Green Score: an Evaluation Scheme for Pedestrian Environment

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Abstract
Pedestrian-oriented transportation has recently emerged as an important issue to supplement transportation modes as a method to reduce traffic accidents and environmental pollution. Compared to the increasing attention, practical studies considering the transportation environment in Korea are very limited. As a first step for studying the service level of pedestrian environment, it is necessary to develop an objective and systematic evaluation scheme. This paper aims to develop the ‘Green Score’, an evaluation system, which can be used to compute and evaluate the service level of pedestrian environment. In this study, we focused on pedestrian axes associated with vehicle crosses for the evaluation. We applied the depth-based index used in space syntax theory in assessing the space structure in terms of the connectivity. For setting the weight values of evaluation criteria obtained from survey, we employed AHP (Analytic Hierarchy Process). The computed scores using these criteria are classified and normalized according to the levels of pedestrian dependency and, finally, displayed on a map. The proposed Green Score system is expected to be applicable in the visualization of pedestrian movements and the evaluation of convenience levels of pedestrian environment.

1. Introduction
For the field of city planning and transportation, sustainable development that considers the two concepts of development and conservation in harmony has recently been gaining popularity. The key to urban planning based on this new planning paradigm is constructing high-density cities tied to complex land use patterns and public transportation systems. As a method of dealing with problems caused by other means of transportation, such as traffic accidents or pollution, there is a growing use of green methods of transportation. An urban settlement environment that restrains an auto-based life style and encourages walking activities

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must be considered in urban planning and design. There have been a number of studies on pedestrian-friendly activities and their support of urban environments, disclosing their measurement indexes. Discussions of the concept of the pedestrian environment have focused on how many physical attractions a place has to induce walking. In other words, the major measurement parameters to explain pedestrian-friendly environments in street design are accessibility, connectivity, continuity, convenience, and safety. Among analytical methodologies, surveys on pedestrians are widely used to evaluate the pedestrian movement space. The current qualitative methodology, however, may have the downside of distorted responses related to satisfaction and uneven measurement results resulting from respondents’ different experiences. In other words, to resolve the problems in current methodologies and qualitative evaluation indexes, quantifying the pedestrian environment index using a GIS (Geographic Information Systems) database and space analysis, as well as quantitatively evaluating the street environment for walking, is critical in the construction of a pedestrian-friendly environment. Therefore, the objective of this study is to develop the “Green Score”, a pedestrian index that simplifies pedestrian environment elements depending on types of walking space with a quantitative index, and evaluating and visualizing the overall degree (in terms of pleasantness and aesthetics) of pedestrian friendliness of the environment, as well as pedestrians’ convenience and accessibility.

2. Design of the Walking Environment System (WES)

2.1 Related Studies

There are some studies on the pedestrian environment that analyzed the physical environment using walking environment evaluation indexes. G. Kim (2002) tried to evaluate the level of pedestrian service from the perspective of side street pedestrian walking behavior (walking traces), while J. Lim (2004)’s study compared estimated levels of pedestrian service by considering characteristics of pedestrian street types (land use). K. Kim (2006) verified factors that influence qualitative pedestrian service level using fuzzy proximate inference, while Y. Kim (2006) gave recommendations for pedestrian street design, putting together land use, walking, and vehicular characteristics, and a general index for service level. T. Kim (2008)’s study suggested a general index for comprehensively evaluating the qualitative and quantitative satisfaction of pedestrians for each type of land use (residential, commercial, and business).

Miller (2000) analyzed pedestrian-related facilities (side streets, crosswalks, etc.) using a check list for each level, while Shaker (2003) presented qualitative items that have an influence on pedestrian satisfaction in the form of check list. Guttenplan (2003)’s study presented a map that analyzed pedestrian service level by inputting pedestrian service level analysis results into GIS. Muraleetharan (2004) verified the relations between user score and quantitative variables by surveying qualitative indexes, and Byrd (2006) compared pedestrian service level models, suggesting the need to comprehensively evaluate both qualitative and quantitative evaluation indexes.

As examples of walking environment evaluation systems, there are the Walk Score and Heat-map suggested by FrontSeat [www.walkscore.com], a software
company in Seattle in the US. They provide means to evaluate the overall pedestrian friendliness of an environment using the unit of community within a city, as well as in the whole city. Their measurement is visualized through five classes by measuring how many accessible points there are from each individual point on foot, and adjusting the value using a weighted estimation method in consideration of the concept of net density. However, the Walking Score only considers pedestrians’ linear accessibility to various convenient facilities, and the walking environment, except for the factor of accessibility, is ignored. Thus, there is a demand for the development of a walking environment index that considers safety, including elements such as the walking environment’s physical characteristics, pedestrian-friendly street design, vehicular traffic, walking safety, the number of the same types of accessible facilities and their weight, actual pedestrian distances, etc.

2.2 Pedestrian Environment Parameters

The methods of evaluating a pedestrian environment index using GIS are summarized in the following. To develop a pedestrian environment index, quantifiable parameters such as mobility, safety, convenience, pleasantness, and environment-friendliness were organized. As a result, 18 quantifiable parameters were selected and they are viewed to have the potential to be used as indexes for the development of GIS. Twenty-one street segments related to pleasantness and safety and nine intersection-related parameters were classified into five areas, described as follows.

1. Intersection safety

Intersection safety parameters include the perception of a vehicle coming toward a pedestrian at a crosswalk, and crosswalk function is measured for mobility and accessibility. Ladder Crosswalk convenient crossing facilities include functions to reduce vehicular speed and improve vision. The absence of crosswalks can be a movement barrier for pedestrians and potentially contribute to conflicts between pedestrians and motor vehicles.

When signals are present, it is vital to allow enough time for all pedestrians to cross the street. Short-signal crosswalk timers can be a movement barrier for pedestrians, and cause hazardous conditions if pedestrians are still crossing when the signals changes. A crosswalk scramble is a crossing treatment which allows pedestrians to cross in all directions, including diagonally across an intersection, while vehicles are stopped in all directions.

Traffic calming features are physical features that reduce the negative impact of motor vehicles use by slowing their speed, therefore enhancing walking and bicycling conditions by slowing the speed of traffic and increasing visibility of pedestrians, alerting the driver to potential hazards or providing pedestrian sanctuary.

2. Traffic

The traffic element of the street segment parameter includes prediction of distance to a pedestrian, collision point with a vehicle, degree of pedestrian injury, pedestrian mobility, etc. The vehicle traffic parameter measures factors that are predictive of exposure distance for pedestrian, conflict points, pedestrian injury severity and
pedestrian mobility. The number of motor vehicle lanes correlates with traffic volume, posted speed limits, noise and air pollution levels, pedestrian activity, and the levels of social capital reported in a neighborhood. A reduction in the number of lanes can reduce crossing distances, thus reducing exposure of a pedestrian to vehicle interaction.

3. Street Design
The street design parameter is an important factor for right of way and the local pedestrian environment, and if well constructed and maintained, it enables the safe walking of pedestrians. The width of a sidewalk is a primary factor in determining the level of safety and comfort for pedestrians walking down the streets. A well-maintained sidewalk is crucial to providing a safe pedestrian environment for pedestrians. Sidewalk obstructions can include out-of-place poles or signs, parked cars, trees, and garbage cans. Curbs provide a physical separation between motor vehicles and pedestrians. Curbs discourage vehicles from parking on the sidewalk. The more driveway cuts in a street segment, which break up the curb, the greater the potential for vehicles to cause an obstruction to pedestrians and create a potential conflict point with pedestrians.

Aspects of the urban landscape contribute to the overall walking experience. Natural elements promote interactions and positive experiences for pedestrians and they can provide a buffer between pedestrian and car traffic. The presence of public seating can encourage leisure walks, especially for the elderly and disabled. Bicycle lanes and parallel parking are two significant streetscape elements that create a buffer for pedestrians. The lateral separation between pedestrians and motor vehicles which supports pedestrian safety.

4. Landuse
The convenient facility and land use parameter includes commercial use and measures the aesthetic aspect of streets. Mixed land use is related to there being a lot of pedestrian traffic and a small amount of vehicle exhaust emissions. Providing a range of artistic and cultural amenities for pedestrians can create a visually interesting environment that attracts pedestrians. Neighborhoods with diverse and mixed land uses can create proximity between residences, employment, and goods and services, reducing vehicle trips and miles traveled and increasing active transportation such as walking and biking. In addition, commercial buildings providing services were found to have a positive effect on pedestrian frequency.

5. Perceived Safety
The perceived safety parameter enables strategic design that integrates street lighting and commercial uses to prevent crimes by improving walk-safety awareness through the physical characteristics of the environment. The cleanliness of a street, which includes graffiti, litter garbage and broken glass, as well as pedestrian lighting are important factors found in many walkability audits. Roadway and sidewalk construction can disturb pedestrian flow and create hazards for pedestrians.

Construction zones can pose safety issues for pedestrians by blocking the sidewalk with heavy machinery and creating alternate routes that are less accommodating for pedestrians. Abandoned or boarded-up buildings may represent
neglect or a lack of adequate funding or impetus to fix neighborhood infrastructure. Abandoned buildings may also increase feelings of pedestrian discomfort.

6. Walk Accessibility
The walk accessibility parameter evaluates the connectivity and accessibility of street segments’ structural space characteristics. Analysis of the physical structure of the space axis of the unit. Analysis pedestrian connectivity and accessibility by using the value of local integration.

3. Construction and Analysis of Pedestrian Environment
3.1 Construction of Pedestrian Environment
We developed a separate system for street segment parameters and intersection parameters to comprehensively evaluate the service level of pedestrian and vehicular pedestrian environment. First, for pedestrian environment evaluation of intersections, points were assigned to facilities at major crosswalk points interrupted by traffic signals, and vehicle and pedestrian flows, vehicular traffic, and walking and safety facilities were separately measured for the street segment. Second, to evaluate the structural space characteristics of the walking path from the perspective of connectivity and accessibility, space syntax was used and connectivity analysis (Global Integration [GI]) was conducted. In addition, to measure commercial land use and the aesthetic aspect of streets, relative weights were applied for each type of facility depending on urban planning and land use, reflecting a walking preference for mixed land use.

Figure 1 Network of GIS at Sadang Station and Results of Axial Map (Intelligibility: 0.6115)
3.2 Application of Pedestrian Environment Evaluation

For synthetic evaluation of the pedestrian environment, facility distribution at intersections and on street segments was quantified, along with the connectivity of the walking network. The Analytic Hierarchy Process (AHP) method was used for the survey results to verify the relations between pedestrian satisfaction and evaluation indexes.

Figure 2 Establish a hierarchy and Weight estimation results

The evaluation results reflect whether each environmental parameter helps in walking. Pedestrian safety is integrated into street segment and intersection design, and the value ranges from 0 to 100 for each parameter, as in the table 1 below, which describes the meanings of each range.

<table>
<thead>
<tr>
<th>Score distribution</th>
<th>Meaning of the Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>100-81</td>
<td>The highest quality, presents the most important pedestrian conditions</td>
</tr>
<tr>
<td>80-61</td>
<td>High quality, presents some of important pedestrian conditions</td>
</tr>
<tr>
<td>60-41</td>
<td>Average quality, presents pedestrian conditions but need to improve</td>
</tr>
<tr>
<td>40-21</td>
<td>Low quality, presents at least pedestrian conditions</td>
</tr>
<tr>
<td>Less than 20</td>
<td>Lowest quality, absence of pedestrian conditions</td>
</tr>
</tbody>
</table>

3.3 Visualization Results of the Pedestrian Environment Evaluation

Using a street segment and intersection identifier, a visual map was created that incorporated the evaluation results for a selected region consisting of street segment and intersection spaces. The map can be created to indicate the overall pedestrian
environment evaluation results, intersection evaluation results, or evaluation results for each sub-parameter. Data for the measurement of evaluation indexes were collected by observations based on the street segment and intersection visualization results. They were then geo-coded, meaning that they were quantified into a score for each link on the traffic map (level 1) by the Korea Transport Institute. Ultimately, adjusted measurement values were summed and categorized according to walking dependency, and these were normalized in the range of 0 to 100. The resulting green scores (synthetic evaluation results) were then mapped for each region.

As shown in the table 2, Sadang-ro, Seocho-ro, Dongjak-daero, and Hyoryung-ro turned out to have excellent pedestrian environments in terms of walking path, with scores of over 0.8, and the Sadang Station vicinity had a score of 0.75 on average, having highly convenient facilities and connectivity overall.
### Table 2 Case study of pedestrian environment Score

<table>
<thead>
<tr>
<th>Link ID</th>
<th>Name of Street</th>
<th>Local integration</th>
<th>Total Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>3761220401557</td>
<td>Sadang-ro</td>
<td>3.31767</td>
<td>0.94885044214</td>
</tr>
<tr>
<td>3761220300059</td>
<td>Seocho-ro</td>
<td>3.31767</td>
<td>0.94752027433</td>
</tr>
<tr>
<td>3761220401539</td>
<td>Dongjak-daero</td>
<td>2.97302</td>
<td>0.87934023295</td>
</tr>
<tr>
<td>3761220401522</td>
<td>Hyoryung-ro</td>
<td>2.95684</td>
<td>0.84853809079</td>
</tr>
<tr>
<td>3761220320665</td>
<td>Songbang-ro</td>
<td>2.95684</td>
<td>0.74410778499</td>
</tr>
<tr>
<td>37612203202361</td>
<td>Nambu beltway</td>
<td>1.47842</td>
<td>0.60512664918</td>
</tr>
<tr>
<td>3761220401556</td>
<td>Samil-gil</td>
<td>1.69831</td>
<td>0.54643910087</td>
</tr>
<tr>
<td>3761220401840</td>
<td>Bulnaru-gil</td>
<td>1.65883</td>
<td>0.5420320766</td>
</tr>
<tr>
<td>376122032334</td>
<td>Kkachi-gil</td>
<td>1.69831</td>
<td>0.53712247527</td>
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<tr>
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<td>Samil-gil</td>
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<td>0.48862619499</td>
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<td>Boram-gil</td>
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<tr>
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<td>Isuchodeung-gil</td>
<td>1.00006</td>
<td>0.4656690530</td>
</tr>
<tr>
<td>3761220701402</td>
<td>Cheongdugot-gil</td>
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<td>0.39583806160</td>
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<tr>
<td>3761220701380</td>
<td>Chammanu-gil</td>
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<td>0.37475586160</td>
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<tr>
<td>3761220401553</td>
<td>Haksu-gil</td>
<td>1.01899</td>
<td>0.35072423499</td>
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<tr>
<td>3761220701401</td>
<td>Dwitbeol-gil</td>
<td>0.21093</td>
<td>0.23656023412</td>
</tr>
<tr>
<td>3761220701318</td>
<td>Dwitbeol-gongwon-gil</td>
<td>0.21093</td>
<td>0.22993039896</td>
</tr>
</tbody>
</table>

### 4. Concluding Remarks

In this, we developed the green score, an evaluation index to measure and quantitatively evaluate pedestrian environmental factors in a city. Future score measurement models must be applied to a virtual system based on the major points of signals in the physical walking space, continuous and consistent lines for walking paths, and regional planes created by urban planning and land use. Relative weights for convenient pedestrian facilities should be applied and comparative analysis will be possible for the convenience of facilities and network connectivity in the pedestrian environment of various regions, such as the vicinities of station or residential areas. Furthermore, this will be used to visualize walking patterns and predict evaluation results of pedestrian environment pleasantness and convenience.

### References


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