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Modeling the Cost of Green Space Investment in Residential Areas in Dar es Salaam City, Tanzania

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ABSTRACT: Understanding the costs of development, maintenance and replacement of green spaces may help in effective planning and development of green spaces. However, traditional methods to ascertain the costs of the same are complex and requires many data and expertise. The objective of study was to develop a mathematical model for estimating the cost of green space investment in residential areas of Dar es Salaam City, Tanzania using structured questionnaires for data collection. The study revealed that the investment cost of green spaces was influenced by income of the households, age of green space, area covered by green space, green space type and settlement where the household resides. The mean calculated from the model looked lower by 0.1% implying that the model can best predict the overall mean of investment cost by 99.9%. The model can be used to estimate the economic value of green spaces in data scarce situations for various purposes like compensation and property valuation.

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Key words: Green spaces; development; replacement; compensation; valuation

Green spaces are all evapotranspiring surfaces-vegetated land, water, unsealed and permeable surfaces whose infiltration capacity has not been compromised. The vegetated lands include urban parks, street trees, vegetable gardens, lawns, grass and shrubs. Water surfaces include wetlands, ponds, rivers, streams, waterways, oceans/sea and lakes. Unsealed and permeable surfaces include open spaces, playing grounds and football pitches (La Greca *et al.*, 2011; Mwageni, N: Kiunsi, R, 2021). Green spaces make cities cooler, more comfortable, less prone to flooding and more attractive to live, visit and invest (Costanza, d'Arge, de Groot, Farber, Grasso, Hannon, Limburg, Naeem, O'Neill, Paruelo, *et al.*, 1997; Daily, 1997; Fisher *et al.*, 2008; Higgins *et al.*, 1997; Kibassa and Shemdoe, 2016; Kosenius *et al.*, 2014).

Green spaces in residential areas vary in size, type, richness, ecological quality, and amenities (Abass, 2021; Mwageni and Kassenga, 2022). The common green spaces in residential plots can broadly be classified into woody plants (trees and shrubs), plot farms, allotments and ornamental gardens. They are used for different social, economic and ecological functions. They are particularly used for shade, cooling, recreation and aesthetic, beautification, biodiversity protection, food, wind and dust control (Mwageni and Kiunsi, 2021). Residential buildings with green space are considered premium (high price) because of the pleasant view, particularly one overlooking water or green space hence add financial value.

Green spaces investment in the world-built environment has gained popularity nowadays albeit their sustainability has been a challenge. Green space investment in residential areas is challenged by climate change which has been contributing to the

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declining levels of green spaces and their ecosystem services (Roy *et al.,* 2018). The expansion and intensification of urban activities and limited enforcement of planning regulations have been posing threats to green space abundances in residential areas (Elmqvist *et al.,* 2015). On other hand, poor choice of green spaces that generate disservices (Dunn, 2010) and the limited financial resources to meet the development and operational costs have been a barrier to sustainable green space investment in residential areas (CLUVA, 2013; Mwageni and Kassenga, 2022). The investment cost for green spaces can vary depending on the community income, size, age, gender, tenure (Budruk *et al.,* 2009; Jenerette *et al.,* 2011; Abass, 2021). Wilson and Xiao (2023) reported that the economic payback on residential green space investment is at least 1.5 years.

The benefits of green space investment is documented with certainty but little is known on the actual cost of green space investment. Understanding cost and benefit of green spaces can help residents and government make tradeoffs between courses of actions with respect to the development of residential areas. However, the methods for determining the cost of green space investment (development, maintenance and replacement) are complex, require many data, and expertise. Hence, the objective of study was to estimate the cost of green space investment in residential areas in Dar es Salaam City, Tanzania using mathematical model.

MATERIALS AND METHODS

Case study selection: This study was considered to be done in other Tanzania's cities which are Mwanza, Arusha and Mbeya but Dar es Salaam was seen to be the best representative City. It is the City having the highest urbanisation rate exacerbated by high population growth rate and density in Tanzania mainland. This has been leading to high conversion of green spaces to residential, commercial and industrial purposes than any other Cities in Tanzania. Dar es Salaam City experiences impacts caused by absences of green spaces than any other City in Tanzania. Therefore, presence of problems related to green spaces disappearance such as floods (storm water problem), heating, disappearance of recreational services and demand-supply gap of ecosystem services from green spaces, make Dar es Salaam City the best representative site to study the investment cost of green spaces.

Data collection method: The study used structured questionnaire. The questions intended to capture the demographic information, land tenure, green space coverage, development, and operation costs of green spaces. Differences of socio-economic and environmental contexts of the City were captured by conducting the study in four settlements (Table 1). The questionnaire was administered in four different settlements (wards) which had different planning status, tenure information, socio-economic and environmental context. Data were collected from 511 households within the settlements. The distribution of questionnaires/respondents in selected settlements (wards) was based on the size of the settlement and availability of residential houses with home greenery, streams and open spaces. In this case questionnaires administered to Makumbusho ward(Very high building density settlement) were 127, Mbezi (High building density settlement) were 150, Mburahati (Moderate building density settlement) were 100 and Yombo Vituka (Low building density settlement) were 134. This was done by administering both closed and open- ended questions to households.

Table 1: Key characteristics of case study settlements

Key information/source		Sample Settlement			
		Kawe	Makumbusho	Mburahati	Yombo Vituka
Population		67,115	68,093	34,123	76,999
Sex	Female	34,689	34,842	17,339	39,361
	Male	32,426	33,251	16,784	37,638
Number of Household		16,778	18,403	9,749	19,249
Household size		4	3.7	3.9	4
Area of ward (Square kilometer)		15.477	1.113	1.7368	5.5453
Building density as of 2017		514	3794	3,095	1,684
Density type as per urban planning space standards of Tanzania, 2018		Super low density	Very high density	High density	Medium density
Planning status	% of planned and built up area	72.38	45.72	28.35	30.39
	% of unplanned and built up area	9.64	54.28	71.65	60.05
	% of un built up area	17.98	0.0	0.0	9.55
Dominant buildings		Double storey	Single storey	Single storey	Single storey
Green space coverage(square meter)		6,627,540	226,065	281,496	1,330,670

Data analysis: In order to ensure data visualization, tables and mathematical equations were used. To enable this, various software such as RStudio version 3.5.2 developed by Joseph J. Allaire in South Bend, Indiana, United States was used. Microsoft Excel for Windows 2010 developed by Dan Bricklin were used to facilitate data analysis. Data from MS Excel were imported to Rstudio for multi-options analysis. To check the statistical significance of the relationship among variables, each inferential statistical test used was attached with either P –Value and F-Value or t-value. For instance, for P-value, relationship was considered significant if the P-value of the data was less or equal to 0.05

Establishment of Mathematical Model for estimating the investment cost of green spaces: The mathematical model for determining the investment cost of green spaces was established by establishing the costs for development, replacement, and maintenance of green spaces. To get the current investment cost, the following inflation equation adopted from Mwageni and Kassenga, (2022) was used to adjust the cost.

$$A_n = A_{n-1}(1+r) \quad (1)$$

Where, A_n=Equivalent monetary cost as of 2019; A_{n-1}=Estimated monetary cost in the previous year; r =Country data on inflation rate in the present year

The adjusted investment costs calculated from normal arithmetic mean was related with environmental, social and economic factors of the households. These included settlement to which the respondent resides, income, area of home greenery, age of green space, the religious affiliation, education status of the person, sex of household owner, the tenure information, green space type and location within the settlement. In order to explain the relationship between the investment cost amongst households and its associations with aforementioned independent variables, the linear regression model was used. Using a linear regression model sounded appropriate since the response variable (investment cost) was in a continuous form. Prior to developing the model, the distribution of the response (dependent) variable was checked to see the normality of data. The method of minimum least square called best linear unbiased estimator was used to estimate the coefficient of the model. The method requires an optimal value chosen to be unbiased and of minimum variance. That can only be achieved if only the response (dependent variable) is normally distributed in the first place. Looking at the distribution, it was noticed that the response (investment cost) variable was not normally distributed. It was skewed to the left, and hence this required the log transformation.

Model selection: The Aikaike information criterion (AIC) was used to examine the exclusion or inclusion of model variables in the general model. Other information that could be used to identify predictor variables were Bayesian Information criterion (BIC), Root mean square error and Cp-Mallow criterion. AIC was chosen as it is geared at finding the best approximating model to the unknown data generating process. The AIC was calculated as in equation 2;

$$AIC = -2 * \max \log L + 2p \quad (2)$$

Whereby; p is the number of parameters in the model; max log L is the maximum log likelihood of the function that produces estimates for the population parameters that maximize the probability of observing data (Hox et al., 2017).

The best model is the one with variables that caused the model to have the lowest AIC value. Thus, stepwise regression method was used that combine both forward and backward selection procedure of model variables. At each stage, an investigation was done to see on whether the variable was supposed to be added or removed to the model. This was determined by looking at the model with the lowest AIC.

Model validation: Model validation intended to look at the quality of the proposed model to serve the purpose. Having known the model, cross validation process was used to validate the model. This involved diving dataset into 2 sets. The first set which was about 80% of the whole data set of which was used for model building and the remaining 20% was used for prediction. The essence of using 20% data set was that the model could perform well on the 80% data set but could perform poorly on the 20% data set.

Model interpretation: Since the response (dependent variable), was log transformed then the interpretation of relative percentage difference in investment cost of the particular categorical predicator variable to reference predictor variable was calculated using the formula$(exp(\beta_i) - 1) * 100\%$. Where β_i is the model estimate.

RESULTS AND DISCUSSION

Factors determining the cost of green space investment: The study revealed that the investment cost of green spaces depends on settlement to which the respondent resides, income, area of home greenery, age of green space, the religious affiliation, education status of the person, sex of household owner, the tenure information, green space type and location within the settlement. This shows that there are ten different options of fitting the regression model. Thus, this called the need for having multiple linear regression model. However, t-test and the *p*-values indicate that five variables had significant contribution to the net cost. These were income of the households, age of green space, area covered by green space, green space type and settlement type (Table 2). This might be due to the fact that having high income in case study areas means more ability to acquire big land and hence more investment on home greenery coverage. Factors like location, settlement and education level were seen to have influence to investment cost of green spaces though statistically not significant. This suggests that further investigations on inclusion or exclusion of these model variables in the general model was needed.

Table 2: Model estimates

Reference predicator of categorical variable	Coefficient	Estimates (β_i)	Std Error	t-value	p-value
	Intercept (General intercept or intercept of reference predictor categorical variable) (β_o)	16.567	2.17	5.884	0.000
	Income/10,000	0.011	0.002	6.407	0.000
Education:Graduate	Education:No schooling	-0.417	0.677	-0.616	0.539
	Education:Others	0.580	0.567	1.023	0.307
	Education:Primary education	-0.130	0.448	-0.291	0.771
	Education:Secondary	-0.097	0.457	-0.213	0.832
	Area covered	0.001	0.001	1.189	0.045
Tenure:Homeowner	Tenure:Legal owner	-0.257	0.239	-1.074	0.283
	Tenure:Owned by relatives	0.418	0.486	0.859	0.391
	Tenure: Residents take care	-0.633	0.543	-1.165	0.245
	Tenure: Tenant	-0.541	0.322	-1.680	0.094
Settlement:Kawe	Settlement : Makumbusho ward	-0.411	0.316	-1.301	0.194
	Settlement:Mburahati ward	-0.802	0.323	-2.484	0.013
	Settlement: Yombo vituka ward	-0.216	0.302	-0.715	0.475
Religion:Buddha	Religion:Christian	1.023	2.084	0.491	0.624
	Religion:Muslim	0.716	2.085	0.343	0.731
Location:Highland	Location:Low land	0.012	0.287	0.042	0.967
	Location: Stream	0.313	0.251	1.247	0.213
Age of respondent		0.008	0.007	1.090	0.276
Age of green space		0.100	0.013	7.944	0.000
Sex	Male	-0.226	0.213	-1.060	0.290
Green space type: Multiple green spaces	Green space type:Allotments	-0.037	0.436	-0.084	0.933
	Green space type:Shade trees	-0.624	0.305	-2.046	0.042
	Green space type:Fruit trees	0.183	0.503	0.364	0.716
	Green space type:House garden	-0.720	0.461	-1.561	0.119
	Green space type:Open agricultural field	0.289	0.558	0.519	0.604
	Green space type: Open Space inside courtyard	-2.500	0.944	-2.650	0.008

The multiple regression model equation based on above variable estimates was as follows

$$
\begin{aligned}
&\mathbf{ln[Investment\ cost|x_i]} \\
&= 16.567 + 0.011 * \frac{\text{Income}}{10{,}000} - 0.417 * \text{No school}_{\text{EDU}} + 0.580 * \text{Others}_{\text{EDU}} - 0.130 \\
&* \text{Primary}_{\text{EDU}} - 0.097 * \text{Secondary}_{\text{EDU}} + 0.001 * \text{Area covered} - 0.257 \\
&* \text{Legal owner}_{\text{TENURE}} + 0.418 * \text{Relatives}_{\text{TENURE}} - 0.633 * \text{Residents take care}_{+} 0.541 \\
&* \text{Tenant}_{\text{TENURE}} - 0.411 * \text{Makumbusho}_{\text{WARD}} - 0.802 * \text{Mburahati}_{\text{WARD}} - 0.216 \\
&* \text{Yombo vituka}_{\text{WARD}} + 1.023 * \text{Christian}_{\text{RELIGION}} + 0.716 * \text{Muslim}_{\text{RELIGION}} + 0.012 \\
&* \text{Lowland}_{\text{LOCATION}} + 0.313 * \text{Stream}_{\text{LOCATION}} + 0.008 * \text{Age of respondent} + 0.100 \\
&* \text{Age of green spaces} - 0.226 * \text{Sex}_{\text{MALE}} - 0.037 * \text{Green space type}_{\text{ALLOTMENTS}} - 0.624 \\
&* \text{Green space type}_{\text{SHADE TREES}} + 0.183 * \text{Green space type}_{\text{FRUIT TREES}} - 0.720 \\
&* \text{Green space type}_{\text{HOUSE GARDEN}} + 0.289 * \text{Green space type}_{\text{OPEN AGRICULTURAL FIELD}} \\
&- 2.500 * \text{Green space type}_{\text{OPEN SPACE INSIDE COURTYARD}} + \varepsilon_i
\end{aligned}
$$

The model has R square of 0.307 which suggest that about 30.7% of variability in the response (dependent variable) can explained by the predictor variables (independent variable). The intercept of the model was 16.567 (the value of investment cost when other factors are kept zero) and when transformed the investment cost of green space since its establishment was TZS 15,665,948 (6,811USD) per household. This has two interpretations. Firstly, green spaces have costs of investment amounting to TZS 15,665,948 regardless of income, tenure, home greenery coverage, religion affiliation, age of green space, Age of the respondents, sex of the respondent, location within the settlement, green space type and education level. Secondly, it represents the average investment cost with regard to their reference predictor categorical variables (Education (Graduate), tenure (Homeowner), settlement (Kawe), religion (Buddha), location (highland)), sex (Female) and green space type (Multiple green space). The average investment cost of green space since its establishment calculated from the model (TZS 15,665,948 (6,811USD) per household) was comparable with the normal arithmetic mean calculated per household (TZS 15,678,771 (1,214USD)). The mean calculated from the model looks lower by TZS 12,763 (6USD) per household, meaning that there is an error of 0.1%. This means that the model can best predict the overall mean of investment cost by 99.9%. Table 3 shows comparison between the model estimates and the normal arithmetic mean for specific categorical variables. It can be noticed that each specific variable has average investment cost of green spaces (TZS) that deviates positively or negatively from the overall mean calculated from the general model (TZS 15,665,948 (6,811USD) per household). The difference between calculated mean from the model and the normal arithmetic mean might be due to the fact that model takes into account data variability by finding the best fit line averaging data points and hence exclusion of outliers. In normal arithmetic mean, outliers were included in mean calculations. This has increased mean due to presence of outliers of very high investment cost. Thus, calculated mean from the model corrects for other variables included in the model while the normal arithmetic mean does not. It implies that, the calculated mean from the model can best express the investment cost of green spaces.

Table 3: Estimates of investment cost per category

Categories/variable	**Estimate**	**Estimate of mean of investment cost from model (TZS)**	**Normal Arithmetic mean (TZS)**
No schooling	$\exp(\beta_0 + \beta_{No\_schooling})$	10,324,187	5,099,035.2
Others	$\exp(\beta_0 + \beta_{Others})$	27,979,985	46,304,642.7
Primary	$\exp(\beta_0 + \beta_{Primary})$	13,756,197	12,170,539
Secondary	$\exp(\beta_0 + \beta_{Secondary})$	14,217,725	14,977,235
Legal owner	$\exp(\beta_0 + \beta_{Legal\ owner})$	12,115,546	21,866,634
Owned by relatives	$\exp(\beta_0 + \beta_{Owned\ by\ relatives})$	23,795,332	8,950,776
Resident take care	$\exp(\beta_0 + \beta_{Resident})$	8,318,562	10,466,702
Tenant	$\exp(\beta_0 + \beta_{Tenant})$	9,120,179	15m367,491
Makumbusho	$\exp(\beta_0 + \beta_{Makumbusho})$	10,386,319	7,219,893
Mburahati	$\exp(\beta_0 + \beta_{Mburahati})$	7,025,100	5,433,861
Yombo Vituka	$\exp(\beta_0 + \beta_{Yombo\ vituka})$	12,622,607	18,174,296
Christian	$\exp(\beta_0 + \beta_{Christian})$	43,575,255	21,280,809.7
Muslim	$\exp(\beta_0 + \beta_{Muslim})$	32,056,162	10,155,593.8
Lowland	$\exp(\beta_0 + \beta_{Lowland})$	15,855,071	6,562,622
Stream	$\exp(\beta_0 + \beta_{Stream})$	21,423,521	18,516,848
Sex (Male)	$\exp(\beta_0 + \beta_{male})$	12,497,010	19,272,355
Allotments	$\exp(\beta_0 + \beta_{Allotment}$	15,096,900	4,026,337
Shade trees	$\exp(\beta_0 + \beta_{Shade\ trees}$	8,393,767	6,319,920
Fruit trees	$\exp(\beta_0 + \beta_{Fruit\ trees}$	18,811,896	11,915,582
House garden	$\exp(\beta_0 + \beta_{House\ garden}$	7,625,436	8,818,197
Open agricultural field	$\exp(\beta_0 + \beta_{Open\ agricultural\ field}$	20,915,478	15,620,085
Open Space inside courtyard	$\exp(\beta_0 + \beta_{Open\ space\ inside\ courtyard}$	1,285,939	141,428,655

The final model for estimating the investment cost of green spaces: The examination of the Aikaike information criterion (AIC) revealed that the predictor variables that caused the model to have the lowest AIC (581.59) are income of the households, age of green space, area covered by green space, green space type and settlement type. Factors like education level, religion affiliation, tenure information, location within settlement, age of the respondent, green space type and sex had no significant influence on the investment cost of green spaces. Thus, the model with predictor variables that were worth to be kept was

$$\mathbf{ln[Investment\ cost|x_i]} = \beta_o + \beta_1 \text{Income} + \beta_2 \text{Age of green space} + \beta_3 \text{Area covered} + \beta_4 \text{Green space type} + \beta_5 \text{Ward} + \varepsilon_i$$

Thus, a final developed multiple regression model was;

$$\ln[\text{Investment cost}|x_i] = 16.661 + 0.011 * \frac{\text{Income}}{10{,}000} - 0.705 * \text{Makumbusho}_{\text{WARD}} - 0.928 * \text{Mburahati}_{\text{WARD}} - 0.320 * \text{Yombo vituka}_{\text{WARD}} - 0.040 * \text{Green space type}_{\text{ALLOTMENTS}} - 0.752 * \text{Green space type}_{\text{SHADE TREES}} + 0.058 * \text{Green space type}_{\text{FRUIT TREES}} - 0.599 * \text{Green space type}_{\text{HOUSE GARDEN}} - 0.115 * \text{Green space type}_{\text{OPEN AGRICULTURAL FIELD}} - 2.345 * \text{Green space type}_{\text{OPEN SPACE INSIDE COURTYARD}} + 0.100 * \text{Age of green spaces} + 0.001 * \text{Area of green space} + \varepsilon_i$$

This model can predict the investment cost of semi-natural green spaces to households with similar attributes. The prediction interval of the model is between TZS 1,164,342.2 (506USD) and TZS 20,875,122 (9,076USD). The model can be applied anywhere within Dar es Salaam City for household(s) with income level between TZS 10,000 to TZS 10,000,000 per month and green space coverage of 1SQM to 1,400SQM.

For instance, using household income of TZS100, 000, area coverage of 24square meters, ward type Mburahati, age of green space 1 year and green space allotment, the model can be used to determine the compensation of investment cost to households. Plugging the variables in the model, the model will predict the log (Investment Costs of green space) of 15.927 in which the log inverse will be equal to 8,260,536 Tanzania shillings (3,592USD).

This implies that the model can be used to predict the economic value of green spaces based on investment cost to households with similar income level of TZS 100,000, area coverage of green space of 24SQM, green space type allotment and an age of 1 year staying at Mburahati. If these households are to be compensated in terms of investment cost of green space since its establishment under the current compensation practices to TZS 8,260,536 (3,592USD) per year is disregarded in compensation issues. This is the benefit that the household can lose if not taken during compensation.

Thus, the model can be used as additional factor to be considered in valuation of houses at sale. The current property valuation does not take into account the investment and hence under estimation of property value at sale.

Limitation of the model: The model can be used in Dar es Salaam City with the following limitations; i) the model can be used for determining economic value of green spaces at geographical spatial scale of residential plot and spatial social scale of household level and ii) The model can be applied to any other cities found in Tanzania but social demographic data need to be collected to update the model.

Conclusion: The investment cost of green spaces is influenced by income of the households, age of green space, area covered by green space, green space type and settlement type. Factors like education level, religion affiliation, tenure information, location within settlement, age of the respondent, green space type and sex had no significant influence on the investment cost of green spaces. This study has revealed that provided other factors are fixed, and addition of 1 square meter of the area covered by green space, the investment cost of green space increases by 0.1%. Individuals who resided in high density areas had a less investment cost of green space per household by 33.7% compared to the individuals who resided in low density area. On average, for every addition of 1 year of the green space, the investment cost of green space was found to increase by 10.5%. The developed model can be used to estimate the average of investment cost of green spaces in households with similar status in either of predictor variables.

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