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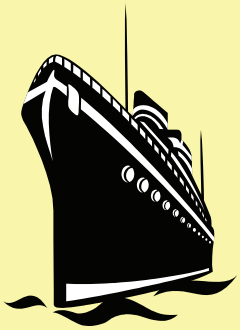

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# Editorial Note

It is with great pleasure that we introduce to you the first issue of our Journal – The Journal of Logistics, Management and Engineering Sciences (JLMES). It has indeed taken quite sometime to have our dreams come true, and I take this opportunity to wholeheartedly congratulate all those who have struggled with us to ensure that our efforts bear fruits by bringing forth their articles for publication, thus making it possible to have the first issue of JLMES out.

As we joyously mark the release of the first issue of JLMES, we would like to draw the attention of our esteemed readers to the fact that the articles which appear in this journal are the ones that were successfully reviewed by peer reviewers. It is our hope, therefore, that each of the article will have something to add to the knowledge of the readers and even give answers to some difficult questions related to Logistics, Management and Engineering issues.

In the next issue, the Editorial Board of JLMES welcomes as many papers as possible on areas related to Logistics and Supply Chain Management, Engineering Sciences, Safety and Environment, Traffic Management, Resources Management and Entrepreneurship, ICT Development and the like.

Once again, we thank everyone who has published with JLMES, and encourage them and many others to bring more papers for future publications.

Cyprian D. Mbowe
Editor In-Chief

# Analysis of Distribution System of Soft Drinks Producers and User's Satisfaction: A Case of Coca Cola Kwanza Ltd

**[1]Daud G. Daudi and [2]Dr. Simon S. Lushakuzi**

[1]Assistant Lecturer, Department of Computing and Communication Technology (CCT), National Institute of Transport (NIT), P. O. Box 705, Dar es Salaam, Tanzania
Email: mambodgd@yahoo.com

[2]Lecturer, Department of Logistics and Transport Studies (DLTS), National Institute of Transport (NIT), P. O. Box 705, Dar es Salaam, Tanzania
Email: slushakuzi@gmail.com

**Abstract**

*This study examines the application of transportation models by soft drink producers so as to meet the customers' demands. Judgmental sampling was used to obtain 10 respondents from each of Dar es Salaam districts making a total sample of 30 respondents. The findings revealed that Coca Cola Kwanza Company has deployed the usage of the System Application and Products (SAP) software that is used to integrate the whole supply chain. This application has appeared to be a useful tool in solving transportation problems. Despite the fact that there are many transportation models, Coca Cola Kwanza uses the Manual Distribution Centers (MDC's) model where the company transports the consignments to the MDC's then MDC's distribute the products further to the stockists.*

## INTRODUCTION

Designing a transportation system is always a challenging task as it should aim at dispatching as many items as possible at the minimum transportation cost. Distribution is done though various modes of transport that should consider the fact that costs are minimized while trying to maximize profit at the same time satisfying customers. Distribution decision is primarily concerned with the supply chain's front-end or channels of distribution that are designed to move the products (goods and services) from the hands of the company to those of the customers. Ordering, handling and shipping, storage, display, promotion, selling and information feedback are the activities involved in the distribution channel. Relationship between channel members must be strong with each member understanding and trusting others on who they depend for product distribution to flow smoothly (Christ, 2009).

Minimizing total transport cost could be arrived at by balancing the distribution centre demands with suppliers' capacities in the existing transportation networks. Transportation model is one of the methods which can be used to minimized total transport costs. The transportation models is primarily concerned with the optimal way in which a product produced at different factories or plants (Supply origin) can be transported to a number of warehouses (Demand destinations). The model application aims at determining the number of units to be transported from each supply to each destination such that total transport cost or total units transport distance is minimized (Mangan *et al,* 2008).

The delivery of enhanced customer satisfaction and economic value through synchronized management of the flow of physical goods and associated information from sourcing to consumption (Lalonde, 1998). Supply chain network analysis and design helps to ensure

companies use best modes of transportation by using best routes, right mix of intermediate assets example storage and inventory to get products where they are needed to meet business goals. Delivering products to customers on a regular basis, chances are that transportation costs will increase. The use of efficient set of routes can be difficult and consuming, but by doing so will improve customer satisfaction and minimize transportation costs. Every time distribution team is working to ensure that product is delivered on time at the lowest cost (Kosansky, 2003).

The services of intermediaries reduce the number of contacts, or exchanges, between producers and buyers, thereby increasing efficiency; especially across longer distances. Intermediaries evolve in the process of exchange because they can increase the efficiency of the process by creating time, place and possession utility. It enables the adjustment of the discrepancy of assortment by performing the functions of sorting and assorting and facilitating the searching process by consumers (Pride and Fevrel, 2000).

Transportation models aim at providing assistance to the top management in ascertaining how many unit of a particular product should be transported from each supply origin to each demand destinations to that the total prevailing demand for the company's product is satisfied, while at the same time the total transportation costs are minimized. Logistics costs now represent a larger percentage of sales. They now account to more than 10% of sales revenues for most companies. Consequently, logistics costs are beginning to erode or at least counter balance many of the economic advantages. Working capital can be reduced by increasing the opportunity for collaboration with carriers and by improving your shipment forecast. Well mapped paths to transformation reduce costs and time involve in the journey (Taylor, 2006).
Logistics costs come from various aspects including Transportation, Warehousing, Material handling, Ordering costs and Inventory carrying costs. These logistics costs results into reducing the profit margins (Goldsby et al, 2005). Transportation costs being one of the types of costs needs to be minimized in planning distribution systems for the soft drinks using various transportation model.

## STUDY OBJECTIVE

### The main objective

Main objective of this study was to analyze the distribution system of soft drinks producers and user's satisfaction at Coca Cola Kwanza Ltd.

### Specific objective

(i) To assess the distribution model used by Coca Cola Kwanza Ltd
(ii) To analyze the relationship between the distribution system used by Coca Cola Kwanza Ltd and user's satisfaction

## MATERIAL

### Distribution channels

A channel of distribution comprises a set of institutions, which performs the entire activities utilized to move a product and its title from the production point to the consumption point. It can also be defined as a sequence of marketing organizations that directs a product from the producer to the final consumer (Kotler, 1997 ; Ashfold 1982). Distribution channel as a part of Supply Chain Management (SCM) can be categorized into three main flows including product flows, information flows and finance flows. Product flows include goods movement from suppliers to customers where as the flow of information is involved with the transmission of orders and status updating of delivery as financial flows consists of credit terms, payment schedule and title ownership arrangements.

### The role of distribution channels

The importance of distribution channels for producers/manufacturers lies in the fact that traders need to include their products into their stores' assortment. Therefore, producers/ manufacturers observe certain types of trading companies, i.e. trading business units and use them in the development and innovation of their channels (Kotler, 2001).

The importance of distribution channels for

economy can especially be seen in the system development and channel integration. Therefore, vertical marketing systems in the USA, for instance, cover 70 to 80% of consumer goods market (Kotler and Keller, 2008). Moreover, vertical marketing systems are especially important from the standpoint of foreign trade, since the introduction of large retail chains into a certain country immediately provides ample opportunity and the need for development of the whole chains, regardless of the fact which producers/manufacturers (domestic or foreign) will become members of such channels.

The importance of distribution channels for national economy is reflected in the activities of its business operators (whether they are traders or producers, or service providers) on any market, domestic or foreign. The preconditions for expanding business activities lie in successful strategies for development, based on modern knowledge management, IT management, human resources management and others. This is how Innovative business structures develop, i.e. value creation chains.

The aforementioned emphasises that the importance of distribution channels should be observed not only as the share of commerce in neither GDP nor employment numbers, but also as the share (component) of value chains in the function of consumption, production and competition development.

In this sense, the ownership of distribution channels can be of vital importance for the development of production in the given country. On the other hand, innovative types of channels, i.e. trading business units provide means for avoiding traditional structures and offer new opportunities for the growth of certain companies, i.e. economic sectors.

Therefore, the importance of distribution channels should be estimated according to the share of such types and business models that are based on contemporary IT.

Channel of distribution is seen as a way through which goods and services move from producers to the final consumer or end user. Every channel of distribution begins with a producer and ends with consumer or end user (Ashfold, 1982)

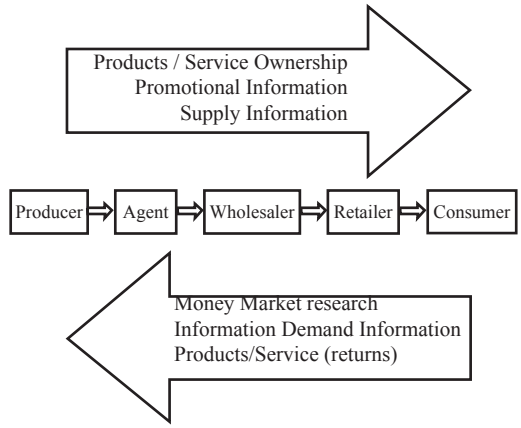



**Figure 1: Supply chain distribution channel**
**Source:** *Pride& Ferrel (2000) Marketing Concepts and Strategies Houghton Mifflin Company [Redrawn]*

**Types of distribution channels**

Channels of distribution are of two types, direct and indirect. The indirect channel is viewed as not having middle person where links the producer and the consumer where as indirect channel differ in terms of the number of levels a product would move before it reached the ultimate consumers.

**Direct channel**

Zero Channel Level: This is the shortest, the most direct and simplest channel involving direct sale of goods and services by producers to final consumer. In this channel level, no middle person or intermediary is present.

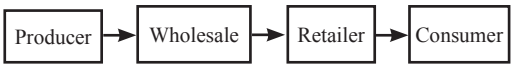

**Indirect channels**

This consists of one level channel, two level channels and three level channels:

*One level channel* is only one middle person or intermediary found. This will be typically a retailer. Under this arrangement a manufacturer sells to one or more retailers who in turn sell to

ultimate consumers.


*Two level channels* is a channel having two intermediaries, wholesaler and retailer. This type of channel is suitable where a producer has limited finance and a narrow product line or where the wholesaler is specialized and provides strong promotional support. Many small producers and retailers find this channel to be the most convenient for selling those goods such as cigarettes, sweets, ground nuts, bottled water, ice cream etc.




*Three level channels* This is the longest of all channels of distribution in which contains three intermediaries who relieves a producer or a manufacturer a role of distribution and other related challenges. The producer hands over his entire output to the selling agent who distributes it among a few wholesalers; each wholesaler sells to a number of retailers who in turn sell to ultimate consumers.


**Transportation System and transportation problems techniques**

The transportation system is the physical link connecting a company's customers, raw material suppliers, plants, warehouses and channel members at the fixed point in a logistic supply chain. The fixed points in a logistic system are where some activity temporarily halts the flow of goods in the logistic pipeline. The transportation companies utilized to connect these facilities affect not only the transportation costs but also the operating costs at these facilities (Coyle *et al,* 2007). Knowledge of transportation system is fundamental to the efficient and economical operation of a company's logistic function. Transportation is a physical thread connecting the company's geographical dispersed operations. More specifically, transportation adds value to the company by creating time and place utility; the value added is the physical movement of goods to the place desired and at the time desired.

Transportation includes infrastructure, vehicles, administration and users and can be viewed in various aspects including engineering, economics and social issues. A transportation system can be narrowly as a single driver/vehicle with its second-by-second interactions with the road and other vehicles (Myer, 2004).

Transportation models are a formal description of the relationships between the transportation system components and their operations. Knowledge of these relationships allows for estimating or predicting unknown quantities (outputs), from quantities that are known (inputs). A transportation model is a simplification of transportation reality.

In general transportation models are models of transportation problems used to determine the most efficient schedule for shipping quantities of a given product or products from given sources to given destinations at the minimum cost or maximum profit (Baradyana and Ame, 2005). For transportation model to be constructed there should be several conditions to be observed:-

i. There should exist several known source of a given product or products,
ii. There should exist several known destinations which require the given product or products,
iii. The amount of the product or products available at every source should either be known or can be found.
iv. The amount of the product or products required at every destination should either be known or can be found.

When a transportation model has been constructed, techniques for solving them can be used like the application of the simplex method or other simple techniques that generates efficient shipping schedules. Simplex Method is an algorithmic (repetitive) procedure which progresses through a series of feasible solutions (transportation schedules) which

are successively improved until an optimal transportation schedule is obtained. It consists of the following procedure:-

i. Finding an initial solution which is feasible from the point of availabilities and requirements of resources.
ii. Examining the solution for optimality (examining whether an improved transportation schedule will lower cost is possible).
iii. Repeating step (ii) until no further improvement is feasible (Srivastava *et al* 1989).

In order to obtain an optimal result for transportation problem two main steps are involved which includes finding the first initial basic feasible solution by using methods like North West Corner (NWC), Minimum Cost Method (MCM) and Vogel Approximation Method (VAM) followed by finding the optimum solution that can be obtained by any of the two methods including Modified Distribution (MODI) or Stepping Stone Method.

**Methods for finding initial basic feasible solution**

*North West Corner (NWC)*

The NWCM is a quick solution to find a feasible initial solution to the transportation problem. It indicates that the quantities transported from the factories (origins) to the warehouse (destinations) must begin in the upper left hand (North West) corner. When this route is fully used i.e. the factory capacity or warehouse requirements are fully utilized depending on which number is lower, the remainder of either the factory capacity or warehouse requirements

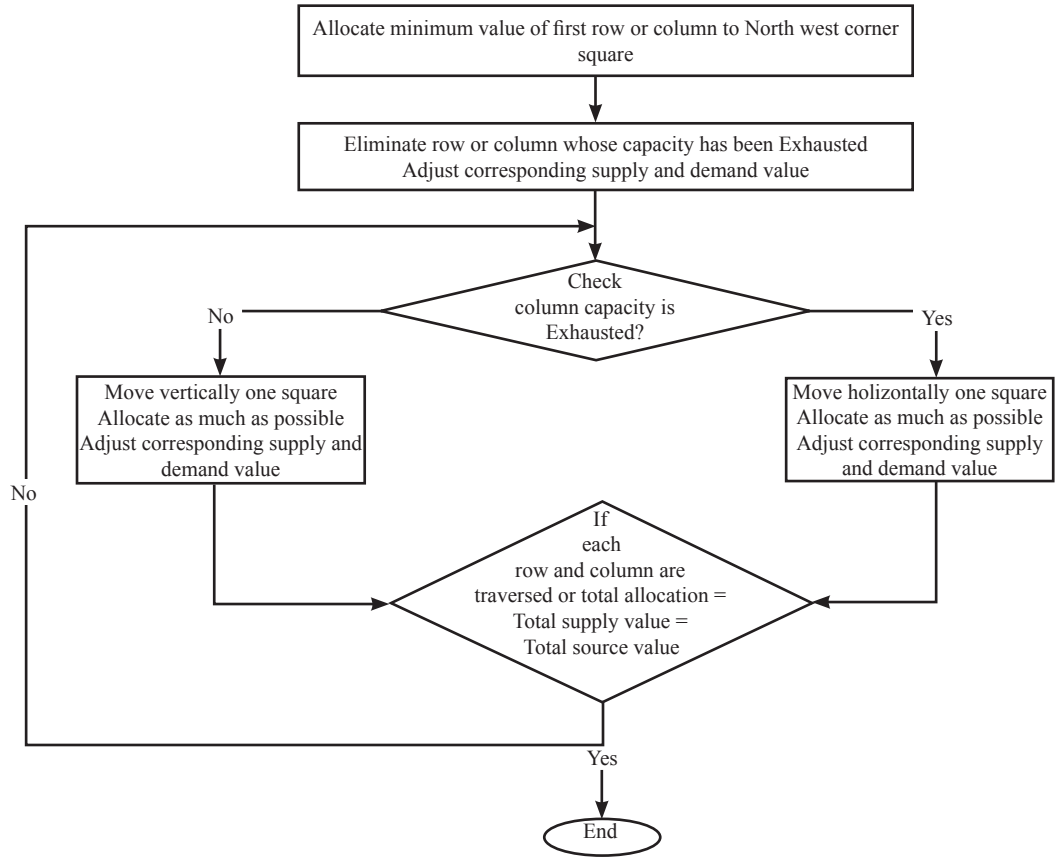



**Figure 2: Flow chart illustration NWCM**

**Source:** *Pride, William M., & Ferrel, O.C. (2000) Marketing Concepts and Strategies Houghton Mifflin Company [Redrawn]*

is then assigned to the new rows or columns until it is fully used. This method ignores any cost information of the transportation problem.

**Minimum cost method/Least cost method (MCM/LCM):**

LCM is very similar to NWCM in that it selects one cell, saturates it and deletes a row or column. This method tries to match demand and supply with some consideration of costs.

The only difference between the least-cost method and the northwest-corner method is in the choice of entering variables. Here, the strategy is to always select the cell with the smallest cost value among all remaining cells as the entering cell. This method begins by the minimum cost from the rows and columns. In this cell a maximum allocation is made to serve the demand and the supply to the cell. The demands and supply are then decreased by the amount allocated to the previously served cell then this is repeated to other cells in rows and columns until the demands and supply are exhausted.

**Vogel approximation method (VAM):**

This approach had been developed for finding the initial feasible solution to the transportation problem. Often it produces an optimal solution to the problem in just one iteration. Although VAM does not guarantee an optimal solution it invariably provides a very good initial solution with comparatively less effort and computation (Srivastava *et al* 1989).

**Methods for finding optimal solution**

There are two common methods for finding optimal solution which are Modified Distribution (MODI) method and Stepping Stone method. Some heuristics are generated to getting better performance. The most efficient method for solving Transportation Problem arises by coupling a primal transportation algorithm with a modified row minimum start rule and a modified row first negative evaluator rule (Glover and Willems, 1974). Transportation Simplex Method and Genetic Algorithms are compared in terms of accuracy and speed when a large-scale problem is being solved. The solution of a real world problem to efficiently transport multiple commodities from multiple

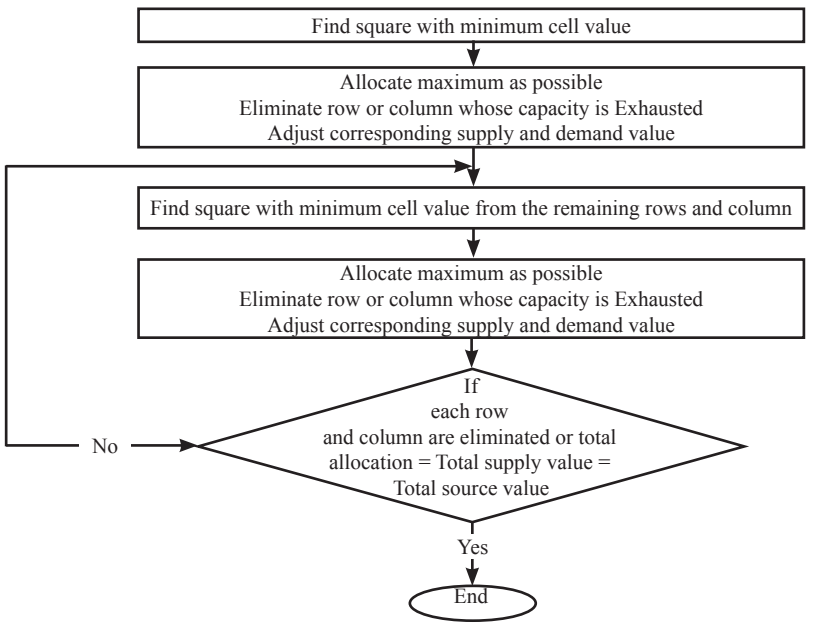



**Figure 3: Flow chart illustration MCM/LCM**

**Source:** *Pride, William M., & Ferrel, O.C. (2000) Marketing Concepts and Strategies Houghton Mifflin Company [Redrawn]*

sources to multiple different destinations using a finite fleet of heterogeneous vehicles in the smallest number of discrete time periods gives improvement by backward decomposition (Poh *et al* 2005).

**Customer satisfaction**

Customer satisfaction is the most widely accepted model, in which satisfaction is a function of disconfirmation, which in turn is a function of both expectations and performance (Oliver, 1997). The disconfirmation paradigm in process theory provides the grounding for the vast majority of satisfaction studies and encompasses four constructs expectations, performance, disconfirmation and satisfaction (Cooper *et. al.,* 1989).

This model suggests that the effects of expectations are primarily through disconfirmation, but they also have found a direct effect through perceived performance on satisfaction (Spreng and Mackoy, 1996). Swan and Combs (1976) were among the first to argue that satisfaction is associated with performance that fulfils expectations, while dissatisfaction occurs when performance falls below expectations. In addition, Poisz and Von Grumbkow (1988) view satisfaction as discrepancy between the observed and the desired. This is consistent with value-percept disparity theory (Westbrook and Reilly, 1983) which was developed in response to the problem that customers could be satisfied by aspects for which expectations may never exist (Yi, 1990). The value-percept theory views satisfaction as an emotional response triggered by a cognitive-evaluative process (Cooper *et. al.* 1989). In other words, it is the comparison of the "object" to one's values rather than an expectation.

Recent literature adds to this perspective in two ways. First, although traditional model implicitly assumes that customer satisfaction is essentially the result of cognitive processes, new conceptual developments suggest that effective processes may also contribute substantially to the explanation and prediction of customer satisfaction (Fornell, 1992; Westbrook & Reilly, 1983). Secondly, satisfaction is viewed as a judgment based on the cumulative experience made with a certain product or service rather than a transaction-specific phenomenon (Wilton and Nicosia, 1986).

The general agreement bases on a view that satisfaction is a person's feelings of pleasure or disappointment resulting from comparing a product's perceived performance (or outcome) in relation to a customer's expectations (Kotler, 2003). Based on this review, customer satisfaction is defined as the result of cognitive and effective evaluation, where standard is compared to the actually perceived performance. If the perceived performance is less than expected, the customer would be dissatisfied. On the other hand, if the perceived performance exceeds expectations, the customer would be satisfied. Otherwise, if the perceived expectations met with performance, customers are in indifferent or neutral stage. Gustafsson *et al* (2005) defines customer satisfaction as a customer's overall evaluation of the performance of an offering to date. This overall satisfaction has a strong positive effect on customer loyalty intention across a wide range of product and service categories.

The only way for the organisation to keep a high level of customer satisfaction and still operate efficiently, is to master the art of optimum level performance which ensures that customers' expectation are consistently met. (Parasuraman *et al,*1990) describes the problem as the "extent of discrepancy between customers' expectation or desires, and their perceptions of the quality of service". The means by which customer expectations are generated includes word-of-mouth communication, personal needs, experience and external communications that influence customers' expectations.

**METHODOLOGY**

The study was conducted in three districts of Dar es Salaam region, i.e. Kinondoni, Temeke and Ilala. The purpose was to examine the usage of various transportation models used in the distribution systems. The targeted group included the wholesalers/agents and retailers

of the Coca Cola Kwanza Company (CCK). By using the Judgmental selection method, a sample size of 10 customers was selected in each of the above mentioned districts resulting into a total sample size of 30. The information was gathered through questionnaires and interviews. The questionnaires were used to these customers whereas the interview with the guiding checklist was conducted to the CCK distribution manager. In the sample size of 30 questionnaires taken to customers, 24 had response and were used for the analysis. The rest of the questionnaires (6), it was difficult to meet with the responsible personnel and thus unable to get their response. By the aid of the SPSS software the data was analyzed.

## STUDY FINDINGS

The findings were based on the distribution system which is applied by the Coca Cola Kwanza Company Ltd to supply and meeting customers' demand at various locations at minimal transport costs. It was found that in the distribution channel there are two channels, one being the direct channel (key clients) and indirect channel (Manual Distribution Centers). The factory serves key clients and MDC's through the following distribution system.

### Coca Cola Kwanza Ltd distribution model

Coca Cola Kwanza Company Ltd has a system of making their products available to customers in even the most remote locations. They have utilized a wide range of innovative distribution methods to accomplish this. Coca Cola Kwanza Company Ltd has adopted an innovative approach known as Manual Distribution Centers (MDC's). In 2008 there were 152 MDC's in Dar es Salaam and 412 in Tanzania as a whole accounting for the 93% of the Coca cola system sales national wide. Coca Cola Kwanza Company Ltd now relies on the MDC's models as its core distribution model in Tanzania. It has created new small businesses, new jobs and increased skills levels and provides a powerful platform from which they offer entrepreneurial opportunities that has opened door to jobs and wealth creation. MDC's are managed by third party distributers. In Dar es Salaam there are about 200 MDC's by now that sell Coca cola product exclusively instead of trying to serve thousands of small retail outlets with small drop sizes. The MDC's owners are actively supported and managed by the bottler who helps each owner establish their operations, including designing routes and methods of delivery and determining the frequency of delivery service required to maintain stock levels.

In 2004, the Coca Cola Kwanza Company Ltd introduced the SAP application software (ERP software) used in various decision making in the company including demand forecasting, inventory management production and financial application that is concerned with improved credit and collection management. When the orders are received from the MDC's the information is entered into the system where they are scanned and demands allocated. These orders/demands are then dispatched to the MDC's towards reaching the final customers. Key clients like supermarkets, hotels, universities and other institutions are served directly from the factory. Factory has sales persons whose task is to collect and establish demands to be served for the key clients. This software is deployed in sourcing the raw materials to the Distribution of finished final products (soft drinks). This application software is essential in allocating the distribution demands at various points. This is possible since the demands/capacities for various points are known.

Coca Cola Kwanza Company Ltd has established routes for its markets including key clients and the MDC's by grouping them according to their locations. These MDC's are served as per orders following the routes established by Coca Cola Kwanza Company Ltd. Orders are served starting with the nearby customers and ending with the customers who are further situated or otherwise sometimes orders are served depending on the volumes starting with the large volumes. This process where the Coca Cola Kwanza Company Ltd serves the MDC's and assisting them in their operations to meet the end customers (stockists) is regarded a forward integration. Using this forward integration

Coca Cola Kwanza Company Ltd pays for the transportation costs for the MCD's distributions i.e. stockists/Retailers. However, the price of the beverages is determined and fixed by the company.

**MDC's distribution model**

It was found out that the majority of them (79.2%) were MDC's and 20.8% were key clients (Retailers). We have found that, all MDC's (100%) do not use the renowned transportation models in their distribution. They deliver as per orders which are served as they are received from various stockists and independent clients. MDC's delivers to their buyers at their own costs if the order is more than 50 crates where as when the order is of less than 50 crates the buyers will incur the cost or will have to pick the order at the MDC's.

**Table 1: Category in distribution**

| S/N | Players in Distribution Channel | Frequency | Percent |
|---|---|---|---|
| 1 | Agent | 16 | 16.7 |
| 2 | Wholesaler | 60 | 62.5 |
| 3 | Retailer | 20 | 20.8 |
| | **Total** | **96** | **100.0** |

**Source:** *Field data-2012*

Table 1 shows that the majority 60 (62.5%) of Coca Cola Kwanza Company Ltd distribution players were wholesaler, 20(20.8%) were retailers and 16(16.7%) were agents. This result reveals that Coca Cola Kwanza Company Ltd applies two level channels distribution system having intermediaries, wholesaler and retailers.

**Problems facing the MDC's**

The problem facing the manual distribution centers Coca Cola Kwanza Company Ltd includes the followings:

**Difficulty in reaching customers (stockist):**

This problem is mainly caused by the fact that customers are located into various points most of which are difficult to be reached or sometimes impassable by vehicles. To meet the customers in these situations man power is needed that proves to be costly and hence reduces the returns.

a) **Deliveries not according to the specifications:**
   This is a common problem that happens when the delivered consignments from the Coca Cola Kwanza Company Ltd does not conform to the specifications of the MDC's.
b) **Lack of reliable storage facilities:**
   MDC's are facing a challenge of not having proper storage facilities with security where the consignments can be safely stored pending forwarding them to the stockiest.
c) **Deliveries not according to the time:**
   This is a problem that happens when the delivered consignments from the Coca Cola Kwanza Company Ltd does not arrive on the expected schedule of the MDC's. This can be caused by problems like delays of unloading at a preceding node, jams on the route towards the MDC's.

**The distribution system used by Coca Cola Kwanza Company Ltd and user's satisfaction**

The MDC's model helps in increasing sales by reaching small scale retail outlets located in densely populated urban areas where by trucks delivery is not effective or efficient and outlets demand are smaller with more frequent deliveries of products. It assists in reducing the transportation costs through delivering in bulky, less frequently as per the orders. Also MDC's brings manpower into the distribution channels (MDC's personnel) who are not direct employees of the Coca Cola Kwanza Company Ltd but yet keen into making sure that products are reaching the final consumers while minimizing transportation costs. However, there is a disadvantage observed on MDC's as the application of them widens the gap between customers at the lower end of the supply chain with the producer and so minimizes the information flow in the chain

**Problems facing the Coca Cola Kwanza Company Ltd distribution system**

The problem facing Coca Cola Kwanza Company

Ltd distribution systems were identified as:

(i) *Low truck turn-around:* This is the ability of a truck to make as many trips as possible. Due to lack of proper facilities at MDC's like empty crates, man power and forklifts, unloading takes too much time and unpredictable durations.

(ii) *Pilling up transportation costs:* These are costs adding up in a course of the situations whereby the salespersons from Coca Cola Kwanza Company Ltd try to meet their targets; by forcing orders to MDC's. As a result when the consignment is delivered while the MDC's do not have the capacity to accommodate the orders and forced to be returned back to the Manufacturer hence increases in transportation costs. All these problems lead into the failure of meeting sales targets.

## CONCLUSION

As per the study it was found that Coca Cola Kwanza is not using the discussed transportation models that are based on the manual application of the transportation model. It is focusing on MDC's model in distributing its products. With this focus it is thus put emphasis on vehicle routing techniques in that they have established routes towards MDC's. Vehicles leave the depot; serve nodes in the network and on completion of their routes they return to the depot of the Coca Cola Kwanza Company Ltd. Every node is described by a certain demand i.e. the amount to be delivered to the nodes is known. Distances from the Coca Cola Kwanza Company Ltd to the nodes (MDC's), capacities of the vehicles providing services and coordinates are known. They have also assisted the MDC's designing routes and methods of delivery to their clients (stockists).

It is known that transportation models are aiming at minimizing shipping costs from the warehouses to the outlets, determining lowest cost locations to the warehouses and, determining minimum costs of production. The model deployed by Coca Cola Kwanza Company Ltd of using the MDC's model takes care of the minimization of transportation costs that has a direct impact up to the MDC's. From the MDC's to the final stockists (consumers) it has proved to be impractical to use the transportation models discussed in the literature. This is due to many factors including their position in the Supply chain, facilities available like bicycles, pushcarts, manual man power, motor bikes, pick ups and other possible means of manual transportation.

## RECOMMENDATIONS

From the study it is recommended that the MDC's operators be sensitized on how to apply the transportation models in planning their routes. This can be done by having a procedure of making sure orders are made a day before delivery so that the transportation routing plan can be sought to minimize transportation cost for any kind of transportation facilities being used.

Since the Coca Cola Kwanza Company Ltd usage of MDC's has proved an important tool for transportation cost reduction, the Company should invest in facilitating on facilities at the MDC's centers which will as a result increase efficiency and in turn assist in the mission of the company of reducing further transportation costs, increase revenues, increase truck turn around and hence bigger profits margins. The Coca Cola Kwanza Company Ltd should have programs to bridge the gap existing between the final customers and the company. This can be through having salesmen making regular surveys and visits so as to obtain and learn various problems facing their customers, knowing their tastes and preferences.

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**LIST OF ABBREVIATIONS**

| | |
|---|---|
| CCK | Coca Cola Kwanza Company |
| DCCT | Department of Computing and Communication Technology |
| DLTS | Department of Logistics and Transport Studies |
| ERP | Enterprise Resource Planning |
| GDP | Gross Domestic Product |
| LCM | Least Cost Method |
| MCM | Minimum Cost Method |
| MDC | Manual Distribution Centre |
| MODI | Modified Distribution |
| NWCM | North West Corner Method |
| SAP | System Application and Products |
| SCM | Supply Chain Management |
| VAM | Vogel Approximation Method |

# Potential of Jatropha Husks and Jatropha Cakes for Gasification

**[1]E.D. Kasembe, [2]G R. John and [2]C.F. Mhilu**

[1]National Institute of Transport,
P. O Box 705, Dar es Salaam, Tanzania; Tel: +255 784 504212
Email: ekasembe@gmail.com

[2]College of Engineering and Technology,
University of Dar es Salaam, P. O Box 35131, Dar es Salaam, Tanzania,
Tel: +255 754 319945 / +255 754 286177
Email: grkjohn@uccmail.co.tz / cfmhilu@hotmail.com

**Abstract**

*This paper presents the results of investigation of fuel properties and their gasification feasibility. Jatropha husk and jatropha cake biomass materials were converted to syngas in a downdraft gasifier whose performance was evaluated in terms of syngas heating value and gasifier efficiency at an equivalence ratio of 0.4 and gasification temperature from 800 to 1400K. Results indicate that both materials have moisture contents of less than 11% and volatiles content of more than 50%, which indicates the potential for exploitation through gasification. For both biomass materials, it is observed that $H_2$ composition increases from about 6% to 14%, $CO_2$ increases from about 8% to 14% while content of $CH_4$ decreases from about 0.6% to 0.008% while CO concentration is reduced from about 21% to 15%, as the gasification temperature is increased. The $H_2$/CO ratio is between 0.3 and 0.97, which is a good indication for syngas use in combustion processes. Maximum syngas heating values were 3119.1kJ/kg for jatropha cake and 2804.3kJ/kg for jatropha husks which could be exploited an alternative fuel for electric power generation in internal combustion engines. Maximum heat conversion efficiencies of jatropha cake and jatropha husks were 70.4% and 73.4% respectively at 900K.*

***Key words:*** Jatropha husk, Jatrophs cakes, Syngas, Gasification, Temperature, Modeling

## INTRODUCTION

Residues from Jatropha oil production industry (jatropha husks and cakes) are produced annually and in large quantities, leaving their high energy content unexploited. At the end of two years Jatropha curcas plant will give seed to its full potential as four hundred hectares which will produce 0.48 million metric tonnes of oil and 1.02 million metric tonnes of oil cakes (Chandra *et al.,* 2006). When jatropha seeds are crushed, the resulting jatropha oil can be processed to produce a high-quality biodiesel that can be used in a standard diesel car, while the residue (press cake) can also be processed and used as biomass feedstock to power electricity generating plants or used as fertilizer (it contains nitrogen, phosphorus and potassium). Singh *et al.* (2008) and Staubmann *et al.* (1997) found that the cake's high organic matter content makes it suitable for biogas generation. A typical sample of jatropha seed cake is shown in Figure 1(a). The jatropha seed consists of the inner kernel and the seed coat known also as outer husk. The outer husks are obtained after decortications of Jatropha seed for oil extraction. Seed contains about 40-42% husk/hull and 58–60% kernels. While a lot of emphasis is being given on use of bio-diesel, which is only about 17–18% of the dry fruit (seed), not much attention is being given to utilize other components of the fruit for energy purposes (Signh *et al.*, 2008). The husks can be fermented as well, but have shown to be a successful feedstock for gasification, achieving similar results to wood (Vyas and Signh, 2007 as presented by Achten *et al.*, 2007). A typical

sample of jatropha husks is shown in Figure 1(b).

*(a)* *(b)*

**Figure 1: (a) Jatropha seed cake (b) Jatropha husks**

The presence of these abundant materials needs to be exploited. Hence, the purpose of this work is to find the feasibility of converting these materials into useful energy products which can be used for many applications. Conventional combustion of residues from biomass remains is already applicable in many regions due to the extended local agricultural activity and additional energy consumption demands. Hence, the idea of replacing this technology with a more environmental friendly such as gasification seems to be very attractive. Moreover, fossil fuel prices act as the driving force for biomass exploitation in energy production systems through the gasification process.

Gasification is one of the major promising technology in which under certain practices leads to higher overall efficiencies (more than 50%) compared to that usually achieved via combustion of about 25–35% (Bridgewater, 1995). Percentages of permanent gases ($CO_2$, $CH_4$, $H_2$, light hydrocarbons) in the gaseous mixture issued from biomass gasification depend on several factors, such as the gasification medium (air, steam, $CO_2$, special mixtures), the characteristics of the biomass (heating value, proximate and ultimate analysis), the heat rate, the temperature and the oxidizing medium amount (McKendry, 2002). Hence the syngas production from jatropha husks and jatropha cakes is studied under air gasification in a modeled downdraft gasifier under atmospheric pressure. Furthermore, the impact of temperature at a constant air equivalence ratio on the syngas yield will be studied. For a better comparison of the produced gas quality of both residues, another parameter, gasifier efficiency has been introduced in the study.

## METHODOLOGY

### Characterization of Biomass Materials

The characterization of biomass is necessary and important to ensure for a successful combustion and gasification of biomass materials. These are defined by the materials composition and heating value that are important for gasification and are determined using the proximate and ultimate analysis, thermogravimetric, differential thermogravimetric. These are standard test methods adopted for establishing various biomass properties.

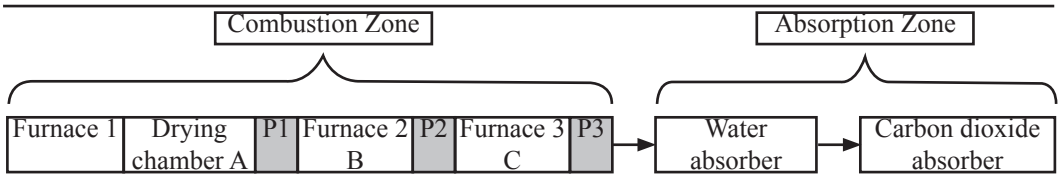
### Proximate and ultimate analysis

### The proximate analysis

The proximate analysis method allows the determination of the moisture content (MC) using the ASTM E871 standard, volatile matter (VM) by ASTM E872, ash content (Ash) by ASM D1102. The fixed carbon was determined as the difference from 100% of the sum of the (MC%+VM%+Ash%). For this study, the Vecslar Furnace Model LF3 was used to determine proximate properties of the selected biomass materials. The maximum operating temperature that can be reached is 1,100$^{o}$C; and is also fixed with a digital controller used to set temperature values needed during various heating operations. The controller is provided with a screen where temperature settings are displayed.

### The ultimate analysis

The ultimate analysis method was used to establish the weight percent of carbon, hydrogen, nitrogen, oxygen, sulfur, chlorine of the selected feed stock materials using the Atomic Absorption Spectrometer (AAS) equipment as shown in Figure 2.




**Key:**

A - High silica glass section B - Cupric oxide filling

C - Lead chromate or silver filling P1, P2 and P3 - Oxidized copper gauze plugs

**Figure 2: Arrangement of tube fillings for combustion tube and absorption train**

**Thermal degradation characteristics**

Thermal degradation characteristics of biomass materials was studied under inert nitrogen condition using a simultaneous thermal gravimetric analyzer (TGA) type NETZSCH STA 409 PC Luxx TG connected to a power unit 230V, 16A, and its layout is presented in Figure 3. Using a Thermal gravimetric analyzer (TGA) arrangement, measurements corresponding to material weight loss in % against temperature, and their corresponding rate of loosing weight are obtained.

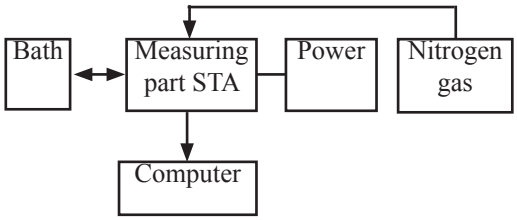



**Figure 3: Thermalgravimetric analyzer layout**

**Gasifier Performance**

Performance was evaluated in terms of calorific value of producer gas and gasification efficiency at different gas temperatures at a constant equivalence ratio. The methodology involved a model formulation using both thermochemical equilibrium and exergy analyses. The model formulated involved only the gasifier unit (Figure 4) in the whole biomass to energy technology chain. This is because an analysis of the efficiency of the gasifier alone can substantially contribute to the efficient improvement (Sues *et al.* 2010).

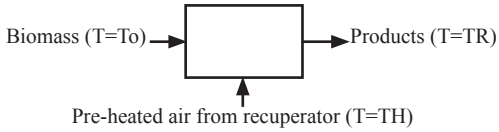



**Figure 4: Schematic diagram of a HTAG gasifier**

Therefore, a simplified gasification mechanism could be explained by using the proposed reactions scheme presented in Table 1.

**Table 1: Gasification Reactions**

| Reaction No. | Reaction Scheme | Chemical Reaction | Eq. No. |
|---|---|---|---|
| R1(a) | $C + O_2 \rightarrow CO_2$ | Oxidation reactions | (1) |
| R1(c) | $CO + ½ O_2 \rightarrow CO_2$ | | |
| R2 | $CO_2 + C \leftrightarrow 2CO$ | Boudouard reaction | (2) |
| R3 | $C + H_2O \leftrightarrow CO + H_2$ | Water gas reaction | (3) |
| R4 | $C + 2H_2 \leftrightarrow CH_4$ | Methanation reaction | (4) |
| R5 | $CO + H_2O \leftrightarrow CO_2 + H_2$ | Water-gas shift reaction | (5) |
| R6 | CH4 +H2O↔H2+CO | Methane reforming reaction | (6) |

**MODELLING**

The biomass involved in the gasification is represented by a general formula $CH_xO_yN_z$ and the gasification equation is represented in Eq. (7) as:

$$CH_xO_yN_z + wH_2O + m(O_2 + 3.76N_2 \rightarrow {}_HH_2 + n_{co}CO + n_{CO}CO_2 + n_{HO}H_2O + n_{CH}CH_4 + (z/2 + 3.76m)N_2 \quad \ldots\ldots(7)$$

In order to obtain the amount of moisture per kmol of feedstock, w, and ash content in the biomass, the output of proximate analysis was necessary. On the other hand, the determination of x, y and z depend on the concentrations of the elements C, H, O and N in the biomass. These are obtained from the biomass ultimate analysis. This pre-analysis is necessary for the determination of the products of gasification; nCO, $nCO_2$, $nCH_4$, $nN_2$ and $nH_2$ which can finally be determined by performing mass/mole balance from Eq. (7) in addition to methanation Eq. 4 and water-gas shift Eq. (5). This is done by assuming the thermodynamic equilibrium where the equilibrium constants for all chemical reactions of ideal gases at 1 atm can be obtained.

The value of Lower Heating value of a gas (LHVgas) referred to the cold conditions of 25°C and 1 bar is obtained by summing the product of mole fraction ($\chi_i$) and lower heating values ($LHV_i$) of each component in the gas as presented by Webber (2008) at the same conditions, and is represented in Eq. (8):

$$LHVgas=\Sigma\chi_i LHV_i \quad \text{.....(8)}$$

When the biomass enters the gasifier at ambient conditions, only chemical exergy is available in biomass ($\varepsilon_{ch,\ biomass}$), air do not react and enters the gasifier at high enthalpies, only physical exergy exist($\varepsilon_{ph,\ med}$), the leaving gas from the gasifier have the chemical exergy ($\varepsilon_{ch,\ gas}$) and physical exergy ($\varepsilon_{ph,\ gas}$), therefore the exergy efficiency ($\eta_{ex}$) results in the expression given in Eq. (6) as from Kasembe *et al.* (2011):

$$\eta_{ex}=\frac{\varepsilon product}{\varepsilon inputs}=\frac{\varepsilon ch,gas+\varepsilon ph,gas}{\varepsilon ch,\text{biomass}+\varepsilon ph,\text{med}} \quad \text{..(9)}$$

From which:

$$\varepsilon_{ch,gas}=\sum_i \chi_i\varepsilon_{ch,i}+R_oT_o\sum_i \chi_i 1n\chi_i \quad \text{.....(10)}$$

$$\varepsilon_{ph,gas}=(h_R-h_o)-T_o(s_R-s_o) \quad \text{.....(11)}$$

$$\varepsilon_{ph,med}=(h_H-h_o)-T_o(s_H-s_o) \quad \text{.....(12)}$$

$$\varepsilon_{ch,biomass}=\beta LHV_{biomass} \quad \text{.....(13)}$$

$$\beta=\frac{1.044+0.0160Z_H-0.3493Z_O[1+0.0531Z_H]+0.0493Z_N}{1-0.4124Z_O} \quad \text{.(14)}$$

Where: $\varepsilon_{product}$ is exergy of the product gas ($\varepsilon_{ch,gas}$ and $\varepsilon_{ph,gas}$) and $\varepsilon_{input}$ is the exergy of the input which is biomass $\varepsilon_{ch'biomass}$ and preheated air ($\varepsilon_{ph,med}$). and $\varepsilon_{ch,i}$ are the mole fraction and chemical exergy of individual gas component i respectively, $R_o$ is the universal gas constant (8.314kJ/kmolK) and $T_o$ is the standard temperature (298K). The values of εch,i for syngas composition component ($H_2$, CO, $CO_2$, $H_2O$, $CH_4$ and $N_2$) are obtained according to Kotas (1985), h and s are enthalpy and entropy of the gas mixture at a given temperature and pressure, $h_o$ and $s_o$ are the values of these functions at standard temperature $T_o$ and pressure (1 bar). The subscript R stands for exit gas from the gasifier and H is for the hot gas from the recuperator. These values are from Stull and Prophet (1971) and the JANAF Thermodynamic Tables as reported by Strehlow (1985). LHVbiomass is the lower heating value of biomass, β is a factor dependent upon mass fraction of oxygen, carbon, hydrogen and nitrogen in the feedstock (Ptasinski, 2007). ZH is H/C, ZO is O/C, and ZN is N/C and H/C, O/C and N/C represent atomic ratios of fuel components H, C, O and N in the solid fuel.

The Matlab equation solver program and Maple programs were used to calculate the formulated model equations to obtain the gaseous concentrations and exergy efficiency values.

## RESULTS AND DISCUSSIONS

### Model Validation

Table 2 shows the comparison between the results of gaseous compositions available from literature and predicted values using this

model relations. The Zainal *et al.* (2001) model presented results using an equilibrium model in a downdraft gasifier with wood material of 20% moisture content at a temperature of 1073K and equivalence ratio of 0.4 with a feedstock ultimate analysis of carbon 50%, hydrogen 6%, oxygen 44%. The model assumes that all reactions are in thermodynamic equilibrium and that the pyrolysis products burns and achieve equilibrium in reduction zone before leaving the gasifier. Table 2 show that, the predicted results are in good agreement with the literature results for CO and $H_2$ which in most cases are slightly higher. Model results for $CO_2$ are desirable because are lower than those presented from the literature.

**Table 2: Comparison of Gaseous Composition – Current Predicted values with Zainal *et al.* (2001) values**

| Syngas | Syngas composition (%) | | |
|---|---|---|---|
| | Current Model | Reference data | % Deviation |
| CO | 18.4 | 19.6 | 6.1 |
| $CO_2$ | 9.9 | 12 | 17.5 |
| $CH_4$ | 0.13 | 0.6 | 78.3 |
| $H_2$ | 17 | 21 | 19.0 |

**The Proximate and Ultimate Analysis**

A preliminary comparison of physicochemical characteristics of those residues revealed that both have low moisture contents of less than 11% favouring their conversion via gasification (McKendry, 2002) as they would probably ignite easily without the necessity of excessive heat for moisture evaporation. Their volatiles content (>50%) indicates their attractive potential for exploitation through gasification. Fuels with high volatile matter content are more reactive, and therefore can be converted more easily into a gas while producing less char. At a preliminary stage, and according to these observations, it might be proposed that both residues could be further exploited for energy production.

The molecular formulas of jatropha husks and jatropha cake based on the ultimate analysis (Table 3) were estimated as: $CH_{1.06}O_{0.58}N_{0.16}$ and $CH_{1.09}O_{0.59}N_{0.22}$ respectively. From both molecular formulas it was concluded that there is no considerable difference in the elemental composition of the residues, as those residues seem to inherent parent biomass (jatropha plantation) properties. Additionally, the jatropha husks's high heating value is higher (20.94 MJ/kg) than that of the jatropha cake (17.98MJ/kg) and have high ash contents of more than 15%.

**Thermal Gravimetric Analysis (TGA)**

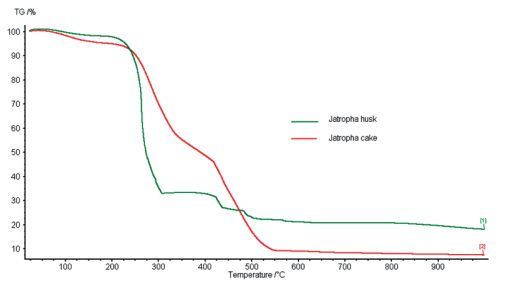
Another important experimental data is also presented, the thermal degradation analysis. This analysis is used as a clarification to the correctness of the presented proximate analysis results and investigates the behavior of biomass sample when heated. The two samples of the biomass materials of jatropha cake and jatropha husks were subjected to thermogravimetric analysis using the TGA. Figure 5 depicts the output of combined thermograms.

**Tabel 3: Expermental values of proximate and ultimate analysis for jatropha cake and jatropha husks**

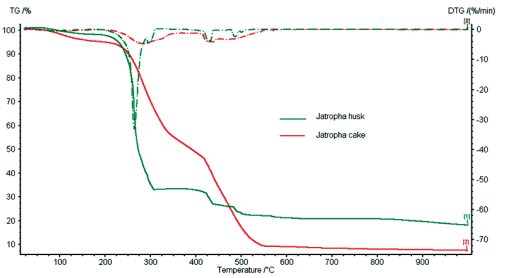
| Biomass type | Ultimate analysis (%), dry basis | | | | Proximate analysis (%), dry basis | | | | Biomass Formulae | Heating Value |
|---|---|---|---|---|---|---|---|---|---|---|
| | C | H | O | N | Moisture | Volatile matter (VM) | Fixed carbon (FC) | Ash | $CH_xO_yN_z$ | MJ/kg |
| Jatropha cake | 34.13 | 4.17 | 30.74 | 8.57 | 8.08 | 55.84 | 13.70 | 22.38 | $CH_{1.06}O_{0.58}N_{0.16}$ | 17.98 |
| Jatropha husks | 33.75 | 4.12 | 30.36 | 11.21 | 10.73 | 55.07 | 13.65 | 20.55 | $CH_{1.09}O_{0.59}N_{0.22}$ | 20.94 |

The first stage (Region I) took place at a temperature around 100ºC, in this stage, there is an elimination of moisture from the biomass sample. The TG curve, Figure 5(a), the apparent moisture content in all biomasses ranged from 2% to 8%. These values are lower than the experimental values in the proximate analysis given in Table 1 which is between 8% and 11%. The second stage (Region II) occurs at temperatures between 200-450ºC and corresponds to the pyrolysis of biomass components. In this temperature interval each biomass sample experienced the greater mass loss of about 80% (jatropha cake) and 70% (jatropha husks). The obtained volatile matter percentage weight obtained from this analysis is observed to be higher when compared with the results obtained from the experimental values emanating from the proximate analysis presented in Table 1 for all biomass materials. The third area, Region III occur at temperatures above 450ºC, this zone evidences the progressive degradation of temperature resilient elements, including heavy lignin fractions and solid chars derived from the carbonisation of the original biomass components. The residue at 1000ºC consists of a mixture of char and inorganic ash. Remnants in jatropha cake are about 9% while that of jatropha husks is about 20%.

It is noted from Figure 5(b) that both the hemicellulose and cellulose peaks for these materials are almost coinciding into one peak, which represent the yield of the both light and heavy volatiles. At this point, jatropha husks have maximum temperature of about 300ºC whilst jatropha cake has a decomposition profile at maximum temperatures of about 285ºC respectively. The peaks for jatropha cake occur at decomposition rate of 5%/min meaning that the materials decompose slowly compared to jatropha husks with a decomposition rate of 26%/min respectively. The deviation between the proximate analysis experiments and thermogravimentric experiments may be due to storage conditions and time evolved the samples in both experiments.




(a)




(b)

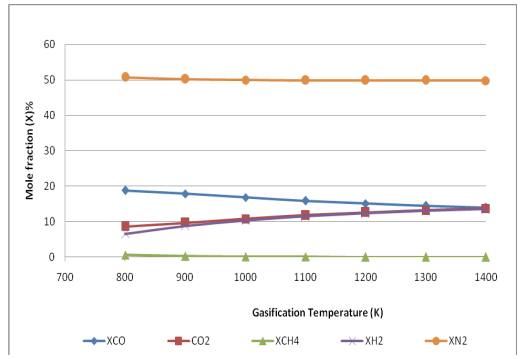
**Figure 5: Jatropha cake and jatropha husks (a) thermogram at 10K/min (b) DTG profiles**

**Effect of temperature on the gas products distribution**

In this study, gasification model runs were performed by varying the temperature between 800K and 1400K and keeping the air equivalence ratio constant at 0.4. Gas composition from jatropha cake and jatropha husks is shown in Figure 6. Generally, it can be observed that $H_2$ composition increases for both biomass materials (from about 6% to 14%) as the gasification temperature is increased due to the effect of exothermal character of water-gas shift reaction ($CO+H_2O \leftrightarrow CO_2+H_2$) predominating around 1000ºK and the water-gas reaction ($C+H_2O \leftrightarrow CO+H_2$) predominating at temperature of about 1300ºK. Water vapour, $H_2O$ and CO promotes $H_2$ production in biomass gasification process via the water-gas shift reaction and water-gas reaction. The $CH_4$ concentration is reduced for both biomass materials (from about 0.6% to 0.008%) as the temperature is increased. This is because the $H_2$ production reactions are endothermic and content of $CH_4$ decrease because the endothermicity in the reactions

favours the steam methane reforming reaction/ methane decomposition reaction ($CH_4+H_2O \leftrightarrow CO+3H_2$).

The $CO_2$ production is noted to increase (from 8% to about 14% for both biomass materials) as the temperature is increased in the current work. While this is the case for $CO_2$, CO concentration is reduced (from about 21% to about 15% for both biomass materials). This trend in the gas composition of the produced gas from the biomass materials in this study indicate the significance of the Bourdouard reaction ($C+CO_2 \leftrightarrow 2CO$) hence, a reduction in the CO concentration. The decrease in CO means a bourdouard reaction shift to the left side, hence increase production of $CO_2$. This concludes that the reduction in CO production is because Boudouard reaction predominates at lower temperature than 900K.

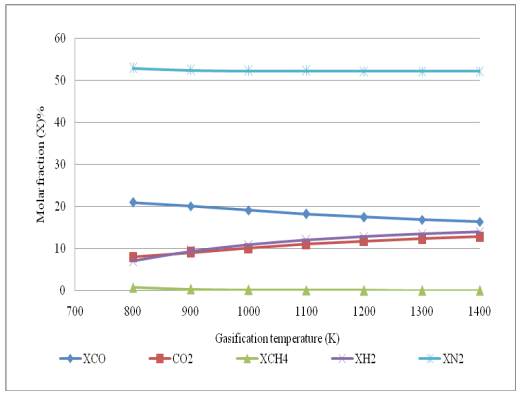



**(b)**

**Figure 6: Effect of temperature on molar composition for CO, CH4, $CO_2$ and $H_2$ gases at an equivalent ratio of 0.4 from (a) jatropha cake (b) jatropha husks**

**Table 4: Effect of temperature on gas ratios from the biomass materials**

| ER | Biomass Material | Gas ratios $H_2$/CO | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Gasification Temperature (K) | | | | | | |
| | | 800 | 900 | 1000 | 1100 | 1200 | 1300 | 1400 |
| 0.4 | Jatropha cake | 0.34 | 0.46 | 0.57 | 0.66 | 0.74 | 0.80 | 0.86 |
| | Jatropha husks | 0.35 | 0.49 | 0.61 | 0.72 | 0.82 | 0.90 | 0.97 |




**(a)**

Furthermore the effect of temperature on gas ratio $H_2$/CO is discussed. The syngas from air gasification generally consists of a $H_2$/CO ratio< 1, which is suitable for combustion but ill-suited for fuel synthesis (Yung *et al,* 2009). Skoulou (2008) reports that a syngas with a molar ratio of $H_2$/CO between values of 1 and 2 ($1<H_2/CO<2$) could be useful for chemical syntheses like methanol, pure naphtha production, Fisher Tropsh synthesis (ratio 2) and oxosynthesis processes (ratio 1). In the present study, the produced syngas showed a ratio of $H_2$/CO varying between 0.3 and 0.97 which indicates that the produced gas is good for combustion. This is shown in Table 4.

**Effect of temperature on the heating value of the syngas**

Considering the heating value of gas produced from both materials (Figure 7), it was found that it follows an increasing trend as temperature increases. An LHV calculation was made according to Eq. (8).

LHV of gas from both materials followed an increasing trend as temperature increased in the region between 800 and 900K, but above

this temperature, an almost constant trend was observed. The temperature at which gas produced during jatropha cake gasification maximized its heating value LHV 3119.1kJ/kg at steady oxidizing conditions of 900K for jatropha cake. In the case of jatropha husks, a maximum value at 900K for LHV of 2804.3kJ/kg. Both gases are considered to be medium heating value fuel and could be exploited as an alternative fuel for electric power generation in internal combustion engines (Lv *et al.,* 2004).

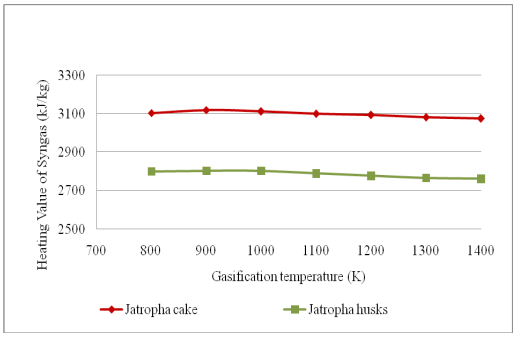



**Figure 7: Effect of temperature on sygas heating values for jatropha cake and jatropha husks**

**Effect of temperature on the gasification efficiency**

For a better comparison o f the produced gas quality of both residues, another parameter has been introduced: the thermodynamic gasifier efficiency defined according to Eq. (9). Figure 8 depicts the gasifier efficiency of jatropha cake and jatropha husks at different temperatures. Jatropha cake seemed to maximize their heat conversion efficiency 70.4% at 900K while efficiency of jatropha husks against temperature, at constant equivalent ratios reaches the value of 73.4% at 900K. This is because some of exergy is present in the form of physical exergy, is used to heat the reactants. This represents exergy losses (irreversibilities) of which can be minimized by altering the ratio of physical and chemical exergy in the product gas.

With this, it can be noted that the irreversibility values tend to decrease with an increase of temperature of up to 900K and from there, a small increment was observed. This concludes that increase in the gasifier temperature has an effect on the exergetic efficiency based on chemical and physical exergy. This might have been caused by a rise in the $O_2$ in order to combust more carbon (some of exergy present in the form of physical exergy which used to heat the reactants), which means more air is required in order to provide the necessary heat of reaction to reach the gasification temperature. The disadvantages of increasing the amount of air causes the reduction of major chemical exergy carrier components such as CO and $CH_4$ and consequently, the first term in the right -hand side of chemical exergy, Eq. (10) is reduced.

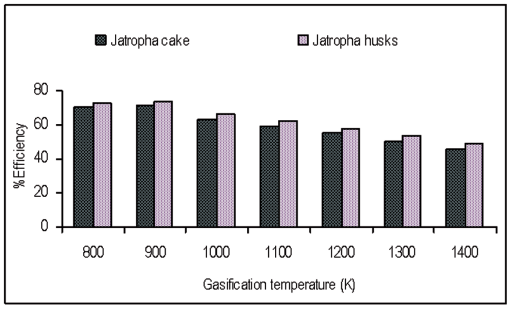



**Figure 8: Effect of temperature on efficiencies at equivalence ratios of 0.4**

## CONCLUSION

The model was able to predict syngas components molar concentration values of carbon monoxide (CO), carbon dioxide ($CO_2$), hydrogen ($H_2$) and methane ($CH_4$), syngas heating values and the efficiencies for both biomass materials, jatropha cake and jatropha husks at gasification temperature in the range of 800K – 1400K at an equivalence ratio of 0.4. Both biomass materials have low moisture contents which favouring their conversion via gasification. Their high volatiles content indicates their attractive potential for exploitation through gasification. The produced syngas showed reasonable $H_2$/CO ratio which indicates that the produced gas is good for combustion processes.

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# Analysis of Service Quality Dimensions and Passengers' Satisfaction: A Case of Ubungo Bus Terminal in Dar es Salaam City Tanzania

**Dr. Simon S. Lushakuzi**

(Lecturer), Department of Logistics and Transport Studies (DLTS), National Institute of Transport (NIT), P.O. Box 705, Dar es Salaam, Tanzania
slushakuzi@gmail.com

**ABSTRACT**

*The main objective of the research was to analyse the relationship between quality of services as measured by reliability, responsiveness, assurance, empathy, and conduciveness of materials on the one hand and passengers' satisfaction in the waiting room services at Ubungo bus terminal in Dar es Salaam city on the other hand.*

*This research was conducted in Dar es Salaam city Tanzania at Ubungo bus terminal. It focused on passengers at Ubungo bus terminal who were thought to be forgotten in the sense that there are existing low standard of terminal services for them. The literature review focuses on key concepts like service, quality, service quality, servqual model and customer satisfaction.*

*A case study design was adopted, with a sample of sixty eight (68) respondents only. Primary and secondary data collected were tested and found to be fit, reliable and valid for making meaningful interpretation. Furthermore, the result indicated that multi-research approach was appropriate in gathering information.*

*The research findings were based on all Total Score Value (TSV) results in the waiting room services at Ubungo bus terminal which indicate unfavourable opinions. Therefore, the null hypothesis that said "The quality of services dimensions are not directly related with passengers' satisfaction in the waiting room services at Ubungo bus terminal." is rejected. The study concluded that, selection of suitable employees, as well as subsequent training and motivation are essential for the waiting room service providers at Ubungo bus terminal.*

***Key Words:*** Service Quality Dimensions, Passengers' Satisfaction, Bus Terminal

## INTRODUCTION

An efficient transport system is necessary to promote socio-economic development in the country. The Ministry of Transport is responsible for setting transport policy at the same time as Surface and Marine Transport Regulatory Authority (SUMATRA) is responsible for establishing standards for regulated transport services, rates/charges, and institute rules and facilitates resolution of complaints as well as disputes.

Currently, there are widespread complaints from Ubungo bus terminal waiting room users regarding unsatisfactory service quality, following frequent and wide ranging decrease of reliability, coordination and consistency of the waiting room services. The procedures of reviewing transport policy regarding the waiting room services at Ubungo bus terminal are not known. So are factors that trigger decision–making aspects. Waiting room passengers at Ubungo bus terminal are forgotten in the sense that there exists no formal terms of

waiting room services for them. Travellers are not quite grasped on what are their intentions. They suffer from being tired, unnecessary delays, uncomforted and security less while they are waiting to travel or to be hosted by their relatives. Since there is limited research on the working conditions of service providers at waiting room of Ubungo bus terminal, the source of passengers' dissatisfaction has not been explored in detail.

This research, aimed at identifying factors affecting services provided at the waiting room of Ubungo bus terminal to establish the extent they can satisfy customers and the subsequent challenges encountered.

## OBJECTIVES OF THE STUDY

### The main objective

The main objective of the research was to analyse the service quality dimensions and passengers' satisfaction at Ubungo bus terminal in Dar es Salaam city.

### The specific objective

In order to accomplish the general objective, the study focused on the following specific objective

(i) To analyse the relationship between the quality of services dimensions and passengers' satisfaction in the waiting room services at Ubungo bus terminal.

## MATERIAL

### Service

Service is as old as the transactions and interactions between people and has been studied since the 1890s, when socialist examined service customer and service personnel in department stores through participation and observation (Pieters & Botschen, 1999). The term "Service" is difficult to define because invariably services are marketed in conjunction with tangible goods. Services require supporting goods and goods require supporting services.

According to Stanton (1981), services are those separately identifiable, essentially intangible activities that provide want satisfaction and that are not necessarily tied to the sale of a product or another service. To provide a service may or may not require the use of tangible goods. However, when such use is required, there is no transfer of the title (component ownership) to those tangible goods. It is the value of these services that determine the volume of purchases (Stanton, 1981). Astroff and Abbey (1998) define a service as the repeat of visits by the convention consumers to the facility, i.e. bus terminals, as the reward for good service. Kotler (2001) defines services as any act of performance that one party can offer to another that is essentially intangible and does not result in ownership of anything. Bteson (1989 as cited in Getz, 1997) states that service is delivered as a bundle of benefits to the consumer through experience created for that consumer. Stanton (1981) characterises services in four categories, namely, intangibility, inseparability, variability/ heterogeneity and perishability or fluctuating demand.

### Quality

Few academic researchers have attempted to define and model quality because of the difficulties involved in eliminating and measuring the contrast (Parasuraman, *et al.* 1985, 1990). Quality is defined as the totality of features and characteristics of product or service that bears on its ability to satisfy stated or implied needs (ISO, 9000, 1994). According to Juran (1988) quality is a fitness of use. On the other hand Crosby (1979) defines quality as conformity to requirement.

### Service quality

As observed by Ghobadian, Speller and Jones (1994), most of the service quality definitions fall within the "customer led" category. Juran (1999) elaborates the definition of customer led quality as "features of products which meet customer's needs and thereby provide customer's satisfaction". As service quality relates to meeting customers` needs, "perceived service quality" would be examined in order to understand the customer (Arnauld, Price & Zinkhan, 2002). Prasuraman, Zenithal and Berry (1988) define quality of service as the gap

between consumer expectations and perception. This view is shared by Samuel (1999) who notes the importance of satisfying the customers` needs and expectations as the main factor in all these definitions. Parasuraman and co-workers (1985) look at perceived quality of service as the difference between customers` expectation and their perceptions of the actual service received. Parasuraman and co-authors (1985) further suggest that it may be the perception of service quality that leads to customer's satisfaction. It means that if the customer perceives the service to be of high quality, then the customer will be satisfied with it. Conversely, others believe that if the customer is satisfied with the service, then the customer perceives the service as being of high quality.

**Servqual**

Further analysis by Parasuraman, Zenithal and Berry (1988) revealed that their original 10 points could in effect be reduced to five determinates of satisfaction, thus leading to the development of the SERVQUAL model, The SERVQUAL model was officially introduced in 1988 and encompasses several unexplored dimensions that have lately attracted research attention in other disciplines. The SERVQUAL instrument is one of the most commonly used constructs when attempting to measure service quality and satisfaction.

SERVQUAL is the first quality scale developed for measuring service quality and it is based on Parasuraman *et al.* (1985) gap theory, which suggests that the difference between consumers` expectations about the performance of a general class of service providers and their assessment of the actual performance of a specific firm in the class derives the perception of service quality. Parasuraman *et al.* (1985, 1988) introduced the SERVQUAL model as a solution for the measurement of service quality. This model measures the gap between the expected and perceived service levels as a solution to the customers' expectations (Kolb, 2005a). The model also measures the tangible and intangible service elements (Figure 1). It investigates the discrepancies or gaps in the consumer – supplier chain to highlight target areas where quality may be improved (Samuel, 1999). According to this quality scale, service quality is broken into five dimensions (gaps):

1) **Tangibles:** Appearance of Physical elements
2) **Reliability:** Dependable accurate performance
3) **Responsiveness:** Promptness and Helpfulness
4) **Assurance:** Competence, Courtesy, Credibility and Security
5) **Empathy:** Easy access, Good communications and Customer understanding.

From the basis of SERVQUAL model (service quality), scores are identified in (Figure 1).

**Service quality and customer satisfaction**

Service quality and customer satisfaction are inarguably the two core concepts that are at the crux of the marketing theory and practice (Spreng & Mackoy, 1996). In today's world of intense competition, the key to sustainable competitive advantage lies in delivering high quality service that will in turn result in satisfied customers (Parasuraman *et al.* 1990). The prominence of these two concepts is farther manifested by the cornucopia of theoretical and empirical studies on the topic that has emanated over the past few years. Therefore, there is no even an iota of doubt concerning the importance of service quality and customer satisfaction as the ultimate goals of service provider (Sureschander, 2002). A basic agreement emanating from a wide range of literature on service quality and customer satisfaction is that service quality and customer satisfaction are conceptually closely related constructs (Parasuraman *et. al.* 1990).

**Theoretical model of the study**

The theory was presented as a visual model (Figure 2). The visual model is useful to translate variables into visual picture (Creswell, 1994). Blalock (1969) recasts verbal theories into causal models so that a reader can visualise the interconnections of independent, intervening and dependent variables. In that case, five independent attributes $R_1$, $R_2$, A, E and

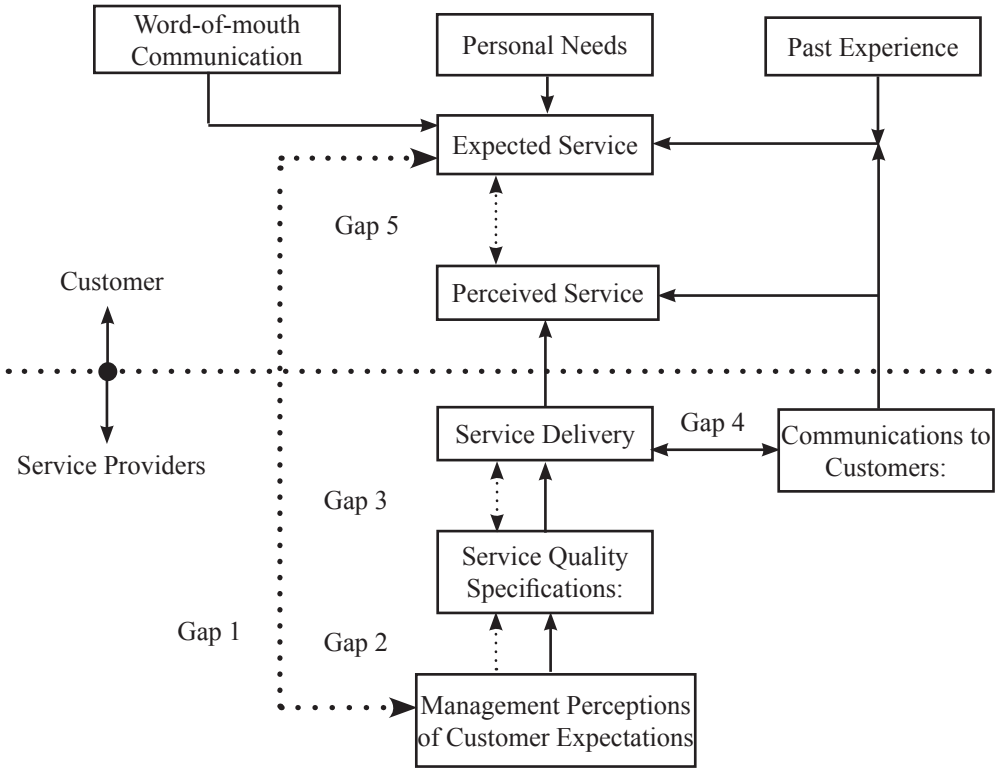


**Figure 1: The SERVQUAL model**
***Adopted from:*** Samuel, (1999).

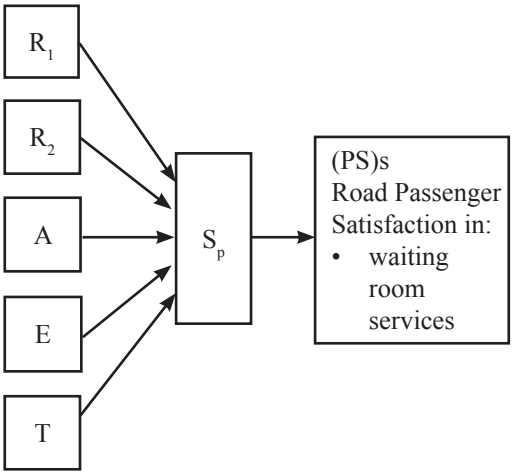


**Figure 2: A Visual model of a theory of service quality as measured by reliability, responsiveness, assurance, empathy and tangibles.**
***Source:*** Developed by Author from Literature Review (Garvin (1984) and (Berry, Zeithaml and Parasuraman, 1985).

T influence a single dependent variable (PS)s mediated by the influence of one intervening variable $S_p$. Where $R_1$ is Reliability, $R_2$ is Responsiveness, A is Assurance, E is Empathy and T is Tangibles, $S_p$ is Service providers, and (PS)s Road passengers' Satisfaction in waiting room services.

## RESEARCH METHODOLOGY

### Research design used in this study

This study employed the case study design. The case study is the research methodology that focuses on understanding the dynamics present in management situation (Mboma, 1999, 1989 cited in Lushakuzi, 2011). A case study is characterised by a thorough study of a unit over a range of variables but always maintaining the unitary nature of the unit of inquiry (Ndunguru, 2007). Aaker, Kumar and Day, (2002) define a case study as a comprehensive description and analysis of a single situation. This design was adopted because it was less expensive, flexible

and easily manageable in the process of data collection and it provides more insight towards obtaining in depth and breadth information about several variables from within a social unit (Lushakuzi, 2011). A combined research approach (quantitative and qualitative) were adopted in order to reduce bias and to minimise errors and disadvantages associated with a single research approach as far as possible (Bell, 1994).

**Study area**

The study was conducted in Dar es Salaam city at Ubungo bus terminal. The choice of Ubungo bus terminal based on its unique status being the major City of Tanzania, centre of government administration, industry, commerce, banking activities and attraction to travellers. Other reasons are with hotels where travellers can stay, several academic institutions, health centres and numerous types of vehicles. With this being the case, Ubungo bus terminal is the interface with various mode of transport; this includes Mwalimu Nyerere International Airport, Dar es Salaam Port, Tanzania Railways Limited (TRL) Station and Tanzania-Zambia Railway Authority (TAZARA) station. Basing on these reasons, Ubungo bus terminal had more indicators to be studied compared with other bus terminals in Tanzania.

**Sample size**

The exact number of items selected from a population to constitute a sample is what we call sample size (Kamuzora, 2008). This includes the respondents from transit cum inter-urban road passenger at Ubungo bus terminal and Dar es Salaam city Headquarters. Roscoe (1975) in Umma, (2006) proposed the following rule of thumb for determining sample size. Sample sizes larger than 30 and less than 500 were appropriate for most researchers. "Due to the qualitative nature of this study, a small sample of individuals or groups was invariably chosen". This was because it was not possible to engage in rigorous examination of all the factors that entailed huge costs and energy expenditure (Lushakuzi, 2011). An increase in sample size will increase the precision of the sample results; a lager sample size does not guarantee the accuracy of the results (Krishnaswami and Ranganatham, 2007). In this respect, this study used a small sample, meaning that the generalisability of the findings was restricted (Table 1).

**Table 1: Sample size**

| Organisation | Respondent | No. | % |
|---|---|---|---|
| Dar es Salaam city Headquarters | City director | 1 | 100 |
| | Officers | 5 | 3.93 |
| Ubungo bus terminal | Terminal manager | 1 | 100 |
| | Terminal engineer | 1 | 100 |
| | Terminal officers | 5 | 65.50 |
| | Waiting room passengers | 50 | 0.87 |
| TOTAL | | 63 | 370.30 |

***Source:*** Pilot survey - 2011

**Sampling technique applied in this study**

In this study, a non-probability or non random sampling (Quota sampling) was adopted to select road passengers for formal interviews. According to Hair, Bush and Ortinau (2006), Quota sampling involves the selection of prospective participants according to specified demographic characteristics or specific behaviour. It is therefore a method of stratified sampling in which the selection within strata is non-random (Krishnaswami and Ranganatham, 2007). The purpose of quota sampling is to ensure that pre specified subgroups of the target population are presented on the relevant sampling factors. The objective of using quota sampling was to have a proportional representation of the strata of the target population for the total sample and have certain characteristics describe the dimensions of the population (Cooper and Schindler, 2003). This technique was adopted because it is considerably less expensive and it takes less time.

**Data processing**

Every field questionnaires was checked for possible errors and incompleteness once

research assistants brought them. Incomplete or erroneous questionnaires were discarded since it was not possible to trace back the original respondents. All completed questionnaires were edited in order to detect errors and omission and the corrections were done. Data was coded by categorizing answers from the respondents into a limited number of classes. In so doing coding errors were reduced to the minimum level. All edited and coded data was organized for computer analysis using statistical package for social sciences (SPSS windows spreadsheet version 15.0).

**Data measurement**

In this study, the approach of 5 points Rensis Likert summated rating scale was adopted by formulating pre-determined statements related to travelling characteristics requiring passengers to indicate which rating corresponded to their own view. This study choose this scale because it captures structures among the measuring variables and is an efficient method of data collection which allows data to be summarised in a simple numerical score and widely used (Willson, 1994 and Esterby-Smith et al, 1995) in (Mboma,1999 and Lushakuzi, 2011).

**Reliability and Validity**

Spilt-half equivalence (Nunnally, 1978) measure of mult-scale using Cronbach's alpha coefficient (Peter, 1989) in Lushakuzi (2011) was used to measure of a mult-scale as the acceptable and most used approach (Churchill, 1979, 1997) in (Mboma, 1999 and Lushakuzi, 2011). The results show that the alpha coefficient reliability statistics is ranging between 0.88 and 0.90, which is above the acceptable minimum of 0.5 (Nunnally and Bernstein, 1994) in (Lushakuzi, 2011). Implying that the sample items were good measuring what is supposed to measure and the internal consistency of the measurements is acceptable. Ensuring of validity, quota sampling was employed within which we selected only those respondents who have similar and controllable characteristics.

**Data analysis**

The item analysis approach was applied by using 5 points Likert scale that, was expressed either as a favourable or unfavourable attitude towards the given object to which the respondents were asked to react. In that sense, qualitative data were converted into Likert scales by developing some justifiable ratio scheme. The response which indicated the least favourable degree of service quality was given the least score (say 1) and the most favourable was given the highest score (say 5). Cross tabulation and percentage differences was used. In cross tabulation two or more of the variables were treated simultaneously, therefore, the numbers of cases that have the joint characteristics were counted (Gilbert & Churchill, 2002). However, the multiple correlation analysis approach was adopted in order to analyse the quantitative data.

**FINDINGS**

**Waiting room service providers vis-a-vis reliability attribute**

Question one asked the respondents to say whether the service providers are able to perform the promised services very carefully or without errors. The respondents marked one of the options that best reflects his/her opinion. Their responses are illustrated in Table 2.

Table two (2) indicates that 14(28.0%) of the respondents disagreed that, the waiting room service providers are able to perform the promised services very carefully or without

**Table 2: Frequency distribution of the respondents on waiting room services**

| Service Providers | | Responses | | | | | Total |
|---|---|---|---|---|---|---|---|
| | | Strongly agree | Agree | Uncertain | Disagree | Strongly disagree | |
| Waiting room service provider | Count | 1 | 19 | 8 | 14 | 8 | 50 |
| | % | 2.0 | 38.0 | 16.0 | 28.0 | 16.0 | 100.0 |

***Source:*** Field survey - 2011

errors; that results reveal that the service provided was considered to be unsatisfactory. 19(38.0%) of the respondents agreed that the waiting room service providers are able to perform the promised services very carefully or without errors; that results reveal that service provided was considered to be satisfactory. Again Table two (2) indicates that, 8(16.0%) of the respondents strongly disagreed that the waiting room service providers are able to perform the promised services very carefully or without errors; that results reveal that services provided were experienced to be very unsatisfactory. Another result indicates that, 1(2.0%) of them strongly agreed that the waiting room service providers were able to perform the promised service dependably and accurately; that results reveal that service provided was considered to be very satisfactory. However, 8(16.0%) of them were uncertain that the waiting room service providers are able to perform the promised services very carefully or without errors; that result indicates that the quality of services provided by bus terminal service providers is experienced to be neither satisfactory nor unsatisfactory. Generally, the results indicate that, majority of the passengers from, were not satisfied with Waiting rooms services.

**Table 3: Total score values (TSV)**

| Service providers | Responses | | | | |
|---|---|---|---|---|---|
| | SA | Ag | Unc | DS | SD |
| Waiting room service provider | 1 (5) | 19 (76) | 8 (24) | 14 (28) | 8 (8) |

***Source:*** Field survey - 2011

Table 3 shows that TSV was between 5 and 79, which is below 150. This result means that the opinion is unfavourable. For that matter, service providers in the waiting room are not able to perform the promised services very carefully or without errors; the result shows further that the service provided was considered to be not reliable and in that sense, a service gap exists.

In measuring the relationship, the analysis shows that there is a significant correlation between reliability attributes and passengers' satisfaction. The relationships are presented in Table 4 which shows that passengers' satisfaction is associated with reliability attribute at 0.05 and 0.01 significant levels.

**Table 4: Pearson's correlation coefficient between reliability attribute and passenger's satisfaction in the waiting room services**

| S/N | Service | Corr. Coeff. | Coeff. of Determination |
|---|---|---|---|
| 1. | Waiting room services | .035 | .12% |

***Source:*** Field survey - 2011

The waiting room services indicate a low degree of correlation between reliability attributes and passengers' satisfaction in the waiting room services at Ubungo bus terminal. Therefore, an increase in performance of the promised services leads to the increase of passengers' satisfaction and vice versa. This result implies that as the performance of the promised services increases the passengers' satisfaction also increases. Again, Coefficient of determination (r2) of these variables that ranges from 0.0 % to 0.12% implies that the variation in satisfaction values is explained by those attributes. Therefore, an increase in performance of the promised services leads to the increase of passengers' satisfaction at the waiting room services. This result implies that as the performance of the promised services increases the passengers' satisfaction also increase

**Waiting room service providers vis-a-vis responsiveness attributes**

Question 2 asked the respondents to say whether the service providers are willing to provide service in time. The respondents marked one of the given options that best reflects their opinions. Their responses are illustrated in Table 5.

**Table 5: Frequency distribution of the respondents on waiting room service**

| Service Providers | | Responses | | | | | Total |
|---|---|---|---|---|---|---|---|
| | | Strongly agree | Agree | Uncertain | Disagree | Strongly disagree | |
| Waiting room service provider | Count | - | 12 | 8 | 24 | 6 | 50 |
| | % | - | 24.0 | 16.0 | 48.0 | 12.0 | 100.0 |

***Source:*** Field survey - 2011

Table 5 shows that 24(48.0%) of the respondents disagreed that the waiting room service providers are willing to provide service in time. These results reveal that the service provided was considered to be unsatisfactory. Twelve (12) or 24.0% of the respondents agreed that the waiting room service providers are willing to provide service in time. These results reveal that the service provided was considered to be satisfactory. Table 5 indicates further that 8(16.0%) of the respondents were uncertain that the waiting room service providers are willing to provide services in time. This result indicates that the quality of services provided by bus terminal service providers was considered to be neither satisfactory nor unsatisfactory. Six (6) or 12.0% of the respondents strongly disagreed that the waiting room service providers are willing to provide service in time. These results reveal that the service provided was considered to be very unsatisfactory. However, the respondents did not respond to a question on the aspect of strongly agree option. This result indicates that the service provided was not considered to be very satisfactory.

**Table 6: Total score values (TSV)**

| Service providers | Responses | | | | |
|---|---|---|---|---|---|
| | SA | Ag | Unc | DS | SD |
| Waiting room service provider | - (0) | 12 (48) | 8 (24) | 24 (48) | 6 (6) |

***Source:*** Field survey - 2011

Table 6 shows that TSV was between 0 and 48 which are below 150. These results mean unfavourable opinion. For that matter, service providers are not willing to provide service without delays. Furthermore, the result shows that service providers were considered to be not responsive. . In that sense, a service gap exists.

In measuring the relationship, the analysis shows that there is a significant correlation between responsiveness attributes and passengers' satisfaction. The relationships are presented in Table 7, which shows that passengers' satisfaction is associated with all responsiveness attributes at 0.05 and 0.01 significant levels.

**Table 7: Pearson's correlation coefficient between responsiveness attributes and passenger's satisfaction in the waiting room**

| S/N | Service | Corr. Coeff. | Coeff. of Determination |
|---|---|---|---|
| 1. | Waiting room services | .618 | 38.19% |

***Source:*** Field survey - 2011

The response for the waiting room services, indicate moderate degree of correlation, implying that passengers who will be fairly satisfied in these services will tend to get a reasonable satisfaction. Again, the Coefficient of determination ($r^2$) of these variables ranged from 0.0% to 38.19%, implying that the variation in satisfaction values is explained by those attributes. Therefore, an increase in willingness of service provider in providing service immediately leads to an increase of passengers' satisfaction at the waiting room services. This result implies that as the willingness in the provision of the promised services increases the passengers' satisfaction will also increases.

**Waiting room service providers vis-a-vis assurance attributes**

Question 3 asked the respondents to say whether or not the service provider/agent's employees have the knowledge and polite behaviour and ability to convey trust and confidence to their customers/passengers. The respondents marked one of the given options that best reflects their opinions. Their responses are illustrated in Table 8.

**Table 8: Frequency distribution of the respondents on waiting room service**

| Service Providers | | Responses | | | | | Total |
|---|---|---|---|---|---|---|---|
| | | Strongly agree | Agree | Uncertain | Disagree | Strongly disagree | |
| Waiting room service provider | Count | - | 14 | 2 | 20 | 14 | 50 |
| | % | - | 28.0 | 4.0 | 40.0 | 28.0 | 100.0 |

***Source:*** Field survey - 2011

Table 8 indicates that 22(40.0%) of the respondents disagreed that the waiting room service providers have the knowledge, polite behaviour, and the ability to convey trust and confidence to their customers/passengers. These results reveal that the service provided was considered to be unsatisfactory. Fourteen (14) or 28.0% of the respondents strongly disagreed that, the waiting room service providers have the knowledge, polite behaviour and the ability to convey trust and confidence to their customers/passengers. These results reveal that the service provided was considered to be very unsatisfactory. Table 8 indicates further that, 12(24.0%) and 8(17.0%) of the respondents agreed that the waiting room service providers have the knowledge, polite behaviour, and the ability to convey trust and confidence to their customers/passengers. This result indicates that the service provided was considered to be unsatisfactory. Two (2) or 4.0% of the respondents were uncertain that the waiting room service providers have the knowledge, polite behaviour, and the ability to convey trust and confidence to their customers/passengers. This result indicates that the quality of service was considered to be neither satisfactory nor unsatisfactory. However, the respondents did not respond to a question on the aspect of strongly agree option; this result indicates that the service provided was considered to be not very satisfactory.

Table 9 shows that TSV was between 4 and 14, that is below 150. This result means unfavourable opinion. For that matter service, provider/ agent's employees have not knowledge, polite behaviour, and the ability to convey trust and confidence to their customers/passengers. The result shows further that the service providers were considered to be unsure of the service they are providing. In this respect, a service gap exists.

**Table 9: Total score values (TSV)**

| Service providers | Responses | | | | |
|---|---|---|---|---|---|
| | SA | Ag | Unc | DS | SD |
| Waiting room service provider | - | 12 (4) | 2 (6) | 22 (4) | 14 (14) |

***Source:*** Field survey - 2011

The analysis using Pearson's Correlation Coefficient indicates a statistically significant linear relationship, between assurance attributes and passengers' satisfaction. The relationships are presented in Table 10, which show that passengers' satisfaction is associated with all assurance attributes at 0.05 and 0.01 significant levels.

The response indicates a moderate degree of correlation between assurance attributes and passengers' satisfaction in the waiting room services. This implies that passengers who will be satisfied with these services will tend to get a reasonable satisfaction. Again, Coefficient of

**Table 10: Pearson's correlation coefficient between assurance attributes and passenger's satisfaction in the waiting room services**

| S/N | Service | Corr. Coeff. | Coeff. of Determination |
|---|---|---|---|
| 1. | Waiting room services | .636 | 40.45% |

***Source:*** Field survey - 2011

determination ($r^2$) of these variables ranged from 0.0% to 40.45%, implying that the variation in satisfaction values are explained by those attributes. Therefore, an increase in knowledge and polite behaviour, and the ability to convey trust and confidence to their passengers leads to an increase of passengers' satisfaction in the waiting room services. This result implies that as the assurance in the provision of the promised services increases, the passengers' satisfaction also increases.

**Waiting room service providers vis-a-vis empathy attributes**

Question 4 asked the respondents whether the service provider's employees listen to every individual customer/passenger very carefully. The respondents marked one of the given options that best reflects their opinion. Their responses are illustrated in Table 11.

**Table 11: Frequency distribution of the respondents on waiting room service**

| Service Providers | | Responses | | | | | Total |
|---|---|---|---|---|---|---|---|
| | | Strongly agree | Agree | Uncertain | Disagree | Strongly disagree | |
| Waiting room service provider | Count | 1 | 12 | 4 | 20 | 13 | 50 |
| | % | 2.0 | 24.0 | 8.0 | 40.0 | 26.0 | 100.0 |

***Source:*** Field survey - 2011

Table 11 shows the majority of the respondents, 20(40.0%) disagreeing that the waiting room service provider's employees/agents listen to every individual customer/passenger very carefully. These results reveal that the service provided was considered to be unsatisfactory. Another 13(26.0%) of the respondents strongly disagreed that the waiting room service provider's employees listen to every individual customer/passenger very carefully. These results reveal that the service provided was considered to be very unsatisfactory. Table 11 shows further that 12(24.0%) of the respondents agreed that the waiting room service provider's employees/agents listen to every individual customer/passenger very carefully. This result reveals that the services provided were considered to be satisfactory. Four (4) or 8.0% of the respondents were uncertain that the waiting room service provider's employees listen to every individual customer/passenger very carefully, this result indicates that the quality of the services provided by bus terminal service provider's employees/agents was considered to be neither satisfactory nor unsatisfactory. Only 1(2.0%) of the respondents strongly agreed that the waiting room service provider's employees/ agents listen to every individual customer/ passenger very carefully. These results reveal that the service provided was considered to be very satisfactory.

Table 12 shows that TSV was between 5 and 48, which is below 150. This result means unfavourable opinion. For that matter, service provider/agent's employees do not listen to every individual customer/passenger very carefully. In that sense, a service gap exists.

The analysis using Karl Pearson's Coefficient of

**Table 12: Total score values (TSV)**

| Service providers | Responses | | | | |
|---|---|---|---|---|---|
| | SA | Ag | Unc | DS | SD |
| Waiting room service provider | 1 (5) | 12 (48) | 4 (12) | 20 (40) | 13 (13) |

***Source:*** Field survey - 2011

Correlation indicates a statistically significant linear relationship between empathy attributes and passengers' satisfaction. The relationships are presented in Table 13, which shows that passengers' satisfaction is associated with all empathy attributes at 0.05 and 0.01 significant levels.

**Table 13: Pearson's correlation coefficient between empathy attributes and passenger's satisfaction in the waiting room services**

| S/N | Service | Corr. Coeff. | Coeff. of Determination |
|---|---|---|---|
| 1. | Waiting room services | .746 | 55.65% |

***Source:*** Field survey - 2011

The response indicates a higher degree of correlation, implying that passengers who will be very satisfied these services will tend to be very satisfied. Coefficient of determination (r2) of these variables ranged from 0.0% to 55.65%, implying that the variation in satisfaction values is explained by those attributes. Therefore, an increase in listening to every individual customer/passenger very carefully leads to an increase of passengers' satisfaction at the Bus terminal. This result implies that as the empathy in the provision of the promised services increases the passengers' satisfaction will also increases.

**Waiting room service providers vis-a-vis tangible attributes**

Question 5 asked the respondents whether the appearance of physical facilities, equipment, personnel and communication materials are conducive to the provision of expected service quality. The respondents marked one of the given options that reflect their opinion. Their responses are illustrated in Table 14.

Table 14 shows that, majority of the respondents, 26(52.0%) disagreed that the appearance of waiting room's physical facilities, equipment, personnel and communication materials are conducive to the provision of expected service quality. These results reveal that the service provided was considered to be unsatisfactory. Ten (10) or 20.0% of the respondents strongly disagreed that the appearance of waiting room's physical facilities, equipment, personnel and communication materials are conducive to the provision of expected service quality. These results reveal that the service provided was considered to be very unsatisfactory. Table 14 shows further that 12(24.0%) of the respondents agreed that the appearance of waiting room's physical facilities, equipment, personnel and communication materials are conducive to the provision of expected service quality. This result reveals that a service provided was considered to be satisfactory. Two (2) or 4.0 of the respondents were uncertain that the appearance of waiting room's physical facilities, equipment, personnel and communication materials are conducive to the provision of expected service. This result implies that the quality of the services provided was considered to be neither satisfactory nor unsatisfactory. However, the respondents did not respond to a question on the aspect of strongly agree option, this result indicates that the service provided was considered to be not very satisfactory

Table 15 indicates that TSV was between 0 and 52 that are below 150. This result means unfavourable opinion. For that matter, the appearance of service provider/agent's

**Table 14: Frequency distribution of the respondents on waiting room service**

| Service Providers | | Responses | | | | | Total |
|---|---|---|---|---|---|---|---|
| | | Strongly agree | Agree | Uncertain | Disagree | Strongly disagree | |
| Waiting room service provider | Count | - | 12 | 2 | 26 | 10 | 50 |
| | % | - | 24.0 | 4.0 | 52.0 | 20.0 | 100.0 |

**Source:** Field survey - 2011

physical facilities, equipment, personnel and communication materials are not conducive to the provision of the expected service quality. In that sense, a service gap exists.

**Table 15: Total score values (TSV)**

| Service providers | Responses | | | | |
|---|---|---|---|---|---|
| | SA | Ag | Unc | DS | SD |
| Waiting room service provider | - | 12 (48) | 2 (6) | 26 (52) | 10 (10) |

***Source:*** Field survey - 2011

The analysis using Karl Pearson's Coefficient of Correlation indicates a statistically significant linear relationship, between tangible attributes and passengers' satisfaction. The relationships are presented in Table 16, which shows that passengers' satisfaction is associated with all tangible attributes at 0.05 and 0.01 significant levels.

**Table 16: Pearson's correlation coefficient between tangibles on bus terminal attributes and passenger's satisfaction in the waiting room services**

| S/N | Service | Corr. Coeff. | Coeff. of Determination |
|---|---|---|---|
| 1. | Waiting room services | .887 | 78.68% |

***Source:*** Field survey - 2011

The responses indicate a higher degree of correlation, implying that passengers who will be very satisfied in these services will tend to be very satisfied in other services. This implies that passengers who will be satisfied with one of the items will tend to be reasonably satisfied with other items. Moreover, coefficient of determination (r2) of these variables ranged from 0. 0% to 78.68%, implying that the variation in satisfaction values is explained by those attributes. Therefore, as conduciveness of the appearance of physical facilities, equipments, personnel and communication materials increases, the passengers' satisfaction at the waiting room will tend to increase. This result implies that as the tangibles in the provision of the promised services increases the passengers' satisfaction will also increase.

**Discussion of Findings**

When the test was conducted regarding reliability, responsiveness, assurance, empathy and tangibles on the waiting room services, the result shows that majority of the respondents 14(28.0%), 24(48.0%), 22(40.0%), 20(40.0%) and 26(52.0%) respectively revealed unfavourable opinions. This result implies that services at waiting room are provided with mistakes or promised are not honoured totally.

Customer satisfaction has developed extensively as a basic concept for monitoring and controlling activities in the area of relationship marketing (Rust & Zahorik 1993). This is supported by researcher's observations that, there were no Public Address Systems installed at Ubungo bus terminal waiting room. In that sense arrival, departures and some relevant information on things like delays are not announced. Service providers are unable to provide correct arrival and departure times for buses as in the main they depend on time estimations. This is supported by results in Table 14 where the majority of respondents 26(52.0%) disagrees that the waiting rooms physical facilities are not conducive to the provision of services. It was observed further that there were no clocks installed at prominent places visible to passengers and service providers, which often affect the service providers required to offer services in time. It was observed that there are not special place reserved for tired passengers to rest, as a result tired passengers are sleep on the floor waiting for services.

The data obtained shows that there is a big number of unauthorised traders, which, often encroach on the passengers and obstruct the flow. It was further observed that there were no special facilities for disabled passengers. The requirement of disabled passengers are not taken

into consideration, the principal requirement would be toilets, which could be accessible by disabled passengers. However, it was observed that there are no high visibility barriers, signs, and textured surfaces for the benefit of the blind or partially sighted passengers.

The information obtained from the respondents revealed that employees of the registered waiting room service provider have no knowledge, skills and ability to convey trust and confidence to their customers. This is mainly explained by very limited training if any, and hence they are characterized by ignorance and lack of confidence. In most cases, employees` behaviour is not in line with what is stipulated in the Transport licensing Act of year 2007. According to URT (2007), no crew of passenger vehicle while on duty shall demonstrate the following behaviour;

(a) Using hostile and abusive language to passengers;
(b) Block or obstruct intentionally other service providers;
(c) Driving above the maximum speed limits in competition of passenger pick up;
(d) Terminating journey before reaching final destination without reasonable cause;
(e) Driving under the influence of alcohol;
(f) Driving in careless or reckless manner or in the manner contrary to the provisions of Road Traffic Act and other laws;
(g) Mistreating or harassing passengers or they would be passengers;
(h) Driving while attending to mobile phone; and
(i) Carry live animals or dangerous load goods in the licensed motor vehicle.

## CONCLUSION

It is highlighted in this study that there is existing gap of knowledge from the reviewed literature addressing bus terminal services. The empirical literature discussed supports the importance of carrying out this study in Tanzania. This study therefore, aimed to provide more insight on the dimensions of quality of service amongst passenger's satisfaction at Ubungo bus terminal the waiting room services in particular. Therefore, this study intended to reveal the importance of the application of the service quality dimensions in service marketing.

In order to satisfy customers at Ubungo bus terminal, service providers should improve waiting room services. This being the case therefore, a change towards positive direction is inevitable. These changes would bring innovative mobility strategies and meet passenger's satisfaction, which would subsequently improve the quality of living of the urban residents through improved mobility options. That needed change is a shifting from the present unorganised, uncoordinated, and unsatisfactory public transport system to a more organised, coordinated and satisfactory transportation system. In this respect therefore, there is a need to have modern waiting room at Ubungo bus terminal that would provide the required level of service at the same time fulfilling current and future needs of travellers. Therefore, selection of suitable employees, as well as subsequent training and motivation are essential for the waiting room service providers at Ubungo bus terminal.

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**LIST OF ABBREVIATIONS**

| | |
|---|---|
| ISO | International Standards Organization |
| SERVIQUAL | Service Quality Framework |
| SPSS | Statistical Package for Social Science |
| SUMATRA | Surface and Marine Transport Regulatory Authority |
| TAZARA | Tanzania Zambia Railway Authority |
| TRL | Tanzania Railway Limited |
| TSV | Total Score Value |
| URT | United Republic of Tanzania |

# The Combustion Characteristics of Biomass Syngas from High Temperature Air, Entrained Flow and Circulating Fluidized Bed Gasifiers

***Mahir M. Said[1], Geoffrey R. John[1], Cuthbert F. Mhilu[1], Samwel V. Manyele[2]**

[1]Department of Mechanical and Industrial Engineering and Technology,
University of Dar es Salam, Dar es Salaam, Tanzania
*Corresponding Author: mahir@udsm.ac.tz, Tel: +255 717 829871

[2]Department of Chemical and Mining Engineering, University of Dar es Salaam,
Dar es Salaam, Tanzania

**Abstract**

*The study has been performed to determine fundamental combustion characteristics of syngas. Three technologies were selected to produce the syngas; High Temperature Agent Gasifier (HTAG), Entrained Flow Gasifier (EFG) and Circulating Fluidized Bed Gasifier (CFBG). Although the material used for production of syngas was the same, wood biomass, the compositions of syngas obtained were different. The adiabatic flame temperatures were determined at different air to fuel ratio. The maximum adiabatic temperature for HTAG, EFG and CFBG syngas at stoichiometric condition were 1846 K, 2250 K and 2234 K respectively. It has been observed that combustion of CFBG syngas produces more nitrogen oxide (NOx) than when using syngas of EFG. The high NOx in CFBG is caused by the high methane content, which increases the adiabatic flame temperature to 2200 K at stoicheometric condition. The lowest NOx emission was observed in HTAG syngas. The adiabatic temperature increased linearly with the preheating temperature, whilst oxygen enrichment increased the adiabatic temperature. It has been concluded that syngas produced from EFG and CFBG are better candidate as gaseous fuel in combustion chamber than HTAG syngas.*

***Keywords:*** Adiabatic Temperature, Circulating Fluidized Bed Gasifier, Syngas, Combustion, Entrained Flow Gasifier, High Temperature Agent Gasifier.

## INTRODUCTION

Biomass consists of variable moisture content, fibrous structure (lignocellulose) and carbohydrate or sugar. The major part of biomass is lignocellulose and unlike carbohydrate material type which belongs to food chain, lignocellulose in nature cannot be digested (Basu, 2010). Since it is not part of the food chain, there has been a growing interest for energy production as it does not threaten the world's food supply.

The lignocellulose consists of cellulose, hemicelluloses and lignin. The composition of these elements in lignocellulose by percentage weight varies in different biomass species. For most lignocellulosic biomass materials, the composition of cellulose is in the range of 40 – 50 wt%, whereas hemicellulose accounts between 25 and 35 wt% and lignin is around 16 – 33 wt% (Mohan et al., 2006). Biomass possess calorific value lower than that of coal, due to high oxygen content in biomass. The oxygen content in the biomass is about 40%, while that of coal is between 7 to 17% (Basu, 2010).

The conversion of biomass into gaseous fuel (syngas) that can be used in combustion chambers (furnaces) can be achieved through gasification. During this process biomass is partially oxidized at high temperature typically in the range of 800 – 900 (Mckendry, 2001). There are three types of gasifiers; these are

fixed bed, fluidized bed and entrained flow gasifiers. This paper discusses the combustion characteristics of biomass syngas from fixed bed, fluidized bed and entrained flow gasifiers, which are represented by High Temperature Agent Gasifier (HTAG), Circulating Fluidized Bed Gasifier (CFBG) and Entrained flow Gasifier (EFG) respectively.

The gasification agent can be air, oxygen, steam or their mixture, while the available technologies are using air or steam. Figure 1 represents biomass conversion process. The three corners of the triangle represent pure carbon, oxygen and hydrogen. The side opposite to a corner with a pure component represents zero concentration of that component. A biomass fuel is closer to the hydrogen and oxygen corners compared to coal. This means that biomass contains more hydrogen and more oxygen than coal contains. Coal resides further toward the carbon corner and lies far to the oxygen corner in the ternary diagram, suggesting that it is very low in oxygen and much richer in carbon. The ternary diagram can be used to describe the conversion process. Carbonization or slow pyrolyis moves the products toward carbon through the formation of solid char, while fast pyrolysis moves it toward hydrogen and away from oxygen, which implies higher liquid products (hydrocarbons). Oxygen gasification moves the gas toward the oxygen corner, while steam gasification takes the process away from the carbon corner (Mckendry, 2001).

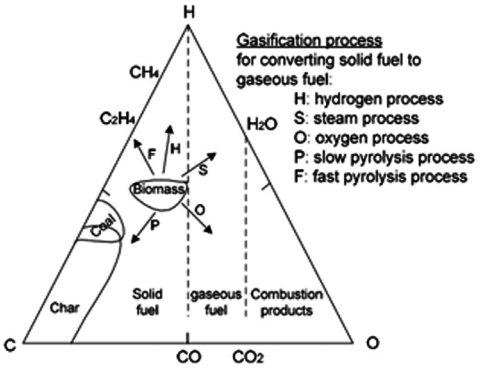


**Figure 1: C-H-O ternary diagram of gasification process (Basu and Kaushal, 2009)**

The most common gasification technologies are Circulating Fluidized Bed Gasifier (CFBG) and Entrained Flow Gasifier (EFG), the syngas from these technogies is going to be compaired with the sygan from High Temperature Agent Gasifier (HTAG). In the CFBG, the biomass is added directly to the bed material and is heated under the oxidation medium (generally air or oxygen, steam is included in the mixture). The velocity is sufficient enough to suspend the bed particles throughout the entire reactor. The sand and char which leave the reactor are separated from the vapors by a cyclone and are returned back to the bed. The syngas passes through the cyclone and further on in the system as shown schematically in Figure 2. The CFB is generally operated at temperatures between 1073 K (800) and 1273 K (1000), yielding a gas containing low concentration of tar.

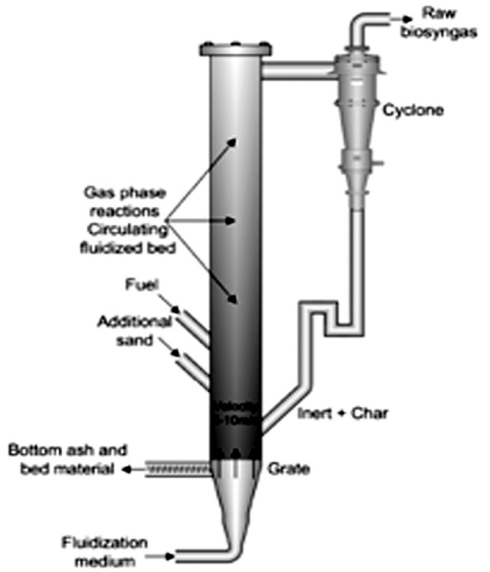


**Figure 2: Circulating fluidized bed gasifier**

The entrained flow gasifier is shown schematically in Figure 3. It is operated at higher temperature more than 1473 K (1200 ) (Hansson *et al,* 2011) and residence time in the range of 0.6-2 s (Van der drift et al, 2004), which is shorter than other type of gasifiers.

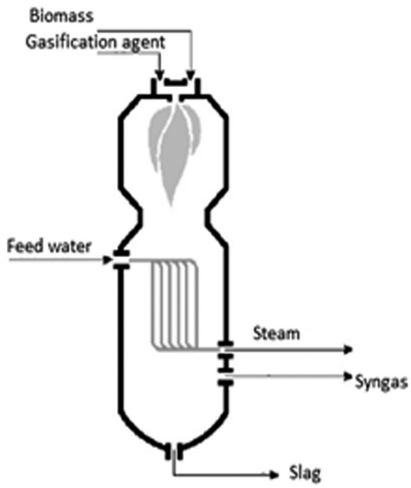


**Figure 3: Entrained flow gasifier**

Very fine particles of biomass less than 1 mm are required since they have to react at a short residence time. The reaction temperature is above 1473 K at moderate pressure between 20 and 50 bar (Basu and Kaushal, 2009). The main products of the entrained flow gasifier are hydrogen and carbon monoxide, other products are produced in small amount, and these are carbon dioxide and methane.

Figure 4 shows the principle of the HTAG-concept, by which biomass is fed at the top and the high temperature agent is supplied at the bottom and permeates through the biomass. The biomass lies on a grate through which high temperature agent is introduced.

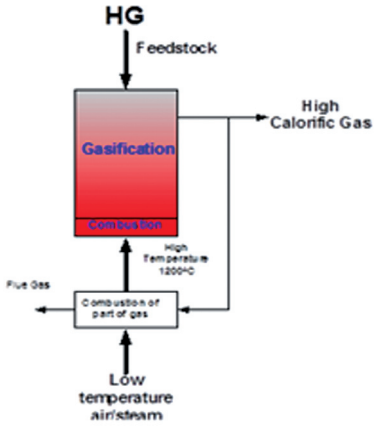


**Figure 4: HTAG operation**

The bed is divided into four zones due to processes that take place. The first zone is oxidation zone, where combustion takes place at the bottom of the bed, the carbon dioxide and water vapor are formed at this zone and the temperature at this zone is around 1273 K (1000). The second zone is reduction zone, where the hot gases from the combustion are reduced to hydrogen and carbon monoxide at this zone the temperature decreases to 1023 K (750). Further up is the third zone, where the reducing gases pyrolyse the downward flowing biomass and produce tars and other products of incomplete gasification. The fourth zone is called drying zone, where gas dries the incoming biomass and then leaves the reactor. The gas leaves the reactor at about 773 K (500) and part of the produced gas is used in a regenerative pre-heater. The regenerative pre heater is used to pre heat the temperature agent to about 1273 K (1000). Yang *et al* 2006 analyzed the performance of HTAG and observed that increasing of feed gas temperature provides high gasification rate and high molar fraction of hydrogen, carbon monoxide and hydrocarbons, which increases the calorific values of the product gas.

**Syngas Production and Combustion Technologies**

The chemical reactions resulting in syngas takes place in a gasification process, when steam is used as gasification agent are given in Equations 1-4.

$$C+H_2O \leftrightarrow CO+H_2 \quad (1)$$

$$C+CO_2 \leftrightarrow 2CO \quad (2)$$

$$CO+H_2O \leftrightarrow CO_2+H_2 \quad (3)$$

$$CH_4+H_2O \leftrightarrow CO+3H_2 \quad (4)$$

The evolving syngas can have low heating value of 4 to 6 MJ/Nm$^3$ when air is the gasification agent. A medium calorific value gaseous fuel with a heating value of 9-13 MJ/Nm$^3$ is predominant where the gasification agent is oxygen and /or steam. The syngas is suitable for combustion processes, but low calorific syngas cannot attain high temperatures required in some combustion processes. Franscisco *et al.,* 2009 studied the combustion characteristics of gaseous fuel with low calorific value (syngas

of different composition) in a porous burner at an equivalent ratio of 0.5. The results revealed that the radiation efficiency of the syngas was between 20 and 30%, which is smaller than that of pure methane at 35%. The flame structure of syngas performed a larger flame length than that of pure methane. Other pioneers in the development of low carlorific gaseous fuels are the Bio-Pro. Bio-Pro have developed FLOX and COSTAIR burners, which have been tested in turbines (Berger, 2007).

## METHOD AND MATERIAL

The combustion of syngas was done at different conditions, in order to determine the effect of the following parameters:

- Air to fuel ratio (λ)
- Oxygen concentration
- Pre-heating temperature

During the combustion process the adiabatic temperature, the enthalpy of reactant and the enthalpy of the product were determined. The adiabatic temperature and composition at constant pressure was used in this study. In this method the temperature of the products was adjusted until the equilibrium composition had an enthalpy which was the same as that of the reactants. Under adiabatic combustion the enthalpy of reactants for all combustion reactions is equal to enthalpy of products for all combustion products as shown in Equation 5 (Turns, 2000).

$$H_{reac}(T_i,P)=H_{prod}(T_{ad},P) \quad (5)$$

Three different compositions of syngas were used during the combustion simulation; syngas from Entrained Flow Gasifier (EFG), High Temperature Air Gasification (HTAG) syngas and Circulating Fluidized Bed Gasifier (CFBG) syngas, the detail composition of the gases is given in the proceeding section. The experiments were done at different conditions; fuel rich, fuel lean, stoichiometric condition and at different oxygen concentrations. The combustion process is governed by the chemical reactions in Equation 6 to 8.

$$2H_2+(O_2+3.76N_2)\rightarrow 2H_2O+3.76N_2 \quad (6)$$

$$2CO+(O_2+3.76N_2)\rightarrow 2CO_2+3.76N_2 \quad (7)$$

$$CH_4+2(O_2+3.76N_2)\rightarrow CO_2+2H_2O+2(3.76N_2) \quad (8)$$

REGEMAT 350 FLOX burner shown schematically in Figure 7 was used to study the combustion characteristics of syngas. It is a regenerative type that heats combustion air to 950oC with a cycle time of 10 seconds. During operation, 80% of flue gas is extracted through the regenerator. In order to study the upper extreme of energy utilization efficiency, the regenerative burner was also operated with oxygen enriched and preheated air. Up to 29% of oxygen enrichment was tested in this work. This case was named as OE, (Oxygen Enrichment).

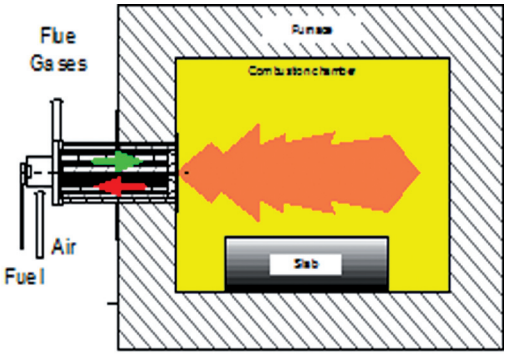


**Figure 5: Scheme of flame in REGEMAT 350 FLOX**

## RESULTS AND DISCUSSION

The composition of syngas produced from EFG, HTAG and CFBG technologies are shown in Table 1. The sygas from EFG has high hydrogen content of 27.2%, CO of 32.1% and CH4 of 15.2%, syngas from EFG has higher energy content (calorific value) than syngas from CFBG and HTAG. The lower energy content of syngas from HTAG is due to high content of nitrogen.

### Combustion of syngas at different air to fuel ratio (λ)

The syngas combustion at different air to fuel ratio **(λ)** enable to analyze the adiabatic temperature, usually the maximum adiabatic temperature of a fuel is obtained, when **(λ)** equals to 1, which means at stoichiometric condition. The excess air increases the mass of flue gas relative to mass of fuel, which implies to corresponding reduction in flame temperature. Also when air

**Table 1: The properties of syngas from EFG, HTAG and CFBG technologies**

| Component | EFG | HTAG | CFBG |
|---|---|---|---|
| Hydrogen (% wt) | 27.2 | 13.7 | 14.9 |
| Carbon monoxide (% wt) | 32.1 | 13.1 | 35.6 |
| Carbon dioxide (% wt) | 14.0 | 8.2 | 14.6 |
| Methane (% wt) | 15.6 | 10.0 | 24.9 |
| Nitrogen (% wt) | 11.1 | 55.0 | 10.0 |
| Low Heating Value (MJ/Nm3) | 9.5 | 5.6 | 8.2 |

is deficient (sub-stoichiometric) the temperature is reduced, because the effective calorific value of the fuel is reduced by the amount equivalent to the calorific value of carbon monoxide which is present in the flue gas. Due to that reasons the high adiabatic temperature is obtained under stoichiometric condition.

Figure 6, Figure 7 and Figure 8 show the variation of adiabatic temperature with λ of EFG, HTAG and CFBG syngas, while Figure 9 shows the comparison of the syngas combustion. The maximum adiabatic temperatures were 2250 K, 1846 K and 2234 K of the respective syngas, also the adiabatic temperature was above 1700 K when λ was between 0.5 to 1.2 for EFG and CFBG syngas, while for HTAG syngas the temperature above 1700 K was obtained when λ is between 0.9 and 1.1. Figure 9 shows the comparison of adiabatic temperatures of the syngas combustion from the three technologies.

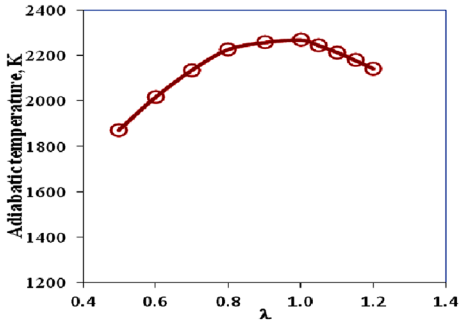


**Figure 6: Adiabatic temperature of EFG syngas at different λ**

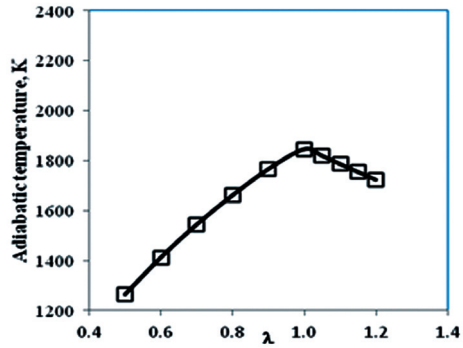


**Figure 7: Adiabatic temperature of HTAG syngas at different λ**

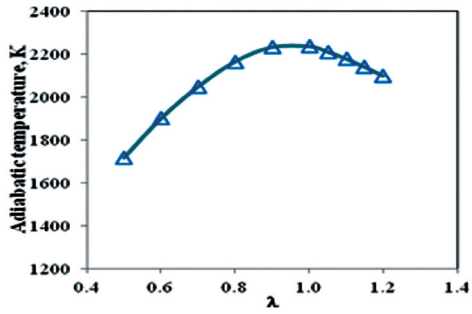


**Figure 8: Adiabatic temperature of CFBG syngas at different λ**

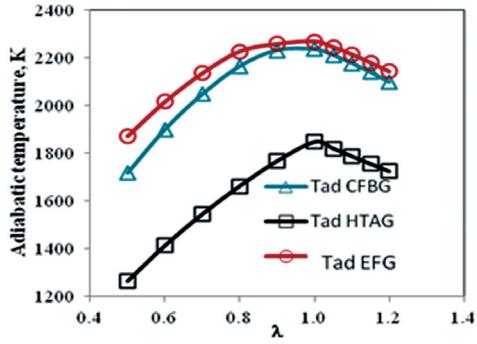


**Figure 9: Comparison of adiabatic temperature of syngas from EFG, HTAG and CFBG technology**

**Effect of oxygen enrichment during syngas combustion**

High adiabatic temperature was obtained by oxygen enrichment. During this process the fuel is easily oxidized since the amount of nitrogen is small, causes the high adiabatic temperature

and reduces the mass of the flue gas. Figure 10 shows the oxygen enrichment of the syngas from HTAG, EFG and CFBG.

The CFBG and EFG curve overlapped each other; this means they almost produced the same adiabatic temperature. It has been observed that adiabatic temperature above 2200 K was obtained during combustion of EFG and CFBG syngas under oxygen enrichment and HTAG has adiabatic temperature below 2500 K. Rapid increase of adiabatic temperature was observed between 21% and 40% oxygen enrichment, a slow increment of the adiabatic temperature was observed above 40% oxygen enrichment.

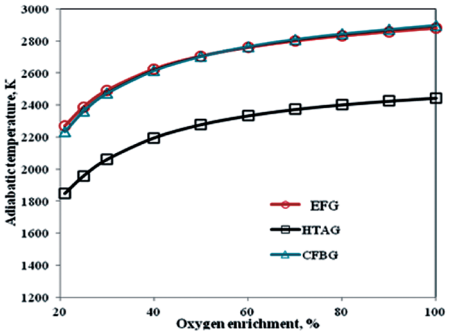


**Figure 10: Adiabatic temperature vs oxygen enrichment during syngas combustion**

**Effect of Pre-heating temperature**

The preheating process increases the adiabatic temperature linearly, as shown in Figure 11. The EFG syngas has higher adiabatic temperature than other syngas. HTAG syngas has low adiabatic temperature because it contains nitrogen; the nitrogen is an inert gas.

Although oxygen enrichment increases the adiabatic temperature, the preheating temperature seemed to increase the adiabatic temperature linearly, by combining these two processes high adiabatic temperature can be obtained as shown in Figure 12 to Figure 15. If both oxygen enrichment and preheating temperature were used, they could produce high adiabatic temperature.

The increase of the adiabatic temperature during oxygen enrichment is due to increase of enthalpy change between the reactant and product as shown in Figure 16 and Figure 17. The energy released is obtained by taking the difference between enthalpy of product and the enthalpy of reactant at same temperature,

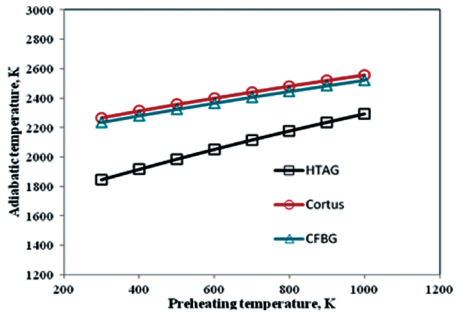


**Figure 11: Variation of adiabatic temperature at different preheating temperature**

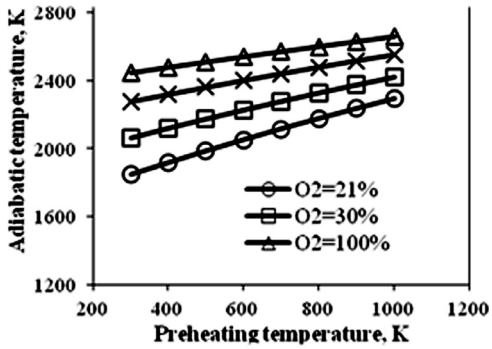


**Figure 12: Oxygen enrichment during HTAG syngas combustion**

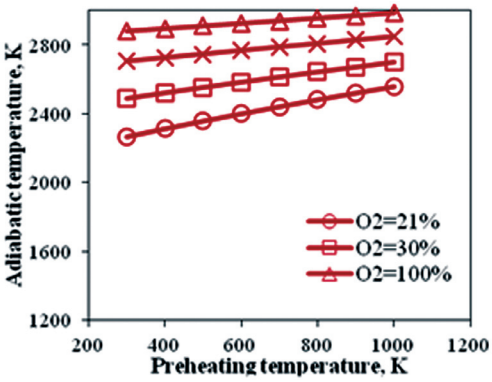


**Figure 13: Oxygen enrichment during EFG syngas combustion**

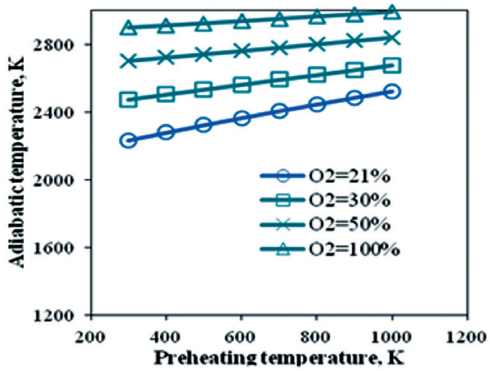


**Figure 14: Oxygen enrichment during CFBG syngas combustion**

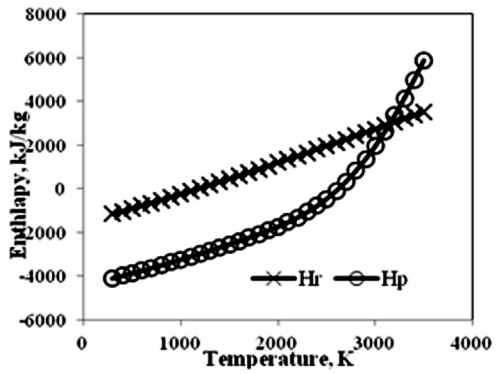


**Figure 16: Syngas combustion under stoichiometric condition**

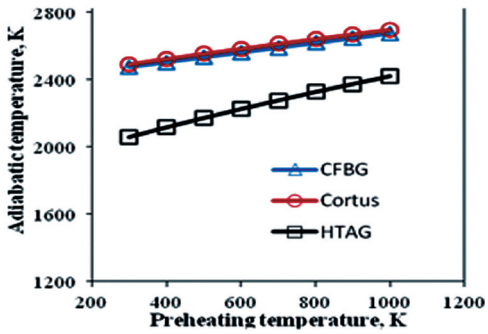


**Figure 15: 30% Oxygen enrichment for EFG, HTAG and CFBG syngas combustion**

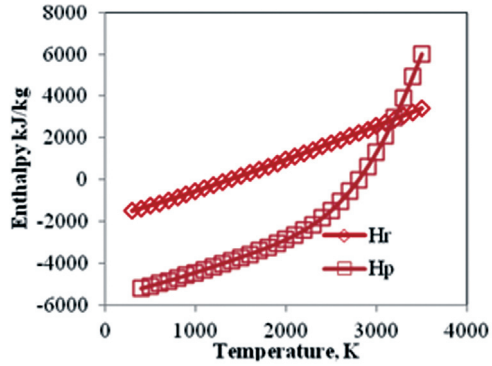


**Figure 17: Enthalpy change under Oxygen enrichment 30%**

so the area between the curves of enthalpies of reactants and products is the energy released during combustion process, the area covered during oxygen enrichment is larger than that during stoichiometric condition as shown in the combined diagram of Figure 18.

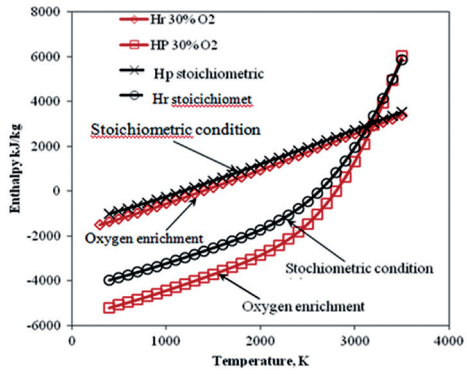


**Figure 18: Combined enthalpy changes during stoichiometric and oxygen enrichment condition**

**NOx formation during Syngas Combustion**

The NOx that was produced during the syngas combustion is thermal NOx as shown in Figure 19, the NOx produced is due to high temperature. This is because thermal NOx generally takes place above 1500 K (Whitty *et al,* 2009). Those fuels that have high adiabatic temperature produce high thermal NOx. This can be shown clearly in Figure 20, the EFG and CFBG syngas produce more NOx than HTAG syngas. It has also been observed that during combustion of CFBG syngas produces more NOx than EFG, the high NOx in CFBG is caused by the high methane content, because the adiabatic flame temperature of methane ($CH_4$) is 2223 K (1950), which causes thermal NOx (Chaos and dryer, 2008).

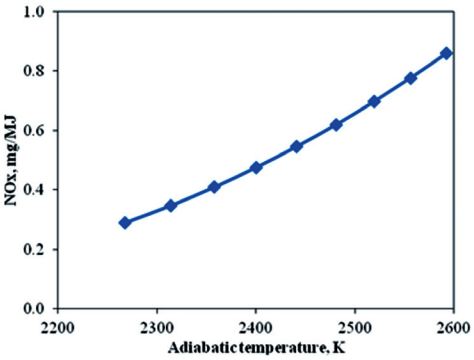


**Figure 19: Thermal NOx produced at different adiabatic temperature**

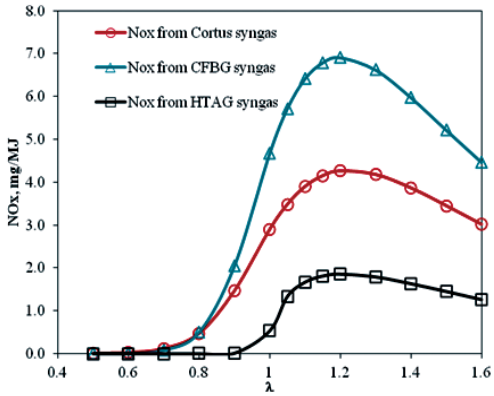


**Figure 20: Variation of NOx formation with air to fuel ratio**

Figure 20 shows that in fuel rich less NOx is formed, this is because all the oxygen is consumed by fuel, while in fuel lean there is excess of oxygen, therefore some part of it is used to oxidize nitrogen to form NOx. The thermal NOx can be reduced by one of the following technologies; flameless, HiTAC or air staging combustion.

## CONCLUSIONS

The high adiabatic temperature is obtained, when air to fuel ratio is equal to one (stoichiometric condition), increasing and reduction of air reduce the flame temperature. Syngas from EFG and CFBG produce high adiabatic temperature between 2200 and 2900 K, while the syngas from HTAG has adiabatic temperature below 2500 K during oxygen enrichment combustion. The preheating temperature of sygan is linearly related to the adiabatic temperature, but also the syngas from CFBG and EFBG has higher adiabatic temperature than syngas from HTAG. The lower adiabatic temperature of syngas from HTAG is due to high nitrogen content. In addition to that the energy release was high during oxygen enrichment, which causes higher adiabatic temperature than stoichiometric condition. Therefore syngas from EFG and CFBG are more suitable to be used as gas fuel in combustion chambers than syngas from HTAG. On the other hand high thermal NOx was observed during combustion of EFG and CFBG syngas, but the NOx of CFBG syngas is higher than that of EFBG due to high content of methane.

## ACKNOWLEDGEMENT

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**NOMENCLATURE**

| | |
|---|---|
| CFBG | Circulating Fluidized Bed Gasifier |
| EFG | Entrained Flow Gasifier |
| HTAG | High Temperature Agent Gasifier |
| OE | Oxygen Enrichment |
| λ | Air to fuel ratio |

# Evaluation of Biogas Generation from Animal Wastes Biomass for Use in Automobile Engines

**[1]Z.M. Mganilwa, [1]P. Ibrahim, [2]K. Iwasaki, [2]F. Tanaka**

[1]Department of Transport Engineering and Technology, National Institute of Transport
P. O. Box 705, Dar es Salaam Tanzania
Email: *zacharia.mganilwa@nit.ac.tz or mganilwaz@yahoo.com*

[2]Laboratory of Food and Agricultural Processing Engineering,
Kagoshima University, Koorimoto 1-21-24, Kagoshima City, Japan

**Abstract**

*Recent environmental concerns and the fuel crisis have prompted significant research into alternative energy sources to fossil fuels. Fossil fuel prices have been unstable and there is concern about their vexation. Biogas has been considered as a possible replacement source of energy to power diesel engines. This study was conducted to assess the generation of biogas from biomass of three animal wastes of chicken, cow and pig. Batch experiments were conducted with biomass of the three animal wastes. The rate of biogas production was found to be 2.467 L/kg, 1.433 L/Kg and 1.483 L/Kg per day for chicken, cow and pig animal wastes, respectively. The produced biogas could be used to power a four stroke diesel engines as an alternative source of fuel. Therefore, millions of tons of animal wastes produced annually in developing countries could potentially power diesel engines to generate mechanical power to do useful work including transportation, farming, electricity generation and crop processing.*

***Key words:*** biomass, animal wastes, biogas, diesel engine, electricity generation

## INTRODUCTION

Biomass has been used as a source of energy throughout history and remains to be an important component of national energy supply in many countries today. It is estimated that biomass accounted for 43% of the energy consumed in developing countries, and one seventh of the total energy consumed in the developed countries (Kitani and Haw, 1989; Larget *et al.,* 2003). The estimated average value of biomass energy consumed in developing countries according to the World Energy Council (WEC) was 15GJ/t per person per year, and approximately 0.5 tones in semi urban (WEC, 2004). The consumption of biomass energy is highly variable in different locations due to factors such as supply, climatic differences, population, economic development and cultural factors.

It is well known that biomass is a very poorly documented energy source. Indeed, the lack of data has hampered sound decision-making when it comes to biomass energy. Despite a number of efforts to improve biomass energy statistics, the inability to fully address the indigenous biomass resource capability, and its likely contribution to energy supply and development, is still a serious constraint to the full realization of its energy potential (WEC, 2009; Rosolio-cell, 2004).

Animal waste biomass has the potential to produce biogas (Itodo and Awulu, 2002). The main components of biogas are methane and carbon dioxide. It also contains hydrogen sulfide, ammonia, oxygen and water vapors. The percentage of each component differs according to feed material and other conditions. It is considered to be one of the renewable sources of energy and it is popular in most rural areas.
Biogas is a non-poisonous and non-toxic gas. When mixed with air it burns with a heating value of 4713Kcal/cu with a blue flame, no soot

or offensive smell. The efficiency of the direct burning of biogas for cooking depends largely on the efficiency of the burner used. Most burners are rated at around 55-60% efficiency (Saxena, 2004). Persson and Bartlett (1981) reported that one cubic meter of biogas comprising 55-70% methane, produces energy equivalent to 0.6L of oil fuel or 6.36 KN/h.

Biogas can also be used as a source of light in rural areas where electricity is not available. Biogas lamps are similar to kerosene lamps and they provide light equivalent to 100 candles with an illumination power of 60W (Stout, 1989).

Recent environmental concerns and the fuel crisis have prompted significant research into alternative energy sources to fossil fuels. Fossil fuel prices have been unstable and there is concern about their vexation. Biogas has been considered as a possible replacement source of energy to power engines (Livestock and Sciences, 2004). A number of experiments using biogas to power engines have shown positive results, however there are many things yet to be clearly understood in its use.

Biogas was found to have a calorific value of 25,000KJ per cubic meter, or 38,400KJ per Kg, with a high octave number (resistance to spontaneous combustion). This makes it ideal for use in internal combustion engines (Picken, 1989; Lubrizol Cooperation, 2004).

It is estimated that potential energy generation from manure is approximately 20EJ worldwide (Wood and Hall, 1994). This amount of energy varies, however, depending on livestock type, feeding conditions and the method of energy recovery. Different researchers have reported different rates of biogas yield from different animal waste and biomass. Converse and Grave (1974) reported a yield of 0.9 $m^3$ to 2.0 $m^3$ per day from cattle and poultry waste. The Environmental Impact of Production and Uses of Energy (ESCAP) reported a biogas yield of 0.0225, 0.025, 0.045, and 0.0075m3/kg from the fresh waste of humans, cattle, pigs and poultry respectively (ESCAP, 1980). Gohary reported a range of 22-40, 40-60, 20-28, 30-40 and 40-50 m3/ton for dairy cattle, pig, human, crop residues and water hyacinth respectively, and 60-115 $m^3$ /ton for poultry waste (Appropriate Technology, 1980). Hughes (1989) reported a biogas yield of 219, 325, 381, and 490 L/Kg for dairy cattle, pigs and poultry waste respectively.

The results of most researchers show that the majority of animal wastes perform satisfactorily in terms of gas yield when they are used in anaerobic fermentation to produce biogas. For the purpose of accurate energy planning, it is important that the biogas yield from different animal wastes is researched under local conditions. This study was conducted to evaluate the biogas production rate of various Japanese animal wastes for use as an alternative fuel in diesel engines.

## MATERIAL AND METHODOLOGY

### Study Area

This study was carried out in the Food and Agricultural Engineering laboratory of Kagoshima University, Japan. The average temperature throughout the experiment period was 25°C. In this environment, the experiment was conducted in a water bath with an automatic temperature control device to ensure the survival of the bacteria.

### Experimental procedures for production of biogas

Batch experiments were carried out using pig, chicken, and cow wastes. Rice straws were used as experimental control. Raw waste of 150 g from cow, pig and chicken were mixed with 150 g of sludge from the pilot plant used to treat pig wastes and this made a 300 g sample which was then placed in a 1 litre flask. For the rice straws 100 g of the dry sample was mixed with 50 g of water to improve its moisture content to produce a sample of 150 g and then this sample was mixed with the sludge (seed) 150 g to produce a total of 300 g, which was then put into 1 litre flask.

Both flasks were sealed and nitrogen gas was pumped in to replace oxygen and create a

perfect anaerobic condition inside the flasks. Flasks were then placed into a water bath with temperature kept at 55°C throughout the experimental time.

The gas was collected under water displacement in measuring cylinders. Measurements of gas percentage were done using a Shimadzu Gas Chromatograph Gc-8A connected to a plotter Shimadzu Chromatopac C – R8A. The gas percentage measurement was done every 12 hours, gas volume was taken every 6 hours and the total time for the experiment was 15 days for each set of experiment.

**Apparatus and Equipments**

The apparatus and equipment used in the experiment are the HACH for measurement of COD and T-N, Portable Total organic carbon analyzer (SIEVERS 810) for measurement of TOC, Heaters for heating the COD samples before measurement, oven for drying sample for the determination of TSS, Centrifuge for preparing sample for the T-N measurement and Gas Chronograph for measuring gas percentage of the samples.

**Chemical material used**

The main chemicals used were the reagents for the determination of T-N, COD and the dilution chemicals. Reagents used are HR+ COD and Ammonia cyanurate reagent. Dilution chemicals were the $H_2SO_4$ acid and Sodium hydroxide (Na $OH_2$) for the dilution of the cellulose and solid particles.

**Analytical Procedures**

The following parameters were monitored throughout the experimental time: volume of gas produced and gas percentage; Total suspended solid (TSS); Chemical oxygen demand (COD); Total Nitrogen (T-N); Volatile soluble solid (VSS); and Moisture content.

The data obtained from the above readings were used to calculate the following basic experimental parameters; T-N removed; COD removed; TOC removed; and TSS removed.

## RESULTS AND DISCUSSION

**Initial and final characteristics of experimental materials**

Table 1 shows the characteristics of the raw wastes and rice straw used in the experiment. The COD of 161,000 mg/l for rice straw was the highest and lowest been 13,000mg/l for the inoculums. Ammonia concentration was the highest for chicken waste (1,865mg/l) and pig waste had 1,570mg/l, and rice straw had the highest TOC of 64,500 ppm. The moisture content varied from 88.69% for the inoculums to 45.6% for the cow waste. The inoculums had a lower TSS of 11.31% and the cow waste had the highest TSS of 54.35%. The carbon nitrogen ratio was highest for rice straw (2,150) and lower for pig waste (10.9).

Tables 2 and 3 show characteristics of the samples at the start and end of experiment one. Table 2 shows that chicken waste and cow waste had the highest and lowest values of ammonia of 1, 245 mg/l and 115 mg/l respectively. Pig waste and rice straw had medium values of 710 mg/l and 290 mg/l respectively. Table 3 shows the percent of COD, TOC and TSS removed which varied from 35% to 77%.

**Table 1 Analytical characteristics of Original Animal waste and Rice straws**

| Measurements | Chicken | Cow | Pig | Rice straw | Inoculums |
|---|---|---|---|---|---|
| T-NH3 (mg/l) | 1,865 | 435 | 1,570 | 30 | 75 |
| COD mg/l) | 49,500 | 100,000 | 52,500 | 161,000 | 13,000 |
| TOC (ppm) | 20,800 | 36,700 | 17,150 | 64,500 | 5,400 |
| Moisture content (%) | 78.15 | 45.65 | 77.60 | 69.04 | 88.69 |
| TSS (%) | 21.85 | 54.35 | 22.40 | 30.96 | 11.31 |
| VS (%-DS) | 79.60 | 63.56 | 88.81 | 82.28 | 72.04 |
| C/N ratio | 11.2 | 84.4 | 10.9 | 2150.0 | 72.0 |

**Table 2: Characteristics of the samples mixed with inoculum at the start of experiment one**

| Measurement | Chicken | Cow | Pig | Rice straw |
|---|---|---|---|---|
| T-NH3 (mg/l) | 1,245 | 115 | 710 | 290 |
| COD mg/l) | 40,500 | 54,500 | 31,500 | 62,000 |
| TOC (ppm) | 14,250 | 21,600 | 11,850 | 22,650 |
| Moisture content (%) | 81.50 | 64.54 | 83.17 | 69.01 |
| TSS (%) | 18.50 | 35.46 | 16.83 | 30.99 |
| VS (%-DS) | 74.94 | 64.22 | 83.45 | 82.46 |
| C/N ratio | 11.4 | 187.8 | 16.7 | 78.1 |

The characteristics of the samples at the start and end of experiment two are presented in Tables 4 and 5 respectively. Table 4 shows that the inoculums had high moisture content of 94 per cent indicating high dilution which might lead to low level of gas production. Table 5 shows the percentage of COD, TOC and TSS removed which varied from 13% for cow waste to 97% for rice straw.

**Biogas production**

Figure 1 shows gas production from chicken waste peaks at 24 hours and 114 hours for experiment one. Similarly Figure 2 shows peaks at 12 hours and 120 hours for the chicken wastes for experiment two. The first peaks show a higher percentage of $CO_2$ than the second peaks, this indicates that at the time of the first peak there is more acid present and therefore less activity

**Table 3: Characteristics of samples at the end of the experiment one**

| Measurements | Chicken | Cow | Pig | Rice Straw |
|---|---|---|---|---|
| T-NH3 (mg/l) | 3,500 | 845 | 845 | 15 |
| COD (mg/l) | 21,500 | 35,000 | 19,500 | 38,000 |
| TOC (ppm) | 7,050 | 11,850 | 7,000 | 12,500 |
| Moisture content (%) | 95.79 | 82.26 | 89.60 | 84.97 |
| TSS (%) | 4.21 | 17.74 | 10.40 | 15.03 |
| VS (%-DS) | 68.84 | 59.75 | 80.55 | 79.18 |
| C/N ratio | 2.0 | 14.0 | 8.3 | 833.3 |
| COD removed (%) | 46.91 | 35.78 | 38.10 | 38.71 |
| TO removed (%) | 50.53 | 45.14 | 40.93 | 44.81 |
| TSS removed (%) | 77.22 | 49.96 | 38.17 | 51.49 |

**Table 4 Characteristics of the samples at the start of the experiment two**

| Measurements | Chicken | Cow | Pig | Rice straw | Inoculums |
|---|---|---|---|---|---|
| T-$NH_3$ (mg/l) | 1055 | 415 | 1185 | 160 | 165 |
| COD mg/l) | 37500 | 56500 | 26500 | 86000 | 9000 |
| TOC (ppm) | 14650 | 21500 | 11300 | 31050 | 41350 |
| Moisture content (%) | 82.42 | 64.61 | 85.79 | 69.07 | 94.07 |
| TSS (%) | 17.58 | 35.39 | 14.21 | 30.93 | 5.93 |
| VSS (%) | 4.38 | 13.31 | 2.11 | 5.75 | 1.64 |
| C/N ratio | 1.39 | 5.18 | 9.54 | 194.06 | 250.61 |

**Table 5: Characteristics of samples at the end of the experiment two**

| Measurements | Chicken | Cow | Pig | Rice straw |
|---|---|---|---|---|
| T-NH3 (mg/l) | 390 | 1275 | 1485 | 225 |
| COD (mg/l) | 3900 | 12750 | 14850 | 2250 |
| TOC (ppm) | 10000 | 17050 | 7500 | 18650 |
| Moisture content (%) | 92.74 | 69.37 | 88.02 | 84.06 |
| TSS (%) | 7.26 | 30.63 | 11.98 | 15.94 |
| VSS (%) | 2.17 | 11.91 | 2.06 | 2.89 |
| C/N ratio | 2.56 | 1.34 | 5.05 | 82.89 |
| COD removed (%) | 89.60 | 77.43 | 43.96 | 97.38 |
| TOC removed (%) | 31.74 | 20.70 | 33.63 | 39.94 |
| TSS removed (%) | 58.72 | 13.45 | 15.69 | 48.47 |

of methanogens. At the time of the second peak there is thus more activity of methanogens.

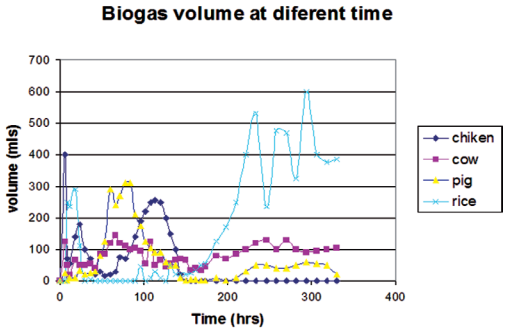


**Figure 1: Biogas yield volume at different time of experiment one**

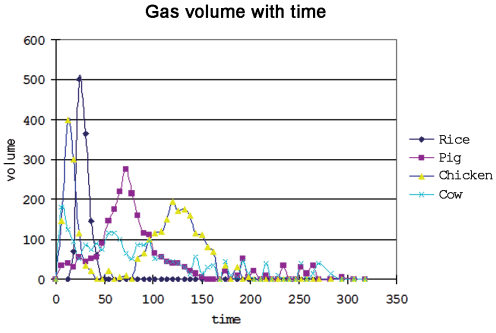


**Figure 2:Biogas yield volume at different time of experiment two**

The gas yield from chicken waste, as shown in Figure 1 was completed after 6 days (144 hrs) of fermentation for experiment one, and after 13 days (312 hrs) for experiment two (Figure 2). The average complete fermentation time for all wastes was 10 days indicating that the fermentation process of chicken waste is faster than the other wastes. Ahring *et al.* (1992) observed similar results and suggested that co-digestion of chicken waste with other materials like castor oil waste materials would improve the short fermentation period. This idea was also supported by Angelidaki *et al.* (1997).

Biogas production in experiment one and two show that the volume of gas produced varies greatly between time intervals and between waste types. Cumulative volumes of gas produced for experiment one and two were obtained after 330 and 318 hours. The final volume of biogas produced for experiment one and two were 3150/2795ml, 3475/2180ml, 3220/2365ml and 6000/1140ml for chicken waste, cow waste, pig waste and rice straw respectively (Table 6). The experiment was carried out in a single water bath with the same conditions and time. The differences in gas volumes obtained could be attributed to the different characteristics of each waste, as shown in Tables 2 and 4.

**The biogas production rate**

The rate of biogas production was calculated using the total volume of gas produced and time taken for the reaction as given in equations 1 and 2. Estimation of rate of biogas production

**Table 6: Rate of biogas production for different wastes**

| Waste | Total gas volume (ml) | | Weight | Time taken (days) | | GPR | Ml/g day | Average |
|---|---|---|---|---|---|---|---|---|
| | Exp 1 | Exp 2 | | Exp 1 | Exp 2 | Exp 1 | Exp 2 | GPR L/Kg |
| Chicken | 3150 | 2795 | 150 | 6 | 13 | 3.50 | 1.43 | 2.467 |
| Cow | 3475 | 2180 | 150 | 14 | 12 | 1.65 | 1.21 | 1.433 |
| Pig | 3220 | 2365 | 150 | 14 | 11 | 1.53 | 1.43 | 1.483 |
| Rice straw | 6000 | 1140 | 100 | 14 | 3 | 4.29 | 3.80 | 4.043 |

was also governed by the following equations:

$$Biogas\ production\ rate\ (GPR) = \frac{Total\ gas\ produced\ (ml)}{Number\ of\ days\ (D)} \quad ....(1)$$

$$Biogas\ production\ rate\ per\ gram = \frac{Total\ volume\ of\ gas\ produced\ (\mathrm{TVG})}{Number\ of\ days\ (D) * Weight\ of\ material\ (W)g} \quad ....(2)$$

Using equations 1 and 2, the biogas production rates per day were computed to be 2.467 l/kg, 1.433 l/kg and 1.483 l/kg for chicken, cow and pig wastes respectively as shown in Table 6.

## CONCLUSIONS

Chicken waste showed a maximum rate of biogas production, however, the active gas reaction time is shorter than the other wastes. Chicken waste would therefore be the best material to use when a large volume of gas required in a short period of time. Similarly it could be used with other waste materials when gas production is required quickly and over a longer period of time, for example when dealing with fuel to power automobile engines.

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## LIST OF ABBREVIATIONS

| | |
|---|---|
| COD | Chemical Oxygen Demand |
| MLSS | Mixed Liquor Suspended Solid |
| $NH_4$-N | Ammonium Nitrogen |
| T-$NH_4$-N | Total Ammonium Nitrogen |
| OLRP | Organic Loading Rate |
| SS | Suspended Solid |
| TSS | Total Suspended Solids |
| VSS | Volatile Suspended Solids |
| VS | Volatile Solids |
| T-N | Total Nitrogen |
| TOC | Total Organic Carbon |
| T-C | Total Carbon |
| BPR | Biogas Production Rate |
| TVG | Total Volume of Gas Produced |
| D | Total Number of Days |
| W/wt | Weight |
| STD | Standard Gas |
| RMP | Rate of methane Production |
| Min | minutes |
| kW | Kilowatts |
| l | Litter |
| $m^3$ | Meters cube |
| mg | Milligram |
| mg/l | milligram per liter |
| $CH_4$ | Methane |
| $CO_2$ | Carbon dioxide |
| C | Carbon |
| O | Oxygen |
| S | Sulphur |
| H | Hydrogen |
| CN | Carbon Nitrogen ratio |
| RT | Retention Time |
| kN/h | Kilo Newton per Hour |

# Road Crashes and Drunken Driving Relationship in Tanzania

**[1]Gilliard W. Ngewe and [1]Batholomew Marcel**

[1]Lecturers, Business and Entrepreneurship Studies Department
National Institute of Transport, P. O. Box 705,
Dar es Salaam, Tanzania
Email: ngeweg@yahoo.co.uk

**Abstract**

*Beverage alcohol is widely enjoyed the world over in countless different settings and by a great many people. It is well recognized that irresponsible drinking patterns to drivers may bring about a range of harmful outcomes. Accordingly, many countries agree on the need to establish regulations that prohibit impaired driving, particularly as it applies to the operation of automobiles on public roads. The setting of maximum allowable Blood Alcohol Concentration (BAC) level is a tool for enforcement and for prevention. In Tanzania, according to the Road Traffic Act No. 1, 1973, Sec. 44; "Any person who while under the influence of drink or drug to such an extent as to be incapable of having proper control of motor vehicle or trailer drives or attempts to drive or in charge of motor vehicle or trailer on any road or other public place shall be guilty of an offence. And sec.49: provides the legal limit to eighty milligrams of alcohol in one hundred milliliters of blood. To underscore the practicability of the stated law, the need to carry out a study was realized. The study deployed documentary reviews to collect secondary data on alcohol sales, profits and annual roads traffic accidents from breweries and traffic police force while primary data were collected using questionnaires, interviews and focused group discussions and analyzed using Statistical Package for the Social Sciences (SPSS). The study found that there is a strong positive association between an increase in sales volume of alcohol and increase in road crashes with Pearson's correlation coefficient r = 0.96. Moreover, 66.7% of the survey respondents estimated that drunken driving contribute to road crashes by more than 50%. This paper is intended to explore the relationship between road crashes and drunken driving, standards and enforcement mechanisms of legislation that prohibit impaired driving particularly as they apply to the operations of automobiles on public roads of Tanzania.*

***Key Words:*** Alcohol intoxication, drunken driving and impaired driving

## INTRODUCTION

Beverage alcohol is widely enjoyed the world over in countless different settings and by a great many people. It is well recognized that irresponsible drinking patterns coupled with certain behaviors, such as driving, may bring about a range of harmful outcomes. Many countries do agree on the need to establish regulations that prohibit impaired driving, particularly as it applies to the operation of automobiles on public roads.

Alcohol intoxication/drunkenness or inebriation is a physiological state that occurs when a person or animal has a high level of alcohol in his/her blood. Common symptoms of alcohol intoxication include slurred speech, euphoria, impaired balance, loss of muscle coordination (ataxia), flushed face, vomiting, reddened eyes, reduced inhibition, and erratic behavior. In severe cases, it can cause coma or death.

Alcohol is metabolized by a normal liver at the rate of about one ounce (one "highball", a normal beer, a regular sized glass of wine) every

90 minutes (Sekularac, 2011). An "abnormal" liver with conditions such as hepatitis, cirrhosis, gall bladder disease, and cancer will have a slower rate of metabolism. It takes roughly 90 minutes for a healthy liver to metabolize a single ounce, approximately one hour per standard unit (Sekularac, 2011). Alcohol's acute effects are largely due to its nature as a Central Nervous System (CNS) depressant, and are dependent on blood alcohol concentrations as follows:

- 20–99 mg/dL - Impaired coordination and euphoria
- 100–199 mg/dL - Ataxia, poor judgment, labile mood
- 200–299 mg/dL - Marked ataxia, slurred speech, poor judgment, labile mood and nausea
- 300–399 mg/dL - Stage 1 anaesthesia, memory lapse, labile mood
- 400+ mg/dL - Respiratory failure, coma and death

As drinking increases, people become sleepy, or fall into a state of unconsciousness. After a very high level of consumption, the respiratory system becomes depressed and the person will stop breathing (Killoran *et al.,* 2010). CNS depression and impaired motor co-ordination along with poor judgment increases the likelihood of accidental injury occurrence. It is estimated that about one third of alcohol-related deaths are due to accidents (32%) and another 14% are from intentional injury. In addition to respiratory failure and accidents caused by effects on the CNS, alcohol causes significant metabolic derangements.

Definitive diagnosis relies on a blood test for alcohol, usually performed as part of a toxicology screen. Law enforcement officers often use breathalyzer units and field sobriety tests as more convenient and rapid alternatives to blood tests. The reliability of field sobriety tests is somewhat questionable although they are commonly used in various jurisdictions worldwide. There are also various models of breathalyzer units that are available for consumer use. Because these may have varying reliability and may produce different results other than the tests used for law-enforcement purposes, the results from such devices should be conservatively interpreted.

Many informal intoxication tests exist, which are generally unreliable and not recommended as deterrents to excessive intoxication or as indicators of the safety of activities such as motor vehicle driving, heavy equipment operation, machine tool use, mining, etc. In determining whether someone is intoxicated by alcohol by some means other than a blood-alcohol test, it is necessary to rule out other conditions such as hypoglycemia, stroke, usage of other intoxicants, mental health issues, and so on. It is best if their behavior has been observed while the subject is sober to establish a baseline.

In Tanzania when listening and reading to mass media like radios, televisions and daily newspapers, data provided on road crashes are irritating and very unpleasant (Batalin, 2001). This is because most of road crashes emanate from reckless driving, including over speeding and overtaking, vehicle defects, overloading, drinking and driving, bad roads and inadequate road signs, pedestrian abuses of road traffic signs and other human errors that most of them are associated with poor driving as ranked in Table 1.1.

According to Road Traffic accident Report (SUMATRA, 2007), the problem of driving while intoxicated is ranked the last (number 8 out of 8 items) in the official statistics in Table 1.1, but the stakeholders are of the opinion that it is a serious contributor to road traffic accidents especially during the evenings and weekends. A scientific study may help to define the actual extent of the drinking and driving problems. Therefore, a road side surveys during the evenings and weekends could be commissioned to assess the problem and identify the mitigation measures because the road traffic accidents are escalating as shown in Table 1.2.

**Related Literature Review**

**Road Traffic Act, 1973 -Tanzania**

a) Driving of a motor vehicle while under the

**Table 1.1: Major Causes of Road Traffic Accidents**

| Causes of Road Traffic Accidents | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | Sub Total | % | Rank |
|---|---|---|---|---|---|---|---|---|---|
| Reckless/Dangerous Driving | 7041 | 6743 | 8179 | 10916 | 9366 | 4318 | 46563 | 54.5 | 1 |
| Defective motor vehicles | 2797 | 2440 | 2641 | 2503 | 2403 | 1164 | 13948 | 16.3 | 2 |
| Careless pedestrian | 850 | 1056 | 1096 | 1463 | 1337 | 566 | 6368 | 7.5 | 3 |
| Excessive speed | 426 | 350 | 340 | 376 | 1409 | 263 | 3164 | 3.7 | 7 |
| Careless motor cyclist | 924 | 827 | 827 | 483 | 757 | 286 | 4104 | 4.8 | 6 |
| Careless pedal cyclist | 1276 | 891 | 891 | 367 | 607 | 359 | 4391 | 5.1 | 5 |
| Intoxication (alcohol) | 170 | 98 | 99 | 68 | 171 | 92 | 698 | 0.8 | 8 |
| Others i.e. bad road/ slippery | 1064 | 1472 | 1417 | 488 | 989 | 768 | 6198 | 7.3 | 4 |
| Total | 14548 | 13877 | 15490 | 16664 | 17039 | 7816 | 85434 | 100 | |

**Source:** SUMATRA- Road Traffic Accidents Report, 2007

**Table 1.2: Road Traffic Accidents 1990-2010**

| ROAD TRAFFIC ACCIDENTS STATISTICS IN TANZANIA MAINLAND | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Year | Reckless Driving | Vehicles Defects | Speed | External Factors | Alcohol/ Intoxication | Careless Motor Cyclist | Careless Cyclist | Careless Pedestrians | TOTAL |
| 1990 | 6,428 | 1,734 | 216 | 2,176 | 109 | 219 | 564 | 651 | 12,097 |
| 1991 | 5,527 | 1,829 | 238 | 2,318 | 163 | 221 | 653 | 653 | 11,602 |
| 1992 | 6,989 | 1,875 | 321 | 2,641 | 170 | 284 | 786 | 791 | 13,857 |
| 1993 | 7,282 | 1,920 | 349 | 2,858 | 187 | 303 | 870 | 819 | 14,588 |
| 1994 | 7,358 | 2,508 | 470 | 2,978 | 171 | 339 | 926 | 1,025 | 15,775 |
| 1995 | 6,836 | 2,804 | 833 | 2,926 | 136 | 369 | 923 | 937 | 15,764 |
| 1996 | 7,577 | 2,308 | 718 | 2,935 | 175 | 367 | 1,053 | 950 | 16,083 |
| 1997 | 8,085 | 2,080 | 362 | 2,845 | 106 | 330 | 946 | 799 | 15,553 |
| 1998 | 6,079 | 1,870 | 446 | 2,967 | 91 | 1,077 | 892 | 1,134 | 14,556 |
| 1999 | 5,745 | 2,283 | 773 | 3,986 | 199 | 1,088 | 1,046 | 850 | 15,970 |
| 2000 | 7,041 | 2,797 | 426 | 3,064 | 170 | 311 | 1,276 | 1,056 | 16,141 |
| 2001 | 6,743 | 2,440 | 350 | 3,418 | 98 | 924 | 891 | 1,096 | 15,960 |
| 2002 | 8,179 | 2,641 | 340 | 3,419 | 99 | 827 | 891 | 1,463 | 17,859 |
| 2003 | 10,916 | 2,503 | 376 | 2,491 | 68 | 483 | 367 | 1,463 | 18,667 |
| 2004 | 9,366 | 2,403 | 1,409 | 2,993 | 171 | 757 | 607 | 1,337 | 19,043 |
| 2005 | 8,952 | 2,234 | 578 | 3,045 | 163 | 1,405 | 758 | 1,248 | 18,383 |
| 2006 | 9,366 | 2,403 | 607 | 2,995 | 171 | 757 | 1,409 | 1,337 | 19,045 |
| 2007 | 8,170 | 1,886 | 1,243 | 5,432 | 320 | 754 | 1,064 | 840 | 19,709 |
| 2008 | 8,531 | 2,178 | 1,769 | 2,468 | 278 | 1,384 | 1,232 | 2,775 | 20,615 |
| 2009 | 11,059 | 2,233 | 1,025 | 2,894 | 221 | 2,347 | 1,701 | 1,259 | 22,739 |
| 2010 | 3,588 | 4,086 | 3438 | 5860 | 580 | 1,987 | 3,906 | 1,220 | 24,665 |

**Source:** Traffic Police, Dar es Salaam (2011)

influence of drink or drugs

**Sec. 44:**

Any person who, while under the influence of drink or drug., to such an extent as to be incapable of having proper control of a motor vehicle or trailer, drives or attempts to drive or in charge of motor vehicle or trailer on any road or other public place shall be guilty of an offence.

**b) Driving of a motor vehicle with blood alcohol concentration above the prescribed limit**

**Sec. 45:**

(l) Any person who drives or attempts to drive or is in, charge of a motor vehicle or trailer on a road or other public place, having consumed alcohol such quantity that the proportion thereof in his blood, as ascertained from a laboratory test for which he subsequently provides a specimen under section 46 of this Act, exceeds the prescribed limit at the time he provides the specimen, shall be guilty of an offence

(2) A person shall not be. convicted under this section of being in charge of a motor vehicle or trailer if he, proves that at the material time, the 'circumstances were such that there was no likelihood of his driving it so long as there was any probability of his having alcohol in his blood in a proportion exceeding the prescribed limit.

(3) In determining for the purpose of subsection

(2) the likelihood of any person driving a motor vehicle or a trailer when he is injured or when vehicle is damaged, the court may disregard the fact that he had been injured or that the vehicle had been damaged.

(4) Notwithstanding the provision of subsection (1), (2) or (3) of this section, any person who, when driving or in charge of, or during any period of duty in connection with the driving of, a motor vehicle licensed under the Transport Licensing Act, 1973, drinks any intoxicating liquor shall be guilty of an offence and shall be liable on conviction to a fine not exceeding ten thousand shillings or to a term of imprisonment not exceeding two years or to both such fine and imprisonment.

(5) Any person who gives any driver or any, person in charge of a motor vehicle, licensed under the Transport Licensing Act, 1973 any intoxicating liquor, whether for reward or not, shall be guilty of an offence and shall be liable on conviction to a fine not exceeding ten thousand shillings or to imprisonment not exceeding twelve months or to both such fine and imprisonment

**c) Blood Tests**

**Sec. 46:**

(1) A police officer may require any person driving or attempting to drive or in charge of a motor vehicle or trailer on a road or other public place to accompany him to a police station or the surgery of a medical practitioner to provide a specimen of blood for a laboratory test there if the police officer has reasonable cause- (a) to suspect him of having alcohol in his body; or (b) to suspect him of having committed a traffic offence while the motor vehicle or trailer was in motion.

(2) If an accident occurs owing to the presence of a motor vehicle or trailer on a road or other public place, a police officer in uniform may require any person who, he has reasonable cause to believe, was driving or attempting to drive or was in charge of the vehicle at the time of the accident to accompany him to a police station or the surgery of a medical practitioner to provide a specimen of blood for a laboratory test; but a person shall not be required to provide such a specimen of blood while at a hospital as patient if the medical practitioner in charge of his case is not first notified of the proposal to make the requirement or objects to the provision of a specimen of blood on the ground that, its provision or the requirement to provide it would be prejudicial to the proper care or treatment of the patient.

(3) If a person required by a police officer under subsection (1) or (2) of this section to

provide a specimen of blood for laboratory test fails to do so and the police officer has reasonable cause to suspect him of having alcohol in his body, the police officer may arrest him without warrant except while he is at a hospital as a patient.

(4) Any person required to provide a specimen of blood pursuant to the provisions of this section who refuses to provide such specimen of blood shall be guilty of an offence and shall be liable on conviction to a fine not exceeding ten thousand shillings and failure to provide a specimen of blood shall be taken by the court as a prima facie evidence that the accused blood alcohol was, at the time when he was driving or was in charge of the vehicle, above the prescribed limit.

**d) Persons authorized to withdraw and analyze blood**

**Sec.47:**

(1) When a person submits to a blood test at the request of a police officer made pursuant to the provisions of section 46 of this Act, only a medical practitioner or registered nurse may withdraw blood for the, purpose of determining the alcoholic content therein.

(2) Chemical analysis of the person's blood shall be considered valid under this section if performed according to methods approved by the Chief Medical officer, by a person possessing a valid permit issued by the Chief Medical officer for this purpose.

(3) The Chief Medical officer may approve satisfactory techniques or methods to ascertain the qualifications and competence of individuals to conduct such analyses and issue permits which shall be subject to termination or revocation at the discretion of the Chief Medical officer.

(4) The person tested may have a medical practitioner, or a qualified technician, chemist, registered nurse, or other qualified person of his own choosing to administer a chemical test in addition to any test administered at the direction of the police officer, but failure or inability to obtain an additional test by such person shall not preclude the admission of evidence relating to a test taken at the direction of a police officer in accordance with the provisions of this section.

**e) Detention of persons whilst affected by alcohol**

**Sec. 48:**

Any person required to provide a specimen of blood for a laboratory test pursuant to the provisions of this Act may thereafter be detained at a police station until it appears to a police officer that the proportion of alcohol in that person's blood does not exceed the prescribed limit.

**FINDINGS**

Driving under the influence of alcohol as a traffic offence is usually difficult to enforce because no specific quantity of alcohol in the blood has been defined by law as constituting an offence and the police are rarely equipped with the breath analyzing equipment. The alternative of having a blood alcohol test by a doctor is also not effective because hospitals and health centers are often far away from the accident scenes or from where the driver is stopped on suspicion of driving while under the influence of alcohol. These circumstances leave a lot of room for corrupt practices, which further endangers road safety, (Batalia, 2001).

Following Batalia's observation the law had to be amended as follows: Sec.49: For the purposes of this Act, the expression ''prescribed limit'' means eighty milligrams of alcohol in one hundred milliliters of blood, (Road Traffic Act CAP 168 R.E 2002)

**SOUTH AFRICA**

**National Road Traffic Act, 1996**

Driving while under the influence of intoxicating liquor or a drug having a narcotic effect, and miscellaneous offences (Republic of South Africa, 1996);

**sec. 64:**

No person shall drive a vehicle on a public road without reasonable consideration for any other person using the road. Driving while under the influence of intoxicating liquor or drug having narcotic effect, or with excessive amount of alcohol in blood or breath;

**Sec. 65:**

(1) No person shall on a public road- (a) drive a vehicle; or (b) occupy the driver's seat of a motor vehicle the engine of which is running, while under the influence of intoxicating liquor or a drug having a narcotic effect.

(2) No person shall on a public road (a) drive a vehicle; or (b) occupy the driver's seat of a motor vehicle the engine of which is running, while the concentration of alcohol in any specimen of blood taken from any part of his or her body is not less than 0.05 gram per 100 milliliters, or in the case of a professional driver referred to in section 32, not less than 0.02 gram per100 milliliters.

(3) If, in any prosecution for an alleged contravention of a provision of subsection (2), it is proved that the concentration of alcohol in any specimen of blood taken from any part of the body of the person concerned was not less than 0.05 gram per 100 milliliters at any time within two hours after the alleged contravention, it shall be presumed, in the absence of evidence to the contrary, that such concentration was not less than 0.05 gram per 100 milliliters at the time of the alleged contravention, or in the case of a professional driver referred to in section 32, not less than 0.02 gram per 100 milliliters, it shall be presumed, in the absence of evidence to the contrary, that such concentration was not less than 0.02 gram per 100 milliliters at the time of the alleged contravention.

(4) Where in any prosecution in terms of this Act proof is tendered of the analysis of a specimen of the blood of any person, it shall be presumed, in the absence of evidence to the contrary, that any syringe used for obtaining such specimen and the receptacle in which such specimen was placed for dispatch to an analyst, were free from any substance or contamination which could have affected the result of such analysis.

(5) No person shall on a public road (a) drive a vehicle; or (b) occupy the driver's seat of a motor vehicle the engine of which is running, while the concentration of alcohol in any specimen of breath exhaled by such person is not less than 0.24 milligrams per 1 000 milliliters, or in the case of a professional driver referred to in section 32, not less than 0.10 milligrams per 1 000 milliliters.

(7) For the purposes of subsection (5) the concentration of alcohol in any breath specimen shall be ascertained by using the prescribed equipment.

**SAB's Position on Responsible Alcohol use**

South African Breweries (SAB) recognizes it has a responsibility to make consumers aware of the dangers arising from the misuse of alcohol. The majority of people who consume alcoholic beverages do so responsibly. SAB aims to ensure that this trend is encouraged. The company believes that effectively combating abuse and misuse requires addressing drinking patterns and behaviors. That means tackling not just chronic patterns of abuse, but also the harm that may result from occasional over- consumption by those whose total overall consumption may not be excessive.

No single action is likely to reduce the problems that the misuse of alcohol can cause. Enforcement of existing laws governing sale, consumption and behavior once intoxicated; education to equip individuals to take personal responsibility for their drinking choices; and self-regulatory controls are the most effective way forward.

**SAB's Strategy to Tackle Alcohol Abuse: beyond Education; drunken driving**

SAB has partnered with local and provincial law enforcement agencies to open state-of-the art Alcohol Evidence Centers (AECs). The AECs are equipped with the necessary equipment to detect a driver's breath alcohol concentration level accurately through a single breath sample.

To date, 15 AECs have been opened around the country effectively covering most major centers in South Africa. SAB expects to double this number of AEC's during 2011/2012; an effort that the business believes will have a significant impact on drunken driving in South Africa.

The accuracy of the data collected at these centres has dramatically improved the prosecution rates of those detained under suspicion of driving under the influence of alcohol. The equipment supplied to the centers includes breathalyzers, a closed circuit television network and a server to monitor the testing process. The breathalyzer machines are able to take an instant and accurate reading of an individual's breath alcohol level. The reading is then used as evidence to secure a conviction of drunk driving.

**South Africans against Drunken Driving (SADD) Sponsorship**

SAB has for a number of years sponsored SADD in their University Drunken Driving Programme. As a result of the funding in 2011, SADD will be able to provide funding to eight universities and technikons, reaching tens of thousands of students through a peer education approach. The aims of SADD's university program are as follows:

- Change attitudes so that: "Friends Don't Let Friends Drink then Drive"
- Teach young people about the effects of alcohol on driving skills, so that they can make a responsible decision and choose to not drink and drive or walk
- Teach young people about the harmful effects of alcohol abuse and advice on alternatives
- Bring down the high injury and death rate as a result of drunken driving in the student population group

SADD's research has shown that responsible driving only comes about because people are afraid of the legal and financial repercussions of their actions. SADD has commented that it "applauds SAB for funding the AECs, as it has been proven that frequent and random breath alcohol testing and appropriate harsh penalties are the only measures that reduce drinking then driving. SADD and SAB's partnership is also now beginning to bear fruit and starting to save lives."

**KENYA**

**The Traffic Act CAP. 403, Rev. 2009**

SEC. 44.

(1) Any person who, when driving or attempting to drive, or when in charge of a motor vehicle on a road or other public place, is under the influence of drink or a drug to such an extent as to be incapable of having proper control of the vehicle shall be guilty of an offence and liable to a fine not exceeding ten thousand shillings or to imprisonment for a term not exceeding eighteen months or to both.

(2) A person convicted of an offence under this section shall, without prejudice to the power of the court to order a longer period of disqualification, be disqualified, for a period of twelve months from the date of conviction, for holding or obtaining a license (Republic of Kenya, 2009).

**Campaign against Alcohol in East Africa**

***EABL flags off the new "Friends Don't Let Friends Drink & Drive" branded taxis***

East African Breweries Limited (EABL) has commissioned another fleet of branded taxis to provide transport services to pub patrons, an initiative that aims to promote and advocate for responsible consumption of alcohol and road safety. Responsible Drinking campaign dubbed 'Friends don't let Friends Drink and Drive' has since been rolled out in Uganda and replicated in Tanzania. The branding of taxis initially began in Nairobi and has so far seen over 160 taxis dispatched to various entertainment joints both in Nairobi and Mombasa.

EABL Group noted that, *"This initiative has been driven by the need to promote responsible drinking habits and ensure the safety of the patrons. We are always seeking innovative ways to address concerns around responsible drinking. Patrons must always ensure their friends don't drive home after a fun night out but take the taxi home or have a designated driver".*

***By the end of 2011 EABL had invested more than Ksh100 Million in the campaign.***

(i) That at the material time the circumstances were such that there was no reasonable likelihood of his driving the vehicle so long as he remained unfit to drive; and

(ii) That between his becoming unfit to drive and the material time he had not driven or attempted to drive the vehicle on a road. In this subsection, the expression "unfit to drive" means under the influence of intoxicating liquor or drugs to such an extent as to be incapable of having proper control of a motor vehicle.

198. (1) Any person who, when driving or attempting to drive a motor vehicle on a road, is under the influence of intoxicating liquor or drugs to such an extent as to be incapable of having proper control of such vehicle shall be guilty of an offence and shall upon conviction be sentenced to either - Driving when under influence of drink or drugs

(a) Imprisonment for a period of not less than six months nor more than five years; or

(b) Imprisonment to be served during a number of consecutive week-ends, not being less than thirty nor more than fifty- two, in this section referred to as week- end imprisonment; and may in addition be sentenced to a fine not exceeding fifteen thousand penalty units.

(3) Where a person is sentenced to week-end imprisonment-

(a) The warrant of the court which passed the sentence shall be the authority for such person to be immediately taken to a prison situated as close as possible to such person's usual place of abode;

(b) The officer in charge of the prison to which such person is taken shall record, or cause to be recorded, the relevant particulars of such person and shall give to him a record book in which shall be recorded by the prison authorities the number of week-ends to be served by him in prison and the dates and times of his surrender to and release from prison; on the completion of the recording of these particulars (which shall take no longer than absolutely necessary) the person sentenced to week-end imprisonment shall be then released until he first surrenders himself under paragraph (c);

(c) He shall surrender himself to the prison at 6.30 p.m. each Friday and be released at 6.30 p.m. each Sunday during the continuance of his sentence.

(4) When considering whether to pass a sentence of week-end imprisonment, the court shall ask the person about to be sentenced whether he has any objection to such course being taken and shall record the reasons given for any objection which may be raised.

(5) If a person sentenced to week-end imprisonment fails to surrender himself at the times and place required and as recorded in the book referred to in paragraph (b) of subsection (3), the officer in charge of the prison shall give written notification of the fact to the court which passed the sentence, and the said court shall issue a warrant for the said person to be arrested and brought before it.

(6) Where, under the provisions of subsection (5), a person is brought before the court by which he was sentenced to week-end imprisonment, the court shall, unless it sees fit to order the continuation and completion of the total number of week-ends to be served in prison, cancel its original order and substitute therefore, making due allowance for any week-ends actually served by him, a sentence of imprisonment for a fixed period of not less than six months nor more than five years (Republic of Zambia, 1995).

**UK Experience**

It is an offence for a person to drive or attempt to drive a motor vehicle on a road or other public place with excess alcohol in his breath, blood or urine as evidenced by a certificate of analysis or printout. Drink driving, driving under the influence of alcohol, drunk driving, driving or attempting to drive a motor vehicle with excess alcohol, driving with excess alcohol, Road Traffic Act, 1988 S.5 (1) (b).

**Drink-Driving and the risk of a Road Traffic Accident**

There is strong evidence that someone's ability to drive is affected if they have any alcohol in their blood. Drivers with a BAC of between 0.02 and 0.05 have at least a three times greater risk of dying in a vehicle crash. This risk increases to at least six times with a BAC between 0.05 and 0.08, and to 11 times with a BAC between 0.08 and 0.10 (Killoran, 2010).

Studies have consistently demonstrated that the risk of having an accident increases exponentially as more alcohol is consumed. Younger drivers are particularly at risk of crashing whenever they have consumed alcohol whatever their BAC level because they are less experienced drivers, are immature and have a lower tolerance to the effects of alcohol than older people.

**Effectiveness of BAC laws**

Overall, there is sufficiently strong evidence to indicate that lowering the legal BAC limit for drivers does help reduce road traffic injuries and deaths in certain contexts. A number of studies have indicated that lowering the BAC limit from 0.10 to 0.08 reduces road traffic injuries and fatalities, although the scale of effect varies. The effect is independent of other control measures in particular administrative license suspension.

Public Awareness and Enforcement of BAC laws

There is sufficiently strong evidence to indicate that publicity and visible, rapid enforcement is needed if BAC laws are to be effective. Drivers need to be aware of – and understand – the law. They also need to believe they are likely to be detected and punished for breaking the law.

A European review of enforcement measures showed that countries fulfilling most of the following criteria have the lowest drink driving figures (Makinen *et al.,*2002):

- Long tradition in drink driving enforcement including low legal limits
- Relatively high objective risk of detection (as measured by proportion of drivers tested)
- Mass media supporting enforcement

**METHODOLOGY**

The study used documentary reviews such as annual reports to collect secondary data on alcohol sales, profits and annual roads traffic accidents from breweries and traffic police force. Primary data were collected using questionnaires, interviews and focused group discussions to obtain data on driver drinking behavior and laws, blood alcohol driver testing and alcohol influencing road accident level. The study sampled three hundred eighty four (384) from VIP, Industrial and Passenger Service Vehicle (PSV) drivers coming from all over Tanzania attending different training programs at the National Institute of Transport in Dar es Salaam who dully filled questionnaires, accepted interviews and focused group discussions and analyzed using Statistical Package for the Social Sciences (SPSS). The researchers held intensive focused group discussions with traffic police at Ubungo Bus terminal station in Kinondoni region of police.

Data analysis was done by statistical tool (Pearson's coefficient of correlation). Correlation show that as one variable changes, the other seems to change in a predictable way.

- All correlation coefficients range from -1.00 to +1.00. A correlation coefficient of -1.00 tells that there is a perfect negative relationship between the two variables. This means that as values on one variable increase there is a perfectly predictable decrease in values on the other variable.
- A correlation coefficient of +1.00 tells that there is a perfect positive relationship between the two variables. This means that as values on one variable increase there is a perfectly predictable increase in values on the other variable.
- The closer a correlation coefficient approaches plus or minus 1.00 the stronger the relationship is and the more accurately you are able to predict what happens to one variable based on the knowledge you have of the other variable.

The correlation coefficient r (also called Pearson's product moment correlation after Karl Pearson) was calculated by

$$r = \frac{\sum_{i=1}^{n} x_i y_i - \frac{1}{n}\sum_{i=1}^{n} x_i \sum_{i=1}^{n} y_i}{\sqrt{\sum_{i=1}^{n} x_i^2 - \frac{1}{n}\left(\sum_{i=1}^{n} x_i\right)^2}\sqrt{\sum_{i=1}^{n} y_i^2 - \frac{1}{n}\left(\sum_{i=1}^{n} y_i\right)^2}}$$

**Data Presentation, Analyses and Findings**

**Data Presentation and Analyses**

Data collected were on the sales of alcohol, profit obtained reviewed from the annual reports of alcohol producing and selling companies in Dar es Salaam and the number of road crashes occurred from 2000 to 2010 was given by Traffic police as shown below;

**Table 4.1: Alcohol Sales and Number of Accidents (2000-2010)**

| | Company A | | Company B | | |
|---|---|---|---|---|---|
| | Xa1 | Xa2 | Xb1 | Xb2 | Y |
| Year | Sales (Tsh.M) | Profit(Tshs M) | Sales (Tsh.M) | Profit(Tshs M) | No. Accidents |
| 2000 | 144,795 | 31,554 | 7,439 | 1,600 | 16,141 |
| 2001 | 125,082 | 29,121 | 8,380 | 2,023 | 15,960 |
| 2002 | 135,059 | 34,218 | 10,132 | 2,415 | 17,859 |
| 2003 | 174,048 | 47,635 | 12,190 | 3,081 | 18,667 |
| 2004 | 197,982 | 57,471 | 14,125 | 3,572 | 19,043 |
| 2005 | 229,644 | 69,332 | 15,651 | 4,215 | 18,383 |
| 2006 | 260,628 | 85,584 | 17,907 | 4,411 | 19,045 |
| 2007 | 314,878 | 95,603 | 26,769 | 6,366 | 19,709 |
| 2008 | 383,181 | 109,168 | 36,409 | 7,891 | 20,615 |
| 2009 | 464,539 | 115,187 | 45,978 | 10,398 | 22,739 |
| 2010 | 527,768 | 133,842 | 64,938 | 14,676 | 24,665 |

***Source:*** URT, (2012)

**a) Quantitative Analyses**

From Table 4.2, a Pearson correlation coefficient results of + .956 was found , this is very close +1, it tells that there is a *perfect positive relationship* between an increase in sales of alcohol (Xa1) as an independent variable and road crashes as a (Y) dependent variable. This means that as values on one independent variable (sales in alcohol) increase there is a perfectly predictable increase in values on dependent variable (road crashes).

From Table 4.3, a Pearson correlation coefficient result of +.96 was found, this is very closer to +1. However, company Xb1 is selling different

**Table 4.2: Correlations between Sales of company $X_{a1}$ Vs Road crashes**

| | | Accidents (Y) | Sales Xa1 |
|---|---|---|---|
| Pearson Correlation | Accidents (Y) | 1.000 | .956 |
| | Sales Xa1 (Tshs M) | .956 | 1.000 |
| Sig. (1-tailed) | Accidents (Y) | . | .000 |
| | Sales Xa1 (Tshs M) | .000 | . |
| N | Accidents (Y) | 11 | 11 |
| | Sales Xa1 (Tshs M) | 11 | 11 |

type of alcohol and is not in competition with company Xa1 again the correlation coefficient results tells that there is a perfect positive relationship between an increase in sales of alcohol (Xb1) as an independent variable and road crashes as a (Y) dependent variable. This means that as values on one independent variable (sales in alcohol) increase there is a perfectly predictable increase in values on independent variable (road crashes).

**Table 4.3: Correlation between Sales of Company Xb1 Vs Road crashes**

| | | Accidents (Y) | Sales $X_{b1}$ |
|---|---|---|---|
| Pearson Correlation | Accidents (Y) | 1.000 | .960 |
| | Sales $X_{b1}$ (Tshs M) | .960 | 1.000 |
| Sig. (1-tailed) | Accidents (Y) | . | .000 |
| | Sales $X_{b1}$ (Tshs M) | .000 | . |
| N | Accidents (Y) | 11 | 11 |
| | Sales $X_{b1}$ (Tshs M) | 11 | 11 |

**Table 4.4: Correlations between Combined Sales of Xa1 +Xb1 Vs Road crashes**

| | | Accidents (Y) | Sales $X_{b1}$ |
|---|---|---|---|
| Pearson Correlation | Accidents (Y) | 1.000 | .960 |
| | Sales Tshs. M ($X_{a1}$ & $X_{b1}$) | .960 | 1.000 |
| Sig. (1-tailed) | Accidents (Y) | . | .000 |
| | Sales Tshs. M ($X_{a1}$ & $X_{b1}$) | .000 | . |
| N | Accidents (Y) | 11 | 11 |
| | Sales Tshs. M ($X_{a1}$ & $X_{b1}$) | 11 | 11 |

**b) Qualitative Analyses**

i. Drivers' license acquisition, age and classes

Regarding drivers license acquisition, the sampled drivers' responses are summarized in figure 4.1, where 77.3% of respondents had obtained their driving license before year 2008. The sampled drivers had shown that 52.6% had obtained class C in their first driver license application while 23.2% had obtained class D and 22.4% had obtained class E. Only 0.3% of drivers obtained class B as is illustrated in figure 4.2.

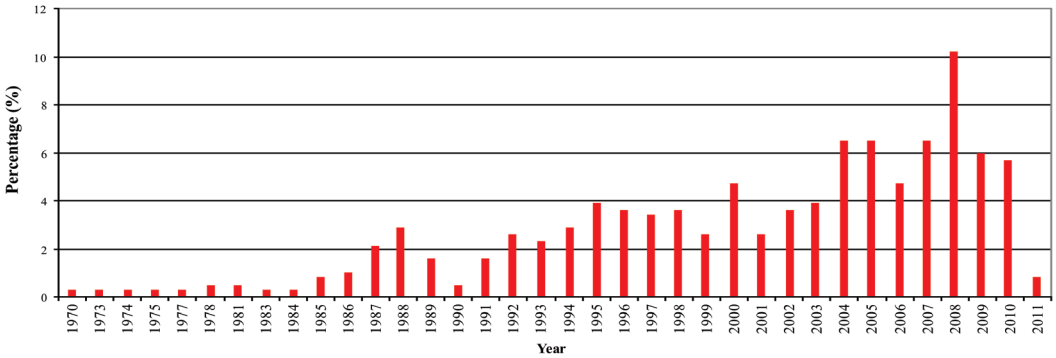


**Figure 4.1: Year you obtained your Driving License**

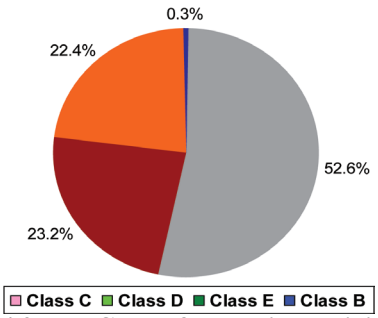


**Figure 4.2: The Class of your First Driving License**

**Source:** Study computations (2011)

Figure 4.3: depicts that there were 27.6% of drivers having license aged more than ten (10) years while 50.0% of all sampled drivers had driving license aged more than four (4) years. Only 25.5% of respondents had driving license aged less than two (2) years.

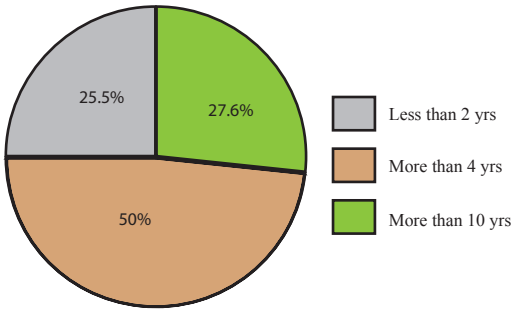


**Figure 4.3: Age of your Current Driving License**

**Source:** Study computations (2011)

### ii. Driver Alcohol drinking behavior

Table 4.5; Present data collected on alcohol drinking behavior. Drivers were required to disclose whether they do normally take alcohol in their social life or not. The responses show that 37.5% of the respondents do take alcohol on regular basis while 62.5% do not. These responses could have been influenced by respondents' awareness on the BAC test, which they were taught in their respective training courses.

**Table 4.5: Driver Alcohol drinking behavior**

| | Frequency | Percent |
|---|---|---|
| Yes | 144 | 37.5 |
| No | 240 | 62.5 |
| Total | 384 | 100.0 |

**Source:** Survey October 2011

### iii. Laws Prohibiting Drunken Driving and BAC Awareness

In determining the level of awareness on laws prohibiting driving under the influence of alcohol, respondents were asked to state whether they know the laws or not. Table 4.6; depicts that 90.6% of the sampled respondents are aware of the laws and only 9.4% are not aware of the laws.

**Table 4.6: Awareness on Laws Prohibiting Drunken Driving**

| | Frequency | Percent |
|---|---|---|
| Yes | 348 | 90.6 |
| No | 36 | 9.4 |
| Total | 384 | 100.0 |

**Source:** Survey October 2011

In assessing the practicability of BAC test in Tanzania, the study requested respondents to state whether they had been tested on BAC for their entire driving life in Tanzania. This question aims at filtering BAC test undertaken to transit drivers while they are beyond Tanzanian borders. Table 4.7 shows that only 6.0% of all respondents happened to be tested once on the BAC in their entire life of driving while 94.0% had never been tested.

**Table 4.7: Drivers Tested by Police for BAC in Tanzania**

| | Frequency | Percent |
|---|---|---|
| Yes | 23 | 6.0 |
| No | 361 | 94.0 |
| Total | 384 | 100.0 |

**Source:** Survey October 2011

### iv. Drunken Driving Influence with Road Traffic Accidents

When the sampled drivers requested to state

their experience on the relationship between driving under the influence of alcohol and the increase in road traffic accidents, 94.3% admitted that there is a relationship and only 5.7% responded that there is no relationship as per Table 4.8.

**Table 4.8: Relationship between Drunken Driving and Road Traffic Accidents**

| | Frequency | Percent |
|---|---|---|
| Yes | 362 | 94.3 |
| No | 22 | 5.7 |
| Total | 384 | 100.0 |

**Source:** Survey October 2011

In analyzing driving license classes and drivers normal alcohol drinking behavior, the two variables were compared using cross tabulation. The study reveals that 44.6% of all holders of driving license class C were found to take alcohol on regular basis. These are qualified drivers to drive passenger service vehicles in Tanzania while 31.5% of all sampled holders of driving license class D were found to take alcohol on regular basis and 29.1% of all sampled holders of driving license class E do take alcohol on regular basis as presented in Table 4.9:

**Table 4.9: Crosstab Class of Driving License against Driver Normal Alcohol Drinking Behavior**

| Driving License Class | Normal Alcohol Drinking | | | | TOTAL |
|---|---|---|---|---|---|
| | Yes | % | No | % | |
| B | 0 | 0.0 | 1 | 100.0 | 1 |
| C | 90 | 44.6 | 112 | 55.4 | 202 |
| C1 | 1 | 16.7 | 5 | 83.3 | 6 |
| D | 28 | 31.5 | 61 | 68.5 | 89 |
| E | 25 | 29.1 | 61 | 70.9 | 86 |
| TOTAL | 144 | 37.5 | 240 | 62.5 | 384 |

***Source:*** Survey October 2011

In collecting views from drivers on the association between drunken driving and the increase of road traffic accidents in Tanzania, respondents were requested to give their estimates in percentage by how much drunken driving leads to road traffic accidents. Figure 4.4 shows that 66.7% of all respondents estimated that drunken driving leads to road traffic accidents by more than 50% of all road traffic accidents in Tanzania while 10.4% estimated that drunken driving leads to road traffic accidents by 40 – 50% and 14.6% estimated that drunken driving leads to road traffic accidents by 10 – 40%.

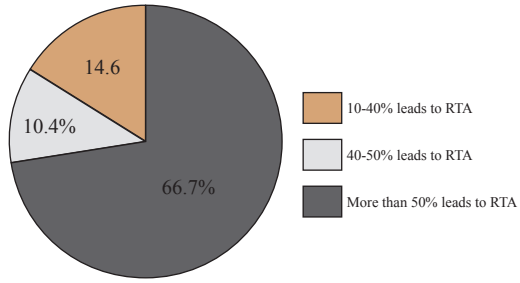


**Figure 4.4: Estimated Alcohol and Drug Association with Road Traffic Accidents**

**Source:** Study computations (2011)

## OBSERVATIONS

a) The study found that the prescribed legal BAC limit in Tanzania is 0.08gm per litre of blood. However, according to Killoran (2010), there is strong evidence that someone's ability to drive is affected if they have any alcohol in their blood. Drivers with a BAC of between 0.02 and 0.05 have at least a three times greater risk of dying in a vehicle crash. This risk increases to at least six times with a BAC between 0.05 and 0.08, and to 11 times with a BAC between 0.08 and 0.10.

b) The perceived practicability of BAC test as part of qualitative findings from focused group discussions held with traffic police at Ubungo bus terminal station is that they had a single non functioning breathalyzer. When enquired from the Traffic Police head office on the number of breathers countrywide, they responded that there are only eighteen (18) units including the one at Ubungo bus terminal station. Moreover, the discussion revealed that in Dar es Salaam most of the road traffic accidents do occur on

weekends especially in Kinondoni region. The reason associated to it is the higher level of economy accompanied with large number of alcohol selling outlets and pubs in the region. However, the law requires a police officer to test any person if has any reasonable cause to suspect him of having alcohol in his body or to suspect him of having committed a traffic offence while the motor vehicle or trailer was in motion. This has led to failure in enforcing the law.

c) Road traffic accident statistics from Traffic Police and Surface and Marine Transport Regulatory Authority (SUMATRA) ranks driving under the influence of alcohol the last cause of road traffic accidents in Tanzania while ranking reckless driving first and followed by defective motor vehicles.
d) Campaigns against drunken driving in Tanzania are at dawn stage mainly being supported by traffic police while alcohol producing companies are not playing the leading role as is the case in other countries such as South Africa and Kenya.
e) The study reveals that 37.5% of all drivers responded to the study do drink alcohol and 44.6% of drivers holding driving license class "C" do take alcohol on regular basis.

**Summary**

a. The study found that there is a strong positive association between an increase in sales of alcohol and increase in road crashes with Pearson's correlation coefficient r = 0.96.
b. Moreover, 66.7% of the survey respondents estimated that drunken driving contribute to road crashes by more than 50%.

## CONCLUSION AND RECOMMENDATIONS

**Conclusion**

The study concludes that the current BAC limit as per Road Traffic Act of 0.08gms per litre of blood to drivers bear the risk of dying in a vehicle crash 11 times compared 0.02 and 0.05gms per litre, which have at least a three times risk to zero BAC. It is currently difficult to practise blood alcohol concentration test due to the serious shortage of breathalyzer in Tanzania. Thus, even the official statistics do not reflect the real situation leading to difficulties in enforcing the law. There are very few campaigns against drunken driving in Tanzania when compared to South Africa and Kenya. Alcohol producing companies in Tanzania have recently started joining the campaigns, where such companies in South Africa and Kenya have long been involved in campaigning to drink responsibly and to not drink and drive.

Furthermore, the study concludes that there is strong positive association between sales of alcohol and road traffic accidents i.e. as values on sales of alcohol increase there is a perfectly predictable increase in road traffic accidents. This is supported by survey findings where 66.7% of respondents estimated that drunken driving contribute to road crashes by more than 50%.

**Recommendations**

a) The BAC to drivers of 0.08gms of alcohol per litre of blood need to be lowered to 0.05gms per litre in order to reduce the risk of dying in a vehicle crash.
b) The Government, alcohol producing and selling companies should use taxes earned from sales of alcohol and as part of corporate social responsibility respectively to put in place the highly needed breathalyzer. This will enhance the effective BAC testing and avail evidence for law enforcement to ensure justice prevails and reduce road traffic accidents in Tanzania.
c) Traffic police should no longer rely on current official statistics because they do not reflect the truth about drunken driving in Tanzania. Reckless/dangerous driving and over speeding are ranked first and second causes of road traffic accidents respectively may be due to drunken driving as there are no enough breathalyzers to test.
d) Alcohol producing companies are recommended to emulate what their counterparts in South Africa and Kenya are doing in order to safeguard the lives of their customers through putting in Tanzania the most effective and long lasting campaigns

against drunken driving and enhance responsible alcohol consumption.

e) Following the strong positive association between sales of alcohol and road traffic accidents, the study recommends to alcohol producing companies to take more corporate social responsibilities in reducing road traffic accidents in Tanzania through road safety education and to sponsor road traffic accident researches.

f) Notwithstanding, after acquisition of enough breathalyzer countrywide the law need to be amended to accommodate smooth practicability of BAC tests. It is recommended that drivers should not be tested after being suspected by police officer of having consumed high quantity of alcohol; instead, every driver should be ready to be tested at every police checkpoint as he will be driving a motor vehicle on a public road. Nonetheless, in all urban centers where alcohol sales outlets are allocated law enforcers are strongly recommended to conduct BAC tests in weekends to motor vehicle drivers and adopt the weekend imprisonment sentence as applicable in the republic of Zambia in order to reduce the weekend road traffic accidents in all urban centers of Tanzania.

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## LIST OF ABBREVIATIONS

| | |
|---|---|
| AEC | Alcohol Evidence Centres |
| BAC | Blood Alcohol Concentration |
| CNS | Central Nervous System |
| EABL | East African Breweries Limited |
| PSV | Passenger Service Vehicles |
| RK | Republic of Kenya |
| RSA | Republic of South Africa |
| RZ | Republic of Zambia |
| SAB | South African Breweries |
| SADD | South Africans against Drunken Driving |
| SPPS | Statistical Package for the Social Sciences |
| SUMATRA | Surface and Marine Transport Regulatory Authority |
| URT | United Republic of Tanzania |

# Study on Aerodynamic Performance of Savonius Wind Turbine for Water Pumping

**[1]Z. M. Mganilwa; [2]S. M. Mpanduji, [2]H. O. Dihenga and [3]M. Nagata**

[1]Department of Transport Engineering and Technology, National Institute of Transport
P. O. Box 705, Dar Es Salaam Tanzania
Email: mganilwaz@yahoo.com
[2]Department of Agricultural Engineering, Sokoine University of Agriculture
P. O. Box 3003, Morogoro Tanzania
[3]Department of Agricultural Machinery, Miyazaki University
1-1 Gakuen Kibanadai Nishi, 889-2102 Miyazaki Japan

**Abstract**

*A Savonius type wind turbine for farm use was designed. The aerodynamic performance of a savonius wind turbine is much influenced by many design parameters such as the overlap ratio, gap ratio, aspect ratio, and the profile of the buckets cross-section. In this study a 2-2 savonius wind turbine with 0.6 m-bucket chord length was designed, fabricated and tested. The effects of the overlap ratio were determined experimentally using a wind tunnel. The results indicated that at wind velocity of 5.5 m/s and 20% bucket overlap ratio; the savonius rotor had the maximum torque and power of 5.2 Nm and 11.75 Watts respectively. When coupled to a diaphragm pump, at 2.5 and 5.5 m/s wind speeds the water discharge were 300 and 660 1/hr respectively, at a maximum head of 4.75 meters. When the wind speed increased to 8.8 m/s the pump delivery also increased to 1,800 l/hr. Savonius wind turbine with proper bucket overlap is useful for water pumping at a site with low wind velocity regime of about 2.5-5.5 m/s.*

***Keywords:*** Savonius wind turbine, aerodynamic, bucket overlap ratio, diaphragm water pump

## INTRODUCTION

Research on natural energy, solar, wind and water stream has been carried out by a number of scientists worldwide (Bhatti and Kothari, 2003). However, it is only in the twentieth century that much research has been done on wind energy in terms of generation and applications (Spera, 1994). The wind energy has diversified applications such as crop drying, threshing and grain grinding, domestic heating and lighting, desalination, irrigation pumping, refrigeration, electric fencing, vermin eradication and insects trapping (Ushiyama, 1985; Reynaldo, 1985). Wind energy turbines are especially attractive for agricultural applications due to the fact that they provide direct mechanical shaft power that minimizes the conversion losses (Gourieres, 1989).

Wind energy technology has not been effectively utilized in Tanzania despite of the existence of wind energy resource (Kimambo and Mwakabuta, 2005). There have been minimal efforts towards wind energy technology development, manufacturing and commercialization. According to Wit (1996), use of wind pumps in Tanzania can be traced to the early 1950s, when several systems were reported to be installed. These were wind machines of the multi-bladed horizontal axis type and were installed for community water supply in rural areas. The number of installed windmills by the year 2000 were 106, among which 44% were reported to be working (Nzali and Mushi, 2004). The contributing factors for

the installed windmills not to work include lack of spare parts, maintenance, abandonment and vandalism. This problem is due to technological dependence on importation of spare parts that could have been produced locally. Other problems that were identified are poor site selection, lack of skills on windmills operation, and abandonment of livestock keeping communities who move in search for their animal feed. Local manufacturers attempted to develop different designs of windmills, however they failed to commercialize the products. In both cases the major draw back is lack of proper raw materials, leading to low quality of locally manufactured windmills and high investment cost.

Various kinds of wind turbines are available in varying modifications. The idea of Savonius rotor was developed in 1924 by a Finnish Engineer, Savonius. Kihedu (2007) reported that wind speed in Tanzania ranges mainly from 2-5 m/s whereby according to Hulscher and Fraenkel (1994), it is classified as low wind speed. The advantage of Savonius type wind turbine is its low cut-in speed so that it can extract wind from slow wind speed. Another advantage is the simple rotor blade structure, which makes it easy to fabricate and the maintenance costs are cheaper (BRI, 1973). Several researchers worked on the configurations of the Savonius rotor blade and reported different overlap ratios (Modi, 1983; Modi and Fernando, 1989; Ushiyama, 1982; 1988; Tokida *et.al.,* 1991; Sargolzaei and Kianifar, 2007; Saha *et.al.,* 2008).

Different optimum overlap ratio of the Savonius rotor has been reported. Purwadi (1985) designed a 2-2 Savonius rotor and found that with a 40% bucket overlap the rotor had better performance than the other overlaps. Results from Herath (1986) work shows that, maximum torque and power of the Savonius rotor were obtained at an overlap of 50%. Also, Ushiyama and Nagai (1988) deduced that, buckets of semi-circular cross-section of savonius rotors has optimum performance with an overlap ratio of between 20 ~ 30 %. Sargolzaei and Kianifar (2007), obtained an optimum bucket overlap ratio of 20% using artificial neural networks (ANNs). Therefore such different reported results need further study on the effects of bucket overlap ratio on the performance of a savonius rotor. This paper aimed at determining the optimum bucket overlap as the design parameter on the aerodynamic performance for a turbine water pumping system.

## MATERIAL AND METHODS

### Design Features and Considerations

#### *Design Considerations*

A wind tunnel with outlet size of 2 m x 2 m with maximum wind speed of 10 m/s was used in the experiments. Therefore for occupying cross-section of the tunnel exit, the blade size was selected as 0.6 m x 0.9 m.

#### *Design Aspect*

A 2-2 blade savonius wind turbine was made with blade position been adjusted axially to get the different overlaps. The maximum mechanical power that could be extracted from the tunnel's wind was approximately 20 watt.

#### *Design Features*

Based on the design aspect and design consideration the functional dimensions of the 2-2 savonius windmill were determined.

#### *Rotor and Bucket Geometry*

The rotor and bucket geometry had semicircle shape with the technical specifications as shown in Figure 1.

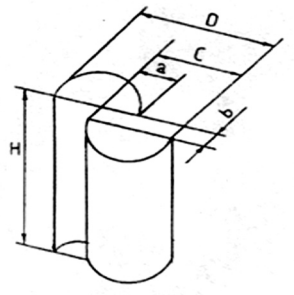


**Figure 1: Rotor and bucket Geometry**

| | |
|---|---|
| Chord length of bucket | C = 0.6 [m] |
| Bucket height | H = 0.9 [m] |

| | | |
|---|---|---|
| Rotor diameter | D = 2C – a | given by equation 1: |
| Bucket overlap | OL = a/C | Where |
| Aspect ratio | AR = H/C = 1.5 | A = 2 H D |
| Shaft diameter | d = 0.0272 [m] | = 2 H (2C – a) for OL 0%, a = 0 |
| Separating gap | b = 0. 03 [m] | = 2 x 0.9 x 2 x 0.6 |
| Swept area | A = 2HD [$m^2$] | = 2. 16 [$m^2$] |

***Determination of the Bucket Overlap, OL***

The blades of the Savonius wind turbine were made such that they could be adjusted axially to get the different overlaps from 10% to 30% .Consider the bucket geometry given in Figure 2.

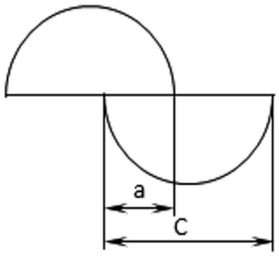


**Figure 2: Bucket overlap**

OL = a/C

► a = OL x C

For 10% overlap, a1 = 0.10 x 0.6 = 0.06 [m]
15% overlap, a2 = 0.15 x 0.6 = 0.09 [m]
20% overlap, a3 = 0.20 x 0.6 = 0.12 [m]
25% overlap, a4 = 0.25 x 0.6 = 0.15 [m]
30% overlap, a5 = 0.30 x 0.6 = 0.18 [m]

***Determination of the Extractable Wind Energy***

Although the theoretical energy in the wind (Pa) can be determined, however the amount of extractable energy (Pe) is limited by the fact that it is physically impossible to extract all the available energy in the wind without bringing the air behind the wind energy conversion system (WECS) to a standstill.

Therefore, an ideal wind conversion system is capable of extracting only about 60% of the theoretical available power passing although a stream having a cross-sectional area, A. The general expression for extractable power is

$$P_e = \frac{1}{2} C_p \rho \eta A V^3 \text{ Watt} \qquad (1)$$

Considering wind speed, V = 5.5 m/s, power transmission efficiency, η = 60 %, power coefficient, Cp = 0.15 (Ushiyama, 1982), Density of air, ρ = 1.25 kg/$m^3$ .Then substituting these values into equation (1) we obtain:

Pe = ½ x 0.15 x 1.25 x 0.6 x 2.16 x $(5.5)^3$
= 20.22 watts
= 0.027 PS

This is the power expected to be extracted from the wind to operate the diaphragm water pump. The diaphragm pump operates at comparatively slow speed, a maximum of about 60 strokes per minute.

***Efficiency, Power and Torque Characteristics***

Any wind turbine or windmill rotor can be characterized by plotting experimentally derived set of curves for power against rotor speed at various wind speeds. The maximum efficiency coincides with the maximum power output in a given wind speed. Usually windmill efficiency is presented as a non-dimensional ratio of shaft power divided by wind power passing through a disc or a shape having the same area as the vertical profile of the windmill rotor. This ratio is known as the "power coefficient, *Cp* and mathematically is expressed in equation 2:

$$C_p = \frac{P_e}{\frac{1}{2}\rho A V^3} \qquad (2)$$

Similarly the torque by windmill rotor produces a set of curves which are non-dimensional measure of the torque produced by a given size of rotor in a given wind speed (torque is the twisting force on the drive shaft). The torque coefficient is expressed as:

$$C_t = \frac{T}{\frac{1}{2}\rho A R V^2} \qquad (3)$$

Where T is the actual torque at wind speed V for a rotor with configuration radius, R. The speed is also conventionally expressed non-dimensionally as "tip-speed ratio, λ". This is defined as the ratio of the windmill rotor tip at radius R when rotating at ω rad/sec to the speed of the wind, V m/sec and is mathematically expressed as:

$$\lambda = \frac{\omega R}{V} \quad (4)$$

When the windmill rotor is stationary, its tip speed ratio is zero, and the rotor is stalled. This occurs when the torque produced by the wind is below the level needed to overcome the resistance of the load. λ = 1, means the blade tips are moving at the same speed as the wind and λ = 2, implies that the tips are moving at twice the speed of the wind, and so on. Sometimes it is preferred instead of curves of power, torque against rotor speed to plot $C_t$, $C_p$ against the tip-speed ratio, λ as another way of showing the torque-power characteristics of windmill.

***Wind power for water pumping***

The wind power have been used for pumping water for quite long time ago, it was in fact the primary method used for watering large areas of the Netherlands from the 13th century onwards (Tewari, 1978). A considerable number of wind pumps are believed to be in use around the world. In windy areas, the clean, low cost and unlimited wind energy can be utilised to generate power to drive pumps. In this case, it is necessary to investigate wind speed at the planned location so as to correctly estimate the power derived from the wind. Generally if the wind speed is equal to 3 m/s or above and can be obtained for over 2000 hours per year, it is said that the utilisation of energy is feasible (Gourieres, 1989).

***Determination of operating conditions***

The instantaneous pumping torque is periodic. The mean torque that needs to be furnished by the windmill is determined from the expression, which relates power and torque (P=TW). The power absorbed by water pumping is:

$$P_p = \frac{wNqH}{\eta} \quad (5)$$

Where,

- w : the specific weight of water (w=9800 N/m$^3$)
- q : the volume of water extracted at every pump stroke (m$^3$)
- N : the rotational speed of the rotor in rpm
- H : total head (m)
- η : the pump efficiency

Thus, the corresponding pumping torque is;

$$T_p = \frac{wNqH}{2\pi N\eta} = \frac{wqH}{2\pi\eta} \quad (6)$$

When the rotor is running normally, the aerodynamic torque, T is equal to the pumping torque $T_p$ thus;

$$T = \frac{1}{2}\rho C_t R A V^2 = T_p \quad (7)$$

If η is constant, $T_p$ keeps a constant value. Water pumps requires relatively large starting torque at low speeds, so various windmill types has limits for adoption for water pumping (Bragg and Schmidt, 1979).

***Fabrication Process and Installation***

The rotor shaft, two vertical frame members, six frame cross members, the blade frame parts, blade holding plate and two frame base plates were cut and machined to size. Three collars for supporting the bearings, the stepped extension shaft for holding the slip ring and four bushes for holding the blade support were machined on the centre lathe. Blade frame members were bent to the required semi-circular form using the 3-roller bending machine. Furthermore, the four blade frames were assembled and welded appropriately. Also the frame base plates were welded at right angles to the vertical frame members. The plastic cloth (sail) was cut to size, and wrapped around the blade frame using nylon rope through the eyelets.

The assembled windmill was installed on the test floor at a distance of 2 m from the tunnel exit. Finally strain gauges, slip ring and on-off pulse switch were fixed on the rotor ready for performance testing.

**Testing Instrument**

The testing instruments used were: Strain gauges, slip ring (type SR 4B), portable data recorder (YEW-3057), and strain amplifier (KYOWA-DMB110) for measuring the torque of the rotor; Anemometer (KANAMAX 24-6111) for measuring the wind speed; ON-OFF pulse switch for measuring the rotational speed of the rotor; Tachometer for physical verification of the rotor speed; Spring balance for calibration of measurements of torque; Wooden gripper for creating load (torque) to the rotor; Stop watch and calibrated 40 litres bucket for measuring the delivery of the pump.

**Performance Test Procedures**

***Determination of the wind distribution at the tunnel exit***

The tunnel exit was divided into 5 equally spaced locations namely top, centre, left, right and bottom. The wind velocity at each location was measured at 0, 2 and 4 m distance by varying the electric source frequency of fan motor. The variance of the average wind velocity at each location for the three distances was compared. The F-test at significant level of 5% was carried through the analysis of variance technique (ANOVA). If the average velocity at the three distances is not significantly different, then installing the wind turbine at any of the distances could not significantly affect its performance.

***Determination of rotor starting characteristics***

To determine the starting characteristics, torque and rotational speed were measured while loading the rotor gradually until it stalls. These values were used to determine power, tip-speed ratio-λ, power coefficient, Cp and torque coefficient, Ct .Varying the wind speed was made possible by adjusting the fan frequency switch at the tunnel control panel and the desired wind speed was set after it has been detected by the anemometer.

The torque was measured by the metering system that consisted of a pair of strain gauges, slip ring, a strain amplifier and data recorder. At the same time the temporary cam made of chalk and tape on the rotor allowed the determination of the rotational speed with an ON-OFF pulse switch signal generated by 1.5 Volts dry cell battery.

***Determination of pump water discharge at various wind speeds***

The Savonius windmill was set at the best bucket overlap ratio (with high $C_p$) after analysis of power-torque characteristics. Then the rotor was connected to the diaphragm pump for determining the water discharge at varying wind speeds from 2.5 – 9.6 m/s.

**RESULTS AND DISCUSSION**

**Wind distribution at the tunnel exit**

The F-ratio of 1.02 is less than 6.93 (critical value) for one-factor ANOVA at 95% confidence interval for all the frequency setting. This indicates that the average wind speeds at the three distances were essentially the same such that installation could be at any distance without affecting the wind turbine performance. For

**Table 1: Distribution of wind speed at the wind tunnel exit at a distance of 2 m**

| | Wind speed, m/s | | | | | |
|---|---|---|---|---|---|---|
| **Frequency (Hz)** | **Centre** | **Top** | **Right** | **Left** | **Bottom** | **Average** |
| 20 | 3.25 | 3.20 | 3.25 | 3.30 | 3.16 | 3.23 |
| 30 | 4.80 | 4.75 | 4.85 | 4.75 | 4.75 | 4.78 |
| 40 | 6.45 | 6.40 | 6.50 | 6.40 | 6.40 | 6.43 |
| 50 | 7.75 | 7.80 | 7.85 | 7.80 | 7.75 | 7.79 |
| 60 | 8.85 | 8.80 | 8.85 | 8.90 | 8.80 | 8.84 |

convenience only, the wind turbine was installed at 2 m from the tunnel exit. Table 1 summarizes the wind speed at 2 m distance, which varied from 3.23 – 8.84 m/s.

**Rotor starting characteristics**

The starting characteristics is defined as the time in seconds that elapses since the rotor begins to rotate and how long does it take to attain its maximum rotational speed at a particular wind speed. Figures 3 and 4 presents the starting characteristics of the savonius rotor at 20% and 30% overlaps. As the overlaps were changed, no significant different results were observed. However, differences were noted as the wind speed changed. At low wind speeds (2.5 m/s) the rotor started slowly. At higher wind speeds the rotor started more sharply and took few seconds to attain maximum steady rotational speed. Higher overlaps developed higher rotor rotational speed. At 5.5 m/s wind speed the maximum steady rotor speed was 50 rpm and 62 rpm for 10% and 30% OL respectively as shown in Figure 4.

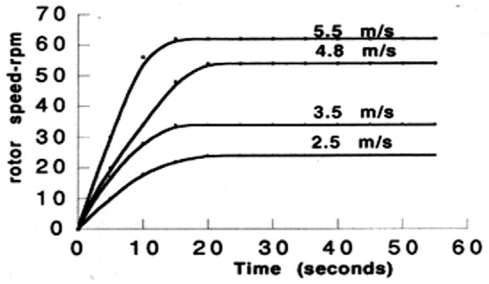


**Figure 3: Starting characteristics at 20% overlap**

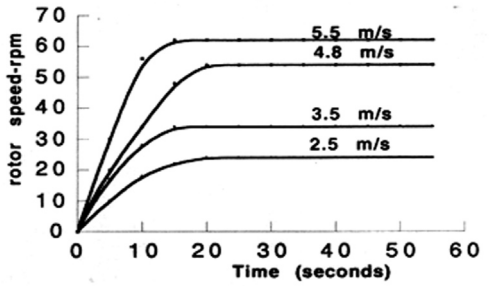


**Figure 4: Starting characteristics at 30% overlap**

**Torque and Power Characteristics**

Figures 5-8 shows the torque and power characteristics of the savonius rotor. The 10% overlap shows to be inferior throughout the experiment. The other overlaps 15%, 20%, 25% and 30% showed moderate similar trends. However, over a wide range 20% OL gave higher values of torque and power. Figures 5 and 6 shows that at wind speed of 2.5 m/s, the 20% OL had the highest torque of 2.8 Nm and power of 1.9 Watts than the rest overlaps. Similarly at wind speed of 5.5 m/s with 20% OL the rotor developed maximum torque and power of 5.2 Nm and 11.75 Watts respectively. Figures 7 and 8 at 2.5 m/s wind speed shows that the 20% OL compared to the other overlaps had the highest power coefficient, $C_p$ and torque coefficient, $C_t$ values of 0.089 and 0.48 respectively. At any overlap, the power coefficient, $C_p$ and torque coefficient, $C_t$ values decreased as the tip speed ratio increased. These results are similar to Ushiyama and Nagai (1988) who found optimum overlap ratio of 20%-30% and Sargolzaei and Kianifar (2007), obtained an optimum bucket overlap ratio of 20%.

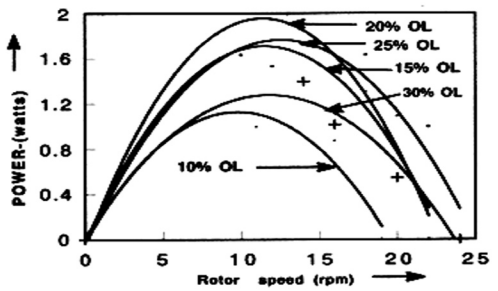


**Figure 5. Rotor speed - Power at 2.5 m/s**

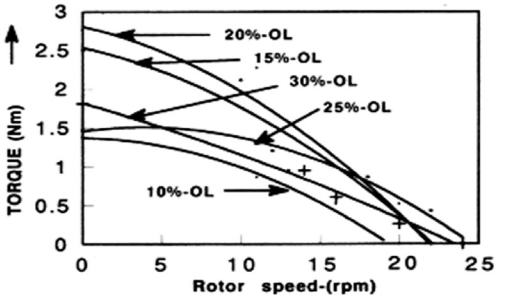


**Figure 6: Rotor speed - Torque at 2.5 m/s**

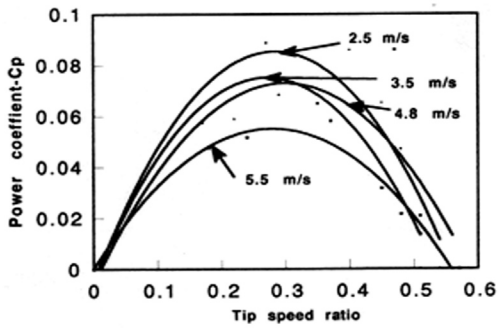


**Figure 7: Power coefficient (Cp) – tip speed ratio(λ) at 20 % OL**

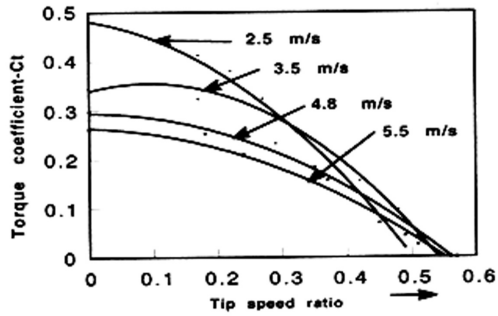


**Figure 8: Torque coefficient (Ct) – tip speed ratio(λ) at 20 % OL**

**Pump water discharge at various wind speeds**

Table 2 and Figure 9 shows the water discharge of the diaphragm pump at an overlap of 20%

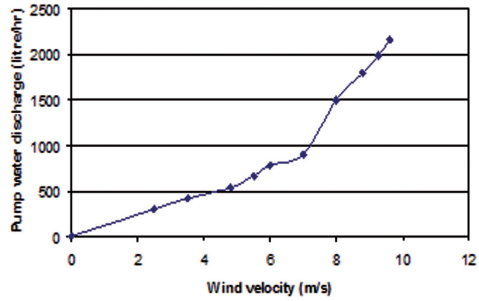


**Figure 9: Water dischage at 20% OL**

with varying wind speeds. The water discharge at 2.5 and 5.5 m/s wind speeds were 300 and 660 l/hr respectively corresponding to 11 and 15 number of diaphragm pump strokes with rotor speed of 22 and 52 rpm. As the wind speed increases to 8.8 m/s the pump discharge also increases significantly to 1,800 l/hr with 22 strokes and rotor speed of 81 rpm.

## CONCLUSIONS

From the study, the following could be concluded;

1. Plastic cloth (Sail) is a useful material for fabricating the blades of a low cost savonius wind turbine.
2. The savonius rotor with semi-circular blades has optimum performance at an overlap

**Table 2: Water discharge of the diaphragm pump driven by the Savonius turbine**

| Wind speed (m/s) | Rotor speed (rpm) | Number of strokes | Water discharge (l/min) |
|---|---|---|---|
| 2.50 | 22 | 11 | 5 |
| 3.50 | 34 | 13 | 7 |
| 4.80 | 48 | 14 | 9 |
| 5.50 | 52 | 15 | 11 |
| 6.00 | 56 | 17 | 13 |
| 7.00 | 65 | 18 | 15 |
| 8.00 | 74 | 19 | 25 |
| 8.80 | 81 | 22 | 30 |
| 9.25 | 85 | 25 | 33 |
| 9.60 | 88 | 28 | 36 |

ratio of 20%.

3. Under proper design configuration, savonius wind turbine can start easily at low wind speed of 2.5 m/s. Therefore, this type of windmill is economically competitive at the sites with low annual average wind speed.
4. Savonius wind turbine when matched properly with appropriate type and size of wind pumps are quite useful for water pumping.

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# Using Compressed Natural Gas in Transport: A Public Expenditures Cutback Perspective in Tanzania

**[1]Gilliard W. Ngewe and [2]Batholomew Marcel**

[1,2]Lecturer, Business & Entrepreneurship Studies Department
National Institute of Transport, P. O. Box 705, Dar es Salaam, Tanzania
Email: ngeweg@yahoo.co.uk

**Abstract**

*This paper examines the scope of rising public expenditures due to transport costs and efforts to reduce it. Transport costs in East Africa are aggravated by ever-increasing price of petroleum in the world market. The paper analyses natural gas as one of the best alternative energy in propelling transport motive powers in Tanzania. It aims at determining the amount of public fund savings resulting from the use of compressed natural gas in public service vehicles based in Dar es Salaam. Natural gas in the form of compressed natural gas (CNG) is important in the transport sector as the combustion of gasoline and diesel results in emission of noxious pollutants. It cost less than gasoline and diesel where there were 11.2 million natural gas vehicles as at 2009 worldwide. The price difference between natural gas and conventional fuels has often been regarded as the most important factor of attracting users to switch to CNG vehicles. The findings of this paper are of great importance to the government budget as they provide the best alternative to save tax-payers' money that can be channeled in poverty alleviation programs. The paper recommends the nation to migrate from gasoline and diesel to compressed natural gas as a major national fuel for the next 50 years in effort to truly cutback public expenditures in public sector transport of Tanzania.*

***Key words:*** compressed natural gas, conventional fuels, public expenditures and public sector

## INTRODUCTION

### Background Information

Since independence, Tanzania has been tackling three major development problems; ignorance, diseases and poverty. In doing so Government expenditure has been on the increase in an attempt to get rid of the problems. Transport service, which plays a crucial role in the growth of the economy (i.e. it facilitates domestic and international trade, contributes to national integration, and provides access to jobs, health, education and other essential facilities) has increasingly been a major uncompromising cost component of Tanzania Government expenditure.

East Africa is feeling the knock-on effects of the sharp rise in global crude oil prices which could hurt economic projections. Analysts say economic growth in Kenya, Uganda, Tanzania, Rwanda and Burundi is threatened by inflation driven by the escalating cost of fuel as countries in the region are net importers of petroleum products (Senelwa, 2011). Masebu (2011) points out that "The price increases have been caused by a rise in the petroleum products prices in the world market and depreciation of the Tanzanian shilling compared to the US dollar - the currency in which purchases of products in the international oil market are made"

This paper aims at examining the scope of rising public expenditures due to transport costs and efforts to reduce as well as estimate the amount of public funds savings that could result from the use of compressed natural gas in public service vehicles based in Dar es Salaam.

The CNG will reduce the amount of harmful exhaust emissions produced by the petrol and diesel-engines such as carbon dioxide, carbon monoxide, nitrogen oxides, sulfur oxides and other volatile organic matters (Mwamnyange, 2010). It intended to determine the amount of tax savings in shillings that can accrue from the use of locally available compressed natural gas instead of imported oil fuels for motor vehicles owned by central, local government and all public institutions based in Dar es Salaam.

**Oil Imports and Price in Tanzania**

It is quite clear therefore that the main drivers for petroleum price movements continue to be the world market prices as well as the exchange rate of the Tanzania Shilling against the US dollar. In line with the prevailing sector legislation, prices of petroleum products are governed by rules of supply and demand (Masebu, 2011).

Table 2 and Figure 1 compare the Oil imports to total imports in Tanzania for the period 2001 - 2010. Both indicate that oil import bills have been increasing at an increasing rate with a decrease in year 2009 during the global economic crunch. On average during a period of 2006 up to 2011 years oil import bill accounted for more than 21% of the total Tanzania import bill.

Table 3(a) and (b) show the increase in Government expenditures, where Figure 2; illustrates the insurance rates, and costs to harden merchant ships against attack (Ploch *et al.* 2011). Some of these costs are ultimately passed on to the consumer. The total economic costs of piracy, though large in an absolute sense, are nevertheless only a small fraction of the total value of worldwide shipborne commerce (Ploch *et al.* 2011).

**Table 2: Oil imports vs. Total imports in Tanzania**

| Years | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|---|---|---|---|---|
| Total Imports, Goods & Services, US$ | 2,209.7 | 2,143.9 | 2,659.2 | 3,457.6 | 4,204.9 | 5,113.4 | 6,274.3 | 8,661.2 | 7,543.2 | 8,974.7 |
| Oil Imports US$ | 200.9 | 177.3 | 367.0 | 575.0 | 847.3 | 1,146.5 | 1,462.1 | 1,922.2 | 1,323.0 | 1,983.8 |
| Oil Imports/ Total Imports bills % p.a. | 9.09 | 8.27 | 13.80 | 16.63 | 20.15 | 22.42 | 23.30 | 22.19 | 17.54 | 22.10 |
| Average for Five years | | | 13.59 | | | | | 21.51 | | |

**Source:** BOT: Economic Bulletins (2001 – 2010)

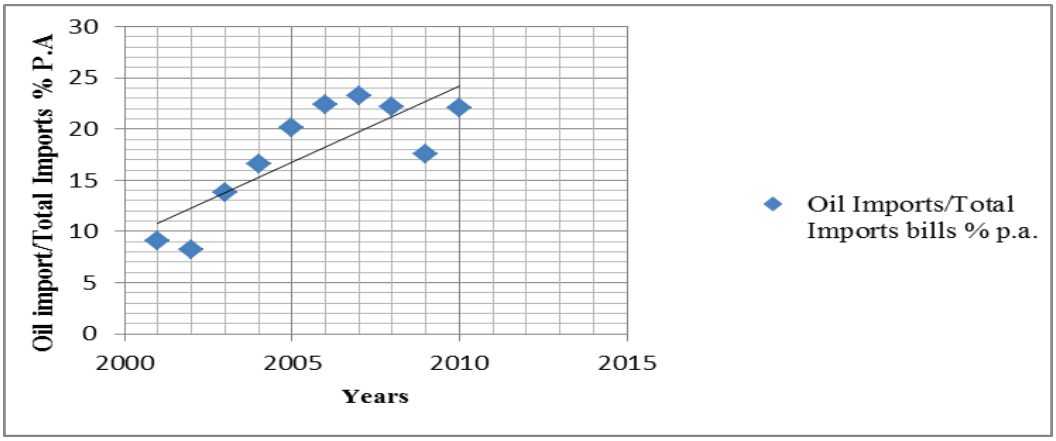


**Table 2(a): Government Budgets; 2006/2007- 2010/2011**

| | 2010/11 | 2009/10 | 2008/9 | 2007/8 | 2006/7 |
|---|---|---|---|---|---|
| Recurrent Expenditures | 7,790,506 | 6,688,254 | 4,726,650 | 3,866,000 | 3,116,121 |
| Public Debt/CFS | 1,756,044 | 1,523,024 | 648,284 | 615,000 | 287,786 |
| Ministries | 4,155,768 | 3,476,243 | 3,083,867 | 2,358,000 | 2,037,536 |
| Regions | 119,580 | 123,013 | 85,743 | 83,000 | 60514 |
| Local Government Authorities | 1,759,114 | 1,565,974 | 908,756 | 810,000 | 730,285 |
| Development Expenditure | 3,819,051 | 2,825,431 | 2,489,480 | 2,201,000 | 1,734,467 |
| **Total Expenditures** | **11,609,557** | **9, 513,685** | **7,216,130** | **6,067,000** | **4,850,588** |

**Table 2(b) Recurrent and Development Expenditures**

| **Financial Year** | **2006/7** | **2007/8** | **2008/9** | **2009/10** | **2010/11** |
|---|---|---|---|---|---|
| Recurrent Expenditures | 3,116,121 | 3,866,000 | 4,726,650 | 6,688,254 | 7,790,506 |
| Development Expenditure | 1,734,467 | 2,201,000 | 2,489,480 | 2,825,431 | 3,819,051 |
| **Total Expenditures** | **4,850,588** | **6,067,000** | **7,216,130** | **9,513,685** | **11,609,557** |

**Source:** Ministry of Finance and Economic Affairs (June 2011)

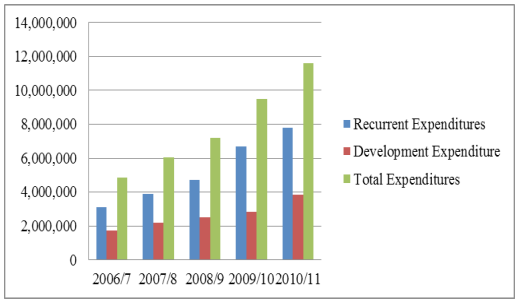



**Figure 2: Government Expenditures (in Millions)**

## Why Alternative Fuels?

The fundamental problem is that the international petroleum market does not allocate oil resources in a socially efficient manner. It does not account for large environmental impacts, and it is volatile and politicized, distorting energy decisions through inappropriate price signals and uncertainty. Four major problems and costs are not captured in market prices:

a) Energy security (dependence on insecure petroleum suppliers.)
b) Indirect economic costs of importing energy
c) Global warming
d) Urban air pollution.

## Transport Energy Futures

According to Sperling and Deluchi (1989), transport energy futures indicate that substituting an alternative fuel for 2 million barrels per day of gasoline fuel, thereby reducing world oil demand, would lower the world oil price by about $2 per barrel when oil is priced at $34 per barrel. If this analysis is correct, those 2 million gasoline-equivalent barrels would reduce the import cost of oil to the United States by about $18 million per day ($6.6 billion per year), or $9.00 per gasoline-equivalent barrel of alternative fuel. The benefit of suppressing short-term oil price spikes may be even larger, because the spikes may be steeper and more disruptive. If oil-importing countries wait for higher prices, they will not be able to respond with alternative fuels for many years. (Wang *et al.,* 1993) High prices could be maintained for 10 years or more as the United States and other oil importers struggle to expedite the transition to non petroleum fuels and replace vehicles that consume only gasoline and diesel.

## Rising Oil Imports

Impose large indirect costs on the national economy, since the outflow of funds to pay for imported oil shrinks demand for domestic goods and services. This cost is difficult to estimate

because it depends on hard-to-assess factors such as how much the exporting nations reinvest their earnings in the United States, what they invest in, the response of exchange rates to changes in terms of trade, and employment in the United States exporting industries. In any event, it has been estimated that the Macroeconomic external costs of rising imports may run as high as $50 per barrel of oil (Sperling and Deluchi, 1989). Thus, even though they cannot be accurately quantified, indirect economic costs is another motivation for introducing alternative fuels.

**Global Warming**

Global warming is caused by increasing atmospheric concentrations of carbon dioxide and other greenhouse gases, many of which are produced by the combustion of coal, oil, and natural gas. Global warming is now attracting much more attention than energy security or indirect economic impacts, partly because its potential costs are much greater, although more speculative. Transport is a large source of greenhouse gases: scientific evidence becomes more certain, the possibility exists that a strong commitment will be made to reduce the use of carbon fuels. It is unlikely that carbon dioxide emissions could be reduced economically by adding control systems to vehicles or refineries. The most feasible strategy for reducing carbon dioxide emissions from transport is less consumption of fossil fuels, either by increasing fuel-efficiency or using non – fossil energy sources (Sperling and Deluchi, 1989).

**The price of crude oil increase trend in the world market**

Due to exchange rate fluctuations, the real price line in figure 3 is only relevant to the United States and countries with a currency tied to the U.S. dollar at a constant rate throughout the period.

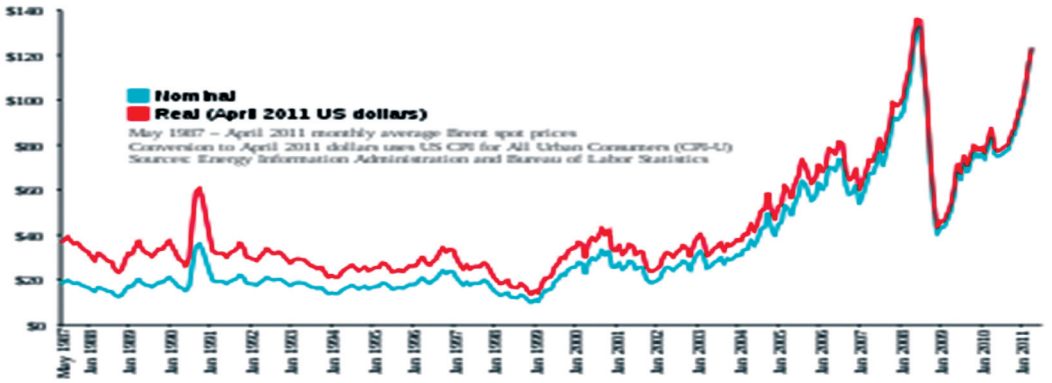
The demand for oil is highly dependent on global macroeconomic conditions. According to the International Energy Agency (IEA), high oil prices generally have a large negative impact on the global economic growth. The IEA has a broad role in promoting alternate energy sources (including renewable energy), rational energy policies, and multinational energy technology co-operation (Sperling and Deluchi 1993).

As the demand for fuel nowadays rapidly increases, according to the industrial development all over the world, the stock of fossil fuel reduces very fast. CNG as one of the alternative fuels is really important to support the transportation sector. Currently, most of the CNG engine vehicle is a converted version whether from the diesel vehicle or gasoline vehicle. To widespread the use of CNG, the refueling network must be established all over the country within the CNG engine vehicle driving range and at the same time the refueling technology and the dedicated CNG engine vehicle technology must be improved.

**Natural Gas in Transportation**

Natural gas has long been considered as an

**Figure 3: Oil price Brent Barrel**




***Source:*** Brent barrel petroleum spot prices, May 1987 – April 2011

alternative fuel for the transport sector. In fact, natural gas has been used to fuel vehicles since the 1930's. There are vehicles running by Liquidified Petroleum Gas (LPG) and Compressed Natural Gas (CNG). In recent years, technology has improved to allow for a proliferation of natural gas vehicles, particularly for fuel intensive vehicle fleets, such as taxicabs and public buses. This CNG is stored in similar fashion to car's gasoline tank, attached to the rear, top, or undercarriage of the vehicle in a tube shaped storage tank. A CNG tank can be filled in a similar manner and in a similar amount of time to gasoline tank, (TPDC, 2007).

**Malaysian Scenario in CNG as an Alternative Fuel**

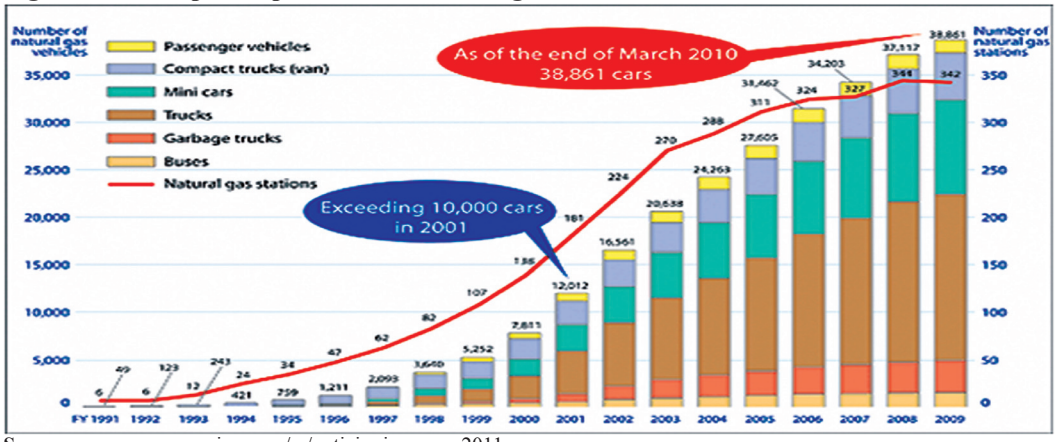
The growth of vehicles number in Malaysia is quite high. This contributed to the more demand on fuel usage and an increase in air pollution. This kind of situation has happened all over the world hence the need for alternative fuel like CNG becomes obvious. As the price of CNG worldwide is very much lower than petrol and diesel; it is 40 – 50% of petrol and diesel price it also reduces the maintenance cost when CNG engines are compared to the existing engines (TPDC, 2007).

The Malaysian government has implemented a few components to encourage the use of CNG as alternative fuel these include:

i. To ensure the continuous availability and fair pricing of the CNG. The current price of CNG is RM0.68 per liter. Compare to the petrol and diesel the price of CNG are lower 65% and 57%.
ii. Additional reduction of the road tax from existing level
    a) Monogas or dedicated vehicles 50% off
    b) bi-fuel vehicles 25% off
    c) dual fuel vehicles 25% off
iii. Tax incentives and other financial incentives for encouraging and facilitating the purchasing of new buses, other vehicles and construction of CNG outlets.

The commercialization of CNG vehicles in Malaysia is far behind compare to other countries like Argentina, Brazil and Pakistan. Currently, there are 40 service stations in Malaysia, providing CNG refueling facilities to a population of around 15,600 natural gas vehicles. The important component to encourage the usage of CNG in Malaysia are developing CNG dedicated engine or using the available CNG dedicated engine in the market; provide a nationwide natural gas infrastructures; develop political willingness to revise the existing law and regulation across disciplines, agencies and government; ensure the availability and fair pricing of the CNG, for the city bus, the routes and ridership must be established and create tax incentives or instruments for encouraging and facilitating new bus purchases and fuel station built-out, (TPDC, 2007).

**Figure 4: The Japan Experience in CNV Usage**




**Source:** www.gnvmagazine.com/.../noticia- japanese 2011

International Agreements on the Green House Gases (GHG), such as the Kyoto Protocol, Gothenburg and UNFCCC, signed by many countries, emphasize on the need for all countries to take immediate action to reduce emission of greenhouse gases and industrialized countries to help the developing countries to finance projects, which aim at reducing emissions of these gases. One of such projects is the CNGV technology, which involves use of compressed natural gas (CNG) to fuel vehicles instead of the traditional petrol and diesel fuels as demonstrated by the Japan experience in figure 4.

It is also believed that the technology can be suitable for Tanzania, especially because natural gas is produced locally at the Songosongo and Mnazi bay gas fields, making it cheaper than the traditional fuels which need foreign currency for importation.

**Natural Gas Development in Tanzania**

Currently there are two proven Natural Gas Reservoirs discovered in Tanzania. The first one is Songosongo Natural Gas Field with a proven deposit of about 1 TCF while the second being Mnazi Bay Natural Gas Field with almost the same estimated deposit of about 1 TCF. The two fields are located on Southern Coastal belt of Tanzania, (Lumato, 2005; URT, 2006; 2007; 2008; 2009). The Mnazi Bay Natural Gas Fields is under development, when it is complete, it would be in a position to produce almost same amount as Songosongo Gas Fields of about 41 MMscfd. The gas produced from this field will mainly be used in Dar es Salaam; The Government of Tanzania through its Five Years Development Plan 2011/12 – 2015/16, contemplates to embark on a 36' natural gas project from Mnazi Bay to Dar es Salaam in the first twelve (12) months of the plan (URT, 2010). This will increase the natural gas supply in Dar es Salaam and reduce further the price of natural gas to the end users, TPDC (2007).

**FINDINGS**

The study aims at establishing the amount of money, which can be saved from public expenditures once the government in Dar es Salaam decides to exploit Compressed Natural Gas in transport. Therefore, the study had first to establish how much diesel and gasoline is consumed by motor vehicles currently owned and run by central and local governments and all public institutions based in the Dar es Salaam region and the corresponding relationship with oil bill.

$$r = \frac{\sum_{i=1}^{n} x_i y_i - \frac{1}{n}\sum_{i=1}^{n} x_i \sum_{i=1}^{n} y_i}{\sqrt{\sum_{i=1}^{n} x_i^2 - \frac{1}{n}\left(\sum_{i=1}^{n} x_i\right)^2}\ \sqrt{\sum_{i=1}^{n} y_i^2 - \frac{1}{n}\left(\sum_{i=1}^{n} y_i\right)^2}}$$

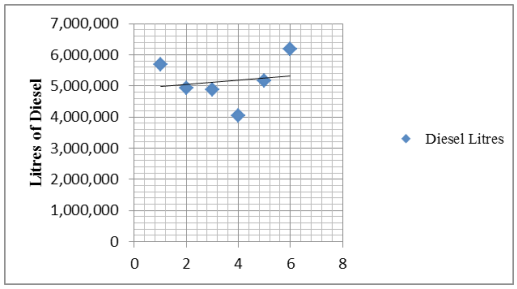
Pearson's Correlation Coefficient was used to determine the relationship between annual oil import bills Vs Public Expenditure budgets as provided in table 1 and 2a. A Pearson correlation coefficient results of + .973 was found, this means that there is a perfect positive relationship between an increase in annual oil import bill(x) and increase of annual Public Expenditures budget(Y) of Tanzania year after year. Therefore, reduction in oil import bill will result in reduction of public spending peri-ceteribas. Then, the biggest challenge here is: "How can oil import bill be reduced in order to cut public expenditures in Tanzania?"

**Table 5: Diesel Consumed by Government vehicles in Dar es Salaam**

| | As at August 3, 2011 Current Price-2031.31 TZS | | |
|---|---|---|---|
| | Years | Diesel consumed in Lts<br>Per Financial Year | Current Value in TZS |
| 1 | 2005/6 | 5,678,481 | 11,534,755,240.11 |
| 2 | 2006/7 | 4,941,624 | 10,037,970,247.44 |
| 3 | 2007/8 | 4,877,345 | 9,907,399,671.95 |
| 4 | 2008/9 | 4,047,165 | 8,221,046,736.15 |
| 5 | 2009/10 | 5,176,150 | 10,514,365,256.50 |
| 6 | 2010/11 | 6,192,580 | 12,579,049,679.80 |
| | Total | 30,913,345 | 62,794,586,831.95 |

***Source:*** Government Procurement Services Agency (GPSA)

**Figure 5: The Average Trend of Diesel Consumption**




From table 5 and figure 5: the conservative assumption made is that the market price of diesel will remain constant throughout the period of next six years i.e. 2011/12 to 2016/17 and the rate of diesel consumption will remain the same, thus government vehicles in Dar es Salaam will consume diesel worth 62,794,586,831.95 TZS only in six years. If these vehicles will be converted to Compressed Natural Vehicle (CNV) the fuel cost will be as follows:

According to TPDC (2007), the cost of natural gas is 40 – 50% of diesel price, therefore;

a) At the lowest price of natural gas:
   40% x 62,794,586,831.95
   = 25, 117,834,732.78 TZS
   Savings from the price of diesel:
   62,794,586,831.95 - 25,117,834,732.78
   = 37,676,752,099.17 TZS
   In six years less the cost of converting vehicles.

b) At the highest price of natural gas:
   50% x 62,794,586,831.95
   = 31,397,293,415.98
   Savings from the price of diesel:
   62,794,586,831.95 - 31,397,293,415.975 = 31,397,293,415.975
   In six years less the cost of converting vehicles

The savings in fuel will be between 37,676,752,099.17 and 31,397,293,415.975 TZS

From table 6 and figure 6: the conservative assumption made is that the market price of petrol will remain constant throughout the period of next six years i.e. 2011/12 to 2016/17 and the rate of petrol consumption will remain the same,

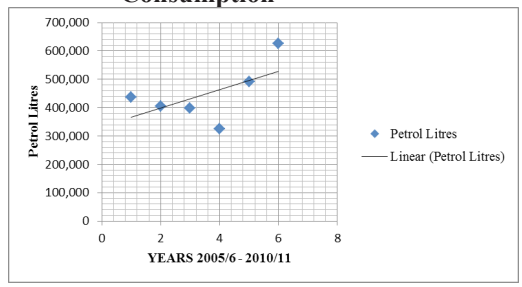
**Table 6: Petrol Consumed by Government vehicles in Dar es Salaam**

As at August 3, 2011 Current Price-2114.12 TZS/Lt

| | Years | Petrol consumed in Lts Per Financial Year | Current Value in TZS |
|---|---|---|---|
| 1 | 2005/6 | 437,234 | 924,365,144.08 |
| 2 | 2006/7 | 404,800 | 855,795,776.00 |
| 3 | 2007/8 | 397,255 | 839,844,740.60 |
| 4 | 2008/9 | 325,512 | 688,171,429.44 |
| 5 | 2009/10 | 491,404 | 1,038,887,024.48 |
| 6 | 2010/11 | 625,729 | 1,322,866,193.48 |
| | **Total** | **2,681,934** | **5,669,930,308.08** |

***Source:*** Government Procurement Services Agency (GPSA)

**Figure 6: The Average Trend of Petrol Consumption**




thus government vehicles in Dar es Salaam will consume petrol worth 5,669,930,308.08 TZS only in six years. If these vehicles will be converted to Compressed Natural Gas Vehicle (CNGV) the fuel cost will be as follows:

According to TPDC (2007), the cost of natural gas is 40 – 50% of diesel price, therefore;

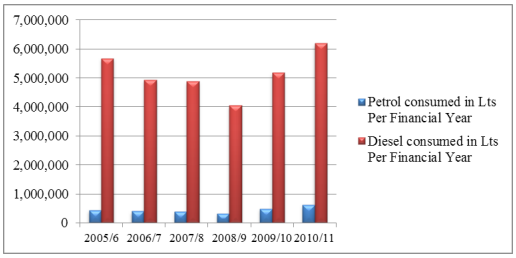
a) At the lowest price of natural gas:
   40% x 5,669,930,308.08
   = 2,267,972,123.232 TZS
   Savings from the price of petrol:
   5,669,930,308.08 - 2,267,972,123.232
   = 3,401,958,184.848 TZS
   In six years less the cost of converting

vehicles.

b) At the highest price of natural gas:
50% x 5,669,930,308.08
= 2,834,965,154.04
Savings from the price of petrol:
5,669,930,308.08 - 2,834,965,154.04
= 2,834,965,154.04
In six years less the cost of converting vehicles

The savings from petrol will be between 3,401,958,184.848 and 2,834,965,154.04TZS However, from figure 5 and 6, both trends depict that the amount of diesel and petrol to be consumed in litres will increase at an increasing rate, hence predicting that the government will spend more on oil imports in the next six years than what it has spent in the past six years. Therefore, if the government will go for compressed natural gas suggested it will save more than the sum of money arithmetically demonstrated above.

**Figure 7: Diesel and Petrol Consumption Volumes**




***Source:*** Government Procurement Services Agency (GPSA)

The government in Dar es Salaam is mainly using diesel vehicle for its day to day activities as there is less volume of petrol consumed in the last six years. This can be related to the price of petrol while compromising other factors like air pollution and price of diesel vehicles.

Recently, the Tanzania Petroleum Development Corporation (TPDC) has prepared a plan to implement an alternative fuel program for all state fleet vehicles. The plan will make it mandatory for government vehicles to be configured in order to use natural gas. According to Mwamnyange, (2010), using natural gas over


**Figure 8: CNG Filling Station in Dar es Salaam - Ubungo**

other traditional fuels like charcoal, petrol, diesel, liquefied petroleum gas and heavy fuel oil will save the government more than 36.62Million US$ in oil products import every year. In the meantime the conversion of vehicles to use natural gas is being carried out at two centers by private companies working with government institutions. Furthermore, the benefits of using natural gas are immense. “Even the environment and forests are targeted in the master plan, as less carbon dioxide and carbon monoxide will be released into the atmosphere.”

However, besides having the conversion centers in place and one natural gas filling station for the last three years, vehicle conversion project has recorded not more than fifty (50) private cars and non – government owned vehicles.

Tax revenues: the Tax Revenue Authority has been enjoying easy fuel tax collection. This can constrain the idea of not using imported oils and convert vehicles into CNV. However, from arithmetic calculations it has been proved that the foregone tax for 171 vehicles using petrol will be recovered through the unused foreign exchange money in settling oil import bills and earn a net saving of 367,906,618.28 TZS

**The Compressed Natural Gas Vehicle Challenges**

1) Lack of Refueling stations:
   a. Most of petrol vehicles can travel up 480 kilometers or more on a tank of fuel. When they run low, they pull into gas station to fill up.
   b. Typically, NGV can go about the same distance i.e. Dar –Dodoma. However,

when they run out of fuel there is no place to fill up

2) Availability of CNG parts: There is some fear that there are no CNG parts. This can easily be eliminated because the technology is widely used World-wide.
3) Research and Development: Research and development activities in Tanzania are too weak. Researchers need to research on NGV materials extensively.
4) As far as fueling automobiles with either Compressed Natural Gas (CNG) or Liquid Natural Gas (LNG), the re-fueling process is slow (slower than using propane), and high pressures are required.
5) CNG use in transport promotion encounters drawbacks from fossil oil profit making traders in Tanzania

**Table 7: Taxes Foregone Vs Import Bill in forex**

| Vehicles | Taxes Forgone |
|---|---|
| VEHICLES | 171 |
| Litres/day | 10 |
| days/year | 365 |
| Litres/year | 624,150 |
| Tax rate | 539 |
| Tax foregone in Tsh | 336,416,850 |
| Tax foregone in $ | 224,277.90 |
| FOREX SAVED | |
| CIF - Petrol (US$) | 989 |
| Conversion litres/MT | 1359 |
| Conversion US$/Tshs | 1600 |
| VEHICLES | 171 |
| Litres/day | 10 |
| days/year | 365 |
| Litres/year | 624150 |
| CIF/litre | 0.727740986 |
| Forex Saved in $ | 454,219.54 |
| Forex Saved in Tshs. | 726,751,258.28 |
| Net Savings (usd) | 229,941.64 |
| Net Savings (Tsh) | **367,906,618.28** |

**Source:** TPDC 2007: Calculated taxes foregone against import bill saved in foreign exchange

**CONCLUSION AND RECOMMENDATIONS**

It can be concluded that Natural Gas Vehicles in Tanzania are in urgent need to be promoted. They will ease the ever increasing public expenditure that is attributed by ever rising of transport costs. With the very conservative assumption of minimum estimation the Dar es Salaam based government vehicle savings will range between 41,078,710,284.018 to 34,232,258,570.015 TZS from the price of diesel and petrol alone. The economy will be able to make foreign exchange net saving from oil import bills equivalent to TZS 367,906,618.28 per year in reduction of oil import. The use of the accrued savings fund will find its way in enhancing activities spelt under the National Strategy for Growth and Reduction of Poverty II (NSGRP II) of Tanzania.

Therefore, the paper calls upon all government stakeholders in Dar es Salaam to act immediately in implementing the Natural Gas Vehicle Conversion project so as to realize the calculated savings while protecting the environment and enhance poverty alleviation in the country. The Natural Gas Vehicle Conversion projects need to be supported by government through putting in place tax incentive policies and clear legal framework. As of today Tanzania is importing natural gas vehicle conversion kits. Import procedures need to be streamlined to smoothen and fasten the process. The Government of Tanzania is recommended to commission researches that in future will enable to produce locally such kits and CNG parts for its sustainability.

Nevertheless, there are more advantages of using compressed natural gas (CNG) to power vehicles such as; it is the cleanest burning fuel available in Tanzania. This reduces harmful emissions, which helps ambient air quality in the central business district and along highways with heavy traffic. There is an abundance of natural gas, and increasing the production of natural gas would make Tanzania less reliant on foreign sources for its energy, which would help to enhance national security. There are many areas throughout Tanzania where natural gas has recently been discovered or commercially prospected by

licensed gas explorers. Notwithstanding, the paper recommends the nation to shift from fossil oil dependence to compressed natural gas as a major national fuel for the next 50 years in effort to alleviate poverty.

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## LIST OF ABBREVIATIONS

| | |
|---|---|
| CNG | Compressed Natural Gas |
| CNV | Compressed Natural Vehicles |
| EWURA | Energy and Water Utility Regulatory Authority |
| GPSA | Government Procurement Services Agency |
| IEA | International Energy Agency |
| LPG | Liquidified Petroleum Gas |
| MMscfd | Million Standard Cubic Feet per day |
| NSGRP | National Strategy for Growth and Reduction of Poverty II |
| TCF | Trillion Cubic feet |
| TPDC | Tanzania Petroleum Development Corporation |
| UNFCC | United Nations Framework Convention on Climate Change |
| URT | United Republic of Tanzania |

# Tumbling the Impenetrable Road Traffic Congestion in Dar Es Salaam: A commuter Service Perspective

**Batholomew Marcel and Gilliard Ngewe**

Lecturers,
Business and Entrepreneurship Studies Department
National Institute of Transport
ngeweg@yahoo.co.uk

## Abstract

*This paper examines the gravity of road traffic congestion problems in Dar es Salaam and proposes some feasible solutions considered necessary to decongest the city. Congestion occurs when transport demand exceeds transport supply at a specific point in time and in a specific section of the transport system where each vehicle impairs the mobility of others. Road congestion in Dar es Salaam is characterized by public transport services that are provided by 6,000 licensed small capacity buses and 84.3% of buses have a carrying capacity of less than 30 commuters resulting into chaotic public transport compelling commuters to go for private cars. The study found that the mean speed from all routes studied was 12.297km/hr, with standard deviation of 2.457km/hr and variance of 6.036km/hr. Challenges associated with congestion include: millions of man-hours are lost as commuter buses and vehicles move at a snail's pace. Work in public and private sectors are not done in time hence affecting socio-economic development. Traffic jams consume tones of fuel bought by foreign currencies and emit pollutants.*

*This paper provides feasible solutions such as; adequate public transport capacity, corporate commuter service providers, heavy occupancy vehicles, alternative work schedules, commuter bus crew training, congestion pricing, pedestrians and cyclist tracks, road pricing, freight distribution system, priority lanes and use of traffic lights if the proposed solutions are applied, the City will be able to enjoy smooth flow of road traffic and travel time saving.*

## INTRODUCTION

Cities are locations with complex spatial structures with high level of accumulation and concentration of economic and social activities that are supported by transport systems. The commonest transport problems are often related to urban areas and take place when transport systems, for a variety of reasons, cannot satisfy the numerous requirements of urban mobility. Congestion occurs when transport demand exceeds transport supply at a specific point in time and in a specific section of the transport system (Ntambala, 2010). Under such circumstances, each vehicle impairs the mobility of others.

If traffic flow exceeds the capacity of a road traditionally we tend to add additional lanes to reduce density and enhance the speed. This is the effect of traditional transport education. If traffic density is decreased, the car transport becomes more attractive, more people use their cars. The speed is enhanced not only to local traffic and finally the same congestion appears, but this time on a higher level. This is the inevitable outcome of traditional transport treatment methods.

Commuter services in Dar es Salaam dates back to the British colonial era when in 1949 a privately owned British company known as the Dar es Salaam Motor Transport Company (DMT) started to provide bus services in the

city. The company's commuter services were confined within the then officially recognized urbanized area of about 2-3 kilometres radius. The commuter services that DMT provided before independence corresponded to a great extent with the then demand to travel apparently due to the smaller size of the city and its population size. The good quality of public transport services offered by DMT continued relatively well until the mid-1970s. According to bus commuters of that time, buses adhered to timetables and delays were minor (Kombe *et al.* 2003). In 1970, DMT was nationalized and it became a public run commuter service company. In 1974 it was renamed to be 'Usafiri Dar-es-Salaam' (UDA).

As Tanzania has marked its 51st Anniversary of independence, public run commuter service organizations have experienced demise as a result of poor public sector management and the failure to satisfy market demand (URT, 2011). This has led to a corresponding increase in less-organized private operators who have filled the supply 'vacuum', as is the case with the daladala operators in Dar es Salaam and Matatu in Kenya.

The population of the city which is about four million people and growing at the rate of 4.3% annually as per 2002 census mostly depends on public transport services for their travel within the City. The city has three municipalities of Ilala, Kinondoni and Temeke while having an area of about 1393 km$^2$. Public passenger transport service in Dar es Salaam city has for many years been unsatisfactory. It is generally poor and unsafe, lacking professionalism, efficiency and quality to commuters. The main factors leading to the above situation include; rapid expansion of the City which has far outpaced the capacity to provide basic infrastructure (such as good roads) and services, poor state of majority of the buses, untrained bus drivers and conductors driven by the pursuit of daily revenue targets payable to the bus owners, non-adherence to traffic rules and regulations and lack of an organized public transport system. The service offered is poor due to overloading in small carrying capacity and overcrowded buses particularly during peak hours, reckless driving, route shortening, harassment of women and schoolchildren and polluting vehicles particularly during peak hours dominated by traffic jams on all major roads in the City.

The commuter services in the city are currently provided by about 6,000 licensed small capacity privately owned buses, known as 'Daladalas' and by about 27 minibuses owned by a public company "Shirika la Usafiri Dar es Salaam (UDA)", DART (2010).

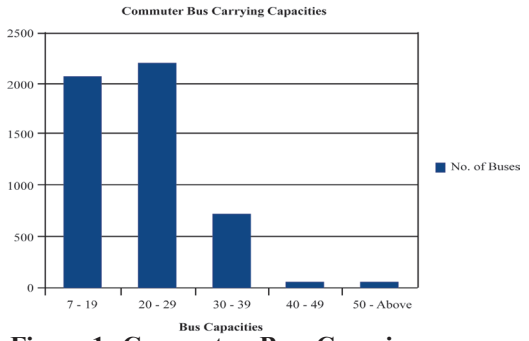


**Figure 1: Commuter Bus Carrying Capacities Distribution**

The land use pattern consists of one central area adjacent to the seashore, which is serving as a focal point where most of commercial, public and government institutions are located. The city is facing a serious problem of road congestion on the arterial road network and the Central Business District (CBD). Increasing population calls for increasing business and accommodation in the city centre, which in turn brings an increased traffic and parking demands and requirements. These increases were not taken into consideration by the transport and city planners during the planning stage, consequently, traffic jams and conflicts in Central Business Districts (CBD).The main cause of road traffic congestion is that the volume of traffic is too close to the maximum capacity of a road or network although there are other causes of road traffic congestion in the case of Dar es Salaam city.

Commuter buses licensed to operate in the city

are of small carrying capacity; about eighty four percent (84.3 %) of buses have a carrying capacity of less than thirty commuters only as presented in figure 1. Moreover, there is an inventory of 3,171 commuter service operators in the city and only 27 operators are registered Limited liability companies with the Business Registration and Licensing Authority, DART, (2010).

There are many empirical studies on the estimation of Values of Travel Time Savings (VTTS), with varying degrees of objectivity and relevance, mostly based on the observation that travelers are prepared to spend money to save time. These values are applied to both forecasting the effects of speed changes on behavior and also for estimation of the social benefit of such savings, in order to calculate value for money of spending public funds on transport investments. A study conducted by the ITDP (2009) revealed that cities with Bus Rapid Transit (BRT) are congested since the rapid speed range from 25-50km/hr as shown in Table 1.

**Table 1: Congested BRT Cities Speed**

| City | Country | Public Transport Speed(km/hr) |
|---|---|---|
| Guangzhou | China | 25 |
| Beijing | China | 21 |
| Seoul | South Korea | 17 |
| Brisbane | Australia | 19 |
| Bogota | Columbia | 25 |
| Jakarta | Indonesia | 21 |
| Curitiba | Brazil | 22 |
| Sao Paul | Brazil | 16 |
| Hangzhou | China | 23 |
| Mean Speed | | 21 |
| Standard Deviation | | 3.202 |
| Variance | | 10.25 |

**Source:** ITDP (2009)

From table 1 it implies that the congested BRT world is moving at a speed of 21km/hr with the standard deviation of 3.202km/hr and Variance of 10.25km/ hr. This prompted the researchers to conduct the study on the level of congestion in Dar es Salaam City.

Basing on the fact mentioned above, the study was conducted to determine the gravity of commuter service road traffic congestion in travel time lost per trip to commuters and suggest ways that if deployed can remove completely the traffic jams problem in the city.

## METHODOLOGY

The study selected the major arterial road network routes, which transverse from the CBD of the city to the densely populated sub urban centers for observation. The selected routes included; Kimara-Posta, Kimara-Kariakoo, Mwenge-Kariakoo, Mwenge-Posta, Airport-Posta, Gongolamboto-Posta and Tegeta-Kariakoo. Primary data was collected in these routes for a period of one month using a participatory observation technique. The data presented in table 2(a) as observed time represent an average observed travel time spent in a particular route for the month of August 2011 on working days only. The study findings were compared to the findings revealed in Table 1. Data collected were analyzed using descriptive statistical data analysis tools. Measures of central tendency and dispersion were calculated to determine the level of dispersion. It measures how similar are the route speed to each other. Normally, the more similar the speed is to each other, the lower the measure of dispersion will be. The less similar the speeds are to each other, the higher the measure of dispersion will be. In general, the more spread out a distribution is, the larger the measure of dispersion will be.

### Data Analysis and Findings

The standard deviation was calculated using the following formula:

$$\sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - \bar{x})^2}$$

Where,
σ = standard deviation,
xi = each value of dataset, = the arithmetic mean of the speed

N = the total number of data points
$\sum (Xi - )^2$ = The sum of $(Xi - )^2$ for all data points

While the variance was calculated by the given formula:

$$\sigma^2 = \frac{\Sigma(x-\mu)^2}{N}$$

Where, μ = is the mean and N is the number of scores.

Data collected were summarized and analyzed in table 2(a) and (b) below:

results with that of table 1, the study findings from Dar es Salaam routes are similar to each other with less dispersion in relation to congested BRT world cities. Therefore, this confirms that commuter routes in Dar es Salaam are at a speed of 12.297km/hr against the congested BRT world cities which are running at a speed of 21km/hr with the standard deviation of 3.2km/hr and variance of 10.25km/hr. The correlation coefficient between cities mean speeds and their respective economic growth rates can be calculated to determine the impact of commuter service congestion and cities' economic growth.

**Table 2(a): Normal Traffic Flow Travel Time Analysis**

| Route | Distance (km) | Time for normal traffic flow (in minutes) @ 24 km/h | Observed time (August, 2011) in minutes | Delayed time | Delay for Round trip per day in minutes | Observed time (Hrs) | Congestion speed Km/h |
|---|---|---|---|---|---|---|---|
| Kimara-Posta | 16.4 | 41 | 115 | 74 | 151 | 1.917 | 8.557 |
| Posta-Kimara | 16.4 | 41 | 118 | 77 | | 1.967 | 8.339 |
| Kimara-Kariakoo | 15.0 | 38 | 93 | 55 | 107 | 1.55 | 9.677 |
| Kariakoo-Kimara | 15.0 | 38 | 90 | 52 | | 1.5 | 10.0 |
| Mwenge-Kariakoo | 10.3 | 25.8 | 42 | 16.2 | 35.4 | 0.7 | 14.714 |
| Kariakoo-Mwenge | 10.3 | 25.8 | 45 | 19.2 | | 0.75 | 13.73 |
| Mwenge-Posta | 11.9 | 30 | 45 | 15 | 38 | 0.75 | 15.9 |
| Posta-Mwenge | 11.9 | 30 | 53 | 23 | | 0.883 | 13.472 |
| Airport-Posta | 11.0 | 27 | 51 | 24 | 40 | 0.85 | 12.941 |
| Posta-Airport | 11.0 | 27 | 43 | 16 | | 0.717 | 15.349 |
| Go/Mboto-Posta | 17.0 | 43 | 72 | 29 | 70 | 1.2 | 14.167 |
| Posta-Go/Mboto | 17.0 | 43 | 84 | 41 | | 1.4 | 12.143 |
| Kariakoo-Tegeta | 24.7 | 61.8 | 131 | 69.2 | 132.4 | 2.183 | 11.313 |
| Tegeta-Kariakoo | 24.7 | 61.8 | 125 | 63.2 | | 2.083 | 11.856 |
| | | | | | | Mean Speed | 12.297 |
| | | | | | | SDEV | 2.457 |
| | | | | | | VAR | 6.036 |

**Source:** Field survey August 2011

From table 2(a) the mean speed from all major routes studied was found to be 12.297km/hr, with standard deviation of 2.457km/hr and variance of 6.036km/ hr. Comparing these

From table 2(b) the problem is even bigger as Dar es Salaam commuter travel time is compared to uncongested Bus Rapid Speed (25-50km/hr). The delayed time per trip when compared to

**Table 2(b): Rapid Traffic Flow Travel Time Analysis**

| Route | Distance (km) | Expected Time with Rapid Bus Flow = 30km/h | Observed time (August, 2011) in minutes | Time difference @ 30 km/h |
|---|---|---|---|---|
| Kimara -Posta | 16.4 | 32.8 | 115.0 | 82.2 |
| Posta-Kimara | 16.4 | 32.8 | 118.0 | 85.2 |
| Kimara -Kariakoo | 15 | 30 | 93.0 | 63.0 |
| Kariakoo-Kimara | 15 | 30 | 90.0 | 60.0 |
| Mwenge-Kariakoo | 10.3 | 20.6 | 42.0 | 21.4 |
| Mwenge-Posta | 11.9 | 23.8 | 45.0 | 21.2 |
| Posta-Mwenge | 11.9 | 23.8 | 53.0 | 29.2 |
| Airport-Posta | 11 | 22 | 51.0 | 29.0 |
| Posta-Airport | 11 | 22 | 43.0 | 21.0 |
| Gongolamboto-Posta | 17 | 34 | 72.0 | 38.0 |
| Posta-Gongolamboto | 17 | 34 | 84.0 | 50.0 |
| Kariakoo-Tegeta | 24.7 | 49.4 | 131.0 | 81.6 |
| Tegeta - Kariakoo | 24.7 | 49.4 | 125.0 | 75.6 |

**Source:** Field survey August 2011

rapid speed, range from 21 minutes (Posta-Airport) to 85.2 minutes (Posta-Kimara).

The perceived impacts of congestion as part of the qualitative findings from group discussions we held with bus drivers in all routes of the city include:

a) Driving found to be harder or more tiring

b) Increased risk of accidents or mishaps

c) Increased fuel consumption

d) Major source of driver stress – making many respondents feeling frustrated, angry, anxious, confused and exhausted.

Also from the group discussions with bus drivers, the following were deduced to be the causes of commuter road traffic congestion in the city; inadequate public transport capacity, private commuter bus owned, untrained crew, unfriendly commuter bus services, no priority bus lanes, centralization of public offices in the CBD, no public transit, damped working hours, un-working traffic lights, no separate pedestrians and cyclist tracks, accidents and poor freight distribution systems.

## CONCLUSION AND RECOMMENDATIONS

### Conclusions

From the findings, Dar es Salaam is congested by 171% compared to congested BRT World Cities. Dar es Salaam commuter travel time is more by 71% than congested BRT world cities.

Challenges associated with the Dar es Salaam city congestion include millions of man-hours lost as commuter buses and vehicles move at a snail's pace (12.297km/hr). Work in public and private sectors is not done in time due to delays thence affecting socio-economic development. Traffic jams consume tones of fuel bought by foreign currencies and emit pollutants compelling for an urgent solution to reverse the trend.

### Recommended ways to tumble commuter traffic congestion in the City

Following the findings revealed on road traffic congestion problems gravity, a commuter service perspective in the Dar es Salaam city; the paper recommends a number of feasible solutions, which if implemented the city will be able to get rid of the congestion problems and be emulated by all other emerging cities in Tanzania. The recommended solutions are

practicable, which comparatively need less capital than other solutions and they can remain feasible in developing cities for the next fifty (50) years of independence. They include;

(i) **Adequate public transport capacity:** According to Tanzania Investment Act no 27 of 1997;

- If wholly owned by a foreign investor or of a joint venture, the minimum investment capital is not less than Tanzania Shillings equivalent of US dollars three hundred thousand (US $ 300,000)
- If locally owned, the minimum investment capital is not less than Tanzania Shillings equivalent of US dollars One hundred thousand (US $100, 000)

The transport sector is partially included in the priority sectors. For instance while trucks enjoy tax relief as capital goods under this law buses do not. Consequently the commuter service investors are discouraged to make meaningful investment. This situation has negative impact on commuter service capacity in the city, which requires heavy investments in High Occupancy Vehicles (HOV) and related equipment. The Act should therefore be reviewed to include buses and related equipment into the capital goods incentive package to attract potential investors in the commuter services.

(ii) **Corporate commuter service providers;** The current bus owners providing commuter services in Dar es Salaam are advised to form companies under the companies Act no. 12 of 2002. This will reduce the number of operators and enhance professionalism and regulatory. Companies to be formed will be able to borrow capital from banks and train their staff to the required standards. It will ease the management of the well trained staff and effect contractual employment of commuter bus crew. In managing company growth it will be possible for them to get into Joint Ventures so as to meet the market demand professionally.

(iii) **Commuter bus crew training;** all stakeholders responsible in commuter service provision should pay attention to commuter bus crew training. Crew should be trained on how to handle commuters (customer service). This will enhance confortability of commuter services in Dar es Salaam and attract private car users to use commuter services. Well trained drivers will drive properly on city roads.

(iv) **Alternate working hours;** encouraging work hours other than the dominant 8 to 4 schedule. One of the causes to traffic congestion in the city is damped working hours. This result into commuter service demand concentrated in two main peak periods of two hours each. Efforts have been made to meet this demand by increasing road capacity, which has never been sufficient and has resulted in an under use of the capacity in the other 20 hours each day. For example the CBD shops can be opened at 10.00 A.M and being closed at 08.00 P.M.

(v) **Unfriendly commuter bus services (abusive language, dirtiness, worn-out vehicles buses);** the current environment of commuter services in the city makes it acceptable only to low income earners and/or to those who cannot travel otherwise. Commuter services operators have created unfriendly environment to their customers thus leading to many people opting for private cars, hence the current road traffic congestion. This behavior can be changed through training of drivers and conductors on how best they can offer their services.

(vi) **Decentralization of public offices in the CBD;** decentralization of public offices will reverse the current one direction movement of traffic towards the city center during morning peak hours.

This can be done by locating the public offices in different parts especially at the outskirt of the city, e.g. Temeke – Ministry of Agriculture Food Security and cooperatives, Ubungo – Ministry of Water and Irrigation. More public offices need to relocate to outskirts of Dar es Salaam.

(vii) **Priority bus lanes;** there should be bus lanes on major routes and expressways that are reserved for buses, taxis and passenger vehicles with several occupants. The goal is to encourage use of buses and high occupancy vehicles that can be seen to travel at higher speed along the reserved lanes by other drivers who may be stuck in traffic jams.

(viii) **Functioning traffic lights;** Active traffic lights will reduce the rate of congestion in urban areas. For congested intersections such as Ubungo, Tazara, Magomeni, Morocco, Mwenge and Fire traffic lights should provide priority to decongest them and ease mobility in the city. In order to achieve this strategy, greater attention is required to ensure traffic lights are functioning throughout and traffic police are not used instead of it.

(ix) **Separate pedestrians and cyclist tracks;** the city should promote and protect cycling as a means of urban transport. All major roads in Dar es Salaam should have physically protected cycle tracks, minor roads should have traffic calming measures (e.g. speed bumps) to protect and encourage walking and cycling, and workplaces should encourage employees to cycle and provide facilities (e.g. showering and cycle parking). In many areas of high population density, the quality of life (enhanced safety, less pollution etc) and the visual attractiveness of streetcapes can be enhanced by excluding vehicles from streets altogether, or limiting access to public transport vehicles. In Europe this has become a distinctive feature of the historic cores of many cities.

(x) **Freight distribution systems;** restrict the movement of large (exceeding 10 tons) trucks on busy route, with high traffic, such as Bagamoyo, Morogoro, Nyerere and Mandela roads. The movement of the trucks should be allowed only outside of rush-hours, especially at night for beverages and sundries distribution in the city.

(xi) **Congestion pricing:** A variety of measures aims at imposing charges (electronic road pricing – ERP) on specific segments or regions of the transport system in the city, mainly as a toll. The charges can also change during the day to reflect congestion levels so that drivers are incited to consider other time periods or other modes.

(xii) **Maintenance/construction at night:** All maintenances or construction works on busy roads should be done during off-peak hours, preferably at night

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**LIST OF ABBREVIATIONS**

| | |
|---|---|
| BRT | Bus Rapid Transit |
| CBD | Central Business District |
| DART | Dar es Salaam Rapid Transit |
| DMT | Dar es Salaam Motor Transport |
| ERP | Electronic Road Pricing |
| HOV | High Occupancy Vehicles |
| ITDP | Institute of Transport Development Policy |
| UDA | Usafiri Dar es Salaam |
| URT | United Republic of Tanzania |
| VTTS | Value of Travel Time Savings |

# GUIDE TO AUTHORS

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