Decongesting the City of Nairobi: Data as a Critical Component in Land Use Planning

Ian Kamau Mbote & Patricia Kameri-Mbote

Abstract

Land use planning in urban areas in Kenya remains the Achilles heel of growth. The increasing mining of data from diverse sources and its use for varied purposes presents an opportunity in land use planning. Data can be used for integrating different uses of land as well ensuring that there is synergy between different uses and users of land. Kenya developed her first National Land Use Policy in 2017 following on the first ever National Land Policy concluded in 2009. This presents an opportunity for leveraging the use data to plan land use and to decongest cities in Kenya. Nairobi, Kenya's capital city and a regional hub, is the most congested city in Kenya. Collation of data from diverse sources and interfacing it can contribute to better planning. Under the devolved government structure introduced by the Constitution of Kenya 2010, Nairobi County is required to develop an Integrated Urban Development Plan. This will be done against the backdrop of current patterns of inequality in urban land use, access and illegal land allocation in most parts of the city. This will in turn nuance the commitment by city authorities to rely on land use planning in development. The population of Nairobi is estimated to be 5 million. The transport and other infrastructure developed at the beginning of the century and minimally enhanced over the years is chocking as more pressure is brought to bear on it. Data from multiple sources is required including city land planners, transport providers and regulators. The draft National Information Communications Technology 2016 anticipates the use of big data for a variety of purposes and proposes to create an internet of things (IoT) industry in Kenya by connecting interrelated devices and systems and enabling them to transfer data over networks without requiring human-to-human or human-to-computer interaction. This is a welcome development. Such a system will interconnect the various actors to ensure seamless interaction for enhanced mobility and efficiency.

I. Introduction

Stereotypically, the concept of a city remains common regardless of its geographical location — a sprawl of structures within and in between which throngs go about their daily activities in a rushed humdrum. Urban infrastructure can be perceived as the pipeline that makes up city residents' logistical nucleus. Without appropriate planning this pipeline is susceptible to failure, having two main facets to blame: the exponential increase in the number of people relying on urban infrastructure and evolutionary paradigm shifts in the environs within which the infrastructure exists. These two agents have been a key decision factor in urban governance since conception of the first city.

A. The origins of the city sphere

The evolutionary journey that led to the current urban setting is a long one, spanning thousands of years and numerous innovative strides. In the fourth millennium Before Common Era (BCE), the first city was born, going by the name Mesopotamia.[1] It is believed that the wheel, chariot and sailboat were invented in this city as one of the first means of facilitating transport of people and goods within the areas of settlement[2]. The Organization for Economic Co-operation and Development[3] provides a developmental synopsis on the growth of cities spanning from the 18th to the 21st Century: In the 18th Century, agricultural yield experienced a boom and the manufacturing trade was created, the result being a labor rush that saw small densely populated settlements around ports and coal mines. By the 19th Century, demand for labor and supply of goods prompted an evolution in transport systems. Steamships and steam trains were invented to facilitate mobility over longer distances. With this sudden ease of movement, industries grew resulting in a second labor rush. The small cities of the 18th Century grew in population size and thus came in the first underground rail system to ease the equally new problem of congestion.

Because of this second labor rush, land around industries became scarce and extremely expensive. Rather than build over a large plot of land, architects in the 20th Century opted to design buildings that extended vertically. This did not solve the problem of continuous increase in population, which put pressure on the available underground rail system. Automobiles were then released to the mass market, allowing workers to live in regions farther away from the city. This was the first instance of suburban life. By this time the city had begun to shape itself as a service area rather than an industrial

1 Leick, G. (2002), Mesopotamia: The invention of the city. Penguin Books Limited, London.
2 Ibid.
3 OECD (2015), The Metropolitan Century: Understanding Urbanisation and its consequences. OECD Publishing, Paris.

one. Ushering in the 21st Century were further advancements in transport networks, technology and infrastructure, which enabled cities to rise in developing countries.[4] The magnetic attraction of life within or close to these urban areas has culminated itself in staggering figures: 50% of the world's population is currently city dwelling, a figure that will rise to 66% by 2050.[5] To put that into perspective, 2050 is forecast to have the current world's population all living within cities.[6]

Bringing the focal point of scrutiny to city growth in developing regions, with a pinpoint on Kenya's capital of Nairobi, the infrastructural burden is twofold given the transitional and to an extent revolutionary state brought about by independence from colonial rule at the juvenile stages of the city's existence. The magnetic pull of the city with the allure of better life

B. Nairobi — A Planning Challenge

Land use planning in urban areas in Kenya is a major growth challenge. There has, for instance, been an upsurge of housing development in Nairobi as well as the proliferation of informal settlements. This has happened without integrated and holistic planning. Nairobi's road network had been developed by 1909[7] but the boundary of Nairobi was extended in 1927 as a result of the rapid population and infrastructure growth. From 1928 to 1963, this boundary remained the same with only minor additions and excisions taking place. In 1963, the boundary was extended to cover an area of approximately 686 km2 from the previous 77 km2.8 The first Nairobi Master Plan was developed in 1927. The second Master Plan was implemented in 1948 with the aim of making Nairobi a more attractive for industrial investment while the 1973 Master Plan was developed by the Kenyan Government, World Bank and United Nations in order to formulate a metropolitan growth strategy for the city.[9] The city has expanded in all directions with neighbouring agricultural areas now included in the built up area loosely referred to as Nairobi. The need for housing has grown over the years as more people moved into the city. Neighbouring areas provide accommodation

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5 Department of Economic and Social Affairs (2017) World Population Prospects – The 2017 Revision: Key Findings and Advance Tables. United Nations, New York.
6 Ibid.
7 Winnie Mitullah, Understanding Slums: Case Studies for the Global Report on Human Settlements 2003.
8 Ibid
9 http://citymasterplan.nairobi.go.ke/index.php/niuplan/background

for the workers who travel daily in and out of the city. This raises the need for interconnectedness through efficient transport systems supported by necessary infrastructure.

Under the devolved government structure introduced by the Constitution of Kenya 2010, each of the forty-seven county governments including Nairobi is required to develop an Integrated Urban Development Plan. This will be done against the backdrop of current patterns of inequality in urban land use, access and illegal land allocation in most parts of the city. This will in turn nuance the commitment by city authorities in Nairobi, Kisumu and Mombasa to rely on land use planning as a guide in urban development. The population of Nairobi in 2009 was estimated to be 4 million.[10] The transport and other infrastructure developed at the beginning of the century and minimally enhanced over the years is chocking as more pressure is brought to bear on it. Traffic jams in Nairobi have increasingly become a nightmare for city dwellers and the expectation that many people will move to the counties is yet to result in notable decongestion. Traffic congestion and the urban sprawl have implications for ecological sustainability particularly considering that concerted efforts to control vehicular smog and deal with waste are yet to be institutionalized.

Nairobi has therefore joined other countries where urban mobility is plagued by issues of congestion, waste and emissions, which in turn have a trickle-down effect on the environment and climate. This calls for action to serve users better and mitigate further harm to the environment. This is not only about switching to eco-friendly transport media. A greater optimization is required. Manufacturers and retailers of transport media should know in real-time the exact number and type of vehicle to convey. In addition, the transport media must have a predictable repair and end-of-life cycle in which they will be recycled and remanufactured to produce new ones. City administrators should be able to make deductions as to which service improvements are required and/or legislative interventions based on peak usage time prediction, availability of infrastructure and geographical layout. Urbanites commuting within the city sphere should have real-time options of multiple transport modes based on their preferences and interlinking city conditions at a particular time and place. This optimization in urban mobility can only be achieved using one key ingredient: Data.

10 Kenya National Bureau of Statistics (KNBS)

Data from multiple sources is required including city land planners, transport providers and regulators. The draft National Information Communications Technology 2016 anticipates the use of big data for a variety of purposes and proposes to create an internet of things (IoT) industry in Kenya by connecting interrelated devices and systems and enabling them to transfer data over networks without requiring human-to-human or human-to-computer interaction. Such a system will interconnect the various actors to ensure seamless interaction for enhanced mobility. This research will look at the origin of the city and the mobility challenges, as well as map the main stakeholders within the urban transport sector. It will then identify the requisite data sources and their link to land governance within a city context with a view to making proposals for a holistic land use policy that uses data. This will be analyzed within the context of the Kenya National Data Infrastructure (KNSDI). This paper highlights the need to use multiple data sets in and outside the land arena to facilitate decongestion and enhance mobility in the city. The authors propose the need to interface data and land governance for future development of the Nairobi metropolis.

II. Land Use Planning

Land is a critical factor of production and land use is an important part of maximizing the value of the land as well as its utility to the users. The major uses of land in Kenya include agriculture, pastoralism, wildlife and forest management and urban development. These land uses do not exist in isolation. They overlap and conflicts often arise between different users of land. The situation is compounded by the absence of or disregard of zoning. It is for instance not unusual to have pastoralists grazing their herds in Nairobi's commercial and residential areas. This is occasioned by erratic weather patterns, which force herders to move in search of pasture for their flocks. Increasing urbanization is also a major factor in Kenya as people move from the rural areas to urban areas in search of employment. For instance, between 2010 and 2015, there was an urban population growth rate of 4.4 % in Kenya.[11] In 2013, the total urban population comprised a quarter (25%) of the total population in the country.[12] This figure is projected to have increased since 2013.

Increased urbanization has necessitated destruction of ecological zones to construct

11 ibid 13.
12 ibid.

houses for settlement and exacerbated human-wildlife conflicts. It has also contributed to the fragmentation of land and conversion of what was formerly agricultural land into residential and commercial uses[13] as noted above. In this regard, the areas around Nairobi on the side of Machakos, Kiambu, Kajiado and Murang'a have progressively been converted into urban areas with concentrations of populations and increased demand for housing and infrastructure. The National Land Use Policy 2017 estimates the urban population in Kenya in 2016 to have been 11,004,417 representing 25% of the total population.[14] Most rapid urban growth centres are in the cities and towns such as Nairobi, Mombasa, Kisumu, Nakuru, Eldoret, Kakamega and their satellite extensions.[15] The 4.4% urban population growth rate from 2010 to 2015 implies a rapid rural-urban migration pattern.

Population growth and urbanization have implications for land use such as ensuring access to water, sanitation, electricity and other services. It also has implications for the growth of urban centres, which has happened largely without planning. In terms of planning, only 30% of urban centres in Kenya are planned.[16] Even amongst the planned centres, informal developments and slums continue to grow. It is currently estimated that about 50 percent of Kenya's urban population live in unplanned settlements, lacking in basic infrastructure provision and services. The absence of clear master-plans or overall guide on the development path within an urban area, providing a balance between new development and essential services and environmental conservation has compromised sustainable development of urban centres. Poor planning and weak urban economies have led to poor housing and neighbourhood quality. As a result of inadequate housing, majority of urban dwellers, mainly low-income households, are compelled to resort to providing themselves with substandard housing in slums. The result is unplanned settlements. The new devolved structures are, however, compelled in law to develop an integrated plan for their areas, including informal settlements, a fact that has led Nairobi to developing a master plan for the first time since the last working plan developed in 1948.[17] The existing land use data is outdated and

13 ibid 21.
14 Kenya National Land Use Policy 2017: 13
15 Ibid
16 Kenya Country Report to 4th World Urban Forum, 2008.
17 The 1948 Nairobi Master Plan-The preparation procedure, scope, content and approval procedures of this master plan followed the 1947 Town and Country Planning Act of Britain. The plan was conceived as a key plan for the general physical, economic and social development of Nairobi for a period of 20 years. It incorporated racial segregation zoning and was linked to the overall budget planning (Mary Kimani and Titus Musungu, Reforming and

inadequate. The data on land uses was developed during the colonial times and has not been updated to match the changing circumstances.[18] Access to land use data is limited to a few institutions that generate the data with little dissemination to the public.[19] The National Land Use Policy notes that data availability; access, interpretation and dissemination are still a challenge.[20] More specifically there is inadequate useful data, and this is also affected by the lack of common definitions and standards of land use; unsystematic and uncoordinated data collection activities; and lack of comprehensive mechanisms for capturing cumulative change manifested through the geographically dispersed, progressive result of human activity such as soil loss, habitat loss and loss of biological diversity. [21]

The National Land Use Policy lists the following principles and values as undergirding it:

- Efficient and sustainable land use management;
- Ecological sustainability;
- Integrity and adherence to the rule of law;
- Food security;
- Access to land use information;
- Amicable resolution of land use conflicts;
- Equity, inclusivity and transparency in decision-making;
- Effective public participation.
- Elimination of discrimination and respect for human rights in land use;
- Public benefit and interest;
- Order and harmony in land use; and
- Adoption of technology in land use management.

Reliable and frequently updated data is a critical part of realizing these values and adhering to the principles. In a fast growing city like Nairobi, data on the number of people needing specific services such as housing and transport is critical to planning the use of the city spaces. Data can facilitate the integration of all urban development sectors for the city of Nairobi. Data on peak usage times of specific routes for instance, and what alternative routes exist would be useful in decongesting the city. It would also be useful in planning the layout of the city in future development plans.

Restructuring Planning and Building Laws and Regulations in Kenya for Sustainable Urban Development (46th ISOCARP Congress 2010)
18 Kameri-Mbote, P. (2016). Kenya land governance assessment framework report (LGAF). Nairobi: World Bank. https://doi.org/10.1596/28502
19 Ibid.
20 Kenya National Land Use Policy 2017
21 Kenya National Land Use Policy 2017

III. Multiple Uses of Data

Over the years, breakthroughs in the Information and Communications Technology (ICT) industry have enabled an ever-increasing number of people to gain access to the Internet.[22] What was previously used mainly in corporations and among the social elite has now developed and transformed the world we live in: sensors and internet-capable computers of all sizes and costs are accessible to urban dwellers.[23] Cyber communities have formed allowing people, governments and corporations to communicate and share data across the globe without having to physically meet.[24] It is for this reason that data streams form the essential ingredient required to achieve a circular mobility in major cities.

The existence of data alone, however, does not translate directly to a seamless network of interconnected platforms working in perfect harmony. Data streams occur in various formats, sizes and rates. Voice data is dissimilar to photographic data, which in turn is dissimilar to text data. Nonetheless, all of these are forms of data. How would this cluster of different data types be termed? Enter the concept of "Big Data".

Any large quantity of structured or unstructured data used in informed decision-making upon its scrutiny is referred to as big data.[25] Big data is characterised using three key attributes[26]:

a) Volume: The quantity of data being collected, varying from gigabytes to yottabytes.
b) Variety: The structured and unstructured data storage formats used by computers.
c) Velocity: The speed at which data is generated and processed.

Whilst there exists a sizeable pool of data to analyse, the sources, technologies as well as algorithms to securely acquire the right data streams are also very important. Figure 4 is an illustration of the steps taken in the refinement of big data.

22 Mohanty et al., 2015
23 Ibid
24 Ibid
25 Rafferty et al., 2016
26 Ibid

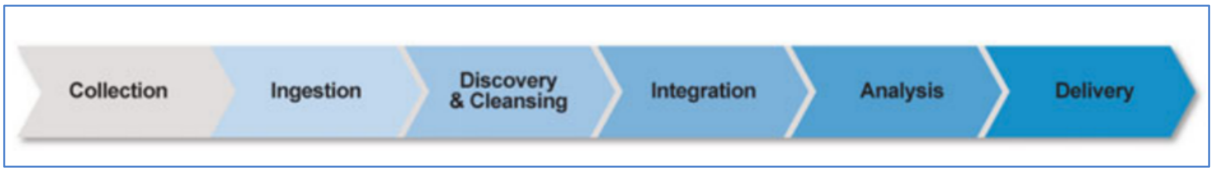

Figure 1: Big Data Workflow (Furht & Villanustre, 2016).

Collection refers to the gathering of all data types (structured and unstructured), followed by ingestion, which is the process of storing it onto a single database. Discovery and cleansing is the act of sorting the data as well as comprehending its content. Integration refers to preparing the data for analysis through indexing and data fusion. Analysis involves gathering of intelligence, statistical data, predictive texts and machine learning. Lastly, delivery is the conveyance of the findings in a format that is applicable in decision-making. [27]

In order to successfully refine big data using these steps, the appropriate technology and algorithms must be implemented. Five key big data technologies include the following:

- Massively Parallel Processing: An array of independent interconnected processors work in tandem to manipulate big data.[28]
- Data Mining techniques and tools: This is the practice of identifying trends in large data streams using algorithms, machine learning and artificial intelligence.[29]
- Distributed file arrays and databases: Commonly linked with Hadoop software, a big data technology in which big sets of information are split down and distributed across a network of connected clusters on a server.[30]
- Cloud computing platforms: This is the execution of big data workflow processes using services offered over the internet (also known as Cloud) by computer server hosts.[31]
- Scalable storage systems: These are computer systems capable of increasing or decreasing performance attributes depending on the task being handled without losing efficiency or accuracy.[32]

With these technologies and algorithms in place, raw data in its various forms can be analysed to identify trends and catch key patterns. There exist, however, some barriers to big data's direct implementation. Given the mountainous amount of data available for manipulation, security and privacy arise as challenges to Big Data adoption. Traditional methods of data protection involved use of cryptographic transmission of data,

27 Furht & Villanustre, 2016
28 Kirk, D.B., Hwu, W.W. (2012) Programming Massively Parallel Processors. Morgan Kaufman Publishers.
29 Xu, G., Zong, Y., Yang, Z. (2013) Applied Data Mining. CRC Press.
30 Sammer, E. (2012) Hadoop Operations. O'Reilly Media Inc.
31 Sosinsky, B. (2011) Cloud Computing Bible. John Wiley & Sons Publishers.
32 Furht, B., Escalante, A. (2011) Handbook of Data Intensive Computing. Springer New York.

authentication-based data access and data encryption. Big Data, being of diverse format and easy availability, enables any device with the right protocols and connected to the IoT to connect to another device over the same network. Policymakers and Big Data service providers must therefore develop protocols, which ensure that individuals' data is kept secure, private and confidential. The magnitude of repercussions that would come to play should there be a data security breach in an urban land use planning system is enormous.[33] The 2016 data security breach by Uber where the company concealed a massive hack that exposed the data of millions of users and drivers is an example of security breaches possible in big data use.[34] The Chief security officer of the firm was fired for concealing the hack and the fact that the hackers were paid $100,000 to delete data and keep the breach quiet.[35] With the rise of terrorism and cybercrimes, the integrity of data is critical for the security of individuals and nations.

A. The Rise in Importance of Data

Traditional methods of planning, forecasting and strategy layout were more reliant on professional experience and industry know-how, with data in the back seat being used as a reinforcement tool rather than a compass. The data in question would also occur as a result of very structured collection methods, which guaranteed a calculated output. From the simple statistical data of census counts in nations to well-structured credit estimation algorithms used by lenders, all of these data sets formed a narrow and often predictable spectrum of outputs.

It was not until the financial crisis of 2007 that the world switched the roles of data and professionals to give the former priority such that decisions were driven by data and not by mere know-how. Data capture technology and techniques increased drastically, making data mining an industry in its own respect. To put this into perspective, the United Nations in a report[36] established that more people own smartphones than those who have access to sanitation amenities. It would then come as no shock that services once involving physical premises, tangible assets and face-to-face encounters have now gone mobile — an advent that has availed vast quantities of data for manipulation by

33 Mohanty, H. Bhuyan, P., Chenthati, D. (2015) Big Data – A Primer. Springer India.
34 See E. Newcomer, "Uber Paid Hackers to Delete Stolen Data on 57 Million People", https://www.bloomberg.com/.../2017.../uber-concealed-cyberattack-that-exposed-57-... Nov 21, 2017
35 Ibid
36 UN News Centre: http://www.un.org/apps/news/story.asp?NewsID=44452#.Wn94LWacaRc

big data experts. The International Data Corporation[37] predicts that over one-third of Fortune [38]500 companies' revenue will be information-based by 2020; pushing the data industry's worth from a cumulative $130 Billion up to a whopping $203 Billion. In the context of land data, there is increased use of global positioning system enabled unmanned aerial vehicles or drones to capture data where previously humans would have been sent to the field to collect data.[39] The potential for big data collection and use in Kenya is immense considering the proliferation of mobile telephony and ubiquity of technology use for diverse purposes.

B. Uses of Data

There exist a multitude of applications for data within the context of pushing private and public institutions' strategies forward. With a global population that is now more internet-savvy than ever before, legacy techniques of service delivery and situational forecast are rapidly being rendered obsolete. Previously, the world's population was largely monotone in their choice of lifestyle — a trait that may be attributed to the pre-millennial generation. With the surge and eminent rise to majority of the latter generations, new means of targeting innovation and forecasting trends are required. These should be able to pick up preferences on a person-to-person basis, and pool them to generate macro patterns: data generated from individuals is concatenated to form big data, which is then mined for purposeful application.

Urban planning is a sector ablaze with demands and requirements from an ever-increasing number of city dwellers. Sustainable development, or the adequate creation of a provision for services, amenities and infrastructure aimed at increasing metropolitan longevity requires pinpoint accuracy. Failure to cater for any emergent needs and/or factor in all influencing factors within the city sphere could be catastrophic. Data is the surgical knife among the available tools for creating a clear-cut path aimed at keeping a city running for decades to come. An example of data integration within urban planning is the Transport for London (TfL) Oyster Card. Users

37 IDC Double-Digit Growth Forecast for the Worldwide Big Data and Business Analytics Market Through 2020 Led by Banking and Manufacturing Investments, According to IDC.
[38] Adam Peake, 'Kenya's ICT Sector, Mobile Money and the Transformation to a Middle-Income Country' March 2013 Intelplace, 102 http://www.glocom.ac.jp/chijo_lib/118/101-113_B_adam.pdf accessed 15 January 2017.
[39] See e.g. P. Kameri-Mbote & M. Muriungi, Potential Contribution of Drones to Reliability of Kenya's Land Information System. The African Journal of Information and Communication (AJIC), 20, 159-169. https://doi.org/10.23962/10539/23500

are able to top up and store monetary credit and information within a chip on a smartcard which they then use to pay for city transport services thus eliminating the need for cash payment.[40] This innovation may provide further value if data on areas and times of most frequent Oyster Card use are noted and analysed as Big Data, preventing potential transport service disruption and warn users of peak times.[41] Participatory sensing, a phenomenon in which data is collected from individuals within a city using their mobile devices and processed as big data to provide refined information is another way in which cities may utilise ICT innovation.[42] What this alludes to is the fact that with the right big data processing algorithms, cities are able to predict peak mobility use times and areas as well as mitigate this. The result would be a smooth-flowing, congestion-free city with people getting to and from their desired destinations in good time.

Another sector in which data's application has proven paramount to its growth is the service industry. Access to bespoke 'tailor-fitted' services such as personal banking and boutique retail was only afforded to society's upper tiers. This made the quality of service below par for those unable or unwilling to pay lump sums for premium treatment — shopping centers were packed to capacity with buyers uncertain of what to purchase, bank halls with queues mimicking ant colonies among many others. With the increased incorporation of data within the service industry, traditional perks only available to the affluent are now commonplace. Music streaming platform Spotify, through careful use of algorithms and big data, are able to curate and predict user tastes on a case-by-case basis that imparts a feeling of having one's own personal disc jockey on standby. Online clothing retailer Enclothed has no physical shops, but through use of big data collected from customers with similar tastes have been able to predict and create fashion trends which have boosted their sales — not to mention that users simply need to log their tastes and preferences and based on this data receive personalized attire recommendations. On-demand television and video streaming platform Netflix has been the poster child of big data's success in service optimization. By logging the average continuous times spent viewing a program, data on "binge-watching" versus "savor-watching" enables the media provider to apply predictive

40 Transport For London (2017) Oyster [online]. Available at: https://tfl.gov.uk/fares-and-payments/oyster
41 Batty, M. (2013) Big data, smart cities and city planning. Dialogues in Human Geography, 3(3) pp. 274-279.
42 He, Y., Stojmenovic, I., Liu, Y., Gu, Y. (2014) Smart City. Hindawi Publishing Corporation, China.

techniques and create content that is bound to succeed. Users are also treated to curations based on their preferences and most frequently viewed items, ensuring that their personal online video libraries are always stocked with exciting titles.

Data-driven product development poses benefits not only to users and manufacturers, but also the environment as a whole. Manufacturers are now engaging their end users more aggressively in their creative process, collecting feedback at every opportunity such as to develop sure-win products for their target markets. Partnerships with retailers have opened up numerous data gateways on purchase trends which can then be used in determining the obsolescence or relevance of a particular good — for instance if more people at a supermarket purchase organic foods over processed foods owing to a larger tacit desire to be healthy, food producers may analyze the exact foods scanned at purchase terminals and overhaul their offering to better suit the new market wave. Another example is the automotive sector, in which car manufacturers embed data capture devices in their vehicles as a means of assessing user behavior; average trip distances, terrain, number of occupants per trip, the list is bountiful. With this data, the companies are able to target consumer market niches with pin-point accuracy. The result is staunch sports-car companies like Porsche and Lamborghini unveiling Sports Utility Vehicles, and primarily premium sedan giants BMW and Mercedes rolling out a mass offering of hatchbacks and entry-level products.

Environmental bodies may also apply data in the enforcement of policy and reform; by using data on plastics manufacture volumes, purchase rate at sale terminals and proliferation mass at disposal, governmental and non-governmental agencies have managed to curb further use of the material in packaging and general use — promoting reuse and recycling. Data on internal combustion engine vehicle manufacture and uptake as well as peak travel times and areas has equipped the European Union with the necessary predictive tools to instill stringent control measures on emissions so as to prevent adverse climate change.

In the medical industry, data has begun to make prognosis and general healthcare a proactive task as opposed to the conventional reactive process. Rather than go to the doctor once symptoms have developed into illness, individuals through wearable sensors may now continuously monitor their health vitals and share this data with professionals, preventing the onset of a large proportion of illnesses. Disease control through infectious disease surveillance is data-led; using crowd-sourced data input from a mobile phone or internet-based registry informs medical centers on areas of potential epidemic uprising and thus allows for appropriate subdual measures.

These examples lie within a myriad of instances where data use has proven detrimental to optimization and growth of industry — among which is the focus of this research: how may data aid land use planning?

IV. Data Use in Decongesting Cities: Examples From Other Countries

Throughout the world, city administrators face the same challenge — demand for public amenities and services exceeds that which may be provided owing to a lightning-paced urban population growth rate. This section shall cover the efforts made on a case by case basis, highlighting the innovative use of data to tackle this urban administration obstacle.

A. Infrastructure

The easiest and most straightforward path towards meeting the high urban infrastructural demand is through collaboration and the availing of data. The first exemplification of this success comes in the form of Transport for London's Open Data scheme. By making all real-time data on public transport status available to the public free of charge, the city of London's administrators have opened doors to third-party developers — extremely skilled companies capable of processing this open data to create solutions that benefit both the city administration but also the general public. Residents in London are able to more accurately plan their journeys using mobile applications tailored to their individual lifestyles, saving time and money. Transport for London (TfL) as a body in turn receives feedback data from these third-party companies, enabling strategic decisions to be made based on data that has been crowdsourced with each use of the mobile application. This could take the form of terminus expansion, route frequency increments or decrements, peak travel hour crowd capacity prediction as well as future development planning.

Another example of data playing an important role in the demand smoothening of infrastructure is Amsterdam. The fitting of sensors and processors within key nodes of the electricity grid in Nieuw West has availed data on demand and peak usage to energy providers. Coupled with an increasing uptake of smart electricity meters, capable of real-time energy use capture, residents and the government alike are able to better manage their energy needs. This combination of data capture and analysis technology with the grid also allows for an increased input of energy from renewable sources — if a household produces more solar energy than is required for that day, the excess may be sold such as to meet demand elsewhere. Similarly, if a home makes use of energy storage through batteries, or in the case of an electric vehicle, the excess may be discharged from these cells at a cost to cater for demand elsewhere. The ultimate goal of having this energy data available is to meet as much demand as possible through renewable sources, thus lowering the city of Amsterdam's carbon footprint.

B. Vehicular Transport

Since the sunset of the 20th Century, vehicles have been manufactured with built-in sensor and computer technology to accurately manage the correct functioning of the engine and drivetrain. The data collected by the onboard sensors was stored within local memory, allowing the vehicle to alert its owner as to any faults or eminent service requirements. As the 21st Century progressed into its first decade, a salient requirement arose for vehicles to capture, process and disseminate data to better serve their function. Datasets on fuel consumption, emissions, location, speed, acceleration and deceleration rate to name a few — all of this data once sent to a server and accessed by remote parties allowed logistics companies to streamline their fleet operation processes, insurers to calculate premiums based on driving style and users to navigate through cities with real-time data on traffic. This only served as a stepping stone, as the years following 2010 saw a new generation of vehicles rapidly emerge into the mainstream: smart cars. These were vehicles accessible to a majority of the market demographic, equipped with internet connectivity as standard and which tailored services to each user's needs. For instance, BMW's ConnectedDrive service offers a suite of services designed around user lifestyle preferences — from shopping trips to planning optimal routes to attend meetings in timely fashion, this data-driven solution offers an interface that similar carmakers have used as a benchmark in the creation of their own data-led solutions.

French carmaker Groupe Renault is among the first to manufacture vehicles using reused and recycled components from older obsolete products. By capturing data on each recycled part and subsequent new components, Renault are able to offer its market vehicles at subsidized prices. This not only benefits the environment through natural resource and raw material preservation but also aids the economy by making vehicles cheaper and creating jobs in recycling plants.

From the commercial vehicular transport end of the spectrum, data has been used in automating fleet conveyance of goods over long distances. The conventional method of hauling goods by road entailed drivers manning large trucks over long distances, a factor which brought with it huge amounts of risk. Cases of driver fatigue and loss of concentration over extremely long periods of time behind the wheel were becoming prevalent, sparking a new wave of innovation — autonomy and intelligent trucking. Companies such as Volvo, Daimler and Tesla are among a growing group of commercial vehicle manufacturers taking advantage of data and computing innovations. Trucks are now able to use data on location and route combined with real-time sensor inputs on road conditions to autonomously drive in a fleet to their desired destination. This would then give drivers a chance to rest when needed thus improving their working conditions.

C. City Users

Today's urban population is more concerned with getting to their point B as quickly and efficiently as possible — stress is not on the platform used to get from point A to point B, but simply getting there in good time period. This would therefore allude to a population willing to accept an electric vehicle transition should it pose the greatest benefits to their mobility needs.

This change in attitude towards mobility may be attributed to the change in the age demographic, namely. Millennials are slowly becoming the predominant age group within cities. This is a generation affiliated with the technology boom; a tech-savvy socio-culturally disruptive group with a different or "fresh" outlook on modern life. Their way of life is seen as being highly colloquial when compared to that of previous generations; the normal working hours in normal office environs has been replaced by location-agnostic roles and office setups that resemble a recreational center. The concept of a dining room within a home is now foreign, as meals may be eaten anywhere deemed fit. A report by Airbnb[43] claims that millennials value travel and experiences over buying a house or a car. This would imply a social characteristic in which people would rather have lasting memories with friends as opposed to investing in what previous generations considered as "must-have" entities. Once more, the desire for data-driven mobility presents itself, as shared mobility platforms would be viewed as a part of the overall experience that millennials place on a proverbial pedestal. This is also evidenced by the decline in the number of fully licensed drivers and average driving mileage within the past two decades. Urban mobility systems must therefore respond to this new wave of user attitudes, otherwise a clash will occur that could see cities collapse.

Millennials are at the forefront of data-driven mobility transition within urban settings owing to their ever-increasing reliance on data, placement of experiences as top priority and steadily decreasing appreciation of ownership. An insight report by Nielsen[44] suggests that 98% of millennials own smartphones; among this demographic, 74% of mobile application activity comes from Facebook with Google Maps registering 55%. Facebook and Google are considered to be within a small cohort of companies monopolising the data industry: also known as tech giants. This would suggest that millennials are more willing to share data, as their activity has propelled these companies to near untouchable in the field of big data mining. With regards to experiential preference and ownership decline among millennials, studies have shown that this demographic group prefers access over ownership: a phenomenon cleverly coined as "NOwnership". Within the context of city inhabitation, urban centres have drawn a strong affinity resulting in the birth of more transit-dependent "Millennial Boomtowns". These are areas that were previously not considered metropolitan, but through millennials' swarming them have developed into new modern city centres where mobility and amenities as accessible services supersede ownership.

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43 Airbnb (2016) Airbnb and The Rise of Millennial Travel.

44 Nielsen (2016) Millennials Are Top Smartphone Users. [online] Available at: http://www.nielsen.com/us/en/insights/news/2016/millennials-are-top-smartphone-users.html

D. Role of Integrated Data

The existence of data alone does not warrant a clear-cut pathway to strategic success. Further, the existence of data in isolated silos only serves to localise the potential benefits that can be gained from its appropriate manipulation — a symbiotic and synergetic relationship is required in order to truly make tangible the gains from data. This brings into play the concept of integration, whereby seemingly unrelated stakeholders and industries collaborate and pool their data to form a framework-guided "Swiss Army Knife" of information.

Within the context of land use planning, data integration may occur as follows. A national Roads Board may share its data on current and future works, providing a pivotal data set which may then be used by urban planners to forecast likely areas of population swarm and congestion. The national Housing Authority may aid in doing so by sharing data on housing trends and statistics, which would then further enable urban planners to pin-point exactly what kind of development shall occur at areas where rapid population increase is likely. Data from this marginal analysis may be shared back to the Roads Board and Housing Authority, with the inclusion of local councils — who through their data may be able to accurately determine the feasibility in terms of amenity provision and public works of such a population swarm occurring. The resultant data may then be conveyed back to all stakeholders, enabling accurate forecast of land use.

Integrated data is a common occurrence in industry — an example of a macro- and micro-analysis of integrated data use in the automotive industry is as shown in Figure 2 and 3 respectively.

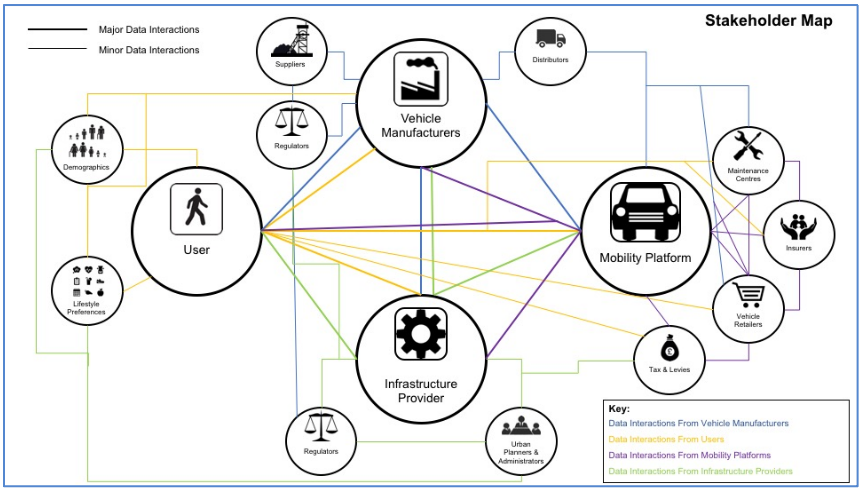

Figure 2: Macro-integration of data in the automotive industry.

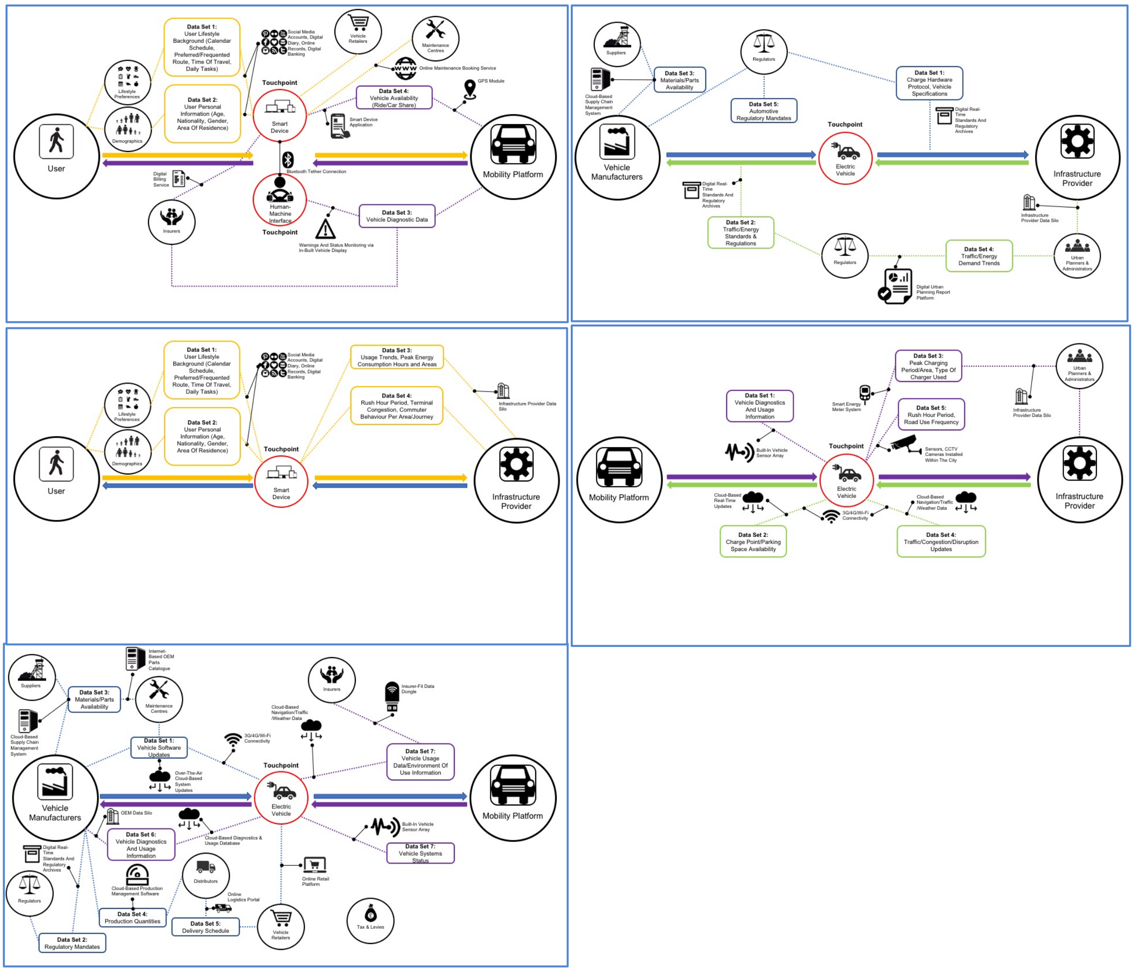

Figure 3: Micro-integration of data in the automotive industry.

V. Lessons for Nairobi

Kenya has been dubbed as a Silicon Savannah in the African continent. It is a cultural and IT hub of the Eastern African region, as well as a major innovation stemming point of Africa. With advents in energy such as M-Kopa providing solar energy to households not serviced by the public grid and banking going mobile through Safaricom's M-Pesa mobile money transfer service, the transition to data-driven solutions in the land sector is beckoning.

The first step towards streamlining land use planning would be to mimic, if not, leapfrog developed cities' strategy of digitizing records within public offices such as to avail civil data sets — these may be managed as separate entities all interconnected through nodes within a central data bank. An expedient way to achieve this would be to digitally map out the city of Nairobi by land allocation codes, identifying the purpose set out per tract of land down to the most minute of measurements.

Algorithms may be set in place such as to enable CCTV data capture intelligently detect areas of peak demand for infrastructure and communicate this to a smart traffic light system. Public transit may also be transferred to a digital platform through which commuters pay fare and plan journeys, with live journey tracking services provided by GPS chips embedded within all Public Service Vehicles (PSV's) — a move that would also facilitate the regulation of the number of PSV's on the road at a particular time, dependent on demand.

Telecommunication companies may additionally be offered tax levies in exchange for bandwidth by the city council of Nairobi, such as to power a metropolitan wireless data network. This would provide the necessary digital fuel to facilitate a transition to integrated data within all public sectors — land registry may be carried out over-the-air directly from the site, a PSV breakdown may be logged in real-time and urban residents may receive live traffic updates through a central access interface.

The benefits do not cease at improved land use planning — employment opportunities would arise as a by-product of public data management, propelling Nairobi's Information and Communications Technology (ICT) industry to new heights.

VI. Conclusion

This paper has looked at the origins of the city sphere and the subsequent demographic shifts in urban population, with a focus on the city of Nairobi and its land governance policies. Land use and its challenges have been discussed, posing the key issues to be addressed by a data-driven land strategy.

The state of the art in terms of data was then highlighted, illustrating key applications of data in the modern world — as well as potential uses in the future. The benefits reaped were explored from the urbanite perspective through to the larger city administration and industry scope.

Touchpoints for using data integration as a catalyst for improved land use planning were identified to bring the concept of data-driven planning to bear in the context of the city of Nairobi. Based on these examples, key lessons were gleaned for wider gains from data integration for Nairobi.

To conclude, successful land planning in Nairobi requires its data bedrock to be captured in an efficient manner, stored and managed using up-to-date technology and techniques, and conveyed in a useful and timely form in order for all stakeholders to reap the maximum benefit. The foundations for this exist given Nairobi's technological base. Increased use of data in diverse spaces requires a supporting regulatory framework for data protection and security to ensure integrity thereof. It is within this context that we propose that land and data governance should be interfaced for optimal benefits for land data providers and users.