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Effects of Urban Spatial Patterns on Building Energy Consumption: The Case of a Commercial District in Dar-es Salaam, Tanzania

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Abstract: The concern over efficient use of energy in buildings has raised a debate from various parts of the world. The justification for this debate emanates from the understanding that continued utilization of non-renewable sources of energy presents a challenge towards sustainable development. In developing countries where urban growth is largely unguided, the capacity of urban authorities to guide orderly spatial development is limited and the challenge towards realization of energy efficient city forms is imminently becoming more apparent. This apathy has resulted into city spatial patterns that do not guarantee effective and efficient energy utilization. The paper attempts to analyze the impact of the urban form, the in-door spatial adaptability on building energy consumption patterns. This study was conducted in one of the rapidly transforming commercial districts of Dar es Salaam, namely Kariakoo. The methods used for data collection included; literature review, field observations and measurements, analysis of plans, maps and interviews with space users and officials. Measurements of climatic elements of temperature and humidity were also conducted. Results indicate the rapid physical transformation of Kariakoo from single storey to multi-storey buildings has culminated into increased energy utilization. However, these transformations have been taking place with little regard to recommended plot coverage and floor area ratios. This has resulted into uncomfortable indoor living conditions and excessive utilization of energy. Adapting to these challenges, most households were putting on electricity light during day time, fans and use of air conditioning units. It has been recommended that building energy consumption patterns can be moderated with appropriate urban, architectural and electrical design within the context of a strong and efficient legal framework. The enforcement of the legal framework can be done by coordinating efforts from various stakeholders from relevant sectors and government institutions.

Keywords: Spatial pattern, Building energy consumption, Kariakoo commercial district, Dar es Salaam

INTRODUCTION

Sustainable cities are those that enable all of their residents to meet their own needs without compromising the needs of other people or future generations [1]. In developed countries, energy consumption is one of the major concerns towards addressing sustainability. Urban centres are being redeveloped with emphasis on compact neighbourhoods, clean transportation and the use of green technologies. In many cities of the developing world are still confronted with challenges such as provision of basic infrastructure, the need to accommodate rapid urban growth, control of air pollution and improvement of living conditions of the urban poor. Although every country has its own policymaking and environmental priorities, cities that do not recognize the impact of emerging urban spatial patterns on energy consumption and environmental costs of unguided development will remain unsustainable.

There is a significant relationship between building sector energy consumption and sustainable development. For example, the building sector in the United States of America is responsible for 39 percent of carbon dioxide (CO_2) emissions, 70 percent of electricity consumption and 40 percent of the country's total energy consumption [2]. The building sector therefore consumes more than half of all the electricity produced and almost a half of all the energy consumed. However, the negative impact of this sector to the environment is on the way energy is produced not the percentage it is consumed. In the United Kingdom, about 40 percent of the energy demand is for low-temperature heat, and for space cooling; about 20 percent is to provide higher temperature heat, 30 percent for operating vehicles and other machines and only 5-10 percent for electricity specific tasks such as lighting, electrolysis and electronic equipment [3]. At the global level, Fig-1 gives an overview of the distribution of electricity worldwide. According to Monterroso[4], the City Lights data serves as a proxy of population distribution or infrastructure at global level (Figure 1). The National Geophysical "city lights" database depicts stable lights and radiance calibrated lights of the world (which includes lights from cities, towns, industrial sites, gas flares, fires, and lightning illuminated clouds). A high concentration of city lights is especially found in industrialized densely populated regions of Western Europe, Japan, and the USA. On the other hand, few "city lights" are shown in economically poorer and sparsely populated regions (e.g. central and northern Africa and South America). Moderate "city lights" are found in several densely populated "developing countries" such as India, Indonesia, Eastern Brazil, and South Africa.

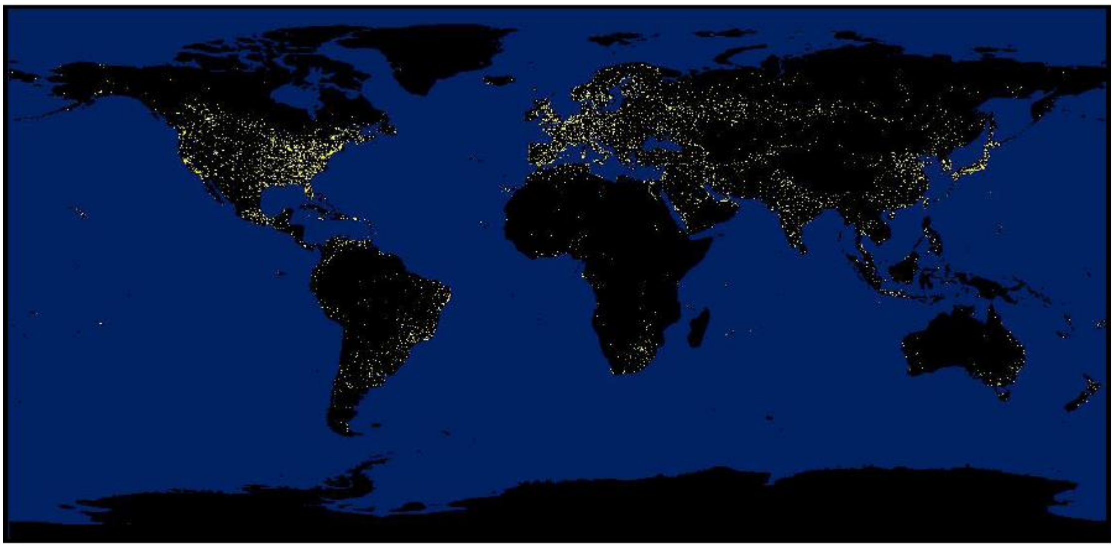


Fig-1: City Lights Map: ***Source: Monterroso, (2008)***

For the purpose of this paper, only electricity consumed in a commercial district of the city of Dar es Salaam. The energy consumption pattern usually vary depending on the life time, the building materials and technology, the geometry, type and use of the building as well as the building services[5]. Urban growth is not only occurring with housing physical expansion but also with business centres that culminates into economic development. Usually, these centres are depicted by multi storey buildings for offices or apartments, and characterized by traffic congestion and high rates of energy consumption. For example, in hot and humid climate zones, utilization of mechanical means to acclimatize indoor environments of multi storey buildings is increasingly contributing to excessive use of energy. While the man-environment interaction is essential for development, efficient energy use is fundamental for achieving sustainable development. Although Africa is endowed with substantial renewable energy resources, consumption of modern and efficient forms of energy is still very low [6]. There are however some exceptions, in the case of Africa, where government interventions have modernized policies and focused them into energy efficiency concepts, for example in Zambia and South Africa.

THE ENERGY- CITY ENGINE RELATIONSHIP

As an engine that keeps running the diverse functions of a city, energy utilization can be broken into three sectors: automotive, industry and commercial/residential buildings. In order to analyze energy consumption patterns, it is needed to know how energy can be measured [4]. Energy measurement can be divided in delivered or primary energy. Delivered energy is the amount of energy consumed for the use of a site or a building, for example, the amount of electricity used and recorded on a bill. Primary energy is the amount of energy used to produce a quantity of delivered energy, for example, to create electricity by gas burning that drives the turbines into a power station. However, production and transportation of energy are not always 100 percent efficient. Due to these inefficiencies in the process, for every one unit of electricity delivered to a consumer, a larger amount of primary energy has been consumed in its creation. For example in the United Kingdom, the ratio between primary and delivered energy for electricity is 3:1, that is, for every one unit of delivered electricity, three units of primary energy are used in its production [4,7]. In this paper, the type of energy to be analyzed is the delivered electricity energy in commercial and residential buildings.

Delivered energy can be divided in three sectors; these are the industry, the automotive and the building sector. For the purpose of this paper only energy in the building sector has been considered. The main focus has been on energy consumption patterns and more specifically, the utilization of artificial lighting and artificial ventilation. The building sector consumes a significant percentage of delivered energy;

therefore, an efficient use of energy in residential and commercial buildings can have positive externalities at the local and global level. Consistent with this debate, the key analytic variable that have been used in this paper include the spatial organization, indoor variations and adaptability. Building energy consumption patterns rely on the good management of the national development system. Although the environmental and economic sub-systems are affected directly in the production and consumption of energy, many other sub-systems have to be integrated and considered in order to achieve energy efficient buildings.

METHODS

Data collection relied on primary and secondary sources. A preliminary reconnaissance study and wandering around in Kariakoo area was carried out in 2008. Prior to reconnaissance, a review of secondary sources of data including the Kariakoo Redevelopment Scheme (2002), national reports, maps, policies and building regulations including students' dissertations who had studied Kariakoo from various perspectives was made. Kariakoo area was divided in three zones of central, western and southern. Within these zones, specific buildings were identified as potential cases for further examination on the basis of their physical and location characteristics. The identification of building height, habitable floors and potential energy consumption patterns was observed. Two blocks from the Central Zone of Kariakoo which had the highest plot coverage of 66 and 67 percent respectively were selected (Figures 2, 3 and 4). In these blocks there has been a tendency to build multi storey buildings to replace the single storey houses. Another methods used to collect data was interviews. Ten interviews to explore the perception of in-door comfort by users and their energy consumption patterns were conducted. Some of the tenants interviewed were foreigners coming from India, Lebanon, Libya and Great Britain; others were from Tanzania mainland and Zanzibar. This revealed the multi cultural nature of the inhabitants of Kariakoo. Key informant interviews with the Dar es Salaam City Council, the Ministry of Lands and The Professional Board of Architects, The Tanzania Electricity Company (TANESCO) as well as informal conversations with investors and building developers were also made. Concurrent with interviews, some measurements were conducted in the buildings. These included; in-door air temperature, out-door air temperature, relative humidity, size of the openings, orientation of the openings, size of in-door spaces and number of mechanical means for lighting and ventilation (Figures 5 and 6). The equipment used for the measurements consisted of compass, a thermometer, a hydrometer and a measurement tape. In-door photographs were also taken to show the in-door spatial distribution and characteristics of the places. Analysis of data was done with the assistance of computer software including Vector Works, Photoshop, Corel Draw, ArcGIS and Google Earth.

It is important to note that T-PO-1, T-PO-2 and PO-1 constituted shops facing the street directly. Therefore the in-door temperature was similar to the out-door temperature. For houses whose indoor measurements were not accessed, measurements were done in a semi-closed corridor that connects the entrance door of the apartments with the stairs. In most buildings, the corridors had openings made of holes in the wall facing to the North West, making it possible to classify the space as intermediate. In order to analyse the external factors affecting the in-door environment, efforts were made to ensure that indoor and outdoor measurements were taken in each building.

RESULTS

The physical transformation of Kariakoo

A house count study on in Kariakoo revealed that by the year 2002, there were a total of 2,142 buildings. The physical transformations in Kariakoo is basically manifest in the replacement of single storey houses, constructed with sand-cement block walls and corrugated iron sheets with multi-storey buildings made of cement-sand block walls and reinforced concrete structure. In general terms, the physical transformation has been following the same practice over the last forty years. However, there has been a change in the height of buildings over the time. Reports show that by the year 1976 only 5 percent of all buildings had more than one storey in Kariakoo. This figure increased to 10 percent in 1992. More changes were noted in the decades to follow and in 2013, the proportion of multi-storey buildings had reached 49 percent (Table 2, Figures 7 & 8).

The urban form transformation is not only affecting height of buildings but also building materials, habitable floor space and density. The application of modern building materials has been going hand in hand with building height transformation namely; most of the buildings have been redeveloped to three or more floors with reinforced concrete structures. Increasingly, glass walls and windows are being used to replace timber. Although the changes in construction materials has improved durability and adding value and security to properties, these new structures are more energy demanding than the traditional buildings. Assuming that each new floor added vertically between 1999 and 2008 constitute a habitable floor space and considering the "empty" and "under construction" plots by 2008, the habitable floor space increased by 166 percent within the period 1999-2005 and by 433 percent within the period 1999-2008 (Table 3). These figures serve to indicate the significant transformation between 2005 and 2008 period whereby the habitable floor space increased by 260 percent.

Fig-2: Location of the case study area (Kariakoo)[8].

Fig-3: Location of selected blocks for specific analysis

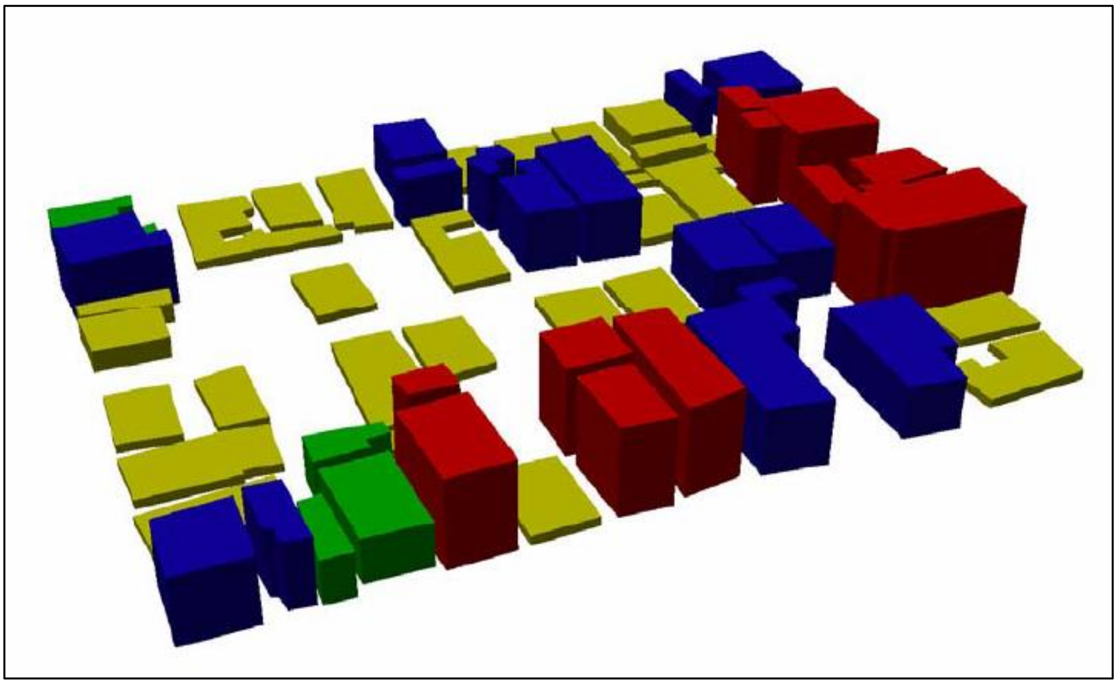


Figure 4: Building height in the selected blocks

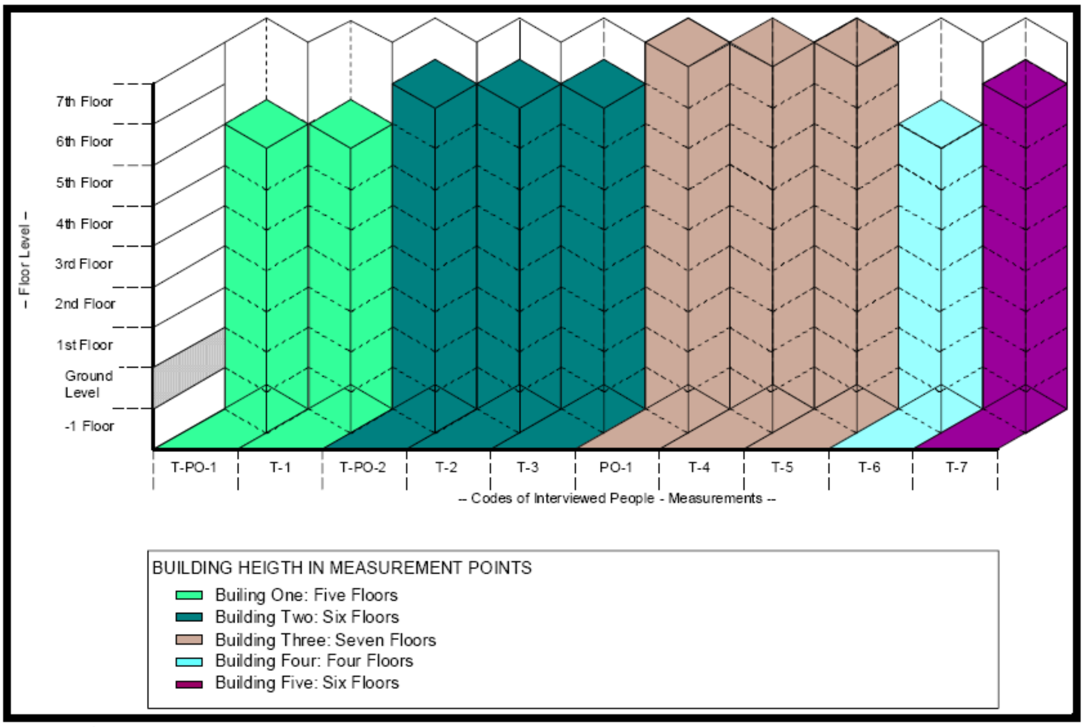


Fig-5: Building height measurement points (Source: Monterroso[4])

Table 1: Codes for interviewed people

T-PO	Tenants and Plot Owners
T	Tenants
PO	Plot Owners
PF	Professional Practitioners
PS	Public Sector
IN	Investors

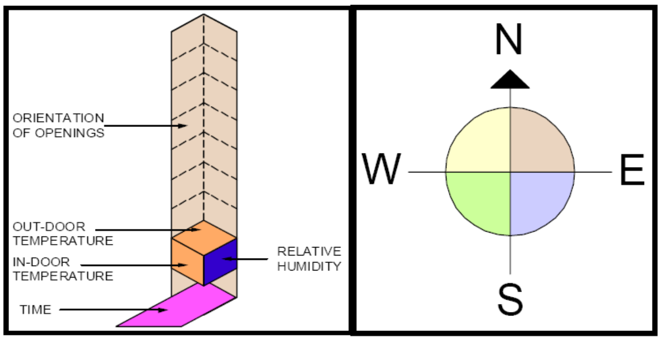


Fig-6: Variables considered for measurement (Source: Monterroso[4])

Table 2: Changing trend of multi storey buildings in Kariakoo

SN	Year	Buildings with more than one storey	% of all buildings
1.	1975	106	5
2.	1992	206	10
3.	1996	369	17
4.	2003	561	26
5.	2006	679	32
6.	2013	1043	49

Source: Monterosso [4], Mchome, Tamla & Mwambata[8], Bhayo [9].

Fig-7: Building spatial pattern in Kariakoo in 1999

Fig-8: Building spatial pattern in Kariakoo in 2008

Photo 3: House forms of Kariakoo facing Mnazimmoja square (2010)

Table 3: Comparison of building height and habitable floors in 1999, 2005 and 2008

Height classification	Number of buildings (1999)	Habitable floor space (1999)	Number of buildings (2005)	Habitable floor space (2005)	Number of buildings (2008)	Habitable floor space (2008)
3-4	1	3	4	12	4	12
5-6	4	20	6	24	11	55
7 or more	2	7	2	14	9	63
TOTAL		30		50		130

Source: Monterosso, [4]

The effects of the new urban spatial pattern on energy consumption

The new urban form is the consequence of the physical transformation that is taking place in Kariakoo. The change of habitable floor space has a direct bearing on the increase in the demand of energy particularly electricity. If the habitable floor space increased by 260 percent in the period of three year, that is, an approximately increasing rate of 87 percent per year, the same logic can be applied to translate into electricity demand. Assuming that each floor will be equipped with mechanical means for lighting and ventilation, in terms of electricity units, each floor added to Kariakoo represents an increase in the energy consumption patterns. Field data revealed that the amount of electricity for a 30 square metres habitable space with equipment of lighting, fans and air conditioners was 660 units per month. This figure increased to 1100 units for a 50 square metres habitable space and 2860 units for a 130 square metres habitable space respectively (Table 4). These estimations are based on data collected from two blocks in the central zone. Although they may seem exaggerated for the cases of other blocks in the other two zones, they are applicable for some blocks of the central zone.

Table 4: Electricity units variation for the years 1999, 2005 and 2008

Electricity units	30 Square metres habitable floor space (1999)	50 Square metres habitable floor space (2005)	130 Square metres habitable floor space (2008)
12 lighting units	360 units	600 units	1560 units
6 Fan units	180 units	300 units	780 units
4 AC units	120 units	200 units	520 units
TOTAL	660 units	1100	2860 units

Source: Monterosso, [4]

In addition to the increase in the habitable floor space, there is another factor of the urban form affecting energy consumption pattern. It is the way the new multi storey buildings have been constructed. Despite the existence of scheme that guides the setting of buildings in Kariakoo, the way buildings were being constructed was not following the redevelopment guidelines. The location of openings was not following the minimum technical standards for in-door natural ventilation and natural lighting.

Inappropriate spacing between buildings blocks natural ventilation and natural lighting into the in-door space. It is common to see multi storey buildings juxtaposed next to each other with windows on their four sides. Yet some buildings casting shadows in the adjacent in-door environment of the abutting buildings (Photo 4). This situation compels space users to deploy mechanical means to provide lighting and ventilation. Ultimately, this culminates into increase in energy consumption patterns. For example, the distance between four buildings was measured at 1.55 metres (B4 and B-3). The distance between B-2 and B-1 was 2.03 metres. The minimum set-backs as recommended by the Building Regulations of 1996 for sides and rear high density plots was 3 metres (Table 5). However, the distances to the street of B-4 and B-1 were only 0.97 and 0.79 metres respectively. Similarly, the distance between B-3 and B-2 was 0.82 metres (Figure 9). Consequently, buildings are compactly sited with limited air circulation and sun light in the indoor spaces.

Photo 4: Compactly built houses blocking natural lighting and ventilation (Source: Monterosso, [4])

Table 5: Town and planning space standards, building lines and set backs

Plot Size	Setbacks (metres)		
	Front	Sides	Rear
High density	3.0	1.5	2.0
Medium density	3.0	3.0	5.0
Low density	5.0	4.0	10.0

Source: URT [10].

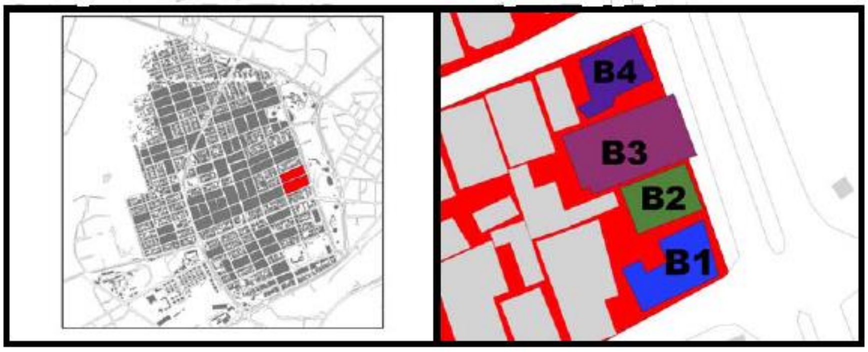


Fig-9: Observed distance between buildings (*Source:* Monterosso, [4])

The problem is not only limited to one building or one user but to several buildings and users. The compact layout of buildings limits cross-ventilation with some rooms necessitating the installation of air conditioners. Although the purpose of this analysis is not to give the exact figures of dark rooms during daytime it serves to show how urban transformations in Kariakoo is impacting significantly on the increase in energy consumption patterns during daytime because of the need for artificial lighting and ventilation.

In-door environment variations

Despite the fact that all measurements were taken within the same season and within the same altitude conditions, the outdoor and indoor temperature varied in some buildings. These variations coincided with three external factors: the time of the day when measurements were taken, the floor level and the orientation of the building (Figure 10).

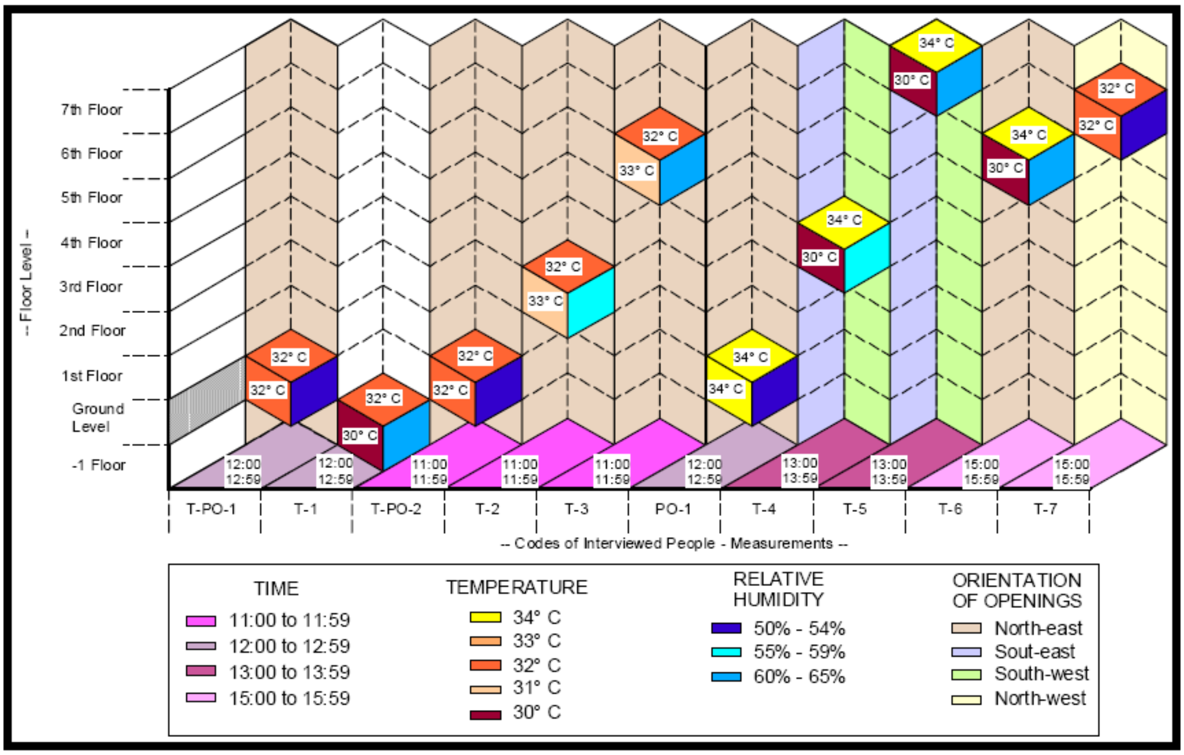


Fig-10: Climatic conditions at different floor levels (Source: Monterosso[4])

Building one comprised of T-PO-1 and T-1. Building two were T-PO- 2, T-2 and T-3; Building three comprised of T-4, T-5 and PO-1. Building Four had only T-6 and Building five comprised of T-7. The measurements taken in Building one were within the same time range and had the same out-door temperature of 32^0C. However, the in-door temperature varied from 30^0C in shop T-1 to 32^0C in shop TPO-1. This variation was attributed to the orientation and location of the building namely; T-1 was located underground the plinth level and there was no electricity while doing the measurements, the temperature was observed to be two degrees lower than the outside shop on the street because the latter was receiving direct heat from the sun. Measurements in Building two were taken under the same time range, between 11:00 and 11:59, all of their openings were facing to the north east and all of them were experiencing the same out-door temperature of 32^0C. The indoor temperature T-PO-2, T-2 and T-3 varied from 32^0C to 33^0C. These variations coincided with the change of the floor level being one degree higher for the second and fifth floor. The relative humidity also increased from 50 to 54 percent in the ground floor to 60 percent and 65 percent in the fifth floor. The measurements done in building three expressed the same out-door temperature of 34^0C but with different orientation and different time range. The in-door temperature remained as 30^0C for T-4 and T-5 and 34^0C for P0-1; however the relative humidity also increased from 60 to 65 percent with increase in height of the floor level. For the case of building four, T-6 revealed an out-door temperature of 34^0C and an in-door temperature of 30^0C. The relative humidity ranged between 60 and 64 percent. Although relative humidity usually decreases with height from the ground, in this case, the opposite was prevailing. This was mainly attributed to the compact development of buildings and limited ventilation in the upper floors apparently because of the compact nature of the built form. Building five, T-7 had the same temperature for the out-door and indoor spaces despite the fact that it was located on the 7th floor.

Photo 5: Two buildings with blocked lighting and ventilation: the case of T-4 and T-5, located along Lumumba Street (Source: Based on fieldwork studies in Kariakoo area, March 2008).

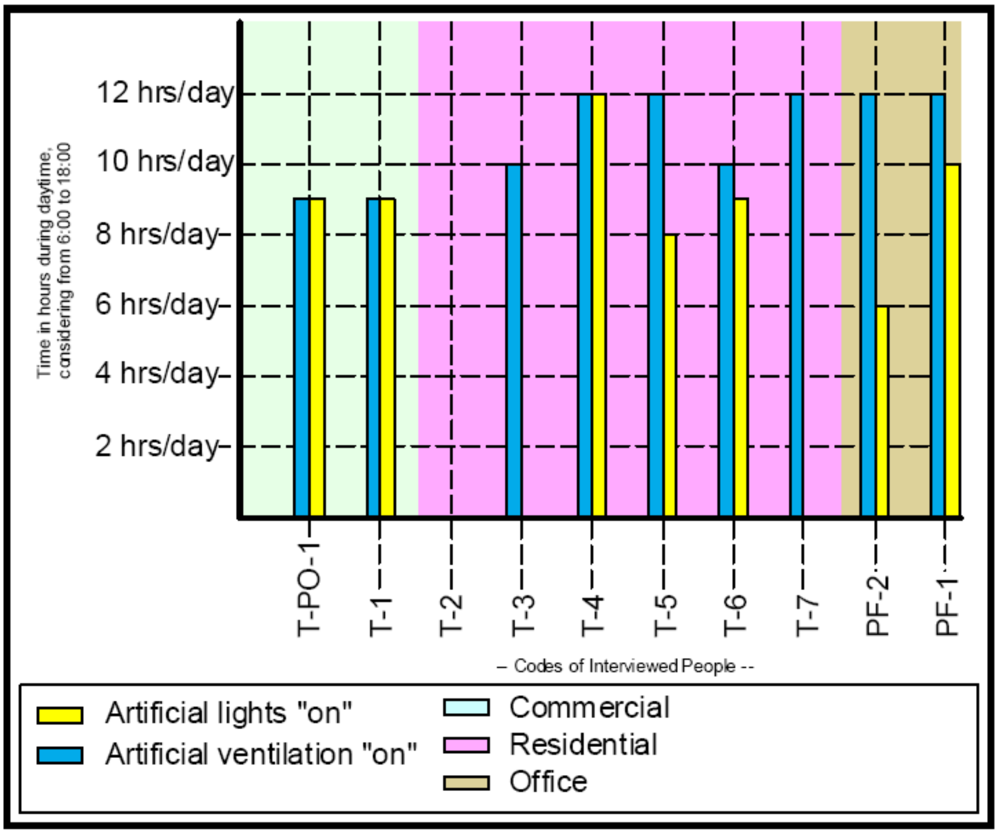
The general picture that emerges from these measurements is that the in-door environment was dependent on the following external factors; out-door air temperature, the orientation of the openings, the area of the in-door space, the volume of the in-door space, the relative humidity, the floor level and the time when measurement were taken. However, the most significant impact came from the orientation of the openings. Natural lighting and natural ventilation was highly affected by the characteristics of the space that the in-door openings faced. For example, if the opening was facing an open area the in-door environment was more comfortable. However, if it was facing another building within a short distance, the in-door environment was uncomfortable.

Spatial adaptability to achieve thermal and visual comfort

Use of artificial lighting and ventilation during day and night times

The spatial adaptability for visual and thermal comfort was captured from seven interviewed tenants and two professionals. One shop keeper responded as follows; *'we switch on lights and fans from the time we open the shop until the time we close'.* Within the residential spaces T-2, T-3 and T-7, residents were not using artificial lighting during daytime instead; they had openings facing an open space to the North West. Residents in T-5 and T-6 switched on the lights for eight and nine hours respectively. They had their openings juxtaposed to a neighbouring building which blocked natural lighting. The latter had an advantage of being in upper levels (T-6: Fifth floor and T-5: Seventh floor). The most critical case was T-4, which was in the third level and was facing two neighbouring buildings. The neighbouring buildings blocked both the natural lighting and ventilation. This situation forced the users to switch on lights and fans for the whole day, from 6:00 to 18:00 (Figure 11).

In the office space PF-2 air conditioning machines were used during the daytime for 12 hours. One respondent reported that: *"we open the office from 8.00 to 20.00 hours. We switch lights for approximately 6 hours per day".* One respondent in PF-1 stated that: *"we use artificial ventilation (fans) for 12 hours of the day and lights are on for approximately 10 hours".* It was further observed that each space user had different energy consumption pattern, which was determined by the kind of activities undertaken in each space. For example, the office spaces needed more electricity during daytime than residential that needed more electricity during night time. Yet, the use of artificial lighting during day time was inevitable in residential houses whenever neighbouring buildings were blocking natural lighting.



Figu-11: Average daily time of utilization of artificial lighting and ventilation (Source: Based on fieldwork, March 2008).

Achieving thermal and visual comfort

The use of artificial lighting and ventilation was analyzed in detail in T-4 and T-5 because both cases had the same orientation, time of measurement and location conditions. They experienced different in-door environment because of varying floor levels. Therefore, the in-door space utilization as a response to the new urban form impacted on their energy consumption patterns in different ways. While users in T-4 had to switch on the lights during day time because of blocked sun lighting in the sitting room there was no need of switching on lights in T-5 because windows were less blocked by the neighbouring building (Photo 6). In T-4 (T-4 Lights Off) the curtains were closed because the neighbouring windows were very close to the adjacent building. The closing of curtains was an attempt to ensure privacy.

Photo 6: Pictures taken in T-4 and T-5 (Source: Based on fieldwork studies in Kariakoo by Monterosso, March 2008)

When users were asked about in-door comfort, they explained the difference of the indoor conditions before and after the construction of the neighbouring buildings. One respondent T-4 said: ...*"the most comfortable space was the balcony. However, the place is no more comfortable because the adjacent building has blocked the cross ventilation".* In costal tropical climate zones like Dar es Salaam City, one of the design requirements for indoor comfort is minimization of solar radiation and maximization of cross ventilation. This was partly reported by one responded in T-5 who said that; *"the most comfortable place of the in-door space is the second bedroom which is located in the middle of the house. It has less contact from sunshine".* A closer examination of photo 6 revealed a difference on how the colour of the neighbouring rooms was brighter in T-5 than in T-4. The difference was attributed to the floor level of T-4 which was located in the third floor and with less sun light as compared to T-5 which was located in the seventh floor with more exposure to sun light.

Cost implications of increased utilization of electricity

Artificial lighting and ventilation was contributing significantly to monthly electricity bills especially to tenants. The monthly bill varied according to the size and type of space in use. The emerging pattern was low for commercial, medium for residential and high for office accommodation. As shown in Figure 11, lighting units were less costly as compared to air conditioning units. Air conditioning units were the highest consumers of electricity followed by fans. Comparing the cases of T-5 and T-6; it was revealed that while T-5 had twelve lighting units and T-6 has six lighting units, T-6 had an average monthly electricity bill of Tanzanian Shillings 100,000 (equivalent to US$ 59), T-5 was paying Tanzanian Shillings 50,000 (equivalent to US$ 29.5) monthly (Figure 11). Air conditioning doubled the costs of electricity as compared to other devices.

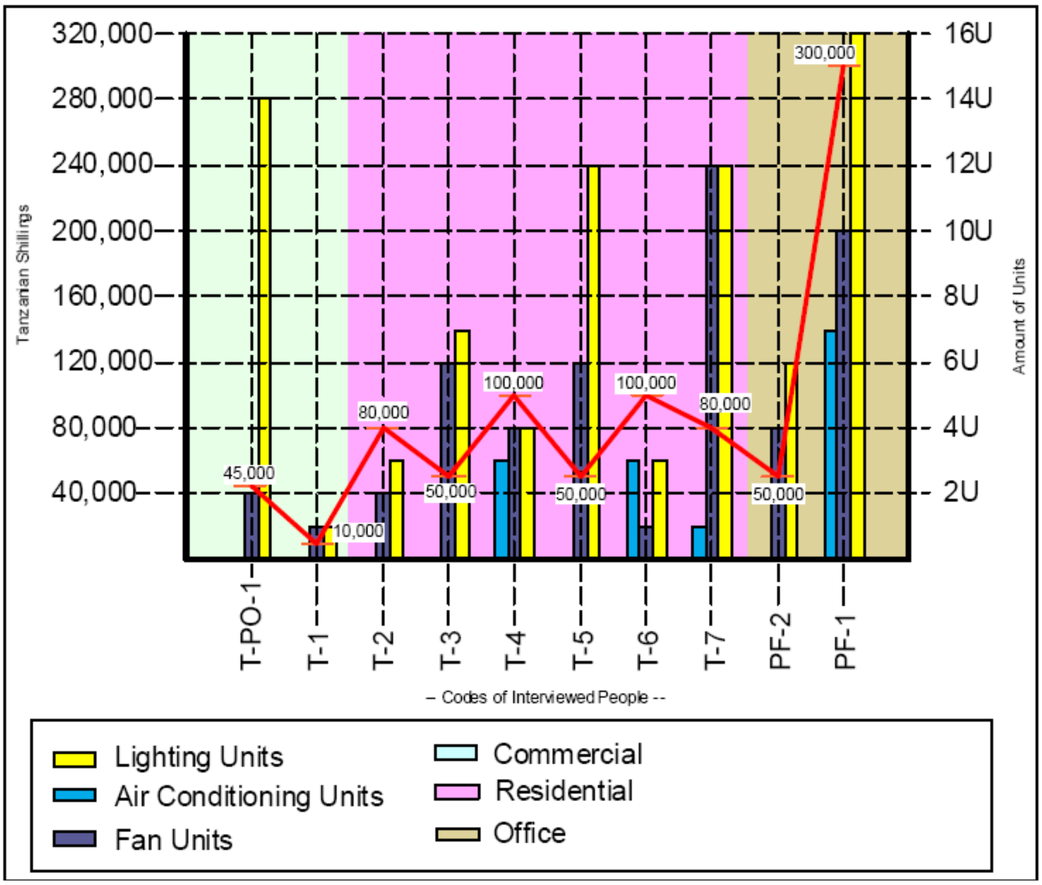


Fig-12: Energy Consumption Costs Implications for Commercial, Residential and Office Units in Kariakoo (Source: Interviews conducted during Fieldwork)

Perception of space users on energy saving

Although some stakeholders raised a concern over energy efficient buildings as a strategy for saving energy, their concerns were yet to be translated into effective strategies to create the anticipated impact. Responses from these people were as follows:

- *"it is possible to save energy using switches operated with sensors, allowing light to be "on" when somebody is in the room and "off" when somebody leaves the room; or also by using automatic lighting systems with timer that at 18:00hours lights are "on" and at 6:00 lights are "off". He also commented on the importance of saving energy: "It saves money because one does not use electricity unnecessary" (response from an investor of Kariakoo).*
- *… "with the utilization of multiple systems for air conditioning instead of a central system is possible to save energy but it depends on the system installed" (responses from electrical engineer and an architect).*
- *…"when a designer considers the orientation of the openings, the size of the openings, the building materials and the volume of air to be contained in the indoor space to have a better design that takes into account energy use in buildings (response from an architect)".*
- *"It helps to save money; also to have the behaviour of saving energy. It is not good to misuse resources, use the resources economically in order to help the other people who need the service" (response from a user).*

DISCUSSION

Emerging from the foregoing section, it is apparent that the key factors that influence increased energy utilization include; size and type of use of space, space location, location within the building and the spatial setting of buildings. Energy (electricity) consumption pattern increased as a result of spatial adaptability of users to the changing in-door environments. Residents used artificial lighting and ventilation during daytime in order to achieve thermal and visual comfort. The increase of energy utilization during daytime had implications on the monthly bill to pay. Bills increase more than twice when one was using air conditioning as compared to fans and they also varied depending on whether the space use was for residential, commercial or office. The Tanzania's Development Vision 2025 indicates that Tanzania's energy demand and end-use structure is still at a low level of development. It has been estimated that about 92 per cent of the final energy consumption at national level is still coming from wood-fuels. Only 0.8 per cent is coming from electricity and 7.2 per cent from petroleum fuels[11]. The National Development Goal underscores that availability of energy is prerequisite for the proper functioning and development of all sectors of the national economy. The Development Goal also recognizes the importance of reliable and accessible energy supplies to facilitate the development of economic activities in the economy while ensuring environmental sustainability [11]. The Vision underscores the need for: encouraging investments in the development of alternative sources of energy; promoting sub-regional and regional cooperation to integrate the national grid with the regional grid; putting in place incentives and regulations to ensure an appropriate balance in the ecosystem and establishing a system of production, procurement, transportation, distribution and end-use that is efficient and environmentally friendly.

With regard to spatial pattern against energy uses, one may argue that the lack of enforcement of existing building regulations and standards are contributory factors to poor quality built forms leading to increased energy utilization. While the Redevelopment Scheme for Kariakoo provides for guidelines on plot coverage, floor area ratio, building height and setbacks, there is a considerable difference between actual implementation on the ground and provisions. On the other hand, building regulations don’t address detailed architectural standards for buildings that have a bearing on indoor living conditions. Critical issues such as minimum air volume per person, minimum opening area per space volume, minimum percentage for ventilation or openings for windows, minimum distance between two windows from one building to another and other technical standards are lacking. Requirements for technical issues such as electricity, water supply, drainage, air conditioning and other services are also lacking. Apart from regulations, Tanzania is yet to put in place incentives to promote energy efficient buildings. Similarly, energy production, supply and demand in buildings is yet to be coordinated to bring together energy suppliers, local authorities and users to effectively manage and improve energy utilization in newly transforming urban centres of Tanzania.

CONCLUSION AND RECOMMENDATIONS

This paper has shown that the on-going building transformations in Kariakoo will culminate into increased number of habitable floor space in the near future. This situation will have an impact on electricity demand, which will increase hand in hand with the physical transformations. It has been also shown that the in-door environment depends on many external variables. The most significant impact comes from the floor level, the orientation of the building openings and spatial organisation of the buildings. The characteristics of the space that the in-door openings face determine whether the in-door space is going to be comfortable or less comfortable. For example, if the building is facing another building within a short distance between the two, it makes the in-door environment less comfortable than the one which is facing an open area. Although multi-storey buildings optimise the valuable land by accommodating more functions and people over the same plot, they also increase the demand for electricity, which has to be managed more efficiently. Energy efficient use largely depends on spatial design of buildings and spacing of such buildings to optimize natural lighting and cross ventilation. In order to optimize energy use in buildings, the following have been recommended:

(i) Establish detailed and specific guidelines for architectural design (indoor and outdoor), structural design, electricity and other services (including air conditioning, lighting and power) and put in place mechanisms for effective enforcement and abidance to these regulations. Outside devices of air conditioning units also produce noise pollution which also has to be considered. These regulations should be adapted to the local conditions and should be scientifically verified.

(ii) At national level, appropriate legal framework on energy efficient use is now wanting. This framework ought to be reinforced in order to moderate energy use in the building sector. This should not only be the responsibility of authorities but also other stakeholders involved in the utilization of energy. Environmental discomfort cannot be solved only by natural means; however, mechanical means should be reduced to a minimum to limit extreme use of non-renewable energy such as electricity. Building energy consumption patterns can be moderated with appropriate urban, architectural and electrical design. Standardization and effective development control are critical instruments to achieve sustainable energy efficient utilization in the building sector.

(iii) Since current plans and regulations are not enough to improve the construction of buildings towards energy efficient utilization, local authorities should establish strategic partnerships with other actors for improved implementation of the plans already supported by national authorities and the community. There is also a need of a strong support from the national level in the enforcement of building regulations and development control.

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