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Analysis of Inter - Connectivity Levels of Urban Street Networks and Social Interactions in Enclosed Neighbourhood in Johannesburg RSA

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Abstract: Many urban residential neighbourhoods are fractionated into mosaics of privatised territories through road closures. This crime-induced urban space adjustment has consequences on the urban network efficiency and the performance of city systems especially in increasing social and economic distances on different groups in the city. The paper attempts to measure effect of road closures on interconnectivity levels of Johannesburg in a GIS platform. It classified the city into different efficiency indexes based on the connectivity level. Using Northern Johannesburg as test case it presents a model to compare neighbourhoods interconnectivity efficiency and present comparative potential of the city based on physical connectivity. It concluded by linking physical connectivity with social connectivity.

Key words: Interconnectivity % permeability % road closures % residential neighbourhoods

INTRODUCTION

Road closures are fast becoming the primary crime control strategies in many African cities. Road closure has been observed to be the least cost approach to neighbourhood crime control. However enclosed neighbourhoods have been criticized for the inconvenience they cause other urban space users especially the motorists and pedestrian, who need to use the closed access to get to their destinations; they hinder access or increase distance travel. Enclosures reduce network permeability in urban system and make it difficult to penetrate through the streets to join arterial roads. The problems of enclosed neighbourhoods have become a challenge to urban managers and other urban gatekeepers in urban administrations, service delivery and distribution of goods in the city. When cities are increasingly fractionated into self-governed territories, accessibility are restricted with attendant problems such as low connectivity to urban services, poor delivery of goods and services; the city markedly becomes less efficient and less productive.

Transportation is the major pivot upon which the city systems subsist, therefore the level of interconnectivity of different segments of the city is a measure of performance of different components of the city and the efficiency of the entire city systems.

This paper attempts a measure of interconnectivity of the city of Johannesburg with the view of providing a model of identifying impacts of enclosed neighbourhoods in the interconnectivity of urban systems. Urban road networks are designed to enhance movement of people, goods and services within urban system, when such roads or links are withdrawn from public use or converted to the use of few; the performance of the city negatively affected. Therefore, permeability or accessibility in an urban system can be estimated at the neighbourhood or from the perspective of the entire city systems to evaluate the efficiency of the cities or neighbourhoods. It is easy to judge a city as efficient if it is well connected to major urban facilities and services; thus the level of performance of such neighbourhood is a function of their connectivity to major nodes of urban functions and service centres or other members of the society. Connectivity index also explains the level of social and economic connectivity in the urban systems.

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The problems associated with withdrawal of access links from urban road network through enclosed neighbourhoods have been variously identified by researchers, authors and enthusiasts on the subject and are succinctly articulated as follows:

- Enclosed neighbourhoods increased reaction time of emergency services
- Enclosure divert traffic to alternative adjacent roads thus causing traffic congestion and surface damage to those roads that are forced to cater for traffic that they are not originally designed for.
- Enclosed neighbourhoods cause impact on the entire networks; especially major arterial roads are subjected to increased traffic as more residential roads are withdrawn from public use.
- Roads networks within the enclosed neighbourhoods tend to deteriorate faster, breaking up when the tar surface is not constantly being compacted.
- Access to service functions, such as water electricity and waste removal becomes difficult as longer time is spent at egress points or during detours.
- Results in longer distances and increased travel time travelled by residents, visitors and other road users.
- When enclosed neighbourhoods have public facilities, such as golf club, schools shopping centres; access to these facilities are greatly hindered by road closure.
- The city's legibility and imageability are negatively affected. (more difficult to give directions to strangers in the city when many streets are enclosed.)
- Access to home business within the enclosure becomes difficult and people working in the neighbourhoods, but live elsewhere like domestic workers and service providers have to travel longer distances to get to their work places.

The impacts of road closures have also been variously examined in the socio, political contexts such as Webster [1], Landman [2] and Fabiyi [3]. However there are yet to be a measurable impact of enclosed neighbourhoods on the performance and interconnectivity of urban systems. This paper seek to fill the gap by providing an attempt to measure the impact of road closures in the interconnectivity of the city of Johannesburg, thus providing basis for further research on the influence of privatisation on urban efficiencies.

Permeability or interconnectivity index provides a scale of measuring the impacts of neighbourhood enclosures on the urban systems. Social distance is related to physical distances; therefore a measure of withdrawal of access links (through privatisation) from urban network system provides insight into the segregation and thus reduction in social connectivity in the city. Connectivity is a measure of a network [4, 5], there are different approaches used to calculating the values of connectivity in a network. The popular one is *gamma* index The gamma index ( ) compares the number of links (L) in a given network to the maximum possible number of links between nodes. This is done by providing a ratio of the two (links). The approach was integrated in a GIS platform for the purpose of calculating permeability ratio (permeability index PI) in this study.

Aim of the study: This study examine the permeability index of the city of Johannesburg, using the level of access withdrawn from public use as basis for calculating permeability or connectivity level. It also examines the relationships of permeability level and social interactions among residents of the enclosed neighbourhoods.

Objectives of study: The objectives of the study includes the following:

- To examine the nature and types of road closures in Johannesburg.
- To compute the level of withdrawal of public access in the enclosed neighbourhood of Northern Johannesburg.
- To examine the relationship between spatial and social connectivity in the northern Johannesburg

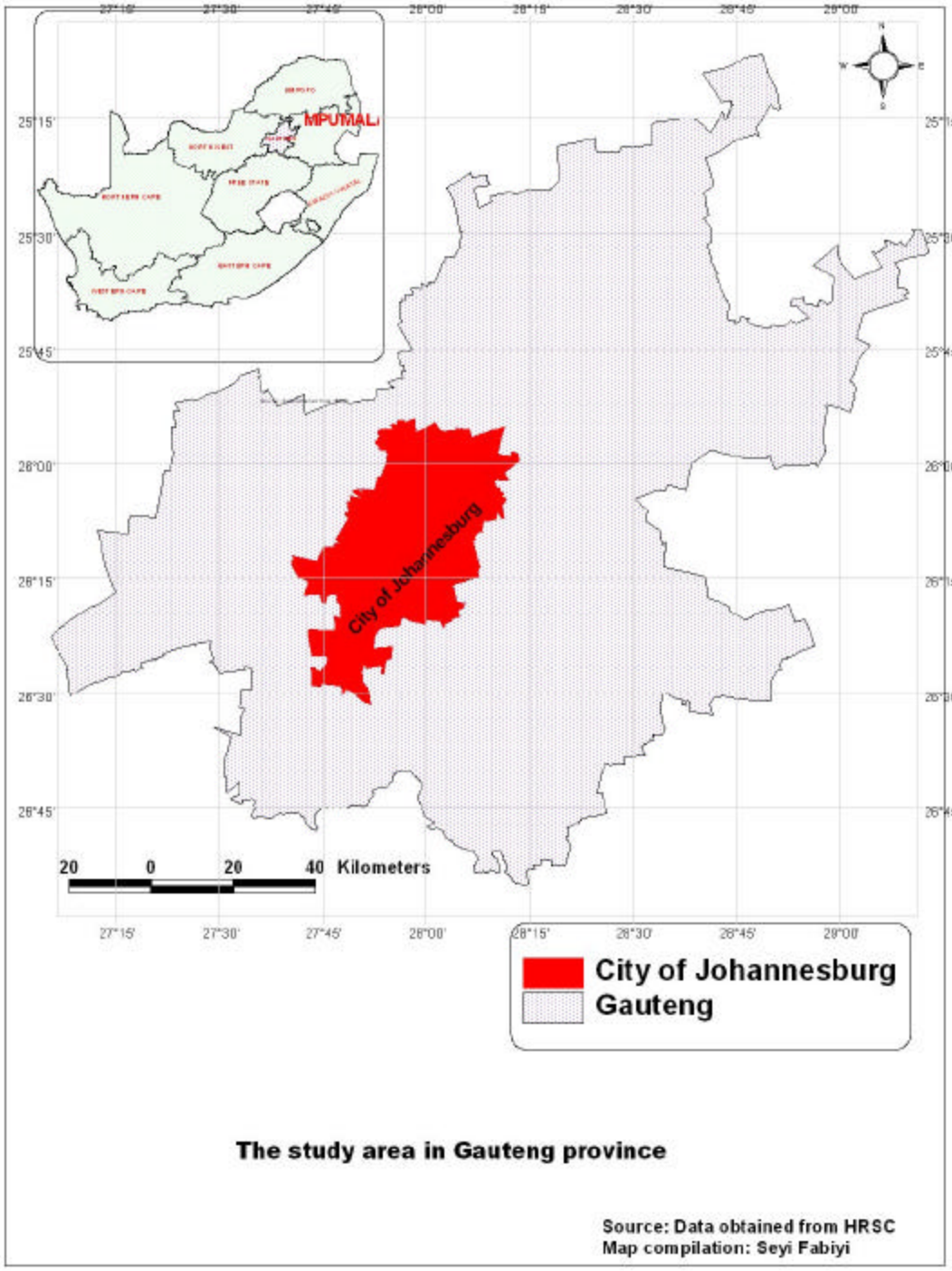


Fig. 1: Location of the study area

2a: Manned boom with camera watch

2b: Palisade gate permanently closed on residential road

Fig. 2a-d: Examples of road closures in Johannesburg

2c: Boom with security personnel give temporary tag to non residents

2d: Palisade fence across neighbourhood street

Fig. 2a-d: Examples of road closures in Johannesburg

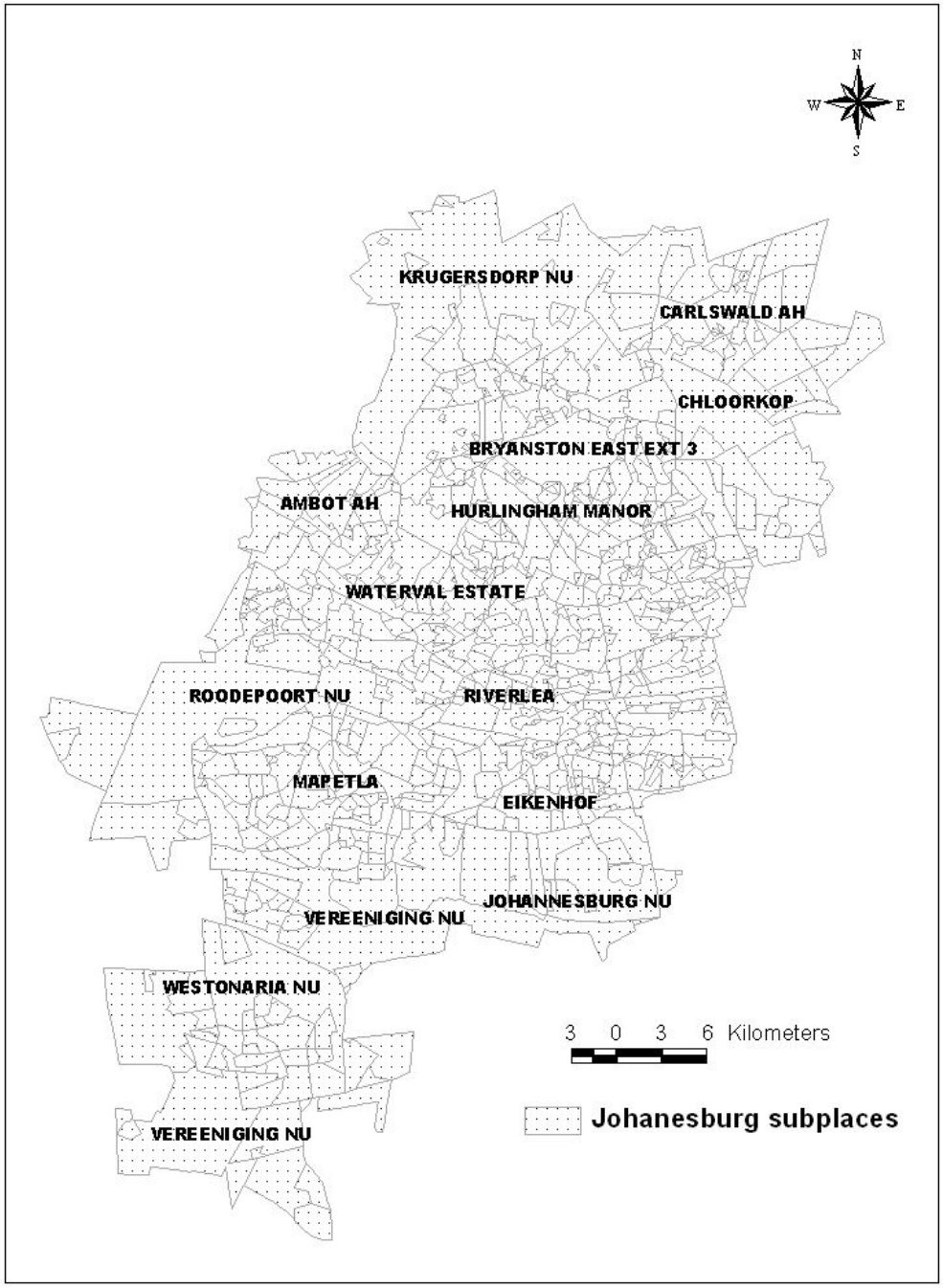


Fig. 3: The city of Johannesburg

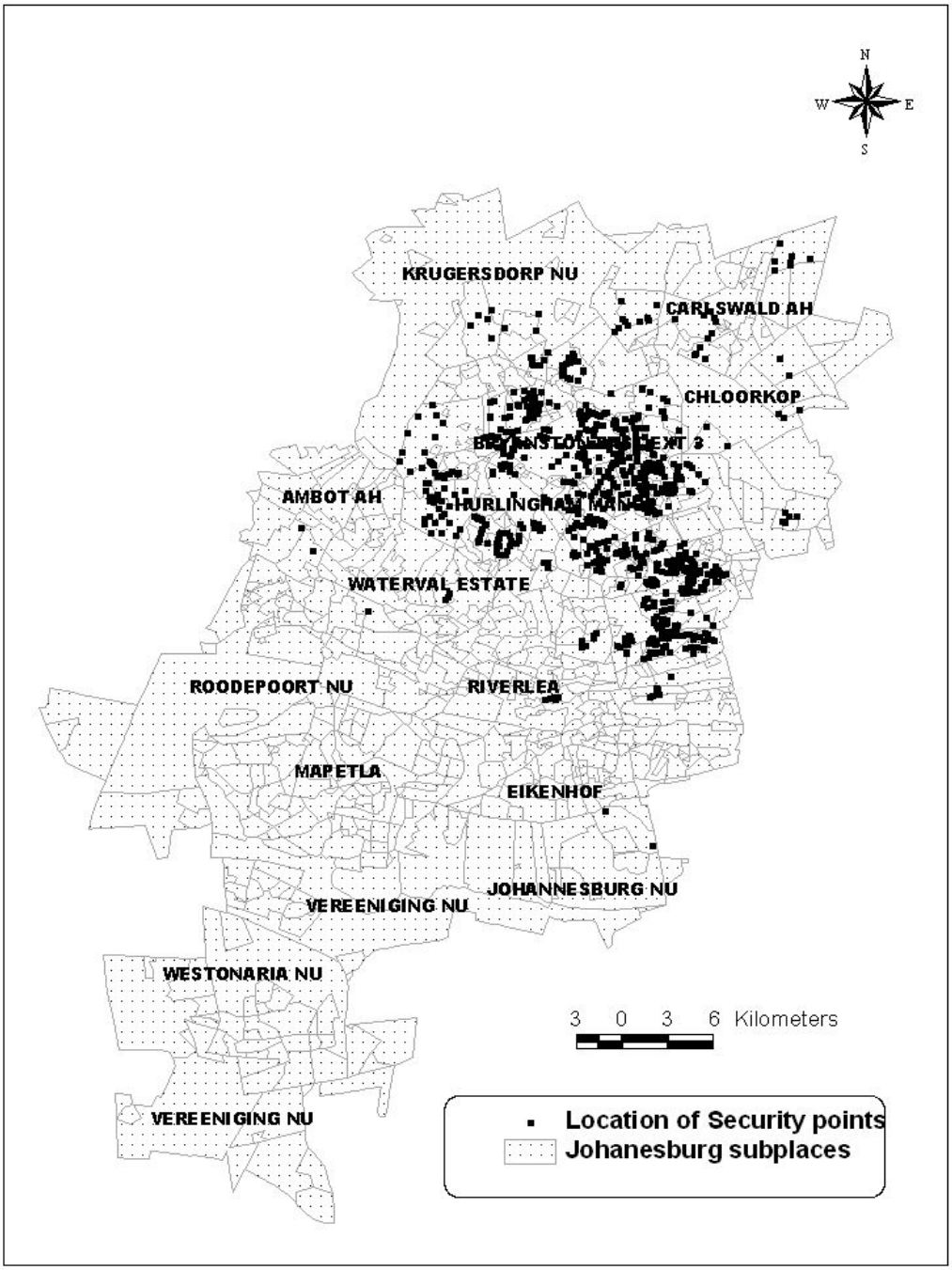


Fig. 4: Locations of road closures in Johannesburg

The study examines the hypothesis that there is a relationship between spatial connectivity and social connectivity in Johannesburg. The next section discusses road closure and social segregation in Johannesburg, section three discuses the methodology of the study while section four presents the results of the permeability index and social connectivity. The last section presents the conclusion and discussions.

ROAD CLOSURES AND SOCIAL DISTANCES IN JOHANNESBURG

The differences in the types and nature of enclosed neighbourhoods have significant implications for issues like travel behaviours [6], Social interaction [1] and responsible citizenships [2]. Authors have put forth viable typologies of gated communities [6-8]. Each of these typologies has different impacts on the urban population within and outside the enclosures (Fig. 1).

Road closures in Johannesburg emerged in the early 1990 with majority springing up between 1994 and 1998 (73%). There are different approaches to enclosures in Johannesburg but the dominant one involves closing off accesses into the neighbourhoods with palisade fences. The remaining outlest are restricted by booms or gates and controlled by security personnel (Fig. 2a-c).

The design of street network in the northern Johannesburg especially favours road closures at minimal cost. The townships in the central areas around Hillbrow and Yeoville, Hughton estate had *grid ion* street network design type, which requires more gates to close off the neighbourhoods. American *randburn* style is common in the northern suburb like Sandton, Brayston Woodmead and Benmore. While *garden city* approach dominates Melville, Auckland park, Parktowns, Hyde parks among others. Consequently in some neighbourhoods especially in the northern parts as shown in the typology of enclosures in the next sections, few road closures are required to enclose the neighbourhoods while more gates are requires in the down towns townships and inner city residential precincts.

Road closure in Johannesburg is clustered towards the northern parts of the city which are mostly white and affluent communities. The Southern half of the city has no form of road closure. Figure 3 shows the location of road closures in Johannesburg as obtained from Johannesburg Road Agency JRA [9].

Types of enclosed neighbourhoods in johannesburg: Five typologies of enclosed neighbourhoods could be differentiated in Johannesburg as presented in what follows:

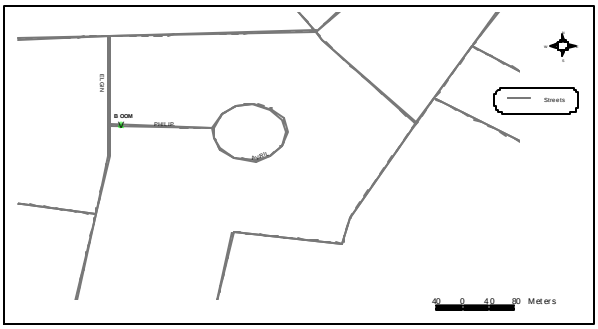
Type 1: Enclosed neighbourhoods: *Cul de sac enclosure* varies in sizes and the number of residents enclosed. Usually between ten (10) to thirty (30) dwellings. They are found where residential street is a dead- end or leads to public spaces or unused open lands. The egress point is usually one and could be controlled by a manned boom or electronically operated gate. In the case of electric gate, remote is given to residents to access gates. This represents a completely privatised street network (Fig. 5a) but has the least impact on connectivity levels of urban systems.

Type 2: Enclosed neighbourhoods: Crescent enclosed neighbourhoods are often utilised the road network design to carve out small enclosed neighbourhoods (Fig. 5b). The crescent is privatised with a permanently closed palisade gate while the electric gate at the other end of the street is controlled through remote control. This type is common along short streets and crescents.

Access of this example of type 2 enclosures is controlled by a boom as shown in Fig. 3, manned by a security personnel. The access is under surveillance for 24/7 by Security Company; visitors are required to register before accessing the neighbourhoods. Temporary tags are given to registered visitors when they are in the neighbourhood. In some cases only residents are allowed into the neighbourhood unmonitored.

Type 3: Multiple- streets single-entry point enclosed neighbourhoods: Multiple street single entry point enclosed neighbourhoods are the most dominant types of enclosure in the northeastern suburbs. It is adopted where there are many

(a)



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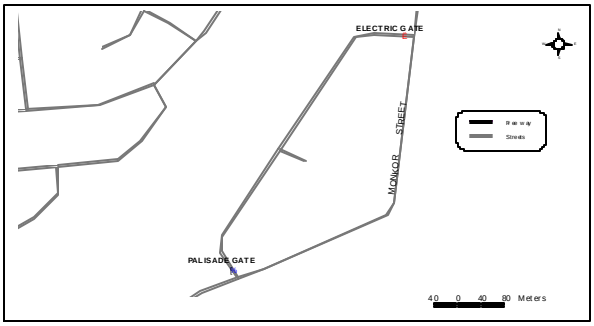

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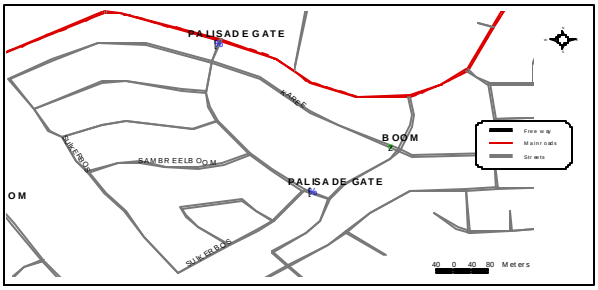

(d)

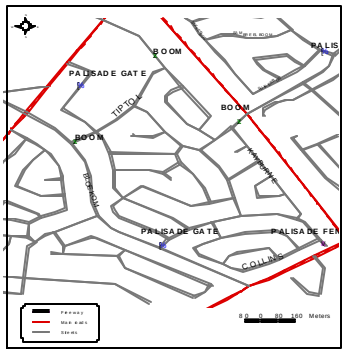

Fig. 5a-d: Types of enclosed neighbourhood in Johannesburg. (a): Cul-de sac type, (b) Crescent type, (c) Multiple streets single egress type (d), Multiple street many egress type

access points to neighbourhoods. More streets are thus enclosed in order to achieve complete restriction of access and reduce maintenance cost. Security personnel often man the entry point adjacent to a major road while other entry points are permanently closed off by palisade gate or fence (Fig. 5c). At the boom, visitors are watched and particulars are obtained. Tags or car stickers could be given to the residents to differentiate visitors from the residents.

Type 4: Multiple streets, multiple entry points enclosed neighbourhoods: These types of enclosed neighbourhood have multiple controlled accesses largely due to nature of street network. There are several access points, thus the neighbourhoods are fragmented by series of access points but still remain holistic entity by the fact that access through the neighbourhood is impossible. The cost of maintaining numerous egress points tend to encourage large neighbourhoods of this type (Fig. 5d). This type is common around grid ion neighborhood designs. Residents in such enclosed are usually forced to go through longer distances to get to their houses as they have to navigate to the egress points before redirecting their routes to their abode.

They also have greatest impact on urban system legibility imageability and permeability. The nature of street network, the cost of maintaining boom and the convenience of getting out of the neighbourhoods are issues often considered in the choice and location of controlled access restriction points (boom). Booms are controlled while the remaining types of gates are permanently closed. Often this type of enclosure involves large number of residents and strong neighbourhood association to manage and maintain. In some cases they may be managed by two or more neighbourhood associations: the associations thus have to agree and collaborate on joint security arrangement within the neighbourhoods.

Agglomeration and segregations factors in Johannesburg: These typologies of spatial fragmentations of urban systems results in different forms of agglomeration and consequent social distances of urban residents in Johannesburg. Johannesburg is a typical example of segregated community. This was principally due to the segregationist policy of apartheid governments and high social and economic inequalities in the systems.

Agglomeration and segregation refer to a process of clustering, wherein individuals and groups shifted and sorted out in space based on their sharing certain traits or activities in common or equal status. The structure of spatial agglomeration in Johannesburg has been well documented in different publications such as Tomlinson *et al*. [10] and Czegledy [11]. The segregation and agglomeration factors in the city of Johannesburg can be broadly classified into four in what follows:

Apartheid spatial engineering: The apartheid government created spatial boundaries of along racial and ethnic lines in the city. Even in Soweto there are agglomerations of people on the basis of ethnic groupings.

Developer's economic interest: The developers consciously define neighbours in their drive to attract customers to new developments. It is common to see advert claiming the environment is a white suburb and secured. Enclosed neighbourhoods are common in the northern new development. The people in these security villages adopt rules and norms that are imposed on them by the developers and the property management agencies. The price or values placed on property in a given neighbourhoods also serves as filter for potential occupant/residents. The property market in South Africa is very active and dynamic, thus very strong in realigning and sorting out urban residents in space.

Migrant or ethnic enclaves: Immigrant from other countries into South Africa especially form Zimbabwe, Nigeria, DRC (Democratic Republic of Congo), Mozambique and Cote-deivorie created migrant enclaves or neighbourhoods. New migrants seek temporary residence in these enclaves and sometimes the residences become permanent abodes. Some of these places were initially occupied by different social group but were gradually replaced by the migrants. Such neighbourhoods could be found around Berea, Hillbrow, Observatory and Alexandria.

Socio-economic factors: People of the same economic and social status will naturally locate in the same neighbourhoods due to their capacities to pay for housing. As people move from one economic class to another, the tendency is to move

residences. The price mechanism regroups people in urban space in time based on the economic positions of families. Discrete status enclaves are found in the city. Property business is very active in Johannesburg and thus residential mobility is very high The location of enclosed neighbourhoods is directly linked to social spatial agglomeration forces in the two cities.

JUSTIFICATION FOR INTERCONNECTIVITY MAPPING OF URBAN SPATIAL SYSTEMS

Social contacts among diverse community members (rich or poor white or black) start from streets, parks clubhouses and a number of informal communal spaces in urban areas. However when many streets are withdrawn form public use, it serve as major setback for urban integration and social connectivity. The street vitality, which depends on the nature, types and extent of interaction and street use, is a major requirement for social connectivity. Reduced connectivity inevitably reduces social capital in the city and negatively impact on the economy.

According to the World Bank [12], Social capital refers to the institutions, relationships and norms that shape the quantity of society's social interactions. The definition embraces the total stock of active social network that binds people, institutions and agencies together, in the form of trust, mutual understanding and the shared values and behaviours that hold members and communities together and even make co-operative action possible [13, 14]. While some types of enclosure encourage cooperative actions within the enclosures, especially smaller *cul de sac* and crescent, others larger ones unduly saddled few residents with the burden of common neighbourhood security. The tension resulting from this experience will further lead to apathy, breakdown of social cohesion and possible collapse of social capital.

METHODOLOGY

Spatial and social connectivity mapping: The road access data was obtained from Johannesburg Road agency (JRA) and was integrated with the road network data obtained from Human Science Research Council (HRSC). Pretoria including Street networks, Main roads and freeways in the GIS platform. The Access restriction points represent nodes or stops on networks. If a stop (road closure) is found on a network (residential street) between two main roads such link is considered inaccessible. An accessible link is residential street that could be used to link major roads without stops or barrier through the residential precinct. All the potential links (with or without barrier) were captured and stored as PAL (potential access link) while all links without any restrictions were extracted as stored as ACL (actual access links) *cul de sac* and other dead end streets were removed from the street network since they are not links to any major road.

The study area was restricted to the northern Johannesburg based on preponderance of enclosed neighbourhoods and time constraints. We used the major road networks to partition the study area into study zones or neighbourhoods. Permeability index was computed for each zone. Permeability index is a ratio of total length of actual access and the total length of potential access.

Social connectivity: The social interactions among the neighbourhoods were measured through attitude measurement questionnaire. The neighbourhood associations within the neighbourhoods were identified ans a sample of sixty two (62) NoAs were interviewed.

The questionnaires featured questions like do you agree that there is cordial relationships between members of this neighbourhoods, do you agree that there is cordial relationship between members of this neighbourhoods and adjacent neighbourhoods? Other questions include, how often do you meet together as members? do you know any available opportunities for socialisation among neighbourhood members? do you agree that these opportunity are maximally harnessed? among others.

The responses were ranked on a scale of 5-1, while strongly agreed score 5 and strongly disagree score 1. Most frequent meeting was scored 5 while the least frequent like once a year was scored 1. The scores were used as index of social

interactions or connectivity and the average score for the neighbourhoods were obtained. The responses were grouped into three classes of social connectivity measurement which are perception of individual that there is social connectivity or not within and with adjacent neighbourhoods, frequency of meeting and socialisation and knowledge of available opportunity for social interaction. The scores were used as variables in a spearman correlation analysis with the connectivity index.

Permeability index mapping: Permeability index mapping is an attempt to measure and map different levels of privatisation of road access within a city and could be used to compare privatisation levels of enclosed neighbourhoods among cities; either in the national or regional context.

The access control points are regarded as *nodes* or *stops* in the network, while residential streets are differentiated from main and arterial roads and regarded as links. Short *cul de sacs* were removed from the entire networks since they are not thorough access link in the networks. The length of all possible access links (potential links) were calculated in the GIS platforms and were saved as Potential access link (PAL), while all the streets that have *stop*s (i.e access restriction points) were removed from the potential access linked networks thus extracting Actual Access Link (ACL). The lengths of all potential access links and the length of all actual access links in each neighbourhoods were calculated and used to compute Access ratio for each neighbourhood (i.e. permeability index PI) index as shown in equation 1.

- Potential access link (PAL) is a neighbourhood street that serve as possible link from one main road to other main or arterial roads(with or without stops).
- Actual Access link (ACL) is a neighbourhoods street that link a major road to other major or arterial roads through the neighbourhoods without stop(node) or access restriction points
- Permeability index (PI) is therefore the ratio of total length (in meters) of neighbourhoods' Actual Access Link (ACL) and Total length (in meters) of Neighbourhoods' Potential Access link (PAL)
- Number of street links in a neighbourhood is denoted by n

ACL for a neighbourhood is computed as $\sum_{I=1}^{n} acl_i$

Which means the sum of $acl_1 + acl_2 + acl_3 + \ldots\ldots\ldots acl_n$

PAL for the neighbourhoods also represented by $\sum_{I=1}^{n} pal_i$

Which means the sum of $pal1 + pal_2 + pal_3 + \ldots\ldots + pal_n$

Therefore pi is computed thus

$$Pi = \frac{\sum_{i=1}^{n} acl_i}{\sum_{i=1}^{n} pal_i} \quad (1)$$

The permeability levels of the entire study area can be computed by the mean of all the neighbourhoods p_is as follows

$$Pi_N = \frac{SP_i}{N} \quad (2)$$

Where N is the total number of study neighbourhoods in the city or study area.

PI index is a value ranging between 0 and 1,When all the links within a neighbourhood are permeable; providing access between surrounding major transit roads through the neighbourhood, the PI index is equal to 1, if all the links are closed by

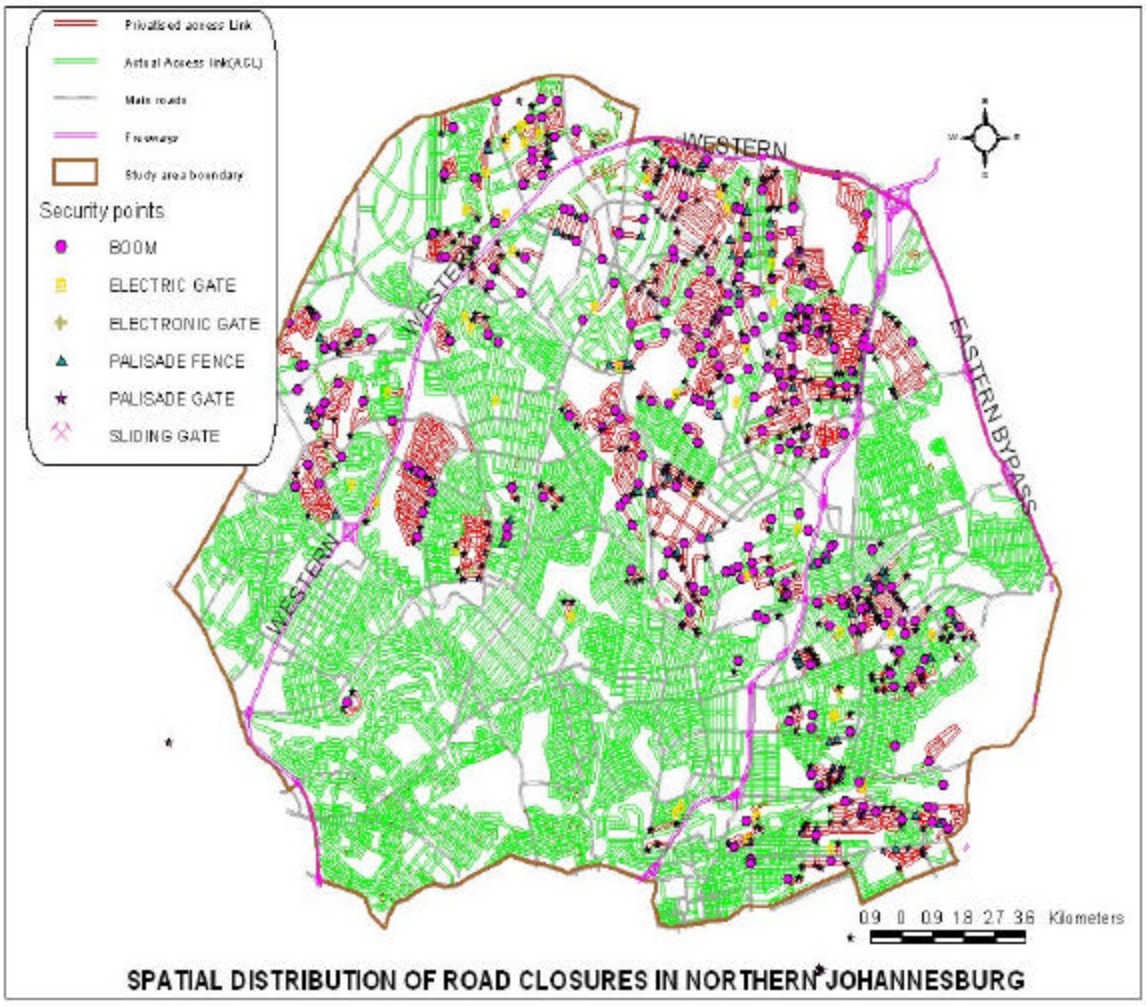

Fig 6: Spatial distribution of access restriction in Northern Johannesburg

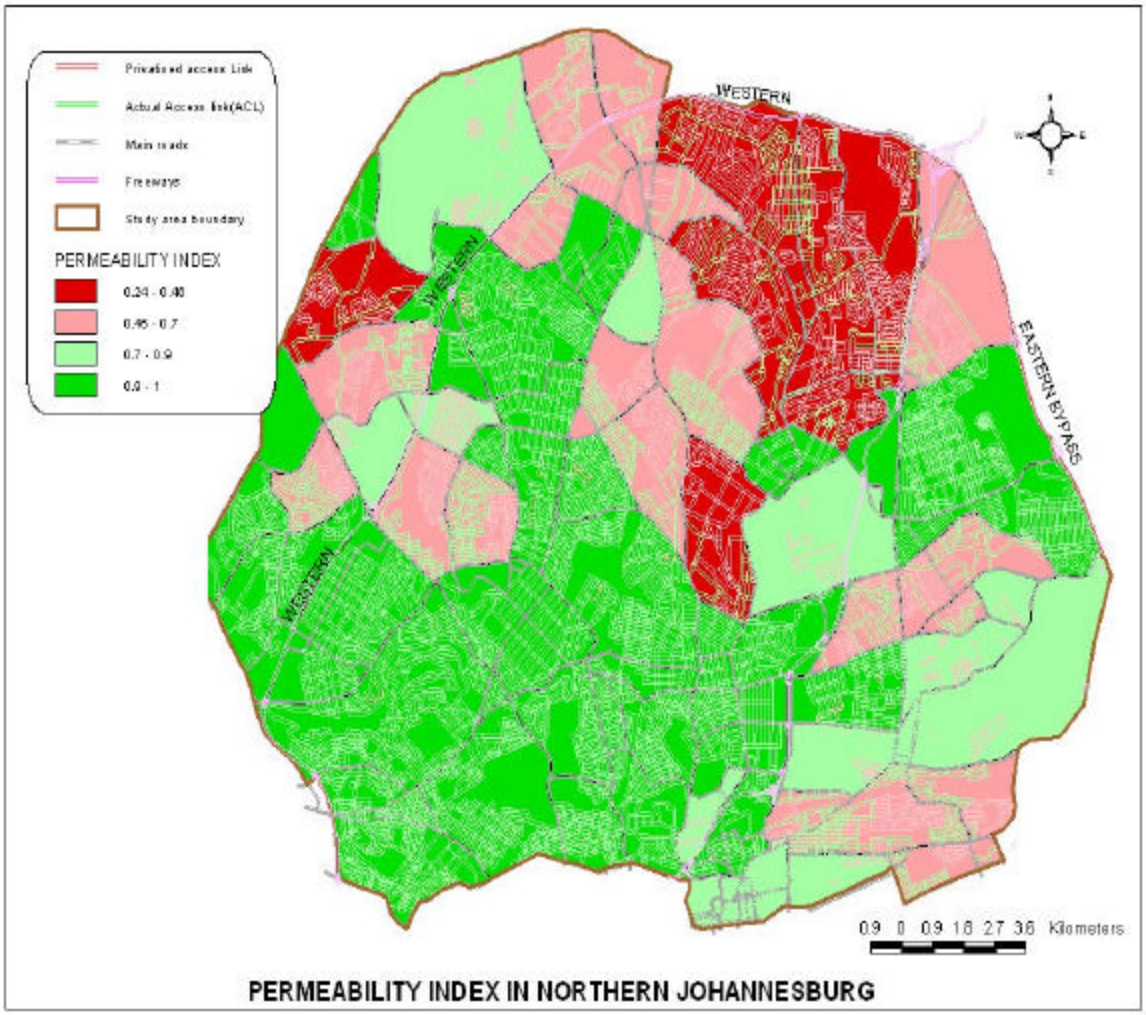

Fig. 7: Permeability index of northern Johannesburg

access restriction barriers (nodes) the neighbourhood has PI index of 0. The values in between these two extremes, measures the levels of accessibility or permeability within the neighbourhoods.

An average index could be computed for the city and thus provides basis to compare different cities in the regional context.

RESULTS OF ANALYSIS AND DISCUSSION

The study is restricted to Northern Johannesburg covering a total of 77 study zones and 735 stops. It has a total of 2563 possible links and 1932 actual access link within the neighbourhoods (Fig. 6).

Figure 6 shows that north eastern suburbs are less permeable compare to the inner city further south and the western parts of the city. It also shows that large enclosed neighbourhoods are common in the northeastern end and smaller enclosures are common in the south eastern and western ends of the study area. The permeability indices are presented in the Fig. 7.

Enclosed neighbourhoods and permeability: Neighbourhoods with low PI index shows condition of high privatisation, high travel cost and low social connectivity. Therefore the mores streets are withdrawn from public use the higher the travel cost for all urban residents both residents and non residents of enclosed neighbourhoods.

There have been some conflicting debates on the effects of enclosed neighbourhoods on the street use within the neighbourhood.

Connectivity index and social connect: The study further investigated the nature of social cohesion and connectivity among residents within the enclosed neighbourhoods and those outside the enclosed neighbourhoods.

Table1: Spearman Correlation coefficients permeability index and social connectivity index among the study cordons

Index of social connectivity	Correlation coefficients within neighbourhood
Perception of social connectivity within neighbourhood	0.497**
Perception of social connectivity with adjacent neighbourhood	-0.287*
Frequency of regular meeting and socialisation	0.392**
Knowledge of available opportunity for social interaction	0.302**

** Correlation is significant at the 0.01 level, * Correlation is significant at the 0.05 level

The analysis showed that the higher the permeability or connectivity level the higher is the level of social interaction (though very weak) within the neighbourhoods. There is however negative correlation between social connectivity and spatial connectivity with adjacent neighbourhoods. It shows that the residents believe they have better interaction with members of the neighbourhoods than members outside the neighbourhoods. It was also observed that the small enclosed neighbourhoods especially the *cul de sac* and the crescent types of enclosed neighbourhoods, there are high levels of social interactions but when the neighbourhood is large especially the multiple egress point enclosed neighbourhoods the interactions become more casual. The comments of the following executive members drive home the points.

"A few of us living in a couple of blocks in two streets meets every 4 to 8 weeks to improve on strategies to combat crime in our neighbourhoods…We are never formalised mostly my husband chaired the meetings and I took minutes but others sometimes took the chair.." Mrs Oniel

An executive member in Fairwood who had been in the neighbourhood for over ten years commented thus:

"People need to control their streets, reduce high walls, overlook the streets talk to neighbours, walk around the neighbourhoods keep properties in decent condition resist over crowding and absent slum lords…."

It clearly express what the NOAs aim at achiving but yet most could not. In most of the neighbourhoods, the members meet only annually while the executive meets once a month. The annual general meetings are the only available opportunities for members to know and interact with one another.

In some neighbourhoods the maintenance of the security points has been commissioned to private security companies, who collect fees from residents and present account during the annual general meetings. Therefore, the withdrawal of street networks does not necessarily translate to improve street use and social interactions. The residents in enclosed neighbourhoods further withdraw into their fortified houses and had little interactions with neighbours and other members of the enclosed neighbourhoods.

Social interactions among members within the enclosed neighbourhoods are further complicated by the differences in opinion on whether to enclose or not. The residents are thus divided into fee-paying members and objectors. These differences often lead to social tension as the report of South Africa Human right commission reveals;

" I found them (road closures) in place one day when I went to collect my post and was told I had to sign a register before entering…" SAHRC report of NDIBA (Open Forum Johannesburg 2005).

"An objector … had a swastika painted on her wall, objector at… have complained that security guards target them and in some instances booms have been dropped on their cars' SAHRC report of NDIBA" (Open Forum Johannesburg 2005)

"In ….. an electric gate was placed across a public road. Those residents who refused to contribute financially were not given remote and were forced to sign before the guards would let them in… to get to their homes.' SAHRC report of NDIBA" (Open Forum Johannesburg 2005)

"…..… had paint poured over her driveway with the inscription 'POES' drawn in the paint" SAHRC report of NDIBA (Open Forum Johannesburg 2005)

These agitations complaints that flood human right commission office is a clear indication that social interactions in the enclosed neighbourhoods of Johannesburg are rather low.

CONCLUSION AND POLICY IMPLICATIONS

City growth had always been associated with increased inequalities between the rich and the poor, when physical barrier is introduced through enclosures the gap can only become widen.

There are divergent views on the impact that enclosed neighbourhoods has on the development of social capital in the city, while a school of though believes that withdrawal of affluent urban residents into the enclosed neighbourhoods leads to increased social cohesion within group and high social connectivity, improved social capital, others school of thought view urban systems in holistic perspectives and suggest that a significant proportion of urban residents vital to development of social capital had been withdrawn from city systems which further leads to increased degeneration of the city and thus increased crime. Social connections enable people to build communities, commit themselves to each other and to mesh themselves into a complex social fabric. Without interactions between divergent groups of the society, trust decays and fear and suspicion prevails, at certain point in time the decay is translated into social vices such as crime and incivility. Social connectivity is weakly correlated with the spatial connectivity in the case of enclosed neighbourhoods. It is obvious that though enclosed neighbourhoods attempts to withdraw streets from the public to the exclusive reserve of a few with

the intention to increase street use and be freer outside homes, the case in Johannesburg is rather different as people further withdraw into their buildings. Enclosure in Johannesburg is thus not to preserve privacy but rather to increase security. It was also observed that majority of the residents in enclosed neighbourhoods subscribe to rapid response services of private security company [15]. The growth in enclosed neighbourhood in Johannesburg is no built on increased social interaction and community spirit rather it is a product of the activities of Private Security Company who promote the 'security goods' like enclosure and panic buttons.

Need for further study: This study is an attempt at quantitatively evaluating the impact of road closures on the social connectivity of enclosed neighbourhoods in the city.

However the results of the analysis reveals that PI index alone is not enough to measure social connectivity in enclosed neighbourhoods. It is necessary to factor some socio cultural differences as weighting of the PI index

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