

SPARKING OFF WALKABILITY

A Computational Approach of Urban Network Analysis on Walkability in TOD Neighborhoods

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Abstract. Existing and proposed Transit Oriented Development (TOD) neighborhoods of Waipahu Transit Center Station in Honolulu, Hawaii are revisited by a proposed computational approach of Urban Network Analysis (UNA). The four measures of UNA: reach, gravity, closeness, and straightness are employed for investigating walkability in these given urban neighborhoods. In each measure, 1) accessibility to transportation 2) intersections frequency, 3) residential building density, 4) commercial building density, and 5) Industrial buildings density are delineated and proposed as vital factors for improving planning and design decisions on walkability patterns around the TOD neighborhoods.

Keywords. Urban Network Analysis, Walkability, Transit Oriented Development.

1. INTRODUCTION

The United Nations statistics show that the year 2007 marked the threshold of a new era since the world's urban population has become more urban than rural. Indeed, more than a half of the population worldwide is living in cities, and its two-thirds are expected to be urbanized by 2050. In the process of urbanization in Northern America, about a half of urban land use is dedicated to transportation-related sectors (Melosi 2005). Private automobile-dependent transportation countries including the USA have been facing imminent problems resulted from the decline of public transit: traffic congestion, pollution, greenhouse gases, energy consumption, loss of open spaces and social inequities (Cervero 1998).

In the sixties, the American-Canadian writer and activist, Jacobs criticized the 1950's urban planning policies and noted the death of urban life. However, she believed, cities have the capability of providing something for everybody, only because, and only when, they are created by everybody" (Jacobs 1961). Jacobs is also convinced that good architecture is not about forms, but that it is rather about the interaction between form and people's use. Today's new paradigm in city planning takes into account city dwellers' conviction that good cities are lively,

attractive, safe, sustainable and healthy (Gehl 2010). The revitalization of normal activities of everyday life (Kunstler 2007), people-friendly design for "lively, safe, sustainable and healthy cities" (The Royal Danish Embassy in London 2014), and the concept of sustainability and liveability (Grant 2006) have been employed for developing smart urbanization, Transit-Oriented Development (TOD), healthy communities, and green cities.

For the New Urbanists, the solution to today's issues is the traditional walkable neighborhood of the past, which means "Neighborhoods should be compact, pedestrian-friendly, and mixed-use," and "many activities of daily living should be within walking distance" ("The Charter Of The New Urbanism" 2015). Walkability is introduced as a vital factor for urbanization in North America with its promise to provide resilient equity, healthy life, and more environmentally sustainable living conditions (Speck 2012). Streets and their sidewalks are the important parts of sustainable and liveable urbanization. The activities on them become decisive factors for making the vibrant of the city (Jacobs 1961). With growing concern of walkability in the life of urban neighborhoods, various design approaches have been applied for planning and zoning, public safety, environmental planning, and energy management. However, the difficulty of measuring urban form in terms of sustainability of city has been the hindrance to incorporate with walkability in the process of developing design proposals (Neuman 2005; Breheny 1992; Williams, Burton, and Jenks 2000). With computational tools, multi-modal data set from the study of spatial configuration of a city have been translated into the source for decision making on accessibility (Anderson 1993), land-use attraction (Tabor 1970), and behavioral pattern (Hillier et al 1987). Furthermore, an urban analysis using data mining techniques with mobile phone data suggests Jacob's four conditions for maintaining a vital urban life hold for Italian cities (Nadai et al 2016).

In this paper, urban network analysis (Sevtsuk 2010; Sevtsuk et al 2012) is employed for evaluating given design proposals of Transit Oriented Development (TOD) neighborhoods around Waipahu Transit Center Station in Honolulu. The evaluation was performed with a set of computational applications (Rhinoceros 3D, Excel and ArcGIS) and the outcomes are compared to one of the existing conditions of the original site with five criteria: 1) accessibility to transportation (bus stops, and rail station), 2) street intersections frequency, 3) residential building density, 4) commercial building density, and 5) industrial building density.

2. WALKABILITY

According to the U.S. Environmental Protection Agency, the way we build our environment, our mobility and travel decision have significant effects on both the human health and the natural environment (EPA 2013, 2-3). Walkability is presented as a solution to improve urban areas (Forsyth 2015). 70% of the American population could walk up to 500 miles for daily tasks, but their walks are limited to 400 meters (or 1/4 of a mile), due to the poorly planned pedestrian environment (Untermann 1984). Only 9% of their trips are made by foot whereas it represents 36% in Sweden (Pucher et al 2003). There have been four conditions for

encouraging people to walk rather than drive: 1) a proper reason to walk (balance of uses); 2) a safe walk (reality and perception); and 3) a comfortable (space and orientation); and an interesting walk (signs of humanity) (Speck 2012). The five-minute walk or the quarter-mile pedestrian shed has been commonly accepted as being the comfortable walking distance someone is willing to walk since it was used for conceptualizing “The Neighborhood Unit” with a church, school, and shops, and bounded by major streets. The problem with the 1/4 mile radius circle is that the distances between two points on a plane are given as a straight-line distance (also called Euclidean or “as the crow flies” distance), which means that it does not take into account safety rules (pedestrians must use sidewalks) and obstacles (walls, bridges, fences, traffic, the width or connectivity of streets). Therefore, despite the implementation of the 1/4 mile radius, the conventional suburban model lacks connectivity between places of residence, places of work, and recreational places, which makes the use of cars inevitable. On the other hand, the high level of connectivity found in traditional neighborhoods fosters walking as distances are shorter. Thus, as a result of this inefficient representation of the 1/4 mile radius circle, this proposed computational approach of urban network analysis is employed for measuring the actual path available to pedestrians based on their location and points of interests.

3. A COMPUTATIONAL APPROACH OF WALKABILITY ANALYSIS

With the local context of the studied area in mind, the analysis parameters that will be considered include street connectivity, the density of residential dwellings, land-use diversity and proximity to walkable destinations.

3.1. TOOLS

For the purpose of this research, Rhinoceros 3D, Urban Network Analysis (UNA) toolbox, ArcGIS 10.2 and Excel are employed; the last two used at an early stage in the process for analysis purpose (data gathering and classification). Then, the Urban Network Analysis (UNA) toolbox, the plugin module of Rhinoceros 3D, evaluates the large amount of information that plays a part in creating architectural forms, assessing environmental conditions and even redefining urban geometries. In GIS, both vector and raster data are employed for representing spatial data. In a vector data model, the three basic symbols (points as XY coordinates, lines to connect vertices with paths, and polygons for areas) represent distinct and separate geographic information (spatial entities), such as the spatial location of walkable destinations, residential buildings, land-use categories and the road network.

3.2. URBAN NETWORK ANALYSIS

The open-source Urban Network Analysis (UNA) toolbox provides effective tools to describe and analyze the city’s complex spatial layout by computing five measures: Reach, Gravity, Betweenness, Closeness, and Straightness. Among them, betweenness calculates and visualizes by-passing traffic or footfall at locations in a spatial network. Among them, betweenness measure indicates the level of frequency of paths used for traffic within a given network radius so

that its application is to identify specific locations rather than overall evaluation. Therefore, our study was conducted with the other four measures in order to focus on the total density of point of interest around the rail station. Three elements are combined to make an abstract representation of any urban environment: 1) links that are paths along which travel can occur; 2) nodes (or intersections) where paths cross and form public spaces; and 3) buildings, which are the central destination points of all human movements (arrival or departure points). The goal is to better understand the relationship between people and places (accessibility, proximity, and adjacency between places and people, for example). The given measures provide important information on how people use their city, what needs to be improved, or how efficient a plan is.

4. CASE STUDIES

4.1. SITE

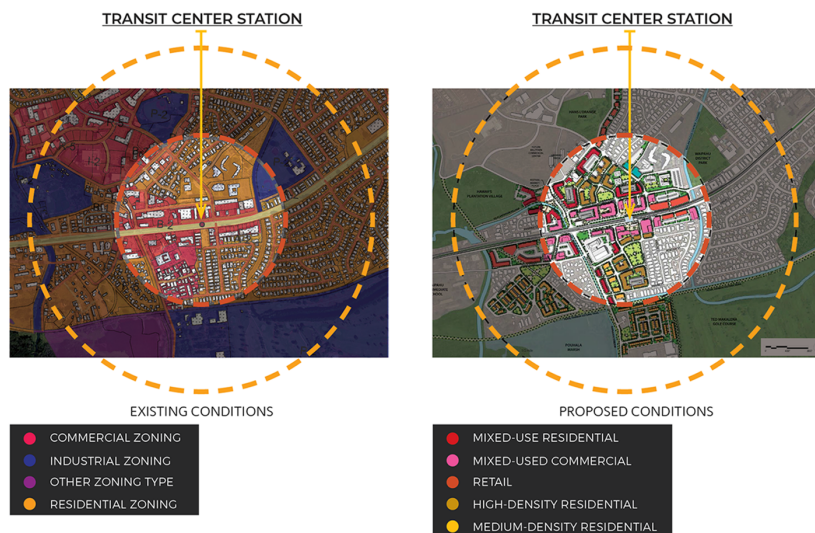


Figure 1. *TOD NEIGHBORHOODS OF WAIPAHU TRANSIT CENTER STATION AND LAND-USE ORDINANCE*.

Transit Oriented Development (TOD) neighborhoods of Waipahu Transit Center Station in the city and county of Honolulu, Hawaii is reviewed. The neighborhoods are currently mostly dedicated to commercial and industrial activities with very few residential zones. To foster improvements around those adjacent communities, the City proposes mixed-use zoning in order to highlight “a connected Green-way Network, Multi-Family Housing, New Mini Parks and Open Spaces, Boulevard Treatment along Farrington Highway and Parking Management and Park-n-Ride Facilities” (“Transit-Oriented Development Home” 2016). The map of existing conditions shows in red a concentration of commercial buildings and in yellow a concentration of residential buildings, whereas the proposed map shows in pink

mixed-uses commercial and in red mixed-uses residential types of buildings.

4.2. DATA COLLECTION & GEOMETRIC REPRESENTATION

Originally the data was collected from a local state database website and in its initial format, the tables of attributes for each feature (buildings, bus stops, ...) revealed themselves to be either incomplete or unorganized. For example, to know if a building is located within a commercial zoned area we would have to look at a separate zoning map, however, it was more useful for us to be able to select a building feature and directly find any information needed (Land-use ordinance, zoning height, and so on).

Table 1. *DATA COLLECTION*.

BUILDINGS				
Cooridonates:	Buildings:	Max Zoning Height:	Actual Building Heights	Actual Buildings Areas
<ul style="list-style-type: none"> • X • Y 	<ul style="list-style-type: none"> • Heights • Volumes • Areas 	<ul style="list-style-type: none"> • 30' • 40' • 60' • 150' • 200' 	<ul style="list-style-type: none"> • 0' to 30' • 30' - 40' • 40' - 60' • 60' - 150' • 150' - 200' 	<ul style="list-style-type: none"> • Residential • Commercial • Industrial • Other Types
PUBLIC TRANSPORT				
Cooridonates:	Bikes:	Subways:	Bus:	Rail:
<ul style="list-style-type: none"> • X • Y 	<ul style="list-style-type: none"> • <i>Number of bike racks</i> 	<ul style="list-style-type: none"> • <i>Number of subway entrances</i> 	<ul style="list-style-type: none"> • <i>Number of buses around location</i> 	<ul style="list-style-type: none"> • <i>Number of Rail station</i>
TAX PARCELS				
Cooridonates:	Parcels:	Type of Adjacent streets	Omitted	
<ul style="list-style-type: none"> • X • Y 	<ul style="list-style-type: none"> • Area • FAR 	<ul style="list-style-type: none"> • <i>Street</i> • <i>Lane</i> • <i>Place</i> • <i>Bldv</i> 	The values in <i>RED</i> have been omitted due to a lack of GIS data available for the location chosen. - This analysis solely relies on the accuracy of the GIS data provided by agencies. <i>This can become a real issue.</i>	

Some initial work had to be done in ArcGIS by joining attributes tables between layers of data, this was done by finding common attributes between each layer of data such as an Attribute ID number (Tax Parcel number). Once this initial work was completed we maintained and continue adding information within Excel. Only then we were able to perform our analysis and build upon them. In this paper the collected data from ArcGIS and Excel are organized into 1) Buildings, 2) Public Transport, and 3) Tax Parcels as shown in Table 2. Once the database is organized, Rhinoceros 3D and its grasshopper plug-in are applied for generating the geometric representations of the collected data. The geometric representations are achieved by computing the links for the street network, nodes for the buildings, street intersections, transit stops, public transport and any other points of interest in the given TOD neighborhoods.

4.3. OUTCOMES

Based on the collected data and their classification, their geometric representation becomes the basis for analyzing walkability of the given neighborhoods with the four measures of UNA: reach, gravity, closeness, and straightness. Each measure is applied to the collected data for finding its index from a transit station to different sets of points: residential building points, commercial building points, other building points, street intersections, and transportation points.

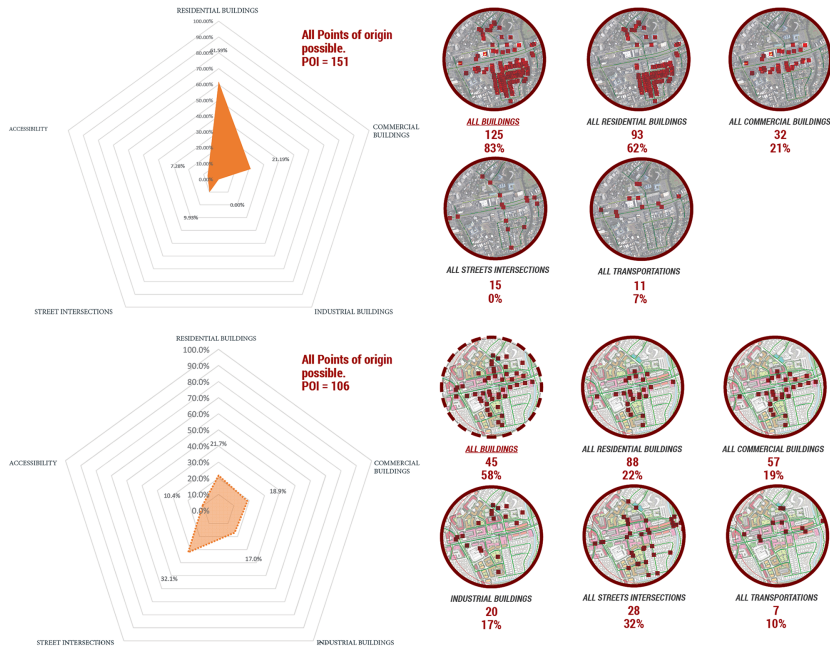


Figure 2. *REACH ANALYSIS: EXISTING (above) AND PROPOSED (below).

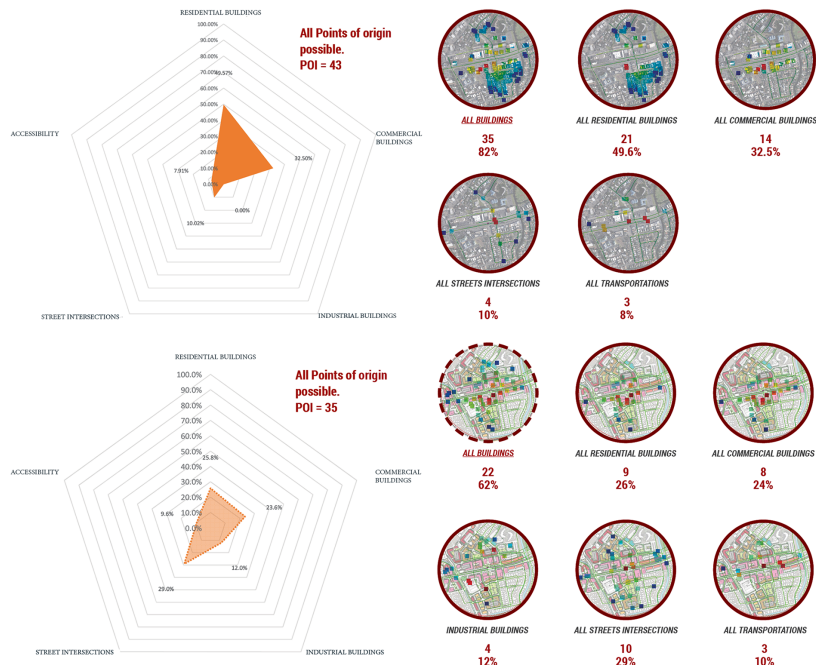


Figure 3. *GRAVITY ANALYSIS: EXISTING (above) AND PROPOSED (below)*.

The index of each measure is shown as a pentagram composed of the percentage of each set of points over all the points. As an example, Figure 2 shows the reach index analysis on the existing and proposed conditions of Waipahu Transit Center Station neighborhoods. The proposed neighborhood plan shows the increase of the reach index in street intersections within a 5 min. walk surrounding the station. It means that the proposed neighborhoods have more possible interactions among people on the streets. The reach index in other building nodes on the proposed also increased. There is a moderate increase of the reach index in commercial nodes and a decrease in residential nodes. Overall it shows that more diverse distribution of buildings in the neighborhood. However, the transportation nodes show less than 10% relative to all the nodes in the neighborhood. (See Figure 3)

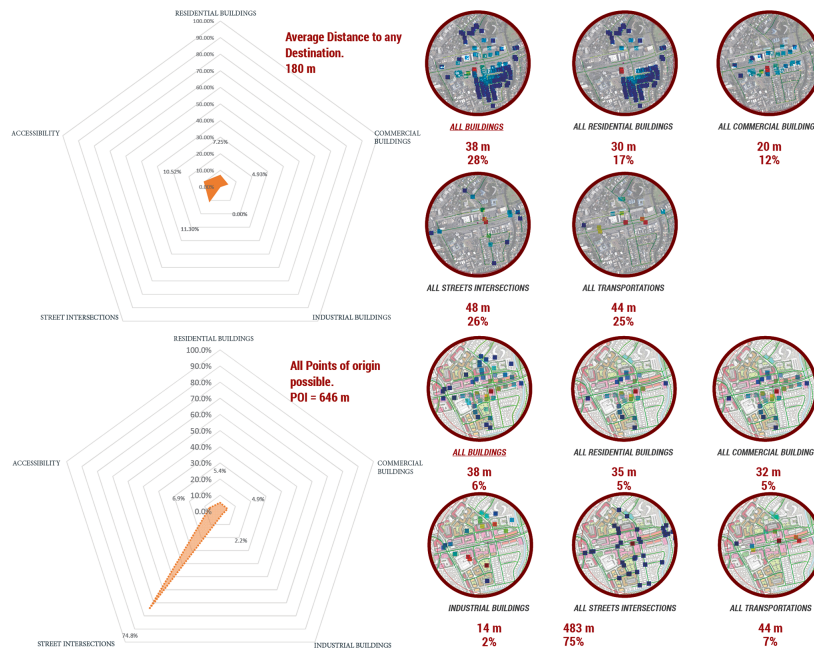


Figure 4. *CLOSNESS ANALYSIS: EXISTING (above) AND PROPOSED (below)*.

The proposed neighborhood plan shows a decrease of the number of buildings but a more homogenized distribution of building types with about 1/4 of buildings being residential and commercial. The Street intersections tripled which suggest more potential interactions between people and buildings. The comparison of the reach and the gravity index graphs for the proposed neighborhood plan shows that the ratio of destination points from the rail station remains fairly similar as the travel distance reduces. Even with a user’s low willingness to walk, it has access to various points of interests as shown in Figure 4. Finally, in the straightness analysis, the average distance of travel has not really changed except for the street intersections distances. The closeness index of the street intersections is off the

chart with 483 m. of average distance from the transit station to any surrounding street intersections. This indicates that the layout of the surrounding streets is still not adequate and that it could be compensated by dividing the size of the blocks or by providing more pedestrian streets between buildings as shown in Figure 5.

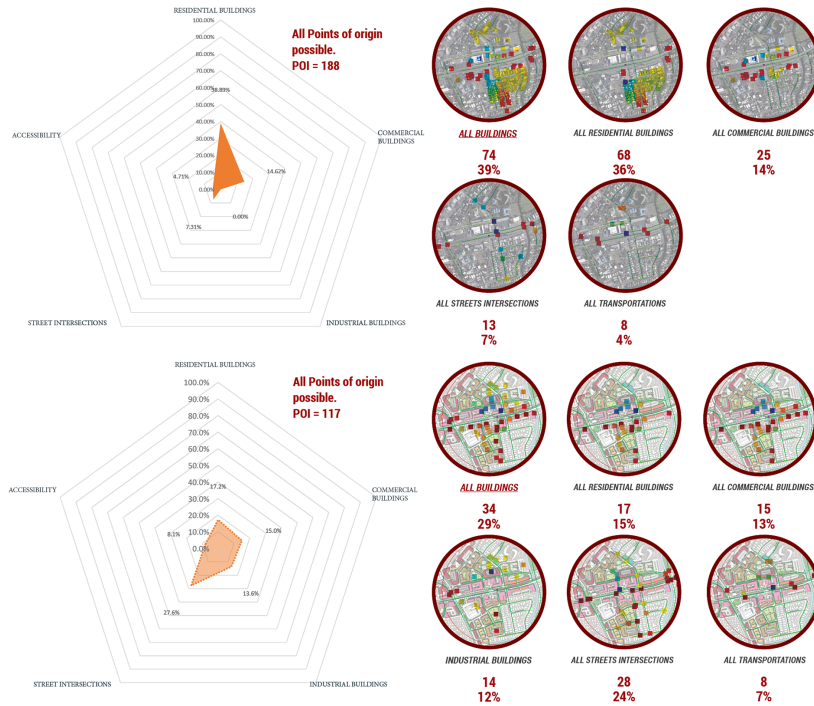


Figure 5. *STRAIGHTNESS ANALYSIS: EXISTING (above) AND PROPOSED (below)*.

In this analysis, the proposed neighborhood plan shows a general decrease of buildings, along a direct path to the rail station. Although the closeness index indicates that street intersections are not close to the station, 24% of the possible traveled distances from the rail station to intersections are still located along a more direct path than other points of interest.

5. DISCUSSION

The focus of this paper on walkability has been limited to 1) accessibility to transportation including bus stops, rail stations, 2) street intersections frequency, 3) residential building density, 4) commercial building density, and 5) density of industrial buildings according to the four measures of Urban Network Analysis (reach, gravity, closeness, and straightness). The proposed approach provides architects with many other sets of information, such as the ratio of land available and the actual amount of built surface; if a location is leaning towards densification or sprawling; or if it is mostly composed of low-rise buildings, as in the case of

Waipahu, for instance. The analysis on building types was done by comparing the reach index and the gravity index of the buildings square footage to the tax parcels square footage and the buildings heights to their respective zoning height map. Such information on building types can have an incidence on an architect's decisions when considering view corridors or shading devices. For future research, the scalability and flexibility of the proposed computational approach will be developed further in order to include various sets of characteristics and functional diversities in the urban environment including public facilities. The proposed approach of Urban Network Analysis allows architects to be more involved in the process of urban planning and design, and to use their expertise to compare aspects of cities more efficiently. From walkability to the field of real estate, this method is only limited by the user's imagination.

Acknowledgement

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