Application of space syntax method to measure spatial connectivity in campus of Institut Teknologi Sepuluh Nopember (ITS)

A M Navastara[1,2], **M Yusuf**[1,2] **and P Navitas**[1,2,3,4]

[1] Department of Regional and Urban Planning, Faculty of Architecture, Design and Planning
[2] Institut Teknologi Sepuluh Nopember, Kampus ITS Sukolilo-Surabaya 60111, Indonesia
[3] PhD Candidate, School of Civil Engineering and Built Environment,
Science and Engineering Faculty
[4] Queensland University of Technology, Australia

Email: ardy.navastara@urplan.its.ac.id

Abstract. In line with ITS's vision to create an eco-friendly campus, there is an effort to decrease the use of private vehicles in ITS campus. The role of pedestrian lanes is very important to encourage and support eco-friendly transportation in campus area. Transportation system should be supported by mode of transport with equal, feasible, and humane pedestrian lane. ITS has already begun to develop pedestrian lanes in parts of their campus. Ideally, the development of pedestrian lanes should be linked to form a network, connecting centres of activities. Therefore, the aim of this research is to determine the level of connectivity of pedestrian ways in ITS's Sukolilo campus area as an input for future development of pedestrian lanes. This study employed on-site observations and connectivity calculations by way of Space Syntax. Analysis shows that 70% of pedestrian ways in the Sukolilo campus are of very low connectivity. This is due to unintegrated pedestrian lanes and poorly coordinated campus development.

Keywords: *pedestrian ways, level of connectivity, space syntax*

1. Introduction

Walking is generally very important in order to reduce the congestion of big cities, even car and motorcycle users must also walk in certain places on their way. Walking also provides access to public transport with ease and also becomes the only means of mobility for citizens using public transport. According to Southworth (2005) there are several benefits of walking such as reducing congestion, safeguarding the environment, promoting social interaction and lastly improving physical and mental health [7]. Spreiregen (1965) said that the best transportation system is the limit of 3-4 kilometres per hour and the coverage is heavily influenced by the physical condition of the pedestrian ways [8]. Also as stated by Gota et.al (2013) that walkability can be linked to the quality of built environment, the urban form and connectivity, safety and desirability to walk and accessibility of infrastructure. In simple terms, walkability can be used to describe and measure the connectivity and quality of walkways and sidewalks in cities [2].

Surabaya city is one of the objectives of research due to its function as one of the metropolitan cities in Indonesia. Surabaya became the object of this study because it is one of the cities in Indonesia with high population density and land use dominated by settlements, office buildings and various trading activities and services. With the existence of the center of business activities and the center of public transportation, the development of activities and the rise of movement, as well as the need for transportation facilities is increasing, so to facilitate the community in the city of Surabaya required the most appropriate mode of walking mode. However, in fact, the existing condition of the pedestrian ways in Surabaya still has many shortcomings such as street lighting, cleanliness, unsuitable width in some locations and some street vendors that occupy pedestrian ways (Faiq, 2017 in http://surabaya.tribunnews.com) [11]. In addition, the existence of permanent barriers that interfere with walking activities such as trees and poles and facilities for the disabled are not well maintained and not evenly distributed. So that people are not accommodated well if doing transit activity by walking and cause problems such as sense of security, comfort and safety.

From the existing conditions, the development of pedestrian ways in the city of Surabaya must be considered in terms of facilities and infrastructures. A good pedestrian way will reduce dependence on vehicles, increase travel, improve the physical visual quality of the city with the consideration of human scale, creating more retail activity and eventually will affect socio-cultural and economic (Shirvani, 1985) [5].

Currently in addressing the existing problems, major cities in the world have started to provide infrastructure to innovative strategies through the application of concepts that promote integration between land users and transportation. One of the concepts applied in major cities in the world is walkable city. Walkable city concept has been implemented in several countries such as Italy, Brazil, USA, Hongkong Singapore, and several other countries (www.walk21.com) [10]. Southworth (2005) defines walkability as an environment built to support and encourage walking with respect to the convenience and safety of pedestrians, as well as connecting people with varied goals in a short time [7].

The walkable city concept in Indonesian cities has not been fully implemented. Thus, in this study, the concept of walkable city as the foundation of research in the development of connectivity system in Surabaya as transit area between modes with other physical scope, so as to maximize the continuity of transit activity from several modes and can assess how far the pedestrian environment can serve the journey which will impact on the overall quality and effectiveness of the transport network.

As one of the metropolitan city in Indonesia, pedestrian ways in the city of Surabaya cannot be said walkable, this is because the pedestrian ways in this region still has many shortcomings in terms of facilities and infrastructure. So, in this study, the concept of walkable city will be the concept used in developing the pedestrian ways. Positive benefit by the development of pedestrian ways with walkable city concept in Surabaya City, that is with the decrease of level of private vehicle usage with the ease of access public transportation safely and comfortable of course by walking. Likewise, in the area of ITS campus and surrounding areas focused on observing the level of connectivity pedestrian ways. From the formulation of the problem can be drawn the following research question: how to develop a pedestrian way using the concept of walkable city in the city of Surabaya, especially in the campus area of ITS and surrounding areas?

Then, the purpose of this research is to formulate the concept of pedestrian ways development based on walkable city concept as one way to create safe, comfortable and dynamic road space to support connectivity of Surabaya City especially in ITS campus area and its surroundings.

2. Method

2.1. Data and Survey

Data collection methods used in this study are primary survey and secondary survey. The primary survey aims to make observations, interviews of respondents and the distribution of questionnaires. While the secondary survey aims to collect institutional data or documents on the pedestrian ways.

2.2. Analysis Method

At this stage of the research, the techniques used are qualitative and quantitative analysis techniques. Both of these techniques are the result of the conclusions of direct survey in the field in the form of observations and questionnaires that are collaborated with the theory and policy survey. In the first objective will use qualitative analysis techniques, while on the second and third targets will use quantitative analysis techniques. Here is a table of data analysis techniques consisting of research targets, analytical techniques used, and expected analysis results.

Table 1. Data Analysis Techniques

No	Objective	Analysis Technique	Result
1.	Identify the characteristics of pedestrian ways at Campus of ITS Surabaya	Descriptive Qualitative Analysis	Characteristics of pedestrian ways at Campus of ITS Surabaya
2.	Analyzing the level of connectivity to pedestrian ways at Campus of ITS Surabaya	Space Syntax Analysis	The level of connectivity to pedestrian ways at Campus of ITS Surabaya

The definition of Space Syntax in the context of urban scale begins with understanding the urban space as a collection of buildings united by the space network flowing between blocks. This network connects one network of road spaces. Structure is the optimal result of all goals to all goals in the spatial system. This is what holds it all together. It has a certain topology, i.e. a certain connectivity pattern [1].

On an urban scale, spatial or urban structures can take an organic, uniform or deform shape. The types of urban networks (grid) universally vary in the way they interweave connecting the part-whole structure. They appear on different scales, and as a result, have different geometric properties. Topological and geometric grid analysis helps us understand the structure of urban spaces and its potential impact on social behavior and economic activity (Hillier, 1996a in Al Sayed et. al., 2014) [1].

Space Syntax researchers have developed many measures for explaining social behaviour, they consist of connectivity (degree), integration, control, choice [1]. The correlation between some of them might describe some characteristic properties of layouts that relate to wayfinding (Conroy Dalton, 2000 in Al Sayed et. al., 2014) [1].

3. Result and Discussion

3.1. General Description

Land use in the Campus Area of ITS Sukolilo is based on the master plan of ITS and the existing condition. Land use on ITS campus consists of three zones: core zone, sub-core zone and supporting zone (Masterplan Revision of ITS 2015) [9]. Pedestrian Ways Network in the Campus Area of ITS Sukolilo is shown in Figure 1. Pedestrian ways on the campus have scattered patterns throughout the campus area.

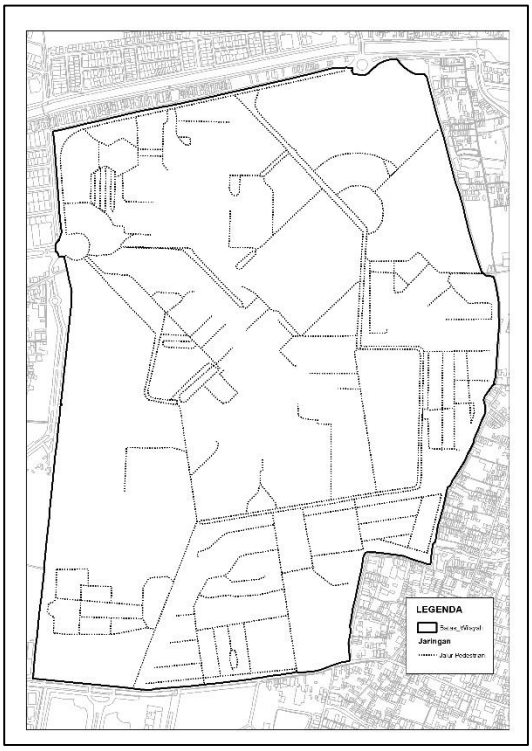

Figure 1. Pedestrian Network Ways on ITS Campus

3.2. Level of Connectivity Pedestrian Ways

In measuring the level of connectivity of a region, Siregar (2014), Hillier, (2007) and Purnomo (2009) argued that it is necessary to know the level of space interaction by considering the dimension of the integrity of the space [3][4][6]. As for which is used as input data in this research are in the form of map map (axial map) and map of connectivity. Axial line is a line of geometry that passes through a point connecting two vertices in a spatial configuration [4][6]. The axial lines are used to describe interactions that may occur in connecting spaces such as roads and other open spaces. The axial lines are expressed in terms of the grid lines connected to each other. While the connectivity map is used to explain the flow of interaction on the axial lines that later define the level of space connectivity on each axial line. In addition, the role of the researcher in determining both maps is very important. This is because the actual determination of the axial lines is still considered subjective by some researchers, so the determination is returned to the scale of research [3]. Therefore, the exact assumptions of researchers are highly expected in this study.

3.2.1. Axial Line and Pedestrian Depth Rate

In the axial map line pedestrian line campus ITS Sukolilo follows can be known pattern of pedestrian ways spread across the entire area of ITS campus. Meanwhile, although pedestrian ways of ITS Sukolilo campus is seen already scattered on almost all campus areas, but the existing pedestrian ways is still not connected completely to each other due to the building or building that separates. In addition, numbering on each axial line can be seen on the map to facilitate the process of further analysis. The numbering of axial lines is done by assigning a number to the axial line considered as a single entity or a segment by the researcher. As can be seen, based on the existing map there are 100 axial lines known to exist on the pedestrian ways of ITS Sukolilo campus used in this study.

In addition to applying the axial line concept, the calculation of connectivity using Space Syntax also implements the concept of distance / topological distance. (Hillier in Siregar, 2014) [6]. The concept of distance is expressed in the depth of the pedestrian ways where 1 step depth means the distance between two directly connected spaces, 2 step depth means the distance between space A and

B where it must pass through 1 piece of intermediate space. As for the area of Campus ITS Sukolilo, the existing pedestrian track has 7 levels of depth as a whole. Level depth is obtained with the assumption ITS Highway as the main entrance to the campus area ITS Sukolilo. The depth of the pedestrian ways that has 7 step depth or depth of space has a lower movement / flow to a place. In addition, 7 step depth states that the distance between space A, B, C, D, E, F, G has 6 pieces of intermediate space that must be passed.

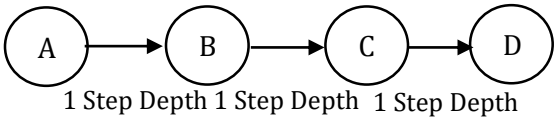

Figure 2. Concept of Step Depth
Source: [1]

As can be seen from the map, the highway ITS serves as the main route with a depth of 1. While the lanes through the main entrance of ITS and the Surabaya Shipbuilding State Polytechnic (PPNS) entrance generally have a range of depth levels of 2-3. The pedestrian ways around the entrance of Arief Rahman Hakim, staff housing, and around the faculty of Industrial Technology have varying depths ranging from 4-5. Pedestrian tracks with a range of depth level 6-7 are found mostly in the student dormitory area. The level range of the pedestrian ways depth is the main input which will be used to define the connectivity value.

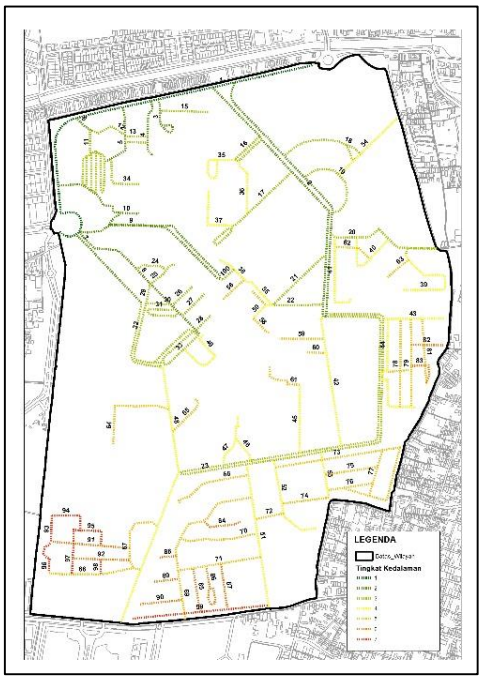

Figure 3. Axial Line and Pedestrian Depth Rate

3.2.2. Level of Connectivity
To determine the level of connectivity, calculations of the total number of spatial configurations contained in the axial line of the study locations. The determination of the space configuration is done by looking at the number of axial lines connected to the axial line to be calculated to determine the number of possible interactions that occur in the space. The amount of space configuration will then state the connectivity value owned by the axial line.

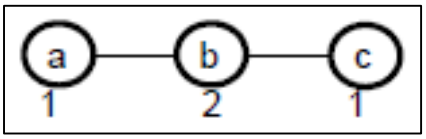

Figure 4. Connectivity Value of Illustrated Space Configuration
Source: [1]

As an illustration, in the picture above is a sample form of connectivity assessment that is viewed based on the number of existing space configurations. The illustration is explained by the following explanation:

- Space a. Only connected directly with space b, so the connectivity value = 1
- Space b. Connect directly with space a and c, so the connectivity value = 2
- Space c. Only connect directly with space b, so the connectivity value = 1

Based on the above explanation, then calculation of connectivity value with the same process in 100 spaces of pedestrian ways of ITS Sukolilo campus. Each pedestrian track space is studied in the configuration of the space so that it has different connectivity values. The following are the connectivity values for each of the available pedestrian ways spaces:

Table 2. Connectivity Value of Pedestrian Ways in Campus of ITS

Space	Value of Connectivity	Space	Value of Connectivity	Space	Value of Connectivity	Space	Value of Connectivity
1	9	26	1	51	5	76	1
2	9	27	1	52	3	77	1
3	2	28	1	53	5	78	2
4	3	29	2	54	2	79	4
5	5	30	2	55	3	80	2
6	3	31	2	56	2	81	4
7	5	32	1	57	1	82	2
8	10	33	3	58	1	83	1
9	2	34	1	59	1	84	1
10	2	35	1	60	1	85	1
11	1	36	2	61	1	86	1
12	2	37	1	62	2	87	1
13	2	38	2	63	2	88	1
14	2	39	2	64	1	89	1
15	1	40	3	65	1	90	1
16	3	41	2	66	2	91	6
17	3	42	3	67	2	92	4
18	2	43	3	68	1	93	1
19	2	44	3	69	2	94	1
20	4	45	2	70	1	95	1
21	3	46	1	71	1	96	1
22	3	47	1	72	4	97	1
23	6	48	5	73	2	98	1
24	1	49	1	74	2	99	1
25	1	50	4	75	1	100	2

In addition, the following is an illustration of the configuration space available in each pedestrian way space, by looking at the depth of each space. In the following illustrations can be seen respectively pedestrian ways space along with its depth and axial lines connecting it.

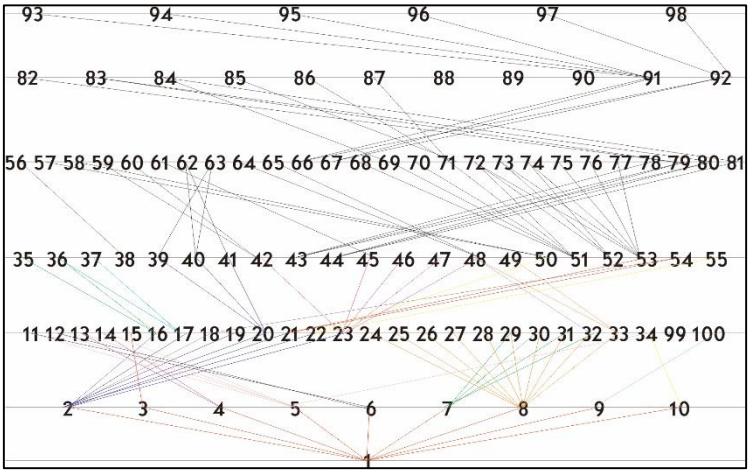

Figure 5. Illustration of Connectivity Analysis

Having known each connectivity value, then done determination level of connectivity by determining the range of connectivity value generated. The range of connectivity levels is determined by the following formula:

$$\text{Range of Connectivity Levels} = \frac{\text{Maximum Connectivity Value}}{\text{Numbers of Depths}} \quad (1)$$

Based on the above calculation, it is found that the range of connectivity levels used in this study is 1. As for using the range then known classification level of connectivity on the map as follows:

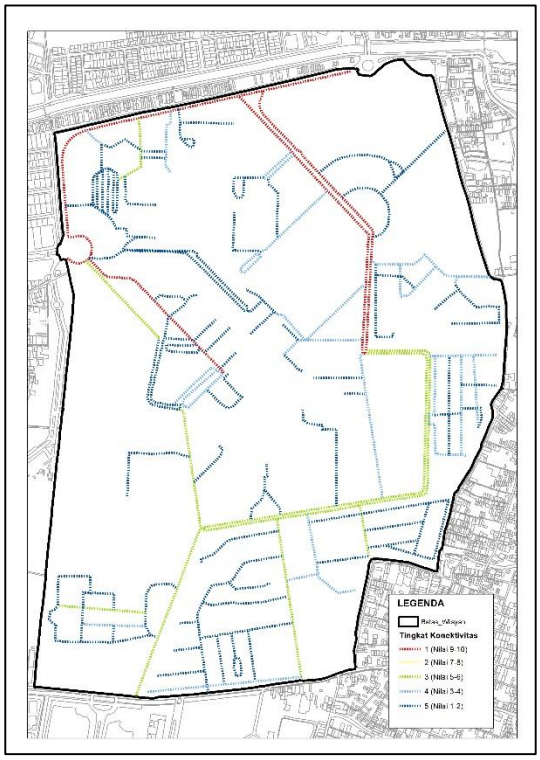

Figure 6. Classification of Connectivity Levels on ITS Campus

In addition, pedestrian ways with a second connectivity level with a 7-8 value range were not found in the Sukolilo campus area. However, pedestrian ways with 3 (5-6) connectivity levels are found in 7 out of 100 existing pedestrian track spaces or about 7% of the total pedestrian lanes on the ITS campus. The pedestrian route with the level of connectivity is found at the entrance point of Arief Rahman Hakim road (Teknik Elektro road), Teknik Perkapalan road, Teknik Sipil road, Hidroteknik road, Teknik Mesin road, and Graha ITS road. Pedestrian ways at this level of connectivity generally connect the ITS campus with Arief Rahman Hakim road which is an alternative way to the ITS campus. In addition, the pedestrian route with the level of connectivity 3 is also the main ways to the spaces that are often used for lecturing activities such as: Faculty of Industrial Technology (FTI), Faculty of Natural Sciences (FMIPA), Faculty of Ship Building Technology (FTK), student dormitory, and sports facilities. The condition of the pedestrian track at this level of connectivity is also quite good and well maintained.

As for pedestrian ways with connectivity level 4 (values 3-4) and 5 (value 1-2), they are generally located on road environments that connect internal campus and staff housing complex. Pedestrian ways at this level of connectivity are quite common in the Sukolilo campus area. On the campus itself, 20% of the total pedestrian ways have level 4 connectivity while 70% have level 5 connectivity. This is because many pedestrian ways, especially on campus internal areas, are unconnected and unintegrated due to building placement.

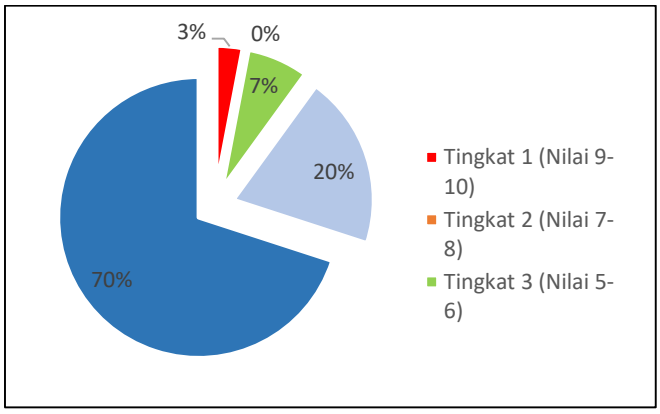

Figure 7. Percentage of Connectivity Level

Based on the above description, it can be seen that currently from all pedestrian ways on the campus ITS Sukolilo 70% of them still have very low connectivity level at level 5 with a range of values 1-2. Nowadays, the new Sukolilo ITS campus has 3% pedestrian ways which based on analysis has good connectivity. This condition indicates that the current development of pedestrian ways within the campus of ITS Sukolilo still need to be done to create a campus environment that is walkable and environmentally friendly.

Based on the analysis and observation so far, the development of pedestrian ways on the campus of ITS has been done mostly on the main lines such as: ITS Highway, Teknik Mesin road, Teknik Kimia road, Teknik Elektro road, and Teknik Perkapalan road. The pedestrian ways on these roads have good accessibility and connectivity. However, these conditions cannot be supported by pedestrian ways in the campus internal area which currently still has a low level of connectivity and the condition is not well maintained. This happens because there is no synchronization between the construction plans of existing buildings in ITS with the accessibility and connectivity of the pedestrian ways. As a result, there are still many pedestrian ways that are not connected to each other due to lack of good structural planning.

Lack of coordination of the building plan with pedestrian ways access in ITS campus area also resulted in the many pedestrian ways in ITS campus area which become abandoned and less well maintained. As an illustration, the campus' centreline that has been planned as the main pedestrian ways in the campus area of ITS is currently poorly maintained and sees very little use by students and

academic community of ITS. This condition is caused by lack of access that connects pedestrian ways to the campus' centreline with other main pedestrian ways on the campus. This has led to fewer pedestrians choosing to use this pedestrian way and resulting in poorly maintained and abandoned trails.

4. Conclusion

From the results of the analysis conducted on the pedestrian level connectivity of ITS Sukolilo Campus, it is known that pedestrian ways on the Sukolilo campus in general do not have good connectivity. This is due to the lack of integrated pedestrian channels, especially in the internal area of ITS campus, not yet coordinated the construction and layout of ITS campus and abandoned and less well maintained some pedestrian ways on the campus ITS Sukolilo.

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