Supply chain mapping and stakeholders' assessment towards the sustainable development goals: The case of the construction sector in the informal settlement of Mathare, Nairobi

Conference Paper

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Publication date:
2020-11

Permanent link:
https://doi.org/10.3929/ethz-b-000455882

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Originally published in:
IOP Conference Series: Earth and Environmental Science 588(4), https://doi.org/10.1088/1755-1315/588/4/042033

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Supply chain mapping and stakeholders’ assessment towards the Sustainable Development Goals: the case of the construction sector in the informal settlement of Mathare, Nairobi.

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Abstract. The UN Sustainable Development Goals are the blueprint to achieve a more sustainable future for all. One of these targets to be tackled by their implementation is the improvement of the livelihood of 1/6 of the global population, housed in unsafe informal settlements. This paper explores the correlation between GOAL11 – Sustainable cities for all - and other aspects of the societies relevant for the achievement of the SDGs – Responsible consumption and production, No poverty, Gender inclusion, Decent work and economic growth - in a mutual and potentially virtuous relationship. The work is based on months of fieldwork conducted in 2018 in the informal settlement of Mathare and in the city of Nairobi, through observation and semi-structured interviews, with the objective of understanding the current productive and economic flows of the construction sector supplying the informal city. From the study, the following statements emerged: a) different final building users (clients) operating in Mathare have access to different building materials, b) the diffusion of materials inside the settlement is strictly related to the access to the shop and to the potential client sites, c) the diffusion of materials inside the settlement is highly impacted by the availability of space both by the supplier store and on the building site, d) the division plays a significant role in the distribution of roles in the construction sector. The study shows the relevance of applying a metabolic approach to the city throughout its supply chain in order to understand its ongoing logic prior to a construction intervention. This allows to understand ongoing construction practices, identify gaps and bottlenecks and propose improvement solutions fitting with the ongoing dynamics. The local economy would benefit from such an approach, tailored on its needs and potentials.

1. Introduction
1.1 The built environment and the SDG Goals.
The Agenda 2030 and its 17 Sustainable Development Goals, are the blueprint to achieve a better and more sustainable future for all. Demographers estimate that by 2050 there will be 9.7 billion people on the planet, an addition of over 2.4 billion compared to current numbers(1). According to the United Nations Population Division, 60% of the world’s population will be living in urban areas by 2030 (2).
Specifically, a significant increase in urban areas will occur principally in Africa and Asia where 90% of the total world population growth is expected to take place by 2050. This population will need energy efficient and sustainable constructions including access to adequate housing and basic services, in rapidly growing cities already struggling on bridging the housing gap (3). It is therefore likely that this will correspond to the rise of urban informality as a response to the housing gap, resulting in inadequate living conditions. How then to guarantee “Sustainable Cities and Communities” for all, as targeted by Goal 11? How to provide the growing population with a sustainable built environment?

In the last decades, significant advancements in the development of sustainable materials, technologies and assessment methods have been achieved (4–10). Technical solutions for a building sector capable of respecting the environment and do not pose a further threat to climate change are now available.

In 2015, the need for new homes across Africa was estimated at 60 million units, a number that does not account for people who will possibly be in need to relocate. With the overall building stock (mainly consisting in housing) responsible for more than 40 percent of global energy use, the housing sector consumes significant amounts of energy and represents the single largest contributor to greenhouse gas emissions (11). It also uses about 40% of resources and generates an equal amount of waste. Considering that 50% of the building stock that will exist in 2050 is yet to be built (12), new buildings are an opportunity for solid sustainable solutions to mitigate environmental pressures and to generate economic growth while providing adequate, dignified and affordable housing to a growing population.

The importance of the constructions and buildings sector with regards to sustainable urban development is now increasingly recognized. In view of the global climate emergency, there exists the urgent need to take stock of all sustainability related experiences in the most critical of ways so as to prevent policy shortcomings of the past to repeat again in the future. Likewise the unprecedented multiplication of substandard constructions and housing solutions on the one side, and the number of carbon-heavy buildings and constructions, are the physical manifestations of a chronic lack of sustainable and adequate housing, mainly, and inadequate public policies around the buildings and constructions sector.

While attention is usually given to the environmental dimension to sustainability, much remains to do in order to strengthen the social and economic dimensions as still, the ultimate objective of sustainability has proven not to be achieved. Most constructions continue to be made by the informal sector and adapt to the availability of cheap industrialized materials and conventional building techniques. Most of which do not provide durable housing options, and are far from adhering to sustainability principles. Therefore, a shift towards a regenerative approach, proposing to provide for more positive benefits rather than trying to harm less, is urgently needed. (13–15). Through this mind shift, the challenge of the housing gap can be seen as an opportunity to restore local economies and ecosystems. We can therefore look at the building sector, which is fundamental for the fulfillment of Goal 11 and Goal 13, as well as can trigger positive impacts in multiple SDG Goals. A regenerative approach in housing delivery (Targets 11.1: Affordable and adequate housing, 11.6 (reducing overall environmental impact of cities, 11.9 Integrated policy/planning), can create sustainable employment opportunities (Targets 8.3 decent jobs, 9.4 practices across the value chain, and 9.5 innovation), can in fact produce the opportunity for innovative solutions to mitigate environmental pressures (Goal 13: Climate Action), prevent resource depletion (Targets 12.2 (efficient use of resources), 12.5 (reduce material waste); 12.7 (sustainable public procurement), and 12.8 (sustainable lifestyles); to generate fair economic growth (Goal 8: Decent Work and Economic Growth) while providing safe and healthy affordable housing for all (Target 3.9 (health impacts from pollution).
Viable solutions now need to be embedded in the current construction practices, including the informal context. While a thorough understanding on the formal construction context has been achieved, the informal settlements habitat have mostly been investigated for its typological and incremental character(16–19), rather than for its building process per se. Just in the last years the informal city construction process has finally been proven to differ from the one of the formal city(20–22), and is now recognized as a socio-technical system with its own logics and dynamics (23). The codification of such logics is now required, in order to guarantee that environmentally sound pilots and exemplary building solutions will actually fit within the on-going practices and processes leading to “Sustainable Cities and Communities” for all.

The current work, developed on the case study of the informal settlement of Mathare in Nairobi, has a double folded objective. First, it wants to provide the understanding of its construction sector, identifying stakeholders and drivers guiding the construction processes. Second, it aims to show how the use of a stakeholder based supply chain mapping helps to highlight strategies for a regenerative construction, where housing for all corresponds as well to the generation of local economic growth.

1.2 The context: Mathare, Nairobi
The city of Nairobi currently hosts an estimate 2 million informal dwellers on top of its 4.3 population, expected to reach 6.24 by 2025 according to the African Development Bank (24). In the meantime, the local housing gap keeps on increasing due to the local government struggle to meet the demand (25). Years after the drafting of the New Urban Agenda, still no significant large settlements upgrading action has been taken to address the living conditions of the ones left homeless in the Kenyan capital (26). In these regards, the informal settlement of Mathare is home to an estimate of 600,000 residents, divided in ten different villages (24). Second in size after Kibera, it stretches for 3.5 km along the Mathare river, both on government and privately-owned land. Currently parts of the settlement are considered formalized and permanent buildings represent the majority of some of its areas. It is also home to the Mathare 4A slum upgrading program, launched in 1992 from the Government of Kenya and developed just in parts, due to progressive complications (27). Within its area of 4 km², enclosed by the road arteries of Juja Road, Outer Ring Road and the unpaved Mathare North Road, providing separation from the formal neighborhood of Drive, Mathare offers a vibrant economy, both within its own system and exchanging with the neighboring settlements.

2 Method
The work is based on six months of fieldwork conducted in 2018 in the informal settlement of Mathare with the objective of understanding the current construction process of the informal city. Data on the housing building process was collected by one of the authors together with the assistance of a local community member, mostly in the informal villages. The research then lead to expanding the fieldwork along the supply chain of the construction sector, in the neighborhoods of Light Industry, Industrial Area, Kariobangi and in the production areas connected to the supply.

The tools used to conduct the research were: observation, photos, mapping and semi-structured interviews. Specific objectives were: i) to identify all the stakeholders involved in the construction sector in the informal city; ii) to identify the drivers and bottlenecks for implementation of diverse building materials and exclusion of others; iii) to map the current practice and its connection to the formal city, where existing. The underlined hypothesis is that a better knowledge of such topics would support a more efficient and grounded development of locally relevant housing implementation plans.
3 Data

The study consisted initially on the compilation of its own database. This was then organized in the following sections i) building materials in the settlement, ii) material supply, iii) construction process, iv) stakeholders analysis

3.1 Building materials in the settlement

Mathare building fabric is not homogeneous, as its development spans from building blocks to iron sheet houses according to the different villages. The most largely locally diffused building technologies are: iron sheet with timber structure, prefabricated board with timber structure, timber planks cladding with timber structure, lightweight concrete blocks, bricks, stone masonry, adobe bricks, wattle and daub (earthen construction with timber frame structure). Due to their thermal behavior, these options provide for a different indoor comfort, being the local climate rigid in winter, dry hot in summer and affected by two intermediate heavy rainy seasons in between. All of the housing units assessed are covered with iron sheet roof, and only stone, bricks and concrete blocks units are provided with foundations. Iron sheet houses represent by far the vast majority of the Mathare informal villages, composed of single storey iron sheet houses, locally referred to as “structures” or “10x10” for their size, expressed in feet. Technologies as stone construction or earth bricks are part of specific implementation plans and programs promoted by NGOs or the municipality. According to the legal land tenure and occupation status of the different wards, a certain level of formality can be observed in the remaining half of Mathare, resulting in four to six storey high stone buildings. The apparent formality of the construction though does not necessarily corresponds to formal security of tenure, legality, proper construction technique or comfort in size and services.

3.2 Material supply

The procurement of building materials takes place both within Mathare and beyond its boundaries. Eleven material retailers have been identified inside the settlement and on its boarder, with an average size of 22 m², almost the double of a typical unit in the settlement. They all sell iron sheet, screws, nails, plumbing elements and tools, and for this reason they are referred to as “hardwares”. Their additional stock changes weather they are located on the streets bordering Mathare, or inside the settlement, along the pedestrian paths. The formers in fact additionally sell, beyond iron sheet, 2.4 m long timber poles suitable for structural use and cement bags. They occupy a bigger surface (around 50m²) both in terms of enclosed selling space and by making use of the wide pedestrian passage suitable for marketplace along the roadway. Their strategic location allows for on-site delivery by truck, and to benefit from the street visibility. Instead, the retailers located inside the settlements cover no additional market beyond iron sheet and, at times, second hand short timber elements. The only two retailers that include soil and gravel, do it in force of the empty lot they have occupied in front of their store, allowing them to expand for around 40 m² beyond their shop.

The condition of having stocking space for sale is mentioned by all retailers as a critical factor. The small stocking space of the retailers in the settlement leads them to select which material to support within a suitable price range. No prefabricated concrete blocks or stone blocks are sold in the settlement, even though they are available in the neighboring settlement of Babadogo, less than 1km from Mathare and significantly less dense. Despite the potential market of such materials, retailers report that it is not convenient for them to invest in bulky elements, as their place for storage would get filled up with one single client’s order. Beyond that, transport of such materials both to the local store and to the client site, is an additional limitation, as no car or truck could be of use due to the narrow paths. An exception to the generic retailer features comes from two distinctive cases consisting uniquely in an empty lot, without any building enclosed space but allowing for gravel, sand and soil sales thanks to the available space and access to the main inner road. The goods property in this case responds to a security man,
while trade happens over the phone thanks to the contact number of the owner painted on the background wall, often employed in a nearby hardware.

The space available in the material stores in Mathare is commented as suiting the local incremental construction process. Due to the limited availability of both economic resources and space for material stock on the building site, the construction usually develops in phases, and materials are ordered progressively. When this is not the case, interviews with structure owners showed that it is common to shop in the neighboring settlement of Kariobangi, known as Light Industry, the biggest material supply in town for the low-income population and located within walking distance from Mathare. There, the retailers combine retail space and material production, having access to larger spaces of more than 100m², constant access to electricity, tools and machineries for material processing.

Beyond that, at times agents intervene in the supply acting as middleman between clients and material producers, advertising their work through posters or word of mouth. They do not have any expenditure on stock having no physical retail store.

3.3 The construction process
The settlement undergoes continues incremental transformations, both in terms of maintenance and new construction in response to recovery after damage or eviction, or vertical incremental expansion.

Data on the diverse building processes have been organized in bill of quantities per each technology implemented in the settlement. This has been calculated for one unit of 10 x 10 feet, corresponding to 9.2 m², in line with the average of the settlement. The technologies considered are: adobe, bricks, stone, prefabricated concrete blocks, wattle and daub, timber, iron sheet and prefabricated boards. According to the interviews with local construction workers and further research, an estimate construction schedule has been drafted, declined into the eight different technologies. The assessment, represented in Figure 1, considers the amount of material delivered (space), measured in m³ and indicated on the vertical axis, and the time of delivery (time), measured in days along the horizontal axis. The schedule refers to currently adopted building practices and not optimal ones, and does not necessarily represent the correct building process. Construction time includes: site preparation accounted for technologies requiring foundations, drying time and scattered deliveries as per local practice.

**Figure 1.** Compared construction schedule for a building unit of 10 x 10 feet in Mathare
3.4 Stakeholder Analysis
A diversity of stakeholders act along the supply chain of the construction sector operating in Mathare. They can be divided in the two main groups of end-users and retailers.

End-users interact with the final product, being it either a building element purchased for repairs or the complete structure. They consist in renters, structure owners, landlords, NGOs and formal entities. Renters represent the majority of them. Their relationship with materials resides in the rental price, set according to the structure materials. Their interest in investing on house modifications is absent, due to the low economic capacity and threat of eviction. Structure owners do own the building without any land property right. They usually build with materials that can easily be disassembled and reassembled elsewhere, as iron sheet or timber, as their security of tenure is extremely weak. Landlords own the land and, in some cases, the structure. They are usually man over 30 years old that have some power in the community. Their interest in materials is oriented towards the smallest investment. The exception comes in the case of their own houses, where materials are for them a tool to showcase their status symbol. Beyond end users belonging to the community, NGOs and formal entities also operate in the territory, usually of projects of public use and larger scale. Their economic capacity is higher than the one of the locals, both in terms of investment on construction, transportation and land surface. For this, it is frequent that they introduce their own workforce and reach out to city distributors accessing a different market and supply.

The retailers that operate along the supply are: informal retailers in Mathare, street retailers (consisting in an occupied surface but no physical store), informal retailers in Light Industry, agents, formal retailers in Industrial Area and producers.

In case of repairs, the construction practice that the most fuels the local market, no contractor is usually involved.

3.5 Stakeholder based supply chain
Due to the emerging role of stocking space identified in the interviews, a simplified supply of the building materials from the three different end users up to the producers have been represented in Figure 2. The dimension of the markers represents the amount of materials processed by the stakeholder, regulated by their space availability. The color of the markers differentiates the type of market, being formal in case of officially registered companies in the formal city, informal in case of informal businesses in the settlement and proximities and semiformal when referring to registered activities making use of informal workforce and (or) soil occupation.
Figure 2. Stakeholder based supply chain mapping for the construction sector of the informal settlement of Mathare, Nairobi

Figure 2 shows how different end users (informal dweller, NGO and formal dweller) act along a different supply. More specifically, it highlights how the local supply at the settlements level is uniquely involved in the informal resident’s market. This can be explained by the limited stocking capacity of the local retailer, working in synergy with the incremental construction of the informal dwellers but unable to cope with large stock and bulky materials as required by NGOs and formal entities. The limited stock capacity of the local retailers makes them non-competitive for end users that can make use of bigger stocking and building spaces, as NGOs and Formal entities. This results in the lack of economic investment at the community level.

4 Results: space constrains in the construction process
Bill of quantities and space use on site, collected through interviews and observation on the building process in Mathare, have been combined and organized per technology. Figure 3 shows a comparison between the available space on site, represented as an hypothetic 10x10 cubic feet corresponding to the housing unit volume, and the actual in situ stock space required for the materials. Considering that the settlement is a highly dense territory, where inner paths are usually around 60 cm to 1 m large, it is correct to consider that the estimate of a 10x10 feet unit for both construction and stock space. Some
materials, as gravel and sand, cannot be piled and occupy a wide surface. The same can be said for elements that need to dry on site, as adobe bricks.

![Material Stocks](image)

**Figure 3.** Comparison of on-site material stocks, for a housing unit of 10x10 feet in the informal settlement of Mathare, Nairobi

While most of the assessment methods look at material stock requirement in m³, this figure shows how this unit provides just a partial understanding of the stocking strategy, as it does not take into account the diverse physical requirement of the materials. Technologies as iron sheet, prefabricated board and timber, which represent by far the majority of the local building stock, manage to comprise the material stock within the unit boundaries. On the contrary, technologies including foundations and massive walls necessarily require a much larger surface for on-site material storage. Furthermore, production on site as per adobe bricks poses the added bottleneck of space for drying, making it the most space consuming technology among the compared ones. The figure shows the significant impact that the technological choice has on on-site logistics due to space availability.

5 Discussion and Conclusion

The study looked at the construction process in the context of the informal settlement of Mathare, Nairobi in order to identify its drivers and bottlenecks.

The assessment highlighted **stocking space** as a major factor in material choice and availability on the market, both on site and along the supply chain. This result can be extended to the majority of urban informal settlements, where access to the site, retail size and possibility of stock by the building unit are all extremely limited. The three-dimensional technical stocking assessment and the compared schedule shows how on site stock is a major driver for construction time. Beyond that, the stakeholders based supply chain shows how end users with a major stocking and transport capacity disengage with the local retail system due to their inability to provide bulk delivery.

The following key operational indication can be extracted by this result: the choice of building materials that do not account for stocking space would likely be rejected by the local community market and users. This reflects on the strategy of material producers working on sustainable solutions (Goal 13 Climate Action) and for the project managers in charge of inclusive implementation plans (Goal 8: Decent Work and Economic Growth), that indeed need to take the space constrain factor into account.
This finding is therefore relevant in order to draft regenerative strategies for the improvement of such settlements, going beyond Sustainable Cities and Communities (Goal 17) as aiming to positively engage with the integration of a diversity of SDGs.

Acknowledgements:
The authors want to thank the community of Mabatini in Mathare, and specially the Why Not Academy, Liveinslums NGO and the community based organization Twaweza for their availability and knowledge. A special acknowledgement is owed to Pepe Henri Ochieng, without whom the success of the extensive fieldwork in Mathare would have never been achieved.

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