International Journal of Engineering Research and General Science Volume 4, Issue 1, January-February, 2016
ISSN 2091-2730

# A Study to Compare the Level of Walkability in Two Urban Neighborhoods of Sri Lanka

Gayani Ranasinghe,[1] Susantha Amarawickrama,[2] Rangajeewa Rathnayake[3]

Department of Town and Country Planning, Faculty of Architecture, University of Moratuwa, Katubadda, Sri Lanka.
Email: gayaniprasadika@gmail.com
Department of Town and Country Planning, Faculty of Architecture, University of Moratuwa, Katubadda, Sri Lanka.
Email:susanthaa116@gmail.com
Department of Town and Country Planning, Faculty of Architecture, University of Moratuwa, Katubadda, Sri Lanka.
Email: rangajeewar@gmail.com

**Abstract—** Walkability was an essential consideration in city planning before the industrialization. But with the development of traffic and transportation planning, automobile priority cities neglect pedestrians and walkways. The quality of the neighboring environment plays a major role in encouraging people to walk when attending their daily needs and thereby people can have enough daily exercises which cause to improve good health. Although past studies have identified a relationship between neighborhood design factors and the level of walkability, this interdependence is poorly understood in urban planning in Sri Lanka. The purpose of this study is to determine factors and conditions that influence walkability in selected two urban neighborhoods in Sri Lanka and to develop two models to compare what design factors enhance walkability for the towns of Panadura and Maharagama. Ninety two (92) factors that affect the walkability in urban neighborhood were identified as the findings of the literature review of this study. Seventy six (76) walkability factors identified through perception surveys were examined within a 100m radius of 70 buffered circles representing 140 participants' residences in Panadura through a questionnaire survey and field observations. The same factors were examined and questionnaire surveys were carried out within a 100m radius of 50 buffered circles representing 100 participants' residences in Maharagama. Chi-square and Bivariate correlation analysis were carried out to identify the most decisive factors for walkability. Multiple Regression analysis was applied to develop models to assess the level of walkability of residents in above selected two urban neighborhoods based on the most significant factors. The findings of Panadura area reveals that people's level of walkability depends not only on built environment factors but also on some factors which are directly linked to "safety" namely feeling of personal safety, availability of unattended dogs on road , reported road accidents, people present on road and houses with opened windows facing either side of the road. Second priority was given to the factors related to the "convenience and comfort", such as paving treatment of sidewalk, width of sidewalk, quality of the maintenance of road, less foul air and clearance of the route. In Maharagama area, people's level of walkability mainly depends on the factors relevant to "convenience and comfort" such as availability of variety of activities either side of road (vendors, playing children on streets ect), width of sidewalk and availability of shade & cover from harsh climate. The methodology and the findings of this study will be helpful to urban designers and town planners to identify the factors that affect to enhance the level of walkability in different urban neighborhoods and to create healthy and livable cities in the context of Sri Lanka.

**Keywords**—Compare, Factors of built environment, Neighborhood, Walkability

## 1. INTRODUCTION

Regular engagement of physical activities such as walking and bicycling will improve public health. Therefore in modern world, people tend to have daily physical exercise through jogging and doing machinery exercises at gymnasiums by allocating more time of their busy life. The quality of the neighboring environment plays a major role in encouraging people to walk when attending their daily needs and thereby people can have enough daily exercises which cause to improve good health. Pedestrianization has become an integral part of the sustainable modern urban design, where pollution-free, convenient, safe, and comfortable pedestrian facilities are ensured (Cervero and Duncan, 2003). Though the influence of factors of the built environment on habitual behavioral patterns such as walking are not yet well understood by behavioral scientists (Sallis and Owen, 1999), but transportation and urban planning researchers have identified some strong patterns of association between walking and the factors of built environment (Frank et al., 2003, Owen et al., 2004, Frank and Pivo, 1995). However, a limited number of studies have done so far to investigate the relationship between factors and conditions of the built environment that affect to enhance the walkability in Sri Lankan urban neighborhoods. This paper discusses definitions and concepts of walkability, built environment and neighborhood. As an outcome of literature review, it elaborates 93 factors of built environment that affect the level of walkability. Chi-square and bivariate correlation analysis is applied to identify the most significant factors which are contributed to enhance the walkability in two different contexts of urban neighborhoods. The main objective of this research study is to compare the level of walkability which can be utilized in planning policy frameworks that guide new development and changes in two selected urban neighborhoods in Sri Lanka.

## 2. Literature Review

Many individuals define walkability using different terms such as proximity, accessibility, and suitability. Walkability is a measure of how friendly an area is for walking. It takes into account the quality of pedestrian facilities, roadway conditions, land use patterns, community support, security and comfort for walking (Ariffin and Zahari, 2013). Walkability is the measure of the overall walking and living conditions in an area and is defined as the extent to which the built environment is friendly to the presence of people walking, living, shopping, visiting, enjoying, or spending time in an area (Abley, 2005). The built environment refers to the physical form of communities (Brownson et al., 2009), which has been operationalized according to six dimensions: residential density, street connectivity, accessibility to services and destinations, walking and cycling (Leslie,2005) defines neighborhood as a physical environment in which all basic community facilities such as school, playground and local shop is provided within walking distance; it is an environment in which community may have an easy walk to a shopping center where they could get their daily household goods, employed people may find convenient transportation to and from work. Foesyth et al. (2007) show that neighborhoods can create and use network, interaction and connection to improve the quality of life as well as help in getting information, ideas, influences and resources. Accordingly, built environment of a neighborhood plays a major role to enhance the walkability by creating networks among the physical forms of communities.

Researchers in planning and transportation have identified diversity of land uses, access to facilities and street connectivity as key aspects for promoting walkability in urban neighborhood (Krizek et al. 2010). Similarly, the proximity of destinations, good weather conditions, safety and well-designed pedestrian facilities can significantly contribute to better perceptions of the walking environment (Ariffin and Zachary, 2013). Frank and Pivo (1995) demonstrate that population density and to a lesser extent, pedestrian infrastructure can affect the rate of walking. As Leslie (2005) mentions more varied and interesting environments creating neighborhoods are conducive to walking. Grid networks, sidewalks, setbacks and parking can be played a role in creating a pedestrian friendly area (Park and Schofer,2006). Furthermore, they show that large setbacks increase the effort required to reach buildings from the street; small building setbacks make commercial establishment and residences easily accessible to pedestrians. Nankervis (1999) shows that weather variables such as temperature and total precipitation impact on walking. According to the study done by Campos et al. (2003), street lighting, width of walk ways, gradient of walk ways, weather conditions, proximity to main transport facilities and signage show a higher degree of importance in encouraging people to walk. At the same time, safety is also a point of concern for pedestrian's walkability. Individuals who live in areas that are more walkable and have lower crime rates get more encouragement to walk more (Doyle et al., 2007). In a similarly vein, Schofer (2006) illustrates that pedestrian activity is associated with the level of personal safety within a neighborhood. Table 1 summarizes identified ninety three (93) factors of the built environment that affect the walkability in urban neighborhood as the findings of the literature review of this study.

Table 1: Factors that affect Walkability in Urban Neighborhood

| Factors | Source | Factors | Source |
|---|---|---|---|
| **1. Socio demographic factors** | Lawrence et al (2007), Ester et al (2006), Lilah et (2005), Ayşe & John (2012)46. | **8.Convenience & Comfort** | Lawrence et al (2007), Kevin (2010), Southworth (2005), Krambeck & Shah (2006), Ester et al (2006), Saelens & Handy (2008), Ayşe & John (2012), Steven (2005),Litman (2005), |
| 1.Age | | | |
| 2.Gender | | 44. Cleanliness of the roads | |
| 3.Ethnicity | | 45.Variety of activities within buffer | |
| 4.Education level of the respondent | | 46. Number of houses with opened windows facing either side of the road | |
| 5.Employment | | 47.Way finding signage | |
| 6.Per capita income | | 48.Walking path modal conflict | |
| 7.Household size | | 49. Ambient sound | |
| 8.Number of employees | | 50.Foul air | |
| 9.Physical Ability to walk | | 51.Continuity of sidewalks | |
| 10.Auto ownership | | 52.Sidewalk width | |
| **2.Mixed land use diversity** | Cervero & Kockelman (1997), Sallis et al. (2005), Steven (2005), Lawrence et al. (2007), Forsyth et al. (2007), Saelens & Handy (2008), Ewing & Cervero (2010), Ayşe& John (2012) | 53.Paving treatment of sidewalk | |
| 11.Residential<br>Commercial<br>Educational & recreation<br>Administrative<br>Agricultural | | 54.Width of Home access road | |
| | | 55. Maintenance of walking path | |
| | | 56.Shade & cover from harsh climate | |
| | | 57.Clear route | |
| | | 58.Vehicle parking facilities | |
| | | 59.Price of parking | |
| | | 60.24hour convenience stores | |

| | | | |
|---|---|---|---|
| **3.Accessibility** | Lawrence et al (2007), Ester et al (2006), Lilah et al (2005), Steven (2005), Sapawi & Said (2012), Krizek et al (2010) | 61.Walking trail length | |
| 12.Number of foot paths | | 62.Covered walkways | |
| 13.Condition of foot paths | | 63.Places for casual contacts | |
| 14.Covered access from fences | | **9.Safety** | Krambeck& Shah (2006), Saelens & Handy (2008), Ayşe & John (2012), Steven (2005), Sapawi & Said (2012) Ariffin & Zahari,(2013), Southworth,(2005), Foster & Giles, (2008), Leslie et al.,(2005), Troy & Grove, (2008), |
| 15.Number of significant barriers | | 64.Personal safety | |
| 16.Development patterns | | 65.Number of crime watch signs | |
| 17.Regional accessibility | | 66.Reported crimes | |
| **4. Connectivity** | Lawrence et al (2007), Kevin (2010), Southworth (2005), Krambeck (2006), Ester et al (2006), Saelens & Handy (2008), Ayşe & John (2012) | 67.Road accidents | |
| 18.Street connectivity (number of intersections within buffer) | | 68.Undesirable land use & activities | |
| 19.Street pattern | | 69.Abandoned buildings & lands | |
| 20.Connectivity between uses | | 70.People present in roads | |
| 21.Number of bus services per day | | 71.Vehicle speed | |
| 22.Linkage of transport modes | | 72.Noise mitigation signals | |
| 23.Efficiency of transport service | | 73.Unattended dogs within buffer | |
| 24.Block size | | 74.Enough street lighting | |
| 25.Block length | | 75.Level of entrapment | |
| **5.Density** | Lawrence et al (2007), Ayşe & John (2012), Steven (2005), Southworth (2005) | 76.Level of visibility | |
| 26.Residential density | | 77.Canopies which block the view | |
| 27.Employment density | | 78.Presence of back lanes | |
| 28.Road density | | 79.Volume/ noise safety | |
| 29.Population density | | **10.Aesthetic** | Lawrence et al (2007), Kevin (2010), Southworth (2005), Saelens & Handy (2008), Steven (2005), Sapawi & Said (2012) |
| 30.Retail Floor Area ratio | | 80.Attractive architectural design | |
| **6.Company** | Troy & Grove, (2008), | 81.Presence of street trees | |
| 31.Walking with another person | | 82.Number of places to exercise | |
| 32.Walking with pets | | 83.Variety in routes | |
| 33. Number of relatives within the buffer | | 84.Narrow & crowded streets | |
| **11.Pedestrian facilities** | Lawrence et al (2007), Ayşe & John (2012), Steven (2005), Schlossberg et al.,(2007), Ariffin & Zahari, (2013), Senevirathna & Morrall, (2013) | 85.Landscaping treatments either side of road | |
| 34.Presence of sidewalks | | 86.Naturally attractive places | |
| 35.Disability infrastructure | | 87.Availability of plazas | |
| 36.Availability of crossings | | 88.Park intensity | |
| 37.Feed bus service | | 89.Visual complexity | |
| 38.Public park within neighborhood | | 90.Transparency of fronting structures | |
| 39.Street lighting | | 91.Coherence of built form | |
| 40.Number of bus halts | | **7.Weather** | Lawrence et al (2007), Saelens & Handy (2008) |
| 41.Open sewers along walking path | | 92.Preferred walking time | |
| 42.Street furniture | | 93.Rainy | |
| 43.Quality amenities in public parks | | | |

Many researchers have developed models to measure level of walkability using different variables. Lwin and Murayama (2011) developed urban green space walkability model to identify how people use the shortest or greenest walking route for different activities by specifying their start and end points. They show that the shortest route is ideal for shopping activities while the greenest route is ideal for walking as a recreational activity. Mitra and Buliung (2014) have used Multinomial (conditional) logistic model to explore correlates of walkability with four travel modes (walk, transit, school bus, and car).Socio-demographics, travel distance, household travel interactions, connectivity and built environment are the criteria used for this model. Manaugh and El-Geneidy (2011) have used Binomial logistic model to examine walkability scores with household travel behavior. It shows that walkability indices are highly correlated with most non-work trip purposes. Additionally, households with more mobility choices are more sensitive to their surroundings. Moreover, Bahrainy and Khosravi (2013), using Iranian new town (Hashtgerd) as case study, have applied multivariate regression analysis to study how under construction environment and urban design qualities (formal–spatial) affect to the walkability and residents' health considering. Maleki and Zain (2011), through partial least square regression model, have identified density, employment, non-residential land use and land diversity as the factors that influence to the distance to facilities in a sustainable efficient residential site design. Furthermore, Cervero (2003) has developed a Walking-choice model to explore the association between walkability and the factors related to street and urban design such as trip purpose, trip distance, slope, rainfall, neighborhood quality and built environment factors. In this manner past studies inform how various factors influence walkability. It appears that past studies have used social, demographic, and environmental factors separately in their models. To our knowledge, past research has not informed us how to different conditions and factors together influence and predict walkability. In the study, we use a combination of social, demographic, design, and other possible environmental factors to predict walkability in a selected neighborhood in the town area of Panadura, Sri Lanka.

## 3.0 METHODOLOGY

The validity and the consistency of ninety three (93) factors that affect the walkability in urban neighborhoods identified above through literature review were ascertained by applying the Delphi technique. Randomly selected town planner, architect, engineer, urban planner, transport engineer, urban designer, project manager & a doctor were the experts who were interviewed to refine the factors. In addition, randomly selected ten members of the general public were interviewed to get their perception regarding the factors that affect walkability. As a result of the perception survey, seventeen (17) factors were ignored since they were not affecting much the walkability in the context of Sri Lankan urban neighborhood. Those factors were regional accessibility, price of parking, 24 hour convenience stores, walking trail length, covered walkways, places for casual contacts, street furniture, quality amenities in public parks, presence of back lanes, volume/noise safety, availability of plazas, park intensity, visual complexity, transparency of fronting structures, coherence of built form and presence of sidewalks.

The data concerning the selected seventy six (76) factors were collected by conducting questionnaire survey, direct interviews and field observation survey. For this study, Panadura and Maharagama urban neighborhoods in the Western Province of Sri Lanka were selected as the case study areas. The residential land uses dominate in activity pattern in Panadura, where high proportions of old residential bungalows occupy large blocks of lands, predominantly indicating more residential land uses (UNDP / UN-Habitat - Sustainable Cities Programme 2002). There is a trend of conversion of agricultural lands for residential activities enhancing the urban neighborhood character of both areas. Litman (2010) states it is more flexible to walk through a shorter distance like 100m, since a longer distance requires a combination of walking and usage of public transport. Therefore, 100m radius buffered circles were drawn around randomly selected 70 houses in Panadura urban neighborhood excluding main arterial and city center. Accordingly, from 70 buffered circles140 participants' residences were selected for the questionnaire survey. Same way, 100m radius buffered circles were drawn around randomly selected 50 houses in Maharagama urban neighborhood excluding main arterial and city center and two houses from each buffered circles were randomly selected being 100 participants' residences for the questionnaire survey in Maharagama.

Time spent for walking to places during a week was calculated considering walking time for each place daily. The total time spent for walking during a week is considered as a dependent variable being a continuous variable. Seventy six (76) factors refined above were considered as independent variables that affect the level of walkability in urban neighborhood of which eighteen (18) factors are categorical variables, thirty eight (38) factors are continuous variables and twenty (20) factors are ranked variables. Mixed land use diversity was examined calculating 'entropy' values within 100m buffered circle of selected houses. "Entropy" value was calculated by applying the following formula developed by Cervero and Kockelman (1997) to assess the similarity in the proportion of the area in parcels devoted to residential, commercial, educational and recreational, administrative and agricultural purposes.

$$H = -1\left[\frac{\sum (P_j) * \ln(P_j)}{\ln(K)}\right]$$

Source: Cervero, R., and Kockelman, K. (1997) 'Travel demand and the 3ds: Density, Diversity, and Design'

Where: H is the Entropy Value, K is the number of different types of land use in the buffer. Pj indicates the proportion of land area in the jth land use type and ln is natural logarithm using e (approximately 2.718) as its basis. Entropy values range between 0 and 1, with 1 representing equal proportion (20%) among the five uses in the neighborhood and 0 representing the presence of a single dominant land use. Auto ownership, ambient sound in area, foul air, bus service, open sewers, attractive and pleasant architectural designs, variety in routes, narrow and crowded streets, covered access from fences, development pattern, connectivity between uses, linkage of transport modes, efficiency of transport facilities, vehicle parking facilities, walking path modal conflict, continuity of sidewalk, quality and maintenance of walking path, shade and cover from harsh climate, clear route, disable facilities, personal safety, unattended dogs, enough street lightings, entrapment, enough visibility, canopies and landscaping treatment either side of the road existed within the buffer were measured on the basis of their 'availability'. Age of the respondent, income level, family members, number of employees, entropy, population density, residential density, employment density, retail density, road density, number of bus services per day, bus halts, foot paths, significant barriers, intersections, block length, block size, vehicle parking, number of houses with opened windows facing either side of the road, way finding signage, sidewalk width, width of home access roads, variety of activities, public park, street light, undesirable lands, abandoned buildings, people present, crime watch signs, reported crimes, vehicle speeds, road accidents, pedestrian crossings, noise mitigation signals, street trees, places for exercises, naturally attractive places and number of relatives within the buffer places were measured as 'numerical values' within the buffer.

Correlation analysis was conducted to ascertain whether the relationship between two continuous variables is linear (as one variable increases, the other also increases or as one variable increases, the other variable decreases) or not. In this empirical study, correlation analysis was used to identify the degree of relationship between walking time and each independent factors and the strength of the relationship between each factors for one and another. For the analysis two types of correlation analysis were used; Pearson correlation analysis and Spearman correlation analysis. Pearson correlation analysis was carried out for thirty eight (38) continuous variables only. Spearman correlation analysis was used only for the twenty (20) numbers of ranked variables (ordinal data) considering the total time spent for walking during a week in to three rank categories (75-150,151-225,226-300) as 1,2 and 3.

Chi-square analysis and bivariate correlation analysis were applied to identify the most effective factors that affect walkability in the selected case study areas. Chi-square analysis was the statistical test used to compare observed data with data expected to be obtained according to specific hypothesis. Further, chi-square test was used to find the relationship between the level of walkability and other categorical variables. This is normally used to investigate the relationship between two categories of variables in order to find out whether they are independent or dependent. Here the dependent variable of the total time spent for walking during a week was categorized into two categories as 75-175 minutes and 176- 276 minutes for Panadura and Maharagama. This is normally tested based on two hypotheses. They are, H0 = Two categories of data are independent. H1 = Two categories of data are dependent .. If the value is < 0.05, H0 is rejected. It shows variables are dependent. Finally, Stepwise Multiple Linear Regression Analysis was used to develop a model to assess the level of walkability (spent time for walking per week by minutes) in Panadura and Maharagama Urban Neighborhoods based on seventy six (76) multiple independent variables.

### 4.0 ANALYSIS AND RESULTS

The assumption of normality of the dependent variable of total time spent for walking in Panadura was identified through bell shaped Histogram and the corresponding P-P plot (which most of the probability values are on or near to the line), coefficients of skewness (0.001), Kurtosis values (-1.007), Kolmogrorov Smirnov Test {D(140)=0.072 ,p=.073} and SharpioWilk Test (0.960,sig .000). These test values evidence that time spent for walking in Panadura is normally distributed and does not deviate significantly from normal. The assumption of normality of the dependent variable of total time spent for walking in Maharagama was identified through bell shaped Histogram and the corresponding P-P plot (which most of the probability values are on or near to the line), coefficients of skewness (0.101), Kurtosis values (-0.740), Kolmogrorov Smirnov Test {D(100)=0.053 ,p=.062} and SharpioWilk Test (0.850,sig .000). These test values evidence that time spent for walking in Maharagama is normally distributed and does not deviate significantly from normal. Mainly, thirty eight (38) continuous variables were considered including the total time spent for walking to calculate the correlation coefficient. Based on the results of the calculation, the relationship between dependent variable and independent variables was mapped. Correlation analysis for Panadura area reveals that ten (10) variables have a strong relationship with total time spent for walking during a week. They are age of the respondent (-0.575, 0.000), number of significant barriers (-0.844, 0.000), number of houses with opened windows facing either side of the road (0.955, 0.000), sidewalk width (0.907, 0.000), variety of activities :vendors, playing children on streets (0.817, 0.000), number of street lights within the buffer(0.962,0.000), people present on roads (0.956,0.000), number of reported road accidents within buffer (-0.935,0.000), number of street trees within the buffer (-0.935, 0.000) and number of relatives hoses within the buffer (0.920,0.000). Twenty eight (28) factors were not up to the expected sign and level of relationship. It means these variables have no significant relation with total time spent for walking. In Maharagama area, people present on the road (0.874,0.000), variety of activities on the road (0.984,0.000) and block length (0.645,0.000) have a strong relationship with total time spent for walking during a week being 33 factors were not up to the expected sign and level of relationship.

Spearman correlation analysis was used to analyze twenty (20) ranked variables and for Panadura area, only six (6) variables were associated with total time spent for walking during a week at 0.05 significant levels. They are efficiency of transport facilities (0.845,0.000), paving treatment of sidewalk (0.696,0.000), quality and maintenance of walking path (0.723,0.000), clear route (0.952,0.000), unattended dogs (-0.790,0.000) and feelings of personal safety (0.816,0.000). In Maharagama area, ambient sound with the environment (0.634,0.000) and availability of covered access from fences (0.805,0.000) are associated with the total time spent for walking during a week at 0.05 significant levels. Chi-square test was used to analyze the eighteen (18) categorical variables and only four (4) variables were related to total time spent for walking during a week at 0.05 significant levels in Panadura area. They are covered access from fences (136.040, 0.000), variety in routes (8.529, 0.003), walking path modal conflict (46.179,0.000) and foul air (33.257,0.000). In Maharagama area, feel personnel safety (9.732,0.045), clearance of the route (21.108,0.000) and connectivity between uses (12.265,0.035) were related to total time spent for walking during a week at 0.05 significant levels. A model to measure level of walkability was developed by applying step-wise multiple linear regression analysis based on significantly correlated factors. Multiple regression model developed for Panadura area indicates that nine (9) factors significantly contribute to decide the level of walkability at 0.05 significant levels. The significant factors are ‘number of street trees within buffer, number of relatives’ or friends’ houses within buffer, feel personal safety when walk surround area, availability of covered access from fences, unattended dogs on the roads within the buffer, age of the respondent, reported road accidents within the buffer, people present on street within the buffer, number of houses with opened windows facing either side of the road. Finally, following model was developed based on the coefficient values relevant to above nine variables:

Level of walkability (Minutes)-Panadura =129.388 + (1.313 * Number of street trees within the buffer) + (5.636 * Number of relatives or friends houses within buffers) + (11.031 * Personal safety when you walk surround area) – (12.197 * Availability of covered access from fences) – (5.911 * Unattended dogs within the buffer ) – (0.282 * Age of the respondent) – (8.514 * Number of reported road accidents within buffer) + (1.434 * Number of people present on street within the buffer) + (1.597 * Number of houses with opened windows facing either side of the road)

It is important to assess how well this model fits into the actual data (goodness of fit of the model). R2 represents the 99.2% of variance in the total walking time can be explained by above nine variables. The F-statistic of 106.05 for the model shows that R2 is significant. Pearson's correlation coefficient of 0.996 indicates that there is a perfect relationship between the values of the total walking time predicted by the model and the values of the total walking time actually observed. F ratio of 1868.897 (>1,sig .000) for this model indicates that the improvement in prediction due to the model is expected to be large and the difference between the model and the observed data expected to be small. The t-statistic tests the null hypothesis that the b-value is 0. All t-statistic values relevant to the above mentioned nine variables contribute significantly (sig value <0.05) to estimate total walking time and indicate that the corresponding b-values are significantly different from 0. The standard error values relevant to b-values under above nine variables are comparatively very small and it implies that most samples are likely to have b-values similar to the one in this sample. It is important to assess whether a model can be used to make inferences beyond the sample of data that has been considered here. This model can be generalized since it has been met assumptions of additivity and linearity (total walking time is correlated with 20 predictor variables), independent error (Durbin-Watson test value =1.950), homoscedasticity, normally distributed error (sample size=140), variable types (continuous and categorical), no perfect multi-collinearity (all variance inflation factor <10), non-zero variance and predictors are uncorrelated with external variables. Sample size of 140 is adequate to test the overall regression model under 20 correlated factors since it indicates medium effect (Cohen's benchmark R2=0.14).

Further, a stepwise regression approach was used, because at the beginning it included all the independent variables and the variables which did not play a significant role to the walking time were discarded step by step. Finally, the best one out of nine models which has lowest standard error (5.305) was selected. Adjusted $r^2$ value indicated that 99.2% variance in total walking time would be accounted for, if this model had been derived from the population of Panadura urban area which the sample was taken. Histogram of the standardized residuals and normal probability plot indicated that the residuals in the model are normally distributed. Number of relatives or friends houses within buffer is making a significant contribution to the model since it has smaller the value of Sig. largest beta value and the largest the value of t. From the magnitude of the t statistic, unattended dogs within the buffer, age of the respondent and number of reported road accidents within the buffer have a similar impact, whereas number of people present on roads and number of houses with opened windows facing either side of the road have a less impact. Partial correlations values of all other excluded variables indicate less than 0.1 that imply their contribution would be very less if they were entered into the model. Multiple regression model developed for Maharagama area indicates that three (3) factors significantly contribute to decide the level of walkability at 0.05 significant levels. The significant factors are variety of activities either side of road (vendors, playing children on streets), width of sidewalk and availability of shade & cover from harsh climate. Following model was developed based on the coefficient values relevant to above three variables:

Level of walkability (Minutes)-Maharagama =118.733 + (21.353 * Number of activities either side of road) + (2.636 * width of side walk) + (1.757 * availability of shade & cover from harsh climate)

Adjusted $r^2$ represents that 97.4% of variance of the total walking time can be explained by above three variables in Maharagama area. The F-statistic of 5.538 for the model shows that R2 is significant. Pearson's correlation coefficient of 0.987 indicates that there is a perfect relationship between the values of the total walking time predicted by the model and the values of the total walking time actually observed. F ratio of 1176.453 (>1,sig .000) for this model indicates that the improvement in prediction due to the model is expected to be large and the difference between the model and the observed data expected to be small. The t-statistic tests the null hypothesis that the b-value is 0. All t-statistic values relevant to the above mentioned three variables contribute significantly (sig value <0.05) to estimate total walking time and indicate that the corresponding b-values are significantly different from 0. The standard error values relevant to b-values under above three variables are comparatively very small and it implies that most samples are likely to have b-values similar to the one in this sample. This model can be to make inferences beyond the sample of data that has been considered here since it has been met assumptions of additively and linearity (total walking time is correlated with eight predictor variables), independent error (Durbin-Watson test value =1.453), homoscedasticity, normally distributed error (sample size=100), variable types (continuous and categorical), no perfect multi-collinearity (all variance inflation factor <10), non-zero variance and predictors are uncorrelated with external variables. Stepwise regression approach was used to select best model out of three models which has lowest standard error (11.317) was selected. Adjusted $r^2$ value indicated that 97.4% variance in total walking time would be accounted for, if this model had been derived from the population of Maharagama area which the sample was taken. Histogram of the standardized residuals and normal probability plot indicated that the residuals in the model are normally distributed. Availability of number of varieties of activities either side of the road is making a significant contribution to the model since it has smaller the value of Sig.(0.000), largest beta value (0.971) and the largest the value of t (57.349). From the magnitude of the t statistic, width of sidewalk and availability of shade & cover from harsh climate have a similar impact. Partial correlations values of all other excluded variables indicate less than 0.1 that imply their contribution would be very less if they were entered into the model.

## 5.0 CONCLUSION

The findings of the two case studies reveal that people's level of workability depends not only on built environment factors but also on some factors such as feelings of personal safety, age of the respondent and availability of unattended dogs. Factors relevant to "safety" play a significant role to assess the level of walkability in Panadura area, such as feelings of personal safety, availability of unattended dogs on roads, reported road accidents, people present on roads and houses with opened windows facing either side of the road. People present on street and feel personnel safety are strongly correlated with the total walking time of the people in Maharagama area. The findings indicate that many people who live in urban neighborhood of Sri Lanka concern about their safety when they are walking. Second priority was given to the factors related to the "convenience and comfort", which can be listed as paving treatment of sidewalk, sidewalk width, quality of maintenance, less foul air, clearance of the route in Pandura area and variety of activities either side of road (vendors, playing children on streets), width of sidewalk and availability of shade & cover from harsh climate in Maharagama area. Ambient Sound with the environment and clearance of the route are also strongly correlated with the total walking time of the people in Maharagama area. McNally (2010) has also stated that 'by creating areas where pedestrians feel safety, welcoming, and comfortable, there is a greater opportunity for lively and walkable streets to become a reality'. The people who live in Panadura area reported high walking time if they have efficient transport facilities and less model conflict which are directly related factors to the "accessibility". Most of the people in Panadura use public bus service as their main transport mode. They have to walk to main bus halts from their homes. It appears that availability of efficient transport facilities motivate people for walking to transit points on their daily trips. Walking is highly encouraging when there is "connectivity" among the different land uses. Block length, availability of covered access from fences and connectivity between uses are strongly correlated with the total walking time of the people in Maharagama area while less covered access from fences enhancing the level of walkability in Panadura area.This study supports the findings of previous studies (Cerin et al., 2006 and Owen et al., 2004), that factors related to "Aesthetic" has a great concern for encouraging walkability. Also, "social company" particularly, presence of relatives and friends within the area concerned contributes to the level of walkability in Pandura area. The findings of the study further reveal that the common factors related to the land use diversity, density, weather and pedestrian facilities could be treated as contributive factors, but not significant enough to affect the level of walkability. This study proves that level of walkability depends on different factors of the built environment and also some other factors under different context. Therefore it is not advisable to apply those developed models to assess the level of walkability in another urban neighborhood in Sri Lanka with different to these two case studies, since the significant factors and the relevant coefficient values may be different with that context. The methodology and the findings of this study will be helpful to urban designers and town planners to identify the factors that affect to enhance the level of walkability in different urban neighborhoods and to create healthy and livable cities in the context of Sri Lanka.

## ACKNOWLEDGMENTS

The Senate Research Grant of the University of Moratuwa, Sri Lanka, funded this research.

## REFERENCES:

[1] Ariffin, R. N. R. &Zahari, R. K., (2013) 'Perceptions of the Urban Walking Environments', Social and Behavioral Sciences, Vol. 105,No. 589 – 597.

[2] Abley, S. (2005) "Walkability Scoping Paper". Retrieved March 04, 2011.

[3] Bahrainy, H., &Khosravi, H. (2013) 'The impact of urban design features and qualities on walkability and health in under-construction environments: The case of Hashtgerd New Town in Iran', Cities, Vol. 31, No.17-28.

[4] Besser, L. M. and Dannenberg, A. L. (2005) 'Walking to public transit steps to Help Meet Physical Activity Recommendations', Preventive Medicine, Vol. 29, No. 4: 273–280.

[5] Brownson, R. C. et al., (2009) 'Measuring the Built Environment for Physical Activity', Cities, Vol.36, No. 99-123.

[6] Campos, M.B., Chiaraida, A., Smith, A., Stonor, T. & Takamatsu, S. (2003) 'Towards a 'walkability index' in Proceedings of the European Transport Conference, Online 24th June 2013, http://trid.trb.org/view.aspx?id=771383.

[7] Cerin, E., Saelens, B. E., Sallis, J. F. and Frank, L. D. (2006) 'Neighborhood Environment Walkability Scale: Validity and Development of a Short Form', Medicine & Science in Sports & Exercise. Vol. 38, No.9: 1682–1691.

[8] Cervero, R., & Kockelman, K. (1997) 'Travel demand and the 3Ds: Density, diversity, and design', Transportation Research D, Vol. 2, No.3: 199–219.

[9] Cervero, R., and Kockelman, K. (1997) 'Travel demand and the 3ds: Density, Diversity, and Design',Elsevier Science, Vol. 2, No. 3: 199-219.

[10] Cervero, R., Duncan, M. (2003) 'Walking, bicycling, and urban landscapes: evidence from San Francisco Bay Area', Public Health, Vol. 93, No. 9: 1478–1483.

[11] Crane, R., &Crepeau, R. (1998) 'Does neighborhood design influence travel?A behavioral analysis of travel diary and GIS data', Transportation Research Part D, Vol.3, No. 4: 225–238.

[12] Doyle, S., Kelly-Schwartz, A., Schlossberg, M., and Stockard, J. (2006) 'Active community environments and health: the relationship of walkable and safe communities to individual health', American Planning Association, Vol. 72, No.1: 19-31.
[13] Ewing, R., &Cervero, R. (2010) 'Travel and the Built Environment', Journal of the American Planning Association, Vol. 76, No.1-31.
[14] Forsyth, A., Oakes, J. M., Schmitz, K. H., & Hearst, M. (2007) 'Does residential density increase walking and other physical activity?',Urban Studies, Vol. 44, No. 4: 679.
[15] Foster, S., & Giles-Corti, B. (2008) 'The built environment, neighborhood crime and constrained physical activity: An exploration of inconsistent findings', Preventive Medicine, Vol. 47, No. 3: 241–251.
[16] Frank, L. and Pivo, G. (1995) 'The impacts of mixed use and density on the utilization of three modes of travel: the single occupant vehicle, transit, and walking', Transportation Research Record, No: 1466- 4452.
[17] Frank, L. D., Andresen, M. A., &Schmid, T. L. (2004) 'Obesity relationships with community design, physical activity, and time spent in cars', Preventive Medicine, Vol. 27, No. 2: 87–96.
[18] Frank, L., Saelens, B., and Sallis, J. (2003) 'Environmental correlates of walking and cycling: Findings from the transportation, urban design, and planning literatures', Annals of Behavioral Medicine, Vol. 25, No.2: 80–91.
[19] Frank, L.D., Sallis, J. F., Conway, T.L., Chapman, J. E., Saelens, B. E. and Bachman, W. (2007) 'Many Pathways from Land Use to Health: Associations between Neighborhood Walkability and Active Transportation, Body Mass Index, and Air Quality', American Planning Association, Vol. 72, No.1: 75-87.
[20] Krambeck, H. and Shah, J. (2006) 'The global walkability index: talk the walk and walk the talk', No.1-29.
[21] Krizek, K. J., Forsyth, A. and Agrawal, A. W. (2010) Measuring Walking and Cycling Using the PABS (Pedestrian and Bicycling Survey) Approach: A Low-Cost Survey Method for Local Communities, Mineta Transportation Institute, San Jose State University.
[22] Leslie, E., et al. (2005) 'Residents' perceptions of walkability attributes in objectively different neighborhoods: a pilot study', Health & place, Vol.11, No. 227–236.
[23] Litman, T. (2010) 'Measuring transportation: traffic, mobility and accessibility', ITE Journal, Vol.73, No. 10: 28-32.
[24] Lwin, K., & Murayama, Y. (2011) 'Modeling of urban green space walkability: Eco-friendly walk score calculator', Computers, Environment and Urban Systems, Vol. 35, No. 5:408-420.
[25] Maleki, M., &Zain, M. (2011) 'Factors that influence distance to facilities in a sustainable efficient residential site design', Sustainable Cities and Society, Vol. 1, No. 4: 236-243.
[26] Manaugh, K., & El-Geneidy, A. (2011) 'Validating walkability indices: how do different households respond to the walkability of their neighborhood? Transportation Research Part D', Transport and Environment, Vol. 16, No. 4: 309-315.
[27] McNally, K. (2010) 'Design Guidelines for Walkable Communities', No. 32: 1-16.
[28] Mitra, R., &Buliung, R. (2014) 'The influence of neighborhood environment and household travel interactions on school travel behavior: an exploration using geographically-weighted models', Journal Of Transport Geography, Vol. 36, No. 69-78.
[29] Nankervis M. (1999) 'The effects of weather and climate on urban bicycle commuters' decision to ride: A pilot survey', Road and Transport Research. No. 8: 85–97.
[30] Owen, N, Humpel, N, Leslie, E, Bauman, A, Sallis J.F. (2004) 'Understanding environmental influences on walking: Review and research agenda', Preventive Medicine, Vol. 27, No. 67-76.
[31] Özbil, A. and Peponis, J. (2012) 'The effects of urban form on walking to transit', Eighth International Space Syntax Symposium, No.1-15.
[32] Parks, J. R., &Schofer, J. L. (2006) 'Characterizing neighborhood pedestrian environments with secondary data', Transportation Research Part D, No. 11: 250–263.
[33] Saelens, B. E., & Handy, S. L. (2008) 'Built Environment Correlates of Walking: A Review', Health, Vol. 40, No. 128-200.
[34] Sapawi, R., &Said, I. (2012) 'Constructing Indices Representing Physical Attributes for Walking in Urban Neighborhood Area ', Social and Behavioral Sciences, Vol. 50, No. 179 – 191.
[35] Seneviratne, P. N. &Morral, J. F. (2013) 'Analysis of factors affecting the choice of route of pedestrians', Transportation Planning and Technology, Vol. 10, No. 2: 147-159.
[36] Southworth, M. (2005) 'Designing the walkable city', Urban Planning and development, Vol. 131, No.4: 246–257.
[37] Troy, A., and Grove, J. M. (2008) 'Property values, parks, and crime: A hedonic analysis in Baltimore, MD', Landscape and Urban Planning, Vol. 87, No. 3: 233–245.