



Sustainable urban development: A review on urban carrying capacity assessment



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ABSTRACT

Urban carrying capacity (UCC) concept is an important barometer and yardstick of sustainable urban development. There are a substantial number of studies dedicated to the broadest sense of the carrying capacity concept, and a plethora of underlying theories and evaluation methods have been reported. However, UCC, i.e. study at the urban setting, is a largely different research theme due to the varied meanings, principles, emphasis, and implications. Studies focused on UCC are still in its nascent period, existing in a limited volume of literature, a loosely knitted theoretical basis, with a lack of credible assessment methods and limited applications. Against this background, this research is aimed at analyzing and summarizing related studies on UCC. Through an extensive literature review, this paper integrates the existing concepts of UCC, reviews current research status, compares the pros and cons of related research methods, summarize knowledge gaps, and makes suggestions for planners and urban managers to ameliorate UCC. It contributes to a better understanding of the UCC concept. The research findings will inspire researchers to advance from the current status, and also provide clues to city managers and urban planners for developing appropriate strategies and actions to improve urban planning and management.

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Introduction

There is a well-recognized pattern that developed countries with affluence are usually associated with high levels of urbanization, for example, the USA's 82% and Japan's 91% (Qi et al., 2013; Tzoulas et al., 2007). It is estimated that urban population will increase to over 70% of the world's total population by 2050 (Shen et al., 2011). However, the fast inflows of rural dwellers to the urban areas inevitably induce numerous challenges to the destination cities (Abernethy, 2001; Saveriades, 2000). The fast growing requirements on carrying capability in many cities have been a significant burden caused by urbanization. Over-carrying capacity in urban development is perceived as massive and over-concentrated development beyond its inherent limits (Oh et al., 2005), and leads to various urban problems, such as traffic congestion, housing shortage, unaffordable housing prices, crowded streets, degraded ecosystem, air and water pollution, increasing demands for waste

disposal, social conflicts, polarized wealth distribution and community severance (Abernethy, 2001; Button, 2002; Heikkila & Xu, 2013; Rengasamy, 2009; Oh et al., 2005; Wang, 2013; Wong, Tang, & van Horen, 2006). These urban problems of over-UCC development can be summarized as four areas of unsustainability: meager urban services, environmental degradation, natural resources shortage and social conflicts.

Nowadays, the issue of over-UCC urban development has spawned various city typologies (Barrett & Odum, 2000), given the largely different demographic and socioeconomic conditions across different cities. It has become a great challenge for urban planners and city managers "to provide inhabitants with a good quality life in their cities" (Shen et al., 2011: 17). Since progressing sustainability is an essential responsibility for urban planning and development, the importance of UCC has drawn great concerns at the international level. UCC concept provides an important guidance for city managers and urban planners to better manage, build, and distribute urban resources, therefore addressing the huge demands from the increasing urban population (Rengasamy, 2009).

However, given a plethora of explanations and discussion surrounding this topic, current studies still lack a universally recognized definition on UCC (Sarma et al., 2012) and standardization for

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a systematic assessment (Summers, 2004). The imprecision of the UCC concept leads to a reconsideration of the concept and its implications. As such, research efforts are needed for clarifying the meaning and principles of UCC. This paper aims to provide a holistic, organized, and insightful understanding of the UCC research. This paper initially reviews the general carrying capacity concept. Then it reviews the links between UCC and urban sustainability. After clarifying the concept, this paper defines the meanings and relevance of UCC; compares the pros and cons of existing assessment methods; identifies knowledge gaps in current studies; predicts the directions of carrying capability research in the future. In the end, recommendations for improving UCC are made.

An overview of carrying capacity concept

The carrying capacity concept was originally derived from animal ecology in the logistic growth curve theory by Verhulst in 1838 (Kessler, 1994; Odum, 1971; Yu & Mao, 2002). The term “carrying capacity” was first formally proposed in 1890s by range managers who had special concerns on land use for grazing livestock (Liu & Borthwick, 2011). Based on ecological theories, carrying capacity refers to the entire amount of a given animal species that the habitat can sustain without yielding irrecoverable damage on the ecosphere. In ecology literature, carrying capacity provides guidance on the sustainable size of a population relative to the supporting ecosystem.

Likewise, a maximum or subsistence level for human population growth may be a useful indicator (Campbell, 1998). Human carrying capability can be defined as the size of population the world can support without damaging the “natural, cultural, and social environment” and degrading future carrying capabilities (Abernethy, 2001: 9). The concept of human carrying capability was first coined by Thomas Malthus. Given the concerns on natural limited factors on earth, Malthus made the cautionary prediction that the earth can only support a limited human population in perpetuity (Lane, 2010). Malthus noted that the world’s human population grows exponentially, whereas natural resources grow arithmetically. Thus, natural resources that support human survival would become finite. The resource constraints often appear as a consequence of rapid depletions of food resources, fossil fuel and fertilizers, fresh water, fertile topsoil, and minerals (Pimentel & Pimentel, 2004). The world will reach its carrying capacity when a population exceeds the availability of resources to support its survival. A number of natural limiting factors, such as disease or famine, will occur to reduce the human population and drag it under acceptable limits. Despite some criticisms, Malthus’s theory forms an important basis for the human carrying capacity concepts (Price, 1999; Seidl & Tisdell, 1999; Yue et al., 2008).

Relevance and meaning of UCC

To address the conceptual elusiveness, an explicate definition of UCC is made, noting the meaning, relevance, components, as well as the implication for remediation of urban planning and management.

By intuition, a higher UCC contributes to “a city that its residents love to live in and take pride in being part of it”, where clean air and water, convenient transportations, functional urban services, and friendly civic environment make its residents feel physically, cultural, and spiritually connected to the city (Wang, 2013: 13). However, given some initial efforts for clearer definitions, e.g. Onishi (1994), Joardar (1998), Summers (2004), Oh et al. (2005), Lane (2010), the UCC concept has yet to be adequately defined (Sarma et al., 2012; Summers, 2004; Tan, Shi, & Sun, 2008).

This paper leads to a more explicate and complete definition of UCC. UCC refers to the limit of urban development from environmental impacts and natural resources, infrastructure and urban services, public perception, institution setting, and society supporting capacity (see Equation (1)). Symbolically, the above relationship can be described as shown in Equation (1). UCC generally consists of two parts, i.e. the natural system and man-made components of a given urban area, which should adequately meet the human demands and retain within a limit for urban development, beyond which instability, degradation, or irreversible damage may result (Godschalk & Parker, 1975; Joardar, 1996; Oh et al., 2005).

$$\text{UCC} = f(\text{Environmental impacts and natural resources, Infrastructure and urban services, Public Perception, Institution Setting, Society Supporting Capacity}) \quad (1)$$

A noteworthy characteristics of UCC is that it is not a static and fixed value but is a dynamic and improvable, and that UCC can be changed phenomenally by the reactions between technology utilization, human preferences, investment, productivity, and consumption patterns, etc. (Arrow et al., 1995; Graymore, Sipe, & Rickson, 2010; Sarma et al., 2012). Fig. 1 provides a schematic illustration of the components of UCC and their inter-relationship:

Environmental impacts and natural resources: It refers to the level of human activity in an urban area where the natural environment can adequately assimilate the waste and pollution, and provide sufficient natural resources without scarifying human’s life quality and the endurance of the environment. The environment is an envelope around the economy (Abernethy, 2001). The environment supplies the essential inputs for economic production and consumption, and in turn also has to receive the waste generated. This concept encompasses two components, i.e. assimilative capacity and resources availability of the natural environment, e.g. Liu and Borthwick (2011). Assimilative capacity, such as water (Gong & Jin, 2009) or atmospheric assimilative capacity (Goyal & Chalapati Rao, 2007), refers to the ability of the environment to carry or assimilate waste without causing adverse impacts to the environment (Liu & Borthwick, 2011). For example, at the bio-centric level, the environmental impacts that endanger the beauty, integrity, and completeness of the biotic community in an urban area should be evaluated (Sarma et al., 2012). Resources availability should be measured with respect to the productivity the urban activities require or generate, such as the supply of food, clean air and water, and buildable land, etc. (Aspeslaugh, 1994).

Infrastructure and urban services: It refers to the level of human activity that infrastructure and urban services can adequately support in the specified urban area without generating degradation of life quality. Development of appropriate and adequate

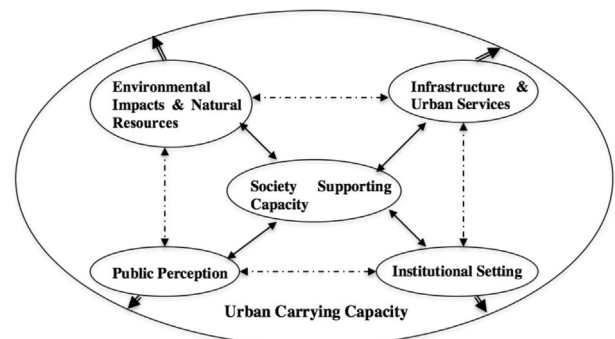


Fig. 1. The components of UCC and their relationships.

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