SPATIO-TEMPORAL MODELLING & THE NEW URBAN AGENDA IN POST-APARTHEID SOUTH AFRICA

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ABSTRACT

This paper presents the potentialities of spatio-temporal modelling in transforming South Africa's previously marginalised townships. Using the Katlehong township in Ekurhuleni as a case study, the paper argues that the hitherto marginalised townships can benefit from a localised implementation of smart-city concepts as articulated in the Integrated Urban Development Framework. Instead of viewing townships as spaces of perpetual despair and hopelessness, the paper appreciates these areas as having the potential to benefit from new smart innovative planning approaches that form part of the Fourth Industrial Revolution. So, the discussion identifies smart transportation modes such as bicycle-sharing, as well as Bus Rapid Transit Networks as critical in promoting mobility in and beyond townships, while contributing to spatial integration and transformation. Using geolocation data, the paper concludes that formerly marginalised townships such as Katlehong can and must form part of the emergent smart cities in South Africa.

1. INTRODUCTION

1.1 Setting the Scene

The long and complex history of South Africa's racially bifurcated cities is known (Lemon, 1991; Parnell, 1993; Maylam, 1995; Dewar, 1995). Moreover, the post-apartheid state's efforts at addressing the injustices of the colonial/apartheid past particularly in cities has also been well-documented (Harrison *et al*, 2014; Mabin and Smit, 1997; Murray, 2008; Oranje and Berrisford, 2012; Parnell and Crankshaw, 2013). At the centre of the post-apartheid state since 1994, is radical spatial transformation. Underscoring this new urban agenda (Caprotti et al., 2017; Cohen, 2015) are various legislative and strategic spatial planning instruments all aimed at creating liveable and humane cities.

Whereas much has been done with regard to spatial transformation, the colonial/apartheid city-form remains, in the main, relatively intact. This is evinced by the present and expansion of relatively poor black townships in all major cities' peripheries. Moreover, the advent of hyper-urbanisation coupled with high-levels of unemployment, has resulted in the proliferation of informal settlements primarily in South Africa's major cities of Johannesburg, Durban and Cape Town (Harrison et al., 2015). In many ways, the black townships continue to symbolise – at least in part – the 'dark-side' of colonial/apartheid urban planning policies and practices (Flyvbjerg and Richardson, 2002: 44).

While the socio-spatial and economic marginalisation of townships remains a pressing challenge for millions of its residents; we present in this paper that townships can, and must be re-imagined and rebuilt as part of the broader spatial transformation agenda. This renaissance of townships can be enabled through the application of new planning techniques, as well as Planning Support Systems (PSS) (Mokoena, Musakwa and Moyo, 2017). Recently, the advent of the smart cities concepts as espoused in various non/governmental actors and the private sector promise to have the needed principles that can be localised for the renaissance of townships, as well as the integration of townships to the broader urban socio-economic, cultural and technological hubs. The use of no-motorised transport, as well as integrated urban transit infrastructure for instance, promote effective and sustainable mobility of people, goods, and ideas, thus allowing for existing and new socio-economic activities to take flourish (Moyo, Musakwa and Mokoena, 2018). Moreover, the embrace of big data as well as new spatial planning and modelling technologies, is likely to contribute to effective planning in townships.

In this paper, we present potentialities of using spatio-temporal modelling in transforming South Africa's previously marginalised townships. Using the Katlehong township in Ekurhuleni as a case study, we argue that the hitherto marginalised townships can benefit from a localised implementation of smart-city concepts as articulated in the government's urban policies, notably the

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Integrated Urban Development Framework (IUDF), as well as the National Development Plan (NDP). Instead of viewing townships as spaces of perpetual despair and hopelessness, we appreciate these areas as having the potential to benefit from new smart innovative planning approaches that form part of the Fourth Industrial Revolution (4IR). So, the discussion identifies smart transportation modes such as bicycle-sharing, as well as Bust Rapid Transit (BRT) networks as critical in promoting mobility in townships, while connecting these spaces to the broader city-fabric, thus contributing to spatial integration and transformation.

2. RELATED WORK

2.1 A Brief note on Post-1994 South African Townships

As stated above, the current conditions of townships in South Africa have not changed much in terms of spatial form and design (Harrison et al., 2015). Well-over 40% of South Africa's urban population live in townships that are located away from the key areas of economic activities. Most of these townships continue to function as subordinate economies to the larger market as intended by the apartheid regime, through systematic under-investment. Given the rapid urbanisation characterising most of South African cities and towns; townships have become more dense and over populated. The proliferation of informal settlements and backyard has also complicated most townships' socio-spatial and economic milieu, as these spaces of informality are also characterised by poverty, unemployment and in some instances, high levels of crime.

Moreover, from a spatial planning perspective, the twin-challenges of rapid urbanisation and high levels of unemployment in townships exert a lot of pressure on municipalities to provide costly basic services, amenities and housing either for free or at a relatively low cost. All these developmental challenges unfold at a time when city governments world-over are compelled to implement pro-poor policies and initiatives in a context characterised by the intensification of global capitalism and its related neoliberal policies (Oranje and Berrisford, 2012). Interestingly, these developmental challenges faced by municipalities unfold in an era where new planning techniques and support systems are pushing local governments to innovatively embrace the Fourth Industrial Revolution and all that it promises to deliver. While on one hand this new 'revolution' is making life more savvy and 'smart' for cities with sophisticated infrastructural architecture; this era also poses a looming threat for under-resourced areas such as those found in South African townships were poverty and unemployment is rife. Notwithstanding, there is a need for urban planners to anticipate and balance these contending demands posed by the Fourth Industrial Revolution , as part of reconstituting a new form of South African urbanism (van Noorloos and Kloosterboer, 2018).

2.1 Key Urban Policy Interventions

The 1996 Constitution of the Republic of South Africa (South Africa, 1996) clearly outlines the role of all three spheres of government insofar as transforming the socio-spatial and economic milieu of municipalities is concerned. Moreover, the Constitution also has an elaborate Bill of Rights that guarantee justiciable socio-economic rights, notable the right to access to housing, water and other related services. These constitutional provisions are realised at municipal level through various policies such as Integrated Development Plans (IDPs), Spatial Development Frameworks (SDFs), the Township Economic Revitalisation Strategy (TERS) and the recently formulated Integrated Urban Development Framework (IUDF). All these policy measures are geared towards promoting spatial integration in post-apartheid cities.

From a smart cities perspective, the IUDF has identified nine policy levers and they include fostering; integrated urban planning and management; integrated transport and mobility; integrated urban infrastructure; efficient land governance and management; integrated sustainable human settlements; inclusive economic development among others (CoGTA, 2016: 8-9). These policy thrusts resonate with the broader smart cities principles that are aimed at making cities liveable through the use of smart and affordable technologies. The IUDF also prioritises an integrated approach to the creation of sustainable human settlements and efficient transport where complimentary, functional and relevant land uses and urban activities are accessible to all urban residents. The framework also strives to promote mixed housing options complimented by multimodal public transport, economic activity, sports facilities, clinics, libraries and business and commercial activity are some of the ways that integrated development can occur. Moreover, Transport Orientated Development is also highlighted as a priority, as it promotes the use of public transport instead of private cars usage, thus bringing about maximum usage of land in spatially targeted areas.

All the aforementioned planning policies are slowly but surely transforming the township space economy (see figure 1). In the City of Ekurhuleni for instance, the Township Regeneration Strategy (TRS) of Ekurhuleni is geared towards revitalising at least four previously disadvantaged areas sitting in four township nodes through the Neighbourhood Development Partnership Grant (City of Ekurhuleni, 2013). Kwesine being one of the nodes selected, is characterised by low density residential development, hostels, low to middle income households and a functional rail and railway station facility. The Strategy also strives to improve mobility through creating a hierarchy of access to reinforced public transport routes for TOD's, while also promoting pedestrian walkability and movement (City of Ekurhuleni, 2013). Mixed developments that include different housing typologies and densities are another focus area incorporating hostels and informal settlements through redevelopment and upgrading respectively (City of Ekurhuleni, 2013).

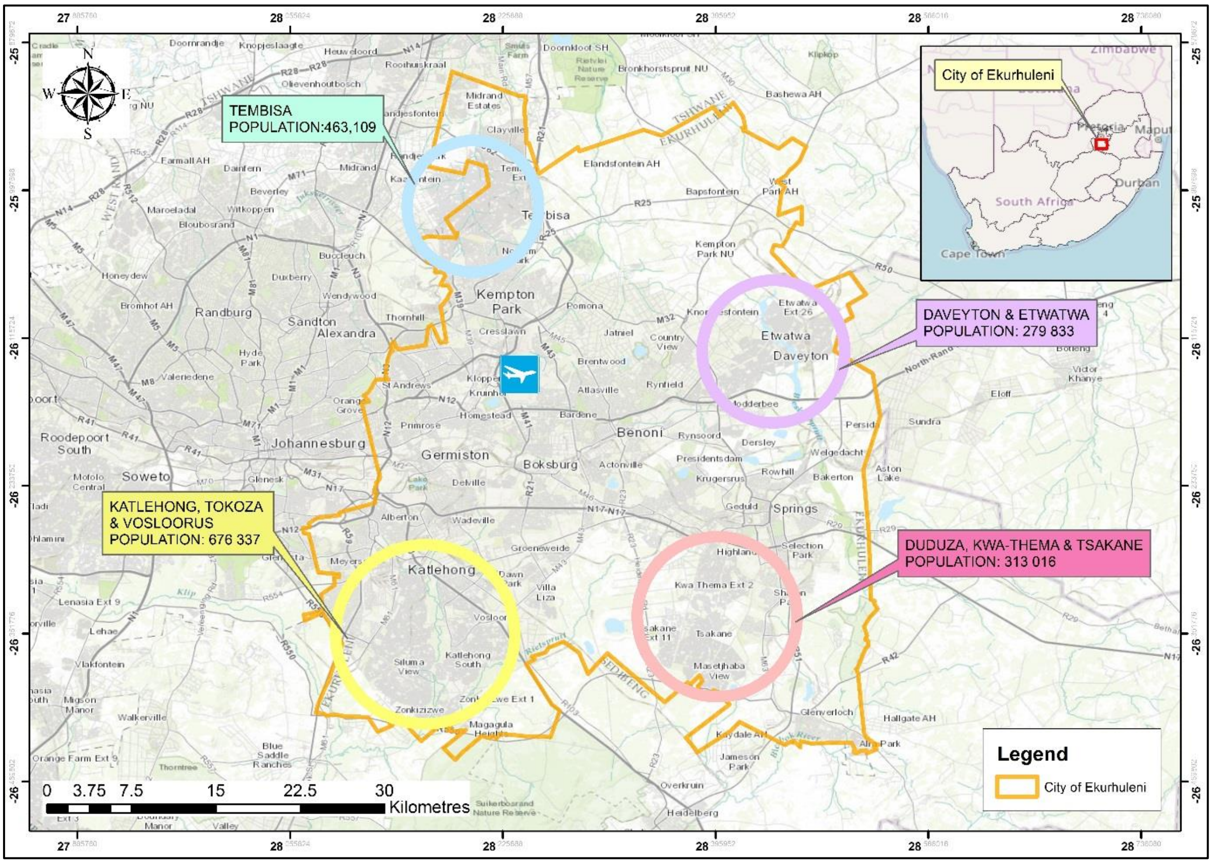

Figure 1: Location of Townships in City of Ekurhuleni

2.1 Connectivity and Related problems

To address the spatial segregation problem in developing countries, improving mobility systems has proven a viable option of link areas which were once marginalised to areas of economic opportunities. However how does one begin to develop a model to ensure sustainable mobility? In some ways this problem of determining where to introduce new routes/edges to a mobility system resembles the school bus routing problem (SBRP) (Newton and Thomas,1969) and the travelling sales man problem (Rosenkrantz et al., 1974) both which fall under a larger class of problem being the vehicle routing problem (VRP) (Toth and Vigo, 2001).

As the VRP is a complex problem, most research on the problem is solved by developing heuristic algorithms. Early studies of SBRP involved presenting an algorithm which minimises the total distance travelled and number of buses given constraints of capacity and time (Newton and Thomas, 1969; Angel, 1972). The algorithm used, sort to identify feasible routes from the school by generating sub-routes, which satisfy the time and capacity constraints, whilst connecting the new routes to the school. Hence for each route there exists a path from the school outwards and inwards (Newton and Thomas, 1969).

Riera-Ledesma and Salazar-Gonz_alez (2012) in solving the SBRP, utilised a branch-and-cut approach which is a form of a location-routing problem. The uniqueness of their approach is that each bus user/commuter is assigned to a potential stop whilst finding the route with the least cost, given that bus users/commuters are going to a common destination and a set of potential stops which are reachable by a subset of the bus users/commuters. This problem is similar to the one, to be solved in this paper, as the bus users/commuters are travelling to a common destination being the industrial areas in Katlehong and have access to a subset of bus/ train stops.

Garroway et al., (1995) offered a multi-objective mathematical formation in solving the SBRP, given a set of spatially distributed pupils to be transported from their homes to and from their respective schools. Using a constraint that the suitability of a site in an urban location for being a pickup location is influenced by characteristics such a proximity to areas of interest and traffic density, they solved the problem by assigning each pupil to a bus stop and then routing the bus to the school.

This technique is quite similar to works done later by Bogl et al., (2015) in solving the SBRP for pupils travelling from home to their school. They calculated the minimum spanning tree of the graph, to ensure that for every pupil at a bus stop, there was a path from the initial pick up point to the destination bus stop near the school. Specific criteria in solving the SBRP in both situations included; the number of routes permissible, total bus route length, load balancing, and student walking distance to bus stop.

Consequently in solving the problem of improving the robustness of the existing public transportation network, there is a need to utilise algorithms which solve the problem of ensuring a minimum spanning tree (to ensure reduced travel time) and improving connectivity of the nodes in the graph (to ensure commuters have alternative travel routes).

3. METHODOLOGY

3.1 Situating Katlehong: The Study Area

Katlehong, the area under investigation is located in the City of Ekurhuleni (see figure 2). The current population of Katlhehong stands at 407,294 People with 124,841 households and Tokoza at 105 827 people with 46 095 households according 2011 census data (STATSSA, 2016). Currently according to Stats SA (2011) the Katlehong township is the third largest township in South Africa after Soweto in the City of Johannesburg at 1, 271 628 in 2011 and Tembisa in the City of Ekurhuleni standing at 463 109. In the City of Ekurhuleni there are four major townships all sitting on the urban periphery of the city centre. The Tembisa Township being in the North, Katlehong and Tokoza to the South, Duduza and Tsakane in the South East and Daveyton and Etwatwa in the east.

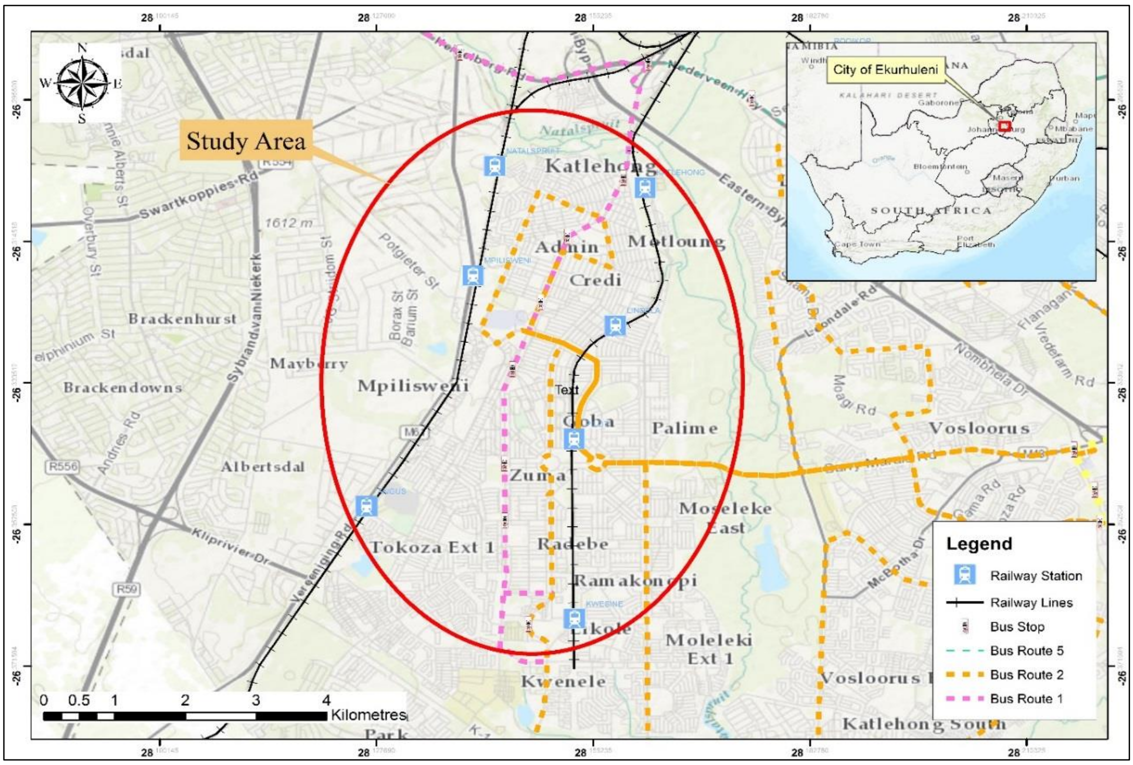

Figure 2: Katlehong (Study Area)

All these low-income areas are characterised by poverty, unemployment and large densities largely attributed to the apartheid systems that deliberately excluded people from meaningful participation in economic activity. The marginalisation of people to urban peripheries meant that commuting to work became expensive due to the amount of money and time used to commute from home to work. In many ways, these challenges continue to this day, as public transport remains fragmented (Harrison et al., 2015).

3.1 Analysis Approach

Creating new non-motorised cycling ‘short-cuts’ in Katlehong, promises to improve the robustness of the existing public transportation network and also travel time for commuters. Hence to improve the public transportation network we represent the existing network as an undirected weighted graph *G (V;E;W)* where *V* represents the set of public transportation bus/ train stops , *E* representing the set of routes between stations/ stops, while *W* represents the set of weights on each edge. These weights are calculated based on travel time between stations/ stops.

The new augmented graph should consist of new short-cuts/routes which shall reduce the total travel time within the study area. We initially propose a set of new routes, and though the use of Kruskal’s algorithm we compute the minimum spanning tree of the network based the travel time as the weight of the edges/routes. After computing the minimum spanning tree of the network, we use the betweenness centrality measures to determine the robustness of the existing and augmented networks.

4. RESULTS AND DISCUSSION

Generally nodes with high betweenness centrality allow the flow of commuters between every pair of bus/train stops, over the shortest paths between them. For the existing network, currently nodes along the Bus Route have the highest betweenness centrality. This could be due to the service quality of the Bus rapid transit system, as most commuters utilise the bus to travel in-between the townships and utilise the Metro-rail for longer trips.

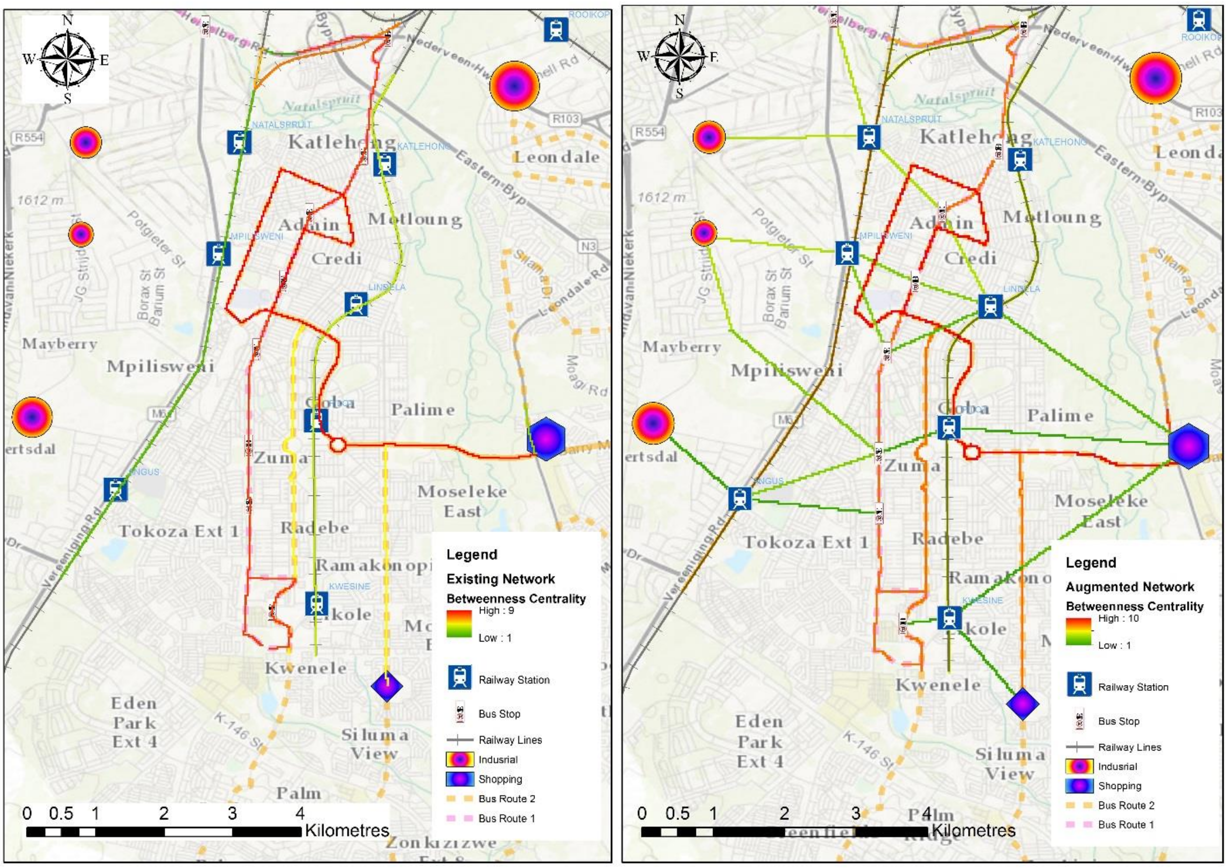

Figure 3: Betweenness Centrality of Existing Network and Augmented Network

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Also given the service quality of the Metro-rail, the travel speeds are generally slow, hence most trips made using the Metro-rail would have an adverse weight during the computation of the betweenness centrality (See Figure 3). However after introducing new routes/cycle lanes, the graph robustness is improved, as commuters of the railway system and bus system can now access both networks through the new routes. The Railway network now has a higher betweenness centrality due to these new connection. The new network has more higher order bus/ train stops, this which lead to reduced travel time for commuters, which will also benefit the service provider as commuters will generally be encouraged to take up more trips within the new network.

The introduction of cycling/ non-motorised lanes has many merits besides reducing pollution, as these cycle lanes shall encourage the community to practise a more healthier life-style as they cannot opt to cycle to their various points of interest. Also there is a positive environmental perspective, when opting for these new lanes, as they will have the least adverse environmental impact during construction when compared to creating new routes for motorised transportation.

5. CONCLUSION

As cities seek to develop and become sustainable, there is a need to include townships in the development plans. The authors have used Katlehong Township, to test the possibility of using Non-motorised transportation to connect commuters to points of interest. Although cycling cannot replace the motorised industry, it can be used by commuters to traverse the last mile of their trip. This which has proven to have economic, social and environmental benefits for the community of Katlehong Township. Future research to test this theory could be to conduct a qualitative analysis to unpack the community's uptake of non-motorised transportation to complete the first and last mile of their trips.

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