

Application of Road Selection Model for Transportation Improvement in Informal Settlements: The Case of Dar es Salaam City, Tanzania

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Abstract

The Road Selection Model was developed for the purpose of transportation improvement in informal settlements that minimises demolition of houses and compensation costs required in roads widening. The need of the model was to guide and support decision makers on challenges of widening narrow roads for accessibility and mobility improvement as part of upgrading informal settlements. This paper explains how the model was applied to produce meaningful results for decision making on roads selection and henceforth its relevance for replication in roads selection for improvement in informal settlements.

Key words: Road selection, Informal settlements, Multiple criteria decision making.

1. Introduction

Application of Road Selection Model (RSM) is carried-out to demonstrate on how the model was used and can be used elsewhere to select roads of the same and/or of different class for improvement among a set of several alternatives. This is governed by the reality that sometimes it is not possible to improve all roads of the same and/or of different types due to budget constraints and thus selection of which road should be selected first is most important. Therefore, RSM is developed to guide and support decision makers on roads selection for improvement according to priority with minimum demolition that would minimize compensation costs but improve transport network in-terms of traffic mobility and accessibility in informal settlements.

This model was developed to improve an empirical formula developed by Karimi *et al.* (2007) for roads widening in upgrading informal settlements in Jeddah, Saud Arabia. It was also developed to improve a statistical method of roads selection that was developed by Community Infrastructure Upgrading Program (CIUP) for roads selection and improvement in upgrading informal settlements in Dar es Salaam, Tanzania (CIUP, 2003a, b, c).

Karimi *et al.* (2007) developed an empirical formula called "Transformability Index" that was used to support decision making on roads widening in upgrading informal settlements in Jeddah, Saud Arabia. However, after testing the model, it was found that the empirical formula lacked a compensation component for widening of such roads and thus its replication in other countries was not possible (Karimi *et al.*, 2007).

The CIUP in Dar es Salaam, Tanzania also established a statistical method of roads selection for improvement in upgrading informal settlements in Dar es Salaam City. This statistical method was used for roads selection according to the percentage of houses to be covered from each type of road. It was established that at least 70% of all houses should be within 300 metres from local distributor roads with 10.0-12.0 metres RoW, and at least 95% of all houses should be within 150 metres from access roads, with 6.0-8.0 metres RoW (CIUP, 2003a, b, c). However, this statistical method was not realised on the ground (CIUP, 2009) due to lack of funds for compensation. Furthermore, the statistical method did not consider the issue of prioritisation in selecting roads for improvement when there was lack of funds for compensation.

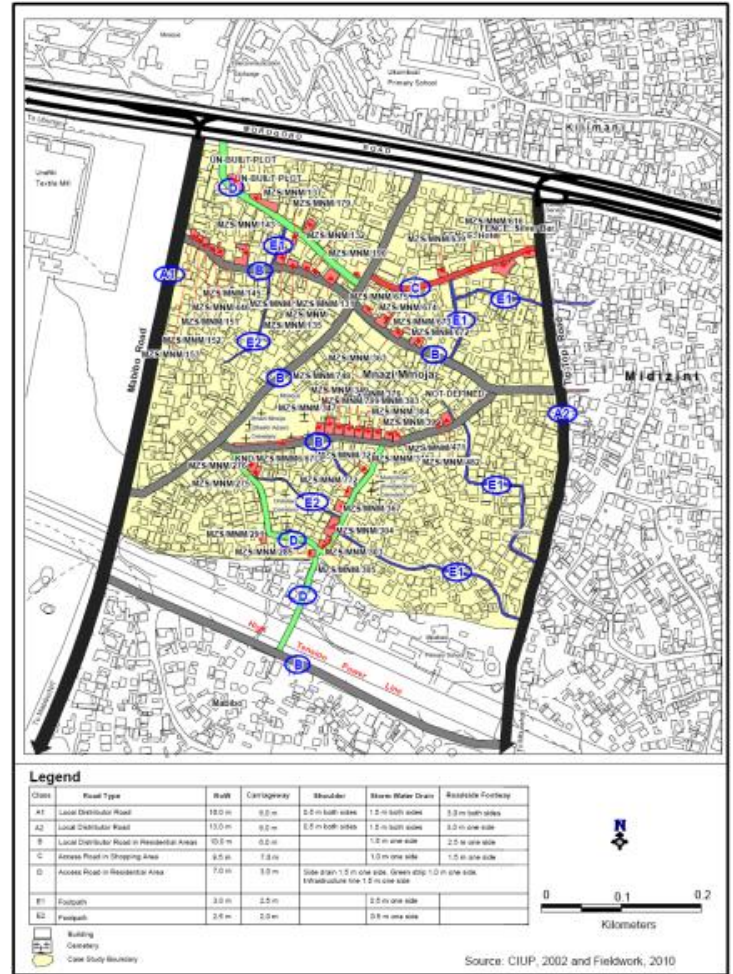
Therefore, the empirical formula established by Karimi *et al.* (2007) as well as the CIUP statistical method could not be used for selecting roads for improvement due to the said deficiencies. Henceforth, this study developed a selection model that considers the issue of compensation for widening roads so that transportation in terms of traffic mobility and accessibility could be improved in informal settlements.

To achieve this target, the RSM was designed to make use of Multiple Criteria Decision Making (MCDM) models (James, *et al.*, 1992; Triantaphyllou, *et-al.*, 1998; Xu and Yang, 2001) that are more relevant to reflect informal settlements upgrading practice. The model will therefore, be used for roads selection for improvement in upgrading informal settlements.

The term “informal settlement” refers to residential housing areas that developed through informal urban land development process and procedures, from land occupation to housing development (Kombe, 1995; Kombe and Kreibich, 2000; URT, 2007a; URT, 2007b). URT (2000) defined informal settlements as “unplanned settlements” denoting settlements that developed without guidance of conventional land use plans and land subdivision layout plans and without statutory land allocation and land development procedures.

2. Application of Road Selection Model in Dar es Salaam City

Application of RSM in Dar es Salaam City was carried-out at Mnazi Mmoja settlement. It involved selection of five types of roads that are available at the Settlement, which are local distributor roads, local distributor roads in residential areas, access roads in shopping areas, access roads in residential areas, and pedestrian footpaths (see Figure 1).



The model (see Model 1) was therefore, used to prioritize roads in each type for the purpose of improvement of transport network with minimum demolition of houses and minimum compensation cost.

$$RSM_{SCORE} = \min_i \sum_{i=1}^j FPC_i + SSC_i \text{ for } i = 1, 2, 3, \dots, j \tag{1}$$

Whereby:
 ‘RSM SCORE’ stands for total score of the Road Selection Model for i-th road within a range of j-th roads, which is a road with minimum score points.
 ‘FPC_i’ stands for total score of the Functional Performance Criteria for i-th road.

'SSC_i' stands for total score of the Space Syntax Criteria for the i-th road. 'j' stands for the number of alternatives of road of the same type assessed in RSM model.

Therefore, application of road selection model involves two components of the model, which FPC and SSC.

2.1 FPC Model and its Functional Performance Analysis

Functional performance analysis explains the functions of each of the five types of roads with the help of travel patterns information. The main purpose of this description is to assist in selection of different types of roads according to their functions as reflected in the FPC Model of the RSM and rank them from the first to the last by using FPC Model (see Model 2).

$$FPC_{SCORE} = \min_i \sum_{i=1}^N r_{ij} w_i \quad \text{for } i = 1, 2, 3, \dots, j$$

(2)

Whereby:

'FPC_{SCORE}' stands for total score of the Functional Performance Criteria for i-th road, which is the road of first priority within a range of j-th roads.

'r_{ij}' stands for rank of priority of i-th road. 'w_i' stands for weight of priority of i-th road.

'N' stands for the number of alternatives of road of the same class.

'j' stands for the last alternative of roads of the same class assessed in FPC model.

This model was therefore, used to rank the following types of roads at the settlement.

2.1.1 Local Distributor Roads

Functional performance analysis of local distributor roads at Mnazi Mmoja settlement involved two roads, which are Tip Top road and Mabibo road. The ranking of the two local distributor roads according to the functional importance of the FPC Model awarded Tip Top road to the first position

with 0.330 points and Mabibo road to the second position with 0.670 points.

2.1.2 Local Distributor Roads in Residential Areas

Functional performance analysis of local distributor roads in residential areas at Mnazi Mmoja settlement involves three roads, which are Euro-96 road, Usangi road and Burudani road. The ranking of the three local distributor roads in residential areas according to the functional importance awarded Burudani road to the first position with 0.170 points; Usangi road to the second position with 0.330 points; and Euro-96 road to the third position with 0.500 points. Furthermore, Mpakani road that connects Tip Top and Mabibo roads at the southern boundary of the settlement was ranked to the fourth position. However, this road was not included in the functional performance analysis because it is not within the administrative boundary of Mnazi Mmoja settlement.

2.1.3 Access Roads in Shopping Areas

Functional performance analysis of access roads in shopping areas at Mnazi Mmoja settlement involves one road, which is Shengena road. The ranking of access roads in shopping areas at Mnazi Mmoja settlement according to the functional importance awarded Shengena road to the first position with 1.000 points. However, this was the only access road that is transforming into Commercial Street while the rest are access roads in residential areas.

2.1.4 Access Roads in Residential Areas

Functional performance analysis of access roads in residential areas at Mnazi Mmoja settlement involves three roads, which are Double-A road, Mwembemkole road and Keenja road. The ranking of the three access roads in residential areas at Mnazi Mmoja settlement awarded Double-A road to the first position with 0.170 points; Mwembemkole road to the second position with 0.330 points; and Keenja road to the third position with 0.500 points.

2.1.5 Footpaths

Functional performance analysis of footpaths at Mnazi Mmoja settlement involves six main footpaths, which are Matitu, Kilumulia, Never-miss, Savannah, Ruvuma and Jitegemee footpaths. The ranking of the six footpaths according to the functional importance awarded Matitu footpath to the sixth position with 0.290 points; Kilumulia footpath to the fourth position with 0.190 points; Never-miss footpath to the second position with 0.100 points; Savannah footpath to the third position with 0.140 points; Ruvuma footpath to the first position with 0.050 points; and Jitegemee footpath to the fifth position with 0.240 points.

2.2 Space Syntax Analysis

Space syntax analysis explains spatial analysis of space available on the ground for each of the five types of roads with space required for each of them according to the minimum planning space standards in-terms of right-of-way. The main purpose of this analysis is to determine the implications for roads widening as reflected in the space syntax criteria and its implications with respect to property demolitions as reflected in the use of SSC Model (see Model 3).

$$SSC_{SCORE} = \min_i \sum_{i=1}^N PD_i + TD_i + PA_i \quad \text{for } i = 1, 2, 3, \dots, j$$

Whereby:

‘ SSC_{SCORE} ’ stands for total score of Space Syntax Criteria for i-th road within a range of j-th roads, which is the road with minimum score points.

‘ PD_i ’ stands for sum of partial demolition of houses along i-th road.

‘ TD_i ’ stands for sum of total demolition of houses along i-th road.

‘ PA_i ’ stands for sum of plots affected along i-th road. ‘N’ stands for the number of alternatives of road of the same class. ‘j’ stands for the last alternative of roads of the same class assessed in SSC model.

Partial Demolition (PD) component of the SSC Model takes into account summation of four components, which are partial demolition of front part of the house, partial demolition of room extended from the main house, partial demolition of front veranda, and partial demolition of a fence as explained in Model 4 below:

$$PD_{SCORE} = \sum_{i=1}^N (PH_i W) + (PE_i W) + (PV_i W) + (PF_i W) \quad \text{for } i = 1, 2,$$

Whereby:

‘ PD_{SCORE} ’ stands for total score of partial demolition of houses along i-th road within a range of j-th roads.

‘ PH_i ’ stands for the number of partial demolition of front part of the main house along i-th road.

‘ PE_i ’ stands for the number of partial demolition of rooms extended from the main houses along i-th road.

‘ PV_i ’ stands for the number of partial demolition of front veranda of the house along i-th road.

‘ PF_i ’ stands for the number of partial demolition of fence along i-th road.

‘W’ stands for weight of analysis of partial demolition variables.

‘N’ stands for the number of alternatives of road of the same class.

‘j’ stands for the last alternative of roads of the same class assessed in SSC model.

Total Demolition (TD) component of the SSC Model takes into account summation of two components, which are building height and relocation of households as explained in Model 5.

$$TD_{SCORE} = \sum_{i=1}^N (TD_i^{BH1} W) + (TD_i^{BH2} W) + (TD_i^{BH3} W) + (HH_i W) \quad \text{for } i = 1, 2, \dots, j$$

(5)

Whereby:

- ‘ TD_{SCORE} ’ stands for total score of total demolition of houses along i-th road within a range of j-th roads.
- ‘ TD_i^{BH1} ’ stands for the number of total demolition of one storey buildings along i-th road.
- ‘ TD_i^{BH2} ’ stands for the number of total demolition of two storey buildings along i-th road.
- ‘ TD_i^{BH3} ’ stands for the number of total demolition of three storey buildings and above along i-th road.
- ‘ HH_i ’ stands for the number of households affected with total demolition of houses along i-th road.
- ‘ W ’ stands for weight of analysis of total demolition variables.
- ‘ N ’ stands for the number of alternatives of road of the same class. ‘j’ stands for the last alternative of roads of the same class assessed in SSC model.

Plots Affected (PA) component of the SSC Model takes into account summation of two components, which are relocation of cemeteries and chopping-off part of un-built plot. Mathematical model 6 explains application of PA model in establishment of SSC score points.

$$PA_{SCORE} = \sum_{i=1}^N (RC_i W) + (UP_i W) \quad \text{for } i = 1, 2, 3, \dots, j$$

(6)

Whereby:

- ‘ PA_{SCORE} ’ stands for the total score of plots affected along i-th road within a range of j-th roads.
- ‘ RC_i ’ stands for the number of cemeteries relocated along i-th road whereby the unit size is 5 cemeteries that are accommodated in an area of 4m x 10m ($40 m^2$). ‘ UP_i ’ stands for the number of part of un-built plot that is affected along i-th road whereby the unit size is 6m x 12m ($72 m^2$).
- ‘ W ’ stands for weight of analysis of plots affected variables.
- ‘ N ’ stands for the number of alternatives of road of the same class.

‘j’ stands for the last alternative of roads of the same class assessed in SSC model.

SSC Model was therefore, used to analyse extent of demolition in the following types of roads at the settlement.

2.2.1 Local Distributor Roads

For the purpose of realizing functional performances of local distributor roads in residential areas, and the purpose of minimizing compensation costs by avoiding massive demolition of houses in widening the road, the proposed minimum space standard for the road is 13.0 metre RoW. In application of this space standard, there is no any house that is going to be affected in widening of Tip Top and Mabibo Roads and therefore, SSC score for each of these roads were 0.000 points.

2.2.2 Local Distributor Roads in Residential Areas

For the purpose of realizing functional performances of local distributor roads in residential areas, and the purpose of minimizing compensation costs by avoiding massive demolition of houses in widening the road, the proposed minimum space standard for the road is 10.0 metre RoW.

In application of this space standard for widening Euro-96 Road, a total of 15 properties are expected to be affected that involves 1 partial demolition of a fence, 4 partial demolition of front veranda, 4 partial demolition of rooms extended from the main house, and 6 partial demolition of front part of the main house. SSC score for the road is therefore, 0.157 points.

In application of this space standard for widening Usangi Road, there is no any property that is going to be affected. SSC score for the road is therefore, 0.000 points.

In application of this space standard for widening Burudani Road, a total of 14 properties and one grave yard are expected to be affected. These are 1

partial demolition of a fence, 5 partial demolition of front veranda, 2 partial demolition of rooms extended from the main house, 5 partial demolition of front part of the main house and relocation of 30 graves at Shaban Adam cemeteries. SSC score for the road is therefore, 0.129 points.

2.2.3 Access Roads in Shopping Areas

For the purpose of realizing functional performances of access roads in shopping areas, and the purpose of minimizing compensation costs by avoiding massive demolition of houses in widening the road, the proposed minimum space standard for the road is 9.5 metre RoW.

In application of this space standard for widening Shengena Road, a total of 4 properties are expected to be affected that involves 2 partial demolition of front part of the main house and partial demolition of 2 fence. SSC score for the road is therefore, 0.042 points

2.2.4 Access Roads in Residential Areas

For the purpose of realizing functional performances of access roads in residential areas, and the purpose of minimizing compensation costs by avoiding massive demolition of houses in widening the road, the proposed minimum space standard for the road is 7.0 metre RoW.

In application of this space standard for widening Double-A Road, a total of 5 properties are expected to be affected that involves 2 un-built plots and 1 partial demolition of front veranda, 1 partial demolition of rooms extended from the main house, and 1 partial demolition of front part of the main house. SSC score for the road is therefore, 0.030 points.

In application of this space standard for widening Mwembemkole Road, a total of 10 properties are expected to be affected that involves 1 partial demolition of fence, 2 partial demolition of front veranda, 1 partial demolition of rooms extended from the main house, and 6 partial demolition of

front part of the main house. SSC score for the road is therefore, 0.126 points.

In application of this space standard for widening Keenja Road, one property is expected to be affected that involves 1 partial demolition of front veranda. SSC score for the road is therefore, 0.018 points.

2.2.5 Footpaths

For the purpose of realizing functional performances of footpaths, and the purpose of minimizing compensation costs by avoiding massive demolition of houses in widening the road, the proposed minimum space standard for the road is 2.5 metre RoW. In application of this space standard for widening Matitu footpath, Kilumulia footpath, Never-miss footpath, Savannah footpath, Ruvuma footpath and Jitegemee footpath, there is no any property that is going to be affected. SSC score for each of these footpath is therefore, 0.000 points. Figure 2 explains extent of demolition required to widen local distributor roads, local distributor roads in residential areas, access roads in shopping areas, access roads in residential areas, and footpaths at Mnazi Mmoja settlement.

3. Prioritization of Different Types of Roads according to the RSM Score

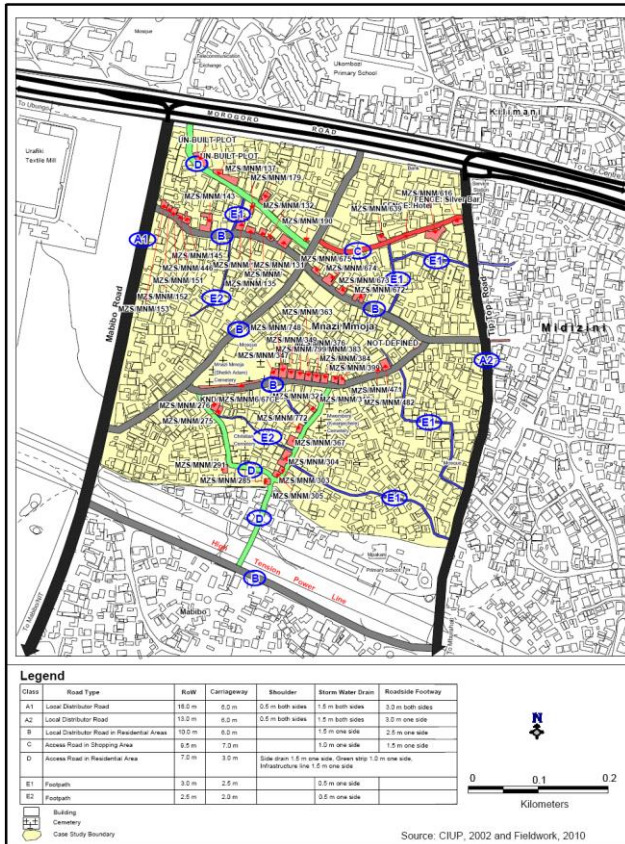
Prioritization of different types of roads for improvement is a result of the application of the RSM that includes FPC Model and SSC Model. The function of these criteria is to establish score points for each type of road of which, a road of less score points in each type of roads is prioritized first for selection in improvement compared to a road of more score points.

Properties that were affected in application of SSC and ranking of the roads are explained in each type of road assessed in the subsequent sections by using the following abbreviations:

‘FPC’ stands for functional performance criteria.

‘SSC’ stands for space syntax criteria.

Figure 2: Roads widening and extent of demolition at Mnazi Mmoja settlement



‘PV’ stands for partial demolition of front veranda.
 ‘PE’ stands for partial demolition of rooms extended from the main house.
 ‘PH’ stands for partial demolition front part of the main house.
 ‘RC’ stands for relocation of cemeteries.
 ‘UP’ stands for chopping-off part of un-built plot.
 ‘TD^{BH1}’ stands for total demolition of one storey building.
 ‘TD^{BH2}’ stands for total demolition of two storey building.
 ‘TD^{BH3}’ stands for total demolition of three storey building.
 ‘HH’ stands for number of households relocated in total demolition of a house/building.

3.1 Local Distributor Roads

Prioritization of local distributor roads involves two roads namely Tip Top and Mabibo roads. The prioritization process which is a result of application of RSM awards a total score of 0.330 points to Tip Top road and 0.670 points to Mabibo road. Therefore, Tip Top road ranks the first priority while Mabibo road ranks the second priority in selection of local distributor roads for improvement at Mnazi Mmoja settlement. Table 1 explains the details of this assessment.

‘PR’ stands for priority rank of the road.
 ‘PF’ stands for partial demolition of a fence.

Table 1: Local distributor roads priority score matrix at Mnazi Mmoja

Name of Road	FPC		SSC										Sub Total SSC	Total Score Points	Priority Rank	
	1.0000		0.0026	0.0026	0.0087	0.0182	0.0009	0.0002	0.1859	0.3062	0.4374	0.0372				
	PR	W	PF	P V	PE	P H	R C	U P	T D BH1	T D BH2	T D BH 3	H H				
Tip Top Road	1	0.330	0.330	0	0	0	0	0	0	0	0	0	0	0.000	0.330	1
Mabibo Road	2	0.670	1.340	0	0	0	0	0	0	0	0	0	0	0.000	1.340	2

3.2 Local Distributor Roads in Residential Areas

Prioritization of local distributor roads in residential areas involves three roads namely Euro-96, Usangi and Burudani roads. The prioritization process which is a result of application of RSM awards a total score of 0.657 points to Euro-96 road, 0.330 points to Usangi road and 0.299 points to Burudani road. Therefore, Burudani road ranks the first priority in selection of local distributor roads in residential areas for improvement at Mnazi Mmoja settlement. Usangi road ranks the

second while Euro-96 ranks the third in priority. Table 2 explains the details of this assessment:

3.3 Access Roads in Shopping Areas

Prioritization of access roads in shopping areas involve one road namely Shengena road. The prioritization process which is a result of application of RSM awards a total score of 1.042 points to Shengena road. Therefore, Shengena road ranks the first priority in selection of access roads in shopping areas for improvement at Mnazi Mmoja settlement. Table 3 explains the details of this assessment:

Table 2: Local distributor roads in residential areas priority score matrix at Mnazi Mmoja

Name of Road	FPC			SSC										Total Score Points	Priority Rank	
	1.0000		Sub Total FPC	0.0026	0.0026	0.0087	0.0182	0.0009	0.0002	0.1859	0.3062	0.4374	0.0372			Sub Total SSC
	PR	W		PF	P V	PE	P H	R C	U P	T D BH 1	T D BH 2	TD BH3	H H			
Euro-96 Road	3	0.500	1.500	1	4	4	6	0	0	0	0	0	0	0.157	1.657	3
Usangi Road	2	0.330	0.660	0	0	0	0	0	0	0	0	0	0	0.000	0.660	2
Burudani Road	1	0.170	0.170	1	5	2	5	6	0	0	0	0	0	0.129	0.299	1

Table 3: Access roads in shopping areas priority score matrix at Mnazi Mmoja

Name of Road	FPC			SSC										Total Score Points	Priority Rank	
	1.0000		Sub Total FPC	0.0026	0.0026	0.0087	0.0182	0.0009	0.0002	0.1859	0.3062	0.4374	0.0372			Sub Total SSC
	PR	W		PF	P V	PE	P H	R C	U P	T D BH 1	T D BH 2	TD BH3	H H			
Shengena Road	1	1.000	1.000	2	0	0	2	0	0	0	0	0	0	0.042	1.042	1

3.4 Access Roads in Residential Areas

Prioritization of access roads in residential areas involves three roads namely Double-A, Mwembemkole and Keenja roads. The

prioritization process which is a result of application of RSM awards a total score of 0.200 points to Double-A road, 0.456 points to Mwembemkole road and 0.518 points to Keenja road. Therefore, Double-A road ranks the first priority in selection of access roads in residential areas for improvement at Mnazi Mmoja settlement while Mwembemkole road ranks the second and Keenja road ranks the third. Table 4 explains the details of this assessment:

3.5 Footpath

Prioritization of footpaths involves six footpaths namely Matitu, Kilumulia, Never-miss, Savannah, Ruvuma and Jitegemee footpaths. The prioritization process which is a result of application of RSM awards a total score of 0.290 points to Matitu footpath, 0.190 points to Kilumulia footpath, 0.100 points to Never-miss footpath, 0.140 points to Savannah footpath, 0.050 points to Ruvuma footpath and 0.240 points to Jitegemee footpath.

Therefore, Ruvuma footpath ranks first in priority, Never-miss footpath ranks second priority, Savannah footpath ranks third priority, Kilumulia footpath ranks fourth priority, Jitegemee footpath ranks fifth priority and Matitu footpath ranks sixth priority in selection of footpaths for improvement at Mnazi Mmoja settlement. Table 5 explains the details of this assessment while Figure 3 shows

priority roads selected for improvement at Mnazi Mmoja settlement.

Figure 3: Priority roads for improvement at Mnazi Mmoja

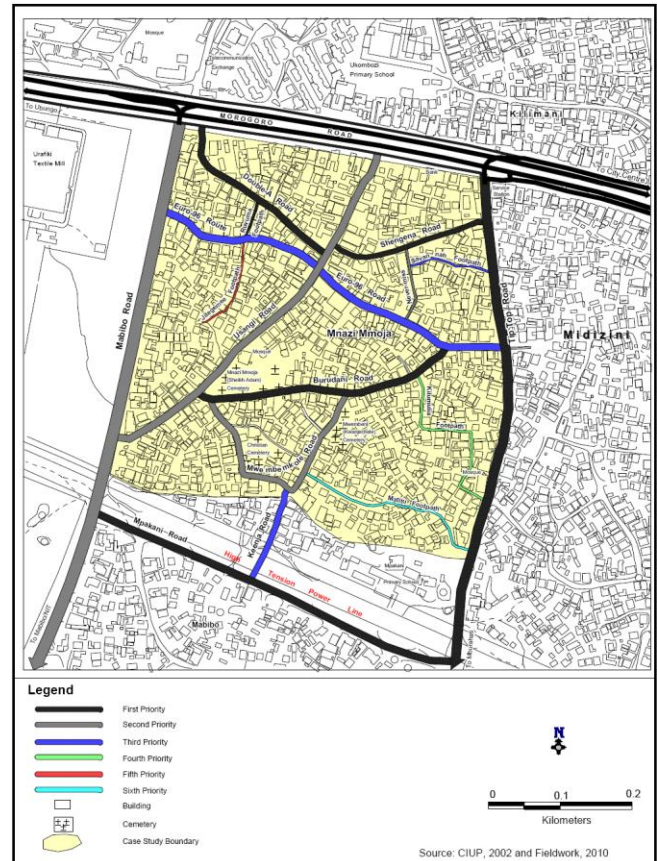


Table 4: Access roads in residential areas priority score matrix at Mnazi Mmoja

Name of Road	FPC			SSC									Total Score Points	Priority Rank		
	1.0000		Sub Total FPC	0.0026	0.0026	0.0087	0.0182	0.0009	0.0002	0.1859	0.3062	0.4374			0.0372	Sub Total SSC
	PR	W		PF	P V	PE	P H	R C	U P	T D ^B H1	T D ^B H2	T D ^B H3			HH	
Double-A Road	1	0.170	0.170	0	1	1	1	0	2	0	0	0	0	0.030	0.200	1
Mwembemkole Road	2	0.330	0.660	1	2	1	6	0	0	0	0	0	0	0.126	0.786	2
Keenja Road	3	0.500	1.500	0	0	0	1	0	0	0	0	0	0	0.018	1.518	3

Table 5: Pedestrian footpaths priority score matrix at Mnazi Mmoja

Name of Road	FPC			SSC										Total Score Points	Priority Rank	
	1.0000		Sub Total FPC	0.0026	0.0026	0.0087	0.0182	0.0009	0.0002	0.1859	0.3062	0.4374	0.0372			Sub Total SSC
	PR	W		PF	P V	PE	P H	R C	U P	T D ^B _{H1}	T D ^B _{H2}	T D ^B _{H3}	HH			
Matitu Footpath	6	0.290	1.740	0	0	0	0	0	0	0	0	0	0	0	1.740	6
Kilumulia Footpath	4	0.190	0.760	0	0	0	0	0	0	0	0	0	0	0	0.760	4
Never-miss Footpath	2	0.100	0.200	0	0	0	0	0	0	0	0	0	0	0	0.200	2
Savannah Footpath	3	0.140	0.420	0	0	0	0	0	0	0	0	0	0	0	0.420	3
Ruvuma Footpath	1	0.050	0.050	0	0	0	0	0	0	0	0	0	0	0	0.050	1
Jitegemee Footpath	5	0.240	0.200	0	0	0	0	0	0	0	0	0	0	0	0.200	5

4 Conclusion

Applications of RSM in roads selection prioritized all types of roads for improvement with minimum demolition of houses and compensation costs but achieve functional performances of each type of a road. In prioritization of local distributor roads, Tip Top road was prioritized in the first rank and Mabibo road in the second rank. In prioritization of local distributor roads in residential areas, Burudani road was prioritized in the first rank, Usangi road in the second rank, and Euro-96 road in the third rank. In prioritization of access roads in shopping road, Shengena road was prioritized in the first rank and it is the only one access road in shopping areas available at the settlement. In prioritization of access roads in residential areas, Double-A road was prioritized in the first rank,

Mwembemkole road in the second rank, and Keenja road in the third rank. In prioritization of footpaths, Ruvuma footpath was prioritized in the first rank, Never-miss footpath in the second rank, Savannah footpath in the third rank, Kilumulia footpath in the fourth rank, Jitegemee footpath in the fifth rank, and Matitu footpath in the sixth rank.

Therefore, in case of budget constraints, all types of roads are selected for improvement according to their ranks that improves transport network. RSM was henceforth realized to be relevant in application in upgrading informal settlements.

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