An Agent-Based MATSim Scenario for Lagos, Nigeria

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Abstract

Presently there is a shift in assessing infrastructure investment decisions in developing regions. Whilst in the past, transport and mobility-related metrics that have worked for developed regions have been used in developing countries, this practice is now changing. Some transport researchers have started to consider inclusive metrics outside of the normal metrics that do not account for issues such as economic inequality among citizens and citizen individual mobility behaviors in developing urban regions which may be very different from that of developed regions. In this same spirit, an agent-based microsimulation framework, MATSim has been applied here to build a baseline scenario for Lagos, Nigeria. At the initial stage is a model using only a population derived from a household travel survey, which serves as a starting point to a full-scale scenario for the whole of Lagos pending access to more data.

Keywords

Agent-based simulation, Lagos scenario, Para-transit public transport, MATSim simulation

1 Introduction

Transport research is mostly carried out in the developed regions which has helped infrastructure innovation to what it is today. While the developing countries are trying to catch up, the progress has been slow and especially hampered by little research, in particular with infrastructural investment decisions being made with the research outcomes of the developed world (Robertson et al. (2015); Choudhury & Ayaz (2015); Dubernet & Axhausen (2016)).

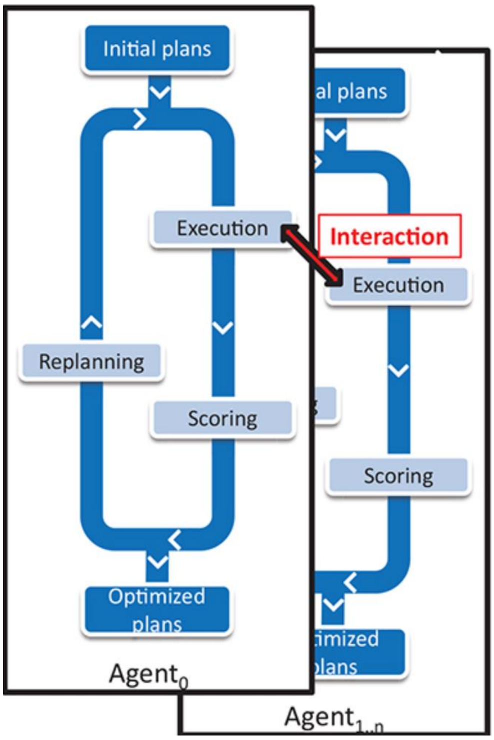
In recent times, research has expanded to the developing world due to the rapid urbanization occurring in the emerging nations. According to United Nations' *World Urbanization Prospects* report, about 90% of global urban growth will happen in Asia and Africa, with Africa tripling its urban population by 2050. Examples of these rapidly expanding cities are Beihai, Delhi, Beijing, Dhaka, Bamako, Kinshasa, Lagos, etc. and with their rapid development in parallel with inadequate infrastructure, there is a need now more than ever to reduce the knowledge gap and provide research solutions that fit the constraints of these regions. This effort can be seen especially in transportation research where different constraints in developing regions have to be allowed for.

Whilst it has been the practice of using purely transport and mobility-related metrics that have presumably worked for developed regions when assessing infrastructure investment decisions in developing regions, there is now a shift. Some transport research focused on developing regions have started to consider inclusive metrics that account for issues such as economic inequality among citizens and citizen's individual mobility behaviors. (Dubernet & Axhausen (2016); Choudhury & Ayaz (2015); Williams et al. (2015)).

1.1 Multi-Agent Transport Simulation (MATSim)

In this same spirit, microsimulation frameworks such as MATSim (Horni et al., 2015) are being extended to cities such as Cape Town, Sao Paulo, etc.. MATSim is an activity-based, extendable, multi-agent simulation framework implemented in Java. It provides a microscopic model of traffic flow and resulting congestion by tracing synthetic travelers' daily schedules and decisions. It offers transport modelers an opportunity to examine mobility behavior of millions of agents on a microscopic scale thereby expanding the 4-steps model to include traveler's characteristics. Each agent in MATSim is treated individually with each agent having its own socio-demographic characteristics which allows for asking more questions that are not or hardly possible with more aggregate approaches. MATSim's process is co-evolutionary where agents hold a set of daily travel plans that are iteratively improved based on scoring mechanisms following the execution of a plan. When agents execute their plans, afterwards, random plans for random agents are evaluated in terms of utility, their executed plans are compared to previous plans and modified, worst plans are deleted if the number of plans exceed a given threshold and better plans are selected for the next day (next iteration) until all agents arrive at a favorite plan which works best and reaches an equilibrium state for the whole population. See figure below showing the co-evolutionary algorithm in MATSim.

Figure 1: The co-evolutionary algorithm in MATSim



Source: Horni et al., (2015)

MATSim is relevant to transport modelling as it allows the scenario to be calibrated to fit the constraints of the study region and adapted to the conditions of the transport system in place. The software requires a description of transport supply (the route network, public transport schedule, facilities), individual day plans containing daily activity chains and an associated score for each activity to determine the priority of the plans selected by each agent.

MATSim's advantages can be seen in its application in the scenarios and information for transport policy making for cities such as Singapore, Zurich and transport authorities such as

Switzerland's national railway operator SBB using a MATSim model of Switzerland for internal decision and support.

Here, MATSim has been used to build a scenario for Lagos State, Nigeria. The result shows a model using only a population of a household travel survey, which serves as a starting point to a full-scale scenario for the whole of Lagos pending access to a more data. With more available data, a full scenario representative of the whole population of Lagos will be done in the next stage. Examples of these kind of work can be seen in (Joubert, 2016, Horni et al., 2016). This paper therefore presents a simple simulation scenario where the synthetic population is under 100,000 and public transport system is minimally represented. It serves as a blueprint that can be used for a more detailed and complex scenario setup in the future.

1.2 About Lagos

Lagos is one of the 36 states of Nigeria and is located in its Southwest bordering the Benin gulf coast. It is the economic and commercial center of Nigeria. It has a total area of 3,600 square kilometers with 22% of it wetland. Its population is estimated to be over 21 million people and a resulting population density of 6,515 persons per square kilometer. Lagos is regarded as one of the fastest growing cities in the world and with a growth rate of 3.2% per annum and is expected to be one of the largest city in the world in 2100 with a population of about 88 million people (Hoornweg, & Pope, 2017.)

Like other rapidly urbanizing cities in developing regions, Lagos is faced with enormous infrastructural challenges especially in coping with transport demand. Issues faced include long distance commuting by its poor masses, severe congestion, increase in air pollution with poor ventilation systems in the commercial vehicles and inadequate regulatory framework for public transportation. With a high population growth rate, rapid infrastructure projects, and over 70% of Lagos suburbs in the form of informal settlements, more than ever there is need for a sustainable mobility system. Lagos may look like a modern metropolis at first glance - especially in the city center - until one is entrenched in the busy streets congested with cars, trucks, motorcycles and people. While not listed among the 10 most congested cities in the world, it is one of the most congested cities in Africa with an average speed as low as 18km/h during the morning rush hour (JICA et al, 2014). A morning/evening commute may take from as little as 30 minutes to up to 4 hours. The topography adds to the issues as the city of Lagos is made up of many islands. The main central business district on Lagos Island and Lekki (see fig 2) is connected to the suburbs by only 3 bridges. This creates a daily bottleneck when accessing the center business district.

Before 1980s there was a railroad system, but due to poor maintenance, the rail system has deteriorated over time leaving road transport as the major transportation alternative for 90% of passenger and freight traffic. There are about 2,600 km of roads and travel demand in 2015 was estimated at 22 million trips per day including 40% walk trips (LAMATA 2015). Public transportation is dominated by disorganized unregulated informal sector in the form of privately operated commercial vehicles that include high occupancy vehicles known as molue buses, low occupancy vehicles known as Danfos, motocycle taxis known as Okada, tricycles (Keke Napep), cabs, and boats. There were LAGBUSes, privately run Bus Rapid Transit (BRT) buses which have been discontinued at present. Public transportation provided by the government include BRT lines which are regulated but only carry about 0.41% daily passenger traffic, federal mass transit train (1% passenger traffic) and Water Transportation system (0.34% passenger traffic) (Oshodi et al., 2016).

Figure 2: Congestion in Lagos Metropolitan Area (Morning Rush Hour)

Source: LAMATA (2014)

In Lagos, since the 1990s several transport studies have been conducted with the assistance of World Bank, EU and JICA, and plans were proposed for infrastructural development, development of railway systems, installation of BRT (Bus Rapid Transit) on major corridors. Lagos State Transport Authority (LAMATA) over the years have collected travel surveys to understand the traffic situation of Lagos. It has built transport models to show traffic flow using aggregate data and person trip behavior on a macro scale. This analysis is featured in the Lagos State Transportation Master Plan (LAMATA, 2014) and shows how passengers concentrate and disperse in major corridors leading to the CBD (e.g. fig 2). This analysis however does not provide a microscopic analysis of the movement of passengers and of the congestion they produce; neither does it feature individual's activity chains thereby limiting the quality of the decisions made for infrastructural development. This creates a research gap that can be solved by the implementation of a MATSIM – based scenario, a multi-agent based simulator.

2 Baseline Scenario Setup

To arrive at a MATSim scenario, MATSim requires data preparation, which includes a facilities file, a population file and a road network file in xml format. A detailed road network for Lagos was obtained from Open Street Map of 09.10.2018 (See fig 4) (https://www.openstreetmap.org/relation/3718182) and a public transport network has been generated using General Transit Feed Specification (GTFS) data provided by LAMATA[1]. The facilities and population files have been created using the 2012 household travel survey data (LAMATA, 2013) provided by the Lagos Metropolitan Transport Authority. While the household travel survey data covers only a small share (0.18%) of the population, it can still be used to provide an overview of the travel demand for the region, but the sampling errors due to small sample have to be kept in mind.

2.1 The Data

The household travel survey data was provided as a Microsoft Access file consisting of four relational tables:

1. HH Data Table providing general information about the households such as the size, vehicle ownership and monthly income. The total number of households in the survey is 17,158;

[1] Private communication

2. PID Table providing information about persons in each household. This information covers, age, gender, employment status, education, work location, etc. The total number of persons in the data is 37,369 with persons under the age of 14 in each household not participating in the survey;
3. TID Data Table is the trip identification table consisting of a description of each person’s trips, trip purpose, trip location, start and end time of trips, etc. This table shows the activity chain of each person in a household. It features trips of only individuals above the age of 14 years. This means that the respondents in this survey are persons who are either going to school or work;
4. TID Stage Table which shows a detailed description of the stages of each trip per person and the travel mode used at each stage. In the TID Stage data, a single trip is broken down in stages to reflect the different modes a person used to go from place A to B. and from this data, a main travel mode has been selected for MATSim population file.

2.1.1 Data Cleaning

From the HH Data and the PID data, sociodemographic attributes – age, gender, employment status, family status, vehicle ownership, income – have been extracted to generate the population file, although these attributes were not used in building the baseline simulation, they have been prepared for further analysis.

Using the TID data, necessary attributes needed has been extracted and renamed. The trip purpose attribute values had to be reduced to 'home', 'work', 'education', 'shopping', 'leisure', 'other'. 'Other' represents trip purposes such as religion, health, accompaniment, visitation (visitation could refer to visiting friends, a sick person at home or at the hospital).

Start time and end times of trips are given in scales that represent an interval of one hour in the raw data. These have been converted to seconds and a value within each interval is selected based on random sampling. Due to this random sampling, trips that started and ended within the same interval sometimes had a negative travel time. This error has been corrected by removing the negative sign. The null values (76 in number) for start and end times have been replaced with average time values of the dataset.

2236 trips in the raw data set have error values where the location attribute of one trip’s destination had erroneously been shifted downwards to the next person’s trip. After correction, three trips have been removed.

From the TID Stage data, the number of modes recorded has been simplified as in the table below. Public transport modes are of many forms in Lagos as even motorcycles popularly called Okada offer a form of public transport that carries one passenger. Hence it was a difficult to simplify the modes. Assumptions were made for modes with small shares. Public

Transport (pt) has been used to label the Bus Rapid Transit (BRT) system whose data have been made available. Furthermore, a main mode has been selected for each trip where public transport is used. This is because, such single trip (e.g. home to work) requires multiple mode changes and since pt for this simulation only features BRT, a main mode has been selected so as to represent the other public transport modes.

Table 1: Mode representation in MATSim

Raw data	**Cleaned data**
Okada	mc
Danfo, molue*, chartered bus	minibus
Car driver	car
Car passenger, taxi	ride
BRT, coaster, school bus, Lagbus, staff bus	pt
Keke napep, tricycle	tricycle
walk	walk
ferry	ferry
Rail	rail
Bicycle	bike
Others	undefined

*classifying molue as a minibus even though it takes 25-100 passengers while minibuses take 20 – 30 passengers is due to their small number and also because they are in the process of being phased out.

To select a main mode for each trip, a unique trip id has been created consisting of the household id, the person id and the trip id. This was done in order to group each unique trip and also merge the TID data with the TID Stage data. One mode is then selected from each trip stages based on the following priority:

car>pt>ferry>rail>minibus>mc>tricycle>bike>walk>undefined.

Null values for modes were converted to ‘minibus’ which has the highest mode share apart from motorcycles.[2]

About 272 person trips in the TID Stage data had no matching information in the TID data and thus these have been removed.

[2] The high share of motorcycles in this data signifies the abundance of short trips where motorcycles are preferred. Also private motorcycle owners in the data set are less than 1% hence the major use of motorcycles are as public transport.

A household shape-file that accompanied the survey has been used to obtain the location of households and their trip destinations. The location coordinates first had to be converted from WGS 84 to Cartesian Coordinate System with the distance unit corresponding to one meter, using EPSG 32631 and then assigned to the different activity locations. This is because MATSim calculates some distances between two points using the Euclidean distance. The coordinates provided in the shape-file are zonal coordinates; hence, a centroid location has been selected for all except for persons whose origin and destination are within the same zone. For these exceptions, random coordinate points are sampled within the zones. Person trips without a matching location value in the shape-file have been removed from the dataset.

After cleaning the raw data, the total number of households and persons used to generate the population file can be seen in Table 2 below

Table 2: Number of households and persons in the population file

	Raw data	**Cleaned data**
Households	17157	17120
Persons	37369	35240
Total Trips	70549	70453
Data: cleaned LAMATA files		

2.2 The Facilities

Knowing the locations of facilities in the region is essential to defining where agents carry out their activities. The facilities file was extracted based on the trips showing locations where persons carried out their activities in the household travel survey and does not cover the complete set of facilities available in the region. The facilities used for this simple scenario only covers work, education, leisure, shopping and others. Over 85% of the facilities are for work. This may be close to reality as Osoba (2015) showed in his research that work and business trips accounted for 77.7% of trips in his survey of over 2500 households in Lagos. [3] Work facilities have further been used to analyze accessibility of workplaces in Lagos.

2.3 The Population

The population file is used to estimate travel demand and it features the daily activities of each agent. The population file contains detailed information of the home location, travel plans, and socio-demographics of the agents, and is then used to generate the activity chains with the

[3] Unfortunately, this data is not available and could not be added to the current data used in this paper.

corresponding activity locations in the facilities file. In MATSim the agents' activity chains are referred to as plans. These activity chains are then converted to xml format.[4]

The population xml file generated consist of 35,240 persons, each person has a list of plans and each plan contains a list of activities and legs. The plans for this scenario are majorly in the basic format; home-work-home or home-shopping-home with only a very few persons engaging in longer activities chain. See plan snippet of the population file in fig 3

Figure 3: Sample Plan from the Population File


```xml
<person id="HH00003PID1">
  <attributes>
    <attribute name="age" class="java.lang.Integer">3</attribute>
    <attribute name="carAvail" class="java.lang.String">never</attribute>
    <attribute name="sex" class="java.lang.String">m</attribute>
    <attribute name="employed" class="java.lang.Boolean">true</attribute>
    <attribute name="studies" class="java.lang.Boolean">true</attribute>
    <attribute name="hhIncome" class="java.lang.Integer">9</attribute>
    <attribute name="mcAvail" class="java.lang.String">never</attribute>
  </attributes>
  <plan selected="yes">
    <activity type="home" x="536146.193850" y="722320.818425" end_time="09:31:06" />
    <leg mode="mc" dep_time="09:31:06" trav_time="01:39:36" />
    <activity type="shopping" x="539599.116097" y="721158.454694" end_time="15:18:34" />
    <leg mode="mc" dep_time="15:18:34" trav_time="02:09:08" />
    <activity type="home" x="536146.193850" y="722320.818425" start_time="17:27:42" />
  </plan>
</person>
<person id="HH00003PID2">
  <attributes>
    <attribute name="age" class="java.lang.Integer">3</attribute>
    <attribute name="carAvail" class="java.lang.String">never</attribute>
    <attribute name="sex" class="java.lang.String">m</attribute>
    <attribute name="employed" class="java.lang.Boolean">true</attribute>
    <attribute name="studies" class="java.lang.Boolean">true</attribute>
    <attribute name="hhIncome" class="java.lang.Integer">9</attribute>
    <attribute name="mcAvail" class="java.lang.String">never</attribute>
  </attributes>
  <plan selected="yes">
    <activity type="home" x="536146.193850" y="722320.818425" end_time="07:59:31" />
    <leg mode="minibus" dep_time="07:59:31" trav_time="03:03:09" />
    <activity type="work" x="537904.399910" y="725782.759973" end_time="20:48:56" />
    <leg mode="minibus" dep_time="20:48:56" trav_time="01:21:50" />
    <activity type="home" x="536146.193850" y="722320.818425" start_time="22:10:46" />
  </plan>
</person>
```


2.4 The Network

The network in MATSim is the infrastructure used by the agents to go from one place to another. MATSim networks are usually generated from Open Street Map (OSM) (Nagel et al., 2016). While OSM uses nodes, way and relation, MATSim uses nodes and links hence the

[4] The code used to convert to xml can be found in the writer file here: https://gitlab.ethz.ch/ivt-vpl/populations/ch-zh-synpop/commit/ed98cf6a383bf093fc85c9614fa1232d0c4f47ed.

OSM network needs to be converted. This converted MATSim network creates uni-directional links, which means a bi-directional road way in OSM network would have two links in MATSim network.

MATSim allows for multimodal network simulation where all transport modes use the same network. Usually in MATSim the modes are car, pt, walk, bike, rail, ferry and undefined.

In the case of Lagos, while a multimodal network is essential, public transport (pt) is disaggregated as multiple private individuals manage modes such as minibuses (Danfo), coaster buses (single-decker minibus with a passenger capacity of 20/30), Molue, tricycles, motorcycles, and government provided BRT buses.

In modeling the public transit for Lagos, this report only includes the BRT system whose GTFS schedules are known and can be used to generate a public transit network. A larger percentage of the public transit in the form of minibuses, tricycles, etc. are teleported in this MATSim simulation pending further data availability. Teleportation in MATSim is used to move vehicles at predefined speed from one place to the other without these vehicles interacting with the network.

2.4.1 Steps to creating a network for MATSim

Create Multimodal MATSim Network. OSM network was downloaded in OSM format and converted to a multimodal network using pt2matsim tool (Poletti, 2016) in preparation for the addition of mixed traffic. In the pt2matsim tool, OsmMultimodalNetworkConverter requires a configuration file which is necessary to input the different road types and the vehicles allowed on each road. See Table 3 for network configuration.

Table 3: Conversion values used when converting the OSM network

Highway Type	No. of Lanes	Free Speed	Lane Capacity	One way	Modes allowed
Motorway	2	33.333	2000	true	car, bus, minibus
Motorway link	1	22.222	1500	true	car, bus, minibus
Trunk	1	22.222	2000	false	car, bus, minibus
Trunk link	1	13.889	1500	false	car, bus, minibus
Primary	1	22.222	1500	false	car, bus, minibus
Primary link	1	16.667	1500	false	car, bus, minibus
Secondary	1	8.333	1000	false	car, bus, minibus
Secondary link	1	8.333	1000	false	car, bus, minibus
Tertiary	1	6.944	600	false	car, bus, minibus, tricycle, mc

Tertiary link	1	6.944	600	false	car, bus, minibus, tricycle, mc
Minor	1	11.111	600	false	car, bus, minibus, tricycle, mc
Residential	1	4.167	600	false	car, bus, minibus, tricycle, mc
Living street	1	2.778	300	false	car, tricycle, mc
Unclassified	1	4.167	600	false	car, bus, minibus, tricycle, mc

Notes: For Lagos, going by the law that commercial motorcycles and tricycles are not allowed on highways, the network configurations have been modified to reflect this law. By doing so, it means that privately owned motorcycle riders will not be able to ply these routes and their mode might be changed in the MATSim run.

Map Public Transit Network to the multimodal network. A detailed explanation behind this conversion can be found in Poletti (2016). GTFS schedule file provided by LAMATA has been used. A normal day's schedule in November has been chosen for the day of the transit system. The GTFS file provided covers only five routes. Forecasted routes for future routes covering the whole of Lagos have been made available and these routes will be used to model routes and schedules for minibuses in future work.

A public transit schedule for MATSim is generated. The transit schedules are then mapped to the network as GTFS does not provide information on how stop locations relate to the road network. Using the PTMapper script of the pt2MATSim, with the following non-default configurations:

- Car, bus, mc, rail, minibus, tricycle has been specified as multimodal modes for the network as the PTMapper will output a network for only specified modes together with the transit networks.
- In transport mode assignment, the different modes permitted on routes are specified along with the scheduled public transit mode.
- Free speed mode has not been set for the buses as the main traffic points which include the three bridges do not have a special lane for the BRT buses. Hence in this simulation, the BRT buses add to the congestion on the roads as any other vehicle. This could also reflect the congestion of the minibuses.

2.5 MATSim Configurations

A few changes have been made to the default settings of MATSim's general configurations to accommodate for the difference in data and adapt the simulation to real-life Lagos conditions. These changes can be seen below

Because the population generated for the MATSim from the household travel survey is a very small fraction of the total population of Lagos (0.18%), the network is scaled down to prevent inconsistencies in traffic flows. This can be done in the MATSim configuration file by reducing the storage and flow capacity of each link. (MATSim Development Team, 2011) Although the norm is to scale down by the same fraction (0.0018), This scale produced so much congestion that cars were stuck on the road for days. Hence there was a need to calibrate using face validation to make assumptions on the right scaling factor. After further adjustment, a scaling factor of 0.042 was used, as this value allowed for closer representation of real life Lagos traffic congestion.

1. MATSim has a default setting where modes can be changed to create a better plan. In the Lagos case, private vehicle users are not likely to change their mode when using a car which is a highly preferred mode of transport. The parameter changeMode has been modified to only public transit vehicles (pt, minibus, tricycle, mc, boat, ferry) disabling any interchanging between private vehicle and public transportation.

2. The default MATSim values for marginal utility of distance and travel time (a unit of 0,-6 for distance and travel time respectively) (Nagel et al., 2016a) has been implemented for teleported modes. This means that the agents in this scenario only care about minimizing travel time. Replanning is then done based on the shortest path. A small percentage (10%) of agents are allowed to reroute an existing plan where they pick a pick a plan from memory and can alter the route between activities, which is then added to the agent's memory. However, the scoring parameters will need to be either backed by real data for Lagos or calibrated for better analysis.

3. There is an option to add a vehicle file to the configuration, which is used to classify the different types of vehicles for every mode. These characteristics include seating and standing capacity, access time and egress time, passenger car equivalents. See Appendix A for the vehicle file. 401 transit vehicles generated from the transit schedule have been added to this file.

3 Output Result and Further Analysis

There is a huge difference between the first iteration and the 100th iteration run of MATSim simulation. In the first iteration agents are assigned the shortest route using free speed. At peak times some routes showed heavy congestion while other routes leading to the same location were free. People in reality would take a higher speed route if the travel time for a shorter route has increased due to congestion. To model this behavior, more than one iteration is needed and for the Lagos scenario, 100 iterations have been run to have the simulation as close to real life using face validation.

3.1 Simulation Results

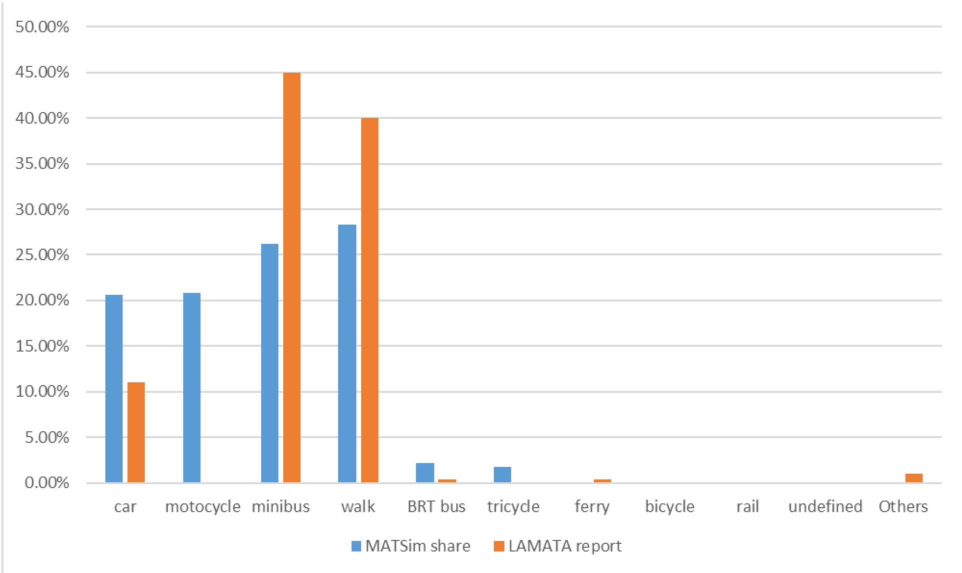
Figure 4 shows a snapshot of the simulation which has been visualized by the VIA software (Simunto, 2018). The red spots signify areas of congestion which reflect the congestion at morning peak hours similar to the congested routes shown in figure 2. At this morning peak hour direction of traffic congestion is toward the CBD and the state government district area.

Figure 4: Final Results: A simulation of Lagos Traffic Scenario

3.2 Mode Share

Part of MATSim's output provides the opportunity to see vehicle interaction on a network. This can be seen in different iterations until equilibrium is approached at the last iteration. In this paper mode choice has not been modeled and only the imputed mode share from the household data has been used.

Figure 5: Mode Share Comparisons



* Source for LAMATA report: LAMATA (2015). “Others” signifies motorcycle, tricycle, bicycle, taxis, articulated vehicles, mini-vans and boats. LAGBuS which has been discontinued had a 1% share in the LAMATA report and has not been added here.

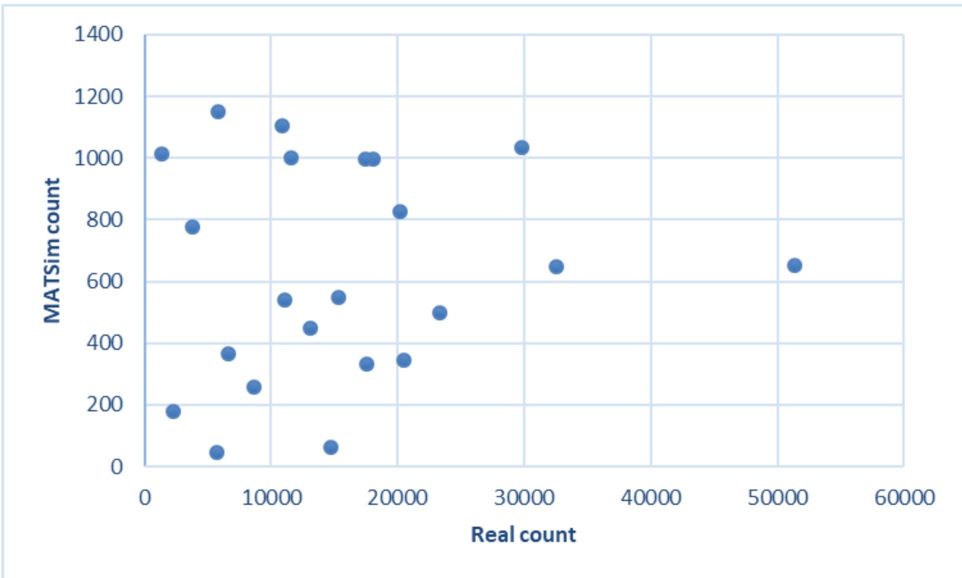
According to a 2012 World Bank and LAMATA report, only 15% of adult population is able to afford the use of private vehicle for their commute which is different from the mode share for MATSim derived from the household data. Differences can be seen between the two mode shares represented where car trips are more in the household survey. Motorcycles which was part of Others – having 1% representation - in the LAMATA report show a large difference. This may be due to changes in policy between the year of the survey (2012) and the 2015 LAMATA report.

MATSim's ability to model mode choice would have provided an added comparison of the fit of the simulation. However, this has not been implemented at this time as only the BRT bus was modeled as public transit. As such, it is essential to expand the public transport in future work as explained in more details in section 4.

3.3 Traffic Count Validation

Traffic count data for nine major counting stations was obtained from LAMATA and have been used to compare the MATSim results. The count data used was for cars and covered the time period from 7am to 8pm. As seen in the figure 6 below, the traffic counts generated in the simulation presently do not match that of real life as the relationship between the two traffic counts is not linear. This means that the scenario model requires further calibration.

Figure 6: Traffic Count Comparison between MATSim and Reality



3.4 Accessibility

Accessibility is a transport planning measure used to assess how connected locations in a study region are compared to other locations

Work trips accounts for 85% of the trips in the household data, as earlier stated, this is not necessarily different from reality. Therefore, here, workplace accessibility has been measured using travel-time-based costs (Hörl, 2017). The events file[5] generated from the MATSim output has been used as input file for calculating accessibility to work places.

Zones have already been defined by LAMATA in their available shape-file for the household survey and these zones have been used as the boundary for accessibility measures. 30235 work trips have been counted and these work trips occurred in 365 zones in Lagos which have been defined by LAMATA.

The accessibility formula

$A_i = log \sum_{j=0} O_j e^{(-\beta * tij)}$ has been used.

O_j is the number of workplace opportunities at a location zone j. t_{ij} is travel time cost measure between locations i and j.

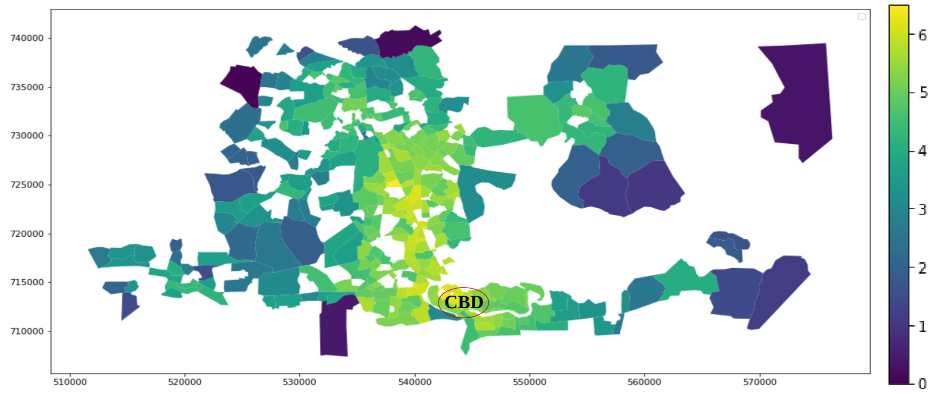
Accessibility is higher when more opportunities can be reached as $e^{(-\beta * tij)}$ serves as a decay function to penalize high travel time costs.

The results, which can be seen in the figure 7a and 7b below, only provides a glimpse of what is intuitive. That is, areas closer to the CBD are well connected and accessible for cars and the BRT corridor (blue line in fig. 7b) is reflected to be accessible compared to other areas. From this result, one cannot yet see how public transport complements car use because mode choice modelling is not in effect. However, this can be extended for further study as explained in the next section.

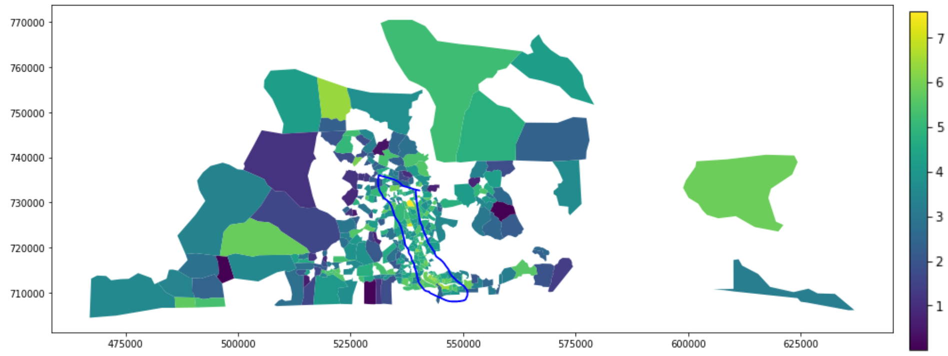
Figure 7: Workplace Accessibility Map for Lagos

(a) Workplace Accessibility Map for Car

[5] The events file is MATSim's documentation of its mobility simulation describing the actions of an object at a particular time. Examples of events include: an agent starts a trip, an agent finishes an activity, a vehicle enters/leaves a road, etc.



(b) Workplace Accessibility Map for Public Transport



4 Further Steps and Discussion

This paper shows the creation of a basic scenario for Lagos. Additional data sources are required for a more realistic scenario. In order to arrive at a useful scenario, the following steps need to be taken:

Expanding the Public Transport Network

At the present stage of this scenario, public transportation is not fully modelled as the minibuses which have a 46% modal share is not properly simulated in the baseline scenario. See fig 5 above.

At present time, because of late arrival of useful data that could be used for specifying the minibus corridors, the minibuses have not been modeled in the scenario of this report. However, further ongoing work will see this data used in the following ways:

- A MATSim schedule will be created using the available corridor data for assumed minibus routes.
- Assumptions will be made of the stop frequency and wait times using the standard BRT wait times
- The first and last bus stops will be configured to represent the minibuses waiting until they are filled with passengers before moving.
- A GTFS schedule will then be created which will be converted to a MATSim schedule just like it was generated above for the BRT buses and added under the pt.

Motorcycles, rail, ferry would continue to be teleported as the mode share is quite small in reality

Population Synthesis

A synthetic population as a model for the population of a whole region based on available travel survey data and census data can be created to serve as the MATSim population. This would enable proper modeling of Lagos as further analysis could be carried out such as mode choice modelling, accessibility measures, forecasting, etc. With availability of the 2006 Census data, Iterative Proportional Fitting (See Müller, 2017; Joubert, 2013) can be used to generate the synthetic population.

Measuring Accessibility

Simple accessibility to work place using travel time has been measured. The overarching purpose of this research is to facilitate a better understanding of accessibility in rapidly urbanizing cities and provide a microscopic model for traffic flow to inform better decision making in transport planning. To expand and generalize accessibility measurement for all of Lagos, a synthetic population will be needed.

Freight inclusion

Freight has been a source of traffic congestion on major roads in Lagos as the trucks used to convey goods, compete with passenger vehicles. Freight traffic could extend miles blocking off smaller roads on major arterial points as trucks queue along the road leading to the ports with the queues extending for long stretches while trucks spend time loading and offloading. Modeling freight using an extended version of the above scenario would contribute to informing policies such as changing the time of trucks on the road, providing different routes for trucks, or providing better routes for users with an optimized routing from MATSim. Also a MATSim module for port processing of trucks could be created to model the Lagos freight transport.

Forecasting

One of the usefulness of MATSim is in the area of forecasting. Currently the Lagos metropolitan government has a master plan for transport infrastructure development. These planned projects can be simulated in the Lagos Traffic scenario to forecast the various effects these plans would have on people's travel behavior

5 Reference list

Choudhury, C. F. and S.B. Ayaz (2015) Why live far? — Insights from modeling residential location choice in Bangladesh, *Journal of Transport Geography*, **48**, 1-9.

Dubernet, T. and K.W. Axhausen (2016) Using a joint destination-mode choice model for developing accessibility measures, paper presented at the *16th Swiss Transport Research Conference*, Ascona, May.

Hörl, S. (2017) A methodology for observation-based accessibility, Paper presented at the *6th Conference of the European Association for Research in Transportation*, Haifa, Israel, September.

Horni, A., K. Nagel and K. W. Axhausen (2016) *The Multi-Agent Transport Simulation MATSim*, Ubiquity, London.

Hoornweg, D. and K. Pope (2017) Population predictions for the world's largest cities in the 21st century, *Environment and Urbanization*, **29** (1) 195–216.

Joubert, J. W. and Q. Van Heerden (2013) Large-scale multimodal transport modelling -Part 1: Demand generation Paper presented at the *32nd Annual Southern African Transport Conference, Pretoria, July 2013.*

Japan International Cooperation Agency (JICA), Japan International Consultants for Transportation Co, Ltd., Yachiyo Engineering Co., Ltd., Chuo Fukken Consultants Co., Ltd., Mitsubishi Research Institute, Inc. (2014) The Second Data Collection Survey on Mass Rapid Transit in the Federal Republic of Nigeria, http://open_jicareport.jica.go.jp/pdf/12245411.pdf, retrieved Nov. 2018.

Lagos Metropolitan Area Transport (LAMATA) (May 2013) *Consultancy Services for the Extension of the Strategic Transport Master Plan and Travel Demand Model to Cover the Mega City Region, TECHNICAL REPORT ON DATA COLLECTON DRAFT* ALG Transportation Infrastructure & Logistics, Lagos

Lagos Metropolitan Area Transport (LAMATA) (December 2014) *Consultancy Services for the Extension of the Strategic Transport Master Plan and Travel Demand Model to Cover the Mega City Region FINAL REPORT* ALG Transportation Infrastructure & Logistics, Lagos

Lagos Metropolitan Area Transport Authority (LAMATA) (2015) Transport Statistics 2015, Lagos Metropolitan Area Transport Authority, Lagos Nigeria

Lagos State Government (2018) Transportation Deal Book Lagos State Government, https://www.lagosglobal.org/wp-content/uploads/2016/05/Transport-Deal-Book-optimized.pdf

Müller, K. (2017) *A Generalized Approach to Population Synthesis*, doctoral zhesis, ETH Zurich, Zurich.

Nagel, K, B. Kickhofer, A. Horni and D. Charypar (2016) A Closer Look at Scoring, in: Horni, A, K. Nagel and K.W. Axhausen (eds.) *The Multi-Agent Transport Simulation MATSim*, 23–34, Ubiqity Press, London

Oshodi, L., T. Salau and O. Udoma-Ejorh (2016) Urban Mobility and Transportation, in Heinrich Böll Stiftung Nigeria (ed) *Urban Planning Processes In Lagos Abuja*, Heinrich Böll Stiftung Nigeria, Lagos.

Osoba, S.B. (2015) Travel characteristics and commuting pattern of Lagos Metropolis Residents: An assessment, *Indonesian Journal of Geography*, **47** (1) 40.

Simunto GmbH (2018) VIA – Visualization and Analysis Tool, webpage, Oct 2018, https://simunto.com/via/

A Vehicles File Description

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