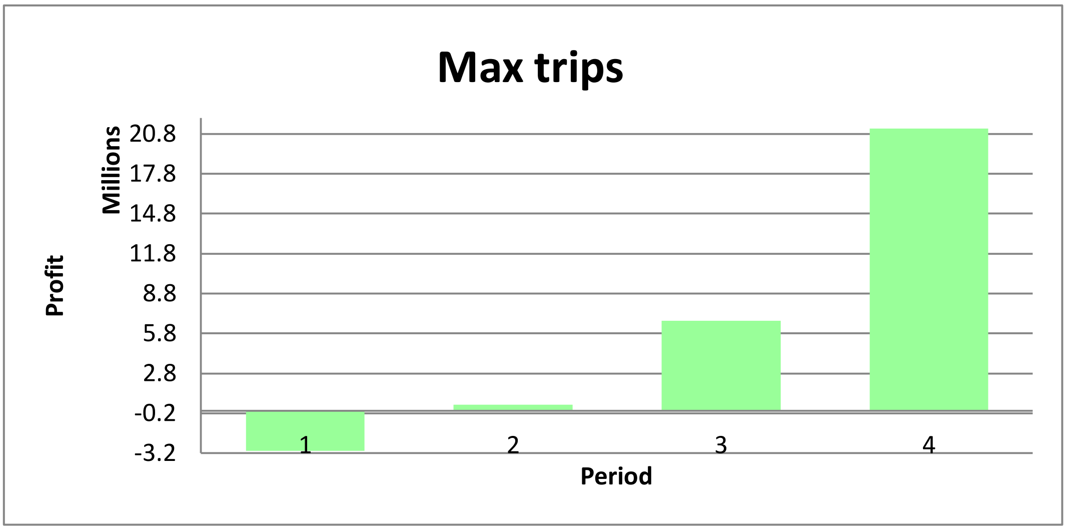


Figure 5.4 Maximum daily trips profit scenario

5.3.6 Scenario 6 Maximum daily trips + earmarked tax

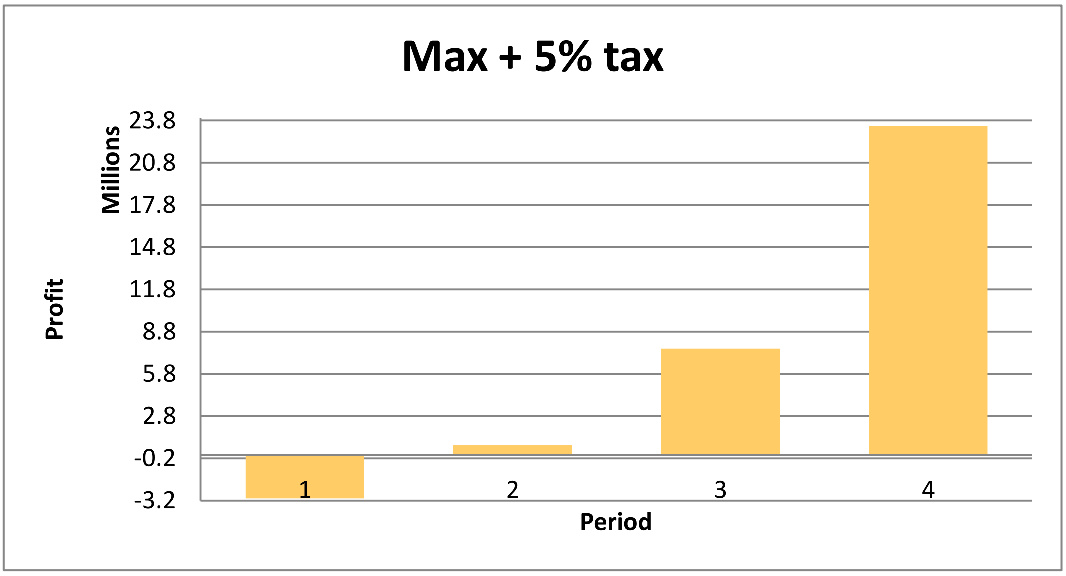
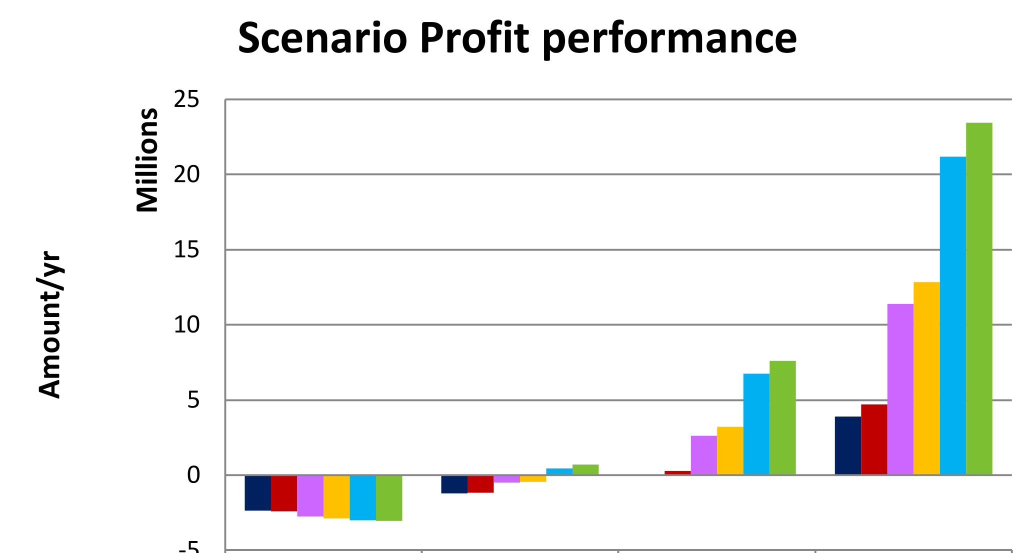


Figure 5.7 Maximum daily trips + 5% tax profit scenario

For the maximum number of trips only the first year running produces negative profit for both scenarios.

5.4 Discussion

5.4.1 Scenario comparison



	1	2	3	4
Min trips	-2351314.81	-1215324.34	-43905.26	3901955.91
Min + tax	-2427413.86	-1160908.23	287105.25	4711262.62
Avearge trips	-2732849.17	-497633.77	2613248.82	11373853.07
Average + tax	-2893112.7	-452813.23	3191407.16	12821771.42
Max trips	-3001509.37	422991.49	6744926.06	21196655.56
Max + tax	-3064058.27	706159.58	7607053.93	23426070.6

Figure 5.8 Net profit increase scenario comparison

Figure 5.8 above gives an outcome of different scenarios simulated. An increase in the daily number of trips with the same number of vehicles and capacity yields an early breakeven point. Showing that transporting more passengers with fewer resources improves operational costs. It also gives an increased profit growth rate as shown by both maximum possible daily trips and maximum possible daily trips coupled with earmarked tax. If earmarked tax and maximum trips are used this would reduce the need for subsidies as the profit growth rate alone can sustain the operations of the system.

5.4.1 Model – Current scenario comparison

a. Fleet size

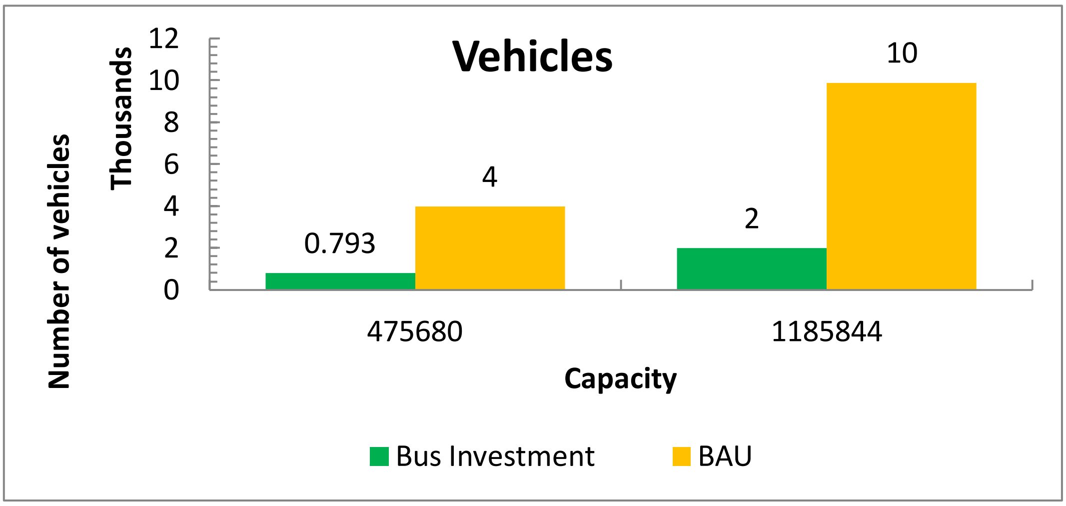


Figure 5.9 Model fleet size comparison with current scenario

Figure 5.9 above shows the results of fleet size comparison between the current scenario and the modelled one. From the results, the modelled simulation reduces the fleet size from almost 10000 to almost 2000 for transportation of the same number of passengers. Hence, it was noted that a reduction in fleet size would result in road vehicle damage and congestion reduction as well as daily trips and fuel consumption reduction as shown by figures 5.10 and 5.11 below respectively.

b. Annual vehicle trips

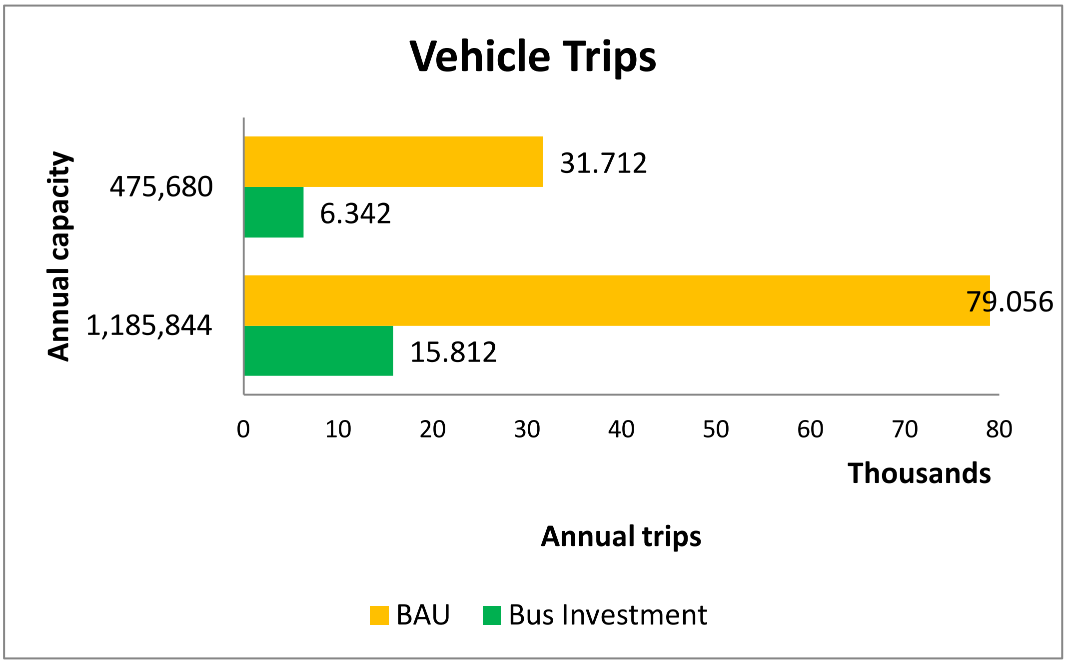


Figure 5.10 Model annual trips comparison with current scenario

c. Fuel consumption

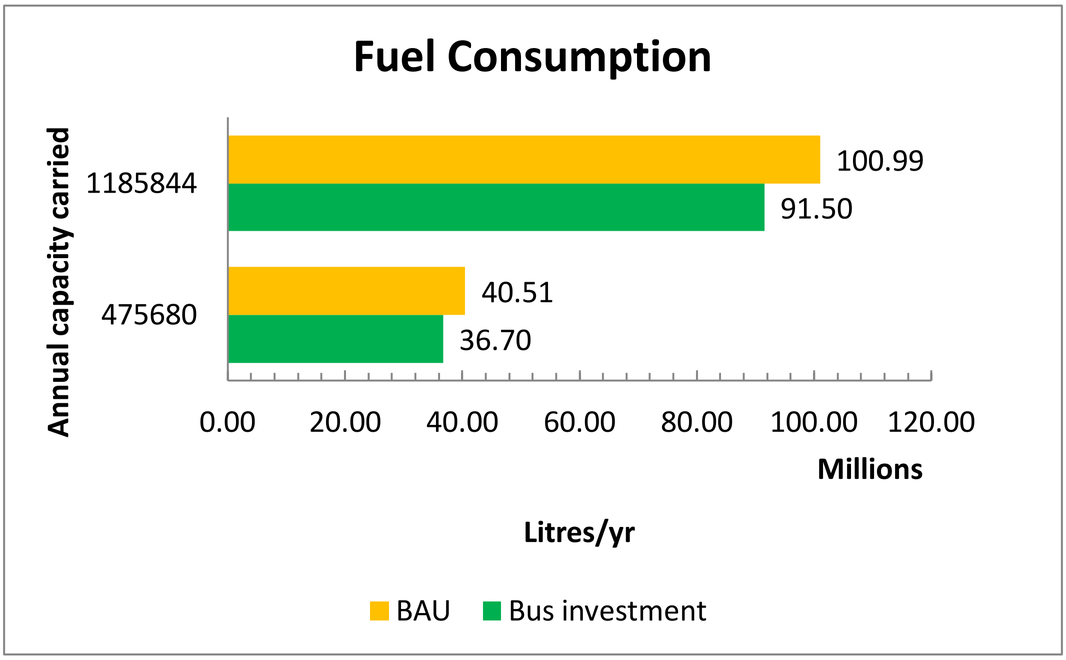
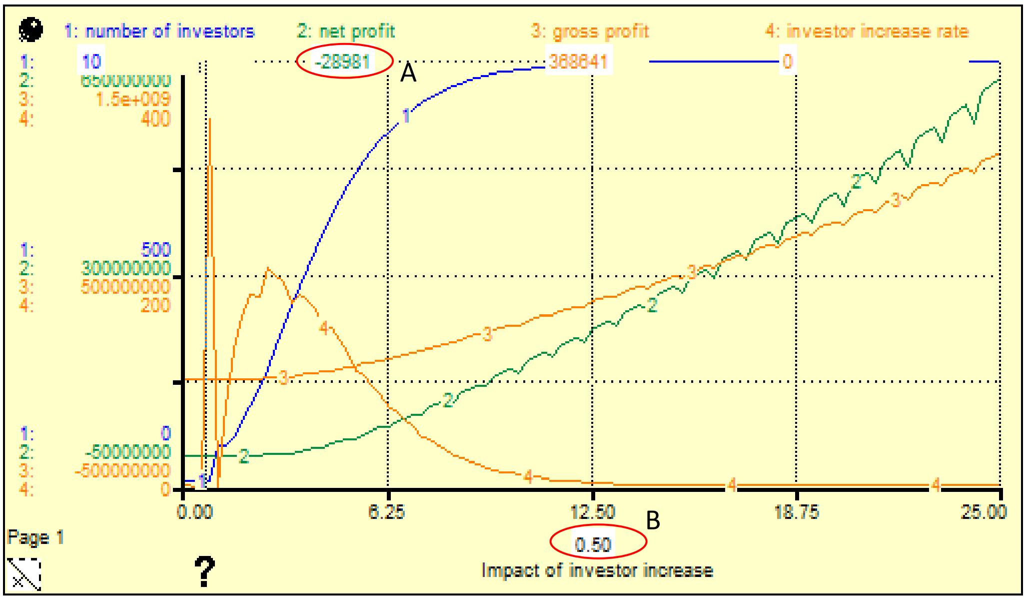
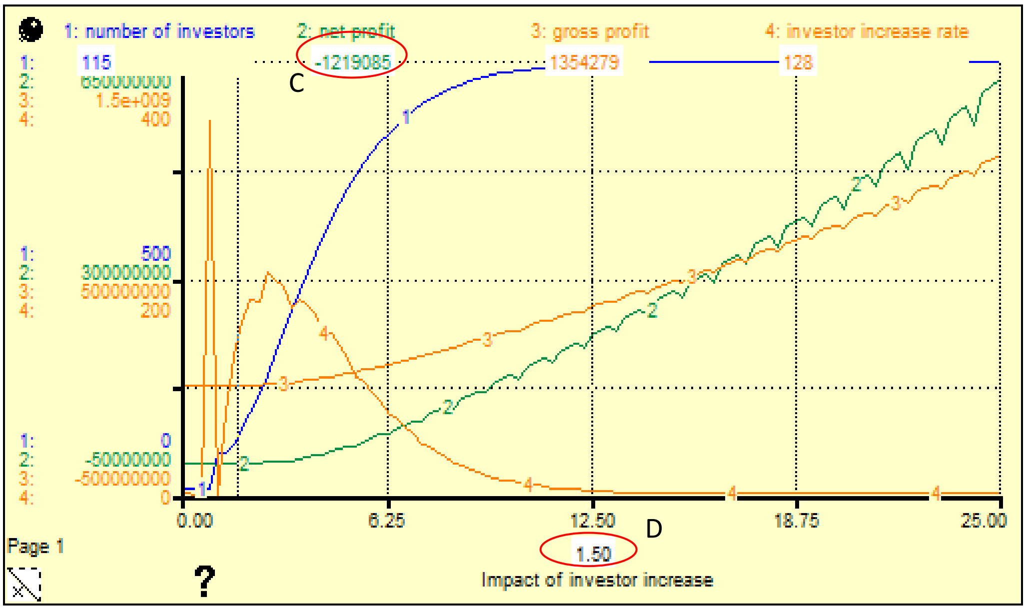


Figure 5.11 Model fuel consumption comparison with current scenario

5.4.3 Investor effect on profit analysis



i. Profit before increase



ii. Profit after increase

Figure 5.12 Effect of total number of investors

Figure 5.12 shows the impact of an exponential increase of investors. Points A, B, C and D indicates the profit values and period before and after increase of the number of investors. Before increase of investor at period shown by point B profit at A is higher than after increase at D shown at period point C. This behaviour indicates that if there is no limit to the number of investors the system may not be able to sustain operations, as more will go towards overhead costs.

5.4.4 Gross profit margin analysis

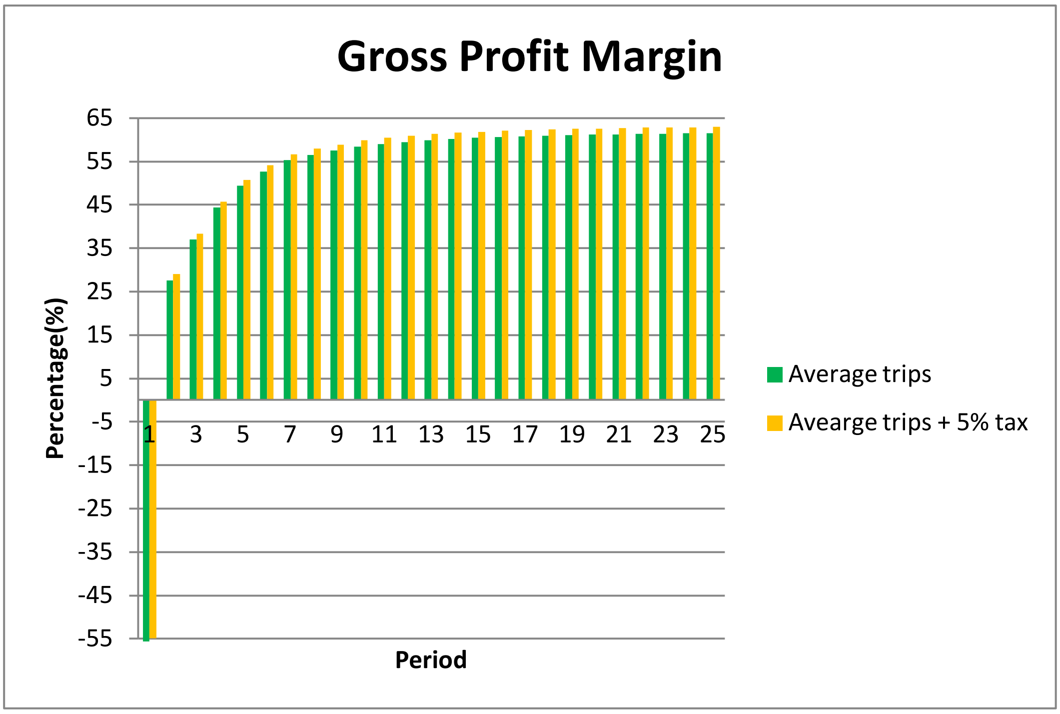


Figure 5.13 Gross profit margin behaviour

Gross profit margin is a measure of profitability by which investors compare to similar companies. It is a metric indication of the financial success and viability of a particular service. Gross profit is the company's profit before overhead, interest and taxes. It is a tool to track efficiency of a business, when increasing it shows business is becoming more efficient. From gross profit margin graph, figure 5.13 above for the first period there a high increase rate of fleet that caused more capital usage than revenue generated through resource acquisition thus, negative gross profit margin. Apart from the first period, gross profit margin trend is a positive increase that shows an increase in system efficiency, which is a good sign that the system operations can be sustained for a longer period, with need of monitoring overheads to get favourable net profits. As the system stabilises or tends to be in equilibrium, the gross profit margin tends to maintain a steady state value.

Looking at the scenarios and comparison made of the formulated bus investment with the current scenario, the aim of the research has been achieved. This was shown by the ability of the bus investment framework model to reduce fleet size, an increasing gross profit margin and an increasing profit. That is the framework model produced is efficient, profitable, have environmental benefits through reduction emissions and affordability will be achieved through fare reduction as profits continue to grow.

Even though there are tangible values in the improvement of the system, the most important thing is the behaviour of the system. It is a guide in decision-making, hence the ability of policy makers to read more and analyse system behaviours is of paramount importance. From the resultant model formulated for the system the dominant behaviour is the exponential growth, thus any decision made must counter that behaviour to balance the system if sustainability is to be achieved. Having maximum possible trips and as few as possible number of investors are the key to successfulness of the system. It advocates for economies of scale where more are transported at a lower cost that allows price elasticity.

CHAPTER 6

6.0 CONLUSION AND RECOMMENDATIONS

6.1 Conclusion

As a result of this research a bus investment model to improve public transport economic sustainability in Harare city was successfully developed. Six scenarios were developed and simulated and the simulation results have shown that all scenarios having the following characteristics:

- ✓ Gross Profit Margin growth trend, gross profit margin measures profitability of the system hence economic sustainability, is achievable.
- ✓ Fleet size reduction for transportation of same number of passengers compared to current scenario.
- ✓ Fuel consumption reduction compared to that of current scenario for same services rendered.
- ✓ Daily trips reduction on the designed system
- ✓ Profitability shown by profit growth trend hence, offering fare flexibility

The System dynamic model can be run and results presented as an initial approach intended to help decision makers in determining the most appropriate actions to be taken to improve chaotic public transportation operations within the cities of Zimbabwe. The above points show operational efficiency of the bus investment system, which does not only reduce non-renewable energy use to serve the future generation, it also has an environmental sustainability bonus package of emission reduction. The sixth scenario producing best results compared to all other scenarios hence, it shows that maximising number of trips with small fleet size is the better way to achieve economic sustainability.

6.2 Recommendations

Since the designed model is a pull method, as a way and means to support the designed framework the government is encouraged to apply push methods that will support the system. These include:

- ✓ Introduction of marked bus lanes, to improve system quality through travelling time.
- ✓ Congestion fee charging as a way to minimise private cars use.
- ✓ Differentiate parking fee for private and public transport.

6.3 Future work

Due to the importance of this topic and its effect on people's lives and future generation, it is has been noted as beneficial to expand this area of research. Having looked at the movable resource, this will become a basis for further improvement of the system's economic sustainability. Public transport system is an integration of both movable and fixed resources as well as a mixture of motorised and non-motorised modes. Using this research as stepping stone areas such infrastructure investment as a way for provision of an integrated motorised and non-motorised together with mass transit modes transport will be the next pot of call that can aid in achievement of sustainable development.

6.4 Limitations

Due the geographical location of the area under study a personal survey or an interview of how the majority feels about policy change, their ideas or views were not taken into consideration hence the main players within the modelled system are the government and investors or public transport operators.

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Biography

Portia Mupfumira is a Harare Institute of Technology staff development fellow, who attained her N.C in Machineshop Engineering 2002 at Harare Institute of Technology in Zimbabwe. She received her B.Tech Honours degree in Industrial and Manufacturing Engineering at the same college in 2009. She was selected to study Masters in Industrial Systems Optimisation under Beasiswa Unggulan Scholarship at Institut Teknologi Sepuluh Nopember in Indonesia in 2012 as part of staff exchange program between the two institutes.

Appendices

Bus Operations

Buses(t) = Buses(t - dt) + (bus_increase_rate - bus_decreasing__rate) * dt
INIT Buses = 5
INFLOWS:
bus_increase_rate = INT(IF(Desired_buses >= 0) AND(capital_investment/bus_cost >= 1) THEN(capital_investment/bus_cost) ELSE 0)
OUTFLOWS:
bus_decreasing__rate = Buses*bus_ageing_rate_fraction
capacity(t) = capacity(t - dt) + (total_daily_capacity) * dt
INIT capacity = INT(0)
INFLOWS:
total_daily_capacity = INT(IF(Buses = 0) THEN(0) ELSE(Buses*capacity_per_bus*daily_trips))
annual_operational_cost = fuel_cost+annual_wages+scheduled_maintenance_cost
annual_population_percentage = 0.4
annual_revenue = (bus_fare*total_daily_capacity*365)
annual_travelled_bus_distance = distance_travelled*daily_trips*365
annual_wages = Buses*wages
bus_ageing_rate_fraction = 0.08333
bus_cost = 90000
bus_fare = price_per_km*distance_travelled
capacity_per_bus = 75
daily_trips = 10
demand = Harare_population*annual_population_percentage
Desired_buses = ((demand-total_daily_capacity)/total_daily_capacity)/time_to_purchase
Fuel_consumption = annual_travelled_bus_distance*Fuel_consumption_rate*Buses
Fuel_consumption_rate = 45.3/100
fuel_cost = Fuel_consumption*fuel_price
fuel_price = 1.46
income_tax = tax_rate*annual_revenue
major_service = PULSE(1500,2/12,1)
minor_service = PULSE(300,(3/12),2)
price_per_km = 0.03
resource_cost = bus_cost*bus_increase_rate
scheduled_maintenance_cost = Buses*(minor_service+major_service)
tax_rate = 0.25
time_to_purchase = 2/12
wages = (450+550)*12
distance_travelled = GRAPH(TIME)
(0.00, 0.00), (0.0526, 5.00), (0.105, 7.00), (0.158, 10.0), (0.211, 12.0), (0.263, 15.0), (0.316, 17.0), (0.368, 19.0), (0.421, 20.0), (0.474, 21.0), (0.526, 22.0), (0.579, 23.0), (0.632, 24.0), (0.684, 25.0), (0.737, 27.0), (0.789, 29.0), (0.842, 31.0), (0.895, 32.0), (0.947, 33.0), (1, 35.0)

GDP

Harare_GDP(t) = Harare_GDP(t - dt) + (change_rate) * dt
INIT Harare_GDP = 9.802E9*0.4
INFLOWS:
change_rate = capital_investment+annual_operational_cost+transport_expenditure
GDP_per_capita = Harare_GDP/Harare_population
road_damage_factor_per_bus = 2.906
road_vehicle_damage = Buses*daily_trips*road_damage_factor_per_bus*365
transport_expenditure = total_daily_capacity*bus_fare*365

Investment

capital_investment(t) = capital_investment(t - dt) + (inflow_rate + investing - depreciation) * dt
INIT capital_investment = 500000
INFLOWS:
inflow_rate = investment_amount*investor_increase_rate
investing = MIN(net_profit,capital_investment*invested_profit_fraction)
OUTFLOWS:
depreciation = capital_investment/life_time
Future_Value(t) = Future_Value(t - dt) + (Change_in_FV) * dt
INIT Future_Value = 0
INFLOWS:
Change_in_FV = FV(Interest_rate,period,Periodic_payment,Present_Value)
Present_Value(t) = Present_Value(t - dt) + (Change_in_PV) * dt
INIT Present_Value = 0
INFLOWS:
Change_in_PV = PV(Interest_rate,period,Periodic_payment,Future_Value)
gross_profit = annual_revenue-(annual_operational_cost+resource_cost)
gross_profit_margin = IF(annual_revenue = 0) THEN(0) ELSE(gross_profit/annual_revenue)*100
Interest_rate = 0.15
invested_profit_fraction = 0.1
life_time = 25
net_profit = (gross_profit+Periodic_payment-income_tax)
net_profit_margin = IF(annual_revenue = 0) THEN(0) ELSE(net_profit/annual_revenue)*100
period = 25
Periodic_payment = PMT(Interest_rate,period,capital_investment,0)
ROR = (((Future_Value/capital_investment)^(1/period))-1)*100
investment_amount = GRAPH(TIME)
(0.00, 30000), (1.00, 35000), (2.00, 20000), (3.00, 30000), (4.00, 17000), (5.00, 30000), (6.00, 5000), (7.00, 20000), (8.00, 35000), (9.00, 9000), (10.0, 15000), (11.0, 25000), (12.0, 10000)

Investor

number_of_investors(t) = number_of_investors(t - dt) + (investor_increase_rate - quit_rate) * dt
INIT number_of_investors = 10
INFLOWS:
investor_increase_rate = attractiveness*available_opportunities
OUTFLOWS:
quit_rate = number_of_investors*quit_rate_fraction
Annual_dividend_per_investor = Periodic_payment/number_of_investors
attractiveness =
(((ROR*ROR_weight)+(gross_profit_margin*Gross_profit_margin_weight))/(Gross_profit_margin_weight+ROR_weight))*(1/100)
available_opportunities = Investor_limitation-number_of_investors
Investor_limitation = STEP(1000,(8/12))
quit_rate_fraction = 0.05
Gross_profit_margin_weight = GRAPH(gross_profit_margin)
(0.001, 0.01), (10.0, 0.04), (20.0, 0.1), (30.0, 0.16), (40.0, 0.25), (50.0, 0.38), (60.0, 0.59), (70.0, 0.79), (80.0, 0.92), (90.0, 1.00), (100.0, 1.00)
ROR_weight = GRAPH(ROR)
(0.001, 0.001), (10.0, 0.06), (20.0, 0.14), (30.0, 0.33), (40.0, 0.53), (50.0, 0.68), (60.0, 0.81), (70.0, 0.9), (80.0, 0.97), (90.0, 0.99), (100.0, 1.00)

Population

Harare_population(t) = Harare_population(t - dt) + (ppn_increase_rate - ppn_decrease_rate) * dt

INIT Harare_population = 2123132

INFLOWS:

ppn_increase_rate = Harare_population*(growth_rate_fraction+in_migration_fraction)

OUTFLOWS:

ppn_decrease_rate = Harare_population*(death_rate_fraction+out_migration_fraction)

death_rate_fraction = 0.0077

growth_rate_fraction = 0.033

in_migration_fraction = 0.49

out_migration_fraction = 0.39