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Matchmaking in Nairobi : the role of land use — Source link

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Matchmaking in Nairobi

The Role of Land Use

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WORLD BANK GROUP
Social, Urban, Rural and Resilience Global Practice Group
December 2016

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Well-functioning cities reduce the economic distance between people and economic opportunities. Cities thrive because they enable matchmaking—among people, among firms, and between people and job opportunities. This paper examines employment accessibility in Nairobi, Kenya and evaluates whether modification of land use patterns can contribute to increases in aggregate accessibility. The assessment is based on simulation of counterfactual scenarios of the location of jobs and households throughout the city without new investments in housing or transport infrastructure. The analysis finds that modifications to the spatial layout of Nairobi that encourage land use clustering can increase the share of overall opportunities that can be accessed within a given time-frame. When commuters travel by foot or using the minibus network, the share of accessible economic opportunities within an hour doubles from 11 to 21 percent and from 20 to 42 percent respectively. The analysis also finds that spatial layouts that maximize the number of households that have access to a minimum share of jobs, through a more even jobs-housing balance, come at the expense of average accessibility. This result is interpreted as a trade-off between inclusive and efficient labor markets.

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Matchmaking in Nairobi: The Role of Land Use

Paolo Avner and Somik Lall

JEL codes: R14, R52, R58, C63

Keywords: Matchmaking, Accessibility, Land use patterns, Urban form, Labor market

Matchmaking in Nairobi: The Role of Land Use

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Abstract

Well-functioning cities reduce the economic distance between people and economic opportunities. Cities thrive because they enable matchmaking – among people, among firms, and between people and job opportunities. This paper examines employment accessibility in Nairobi, Kenya and evaluates whether modification of land use patterns can contribute to increases in aggregate accessibility. The assessment is based on simulation of counterfactual scenarios of the location of jobs and households throughout the city without new investments in housing or transport infrastructure. The analysis finds that modifications to the spatial layout of Nairobi that encourage land use clustering can increase the share of overall opportunities that can be accessed within a given time-frame. When commuters travel by foot or using the minibus network, the share of accessible economic opportunities within an hour doubles from 11 to 21 percent and from 20 to 42 percent respectively. The analysis also finds that spatial layouts that maximize the number of households that have access to a minimum share of jobs, through a more even jobs-housing balance, come at the expense of average accessibility. This result is interpreted as a trade-off between inclusive and efficient labor markets.

1 Introduction

Cities bring together people, ideas and capital so as to benefit from agglomeration economies which stem from proximity and exchanges (Glaeser and Kahn 2004; Ciccone and Hall 1996). The most common sources of urban agglomeration economies arise from: 1/ labor market interactions (pooling), 2/ linkages between intermediate and final goods producers or input sharing and 3/ knowledge spill-overs (Rosenthal and Strange 2004) [2]. In this paper we are primarily concerned with agglomeration economies that arise from labor-market interactions or matching, sharing Bertaud's (2014) view that cities can primarily be seen as labor markets.

The analysis presented in this paper shows that in Nairobi County, Kenya, employment accessibility tends to be limited for a large share of the population that cannot afford to purchase cars. This situation is problematic both for productivity and for livability. On the productive side, it limits the effective size of the labor markets, thereby preventing workforce/employer sorting which hampers the

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[1] The authors are grateful to Sarah Elizabeth Antos for performing the network analysis which provided the automobile transport times matrix and to Annie Bidgood for GIS assistance. Joel Hamann ensured the processing of the matatu GTFS data through a Dijkstra algorithm that he also coded. Dean Cira and Sheila Kamunyori's guidance as well as efforts to put us in contact with counterparts in Nairobi and locate datasets are highly appreciated. The authors would also like to thank Nancy Lozano Gracia, Adrien Vogt-Schilb, Gunnar Eskeland, Vernon Henderson, Roger Gorham, Tony Venables, Paul Collier, Daniel Rodriguez, Marianne Fay and Stephane Hallegatte for comments on this work and crucial suggestions.

[2] A more comprehensive list differentiating between up to 12 types of economies of scale can be found in the 2009 World Development Report (World Bank 2009, p 128).

potential for agglomeration economies (Duranton and Puga 2004). Empirical evidence indicates that accessibility, measured as the number of opportunities an individual can access within a given amount of time, matters for productivity in cities. Prud'homme and Lee (1999) demonstrate that the elasticity of productivity to the share of jobs accessible within 30 minutes for the average worker in 23 French cities is 0.15. From an employer's point of view, Cervero (2001) shows that in the San Francisco Bay area there is weaker yet positive evidence that labor-marketshed[3] positively influences worker productivity levels. Melo et al. (2013) show for a sample of US cities that increasing accessibility to jobs results in increased productivity as measured by real wages. The authors report that a doubling of the number of jobs accessible per worker within a 20-minute thresholds results in an average increase in real wages of 6.5%. Venables (2015) identifies that commuting costs and thus average accessibility matters in urban settings. In order to attract skilled workers, firms must compensate for their travel costs by offering higher wages. While this will benefit households, it can prevent firms from reaping productivity gains and entering international markets because the average wage needed to compensate workers is higher than competitive international standards.

From the perspective of households, accessibility constraints in developing country cities may be manageable in the short-run, as long as local employment within low-wage, non-tradeable (and often informal) service sector occupations dominates; but as the nature of employment shifts from non-tradable services to manufacturing and tradable services, and from informal to formal, requiring higher firm density, the demands for metropolitan-wide accessibility can be expected to increase. Indeed, there are indications that in order to remain within reasonable commuting times of their jobs, households are ready to compromise on living conditions. In Nairobi, most residents of informal settlements have jobs and comparatively high levels of education relative to those living in formal housing, yet their living conditions remain basic (Gulyani, Talukdar, and Jack 2010). This situation probably reflects a premium already placed on accessibility. The Spatial Mismatch Hypothesis literature (Kain 1968), although primarily focusing on Black minorities in the US, also links labor market outcomes to measures of job accessibility. There is evidence that physical segregation of unskilled workers away from job opportunities leads to high commuting and job search costs which can partially explain higher unemployment rates and lower average wages[4].

From a research and policy design perspective it is important to understand whether and how to increase metro-wide accessibility and reduce commuting costs to enable labor market pooling, one of the main sources of agglomeration economies. A large and growing body of literature on "excess commuting" is strongly related to the topic of accessibility and provides insights on how to reduce commuting distances within cities. Excess commuting literature (Hamilton and Röell 1982; White 1988; Small and Song 1992) is primarily concerned with documenting the 'jobs – housing balance' and measuring how much commuting is "wasteful" or in excess of a theoretical minimum (the minimum commute indicator). The definition of excess commuting has triggered a number of contributions in particular aimed at i) understanding the reasons for the existence and magnitude of excess commuting and ii) understanding how to craft land use and transport policies to reduce both the level of the minimum commute and the associated excess commuting (Ma and Banister 2006). However, the excess commuting literature ignores the benefits of large labor markets, which by pooling large

[3] Number of workers that can access work within a defined peak period ranging from 30 to 60 minutes.
[4] see Gobillon et al. (2007) for a detailed review of theoretical explanations and empirical evidence of spatial mismatch.

numbers of workers and job opportunities, allows for sorting and matching between employers and employees[5].

For these reasons, in this paper, we focus on metrics that capture accessibility to all employment opportunities in Nairobi as in Peralta Quiróz and Mehndiratta (2015). The purpose of the study is first to provide a diagnostic of the current situation in terms of access to jobs in Nairobi but also to initiate a discussion on ways in which residents' accessibility can be improved. There are two main ways of enhancing accessibility: (a) build more or better transportation infrastructure, (b) help land uses evolve and adjust so as to allow for smooth connections between residential areas and opportunities. While the first possibility has triggered both a vast amount of literature and many investment projects, the second has received less attention. Transport projects are often necessary to 'de-crowd' cities, but improving the coordination of land uses throughout the urban area can probably achieve some of this goal without the extra costs of financing transport projects. There are typically two ways of changing land use patterns. The first one is to change the residential building stock for example by investing in more floor space in close proximity to opportunities or to transit stations. Advocates of compact city or Transit Oriented Development have focused on these options. The second is to consider the current building stock as fixed and to spatially allocate this capital so as to improve overall accessibility to opportunities. In this paper we investigate the second option and whether accessibility can be enhanced without additional investments. Developing economies are capital constrained so there is value in looking at whether or not it is possible to increase accessibility without additional financing. The assessment is based on the simulation of counterfactual scenarios of the location of jobs and households throughout the city without new investments in housing or transport infrastructure.

We derive a number of results from our analysis. The main result is that modifications to the spatial layout of Nairobi can increase the share of overall opportunities which can be accessed within a given time-frame. When commuters travel by foot or using the minibus network, the share of accessible jobs within an hour doubles from 11% to 21% and from 20% to 42% respectively. This result is important because it demonstrates that careful land use planning and zoning which is coordinated with transport infrastructure can lead to more integrated and efficient labor markets without large costs. Secondly, our results show that accessibility to employment is already a crucial determinant of the spatial layout of Nairobi, with people and employers choosing their locations so as to reduce commuting times and costs. Finally, we find that promoting equity in the access to jobs will result in mixed land use patterns and more even job-housing balance. Small labor markets, matching employment supply and demand locally, will however emerge at the expense of average aggregate accessibility and a fully integrated labor market which is conducive to the manifestation of agglomeration economies.

The paper is structured as follows: Section 2 provides background information about the current urban form in Nairobi County and the mobility of its residents. Section 3 presents the data sources used to investigate accessibility patterns, the distribution of residents and jobs as well as transport costs proxied by transport times for three transport modes: cars, matatus and pedestrians. Section 4 presents the results of the accessibility analysis for Nairobi as it is today. In particular it provides graphic evidence that accessibility is uneven geographically but also depending on whether residents have access to cars. Section 5 then introduces the main innovation of the paper which is to investigate

[5] Although some authors (Niedzielski 2006; O Kelly and Lee 2005) have paid attention to worker and job characteristics so that the matching pattern yielded by solving the transportation problem is more realistic.

accessibility measures under alternate and counterfactual land use patterns. We find that land-use changes can enhance aggregate accessibility in Nairobi and promote a unified labor market even in the absence of transport and building investments. Section 6 concludes. The Appendix discusses methodological and data choices and limitations.

2 Context: Urban form and mobility

Nairobi County is rapidly growing: Its population grew by one million people over the last decade reaching 3.1 million people in 2009[6] and was home to approximately 3.2 million people in 2012[7]. While residential development is spread out, featuring clusters of high density pockets throughout the city, Nairobi's employment arrangement follows a highly monocentric pattern. Land use areas which are likely to host most formal jobs, such as industrial, commercial and public facilities remain highly concentrated in the urban core, with only limited activity occurring in other emerging centers. New road and highway infrastructure, higher land prices, increased rates of car ownership, and other factors appear to be fueling a discontinuous or "leapfrog" outward growth in peri-urban settlements and along major road corridors.

Small, privately-owned, and artisanally operated buses and vans, known locally as matatus, form the backbone of public mass transportation services in the Nairobi metropolitan region. Matatus and walking dominate the mode share. Eighty-three percent of all trips include walking as the major or secondary mode of travel. Forty-one percent of all trips are walking only, 42 percent involve other modes, mainly matatus (63 percent) and buses (21 percent). Only 17 percent of all trips are made without walking, among which, more than half (54 percent) are completed by passenger cars and 13 percent are made by motorcycle (JICA 2013). Compared to other large cities in Africa, Nairobi has the largest share of walking trips despite rising and relatively high motorization rates compared to other major African cities (JICA 2006; JICA 2014; Kumar and Barrett 2008).

The overall average travel time per trip in Nairobi is 47 minutes, but differs when compared by gender, age, personal income level, mode, and trip purpose. Higher earners generally make longer trips (by time), while average travel times for motorized modes hover between 54 and 60 minutes per trip (excluding motorcycles, which average 38 minutes per trip).

Traffic congestion is a growing problem in Nairobi, resulting from rapidly increasing population and the crowding of motorized traffic onto a limited street network. Indeed, IBM ranked Nairobi fourth highest in its "commute pain" survey in 2011, indicating that the city hosted one of the world's longest traffic jams, 2.1 hours. According to the World Bank's Kenya Urbanization Review (World Bank 2016), increasing average commuting speeds from the average recorded 13.5kph to 20 kph would save $54.1 million USD per year and decrease time spent traveling by 30 percent. Increasing average travel speeds to 30 kph would save $93.4 million USD per year and decrease time spent traveling by 54 percent.

[6] as measured by the Kenyan Census.

[7] according to landscan data (Bright, Rose, and Urban 2013).

3 Accessibility in Nairobi: Methodology

In order to assess accessibility in Nairobi we need information about 1/ where people live, 2/ the transport networks and 3/ where opportunities (jobs, schools etc…) are located.

3.1 Population distribution

Population densities at a global scale are available through the Landscan 2012 dataset in raster format (Bright, Rose, and Urban 2013). We used 2012 data and extracted population densities for 1square kilometer cells for the Nairobi County region. We used the sub-locations administrative boundaries to extract the data.

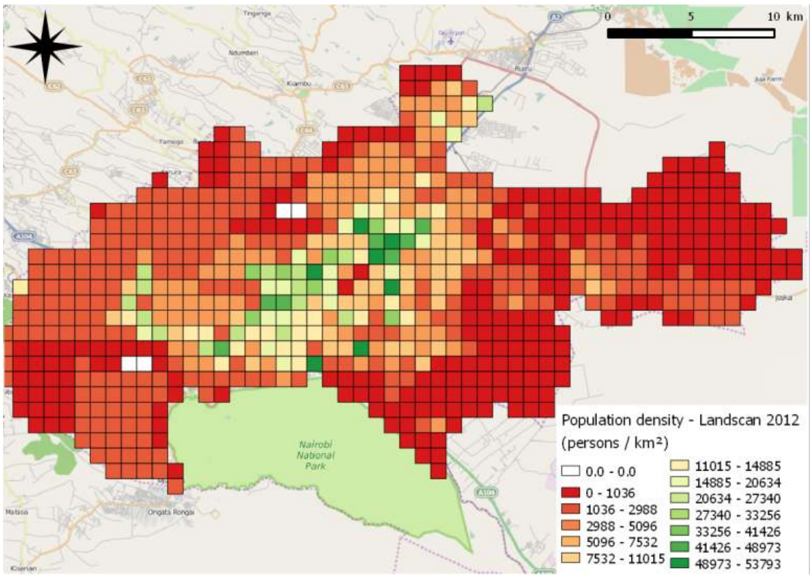


Figure 1: Population densities as provided by Landscan database for 2012. This worldwide raster map is intersected with the administrative boundaries of Nairobi.

3.2 Transportation costs

The model accounts for various transportation modes: walking, driving and using the informal minibus (matatus) network. As a first step we proxied the transport costs of reaching any given location in Nairobi through transport times (see discussion of data limitations in the Appendix). Data for the 'matatu network' are available online in GTFS (General Transit Feed Specification) format[8]. These data were compiled by the DigitalMatatus consortium comprising University of Nairobi, Columbia University, MIT and Groupshot (Williams et al. 2015; Klopp et al. 2015). The GTFS data were processed using a Dijkstra algorithm[9] which provided us with times to reach any matatu station from any other in the urban area. Travel times to reach the closest matatu station were computed based on straight line distance or 'as the crow flies' from the center of each grid cell shown in Figure 1.

[8] GTFS data or General Transit Feed Specification is a common format for public transportation schedules and associated geographic information. It is a collection of multiple csv files which describe transit routes, stops (including geographic coordinates), travel times between stops and a number of other public transit properties.

[9] Dijkstra's algorithm is an algorithm for finding the shortest path between two nodes in a graph which may represent for example road networks.

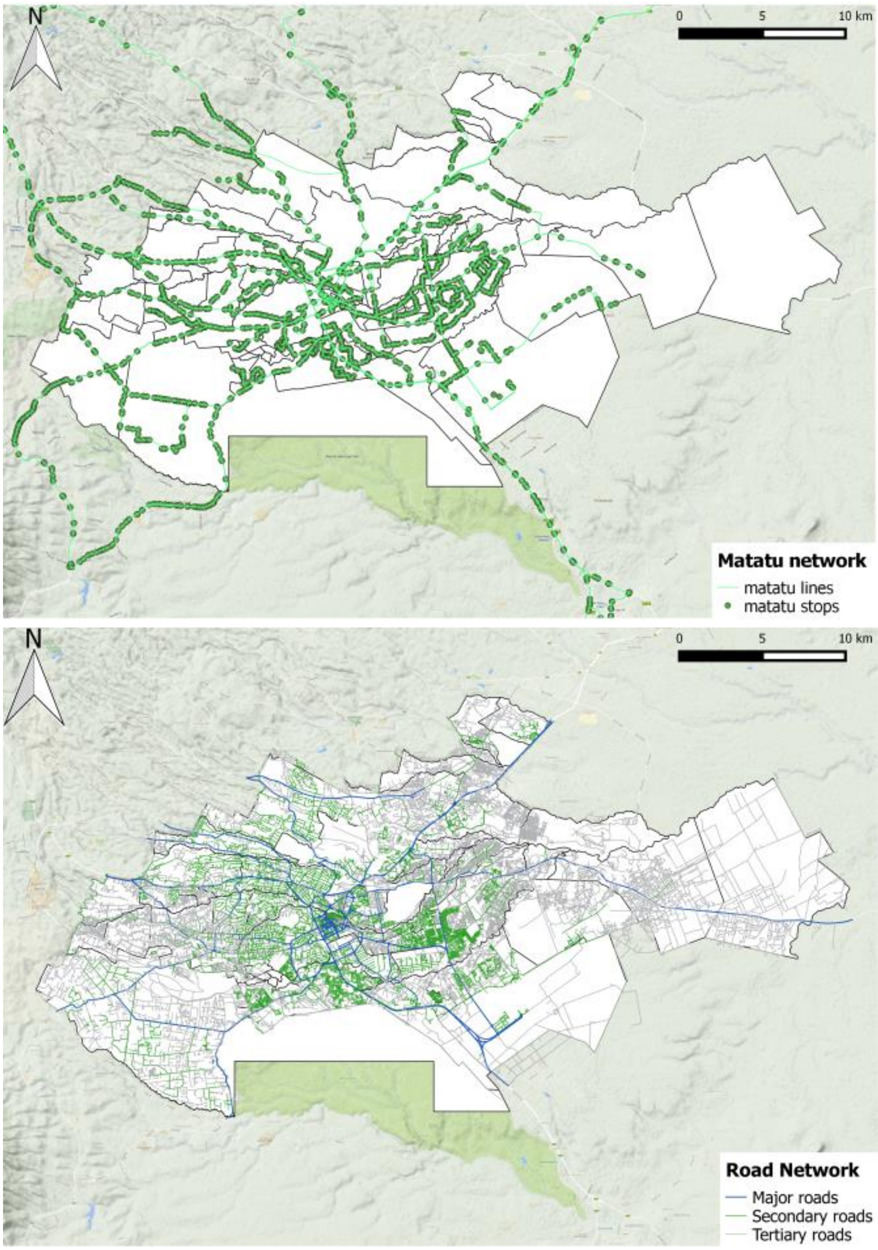


Figure 2: Matatu network and stops (top) and road network and hierarchy (bottom)

The transport times for roads were computed through a network analysis using the layers provided by OpenStreetMap (OSM). Three different travel speeds were assumed based on the road category. First order assumptions were made that 1st class roads would carry vehicles traveling at 60km/h, 2nd class roads at 40km/h and finally 3rd class roads at 30km/h. With congestion we have travel speeds which are much lower: 30, 16 and 12km/h. Finally, walking times were calculated based on bee-line distances assuming an average walking speed of 4 km/h.

3.3 Accounting for opportunities

No data are available to the best of our knowledge on the number of jobs and location within Nairobi (see Appendix for a discussion). As a proxy we used the number of sq meters of land used for commercial, industrial, mixed residential and commercial or mixed industrial and residential to proxy for the location and amount of opportunities in each cell of the grid. We computed these data using the land use map for 2010 produced by Columbia University (Columbia University, CSUD 2010).

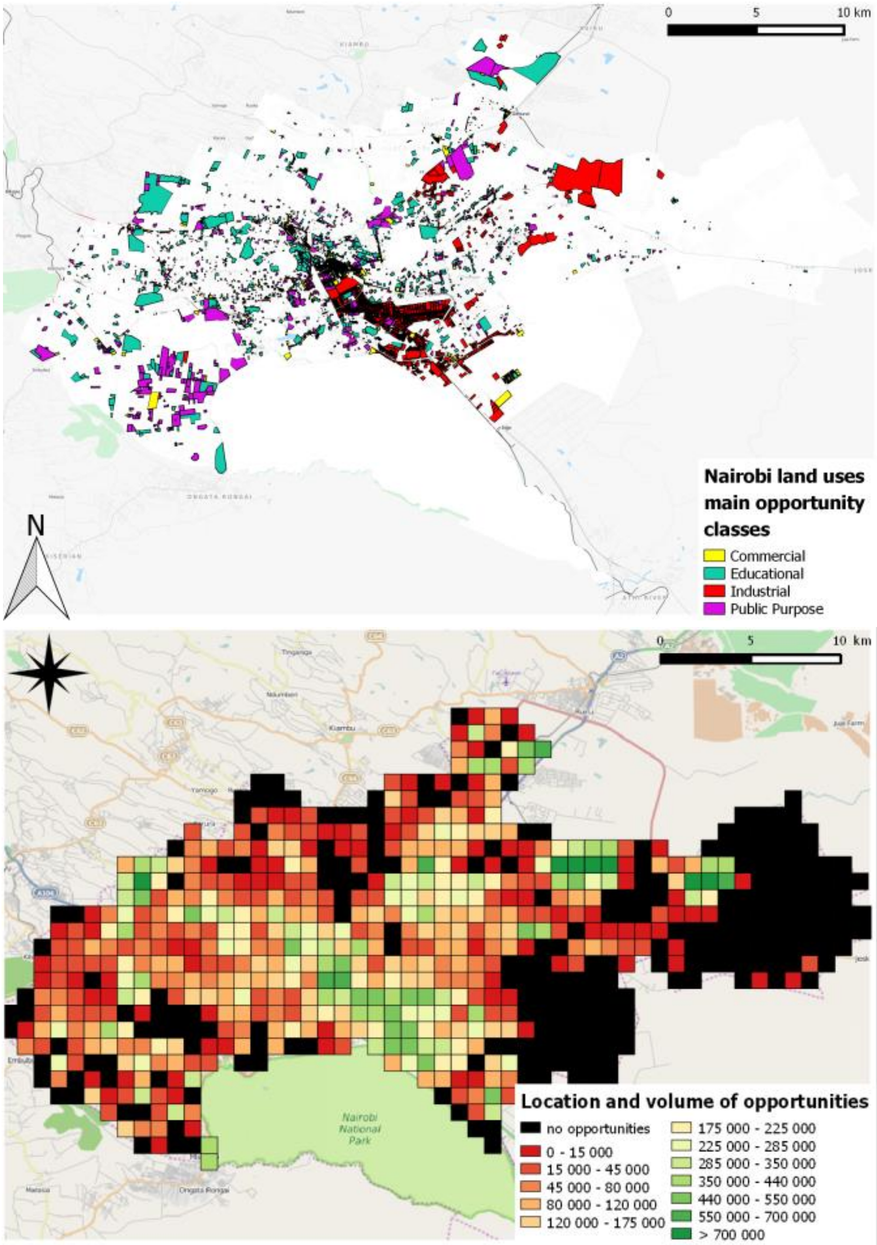


Figure 3: Top panel/ Official land-use map used to extract 'opportunities' level and location. Are considered as opportunities any sq meter of land used for commercial, industrial, mixed commercial-industrial and mixed residential-commercial. Bottom panel/ Extraction from the land use map to the left. This map represents the 'opportunities' in terms of sq meters of land allocated to the purposes listed above.

4 Accessibility in Nairobi

There are a number of ways to characterize accessibility in an urban area. As a first step we will focus on the share of total opportunities that can be accessed in Nairobi in a given time-frame using various transport modes at a grid cell level. We use grid cells of approximately one square kilometer as the unit of analysis instead of administrative boundaries. This has two main advantages: first it is convenient as this matches the resolution of the landscan population dataset, second it provides finer grain information on accessibility levels in the urban area. The alternative would be to use the lowest level of administrative boundaries in Kenya, sub-locations, but these remain large. There are 112 sub-locations in the area of analysis while our method represents 731 grid cells.

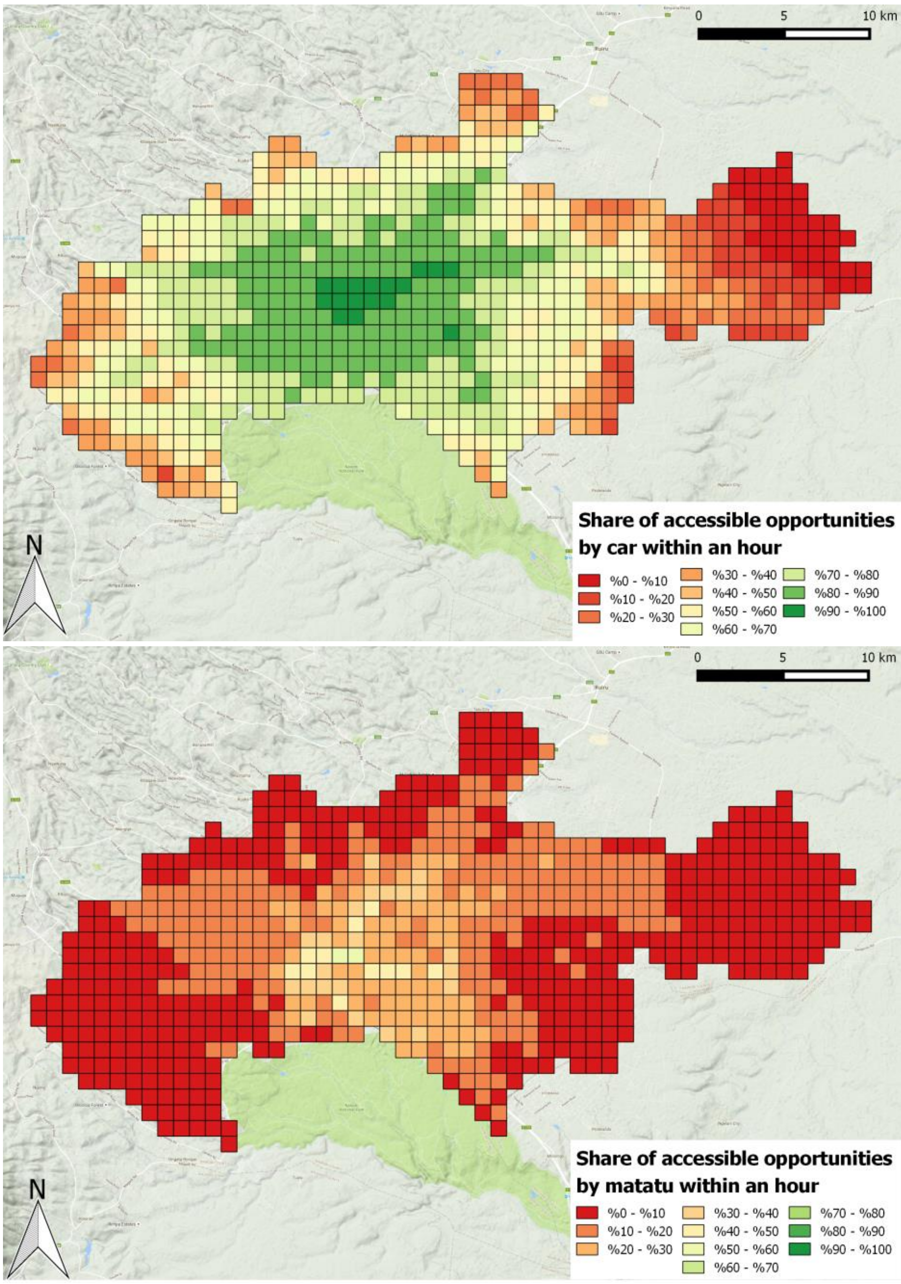


Figure 4: Share of accessible opportunities within one hour of traveling for cars on the top panel and matatus on the bottom panel.

On average, car users within Nairobi can access respectively 31%, 58% and 77% of total opportunities within a 30, 45 and 60 minutes timeframe in congested conditions. For "matatu" users the situation is drastically different as on average they can only access 4%, 10% and 20% within a 30, 45 and 60 minutes timeframe. These accessibility figures to formal employment opportunities for public transport are low. By comparison, in the metropolitan area of Buenos Aires, accessibility figures using public transportation are 7%, 18% and 34% for the same time thresholds (Peralta Quiros 2015). Preliminary analysis of these figures tends to indicate that Nairobi is a city which is built for cars. But car use represents only 13% of trips for all purposes while matatus and walking are massively favored with respectively 28% and 41% of trip mode shares for all purposes (JICA 2013; JICA 2014). In parallel, although private car ownership rates are higher in Nairobi than in other African cities, they still remain low at around 84 cars per 1000 persons (Kumar and Barrett 2008; NORC at the University of Chicago

2013). This seems to indicate that most households in Nairobi will benefit from opportunity accessibilities closer to the lower levels shown on the bottom panel of Figure 4.

Share of Nairobi's opportunities accessible within a given time-frame depending on the transport mode used				
	Cars		Matatus + walking	Walking only
	Uncongested	Congested	Congested	Uncongested/Congested
< 30 mins	57%	31%	4%	3%
< 45 mins	85%	58%	10%	7%
< 60 mins	96%	77%	20%	11%

Table 1 : Average share of Nairobi's opportunities accessible within a given time-frame depending on the transport mode used

Another important feature is the spatial pattern of accessibilities throughout the urban area of Nairobi. It is interesting to characterize whether accessibilities levels are evenly distributed or not. One way to capture how equally distributed accessibilities are in Nairobi is to produce Lorenz curves and calculate the attached GINI coefficient. While this measure has mostly been used to characterize income distribution patterns it can be of use to look at accessibility spatial disparities.

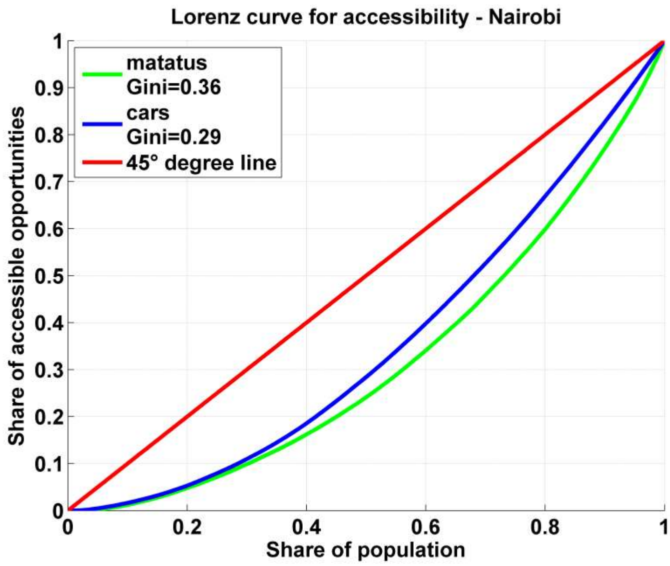


Figure 5 : Lorenz curves showing spatial inequality in accessibility to opportunities throughout the urban area of Nairobi using cars (blue curve) and matatus (green curve)

It can be seen from Figure 5 that depending on the transport mode used, accessibility to opportunities within a given time frame (here 30 minutes) is more or less equally distributed throughout the urban area of Nairobi. In particular, it can be seen that accessibility to opportunities using matatus as a commuting mode is more spatially unequal than if households used cars. Indeed the Gini coefficients associated to both these modes are 0.36 vs 0.29. However, as was highlighted previously residents of Nairobi rely much more on walking and matatus than they do on cars. As a consequence and because of the inherently localized nature of informal collective transport, accessibilities to opportunities in Nairobi are de factor unevenly distributed.

5 Assessing alternative spatial layouts in relationship to accessibility

The indicators computed above give us some information about accessibilities using either cars, matatus or walking for the current spatial layout of Nairobi. They however do not provide information as to the more or less desirable spatial distribution patterns of jobs and households. The question that arises is then: "is it possible to achieve higher accessibility levels by changing land use patterns for a given amount of invested capital in transport infrastructure and commercial and residential stock?". To illustrate our questioning we show below a very schematic situation before going back to Nairobi.

5.1 A schematic situation

Imagine a city that comprises 49 distinct locations, each of them of 1km². Costs of traveling are solely based on distance (no time costs at this stage) and the unit cost is typically 1. There are 9 opportunity centers in this city (business centers, malls…) – represented by white cells below – which the residents of the city can access. Given this grid it is possible to imagine many possible spatial layouts. Let us focus on three specific spatial layouts which match – albeit in a simplified manner – stylized urban forms that can be encountered in the literature: the mono-centric city, the decentralized city and the urban village city.

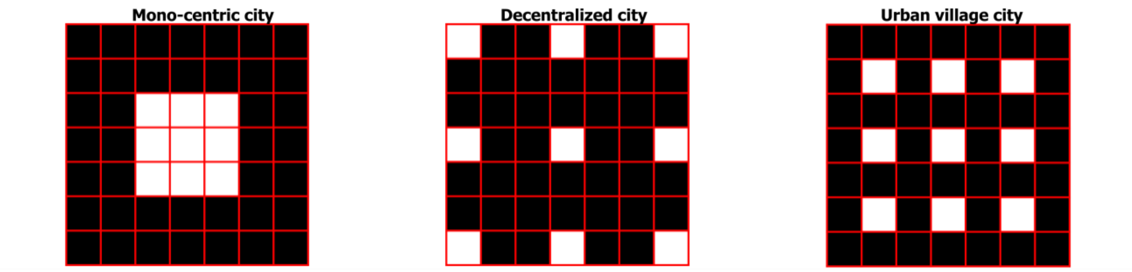


Figure 6: Three stylized cities that differ by their spatial layout. They share the same number of residents, the same number of opportunity centers and the same stock of structures (buildings). White cells are 'opportunity locations' while households reside in all cells of the urban area.

Given the spatial layout of a city, it is possible to calculate a measure of each resident's accessibility to these opportunities and then to compute an average accessibility metric. The following maps show individual residents' accessibilities.

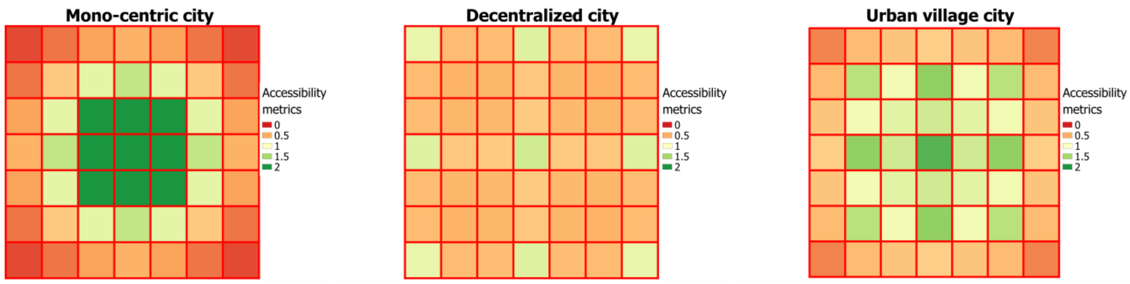


Figure 7: Accessibility measures for the residents of the three stylized cities

It should then be possible to rank these cities in terms of aggregate accessibility. We do not perform this calculation here as the purpose of this section is purely illustrative and any results that we would achieve would be highly dependent on the underlying assumptions. The aim would however be to achieve a ranking of the stylized cities in terms of aggregate accessibility as imagined in Table 2.

Ranking of these stylized cities in terms of accessibility		
Mono-centric city	**Decentralized city**	**Urban village city**
1?, 2?, 3?	1?, 2?, 3?	1?, 2?, 3?

Table 2 : Which stylized city performs better in generating accessibility?

5.2 How does Nairobi perform?

To move away from the stylized cities presented above but still with the idea of evaluating whether alternative spatial layouts could enhance accessibility we conduct a series of tests. Keeping constant the transportation network and the overall building stock[10], we randomly re-shuffle all opportunities and people throughout the urban area and re-compute for each outcome indicators of how the city performs in connecting households with opportunities. Proceeding in this manner, 10,000 different distributions are produced.

[10] This assumption is tantamount to not allowing for building stock densification. As a result, the urban footprint of Nairobi County is not allowed to shrink. Hence, the exercise conducted here does not investigate the accessibility outcome associated with smaller urban areas and overall densification. It is solely based on the reallocation of jobs, households and building infrastructure for a given amount of invested capital in building and firm structure and in the transportation network.

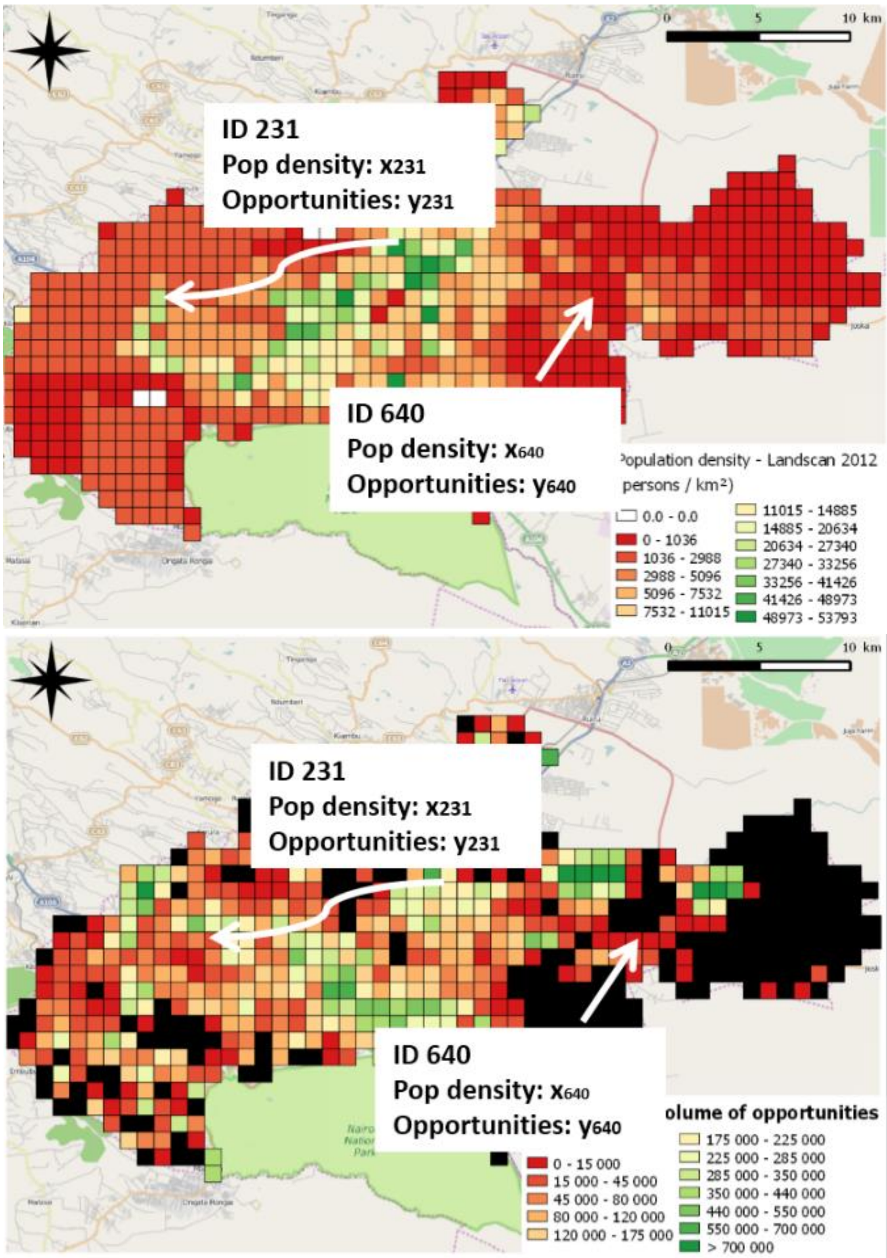


Figure 8 : Illustration of the exercise conducted for this study. All pixels are characterized by a population density and a number of opportunities (commercial, educational and industrial floor space). 10,000 random permutation of these grid cells are performed, resulting in 10,000 counterfactual spatial layouts, to evaluate whether accessibility can be enhanced through changing the land use patterns, i.e. the location of population and opportunities.

The results of the simulations described above indicate that Nairobi in its current spatial layout performs better than any of the 10,000 counterfactual scenarios in providing access to opportunities to its residents. It can be seen from Figure 9 that the aggregate accessibility for the current spatial layout of Nairobi – around 77% of all formal economic opportunities can be reached within an hour on average when all transport modes are available – represented as a green dot on the bottom right side of the figure is an outlier. Most of the random counterfactual scenarios achieve aggregate accessibility figures that are considerably lower, mostly between 45 to 55%, with frequency spikes shown in Figure 9 around 50%.

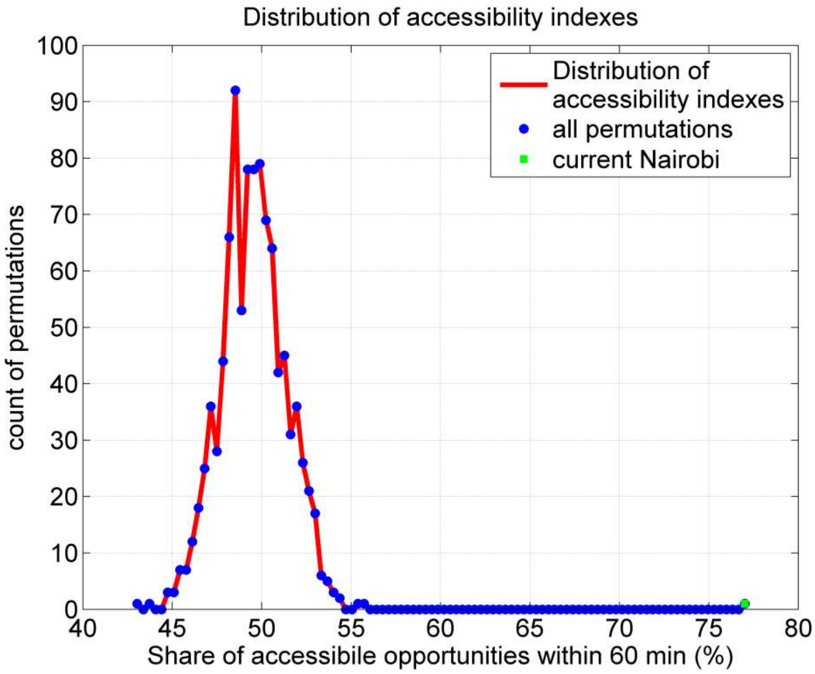


Figure 9 : Distribution of the accessibility indexes in all counterfactual scenarios (blue dots) and in current Nairobi (green dot).

The conclusion from this exercise is that businesses and households, when deciding where to locate within Nairobi, take into account the existing transport network and the location of opportunities. This is consistent with the theoretical basis of the classic urban economics' framework (Alonso 1964; Brueckner 1987; Fujita 1989; Wheaton 1974). The spatial layout of Nairobi reflects a complex self-organization process whereby households seek to locate within reasonable distances of jobs and public amenities, maximizing accessibility within the constrained environment of sub-optimal transport investments, and governance challenges related to land-use planning and development control and enforcement. As a consequence, the current spatial layout of Nairobi, which is a result of millions of individual decisions, is a reasonable outcome in terms of overall access to total opportunities given the constraints on capital investments in transport infrastructure and residential structures in the sense that it outperforms any random permutation which is computed.

5.3 Aggregate accessibility-improving spatial layouts

Comparing the current spatial layout of Nairobi to a large number of random permutations demonstrates that it performs better than random in terms of aggregate accessibility outcomes. However, it is not possible to infer from this exercise that the current spatial layout of Nairobi is "optimal" in providing accessibility to economic opportunities to its residents or, less ambitiously, that it cannot be enhanced. The 10,000 random permutations performed above indeed only represent a very small share of the 731![11] potential permutations that could be produced.

[11] Nairobi County is divided into 731 km² grid cells. The number of permutations or arrangements of these grid cells is equal to 731! (or factorial 731) which is a huge number – in fact Matlab returns "Inf" when queried about it. To get a sense of the numbers 100! is close to $9*10^{157}$, which makes any systematic exploration of all permutations computationally impossible.

5.3.1 Searching for accessibility improving spatial layouts: Methodology

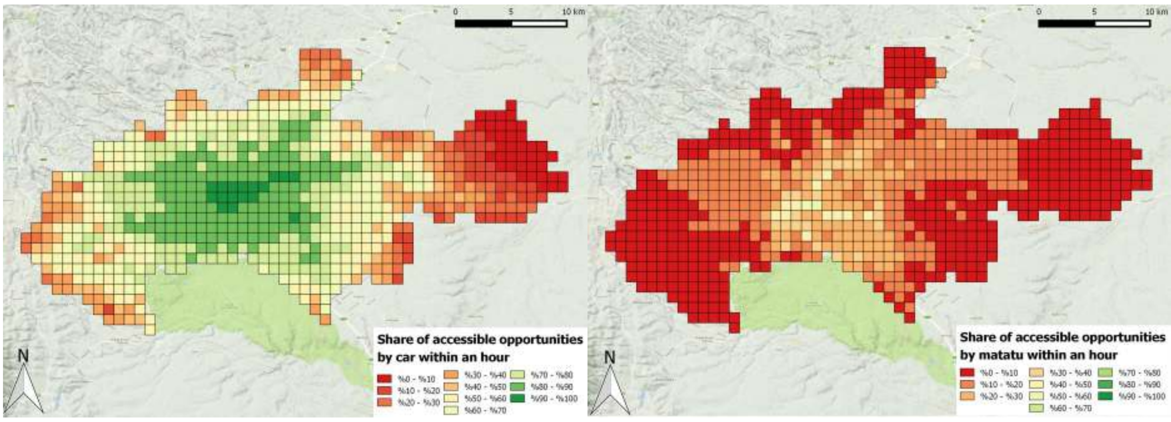
Another way of exploring the potential permutations is required. This second exercise aims to assess the most efficient spatial coordination of land uses, keeping, as previously, the transportation network, population, number of jobs and building stock constant. The methodology relies on a hill-climbing optimization procedure which only switches grid cells 2-by-2 starting from the current spatial layout of Nairobi (instead of permuting all grid cells at once as in the previous exercise). When this initial permutation increases overall accessibility, the new spatial layout becomes the baseline and a new iteration is performed. If this permutation is not successful, the permutation is discarded and another one is tested. This process is repeated a number of times to try to converge to an optimum. A hill climbing procedure is conducted for each mode and for the combination of them and also for each time threshold. Therefore, an aggregate accessibility spatial layout is found for example for the special case where only matatus and walking are available as a transport mode and where the time threshold for calculating available opportunities is 45 minutes. This spatial layout will differ from the aggregate accessibility improving land use pattern found through hill climbing when the only available transport option is cars and the threshold is 45 minutes again. It will also differ from the spatial layout where the only transport option is matatus and walking but where the time threshold is 60 minutes. In total, twelve aggregate accessibility improving spatial layouts are computed: for all modes (walking, walking and matatus, cars, combination of any mode) and for all time thresholds (30, 45 and 60 minutes).

5.3.2 Accessibility gains and land use profiles

Performing 100,000 iterations using this hill climbing procedure it is shown that overall accessibility can increase substantially in Nairobi. Results reported in Table 3 indicate that alternative land use patterns can increase overall accessibility by 15% for cars (from 77% to 92.5% of accessible opportunities) and can even double the share of formal economic opportunities which can be reached within an hour using matatus (from 20% to 42%) or traveling by foot (from 11% to 21%). This is the central result of the paper.

These conclusions indicate that even if Nairobi's spatial layout performance is tolerable in connecting people to opportunities as demonstrated in the first exercise, there is still considerable room to increase accessibility through better land use coordination. Achieving such outcomes, however, will require very strong governance structures, enforcement policies and planning capabilities.

a/ Initial spatial layout



b/ With aggregate accessibility improving spatial layouts

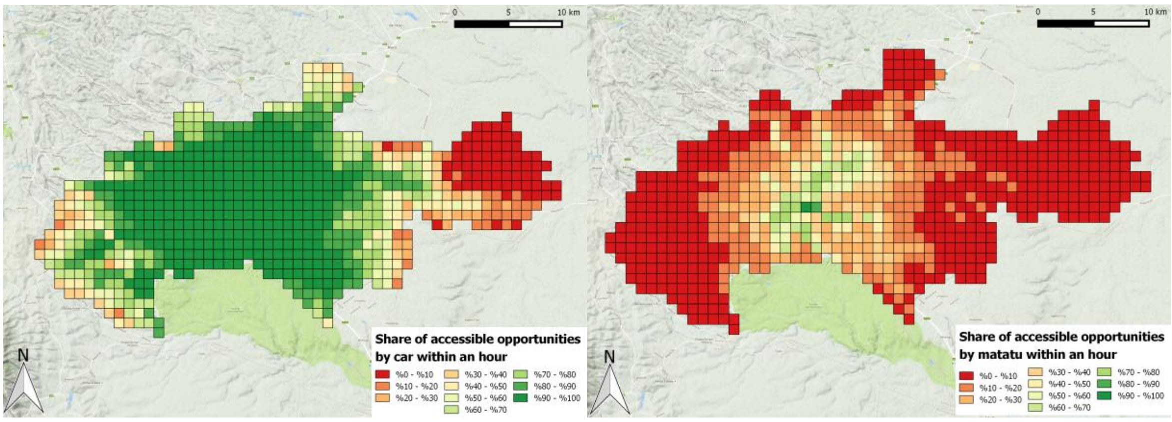


Figure 10 : Comparing accessibilities to formal economic opportunities in the initial and aggregate accessibility improving spatial layouts for cars (on the left) and matatu (on the right) transport within an hour

Figure 10 shows the shares of accessible opportunities at the pixel level in the initial and improved spatial layouts. As in Figure 4, the higher potential accessibilities with cars compared to matatus appear clearly. The increase in aggregate accessible opportunities is however larger with matatus when accounting for population changes as seen in Table 3:

Share of Nairobi's opportunities accessible within a given time-frame depending on the transport mode used in the current and alternative spatial layouts of Nairobi						
	Cars		Matatus + walking		Walking only	
	Initial	**Alternative**	**Initial**	**Alternative**	**Initial**	**Alternative**
< 30 mins	31%	55%	4%	7%	3%	5%
< 45 mins	58%	83%	10%	21%	7%	13%
< 60 mins	77%	96%	20%	42%	11%	21%

Table 3 : Share of Nairobi's opportunities accessible within a given time-frame depending on the transport mode used in the current and alternative spatial layouts of Nairobi

Looking at the spatial distribution of households and formal economic opportunities in the aggregate accessibility improving scenarios for cars (b/) and matatus (c/) in Figure 11 and comparing to the initial spatial layout (a/) is telling as how to increase overall accessibility[12]. In both cases higher aggregate

[12] Because the hill climbing procedure is exploratory in nature, it is not possible to claim that the aggregate improving spatial outcomes are optimal. It is however the case that, as the 100,000 permutations are performed, there are progressively fewer permutations between cells that yield a better accessibility outcome, indicating that the solver is progressing towards an optimum. A corollary to this precision is that more than one spatial

accessibilities are associated with a concentration of households and economic opportunities in the vicinity of the center of Nairobi County, which is also the central connecting node of both the major roads and the matatu network – which mostly runs on major roads.

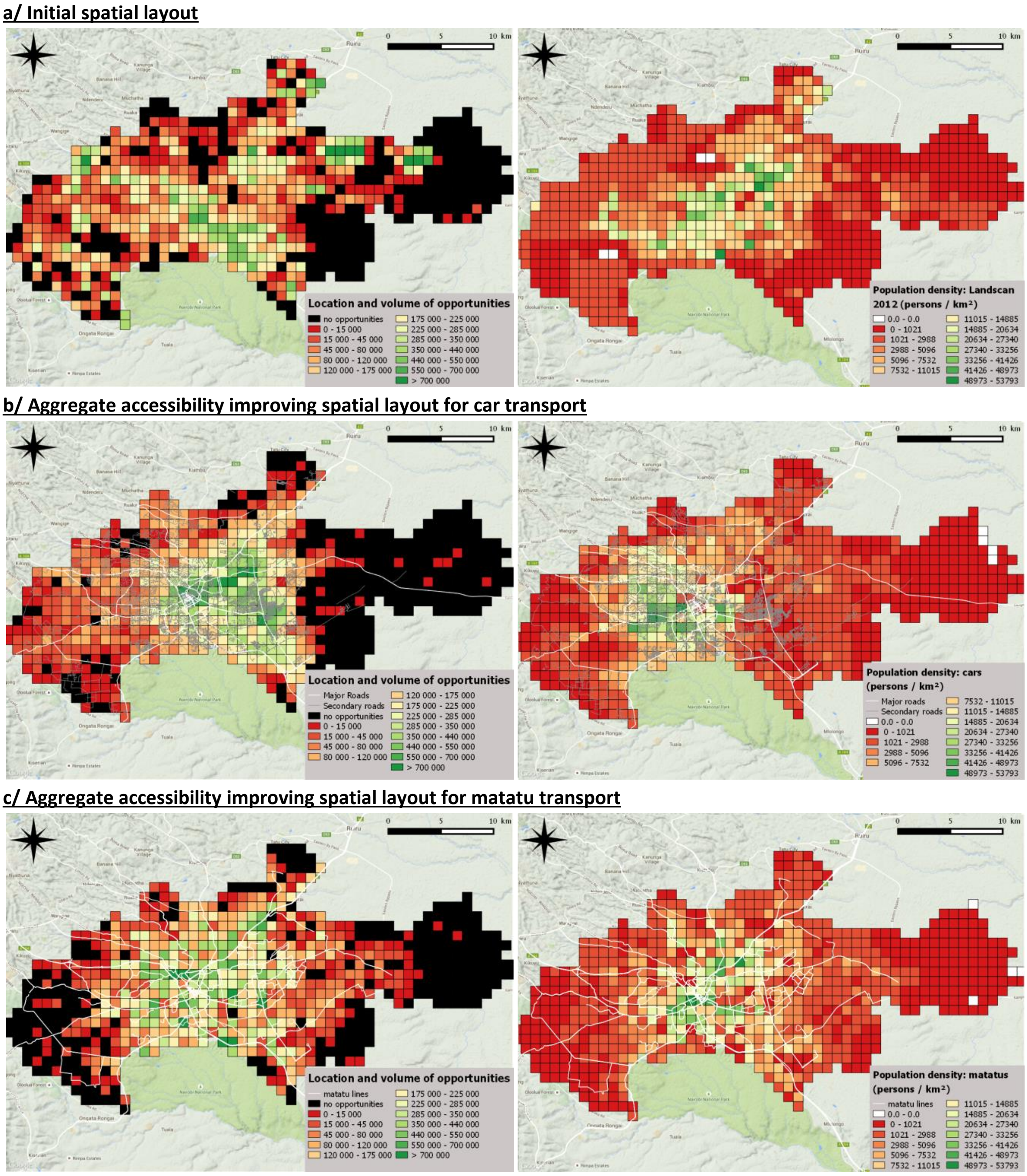


Figure 11 : Distribution of formal economic opportunities (left) and population (right) in the initial and aggregate accessibility improving spatial layouts for cars or matatu transportation.

An interesting difference between both aggregate accessibility improving spatial layouts is that the one computed for cars segregates between residential and economic uses, with the highest population densities located to the West of the CBD and the economic opportunities mostly to the East. Conversely the improved spatial distribution of population and economic opportunities for matatus is

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outcome can generate the improved aggregate accessibility outcomes displayed in this study. Numerous iterations have however shown that they all tend to resemble the ones that we display here.

much less segregated with more of a mixed land use outcome. The difference between these two outcomes can tentatively be explained by the fact that matatus only run on major roads (matatus in essence provide localized services) whereas cars can use secondary or even tertiary roads and thus can reach locations (close and more distant) easier and without relying on walking for a portion of the trip. These spatial outcomes and their differences, which we do not claim to fully explain, appear consistent with the observations and the literature concerned with urban form and travel behaviors which indicates that mixed land use patterns are better suited to a combination of collective transport and walking (Cervero 2002; Cervero and Kockelman 1997). Both accessibility improving spatial layouts tend to have highest population and formal economic opportunity densities along major roads and in close vicinity to the CBD of Nairobi. It is worth pointing out that the tendency towards central concentrations of households and economic opportunities is achieved in both cases without accounting for agglomeration economies which would tend to encourage further this phenomenon. It should equally be noted that this exercise does not account for potential increase in congestion levels as a result of modified commuter flows (see Appendix for a more detailed discussion of the implications of such a simplification). Congestion forces would conversely tend to discourage higher concentration which is linked to higher land or real estate prices and longer travel times because of increased traffic congestion.

5.3.3 Is there an efficiency vs equity tradeoff? How about losers?

The results presented above show that on average residents of Nairobi could achieve higher accessibility levels to employment opportunities with alternate spatial layouts. However, this does not address whether some people would lose from land use reorganization or whether the new land use configuration reduces inequality in the access to jobs across the urban area. In other words is there an efficiency vs equity tradeoff associated with aggregate accessibility improving spatial layouts?

Figure 12 shows the spatial inequalities in access to formal economic opportunities for residents in Nairoby County in the aggregate accessibility improved spatial outcomes for matatus and cars. For cars, the Lorenz curve is very similar to the one displayed in the current Nairobi (Figure 5) and the associated GINI coefficient remains virtually identical. For matatu users conversely, the spatial layout which maximizes their aggregate accessibility is associated with a rise in spatial inequality. The GINI coefficient increases from 0.36 to 0.40 and the Lorenz curve is more convex. This rise in inequality in access to employment opportunities using matatus is due to the fact that the land use reorganization will tend to benefit the most centrally located people more than the rest of the metropolitan population.

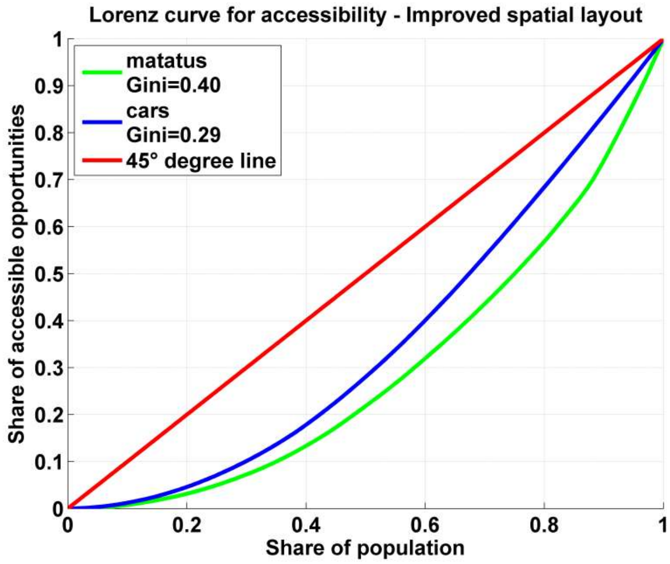


Figure 12 : Improving aggregate accessibility for matatus comes at the expense of equality in access to economic opportunities for all residents in Nairobi as the GINI coefficients increases with respect to the initial spatial layout

This situation seems to point towards a trade-off between overall efficiency associated with one unified labor market and the equality concern which aims to provide similar levels of accessibility to all residents of Nairobi. But having a more spatially unequal distribution of employment accessibility does not imply that there are losers. After all, it is possible to achieve a situation where everyone gains from a different land use pattern and yet still have increased inequality if some gain more than others. It is therefore important to understand if the alternate land use configuration which promotes higher average accessibility levels can lead people to lose access to jobs and how badly they are impacted.

As a first step, tracking how cells move within Nairobi County from the initial to the aggregate accessibility improving spatial layout, it is possible to quantify winners and losers of the spatial reorganization. Nairobi residents mostly gain in terms of aggregate accessibility from the spatial reorganization: at least 80% winners. However, there is a non-negligible share of losers which varies depending on the transportation mode used and the time threshold retained to quantify the share of accessible formal opportunities. For pedestrians and matatu riders the share of losers ranges from 16% to 20%. For car drivers/passengers the share of losers is lower, ranging from 15% for the 30 minute threshold down to 2% for the 60 minute threshold.

Average accessibility gains and losses from the spatial reorganization						
	Cars		Matatus + walking		Walking	
	Average access gain	Average access loss	Average access gain	Average access loss	Average access gain	Average access loss
<30 mins	29%	10%	5%	1%	3%	1%
<45 mins	28%	13%	14%	3%	8%	2%
<60 mins	18%	8%	28%	5%	12%	3%

Table 4: Average share of total opportunities whose access to is gained or lost in the aggregate accessibility improving spatial layout compared to the initial situation for various modes of transport and time thresholds.

The extra formal economic opportunities accessible to winners of the spatial reconfiguration are much higher than the loss of accessibility for the losers. This is very apparent for matatu riders and pedestrians as shown in Table 4. For example, the average matatu rider winner has access to 28% more opportunities within an hour’s travel than in the baseline while the loser only has access to 5% fewer economic opportunities.

There are several conclusions which can be drawn from looking at how alternative aggregate accessibility improving spatial layouts will affect Nairobians and how gains and losses are distributed. First, many more will gain than lose from the spatial reconfiguration: 80% at least. Second, there is however a non-negligible share of losers ranging from 2% to 20% with average shares for pedestrians and matatu riders between 16% and 20%. Third, the average gains in accessibility for the winners are much larger than the average losses for the losers and this is particularly true for pedestrians and matatu riders. Finally, the average accessibility losses for the losers are typically limited for pedestrians and for matatu riders: from 1% to 5% depending on the travel time threshold. So, although the concern that a spatial reconfiguration will create losers should be acknowledged and addressed to the extent possible, we argue that it should not impede the overall goal of providing many more with increased accessibilities.

5.4 Localized accessibility: Inclusive vs integrated labor markets?

In this section the aim is to investigate accessibility improving spatial configurations where the objective is no longer to promote market wide accessibility but more localized accessibility, i.e. to increase the share of people that have access to a significant share of formal economic opportunities. We carry out this exercise for two reasons. First, following up on the previous section and the discussion of winners and losers from land use reorganization, to investigate counterfactual scenarios where the focus is on labor market inclusion (even if partial) rather than on overall efficiency. We wish to understand if the spatial outcomes of these two exercises differ drastically or not. Second, because while their benefits are well documented, the exact criteria of what constitutes large and integrated labor markets is not[13].

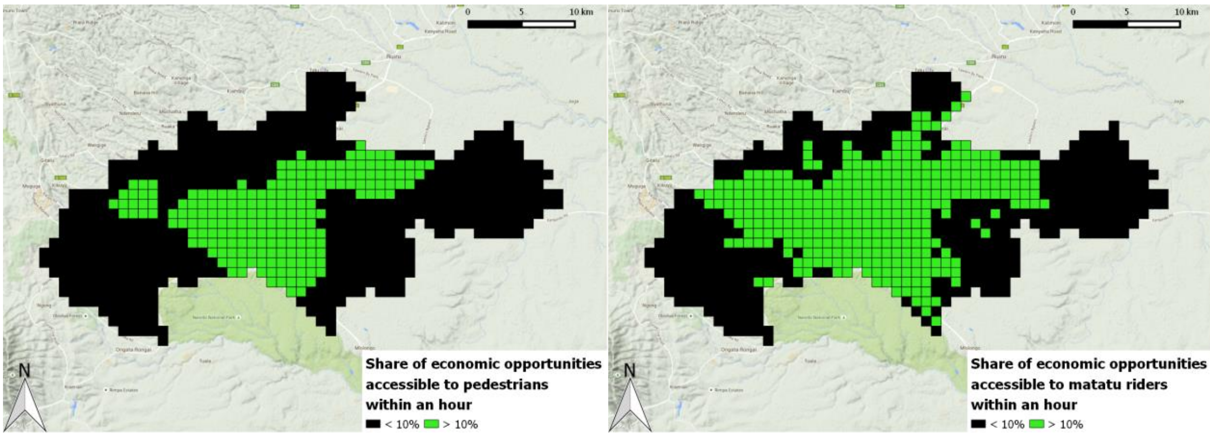
5.4.1 Without agglomeration economies

Instead of investigating the average access to jobs in Nairobi County we are interested in assessing the share of residents that have access to a “reasonable” amount of formal economic opportunities within a given time-frame and how land use patterns can affect this share. As a first step, we define the reasonable amount of economic opportunities to be 10%[14] of the total in Nairobi County. We then, as previously, use a hill climbing procedure to simulate accessibility improving spatial layouts (again keeping the housing stock and transportation network constant). We perform this analysis for all transportation modes, but will focus mainly in this section on the localized accessibility of pedestrians and matatu riders as they are the most likely to benefit from improved local accessibility as the distance they can travel in a given time-frame is much shorter than for car drivers.

[13] Angel and Blei (2015a) for example claim that what matters for productivity is not metropolitan wide potential access to jobs but to ensure that residents can access their actual job within a reasonable travel time.

[14] Other thresholds were tested (5% and 20%). The results for the 5% threshold look very similar to those of the 10% threshold. For the 20% threshold however, the urban form is closer to that of the overall accessibility increasing spatial layout.

a/ Initial local accessibility



b/ Improved local accessibility

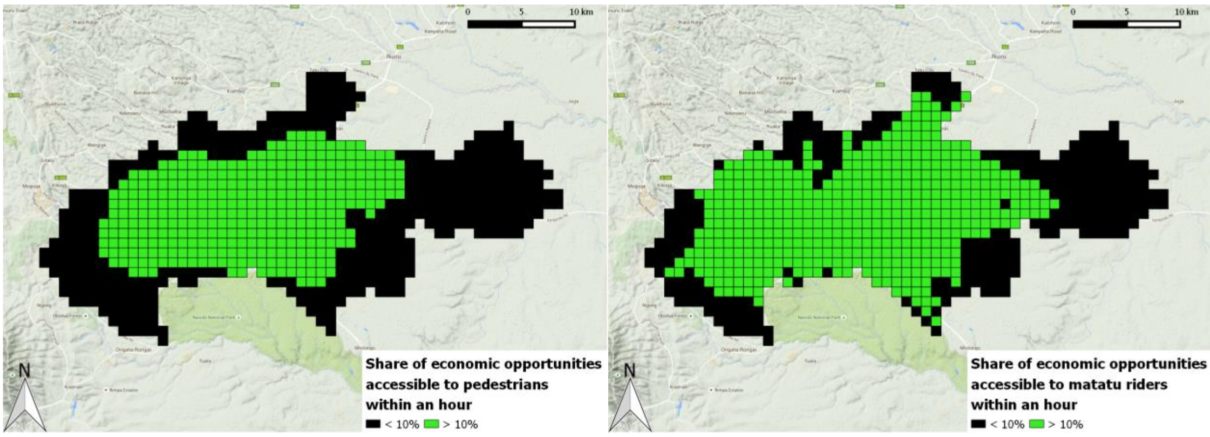
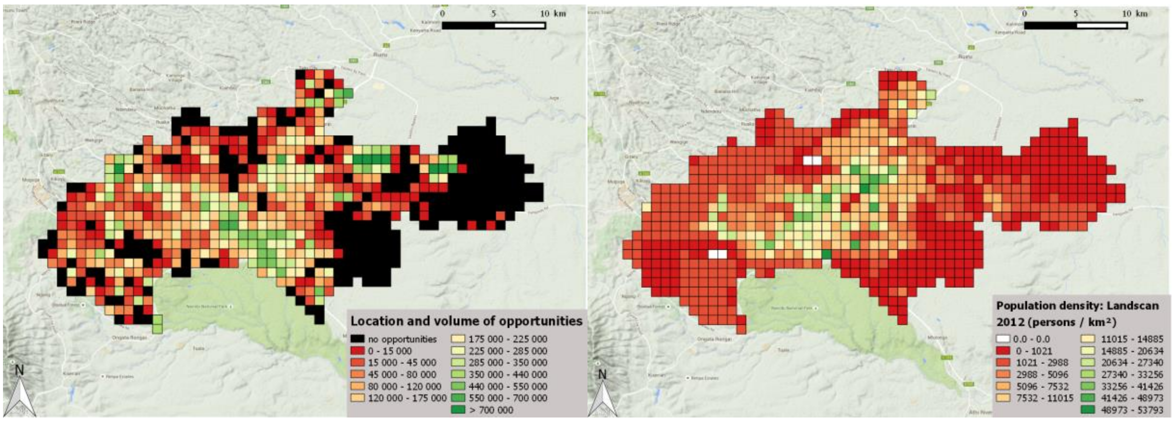


Figure 13: Comparing local accessibilities to formal economic opportunities in the initial and local accessibility improving spatial layouts for pedestrians (on the left) and matatu transport (on the right) within an hour

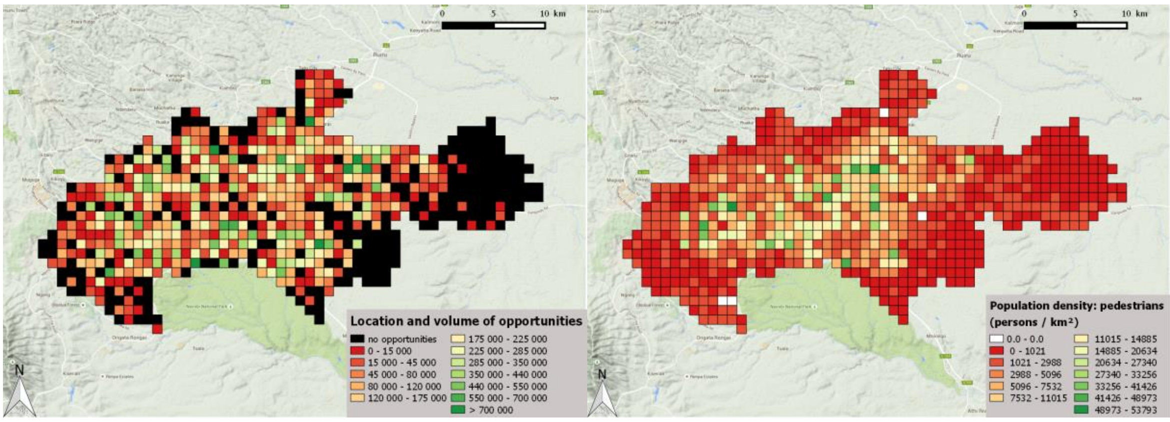
Figure 13 shows that by modifying the spatial distribution of formal economic opportunities and residents it is possible to increase the number of areas within Nairobi County where Nairobians have access to at least 10% of countywide economic opportunities within an hour. The number of cells where local accessibility is above 10% increases from 200 to 337 for pedestrians (from 27% to 46% of Nairobi County area) and from 325 to 449 for matatu riders (from 44% to 61% of Nairobi County area). Accounting for population changes, the hill climbing procedure yields spatial layouts which can increase local accessibility for pedestrians from 63% to 91% of residents with access to at least 10% of formal economic opportunities and for matatu riders from 80% to 97% within an hour[15].

[15] Shares of residents with access to at least 10% of economic opportunities evolve like follows: pedestrians: from 0%, 22%, 63% to 0%, 75%, 91% for the 30, 45 and 60 minute thresholds; matatu riders: 1%, 45%, 80% to 16%, 81%, 97% for the 30, 45 and 60 minute thresholds; for car drivers/riders: 88%, 98%, 99% to 99%, 100% and 100%.

a/ Initial spatial layout



b/ Local accessibility improving spatial layout for pedestrians



c/ Local accessibility improving spatial layout for matatu transport

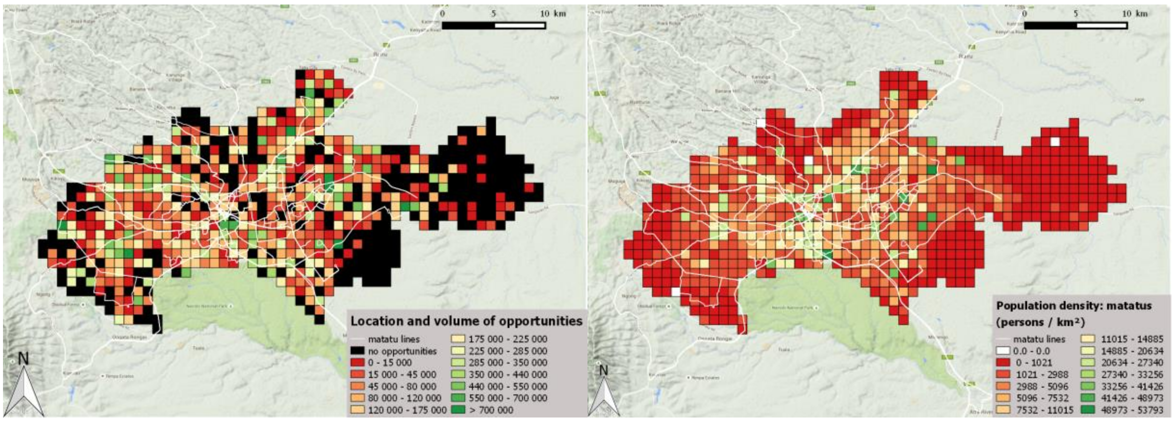


Figure 14: Distribution of formal economic opportunities (left) and population (right) in the initial and local accessibility improving spatial layouts for pedestrians or matatu transportation

It can be seen from Figure 14 that when the objective is to increase the share of residents that have access to a "reasonable" amount of economic opportunities, the resulting spatial patterns (in panel b/ and c/ of Figure 14) display much higher levels of dispersion mostly in economic opportunities but also to a lesser extent in population compared to the highly monocentric and concentrated initial spatial layout. This can be seen from the scattering of green colored cells representing high levels of economic opportunities. Simulations therefore confirm that increasing mixed land uses can improve local accessibility levels to some economic opportunities. This is not surprising as it locally improves the job-housing balance.

The question that follows is whether there is a fundamental tradeoff between focusing on inclusive labor markets and the integrated labor market which increases average accessibility to employment investigated in section 5.3. Table 5 provides some relevant results.

Share of Nairobi's opportunities accessible within a given time-frame depending on the transport mode used in the current and alternative spatial layouts of Nairobi									
	Cars			Matatus + walking			Walking only		
	Initial	**Local access**	**Aggregate access**	**Initial**	**Local access**	**Aggregate access**	**Initial**	**Local access**	**Aggregate access**
<30 mins	31%	23%	55%	4%	4%	7%	3%	3%	5%
<45 mins	58%	46%	83%	10%	12%	21%	7%	9%	13%
<60 mins	77%	71%	96%	20%	17%	42%	11%	11%	21%

Table 5: Comparison of average share of accessible formal economic opportunities in the initial spatial layout, in the local accessibility improving spatial layout and in the aggregate accessibility improving spatial layout

Table 5 shows the average share of accessible jobs in Nairobi County in the initial spatial layout and the two alternatives which have been discussed in this paper: the aggregate accessibility improving and the local accessibility improving spatial layouts. There are two important messages that come out from these numbers. First, the local accessibility improving spatial pattern performs less well on average than the aggregate accessibility improving spatial pattern in connecting people and opportunities for all modes and all time thresholds and for a given transportation network. For the 60 minute time threshold the figures read 21% of accessible opportunities vs 11% for pedestrians, 42% vs 17% for matatus riders and 96% vs 71% for car passengers. Second, with two exceptions (for pedestrians and matatu riders for the 45 minute threshold) the local accessibility improving scenario does not perform better and sometimes worse (for car drivers/passengers for all time thresholds and for matatu riders for the 60 minute threshold) than the initial baseline in providing residents with overall access to opportunities. Nairobi planners and policy makers should therefore be aware of the trade-off that exists between locally promoting, through land use planning decisions, a balance between jobs and housing and a unified and thick countywide labor market. Whereas the first option can provide some measure of access to economic opportunities, it might fail to deliver a strong integrated labor market and hence hinder an efficient pooling of workers and employers which is one channel through which agglomeration economies are achieved.

5.4.2 With agglomeration economies

Here the idea to be investigated is associated with the intuition that planning options which would favor access to a reasonably sized labor market instead of to all opportunities could result in more employment options for many residents but also decrease the possibility of achieving industrial or commercial clusters of a sufficient size to reap the benefits of increasing returns and knowledge spill-overs. To represent these agglomeration economies we will associate a bonus to grid cells neighbored by cells with high formal employment opportunity counts. This is done in a simplified manner by calculating the sum of formal economic opportunities within a 3km radius of each pixel and by associating a share of this sum (typically 5% in this exercise) to the pixel. The total amount of jobs in Nairobi County will therefore vary depending on the distribution of employment opportunities in the alternative scenarios. The more clustered the employment areas (the pixels), the higher the absolute amount of economic opportunity in Nairobi. In terms of accessibility, this exercise will tend to favor short travel times to large employment zones. While there are many other ways of representing the agglomeration economies associated with intra-metropolitan area firm clustering[16] and the choice of the parameters can also be discussed (Gaigné, Riou, and Thisse 2013; Lucas and Rossi-Hansberg 2002), this exercise nonetheless captures the idea that employment density and firm clustering are productivity enhancing.

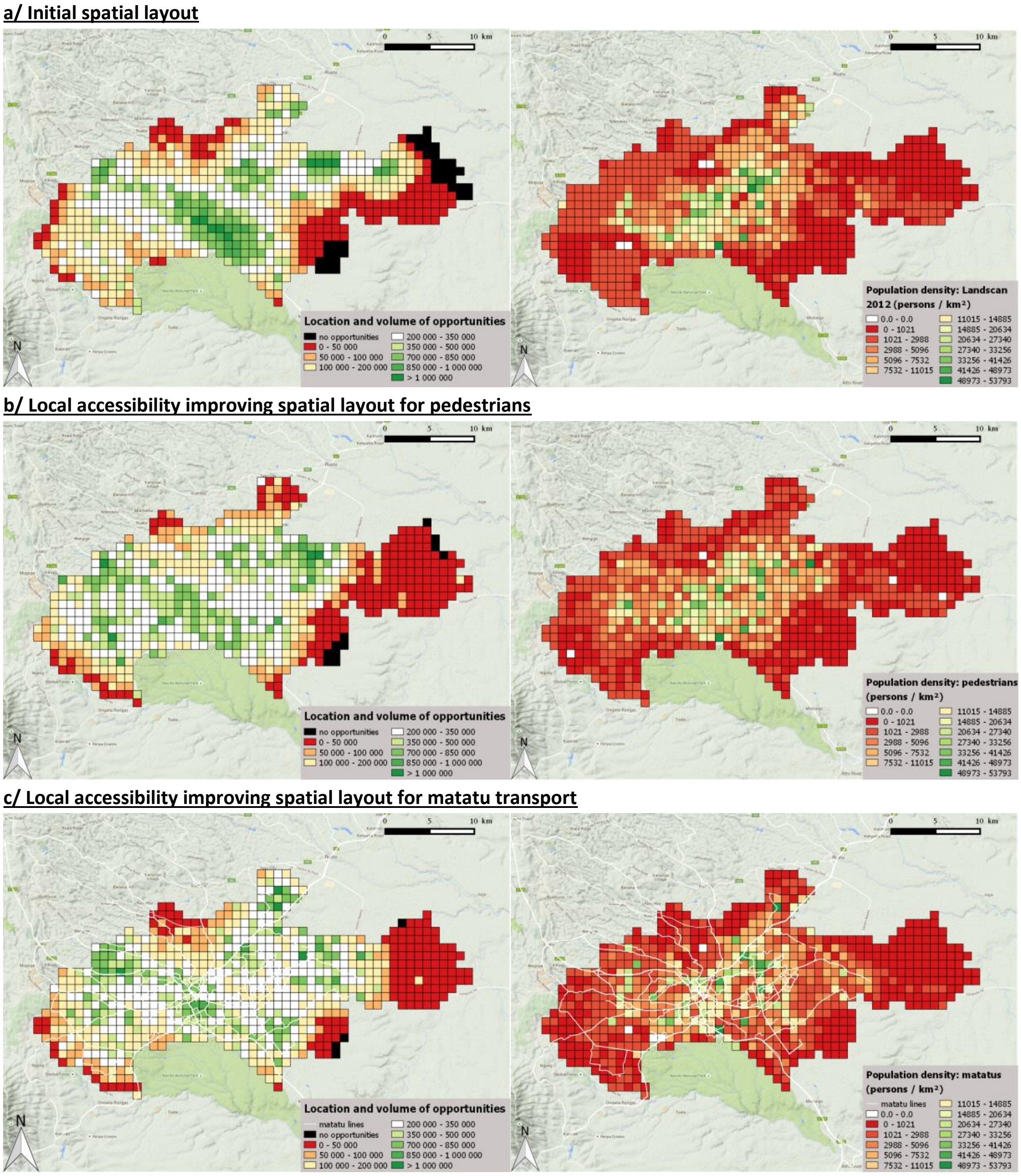


Figure 15: Distribution of formal economic opportunities (left) and population (right) in the initial and local accessibility improving spatial layouts for pedestrians or matatu transportation building in agglomeration economies

It can be seen from Figure 15 that the absolute amount of formal economic opportunities changes with the introduction of agglomeration economies with higher maximums and many less cells with no opportunities. However, the conclusions that we reach as to the distribution of households and

[16] For example, we could have introduced a distance decay function to weigh the benefits of employment opportunities differently according to the distance to any given pixel.

economic opportunities in the local accessibility improving scenarios only marginally change compared to the maps presented in section 5.4.1 for local accessibility without agglomeration economies. We can however observe slightly less dispersed employment opportunities and more polycentric patterns as the agglomeration economies favor clustering of economic activity.

Angel and Blei (2015a; 2015b) rightfully claim that self-organization processes ensure that as metropolitan areas grow, they also become more productive in a large part because commuting costs do not increase at the same pace as population nor land consumption. We concur with this analysis and have ourselves provided indications (see section 5.2) that the spatial layout of Nairobi County is the result of a complex self-organization process where accessibility to economic opportunities and commuting costs play a central role in the location of residents and economic opportunities. Angel and Blei demonstrate for U.S. cities that there are three processes which can explain why commuting costs only marginally increase with population: "increases in population density, locational adjustments of residences and workplaces to be within tolerable commute range of each other and increases in commuting speeds brought about by shifts to faster roads and transit systems".

There are a few differences which we however believe deserve a specific discussion. A main difference between our study and Angel and Blei's is that we focus on potential accessibility whereas theirs looks at actual pairs of residences and jobs. We believe that focusing on potential accessibility makes sense in the Nairobi context for at least three reasons: 1/ when land markets are imperfect (high transaction costs involved in land buying/selling, unclear land titles…), as is often the case in developing country cities, moving costs for firms or residents are high which indicates that intra-urban locational adjustments to remain within reasonable travel times of jobs may not be possible or not smooth nor costless. Therefore, if and when one workplace moves, there is value in having access to a wider array of employment opportunities within a given time frame to increase the employer/worker selection process. 2/ In cities where unemployment levels are high, the spatial mismatch literature (Gobillon, Selod, and Zenou 2007) shows that spatial isolation from large job pools can diminish employment outcomes of residents in part because geographic segregation and low accessibility increases job search costs. 3/ Part time jobs – whether formal or informal – are widespread in developing country cities and increasingly so in the developed world. Having access to more than one employment opportunity is therefore central.

Angel and Blei also advocate that more transport connections are needed and that there should be a focus on increasing travel speeds. We agree in part with this statement, and Nairobi, suffers crippling congestion costs which need to be addressed. But many developing country cities also face huge challenges in terms of housing, sanitation and access to basic services which are worsened by enormous population influxes with only limited financial capacity to cope. And transportation investments – although necessary – are hugely costly. There is therefore value in investigating options which could increase employment accessibility at lower costs. We believe smart planning which would be attentive to residential access to economic opportunities could provide at least part of the answer.

6 Conclusions

This study has demonstrated that land-use change can substantially contribute to the creation of a unified and deep labor market in Nairobi even in the absence of investments in transportation networks and in the building stock. Our central result is that the share of jobs that can be accessed within an hour doubles from 11% to 21% and from 21% to 42% for pedestrian and matatu users respectively with alternative spatial layouts. Achieving such an outcome is central to reaping benefits from agglomeration economies by allowing matching and sorting between potential employers and workers. The long travel times associated with very high shares of walking and reliance on matatus currently displayed in Nairobi are indeed indications of a fragmented labor market where simple geographic proximity is outweighed by commuting costs. This lack of accessibility has negative consequences for productivity, as argued throughout this paper, but also for livability as they are indications that in order to remain within reasonable travel times of economic opportunities, households may be willing to compromise on housing conditions and access to basic services.

Several other findings emerge from our analysis. First, accessibility is already a central determinant of the locational decisions of households and employers. This is demonstrated by Nairobi's current spatial layout largely outperforming 10,000 random counterfactuals in terms of aggregate accessibility to employment opportunities. This finding supports urban economic theories, beginning with Alonso (1964), which aim to explain the spatial distribution of people and land rents in urban areas as a tradeoff between the proximity to jobs and larger associated housing costs. Carefully designed plans coordinated with current and future transportation networks can facilitate the search for accessible locations, thereby allowing agglomeration economies to emerge (Rossi-Hansberg 2004). Second, the promotion of spatial layouts that would provide some minimum level of employment accessibility to as many households as possible would lead to small scale local labor markets at the expense of an integrated labor market. We interpret this as a tradeoff between equity and efficiency or in other terms between inclusive and efficient labor markets. However, our simulations also show that winners from spatial reorganizations aimed at increasing employment accessibility at large are far more numerous than losers. Winners' gains in terms of accessible jobs are also larger than losers' losses.

This study explicitly links employment accessibility to intra-city distribution of people and activity. As such, it is, to the best of our knowledge, an innovative attempt to tackle accessibility through a land use and planning lens instead of through a more commonly used transportation approach. This methodology suffers from some limitations that we hope future work can address. While we detail all these limitations extensively in the Appendix, we want to discuss the main drawback briefly here. The methodology we employed is a-economic in the sense that it disregards the economic forces which guide the structure of an urban area. In particular, it does not account for centripetal congestion forces which can take the form of traffic jams, higher land and housing costs and which would tend to discourage the concentration of people and activities and the associated increase in accessibility. An avenue for future work would be to incorporate our accessibility approach which focuses on land uses to an economically founded model that explicitly describes household and employers' locational decisions.

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Appendix: Data and methodological issues

This study relies on a relatively small number of assumptions and simplifications to work around the absence of data in some areas. It also constitutes only a first step towards a more comprehensive tool to integrate land use changes as a policy relevant option to achieve thicker and more efficient labor markets. As such some methodological choices and data related issues deserve to be discussed.

Data choices:

- Imperfect data about number and location of jobs: the amount and location of formal economic opportunities are inferred from a detailed land use map, associating them with the quantity of land used for industrial, commercial and public utility purposes. This is suboptimal as it does not provide exact information about job numbers and location. The correlation between land uses and economic opportunities is loose: it is indeed uneasy to associate number of square meters used for industrial purposes with a number of industrial jobs. The same applies for commercial activities etc... But even accepting the bold idea that job numbers are proportional to number of square meters, the land use map used in this study does not provide information about building heights, only land plot size. Therefore, one storey buildings are considered in the same way as six storey buildings. The strong assumptions that we make are the unfortunate consequence of the lack of data. We will however pursue efforts aimed at identifying or producing more accurate sources for counting and locating formal jobs in the urban area of Nairobi County. As a follow up to this study the team will apply the same methodology to assess accessibilities and their potential enhancements through land use occupation changes in Kampala, Uganda. In Kampala, detailed registries on employment quantities and locations exist and will increase the accuracy of our conclusions.
- Other public or collective transportation options besides matatus: In parallel to the informal minibus system – matatus – discussed in this paper, there exists both a formal bus system and railway commuter service in Nairobi. Buses operate on roughly 67 routes and carry a smaller percentage of the population than matatus (350,000-400,000 passengers per day). With competing companies, bus service is not provided in an efficient manner, maintenance suffers, and profitability margins are low. Contributing to the inefficiencies of the public transport system is the fact that many of these buses travel along the same routes as the matatus, competing for limited space in the already congested CBD (Consulting Engineering Services (India) Private Limited 2010). Also complicating matters is that routes have been optimized to maximize efficiency for the operator and not coordinated to an efficient level in maximizing passenger comfort or convenience. Nairobi was founded as a railway town, and its rail infrastructure remains well connected to the city center. Rift Valley Railways (RVR) offers twice daily service on five commuter rail routes in the Nairobi metropolitan region, averaging 2,300 to 6,900 passengers per route. While commuter rail is an economical mode of public transport, at present it serves only a tiny fraction of the daily commuting needs of the Nairobi general public. The most commonly cited reasons by Nairobians for not utilizing the system are concerns with safety and comfort, along with protracted travel times and difficult access to stations (Consulting Engineering Services (India) Private Limited 2010). Both these transport modes carry only a fraction of daily commuters in Nairobi so their initial omission is not too problematic; in the future however the team will look to integrate these networks into the analysis.
- Monetary costs of the various transportation options: The analysis conducted in this study only considers transport times in determining accessibilities. A more complete analysis would reason in

terms of complete costs, accounting both for time opportunity costs and monetary costs. Lack of data prevents the team at this stage from performing this more complete investigation. In particular, matatu fares vary depending on the time of the day, the level of congestion, the length of the trip, weather conditions and so on. It is therefore difficult to ascertain with reasonable confidence the monetary costs of a matatu trip.

Methodological limitations:

- Representation of economic forces in location decision behaviors: In the model presented and discussed above there is no representation of household and formal employers'/firms' behavior when deciding where to locate. As a result of this omission there is no possibility of capturing the real estate or land market which is both a result of and a factor in household and economic activity location decisions. High land prices which can result from high demand might prevent some activities from locating in some areas and instead push them towards less desirable (and hence less accessible) locations. In this respect, the model and results presented above overlook an important location decision factor and can be tagged as a-economic, thereby representing an informative yet schematic and maybe idealized outcome. A critical avenue for policy oriented research, which is beyond the scope of the present effort, would be to build an economically grounded location decision model for both firms and households which could represent optimal land use occupation with respect to economic opportunities.
- Representation of local characteristics: the desirability of certain locations for their inherent qualities or conversely the disamenities associated with proximity to certain areas (industrial locations for example) are also disregarded and could play a role in local sorting of households and firms. Ideally, the economically grounded location model for firms and households advocated for above would capture the role of amenities. In its absence however, future work along the lines of this study could integrate the inherent desirability or undesirability of certain locations through simple coefficients encouraging or discouraging certain land use patterns.
- Addressing congestion: Although congestion is accounted for in this study in the baseline situation – the current spatial layout of Nairobi – through realistic transportation speeds, the impact of changing the location of households and formal economic opportunities on these congestion levels is not represented. However, changing the spatial pattern of Nairobi will also modify the direction and intensity of commuting flows, possibly saturating some road links in some areas whilst relieving congestion in some others. The aggregate accessibility improving scenarios both display a higher concentration of households and formal economic opportunities in the vicinity of the city center which is likely to overall increase congestion in these areas. The model, however, falls short of integrating this feedback loop when calculating accessibilities. A future improvement would be to endogenously estimate congestion levels based on commuting flows on the basis of Bureau of Public Roads (BPR) speed-flow curve or a Macroscopic Fundamental Diagram (Geroliminis and Daganzo 2008).