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An Investigation of Urban Gravity to Develop a Better Understanding of the Urbanization Phenomenon Using Centrality Analysis on GIS Platform

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Abstract

A city is a large and permanent human settlement which are usually associated with urban areas. An urban area has complex systems for several aspects such as sanitation, utilities, infrastructures, land use, building development, and transportation. These elements are the major factors which are characteristics of urban areas by the process of urbanization, which conducted an urban area to create its own attractiveness to attract urban activities to be settled in the same area. Urban gravity is subjected to study in order to understand an urban dynamic and development phenomena to assist urban planners in the decision making process. Urban gravity illustrates where urban activity has clustered through interpreting urban density intensification. The study has introduced the centrality tool analysis by using Gravity index in Urban Network Analysis (UNA) which runs on the Geographic Information System (GIS) platform. The urban area of Fukuoka city, Japan, has been the focus for the study according to the proposal of the study which aimed to investigate the gravity value in different types of building usage in Fukuoka city due to real estate development aspects such as public facilities, mixed usage, detached houses, and commercial buildings by illustrating appropriate areas with high potential in each building type. This is calculated by the interaction between building information and street networks. The study also aims to develop a better understanding of spatial configurations of cities, in term of urban spatial analysis.

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Keywords: Urban Gravity; Attractiveness; Urban Planning; Intensification; Decision Making

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1. Introduction

In the field of urban development, the phenomenon of urbanization has seen an upsurge in recent years (Moore Higgins, 2016). Urbanization occurs consequently to population and infrastructure expansion, and establishing social and business dynamics (Vilar Cartes, 2016). An urban development is dependent on its configuration that consist of complex systems: sanitation, utilities, infrastructures, land usage, building development, and transportation (Jenks Jones, 2010). The densely concentrated populations and built environments of developing cities are expressed as expansion (horizontal) and intensification (vertical) of physical growth (Sun et al, 2014). In accordance to the spatial planning scale, urban characteristics are defined as a consequence to the urban centrality dynamic process constituted by configurational forces (Mekonnen, 2012). In a given area, urban activities amalgamate, and as a result generate an appeal to attract further urban activities in the same region (Joubert, 2015). Urban gravity is a representation of the spatial attractiveness of an area to describe urban development levels of the land use (Kim Sohn, 2002).

The illustration of urban gravity enables interpretation of urban density intensification by the clustering of urban activity (Krafta, 2001). The attractiveness of an area has benefits for work, social interaction, and sight-seeing purposes (Alfeld, N.d.). Furthermore the utilization of urban gravity is advantageous as a method of measuring and estimating the affordability of housing, well connected (Jenks Jones, 2010). In this study, urban gravity is investigated to gain further knowledge on urban dynamics and the development phenomena, as to facilitate decision making processes of urban planners.

2. Methodology

2.1. Study Area

This study focused on the subway station districts within a 1,000 meter radius of each station of the Fukuoka city subway network to investigate a gravity phenomenon in different activities of urban development. The Fukuoka subway is located in the downtown of Fukuoka city which has the most development of the Fukuoka prefecture. Each station has its own characteristics depending on its environment. The Fukuoka city subway system consists of 3 lines and contains 35 stations. The service area network covers all of Fukuoka city's downtown including up to 7 municipalities. The subway station district land usage planning has special characteristics to prompt commuters for easy access to subway stations. In addition, there are factors which characterize the differences of each station's area. According to the analysis of urban form elements, the urban morphological attributes of an urban area is at all scales. The physical features are the transportation network, population density, building usage, Land usage and urban layout are the indicators which assisted in defining a special characteristic of the subway station districts on the subject area.

2.2. The Measurement of Gravity Index

Urban centrality studies assisted in defining the urban development in a city's center area. There are several indicators of urban network centrality measurements such as reach, gravity, betweenness, closeness and straightness (Sevtsuk Mekonnen, 2012) to study the urban development phenomenon, particularly in spatial scale to interpret the different levels of development in each district, as well as special zoning areas. According to urban centrality studies, this study is mainly used by utilizing the gravity index in urban network analysis (UNA) toolbox which runs on the geographic information system (GIS) platform. UNA is used to investigate the potential of urban development, especially in subway station districts because of the usages in building, land, as well as real estate development in the areas between two stations have developed respectively to its spatial network. This study used the best route on network analysis to represent the highest potential route in the network, by which the subjected stations that are connected. The Gravity index calculated the number of destinations and the attractiveness of the destinations, as well as the travel cost of approaching these destinations into a single value. The gravity index also additionally measures factors in the travel cost required to arrive at each of the destinations. The gravity index, $Gravity^r$ (i) of a node i in graph G at a radius r is based on the interpretation that centrality is inversely proportional to the shortest path distance between i and each of the other nodes G that are reachable from i within a geodesic distance r. The normalization of the gravity index illustrated as: