AN APPROACH TO OPTIMIZE THE LOCATION DECISIONS OF PUBLIC PARKS IN COLOMBO

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Abstract

Among the public services offered by the government of Sri Lanka, public parks can be identified as one of the crucial elements. With the increasing trend of building new public parks, it is necessary to identify the factors that may contribute to the optimum usage of parks. Literature on public park usage mostly discusses on impact of non-locational factors such as design elements, behavioral and psychological factors on the functionality. Therefore, this study aims to develop an approach to optimize public park location decisions based on functional efficiency. First, the usage of public parks was determined by standardizing the google visit data based on aggregated and anonymized data from users who have opted to allow access to Google Location History. Second, a questionnaire survey with a total sample of 165 park users was carried out to develop a user profile for parks and to understand its relationship with usage. Then the factors, which correlate with park usage, were used to define the factors of recreational attractiveness. These factors are share of population in the age group of 15 to 24, share of population in the age group of 45 to 65, share of population in the major ethnic group, street connectivity, park size and number of competitors in the neighborhood. In order to calculate the recreational gravity of each public park, data was obtained on defined attractiveness factors from each Grama Niladhari Division in the market range of each park and the distance from each GND to each park. Next, it modeled the gravitation relationship between usage and recreational gravity of each case study. Finally, the applicability of the derived model was tested with three additional cases. Accordingly, the model predicts the functionality with -15% variance for moderate size parks, -25% variance for small parks, and -35% variance for large parks with R^2 of 0.66. Therefore, the model needs extension with some additional factors. Importantly, it highlights the importance of considering locational factors along with non-locational factors to optimize the public park location decisions.

***Key words**: Market Range, Functionality Level, Recreational Gravity, Public park usage*

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Introduction

Economic and social development would be the ultimate benefit by improving the quality of life of people by offering better public facilities (Badescu et al., 2016). Properly designed public parks and walkways will contribute to improve the health of people thus producing a healthy population. This can be highly beneficial to achieve the goals of living a qualitative life in Sri Lanka. On the other hand, being a developing country, Sri Lanka faces many financial constraints. Therefore, it is necessary to use the available limited resources in an effective way with a strategic intervention.

Considering the public facilities/services distribution, we can observe two forms: efficiency-based and equity-based distribution. Equal distribution can be identified as equal access to public facilities which is measured by distance to main services (Hu et al., 2018). Efficiency based distribution on the other hand focuses on functionality of the services (McAllister 1976). It mainly concerns the scale of the facility provided and usage. The most essential facilities like hospitals and schools need to be distributed on an equity-basis. Normally, a hospital should be accessible within 15 minutes. Likewise, the respective Local authorities practice guidelines based on accessibility and serviceability by based on planning standards.

Infrastructure facilities such as markets, and playgrounds are distributed based on an efficiency approach. When considering the private sector facilities such as super markets, location decisions of those are based on the efficiency basis. Unlike in the past, in deciding locations, they now consider threshold levels and factors such as “proximity to customer, business climate, proximity to suppliers, infrastructure facilities, and host community” (Operations Management, 2014). Such tools and standards are useful for the location decision making of efficiency based public infrastructure and services.

Most of the studies and feasibility reports concluded so far are concerned on the serviceability of public facilities. This research aims to ascertain whether the root cause behind the failures of public parks is associated with location optimization. Accordingly, this study develops a location optimization approach for public parks in Colombo based on the functional efficiency.

Theoretical Basis

In Economics, the public goods are defined as non-excludable and non-rival. The provision of public services plays a major role in urban planning. Public goods/services shape the comfort of citizens (Ellis and Schwartz 2016). Erkip (1997, 354) has pointed out four factors that affect public service distribution pattern: “(1) The availability of resources (2) Distribution of population and its socio-economic characteristics (3) The intensity of political demands and (4) The needs of the citizens.”

“Equity and efficiency are of the fundamental paradoxes faced in the economics and how to coordinate the relationship between the two is known as the “Riddle of the sphinx” in the sphere of economics”(Hu et al., 2018, 1). Efficiency refers to how well an economy distributes scarce resources to meet the needs and wants of citizens optimally. Equity approach is linked with the concepts of fairness and social justice.

Tahmasbi et al (2019) have identified equity measures in order to quantify equity. Accordingly, there are statistical measures to quantify the equity/ inequity among diverse groups without considering the spatial location and variation. Examples are the Gini coefficient, Variance, and entropy index. At the same time, there are location-based indices of equity like accessibility measures used to emphasize the spatial variation of the data. Factors that contain inaccessibility frameworks are land use, transportation, and temporal and individual components.

Public parks can be identified as fixed facilities. Oh & Jeong have identified four factors of planning public park distribution i.e. "(1) Maximum distance (2) Service area ratio (3) Service population ratio (4) Service" (2007, 28).

Cohen et al (2007) have confirmed the relevance of factors like Demographic description of parks and surrounding neighborhoods. This includes factors like population in 0.5-mile radius, in 1-mile radius and in 2-mile radius, race/ethnicity, households in poverty, aged older than 60 years, average percentage of time each area of the public park used, comparison of neighborhood park characteristics together with number of people observed, and energy expenditure per person. Esther, et al (2017) have examined the relationship between elderly satisfaction and design of public parks and introduced factors like social connection and mobility, social participation and inclusion, physical environment and supporting facilities, accessible public transport, outdoor urban furniture and connection to nature, proximity to amenities and familiarity with the environment.

In Sri Lanka context, the literature on public parks can be divided mainly into four areas of design and architecture (walkability (Dilhan 2014), heat (Nasir et al. 2013), design elements (Oshani and Wijethissa 2015; Gunathilake 2015; Amarathunge 2010; Arunadeepa 2007), green spaces (Li and Pussella 2017; Amano et al. 2018; Karunananda et al. 2018)); health aspect (Katulanda et al. 2013; Amano et al. 2018); economic aspect (Ratnayake et al. 2017); and social and behavioral aspect of parks (De Silva and Samarasinghe 1985; Pussella and Li 2019; Dilhan 2014). The location aspect has not received due consideration in any of these studies. Additionally, the Urban Development Authority (UDA) has declared standards regarding public outdoor recreation spaces. The minimum standard is 3.5acres of land per 1000 persons to be allocated for outdoor recreation spaces. Accordingly, the different levels of parks are level 1- pocket parks, level 2 - mini parks, level 3 – local parks, and level 4 – community parks.

According to Roberts (2015) a threshold level can be identified as a way of defining the limits of distribution of goods and services which can be expressed with market range and threshold population.

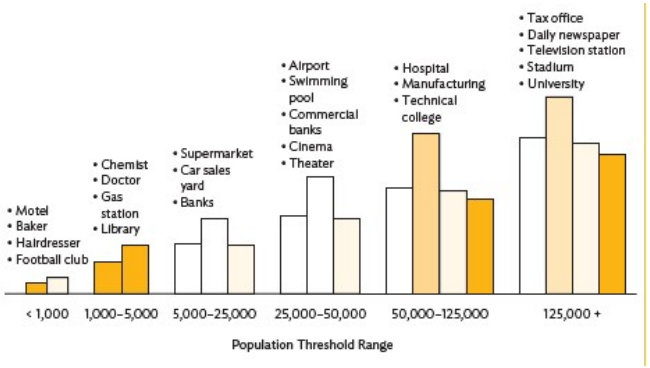

Figure 1: Threshold levels for urban facilities
Source: Roberts, 2015

According to Stewart (as cited in Hansen, 1959) one of the measurements of accessibility is potential of population concept. The concept explains that the possibility of having contact with group of people which is directly proportional to the size of the group and inversely proportional to the distance or separation from that group. In this study, he has developed a measurement for accessibility using gravity model concept. Then the study has determined the relationship between residential growth and accessibility to shopping, employment and social opportunities.

Suitable locations for green spaces or public parks have been examined by Jawad et al. (2018) using GIS applications. Wang, et al. (2015) have examined the influential physical and non-physical factors for accessibility for public parks. An integrated model has been produced incorporating the five dimensions of physical, transport, knowledge, social, and personal.

Some scholars have measured the equality of public park service (Pawinee et al., 2003). This particular article has used a Voronoi diagram considering the dispersion of parks in a transport view. The indicators used are transportation network, public transport and pedestrian accessibility. Size of the park also have been taken into consideration. According to Neema & Ohgai (2010), a multi objective model can be used for facility location planning. The model is called genetic algorithm based multi objective optimization model (GAMOOM). Factors considered are population, land use, noise influence and air quality.

Research Methodology

It is important to examine the variables, which affect the functionality level when redefining of threshold levels of public parks. Thus, a content analysis was conducted to find the determinants of functionality level using the recently published articles (Table 1).

Table 1: Variables and Sub Categories

	Variable	**Sub categories**
1	Population	Total Male Population
		Total Female Population
2	Accessibility	Distance to Nearest Town
		Distance in Time
		Number of bus stops near the park
3	Income level	Rs. 15,000-30,000
		Rs. 30,000-45,000
		Rs. 45,000-65,000
		>65,000
		Single detached houses
4	Transport Network	Type A
		Type B
		Type C
5	Ethnic profile of the population	Majority Population
		Minority Population
6	Age profile of the population	below 14 Population
		15 – 24 Population
		25-44 Population
		45-65 Population
7	Park size	Park size
8	Number of parks in the neighborhood (competitors)	Number of parks in the neighborhood within 500m (competitors)

Twelve public parks have been selected which illustrated in figure 2 below (Gangarama park, Urban wetland park, Beira Linear park, Weras gaga park, Keli madala-borelasgamuwa, Diyasaru park-Thalawathugoda, Katubeedda walkway, Viharamahadevi park, Sri parakumba peace park Rajagiriya, Diyatha uyana, Aldeniya Suwatha park Kadawatha, and Sathutu uyana) in Western Province as case studies of this research. All these parks come under the localized facilities based on the Urban Development Authority's categorization of parks. These selected parks show some variability in terms of functionality, which was useful in analysis.

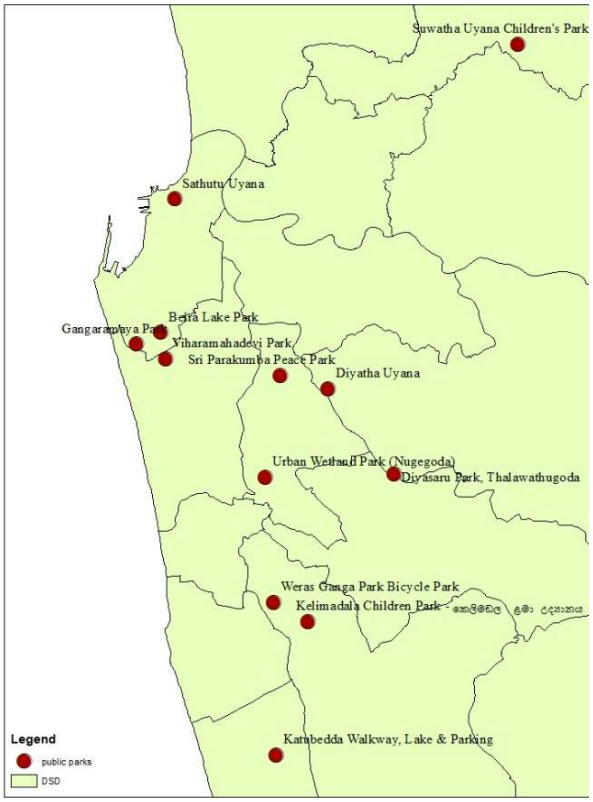

Figure 2: Locations of selected 12 public parks

To determine the functionality level of the selected parks, the user visitation data were collected from Google visit database. Google visit data use aggregated and anonymized data to produce visit data. For example Figure 3 shows the visitation of a park in different time slots of a day.

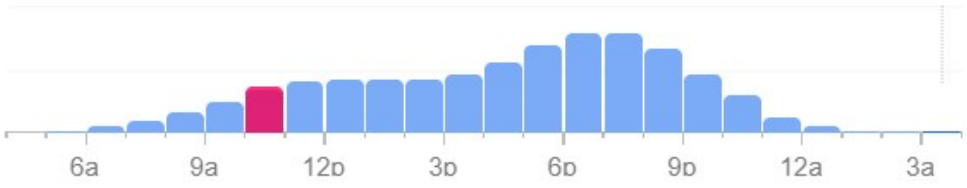

Figure 3: Google Visit Data
Source: Google inc, 2019

The data was based on average population who spent their time in parks using the Google data. The data interprets the level of business within a day at every hour. Scoring technique was employed for statistical adjustments of the Google visit data in order to improve the accuracy ("Encyclopedia of Survey Research Methods," 2008).

Table 2: *Scoring technique*

Functionality Level	Score
Not busy	1
Not too busy	2
Little busy	3
Busy	4

Using the above method, a value can be assigned for the functionality level of each selected park (per week). Then a questionnaire survey was carried to generate a user profile for each of these parks. The purpose of this questionnaire survey was to find relationships between the functionality levels and user characteristics. The questions related to basic information of users, frequency of park usage and overall satisfaction of the park is included in the survey form.

Slovin's sample calculating formula used to determine the sample size for the questionnaire survey. This formula is used when the characteristics of the population is unknown. Here "n" denotes the sample size, "N" denotes the total population, and "e" for the sampling error.

$$n = N / (1+Ne^2)$$

The sample was determined with 90% confidence level and the minimum sample required was 165. Then the sample was divided among selected parks based on identified functionality level of less functioning, moderately functioning, and high functioning.

To examine the relationship between the functionality level and user characteristics, Spearmen's correlation analysis was carried out using SPSS (Statistical Package for the Social Sciences) software. User characteristics, which had significant relationship with the functionality, were used to define the recreational gravity of each park. The basic gravity model principles were used with the application of distance matrix into the significant user characteristics. Then a local market range was defined for each of the park and collected data on selected user characteristics within those market ranges. Then model of functionality depends on recreational gravity was arrived.

Finally, the developed model was validated using different three (03) new case studies to represent less functioning, moderately functioning and high functioning park categories. They are Beddagana wetland park, Cotta Road Children's park, and crow island beach park.

Findings

Table 3 below provides a summary on the characteristics of the sample. Majority of the sample were male (56%), between the age group 25 to 44, had education upto secondary level, and income above Rs.65,000 per month. 42% of them were in the mid-career level. When considering

the visiting pattern for parks 40% accounts for several times a week visitation category. More than half of the respondents which is 70% were satisfied on the park they visit. Nearly 60% use private mode for transportation whereas 40% of the respondents use the public transportation. Majority surveyed are local but 7% accounts for foreign respondents.

Table 3: Characteristics of the respondents

	Count (Percentage %)		Count (Percentage %)
Age group		**Occupation Category**	
Below 14	0	Early career	35.5
15 - 24	20.9	Mid career	42.7
25-44	59.1	Senior career	21.8
45-65	19.9	**Income level**	
Gender		15,000-30,000	16.4
Male	56.4	30,000-45,000	27.3
Female	43.6	45,000-65,000	26.4
Ethnic group		Above 65,000	30
Majority	75.5	**Nationality**	
Minority	24.5	Local	92.7
Education Level		Foreign	7.3
Primary	2.7	**satisfaction**	
Secondary	51.8	very satisfied	16.4
Tertiary	45.5	satisfied	70
Mode of Transport		neutral	13.6
foot	6.4	**visiting pattern**	
public	36.4	Everyday	2.7
private	57.3	Once a week	24.5
		Several times a week	40
		occasionally	32.7

Source: Complied by authors based on primary data collection

Apart from this questionnaire survey five (05) Key Informant Interviews (KIIs) were carried with the representatives of Urban Development Authority (UDA), Sri Lanka Land Development Corporation (SLLRDC), and local authorities regarding the determinants of public park locations. Accordingly, these institutions do not practice a standard way to decide park locations. The most practiced method is the wetland conservation concept as a strategy to conserve wetlands. Further, these institutions follow the regulation of minimum standards for the allocation of outdoor recreation spaces (3.5 acres of land per 1000 persons).

As the first step of developing a method for optimization of park location decisions, functionality of the 12 case study parks were calculated.

Table 4:Functionality Level of the parks

	Monday	Tuesday	Wednesda	Thursday	Friday	Saturday	Sunday	week
Diyasaru Park Thalawathugoda	19	24	25	24	24	35	40	191
Beira Lake linear park	24	29	24	20	23	30	29	179
Katubedda Park	44	45	43	41	46	47	46	312
Gangarama Park	24	24	24	24	24	24	24	168
Sri parakumba peace park rajagiriya	24	24	24	24	24	24	24	168
Sathutu uyana	24	24	24	24	24	24	24	168
Viharamahadevi	40	33	34	41	53	61	63	325
Weras gaga park	23	25	29	25	30	45	45	222
Diyatha	63	55	47	44	51	75	71	406
suwatha park - kadawatha	18	20	24	24	20	29	36	171
Urban Wetland Park Nawala	37	36	35	39	50	55	55	307
Kelimadala - Borelasgamuwa	24	22	25	23	25	40	43	202

After calculating the functionality level, the levels were categorized into three main categories which are high functioning, moderately functioning and less functioning. Accordingly the sample contained three (03) highly functioning parks, four (04) moderately functioning parks, and five (05) less functioning parks as detailed in Table 5.

Table 5: Categorization of selected parks based on functionality

Diyasaru Park Thalawathugoda	1.5
Beira Lake linear park	1
Katubedda Park	2
Gangarama Park	1
Sri parakumba peace park rajagiriya	1
Sathutu uyana	1
Viharamahadevi	2.5
Weras gaga park	2
Diyatha	3
suwatha park - kadawatha	1.3
Urban Wetland Park Nawala	2.3
Kelimadala - Borelasgamuwa	1.5

Less functioning
Moderate functioning
High functioning

Source**:** Complied by authors based on primary data collection

As the second step, spearman's correlation analysis was conducted between park functionality and the user attributes collected through questionnaire survey. Accordingly, only distance to the town, population between 15 to 24, population between 25 to 44, population share of the major ethnic group, park size, and number of competitors (other parks) were significant at least at 0.05 level.

Table 6: Spearman correlation between park functionality and location attributes

			Fun_outof5
Spearman's rho	Dis_Town	Correlation Coefficient	.851**
		Sig. (2-tailed)	.000
	Age15to24	Correlation Coefficient	.582*
		Sig. (2-tailed)	.047
	Age25to44	Correlation Coefficient	.596*
		Sig. (2-tailed)	.041
	Per_Ethnic_Major	Correlation Coefficient	.207*
		Sig. (2-tailed)	.018
	Park_size	Correlation Coefficient	.662*
		Sig. (2-tailed)	.019
	Num_competitors	Correlation Coefficient	-.657*
		Sig. (2-tailed)	.039

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

In the third step, above significant user attributes were collected from a defined market range of each park using collected user profiles through the questionnaire survey. Then the collected data was employed to calculate the recreational gravity of each park as below:

$$Recreational\ Gravity \propto \frac{Attractiveness}{Distance^{b}}$$

$$\textbf{\textit{Attractiveness}} \propto \frac{Bus\ stops\ near\ the\ park \times 15\ to\ 24\ age\ category\ population \times 45\ to\ 65\ age\ category\ population \times park\ size \times Ethnic\ majority\ population}{(Number\ of\ competitors\ in\ the\ neighborhood + 1) \times Distance^{2}}$$

The Table 7 below provides the calculated recreational gravity of each park.

Table 7: Recreational gravity of each park

Park name	Functionality level of the park	Recreational gravity
Sathutu uyana	1	0.774858491
Sri parakumba peace park	1	1.46005918
Gangarama park (Kaladoowa)	1	5.16442434
Suwatha park Kadawatha	1.3	5.456400079
Weras gaga park	2	22.2975158
Diyasaru park Thalawathugoda	1.5	22.43312772
Beira lake linear park	1	30.60845335
Katubedda Park	2	91.81398158
Urban wetland park Nugegoda	2.3	127.2087952
Kelimadala Borelasgamuwa	1.5	203.0181809
Diyatha uyana	3	292.3018355
Viharamahadevi park	2.5	2105.45881

The plot of functionality against the recreational gravity of each park to identify any patterns is shown in Figure 4. This plot closely follows polynomial relationship between park functionality on recreational gravity with a r^2 of 0.66. Accordingly it can be stated that the 66% of the variability of park functionality is attributed by the calculated recreational gravity using selected park location attributes.

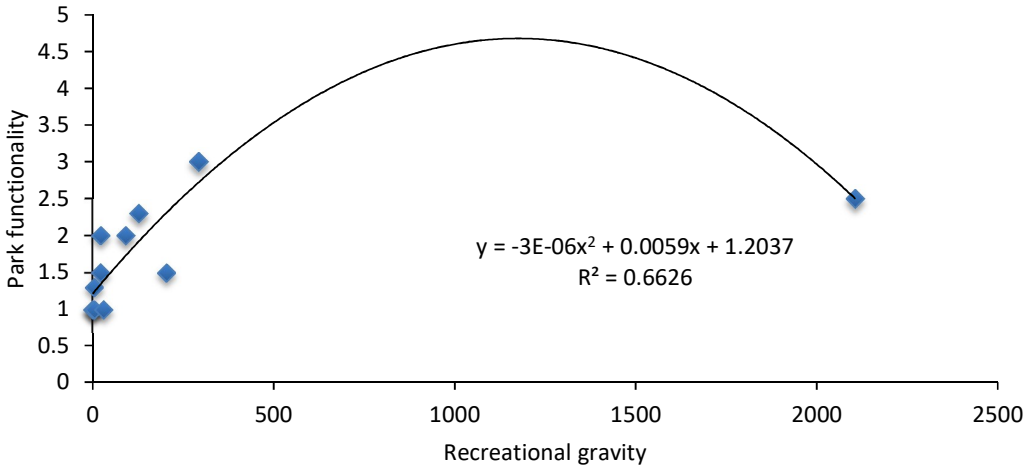

Figure 4: Plot of park functionality on recreational gravity

The last step was to validate the above model using some additional case studies to represent three park functionality categories. Accordingly, data were collected relevant to three (03) case studies of Beddagana wetland park, Cotta Road Children's park and crow island beach park were collected. Then the modeled functionality levels based on the recreational gravity and actual functionality from google visit data were compared.

Table 8: Comparison on modelled and actual functionality levels

	Recreational gravity	Modelled functionality	Actual functionality level	Variation	% Variation
Crow Island Beach park	0.02	1.203818	1.61	-0.40618	-25%
Cotta road childrens' park	0.03	1.203877	1.42	-0.21612	-15%
Beddagana wetland park	1.61	1.213191	1.88	-0.66681	-35%

Accordingly modelled functionality levels were up to 35% less than the actual functionality levels.

Conclusion

The main objective of this paper was to find a location decision optimization approach for public parks in cities in western province, Sri Lanka. Mostly park usage and functionality are discussed associated with the park features and design elements rather than its locational attributes.

The theoretical discussion reveled the concepts associated with functionality such as threshold population, market range, and spatial gravity. Additionally it divulged location optimization factors such as total population, accessibility, income profile of the population, transport networks, ethnic profile of the population, age profile of the population, size of the facility, and

number of competitors. Once of these factors were tested with a selected sample of 165 park users of selected 12 parks in Colombo. Only distance to the CBD, population in age group between 15 to 24, population in age group between 25 to 44, population share of the major ethnic group, and the number of competitors (other parks) in the neighborhood were significantly (at 0.05 level) related with park functionality calculated using the Google visitor data. Then these variables were used to construct the gravitational formula for urban parks in Colombo. It showed a pattern of polynomial model with r^2 of 0.66. Finally, the applicability of the model was tested using three additional case studies, which showed -15% to -30% variation.

With the r^2 of 0.66, we can conclude that locational attributes of parks can express about 66% variability of park functionality. Other park elements like design, facilities, theme, etc may contribute to the remaining variability of the park functionality. Thus, the model can be further extended with the inclusion of those factors. Additionally, this model should be further refined with additional case studies with a large variability of functionality levels. The functionality levels and recreational gravity of the selected 12 case studies are clustered around lower and upper ends of the curve. Importantly this model highlights the dis-economies of scale in terms of park size for large parks like Viharamahadevi Park.

In conclusion, this paper highlighted the importance of location attributes and functionality aspects of urban park location decisions compared to equity based approach of infrastructure provisions. The framework successfully interpreted park functionality into some extent and showed areas for further improvements. Therefore, it is suggested that the planners should put more emphasis on the functionality aspect of the urban parks with location attributes when they evaluate alternative locations for urban park developments.

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