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Introducing a New Urban Utility Index Concept that Combines Urban Growth and Disasters

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Abstract The objective of this study is to introduce the urban utility concept that combines urban growth and urban disasters in the aspect of a conceptual theory. While many studies focused on the dollar amount damaged from a disaster, it requires adding not just building damages or human body losses but also the quality of life satisfaction. An issue in measuring the quality of life satisfaction needs to introduce a proper mode quantifying it. This study introduces the urban utility change in measuring the negative impacts of a disaster on urban life, which has been rarely investigated. To identify urban utility, urban flooding that is a cross-sectoral agenda and important to both developed and developing countries was adopted to respond to its increased frequency and damages, encouraging governments to focus on flood control policies. By combining a literature review on urban utility and urban growth, this study defined the urban utility concept as a net benefit of a resident with earnings subtracting housing and commuting costs. The theoretical study also explained that urban utility and its components dynamically change as per urban growth and disasters that even reversely affect urban growth. Because the urban utility can be one of the useful indices to appreciate the relationship between a disaster and urban growth, it is highly expected to apply for similar disaster impacts on urban areas, including COVID-19 and various global warming issues.

Keywords urban disasters; urban utility; urban growth; COVID-19

I. Introduction

Disasters occurring in an urban area affect urban growth. These may include earthquakes, landslides, tsunamis, tropical cyclones, floods, wildfires, droughts, and pandemic diseases, and some of these may occur together. In August 2021, Hurricane Ida hit parts of U.S. southern states, and the COVID-19 is an on-going pandemic. Among the listed disasters, urban flooding is one of the most

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damaging and frequent disasters, generating more than 30 percent of all disasters between 1945 and 1986 (Glickman et al, 1992; Shah, 1983; Dworkin, 1976; Sheehan and Hewitt, 1973). Even the recent records suggest that both flood frequency and severity are on the rise and likely to worsen in the face of climate change (Dewan, 2013). It is a trend, as developed countries have over two-thirds of the population in cities, and developing countries are urbanizing much more rapidly than ever, even regardless of their income level.

The damage of disasters is less predictable, and the impact would be significant enough to affect a local economy, human losses and eventually urban growth. Therefore, there have been many studies that investigated impact measurement in physical damages and human losses in case of urban disasters. The results have been usefully applied in estimating insurance amounts and developing strategies for prevention and/or recovery activities. However, these economic impact measurements barely include the quality of urban life components, which would be one of the main determinants of urban growth. The quality of life can be a critical element to be considered in disaster recovery activities, as some studies explain that people tend to move to another location where higher utility is provided. Perhaps, urban utility is one of the good indices to represent individual satisfaction of life. The objective of this study is to introduce the urban utility concept that combines urban growth and urban disasters in the aspect of a conceptual theory.

The second section explains the impact of urban flooding on diverse society dimensions where the government's attention is urgent. In the third section, methods to measure economic impacts are discussed, addressing the advantages of each method. In the fourth section, theoretical studies on urban utility and urban growth are discussed, and the urban utility concept is defined. The conclusion discusses the application of the urban utility concept to other types of disasters including COVID-19, urban growth strategies, and developing countries' urban project preparation, and further proposes a quantitatively applied approach that provides an example of the urban utility analysis.

2. Urban Flooding

Water disasters relate to many important policy issues such as insurance, flood control, tourism, housing, recovery and resilience of the affected areas, economic damages, relocation of residents, and so on (Richardson et al., 2008). The character and severity of impacts from disasters depend not only on the disasters themselves but also on the levels of exposure and vulnerability. Disasters, exposure, and vulnerability are influenced by a wide range of factors, including anthropogenic climate change, natural climate variability, and socio-economic development (IPCC, 2012).

Especially, flooding is one of the most serious natural hazards that any country has faced over the last few decades, causing significant damage to infrastructure, public equipment, and private property with economic losses. For example, in the Colorado flooding that started on September 9, 2013, at least 9 persons were dead (Dokoupil, 2013). The impacted areas range from Colorado Springs (70 miles south from Denver) and Ft. Collins (65 miles north from Denver). The flooding closed or damaged many roads in the areas, including several important interstate and U.S. highways such as I-70, I-25, I-225, US-6, US-34, and US-36. Note that according to Oldham (2013), the town usually accommodates about 2 million guests annually and contributes to the highest record of sales-tax revenue in July. Since the floods hit, Estes Park has been trying to get back to normal businesses from the devastating flooding, where the Elk Fest went on as planned. However, attendance at this year's Elk Fest was reduced (CBS4, 2013).

As experienced from the flooding stemming from Hurricane Sandy, due to the most coast-concentrated population and economy in the U.S., New York City's geographical location puts the city exposed to a high level of vulnerability from the threat of flooding. However, it is still ambiguous how much the recent physical destruction and social damage caused by Hurricane Sandy demonstrated the fragility of New York City's physical and cultural urban environmental systems. While Aerts et al. (2013) comprehensively analyzed the flooding risk and its consequences associated with Sandy, the majority of these types of studies have depended upon governmental reports, focusing on the magnitude of direct building losses or on speculations about future impacts on a damaged area.

One of the most damaging urban floods in U.S. history would be Karina in New Orleans where local society and economy were severely affected. There was a displacement of 400,000 individuals, estimating the total economic loss in New Orleans at \$62.1 billion (Park et al., 2008). Despite the Federal Government's funds of \$114.6 billion, the actual amount spent was estimated at \$69.4 billion until August 2007 (Fessler, 2007). Despite steady population increase since 2007, New Orleans has not yet fully recovered to the economic status of pre-Katrina equilibrium, reaching about 90 percent of 2004 according to American Community Surveys (ACS, 2018).

Urban flooding is a global issue, which is now more significant to the developing world, where urbanization is rapid, and the chances of flooding have increased. Records show that both flood frequency and severity are on the rise and likely to worsen due to climate change (Dewan, 2013). It is also important to highlight Sub-Saharan Africa, as Sub-Saharan African cities are among the fastest growing – showing 10 percentage points increase in urban population between 2000 and 2020 (Figure 1). Ethiopia has increased its urban population from 10 million to 23 million between 2000 and 2018 and anticipates reaching 42 million urban population by 2037. As the cities become larger and sprawl, more significant urban flood impacts tend to result. In Addis Ababa, at least 7 people have drowned in flash floods on August 17, 2021 (Floodlist, 2021). In Senegal, stormwater flooding has affected an estimated 400,000 to 600,000 people per year. The total cost was estimated at $104 million, including almost 56 million for damages and 48 million for losses from the flooding, 2009 (World Bank, 2021).

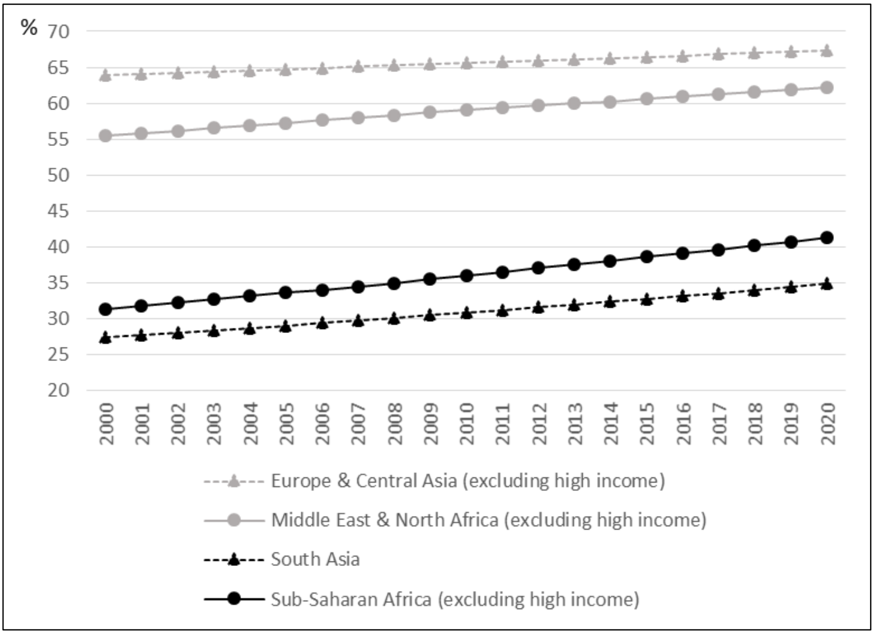

Figure 1 Urban population (% of the total population) - Sub-Saharan Africa, South Asia, Middle East & North Africa, Europe & Central Asia (excluding high income) (the figure modified from the source)

Source: World Bank (2021)

3. Measuring Urban Flooding Damages

This section introduces approaches to measuring urban utility change and their advantages stemming from urban flooding damages, highlighting the aggregate impact that is applied to an area instead of an individual. As clearly addressed in Park et al. (2013), the economic impact readings have not accounted for indirect effects via economic and trade linkages, even though most direct economic losses lead to further economic losses via inter-industrial and interstate economic relations. This is because measuring economic damages stemming from business interruptions of a flooding event involves various data collection processes. Further, urban growth will be affected by a disaster occurrence, including urban flooding. It is not surprising that studies on the economic impacts of flooding are numerous.

Traditionally, it is quite straightforward to analyze the economic impacts stemming from flooding. If using data, a macro approach is widely applied. By collecting information from HAZUS (Hazard U.S.) software and adjusting the estimated HAZUS damages using other statistics because HAZUS measured the direct economic losses on the basis of land use type sector classification system, a study estimates direct economic impacts by industry sector type after collecting actual business damages in the disrupted area (Lim et al., 2020). Then, to estimate additional indirect and/or induced damages with an economic input-output model, a study measures the total economic impacts experienced in the flooded areas (Park et al., 2008; 2013). Additionally, some studies trace economic recovery paths after the flooding event using the data collected (Park et al., 2017a; 2017b; 2017c; 2011).

The flooding impact analyses in the U.S. are mostly related to hurricanes. For example, Hurricane Katrina destroyed a large portion of the residential areas of New Orleans. A flood following Hurricane Katrina devastated Crescent City, and the disaster has been recorded as one of the most damaging natural disasters in U.S. history, resulting in an 80 percent of flood for New Orleans and over 1,800 casualties (Louisiana Geographic Information Center, 2005). Another hurricane, Rita, followed and caused major wind and rain damage on eastern Texas. Because Louisiana had been severely devastated in the preceding days, the damage from Rita was considered far less than that of Katrina despite the total number of fatalities as 130 (Knabb et al., 2006). Several groups estimated the dollar valued physical damages as well as economic impacts on the damaged region and the entire country. While the previous experiences gave us many important lessons on hurricanes, it is unclear how flooding events directly affect the flooded region and the state, and how recovery plans and executions contribute to recovering the economic losses by re-opening the disrupted businesses by modifying with the survey of the affected area after the disaster.

In the U.S., the National Interstate Economic Model (NIEMO) that includes 47 industry sectors and 50 U.S. states, the District of Columbia, and the rest of the world (Park et al., 2007) have been applied for the economic impact measurement. The most significant merit of applying NIEMO is to provide the interstate and interindustry economic impacts, once direct economic losses are provided. NIEMO has been applied for numerous state-wide, and national economic impacts in the U.S. After measuring direct business losses for the flooded areas survey data and HAZUS data, a NIEMO-type economic model application can provide spatially distributed indirect, induced, and total economic losses occurring at the impacted region.

Urban flooding damage is commonly measured by economic models, but these approaches have been designed to measure economic impacts to regions or groups of industry. As a component of regions, individuals are also affected by urban flooding, but measuring disaster impacts to individual scale has been barely investigated, especially for individual satisfaction of life. This measurement would bring useful findings to society if individual satisfaction of life can be defined and quantified.

4. Urban Utility and Flooding Impacts

While most studies only focused on the damaged areas accounting for their negative economic damages, it is difficult to find articles investigating economic indices which deal with urban life. This section introduces the urban utility concept and its theoretical relationship with urban growth and urban disasters.

Traditionally, the urban utility concept has been regarded as one of the economic indices affecting city-size. A city-size is affected by the aggregated individual utilities because individuals tend to locate in the area where utility is optimized. People move to another location where utility is higher under the assumption that cities are formed and developed by atomistic decisions of consumers and firms rather than a centralized action (Abdel-Rahman, 2003). Maximizing utility is common behavior in a free market economy. This behavior also applies to adjacent cities through dynamic human migrations. The equilibrium population of a city is determined when the utility gap is minimal between the city and its adjacent areas. Along with the population increase, earnings tend to increase until the population reaches an equilibrium (Glaeser, 1999).

The individual urban utility is the net benefit per worker, but the concept is yet clearly defined. Some economists use earnings, housing costs and commuting costs in explaining urban utility change and city size. As discussed in Glaeser (1999), locational decisions maximize expected lifetime earnings subtracting lifetime commuting costs. Earnings are the main source of benefit for hired individuals, while commuting costs are the subsequent cost between workplace and home. These two variables affect an individual’s locational selection process. Muth (1969) used housing costs and commuting costs in explaining consumers’ behavior to maximize utility. Consumers choose locations where the marginal savings in housing costs balance the increase in commuting costs. Brueckner (1983) further explained the relationship between housing costs and the individual urban utility. Utility and housing costs are negatively correlated because the utility level falls when housing costs increase.

Thus, the individual urban utility as the net benefit of a resident living in an area can be measured with earnings subtracting housing and commuting costs, although there are other perspectives. Some urban economists discuss the quality of life as another measurement for determining urban growth. They explain that urban growth is determined by wage, housing costs, and amenities. Unlike conventional economists who consider wage as the major variable for determining urban growth, Kemeny (2012) argues that the importance of wage reduces with adjustment of labor supply equilibrium via migrations during the 1980s to 2000s. Amenities are also one of the most frequently considered components which may determine the quality of life. According to Kemeny (2012), there is a strong correlation between amenities and wages. For example, workers in urban areas are more willing to trade their wages for warmer winters. These amenities include diverse indices, such as mean January temperature, climate and terrain, transportation, health care and environment, crime, recreation, arts, and education. However, there is a limitation in applying temperature indices to some regions where temperature change over the year is minimal. Also, many other amenities may affect the process of deciding individual locations. However, these amenity factors were barely investigated for their relations with urban growth. To add the amenities will be another study to be pursued in the future, and therefore, this study rather focused on suggesting variables that determine the urban utility concept while the amenity variable can be added if verifying the relevant studies.

Few studies have discussed the relationship between urban growth and urban flooding from urban utility component perspectives. Disasters may seem to bring a brief economic gain due to increased earnings and employment in the affected area where restoration activities are implemented by the government, international organizations, and insurances. However, flooding impact is not a positive economic force. According to Guimaraes et al. (1993), restoration activities as a result of Hurricane Hugo did not bring regional economic growth. Hugo resulted in the loss of lives and physical damage of $6.3 billion in the Southeast United States and the Caribbean Islands in September 1989 (South Carolina Budget and Control Board, 1991). In the analysis, income gains were neutral overall, despite a major surge in construction, retail and other sectors. Housing costs demonstrate more straightforward negative impacts as a result of disasters. For example, Katrina caused the monthly median rent increase by 48 percent between 2004 ($566) and 2006 ($838) in New Orleans (Vigdor, 2008). The rent increase results from relatively higher rental demand than the supply of decently conditioned housing in the area. The high rental demand is common in other countries, especially for a short term rental market. In Australia, the demand for rental housing significantly increased after the Brisbane flood in December 2010 because the residents immediately sought alternate accommodation for a short term (Eves, 2014). Commuting costs are also affected by disasters. Commuting time tends to decrease as residential density declines as a result of urban flooding if transportation infrastructure damages could recover relatively faster to the pre-disaster operation level than the recovery of residential density. It is common to see larger cities have longer commuting time than smaller cities, but this relation is more influenced by a spatial structure. According to Gordon et al. (1989), commuting economies favor low residential densities and high industrial densities. The flooding in New Orleans changed the spatial structure in the city between 2005 and 2006, resulting in a decline in commuting costs.

The variables of the individual urban utility dynamically change as a result of urban flooding and recovery activity. When significant urban flooding affected New Orleans after Hurricane Katrina hit, the local resident permanently or temporarily left the city, quickly declining the city size in half. Some people had returned to the city due to the subsequent recovery activity with newly created jobs, resulting in an increase in earnings. The housing costs also increased high due to the limited number of well-conditioned housings in the market, while travel costs declined due to lesser density in the city (Figures 2, 3, and 4). These are explained by the microdata between 2005 and 2016 collected from IPUMS USA (https://usa.ipums.org/usa/). The city population has continuously increased due to the city's attempts to implement diverse policies to attract jobs, provide subsidies for housing, and improve and diversify transportation modes. Though these data duly explain the relationship between urban growth and urban disasters from urban utility component perspectives discussed in the previous paragraph, this brief data investigation contains limitations for economic analysis because this investigation lacks in considering consumer price index, types of housing costs, and other significant events which may also affect the urban growth.

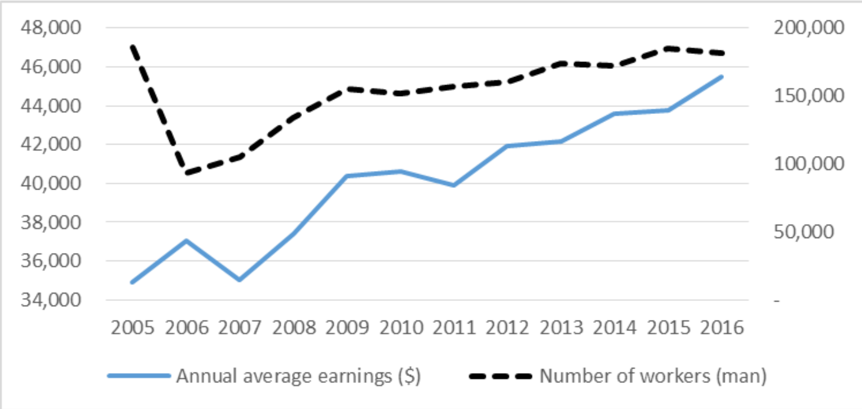

Figure 2 Annual average earnings and number of workers in New Orleans between 2001 and 2016 (the figure modified from the source)

Source: Steven Ruggles, Katie Genadek, Ronald Goeken, Josiah Grover, and Matthew Sobek. Integrated Public Use Microdata Series: Version 7.0

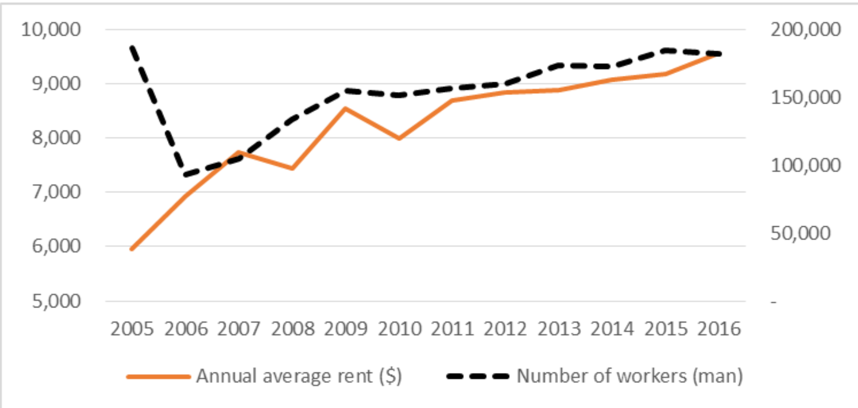

Figure 3 Annual average rent and number of workers in New Orleans between 2001 and 2016 (the figure modified from the source)

Source: Steven Ruggles, Katie Genadek, Ronald Goeken, Josiah Grover, and Matthew Sobek. Integrated Public Use Microdata Series: Version 7.0

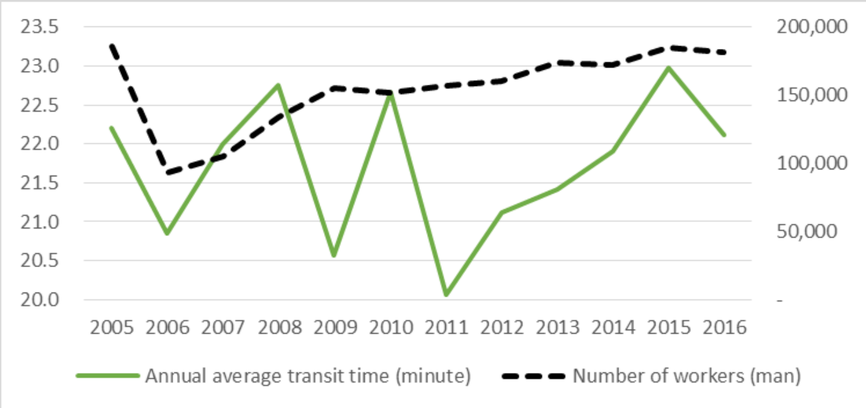

Figure 4 Annual average travel time and number of workers in New Orleans between 2001 and 2016 (the figure modified from the source)

Source: Steven Ruggles, Katie Genadek, Ronald Goeken, Josiah Grover, and Matthew Sobek. Integrated Public Use Microdata Series: Version 7.0

5. Urban Utility and Flooding Impacts

On August 29, 2021, Hurricane Ida made landfall in New Orleans as a category 4 hurricane, stronger than Hurricane Katrina made sixteen years ago. Disasters can be repetitive and less predictable in their damages. Recovery activities are subsequently necessary, and it is now the moment to discuss individual satisfaction of urban life in parallel with impact measurement through exploring urban utility concepts. The urban utility concept can be one of the useful indices to appreciate its dynamic relationships with urban disasters and urban growth. This concept would be applicable to other types of disasters, such as COVID-19, as the pandemic disease affects individual's decision in housing types and transportation modes, as well as characteristics of jobs, has changed as a result of social distancing. Workers prefer home-based work, and they become less dependent on office location, which in turn will be more likely to affect the worker's decision on where to live.

Urban growth strategies should be prepared without being damaged by any unexpected disasters. It is really rare to find data accounting for how long local businesses and residents have been shut-down and re-opened after a flooding disaster. This returns to the discussion on urban utilities. The urban utility concept will inform planners, engineers, and administrators to better prepare countermeasures to urban disasters through improving jobs, housing, and transportation conditions as well as physical disaster prevention if available. Aside from alleviating urban disaster impact, this concept is also useful in sustainable urban growth, as jobs, housing and transportation are the key components required by a city to become or remain a competitive city in the area to sustain its population, economy and quality of life, as the urban utility concept helps devise strategies to affect individual's decision making mechanism on where to live.

This study also advances our understanding of how the flooding event could affect the urban areas in developing countries and even other developed countries that may have a similar disaster. Based on the net-benefit approach, we can eventually evaluate if various adaptation and resilience efforts that each jurisdiction has made could be effective with/without the disaster. Indeed, African Countries become exposed more frequently to flooding disasters. It is important to highlight because these countries are urbanizing more rapidly than any other continent where a number of large urban projects are being prepared and implemented. These countries are also challenged by informal jobs, informal settlements, and limited transportation modes. This study suggests to include improving these three lacking components in their project preparation in order to pursue the resilient and sustainable development of cities.

Therefore, the urban utility can be a representative concept to indicate how the citizens involved in disasters would experience a better quality of life by comparing with and without the disasters. A quantitatively applied approach that provides an example of the urban utility analysis can be a useful study to be pursued in the near future.

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