# Decision System in the Movement of Pedestrians

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**Abstract**
*The research addresses the questioning about how the spatial configuration and the conditions of the sidewalks influence the decision system in the movement of pedestrians. The possible answer to the question stems from the hypothesis that there is an interrelation between the distance of the course and the facilities offered for locomotions, i.e., if, in their movements, the pedestrians prioritize, in addition to saving on routes, sidewalks that offer better moving conditions, it would be possible to indicate and describe the most important factors that determine this movements. In methodological terms, through complementary focuses, what is discussed are some of the main factors linked to sidewalks which intervene in the movement of pedestrians, namely: the configurational focus related to the Space Syntax method (Hillier & Hanson, 1984), i.e., the influence of the urban street network as an inductor of pedestrian movements; and a focus on the usable conditions of the sidewalks, linked to the Level-of-Service (KHISTY, 1994), i.e., it detects why the movements occur and where the movements and locomotions of pedestrians are spatially located. The crossing of the Space Syntax and Level-of-Service techniques makes it possible for both the constituent parts of the system of sidewalks and the series of elements involved in the movement of pedestrians to be related and evidenced. The methodological procedure adopted makes it possible to harmonize syntax measures (Space Syntax) with performance measures (Level-of-Service), so as to describe and understand great part of the pedestrian movement dynamics in the downtown area of Santa Cruz do Sul/RS, which constitutes the case study. With regard to the results obtained, they are considered promising, as far as they contribute toward the debate about an actual issue of undisputable importance in the area of urbanism, whose systemic focus is a natural result of the research process which involves the study on the movement of pedestrians in downtown areas. Key-words: pedestrian movement, downtown areas, level-of-service, spatial configuration.*

## Introduction

The survey intends to analyze the main conditioning factors that influence the movement of pedestrians along the sidewalks of central city areas. Basically, two factors are considered to be the most relevant for the foundation and development of the investigation, namely: the selection of the most direct route and the search for the best way to move.

The selection of the most direct route indicates the process through which the pedestrian chooses, from a group of routes, the shortest distance from a point of origin to the destination. In this analysis dimension, the spatial arrangement of the sidewalks is essential in the articulation and orientation of the locomotion of pedestrians in urban environments, which makes it possible to achieve, to a minor or major degree of accessibility , the different urban activities. However, as a rule, there are no spaces that could be reached directly from any space (shorter routes). This is due to route restrictions imposed by the constructed forms (buildings, urban estate, street crossings, etc.), which, depending on their configuration and use, establish barriers and passages, directing the movement of the pedestrians. Central to this notion is the accessibility

concept , seeing that some spaces can be more accessible than others, that is, pedestrians tend to choose more direct routes, which require less time and are less energy-consuming. On the other hand – complementary to the choice of the more direct route – the search for the best manner to move is a wider notion about the decision taken by the pedestrians within the locomotion alternatives, such as: where to do the shoppings, which is the safest and/or most pleasant route, and so on. This search for space may take place in areas that are not necessarily part of a group of most direct routes, as they relate local choice potentials linked to the using conditions specific to each stretch of the sidewalk. Therefore, the analytical structure on the movement of pedestrians along sidewalks, incorporates, in addition to geometric factors, those linked to the conditions of the sidewalks which affect the movement decisions of the pedestrians, such as: safety, comfort, access equity to urban activities, among others.

The movement of pedestrians is therefore an interpolation between the length of the route and the facilities made available to place-to-place movements. As the movement of pedestrians is related with both the special arrangement and the conditions of the sidewalks, to relate them is considered to be a procedure particularly appropriate to evaluate these spaces. On compatibilizing the special configuration with the conditions of the sidewalks, it is possible to understand which parameters linked to the choice of the most direct route and the search for the best locomotion that more directly affects the movement of pedestrians in the urban circulation system in the towns. The basis of the investigation problem of this research is thus formulated, which tries to understand the dynamics of the pedestrian movement in central areas, evidencing the major conditioners that influence the movements along sidewalks. The research delimits the following debate: How do spatial configuration and the conditions inherent to the sidewalks influence the decision-making system in the movement of pedestrians? The possible answer to the proposed problem is based on the following hypothesis: if, in their movements, the pedestrians give priority, in addition to route savings, to areas which provide them with better routes, it would be possible to describe and indicate the most important factors that determine the choice of locomotion from place to place. This hypothesis considers that although urban space provides people with a diversity of opportunities (like, for example, leisure and social interaction), there could be certain conditions inherent to the sidewalks that would make it easier to achieve these opportunities. Moreover, in a certain manner and intensity, the movements of the pedestrians would be facilitated, inhibited or defined by the spatial configuring properties, and/or by the relational position between them.

In practical terms, the empiric object for the study of a case corresponding to the dynamics of people locomotion in the downtown area of Santa Cruz do Sul / RS, whose central area's representativeness makes it possible to better operationalize the methods adopted so as to respond to the proposed problems and confirm the suggested hypothesis.

## Fundamentation

The aim of the literature revision is to provide a general view on the studies already conducted on the subject and enrich the knowledge basis. However, only the approaches to the research work related to spatial configuration (Space Syntax) and to the conditions of the sidewalks (Level of Service) will be emphasized and described succinctly.

Space Syntax (Hillier & Hanson, 1984) poses as the most satisfactory method in cases of urban morphology, for its capacity of retaining the essential quality of public space: the topological relation between spaces. It is a widely spread method and of simple applicability. At spatial syntactic analysis, only the movement based on route selection savings is at stake. The focus allows for the establishment of correlations or reciprocal influences between the movement of pedestrians and the spatial arrangement that structures the sidewalks. On the other hand, the analysis of the sidewalk conditions through the Level-of-Service concept adopted by Khisty (1994) considers Performance Measures (PMs) able to describe and qualitatively measure the group of specific characteristics of each individual sidewalk. Within this context, it is an essential method to research, as it explains a particular phenomenon with regard to its relevant aspects, and makes it possible, through a previous description of the reality under study, infer more precisely on the movement of pedestrians.

## Space Configuration: Space Syntax

From the urban morphology studies, Hillier e Hanson (1984) developed the Space Syntax concepts, so as to make studies on the configurational relations possible. The basis for the studies is the premise that there is a social logic that derives from the space, that is, the social relations are intimately linked to the morphological configurations of urban spaces (Teklenburg et al, 1991: s/p; Penn, 2001: 4).

Space Syntax was conceived to represent the urban networks through a successive set of spaces, and it is possible to reduce the complexity of its configuration to a basic characteristic – its linear dimension. Space Syntax defines the urban network as a system of lines that link origins and destinations, where the movement may take place from all origins and destinations. The movement along these lines composes the network, which will be determined substantially by syntactic measures.

With regard to the accessibility concept, Hillier e Hanson (1984) replace the metric measure with the topological one and adopt the concept of axial line for the description of public spaces. The Axial Lines – utilized to calculate the integration of the system – can be defined as the biggest extension possible in straight line between convex spaces . What is understood by convex spaces is the relation of unrestricted visibility and domain in spaces (Hillier et al, 1993: 29-66). The decomposition of the route network into axial lines is represented by the axial map, which consists in the set comprising the smallest number of the biggest straight lines capable of covering all the system's convex spaces.

Distance in Space Syntax is called depth, which consists in the topological distance (which is not dependent on metric and/or geometric relations) of a line to all the other lines of the system (Hillier and Hanson, 1984: 82-102). The integrating conditions of public space into Space Syntax are related to the symmetrical and asymmetrical notion of a given morphology. A description is symmetric when the relation between spaces is equal for both; a description is asymmetric when, in order to relate one space with another the intervention of another space is necessary (Hillier and Hanson, 1984: 94). The sociological meaning of symmetry and asymmetry considers that "the more the descriptions are symmetrical, the bigger the trend for the integration of social categories, while contrarily, the more asymmetrical, the bigger the trend toward the segregation of social categories" (Hillier and Hanson, 1984: 96-97). Therefore, the configurational properties of urban space are described from two basic dimensions: global domain (axiality; symmetry) and the local domain (convexity; asymmetry). The global domain is more related to the penetration and movement of people alien to the system as a whole, while the local domain is more related with the appropriation and concentration of people familiarized with parts of the system. Examining how integration is distributed over the urban network at global and local levels, one can have a notion of how a town with different space configurations generates what Hillier (1997) called Meeting Fields, i.e., locomotion patterns create chances for social integration, exchanges and community life (Hillier et al, 1993: 29-66; Hillier, 1997: 335-368; Peponis et al, 1997: 341-358). Consequently, the spatial configuration of any town can be seen as a potential for the social relations of its inhabitants.

Although the movement may vary from person to person, it presents certain recurrence patterns which delimit a certain spatial behavior. Hillier et al (1993) consider that towns have strong intrinsic mechanisms capable of generating, maintaining and controlling a great part of the locomotion pattern in urban apace. This notion of "movement saving" (or Natural Movement) demonstrates that the evolution of spatial organization, first generates movement patterns, which then influence on how to use the ground, and then, in turn, generate multiple effects on movement. These activities take advantage of the route, acting as a multiplier at the original flows. It is considered that the urban format has a relative autonomy with regard to the numerous environment influences, thus possessing a dynamics of its own capable of determining spatial movement patterns.

## Sidewalk Conditions: Level of Service

The movement of pedestrians in urban spaces can be studied through analogies with the flow of fluids composed of particles (Henderson, 1971: 381-383 E 1974: 509-515; Helbing, 1995: 3164-

3169). However, contrary to the inert particles to the flow of which the movement of pedestrians is being compared, people have preferences and evaluate the moving conditions (Gonçalves, 1978: 24-25). The fluid flow laws are known and can be expressed by the following parameters: flow, speed and density (Gonçalves, 1978: 20). The values of the mentioned magnitudes (flow, speed and density) remain within certain variation limits. The combination of the factors previously defined with the notion of comfort leads to the Level of Service concept (Gonçalves, 1978: 21-25).

The studies on vehicle traffic gave origin to the level of service concept, which was initially applied to define and evaluate the relation between flow, speed and density on roadways (Highway Ca¬pacity Manual, 1965). Level of Service was conceived as a qualitative measuring instrument of the utilization conditions that affect the movement of motorized transport modes.

Fruin (1971b) considers that pedestrians, similar to vehicle movement, also have abilities to select routes, change direction, pass slow walking pedestrians and the freedom to choose the desired speed. Parting from this ascertainment, Fruin (1971 a, b) correlates theories directly derived from studies on vehicle traffic with the principles of psychology and ergonomics to suggest the use of the level of service at sidewalk analysis. In this case, the level of service describes the amount of pedestrian conflicts within the amount of space available within a certain time frame (Gonçalves, 1978: 26).

Based on Fruin's work (1971a), the Highway Manual Capacity - HCM (1985: 13.1–13.29) points to orientations for analyzing transport installations, debating sidewalk planning and operationality. HCM (1985) admits that sidewalks are more complex in comparison with vehicle installations, although the principles of the pedestrian movement analysis, just like the quantitative fundamental relations between flow, speed and density are similar to the ones utilized for vehicle traffic.

The misleading simplicity of pedestrian movements in public spaces has led many researchers to focus their attention almost exclusively on the flow-speed-density relation to project and evaluate the sidewalks, insisting on treating people as vehicular units.

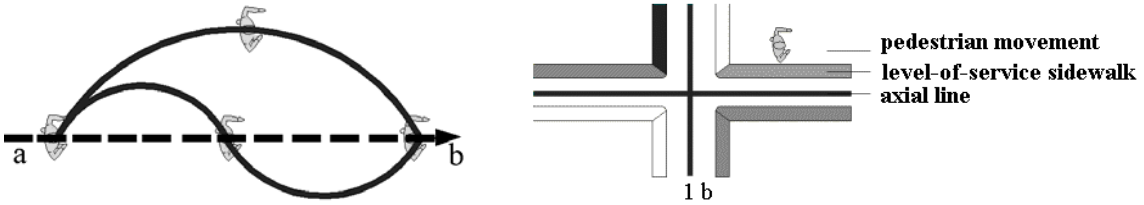
Khisty (1994: 45) criticizes the manner the level of service issue had been treated up to that time, particularly the method utilized by the Highway Capacity Manual of 1985, based on the flow, speed and density of people, which suggests the consideration of environmental factors (comfort, convenience, safety, security and saving), however, without determining any guideline to measure or use them. Khisty (1994: 46) in his methodology defines these factors as being Performance Measures, and, in addition to the five factors addressed by HCM (1985), the degree of attractiveness and coherence of the system (KHISTY, 1994: 46-47).

The technique for hierarchizing the importance relative to each degree of performance is an opinion survey that combines the pair comparison method with the technique of Constant addition. The pair-comparison method indicates, through a matrix, all the combination chances of every performance measure with all the other measures. On the other hand, the Constant addition technique permits the respondent to attribute and distribute – while comparing all the possible pair combinations – a value (generally from 0 to 10) to each one of the performance measures under analysis, being '0' the one of the lowest quality, and '10' the highest quality. The final evaluation of a stretch of sidewalk is obtained from the sum of marks attributed by the technical researcher to each one of the performance measures (according to the result of the field research to measure the degree of pedestrian satisfaction), weighed by the relative importance of each performance measure .

## Methodology

A total of 67 blocks were selected from the central area of Santa Cruz/Brazil, comprising four squares, 2 monuments and 1 park, which together cover 22 street sections and 178 sidewalks. Through a pilot study it was necessary to establish a previous knowledge of the place and test the research tools. Parallel with the pilot study, the functions related to the use of the ground in the studied area and a survey of the other physical components were also recorded and classified. Based on the complete street map of the town, the axial lines, representing the continuous structure of these open spaces, were drawn up. The representation of the axial lines gave origin to

the question on how to associate the accessibility lines (axial lines) with the levels of service and the respective movement rate of pedestrians, which was considered and represented as an axial event (figure 1a). Therefore, each axial line, by representing one or more specific segments of sidewalks, was also associated with the respective levels of service and the average rate of pedestrian movement (figure 1b).




(a) (b)

***Figure 1***

***(a)*** *Movement of pedestrians as an axial event. The dashed line indicates a minimal route between two points. The curved lines schematically indicate the deviations between two points;* ***(b)*** *Correspondence between axial line, level of service and pedestrian movement (source: original from author, 2009).*

Upon integrating axial lines and performance measures, the graphic environment made it possible to verify in a faster and more efficient manner the impact that any alteration to one or more attributes will have on the others. Studying the performance per sidewalk segment made the correlation of different attributes in one graphic environment viable. The "decomposition" principle disaggregated the object in parts and located attributes in the disaggregated parts, allowing for an exclusive exam of each attribute, making detailed checking available at each axial line.

The next phase of the study consisted in investigating the movement of pedestrians and respective counts. The category of pedestrians considered by the survey was focused both on those who have an appropriate grasp of traffic risks and those with some kind of disability and/or locomotion difficulty. Nevertheless, the survey disregarded the children who, upon being conducted by adults, could have their locomotion influenced by them. Counts were made on normal days, i.e., as far as possible, atypical days and festive days were avoided. Conducting pedestrian counts along the whole length of each axial line during several hours of the day made it possible to analyze the sidewalks as gathering locations, social interchanging, etc., such as, identifying some characteristics of important behavior patterns of a great number of stationary activities in public spaces. Counts of pedestrian movements were also carried out through static observation points (gate) of each sidewalk segment. These involved records of the number of people passing specific points (gate) during a certain period of time, indicating the presumable flow of pedestrians at each point of the system under analysis. The number of passing pedestrians was counted at five-minute intervals, from 8 am to 6 pm, and all counts were conducted every day of the week, except on Sundays. Each route was surveyed five times, for five standard time periods: 8 am to 10 am, 10 am to 12 am, 12 pm to 2 pm, 2 pm to 4 pm and 4 pm to 6 pm. The counts of average pedestrian movement per sidewalk stretches over several hours of the day were recorded on specific forms.

With regard to the level-of-service evaluation of the sidewalks through performance measures, the methodology suggested by Khisty does not stipulate a fixed number of attributes to be considered at every Performance Measure (PM), in this case, each PM was described utilizing a maximum of three attributes to facilitate the application of the field survey (optimization of time spent on questionnaires and on the analysis itself). The performance measures and the respective description of the attributes are as follows: a) Attracters: importance of the edified physical and functional elements related to the spatial dimension; b) Transport: importance of multi-modal facilities linked to pedestrian routes in an efficient system; c) Continuity: importance of the aspects relative to the visual and physical permeability of the sidewalk and its integration to the several

points in town; d) Security: importance of social and spatial organization for providing physical integrity to pedestrians; Comfort: importance of the set of ergonomic elements that interfere with locomotion.

Each performance measure was given a specific form containing the description of the attributes corresponding to each point to be attributed. Notes and remarks referring to each sidewalk were recorded on a set of five technical forms. Each technical form features a 0 to 5 evaluation mark, and each mark describes a specific condition of each Performance Measure.

The relative importance attributed by the pedestrians to each performance measure was defined through questionnaires, based on the pair comparison method and the pertinent sum proposed by Khisty (1994). The standard form consists of a key question and a series of multiple-choice answers, at which the respondent, through the pair-comparison method distributes marks to the aspects he deems most important in a sidewalk.
To obtain the level-of-service, in the first place, it was necessary to read the observed data, and then, it was necessary to numerically organize these data, so as to allow them to be treated mathematically. Within this sense, adapting the measures to the performance (KHISTY, 1994) and taking into consideration the method suggested by Ferreira and Sanches (2001), it was possible to establish the following equation [see eq. (1)]:

$$NSp = pA.(A) + pT.(T) + pCT.(CT) + pS.(S) + pCF.(CF) \quad \text{eq. (1)}$$

Where: NSp is the weighted level-of-service measure; A, T, CT, S, CF represent respectively the marks obtained at the technical assessment of the Attracter PM's, Transport, Continuity, Security and Comfort; and pA, pT, pCT, pS e pCF respectively represent the weighting factors of the Attracter PM's, Transport, Continuity, Security and Comfort.

This research procedure comprised five steps (KHISTY, 1994: 48-49): 1st- spaces for pedestrians were evaluated through forms containing the detailed descriptions of 5 performance measures and the corresponding marks were attributed (0 to the worst, and 5 to the best); 2nd – based on the opinion survey, the sum constant and the pair-comparison method was applied to determine the relative weight of each performance measure; 3rd- the points were multiplied by the weights of each corresponding performance measure; 4th- the product of each weighted performance measure was added up to obtain the capital sum, and 5th – a level of service was attributed to this capital sum. A 5-point alphanumerical scale was adopted for the six levels of service, namely: NS: A (5 points); NS: B (from 4 to 4.9 points); NS: C (3 to 3.9 points); NS: D (2 to 2.9 points); NS: E (1 to 1.9 points); NS: F (0 to 0.9 points); respectively from the best to the worst rating.

Techniques and statistical procedures were utilized to check the degree of dependence of the analyzing units involved (syntactical measures and counts). The correlation coefficient was adopted to check the degree of association between two X and Y random analysis units. The possible functional relations between variables were assessed through the determination coefficient ($r^2$) which consists in the explanation proportion of the value variabilities through the regression equation. To check the degree of dependence of a set of variables the Multiple Linear Regression Analysis – MLRA -was used. This statistical function relates a series of 'k' independent variables (performance measures syntactical measures), to a 'Y' dependent variable (pedestrian movement flow). The adoption of these statistical procedures made systematic tests possible, since the composition of the MLRA furnishes a flexible structure capable of measuring the influence of different analysis units on one another.

## General Range Of Results Obtained

In general terms, it was observed that the unequal distribution of pedestrian flows is due to reasons related to sidewalk conditions and configuration. Pedestrians frequently choose the most direct distance (shortest way) as primary strategy between long distances, however, as they enter the chosen space, the space configuration is superseded by the sidewalk conditions This explains why in some cases there is more movement along one sidewalk than the other, even if the

distances made available by both are the same. The findings of the survey indicate that, besides the distance, levels of service are important and produce a high correlation between the locomotion preferences.

It was possible to verify that the complex relations of pedestrians in urban environments can only be understood by the interactions between them and the various elements that the space consists of. The spatial arrangement of the movement lines on sidewalks makes it possible to understand the general logics which conditions the movement of pedestrians, it is however the levels of service that make the micro-accessibilities viable at the inter-block scale.

Along the line of movement there are variations in the arrangement of the objects in the space and, consequently, the movement of pedestrians alternates between them. The results of the case study confirm that there are other factors, besides spatial configuration, which are important in explaining the movement of pedestrians. The conjunction of a series of variables makes a better understanding possible, as compared to only one variable. The configuration primarily determines the selection of routes by he pedestrians, however, later on, successive choices of movement occur in a Constant exploratory itinerary. At the different focuses one can identify that, directly or indirectly, the movement of pedestrians is influenced by factors linked to the configuration and to the using conditions of the sidewalks.

The multiple linear regression analysis revealed a strong correlation ($r^2$ 0,8958) between the movement and the different measures utilized by research. Generalizing the results obtained from the study area, it is possible to infer that the majority of the pedestrians, walk in light of both the possibility to access more directly the spaces and by the specificities inherent to the conditions provided by the sidewalk.

## Discussion

The range of this research was fundamental in the attempt to unify (methodologically) the approach to a phenomenon common to towns, the movement of pedestrians. The basic concern of the survey was to analyze physical and spatial inducers of pedestrian movements, according to two complementary sources: spatial configuration, at which morphology determines quite a great part of the movement of pedestrians and the movement decision systems, regarding the conditions of the sidewalks in view of certain specific characteristics presented.

The problem under study made it possible to ascertain that, as important as analyzing the spatial relations between sidewalks are the implications of the conditions offered by these spaces to the decision of the pedestrians. It was perceived that the problem could even be better understood through a continuous and systematic process, in which the different conditioners that affect the problem of the movement of pedestrians might be related.

The study on the movement of pedestrians cannot be well understood at a generalized level, nor can it be solely focused on a particularized level. The major problem of investigation was how to evaluate the movement of pedestrians in detail in its parts without overlooking the notion as a whole, and vice-versa. It was necessary to associate methods that associate these two fields. In spite of the significant contribution from Space Syntax and the level of service toward the understanding of the dynamics of pedestrian movement, quite paradoxically, they are parallel and not linked. Therefore, by integrating such approaches, the survey tried to contribute toward a better understanding not only of the movement of pedestrians, but of the methods themselves. Evidently, it became clear that it would be a mistake to consider only one method to the detriment of the other, once both clearly complement themselves as to the understanding of the movement of pedestrians.

Through data correlation it was possible to examine and confirm the hypothesis that both spatial arrangement and sidewalk conditions have some impact and reciprocity on the movement of pedestrians. In short, it was the confirmation of the hypothesis that the amount of pedestrians that select and cover the smallest distance is directly proportional to the increase in opportunities and facilities offered by sidewalk conditions.

Advantages that can be enunciated to describe the sidewalk case study, from a surveyed reality, consist in the degree of abstraction and simplicity of the mathematical algorithm (Space Syntax) and the need of few data observed on the performance measures forms (Level of Service). This facilitated the statistical treatment of the data, proving their efficiency as an investigation tool, and the confirmation of certain correspondences between the adopted measures.

The current procedures for pedestrian analysis – at least those that are part of the scope of this survey – if applied separately, are incomplete in the understanding of the complex network of information which has an influence on the attitudes of pedestrians in urban space. Within this context, research contributes significantly by linking them. Such things that syntactic measures do not respond with regard to pedestrian movement, performance measures do it and vice-versa.

Within the contributions to the scientific area, some new facts, discovered throughout the survey, are mentioned, and of note are the following: the incorporation of aspects relative to syntactic measures and performance measures to explain the movement of people on sidewalks was a relevant contribution to this research; the target of the methodology was to present already existing methods, however complementary and adapted to the particularities of the suggested study; the significant improvement of the correlation of measures in view of the sum of the values found along the axial lines; the increased inclusion of the attracter measures, especially with regard to the basic characteristics of the constructed form; and, the possibility to associate mathematically performance measures and syntactic measures.

As the survey was drawing to a close, new instigating points started arising, and they could be focused on at some later surveys and which, in a way, represent a real continuity of the present study. The target subject and the type of instruments utilized are ample and fertile, which might encourage would-be researchers. The findings of the research address more important aspects of pedestrian locomotion and described some techniques that could be utilized. Evidently, given the evolution of the methods approached at this research, which aimed at arising new questionings about the issue, so as to make it viable for future complementation to be incorporated into the adopted methods.

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