Fundamental Diagram For Spatial Analysis Of Urban Traffic Flow: A Case Of Kenya's Nyeri Municipality

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***Abstract*—Nyeri town's historic background and strategic position it occupies in Kenyan politics has contributed to its infrastructural development. This has resulted in unprecedented traffic congestion. This congestion, besides leading to a number of traffic-related accidents, has derailed the economic development due to the time wasted in traffic. It is against this backdrop that this study sought to establish fundamental traffic flow models and derive the flow characteristics associated with traffic operations in the town. The study was guided by a number of important models which included speed density model, speed flow model, and flow-density model. The study relied on macroscopic data based on traffic characteristics at an aggregated level. The data collection methods addressed traffic flow, average speed, free-flow speed, traffic composition and directional distribution. The collected data was analyzed using both classification analysis and event count analysis. The study found that MFD could be employed to enhance accessibility in Nyeri town. The study deduced that there were certain road links that performed better than others which was concluded to be very significant to urban roads planners and engineers. The study recommended that the designed capacities of the road segments should be provided so that further analyses that pertain to comparing the performance levels of different links can be undertaken.**

Keywords—Microscopic fundamental diagram, Nyeri town, spatial analysis, traffic flow, traffic flow models, traffic operations.

1. INTRODUCTION

Analysis of traffic flow and modeling of vehicular congestion has mainly relied on fundamental laws, inspired from physics using analogies with fluid mechanics, many particles systems and the like. One main difference of physical systems and vehicular traffic is that humans make choices in terms of routes, destinations and driving behavior, which creates additional complexity to the system. While most of the traffic science theories make a clear distinction between free-flow and congested traffic states, empirical analysis of spatio-temporal congestion patterns has revealed additional complexity of traffic states and non-steady state conditions (Munoz & Daganzo, 2003; Helbing et al., 2009). Thus, the known fundamental diagram, initially observed for a stretch of highway to provide a steady-state relationship between speed, density and flow, is not sufficient to describe the additional complexity of traffic systems; it also contains significant experimental errors in the congested regime for a highway stretch (Kerner and Rehborn, 1996) or for a city street (Geroliminis, 2008). Nevertheless, it was recently observed from empirical data in Downtown Yokohama that by aggregating the highly scattered plots of flow vs. density from individual loop detectors, the scatter almost disappeared and a well defined Macroscopic Fundamental Diagram exists between space-mean flow and density (Geroliminis, 2008). The determined MDF is important in the study of the performance of the road networks.

Performance of road networks over the years is typically measured at link and intersection levels and this makes it quite difficult when assessing the performance of an entire network. To be able to put effective traffic and transport management practices in place for an entire town, it was ideal to consider measuring performance of roads at higher levels. This will also help in determining the state of the network. The performance of a town's road network which can be studied at a macro level could be attributed to the planning of the town. A well planned town has, as part of its network characteristics, good accessibility and mobility, thus, less congestion.

Nyeri town, to which the study was delimited, is served by a reasonably well-maintained tarmac road network connecting it to Nairobi, Nakuru, Nanyuki, Othaya and other surrounding towns. Most transportation of cargo to and from Nyeri is by road, although the town has a largely underutilized railway station at Kiganjo (about six kilometres out of town towards Nanyuki) on the branch line of the railway from Nairobi to Nanyuki, and an airstrip at Mweiga (about 15 Kilometres out of Town towards Nakuru) and another airstrip at Nyaribo (off the Nanyuki - Naromoru highway). The traffic congestion evident in the town was a reason good enough to necessitate a study on fundamental traffic models.

2. STATEMENT OF THE PROBLEM

Nyeri town is not only the capital of Nyeri County but it has till 2013 been the administrative headquarters of the previous Central Province that comprised of the current Nyandarua, Kiambu, Nyeri, Kirinyaga, and Murang'a Counties. Its historic background and strategic position it occupies in Kenyan politics has contributed to its infrastructural development. This has resulted in unprecedented traffic congestion. This congestion, besides leading to a number of traffic-related accidents, has derailed the economic development due to the time wasted in traffic. It is against this backdrop that it was necessary to formulate measures which would potentially address this challenge. Therefore, it was important to carry out a study on fundamental traffic models and derive the flow characteristics associated with traffic operations in this town.

3. STUDY OBJECTIVE

To establish fundamental traffic flow models and derive the flow characteristics associated with traffic operations in Nyeri town

4. RESEARCH QUESTION

What are the fundamental traffic flow models and flow characteristics associated with traffic operations in Nyeri town?

5. THEORETICAL FRAMEWORK

5.1 Speed - Density Model

The development of a traffic flow model begins with a relation between speed and density (van Maarseveen et al., 2005). The relationship between these two parameters provides essential information for planning purposes, which is one reason why the MFD is being investigated for Nyeri. In real life situations, a typical example of this relation is shown in Figure 2-2. The graph shows that when a single road user uses the roadway he/she could drive at any desirable speed because density *(k)* is low; this is the free-flow speed *(u_o)* since the choice of speed is not limited by other road users. When more and more drivers begin using the roadway, density increases and the speed decreases significantly (because of the many interactions amongst vehicles) till the road capacity is reached. When the product of density and speed results in the maximum flow, the capacity is reached and the speed at this point is referred to as optimum speed u_c, often called critical speed, (Highway Capacity Manual, 2000).

At a point in time, density becomes so high such that all vehicles stop and speed is now zero; the density at this point is the jam density, k_j. Information such as the measure of these parameters from this diagram (Figure 1) will aid the town authorities in planning the town by knowing how various land uses contribute to this u-k diagram as a result of land use transport interactions. Also, the town's free flow and critical speeds are essential for planning, traffic management and safety purposes. Knowledge about the town jam density helps to put in place effective measures to control traffic flow in the city so that the city's flows do not get to such high levels of density.

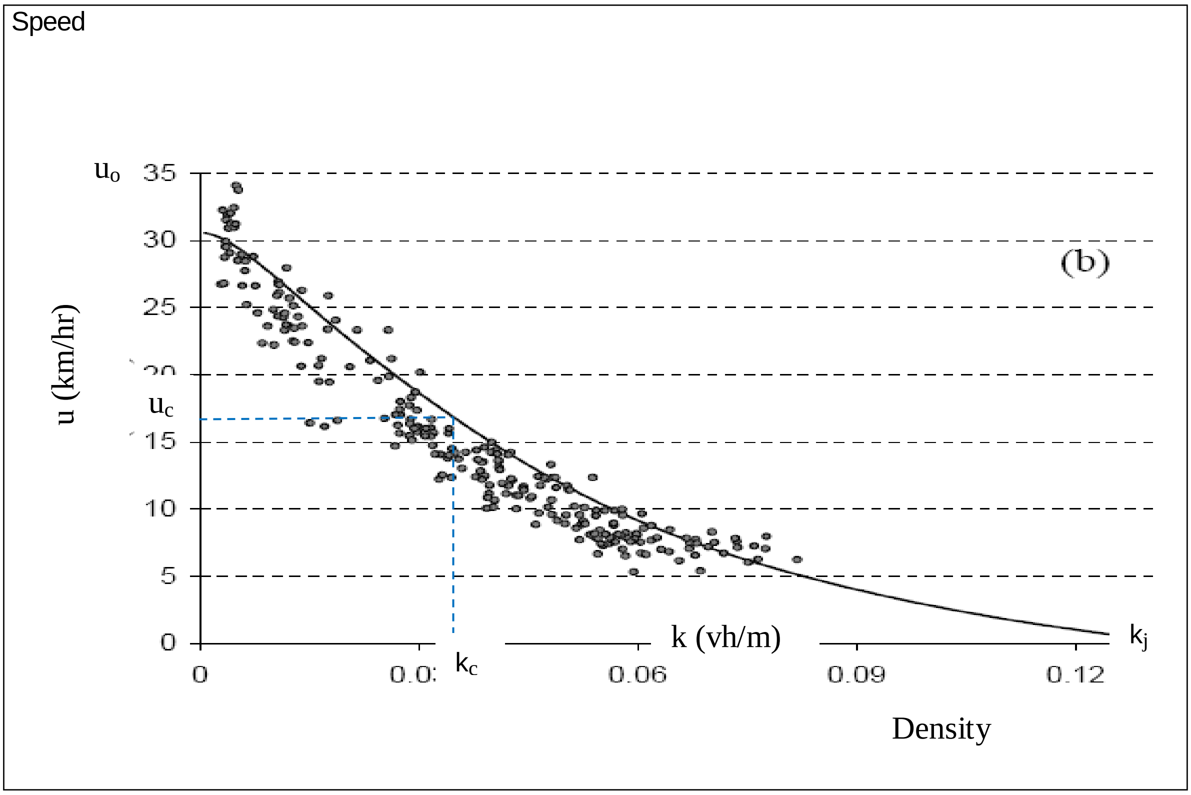

Figure 1: Speed- density relation for the city of Yokohama, Japan (Geroliminis & Daganzo, 2008)

This kind of relation can be shown theoretically as:

$u = u_o(1 - \frac{k}{kj})$ ………………………………….(1)

Where:

k = density

k_c = critical density

k_j = jam density u = speed

u_o = free speed u_c = critical speed

5.2 Speed- Flow Model

An aggregation of the average speed *(u)* and flow *(q)* of vehicles on the road network in the Nyeri town could establish a relation such as in Figure 2, if the town has the overall traffic characteristics as such. Density *(k)* can be derived from equation 1 as:

$k=k_s(1-u/u_o)$ ……………………………(2)

Substituting equation 2 the flow can be obtained as shown in equation 3

$q=k_s(u-u^2/u_o)$ ……………..……….......... (3)

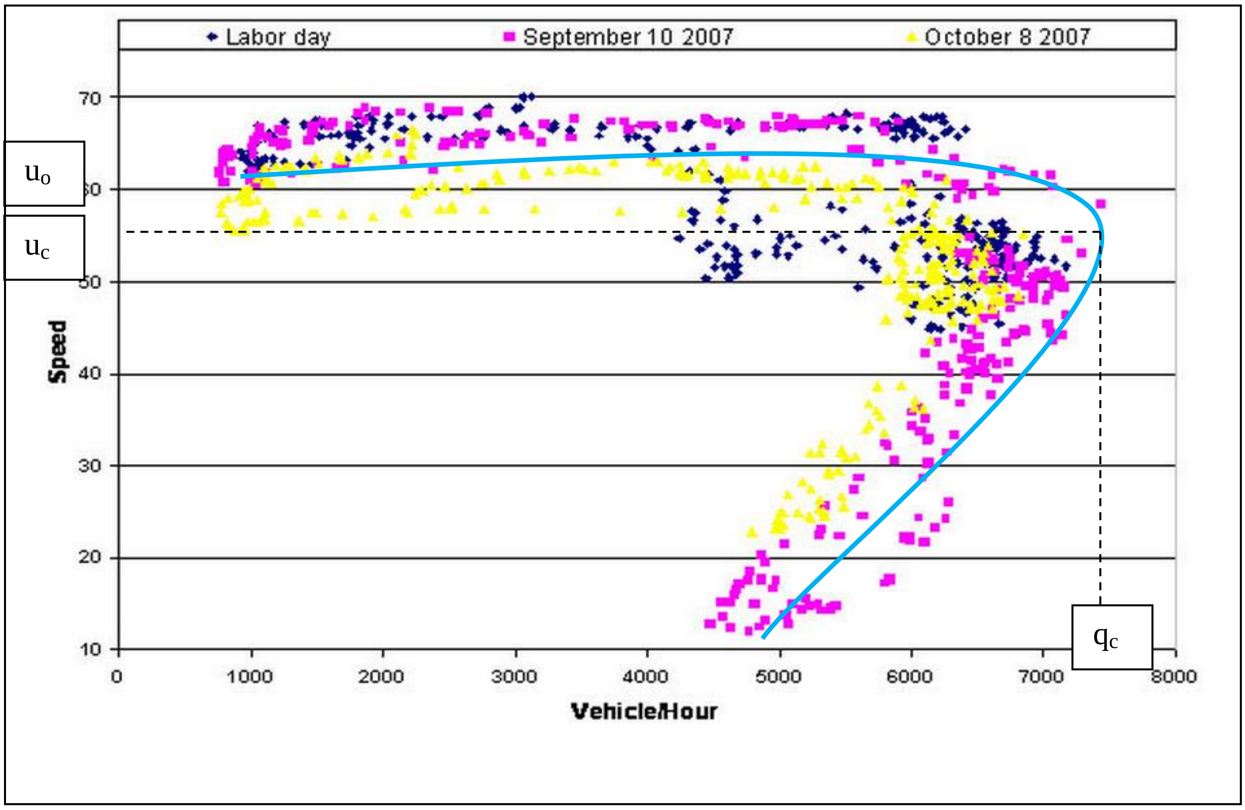

Figure 2: Speed-Volume Relationship observed on Northbound I-405 (Los Angeles), three Mondays in September-October 2007 (Federal Highway Administration, 2009)

Through the study of the relationship between these parameters, one is able to interpret and know the kind of relation between land use and transport that contributes to this type of graph. Initially with no vehicles on the roadway, speed and flow are both zero. As the number of vehicles increases, the flow increases and speed decreases due to the vehicles interactions, until a capacity is reached; then flow decreases with decreasing speed. The capacity of the road is reached at this point. Also at this point, the maximum flow *(q_c)* and critical speed *(u_c)* can be known. These are vital information that can help engineers and planners further to plan towns to meet the ever increasing traffic demand levels.

5.3 Flow-Density Model

Another model, which is a relation between flow on a network and the corresponding density, is a fundamental diagram of traffic flow. Theoretically, this model can be obtained as shown in equation 4. It is derived by comparing previous equation. Thus flow q-k diagram is illustrated in Figure 3:

$$q = u_o(k - k^2/k_s)$$

Where;

q = *flow* u_o = *free speed*

k = *density* k_s = *jam density*

Some characteristics of an ideal flow-density relationship which serve as very useful information for planning purposes are that when there are no vehicles on the road way (thus no flow), density is also zero. When the flow increases, density also increases till the road reaches its capacity when flows reduce because density is increasing. At this capacity, the critical density of the road can be known. From such models, it is able to determine what the jam density and maximum flow of the town are. Engineers can also deduce from the same model at what density the town produces its maximum flow.

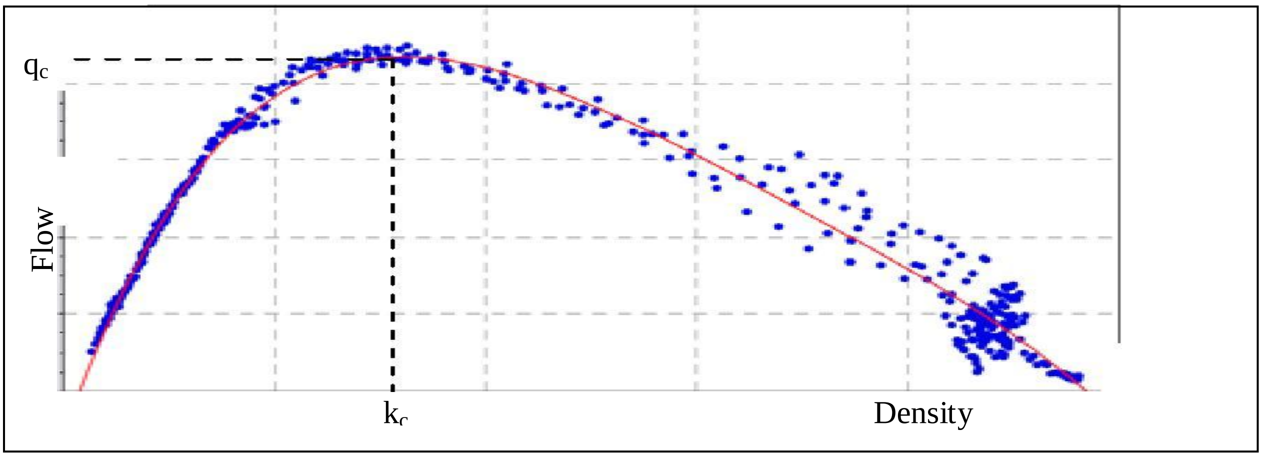

Figure 3: Relationship between flow and density for the city of San Francisco network (Geroliminis & Daganzo, 2007)

The discussions on the relationships between the three macroscopic parameters show that essential information required for planning and traffic operation purposes can be found in such diagrams. It is only after modelling and establishing such diagrams, that such information can be obtained to plan a town and road networks so as to be able to accommodate the ever increasing traffic demand. Once that is factored in planning purposes, mobility and accessibility will also be enhanced.

6. EMPIRICAL REVIEW

This section illustrates a review of empirical studies that have so far been conducted in respect of macroscopic fundamental diagram and traffic flow.

6.1 The Use of GIS in Traffic Flow Analysis and Management

Geographic information systems (GIS) have helped to shape the evolution of transportation engineering and planning and now serve as an integral element in managing traffic and transportation systems. Given the complex multimodal and multijurisdictional issues that fall under the umbrella of traffic management, many GIS transportation applications have been designed for collection, analysis, and distribution of data. The ability to combine maps with extensive databases makes GIS ideal for considering spatial and temporal dimensions of traffic systems (Han et al., 2002).

The ability to share, manage, model, and visualize data has and will lead to breakthroughs in gathering traffic data, disseminating travel information and advisories, increasing the safety of transportation systems, and optimizing transit. As it is not possible to canvas an entire roadway network with traffic cameras (nor is it possible to have enough people to view that many cameras), one must rely on traffic data such as speeds and volumes to assess performance of a system. Given spiraling congestion of traffic across the globe, this data is also necessary for analyzing and then optimizing transportation systems. Likewise, transit systems must also be optimized through sensitivity to demand and intelligent transportation planning. Finally, an optimized system will only perform as well as the motorists, who require information to make good decisions and who should be afforded a system that is safe. All of these needs may be effectively and efficiently facilitated through the application of open and compatible GIS platforms.

Travel times and speeds are the data traditionally used when assessing the level of service provided by a highway network. Unfortunately, the availability of this data is typically restricted to point sensor locations. Data may only be gathered where a sensor, such as a loop detector, is present, but cost of installation and maintenance, and the necessity to make cuts in pavement for installation, limit the number of sensors that can be installed. An appealing alterative to the traditional point sensor is the probe sensor, where a vehicle in the system relays speed and location data. Meaker and Horner (2004) explore an existing source for this probe data: the network of automatic position reporting systems (APRS) that have been established by amateur radio operators principally to serve mobile radio stations. These APRS systems collect location and speed data from mobile GPS receivers in probe vehicles, which then becomes available in real-time over the internet. Large amounts of this data are available in urban areas, particularly along the west coast and in the northeast. Since the location data is georeferenced, it may then be brought into a GIS as a layer of points for traffic assessment and analysis.

GIS may be used not only for estimating parameters of traffic, but also for estimating the parameters of specific traffic elements. Since heavy trucks account for a disproportionate share of incidents and resulting injuries and fatalities, these vehicles deserve special attention in traffic analysis and volume estimation. Unfortunately, state-of-the-practice commodity-based and vehicle-based modeling techniques tend to perform marginally at best. Using classification counts, socio-economic data, and statistical models, however, a GIS platform can be developed that provides more accurate truck volume, flow, and percentage estimates than can be derived from existing methods. Moreover, the platform may allow for automatic updates to reflect new data (Boilé & Golias, 2004).

Shifts and increases in population create new and complicated demands that existing transportation infrastructure is poorly equipped to accommodate. A large, dense population and issues of cost often mean that more highway lanes cannot simply be added or number of buses best of existing infrastructure and optimize current and new additions to mass transit.

Seeing a solution to Indian transportation issues through optimal use of public transportation through integrated transportation planning, Vermaand Dhingra (2005) developed a GIS-based model for establishing an optimal rail corridor as part of the larger goal of creating an efficient demand-sensitive multimodal mass transit system. The model identifies transit demand and then uses an heuristic algorithm in *TransCAD* GIS software to identify an optimal rail corridor, which can then be displayed graphically.

Naturally, traffic performance is at the mercy of any dangers to motorists that are present in the system. Traffic accidents stop or slow traffic in the direction of flow, create queues, slow traffic in the opposite direction ("rubbernecking"), and continue to adversely affect traffic flow well after they have been cleared. To make matters worse, these dangers may not be readily apparent when engaging in transportation planning or safety analysis. GIS can again be helpful in this regard, as demonstrated by Khattak and Shamayleh (2005). They first learned that GIS visualization is successfully being used for transportation safety, public information relaying, and land use and transportation integration applications. They then succeeded ingathering light detection and ranging (LiDAR) data, inputting the data into Arc View, creating 3-D models, and visually identifying areas that contained obstacles to safe passing and stopping sight distances.

Montufar (2002) demonstrated that the benefits of GIS could be extended to heavy truck safety analysis as it relates to road design, traffic engineering, and highway maintenance. GIS stands out from other techniques due to its ability to integrate collision, location, and traffic databases and conduct spatial analyses. It is safe to say that traffic management and transportation systems have a great deal to gain from continued use of GIS. Spatial analysis and data visualization open new windows in transportation analysis and safety assessment. Graphical representations of data aid analysis can be used to keep travelers informed and able to make intelligent decisions, whether on the road, at a transit station, or at home. Integrated GIS databases allow for effective, efficient, user-friendly data storage, management, and distribution. GIS-based modeling applications allow for a better understanding of the transportation system than was once possible and can be used to optimize existing or planned systems. Real-time traffic performance as determined by GIS can be crucial for traffic monitoring and incident management.

7. CONCEPTUAL FRAMEWORK

The study was guided by a conceptual framework as shown in Figure 2 relating the dependent and independent variables.

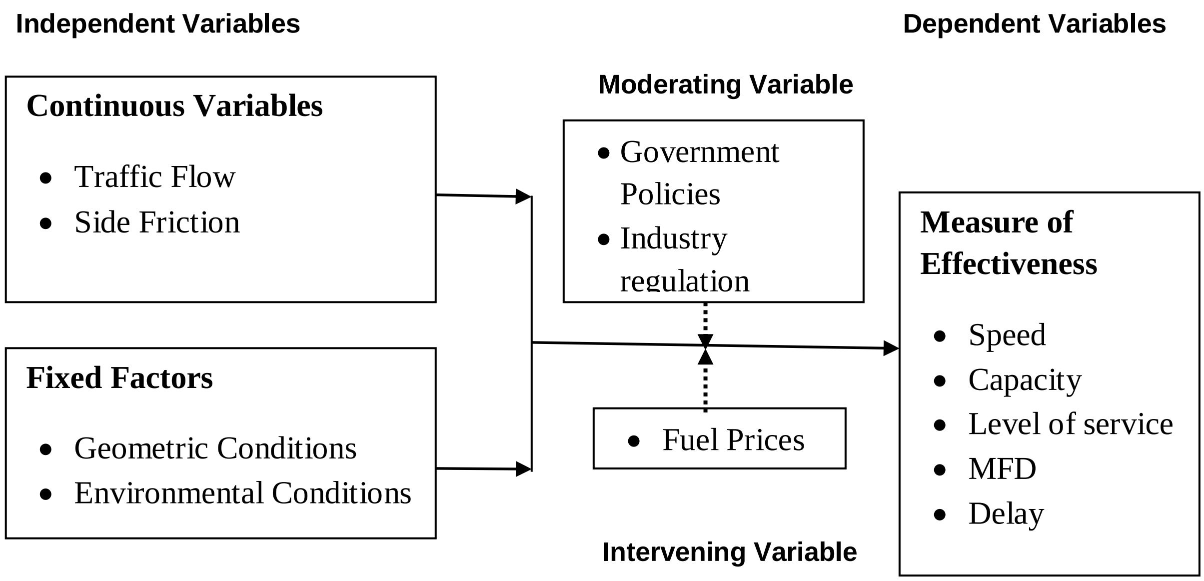

Figure 4: Conceptual Framework

As illustrated in Figure 4, traffic flow was the independent variable while traffic operations constituted the dependent variable. In essence, the study rode on the premise that traffic flow hypothetically influenced traffic operations in Nyeri town, Kenya. In the same light, government and industry regulations acted as the intervening variable. This implied that these regulations confounded traffic flow and traffic operations in Nyeri town.

8. RESEARCH METHODOLOGY

This section identified the data requirements for the research study. The types of data and how they were

collected, which is essential to help provide answers to the research questions, was discussed in this chapter. The instruments required in collecting the data and how these data were validated has also been outlined. Useful information was derived from data through analysis. Lastly, a brief description of the analysis has been made.

8.1 Types of Data and Sources

Due to the nature of information required, speed, flow and density, and the unavailability of secondary traffic flow data for Nyeri town, collection of primary data for this study was done. The type of data that was collected was macroscopic based on traffic characteristics at an aggregated level.

8.2 Sampling

Urban roads in Nyeri town are functionally classified as arterial, collector, or local streets. Arterial roads are designated for major traffic movements with high volumes and high design speed. Collectors are designated for reduced movement function and may be either primary or secondary. Local roads are designated primarily for accessibility. All the roads are two-lane two-way facilities. The common lane width for arterials is between 3.5m –3.7m and for collector and local roads is between 3.0m – 3.5m. Most of arterial and collector roads have shoulders some of which are unpaved. Speed limits for major arterial range from 50km/h-80km/h depending on location within the town area while for most collectors is below 50 km/hr, and most local roads are rarely posted with any speed limits. Parking lanes are common on downtown streets, which are local streets and essentially function for accessibility. Mostly, collector and local roads outside the Central Business District (CBD) are characterized by unpaved and undesignated walkways. Generally, only part of the observed network especially arterial and collector roads was suitable for this study. Many of the local roads was considered unsuitable due to the very short lengths. Moreover, this study was essentially for mobility roads and thus local roads were of less interest.

8.3 Traffic Data Collection Methods

In order to meet the objectives of this study, it was necessary to undertake a field data collection exercise that covers the whole town. Amid financial and time constraints, it was important to develop cost-effective, simple, and accurate methods for data recording, storage and reduction. The primary source of traffic data collection is through establishment of regular manual traffic counting programmes and spontaneous automatic counters along the public road network. Origin – Destinations survey is a special way of carrying out traffic counts/survey, whereby the data collected relates to the use of the road by vehicle category. The various types and methods used to collect traffic data provide good and valuable coverage of the required traffic information for decision making and planning of both development and maintenance of the road network. The approach to data collection focused to address the following traffic flow variables:

i) traffic flow,
ii) average speed,
iii) free-flow speed,
iv) traffic composition and
v) directional distribution.

8.4 Data Preparation, Validation and Reliability Checks

Researches of this kind that have their data being collected by devices will always have to be prepared and validated so as to deem them reliable since conclusions and recommendations was made based on the data, after analyses. Series of operations was performed on the primary datasets, so as to prepare them for analysis in further stages.

8.5 Data Limitations

Data collected by MetroCount Vehicular classifier faced some limitations to some extent and the data for this particular research is not an exception. Some detectors are very sensitive so they record two very close vehicles as one long vehicle. Also some malfunctioned detectors were taken out of their loops due to road maintenance works and resurfacing works. Vandalism of the tubes and in some cases the classifier themselves, might contributed to lack of data on some the locations at sometimes. Also with regards to the volume data, it is expected that not all the locations will have data all the time. This meant that although the research was conducted at the town level primarily, the locations which will have data were assumed to be representative of the whole town and this may have an implication on the outcome of the research.

8.6 Data Analysis

Traffic data analysis was performed by the MetroCount Traffic Executive MCReport. The power of MCReport lies in the simple philosophy of the MetroCount Vehicle Classifier System - store every axle event. Axle stream data analysis opens up a world of possibilities for characterizing a survey site. MCReport has two distinct modes of traffic data analysis which were adopted in the current study:

i. Classification analysis, and
ii. Event count analysis

9. FINDINGS AND DISCUSSIONS

This section put into perspective findings and interpretations relative to characteristics touching on traffic flow and traffic operations. On focus were speed, density and traffic flow.

9.1 Speed Data

A time series analysis of speed was performed on all the links and the following graph (Figure 5) was generated.

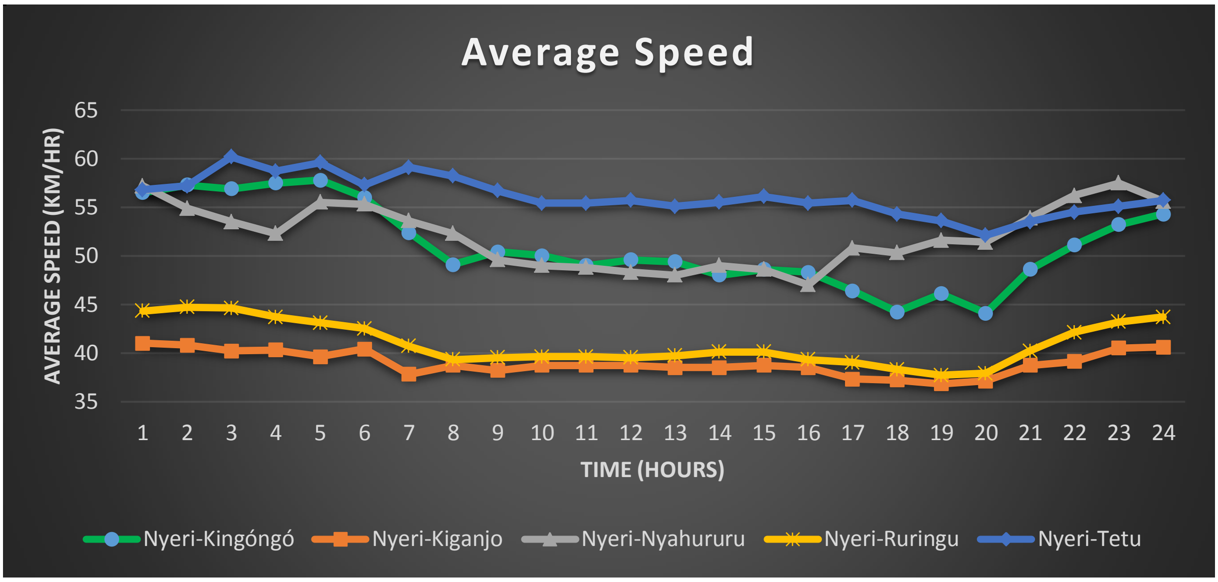

Figure 5: Average Speed Graph

The average speed for the links was 48km/hr. The highest speeds were recorded between 0300hrs and 0400hrs and 2200hrs and 2400hrs. These speed correspond with the times when traffic volume is the lowest hence there is little vehicle interactions. Speed in all the links decreases gradually from 0600hrs until 2000hrs when the lowest speed in the network is reached. The speed graph shows that morning peak periods are 0700hrs to 0800hrs and evening peaks occur between 1700hrs and 1800hrs just as the volume graph indicated. There was a clear repeatability of hourly variations on all roads. Vehicle volume was below 200v/hr before 0600hrs and then increased steadily up to 0800hrs. Volume varied slightly between 0900 hrs and 1900 hrs after which it decreased steadily.

9.2 Speed Density Models

The speed density models constituted macroscopic fundamental diagrams that were generated. Vital road network characteristics like free flow speed; critical speed and jam density can all be obtained from the speed-density model. However, in this research the speed-density model was used to obtain the free flow speed and critical speed. These speeds were later reviewed in the other two models. Table 1 shows the free flow speed and critical speed from the speed-density model. Figures 6, 7, 8, 9, 10, 11 and 12 show the fundamental diagrams for each link in the network.

Table 1: Free Flow Speed and Critical Speed for all Roads

Road	Free Flow Speed	Critical Speed
Nyeri-King'ong'o	75	55
Nyeri-Nyahururu	70	50
Nyeri-Kiganjo	55	40
Nyeri-Ruringu	60	40
Nyeri-Tetu	50	55
Ruringu-Othaya	75	40
Ruringu-Marua	55	55

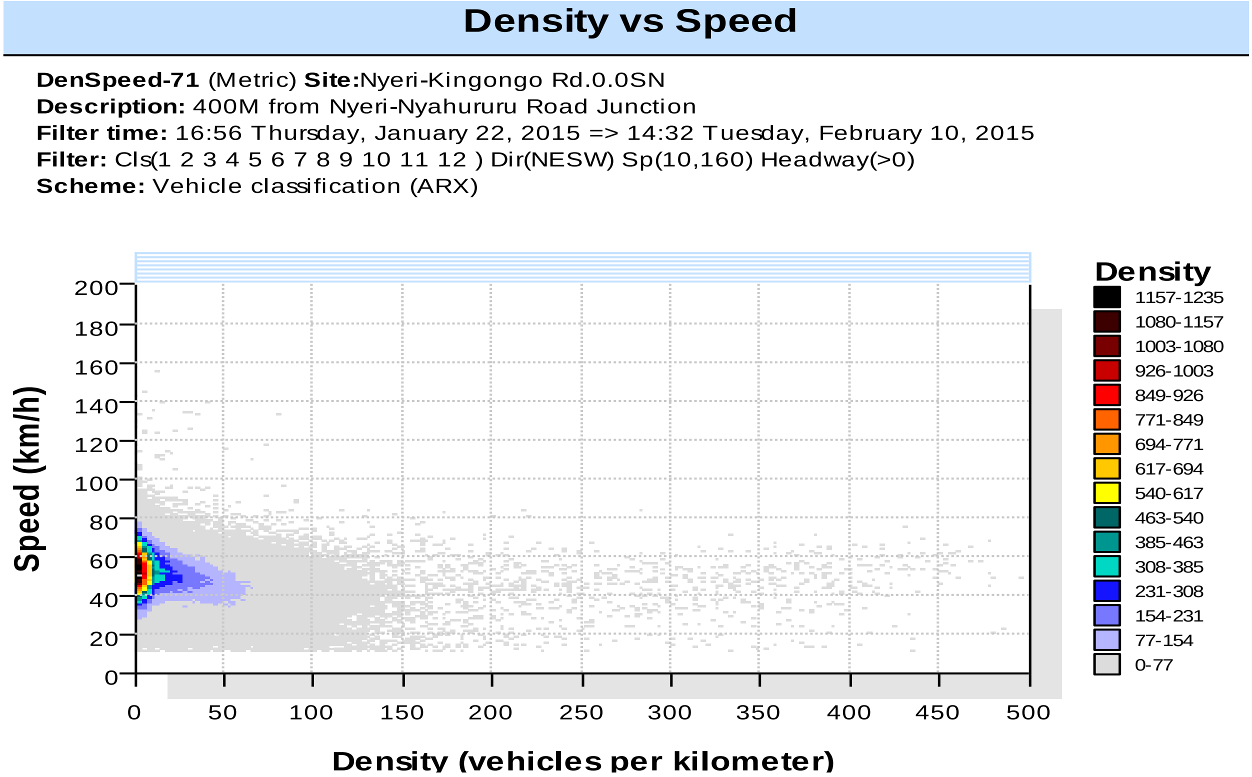

Figure 6: Speed - Density Model for Nyeri-King'ong'o Road

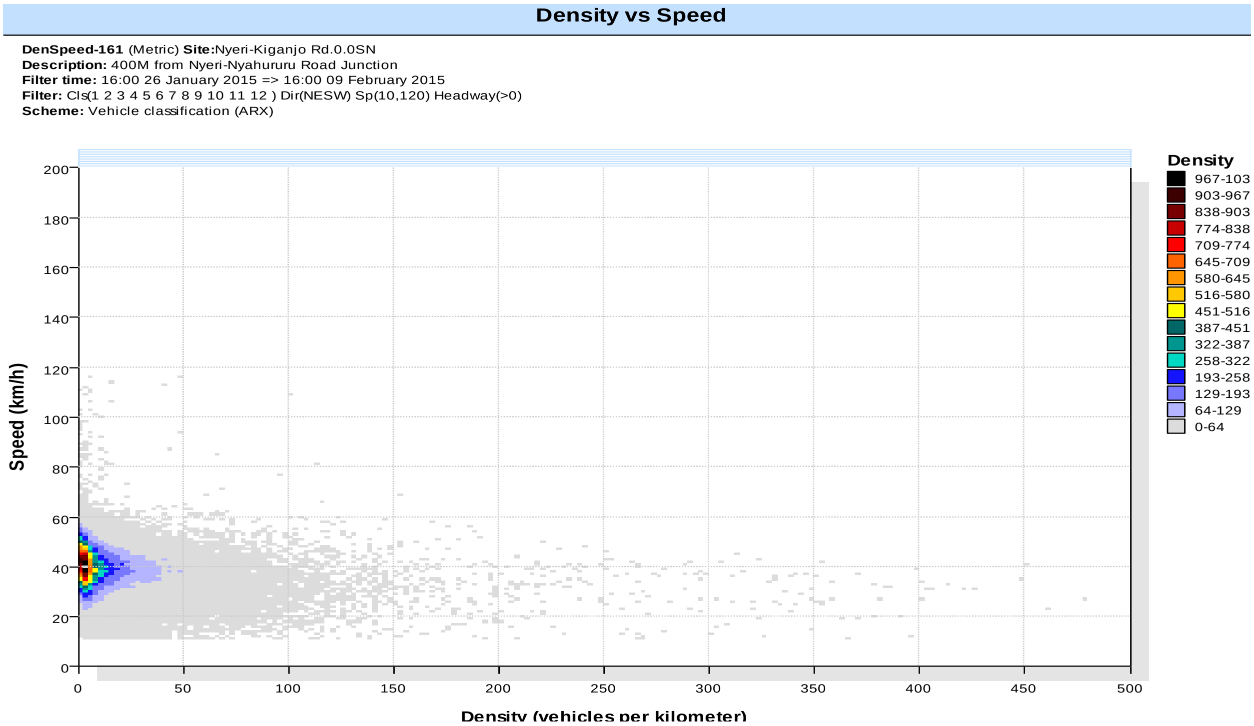

Figure 7: Speed - Density Model for Nyeri-Kiganjo Road

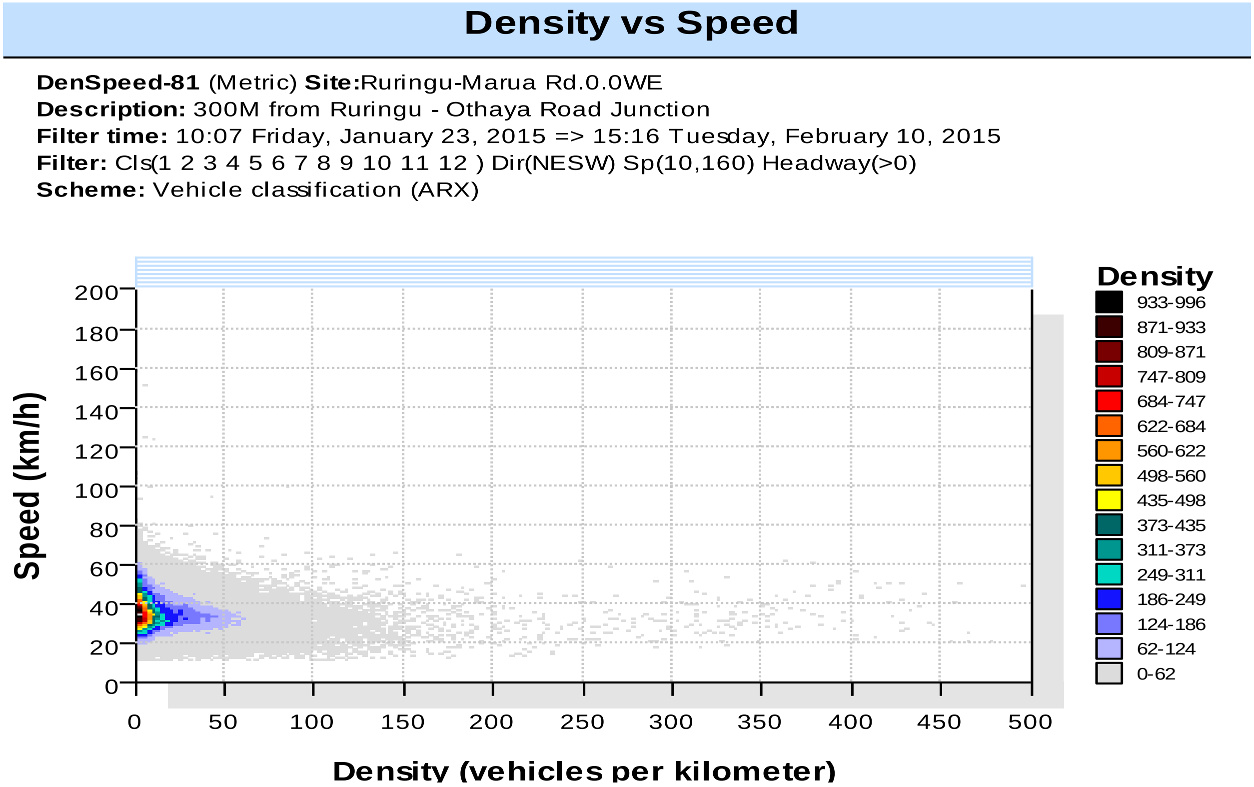

Figure 8: Speed – Density Model for Ruringu-Marua Road

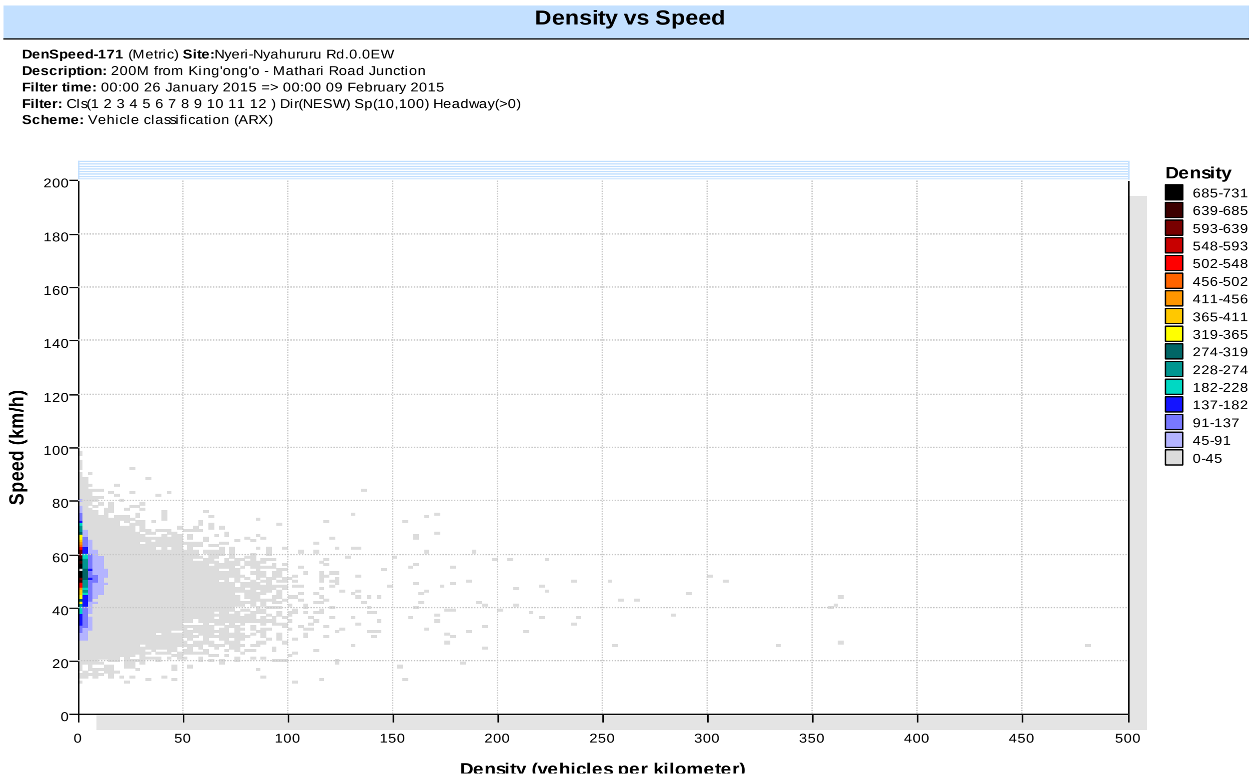

Figure 9: Speed -Density Model for Nyeri-Nyahururu Road

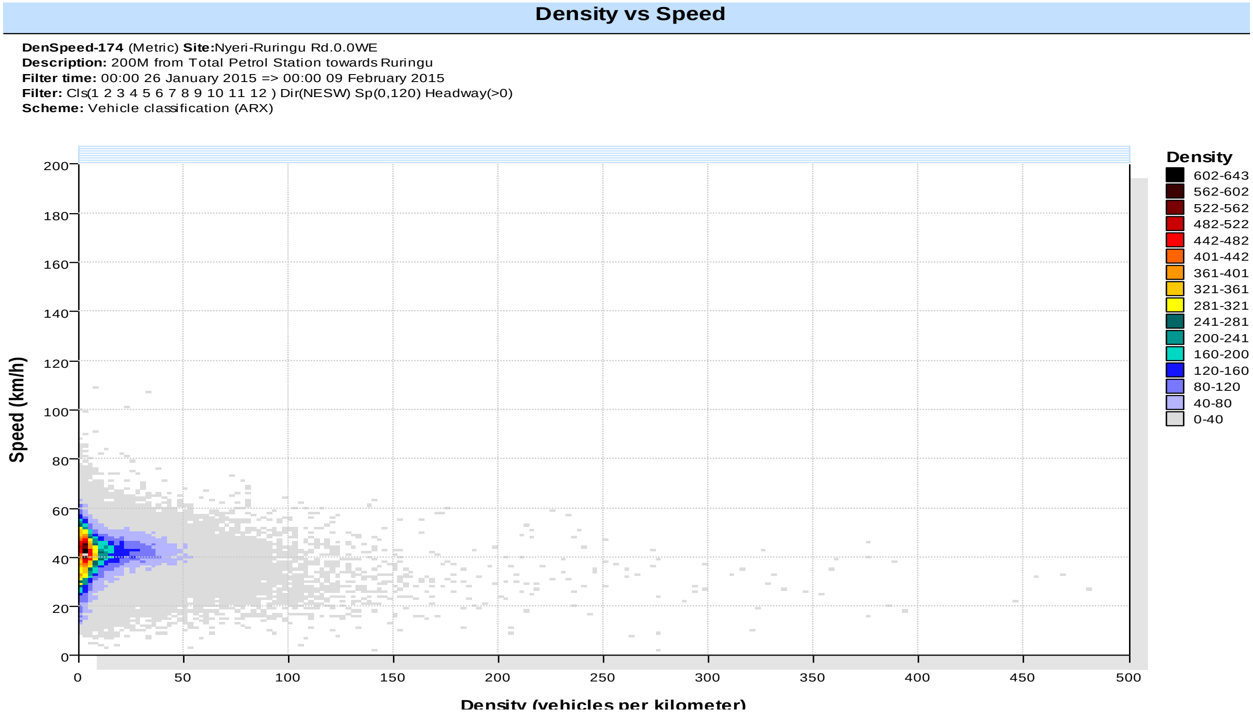

Figure 10: Speed – Density Model for Nyeri-Ruringu Road

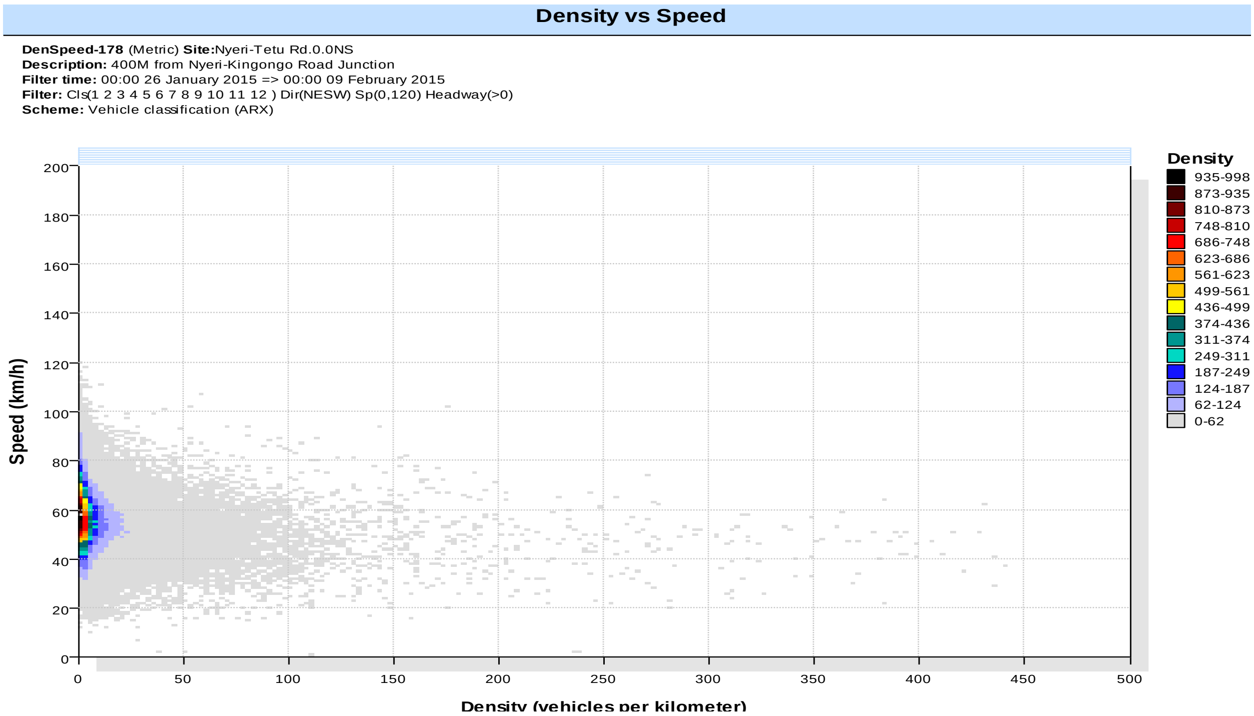

Figure 11: Speed – Density Model for Nyeri-Tetu Road

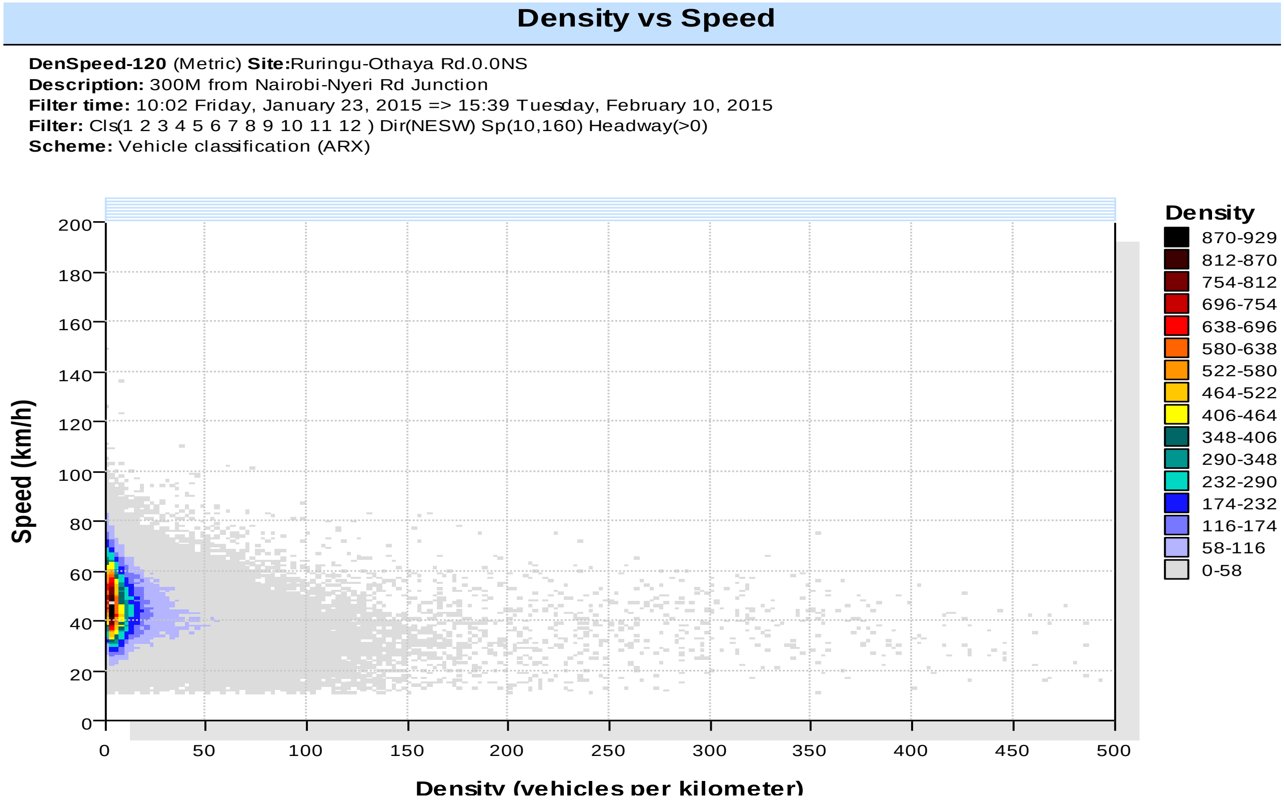

Figure 12: Speed – Density Model for Ruring'u-Othaya Road

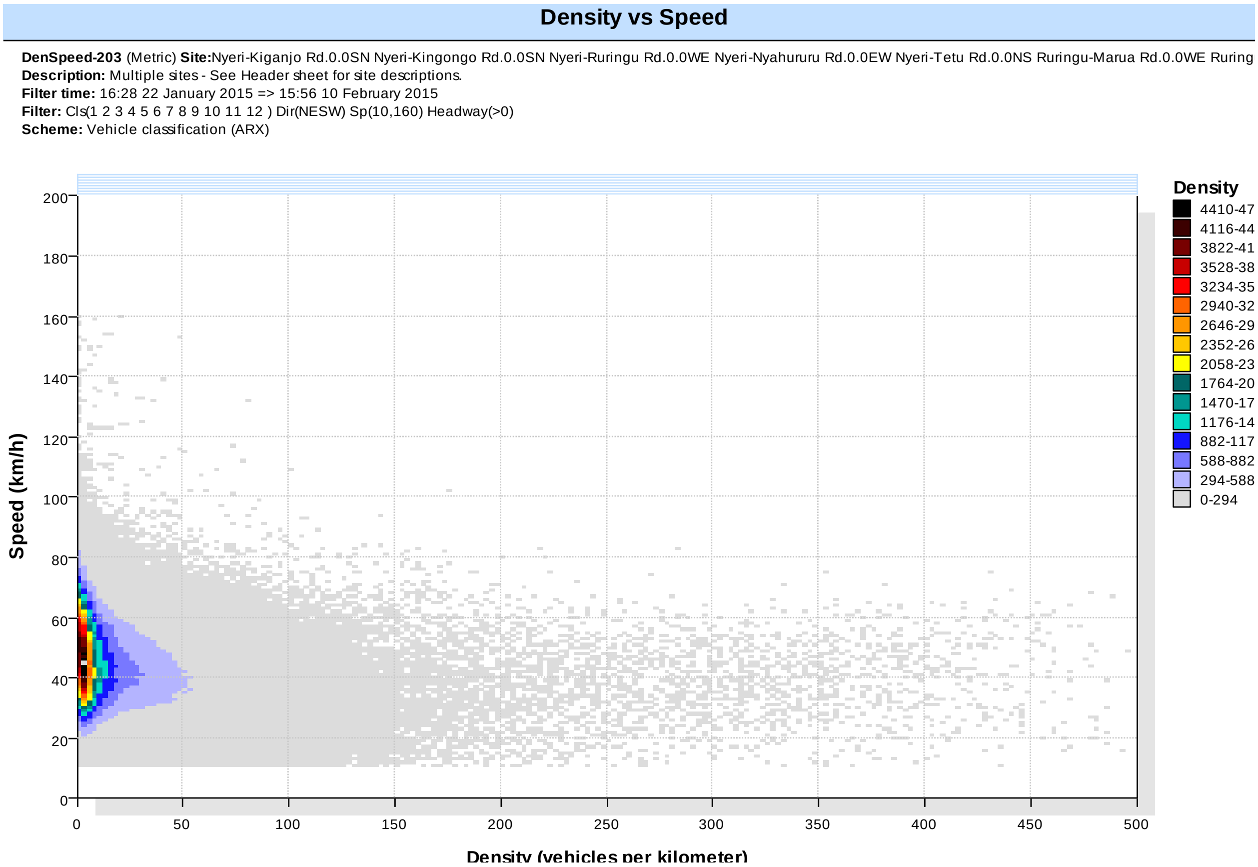

Figure 13: Speed - Density Model for the Entire Network

9.3 Discussions

9.3.1 Properties and Characteristics of the Network

The roads considered in this study are all two lane single carriage way, ranging from functionality class D to B. Nyeri-King'ong'o is a national trunk road linking the Nyeri and King'ong'o town centers. Nyeri-Nyahururu is also a national trunk road linking the town centres of Nyeri and Nyahururu. Nyeri-Nyahururu, Nyeri-Ruringu and Ruringu-Marua are the other national trunk roads linking their various principal town centers. Nyeri-Kiganjo is a class C road feeding Nyeri-King'ong'o road. Ruringu-Othaya is the other class C road linking the provincially important centres of Ruringu and Othaya. Nyeri-Tetu is a class D road and links the locally important centers.

All the roads in this study are in good condition and are properly maintained. There are no visible pot holes or any other road defects. According to the Road Design Manual, the Nyeri-King'ong'o, Nyeri-Nyahururu, Nyeri-Ruringu, and Ruringu-Marua roads are desired to have full level of access control. The level of access can be reduced to partial control on these roads due to practical reasons and financial constraints. The desirable level of access for Nyeri-Kiganjo and Ruringu-Othaya roads is either full or partial control but can be reduced to partial control. Nyeri-Tetu road was desired to have partial level of access control and can be reduced to unrestricted access control. The basic capacity for all the roads considered in this study is 2000pcu/hr (RDM).

9.3.2 Speed

Nyeri County has a rugged terrain. The design speed for such a terrain, according to the RDM, is 70-100 km/hr for class A and B roads, 60-90 km/hr for class C roads and 50-80 km/hr for class D and E roads. Nyeri-King'ong'o and Nyeri-Nyahururu roads had operating speeds corresponding to the values in the RDM. Nyeri-Ruringu and Ruringu-Marua, however, had operating speeds lower than they were designed for. This shows they were the worst affected roads by congestion. Nyeri-King'ong'o road had the highest capacity and vehicles on this road travelled at the highest speeds. This is an indication that there no congestion experienced on this road probably due to minimal vehicle and pedestrian interactions. The average critical and free flow speed for the entire network are 48km/hr and 63 km/hr respectively as illustrated in Figures 4-25 and 4-26.

The free flow speed recorded on both Nyeri-King'ong'o and Ruringu-Othaya links were 75km/hr which was higher than the posted speed limit (PSL) on that link. The PSL on this links is 60km/hr. This was an indication that there is no congestion experienced on these two links at low densities. It could also mean that these roads, being national trunk roads, enjoy partial to full access control. The drivers were allowed to travel at the highest speeds possible without any interruptions .Nyeri-Nyahururu road followed in second recording a free flow speed of 70km/hr. This speed is higher than the PSL of 60km/hr. Nyeri-Ruringu link recorded a free flow speed of 60km/hr which corresponds to the PSL for the road. Nyeri-Kiganjo, Nyeri-Tetu and Ruringu-Marua recorded the lowest free flow speeds i.e. 55km/hr, 50km/hr ande55km/hr respectively. These speeds were slightly lower than the speed limit for all the roads. Individual links like Nyeri-King'ong'o, Nyeri-Tetu and Ruringu-Marua had the highest critical speed of 55km/hr which was greater than the critical speed of the entire network On the other hand, Nyeri-Kiganjo, Nyeri-Ruringu and Ruringu-Othaya had the lowest critical speeds of 40km/hr.

9.3.3 Density

From Figure 4-2, the jam density for the network is 50veh/km. The low volumes in Nyeri-Nyahururu and Nyeri-Tetu roads are partly responsible for this low jam density (20Veh/Km). Thus, the users of the two roads rarely experience congestion. Nyeri-King'ong'o has the maximum density of 40 Veh/Km, however, this is still below the overall network jam density.

10. CONCLUSIONS

The study concluded that MFD could be employed to enhance accessibility in Nyeri town. The findings concurred with earlier observation by Geroliminis and Daganzo (2007. It was inferred that Nyeri town may not be congested enough to be given such measures but these can be thought of and applied where necessary in future instances.

The study also deduced that there were certain road links that performed better than others. This was concluded to be very significant to urban roads planners and engineers since it could enable them to further plan traffic flow within Nyeri town. The study findings led to the conclusion that there existed a macroscopic fundamental diagram (MFD) for Nyeri town. In the same perspective, it was inferred that speed and traffic flows were indeed related. The strong correlation between the two constructs also gave an indication that albeit the perception that other factors may contribute to speed variations on the network, traffic volumes accounted for the greatest proportion of variation of speed on Nyeri town's network.

10. Recommendations

Based on the observations and findings from the research, recommendations have been made and possible areas of extension for this research study. The data available for this research covered 18 days, 12 weekdays and 6. Due to time constraint, the researcher restricted his study to these days only and it is recommended that further studies should be carried out into the other days where traffic variations for these days could be determined and further explored. For instance, traffic variations could be studied between weekdays and weekends so that traffic circulation within the town would be well understood and appropriate steps put in place to enhance traffic flow. Under this same theme, it is recommended that the designed capacities of the road segments should be provided so that further analyses that pertain to comparing the performance levels of different links can be undertaken.

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