How to Identify Efficient Indicators or Indices for Applicable Urban Sustainability Assessment?

Li Shen
Department of Geography and Planning
University of Saskatchewan
Saskatoon, SK S7N5C8, Canada.
&
Sustainable Cities International
West Hastings Street, Vancouver, V6B1G8, Canada.

Xulin Guo
Department of Geography and Planning
University of Saskatchewan
Saskatoon, SK S7N5C8, Canada.

Abstract

Previous literature indicates that it is difficult to successfully select efficient indicators or indices for urban sustainability evaluation.In this paper, we attempt to theoretically address this challenge. Based on a discussion of the interpretation of sustainability, the capital framework approach, sustainability indicators and indices, and conceptual models, we have concluded that good sustainability indicators should meet four requirements including being reflective of appropriate interpretations of sustainability, being responsive to the community capital approach, being developed within an integrated conceptual framework, and being consistent with commonly accepted indicator selection criteria.

Keywords:urban sustainability, indicator, indices, capital framework, criteria, conceptual framework

1. Introduction

Since the industrial revolution in 1760, increasing anthropogenic activities have dramatically disturbed our natural ecosystem. Unprecedented popular growth, overconsumption of resources, environmental degradation, climate change, poverty, inequity, and wars have imposed great threats to human surviving andour future development (Hopwood et al., 2005). Therefore, sustainability and sustainable development were proposed as a promising path to address such issues (Kidd, 1992). An impressive report titled *Our Common Future*(or*the BruntlandReport*)(UN, 1987),presented in UN World Commission on Environment and Development Conference in 1987 put forward an generallyadopted definition of sustainable development as "*developments that meet the needs of present without compromising the ability of future generations to meet their own needs*", which then attracted global attention to sustainable development in both academia and public discourse.Another international sustainability wave was promoted by the Earth Summit in Rio de Janeiro in 1992 with an action plan *Agenda 21* approved by over 70 countries for devotion to sustainable development (UNCED, 1992). With the broad popularity of sustainability, a key issue has arisen "how can we transform the theoretical concept or philosophy into real measurements?" More and more researchers and practitioners recognized and recommendedquantitative sustainability indicators and indices aspossible instruments in sustainability evaluation (Maclaren, 1996; Weng and Yang, 2003; Keirstead, 2008; Wu and Wu, 2012). However, another critical concern has emerged "how to identify efficient indicators and indices in applicable assessment?"

Existing literature indicates that efficient sustainabilityindicatorsand indices cannot be identified successfully without an explicit interpretation of sustainability, an integrated capital framework approach, an appropriate conceptual framework, and an accepted set of section criteria. Those four elements constitute the fundamental considerations for defining the characteristics of 'good' or 'useful' sustainability indicators and indices.

This paper attempts to address the challenge of how to identify useful indicators and indicesfollowing the aforementioned four bases. Section 2, 3 and 4 provide a critical review of some major philosophies and methodologies related to the core issue, serving as a background for the discussion of problem solution in Section 5.

2. Interpretation of sustainability

2.1 Definitions of sustainability

Identifying an adequate definition of urban sustainability is recognized as the foremost step for the further development and implementation of practical sustainable measures (Wu and Wu, 2012). So far, a universally accepted interpretation of urban sustainability has not yet been formed due to the intrinsic interdependence of development processes and socioeconomic structures. A variety of definitions have been proposed based on diverse specific environmental and socioeconomic contexts. Some regard it as a desirable goal while others take it as a process (Newman, 2007). In spite of the popularity of this definition, its vagueness and generality still cannot be avoided. This is not supposed to be criticized because of the complexity, multifacet, and priority of components for different development contexts and goals (Weng and Yang, 2003).

2.2 Three key components of sustainability

According to the fundamental components of the triple bottom line (TBL/3BL) *social, ecological (environmental),* and *economic* or the basic domains of the three pillars *people, planet,* and *profit, environmental quality, social quality,* and *economic development* are universally regarded as three critical elements of sustainable development. The environmental aspect is highly related to ecosystem integrity; the economic goal should achieve maximized well-being in monetary measurements; the social one should emphasize individuals' justice and requirement (Weng and Yang, 2003). This three-dimension concept of sustainability based on the TBL/3BL can be illustrated in Wu and Wu (2012).Similar adoption of such descriptions can also be found in Esquer-Peralta (2007) and Samuel et al (2013).

2.3 Two paradigms: weak and strong sustainability

When it comes to the issue "whether the natural capital (exhaustible capital) can be substituted by human-made capital (produced or manufactured capital)",the concept of sustainability falls into two distinct paradigms namely "weak sustainability" and "strong sustainability".Typically strong sustainability is espoused by most ecologists and natural scientists but rebuked by neo-classical economists whose standpoints favor weak sustainability (Kuhlman and Farrington, 2010).

Weak sustainability emphasizes that natural resources can be alternated or compensated by certain manufactured capital whereas strong sustainability accentuates no substitution of natural capital by anyproduced capital owing to the limitations in growths and techniques (Daly, 1997; Ekins et al., 2003). In other words, in perspective of weak sustainability, as long as the total stock of man-made and natural capitals is constant over time, then the system can be regarded as sustainable with unrestricted replacement and transformation between different forms of capital.A representative example of weak sustainability is the ecological modernization. However, Connelly and Roseland (2010) pointed out that economic modernization is recognized as a symptomatic and reform-oriented approach primarily dependent upon technologies, financial regulations, and economic growth. They are more characterized by specific project or issue as opposed to integrated strategies. A transformative goal is needed to challenge the essential patterns, structures, and core values. Additional criticisms about weak sustainability were raised about capital measurements based on monetary units and conflicts with environmental resilience (Vatn and Bromley, 1994).

On the contrary,people in strong sustainability paymore attention to the unavoidable limitationsof technical advancementrather than economicgrowth (Connelly and Roseland, 2010). Strong sustainability insists that the process of depleting natural resources is irreversible and the extinct species are unable to recover. Some ecologists argued that no manufactured capital can serve as a substitute for some necessary life-supporting resources (Alberti, 1996). However,Breheny (1990) holds that substitute of some natural resources with human-made capitals (e.g., buildings, roads) is necessary for better living places. Local sustainability requires improvements of both physical environment and socioeconomic conditions in communities simultaneously (Haughton and Hunter, 1994).

2.4 Sustainable community development and communitycapital framework

Sustainable development and sustainability assessment can be conducted at different spatial scales (local, regional, national, and global). In particular, local sustainable development has gained increasing attention as the first step to expand sustainability to larger scales. As one of the strong sustainability philosophies, sustainable community development (SCD) has been recognized as an effective manner to promote local sustainability in a synthetic mode (Connelly and Roseland, 2010). SCD interprets target region as a complicated system withinteractions between multiple factors at different spatial and temporal scales. It can be achieved by balancing and integrating all components of the whole system. SCD alsostresses facilitating community awareness and public participation based on a shared knowledge of the common sustainable goal (Connelly and Roseland, 2010).

To achieve a sustainable community, community capital approach is regarded as a useful approach for implementing sustainable development. It helps conducting an integrated analysis for a thorough and comprehensive understanding of what sustainability means, what the conflicts and competing priorities are, and how to reach the sustainability. Capital is the simplicity of "means of production". A community capital framework with six fundamental forms of assets was proposed by Roseland to illustrate this method, as indicated Roseland (2005). In this framework, *natural capital* can be explained by environmental or ecological capital, whichcomprises renewable resources (e.g., food, water, and energy), non-renewable resources (fossil fuels, minerals), ecosystem services and functions (Ekins, et al., 2003). For instance, vegetation can absorb harmful pollutants and maintain soil condition and reduce surface temperature, green space is regarded as a typical natural capital for urban sustainability.

Social capital is commonly accepted as the relationships, networks, shared information, and interactions between individuals as well as collective institutions (Coleman, 1990; Putnam, 1993). It is described as a strong holding force that connects other types of capital together. Unlike other forms of capital, the inexhaustible social capital will increase with the use increasing. However, it is specific to particular context and normally cannot be transferred from one community to another (Ostrom, 1993). It requires a long time to create social capital on account of the subjective resistance emerged from people involved (Dale & Newman, 2010). It should come as no surprise that building social capital can enhance the community vitality and cohesion while decreasing social capital can lead to chaos and collapse of a community (Jacob, 1961).

Physical capital (or produced or manufactured capital) refers to the fundamental infrastructure and material resources for basic living and profit production(Rainey et al., 2003). It can include shelter, access to water and energy, machinery, equipment, plants, public transit infrastructure, and so on. Enhancing physical capital demands economic investment to improve the conditions all the aforementioned items.

Economic capital is defined as the tools how we measure and exchange resources in material lives. Financial (cash, loans, shares, stocks) and business (companies) are typical economic capitals based on a stable economyin a particular community (Meadow, 1998). It is critical to urban sustainability because of facilitating material well-being and based on production and services. Encouraging economic diversification by promoting consumption of local production, and supporting local entrepreneur are efficient ways to enhance economic capital.

Human capital refers to health, personal skills, education, leadership, emotions, creation that promotes individual well-being (OECD, 2001). Human capital contributes community sustainability because it can increase labor productivity and residents' competencies to reach their life goals. Human capital can be maintained by guaranteeing the basiclivelihood requirementsand strengthening political equity and democratic freedom (Callaghan and Colton, 2008). Human capital can also be enhancedby developingother forms of capital. For example, environmental amelioration can increase individual pleasure while physical capital can provides necessary living infrastructure such as housing, schools, and medical service. Economic capital such as employment can provide income for household expenses. Peace and safety as important social capital can create a harmonious external environment for living and development. Also, cultural diversity and identity play an important role in improving human well-being or Quality of Life.

*Cultural capital*mainly refers to both tangible and intangible resources resulted from shared historical experience within a community. It is identified as common treasure dependent upon commonly accepted customs, heritage, values, and worldviews formed in collective activities (Roseland, 2010). Stories, food, arts, ceremonies, languages, architecture, characters, and costumes all fall within this category.

Cultural capital has significant influence on the development of other types of capital based on the same ethical standards and consistent perception. Cultural capital dramatically helps attract extensive human resources such as creative class of professionals in abroad range of business, law, science, art, medical care based on the "3Ts" (technology, talent, and tolerance) the city can provide (Bain, 2010).

Based on the six forms of community capital, this framework can provide clear objectives and approaches for community sustainable development. Both local government and community citizens are required to improve the overall capital through collaborative engagement.Although there exist trade-offs when it is comes to increase all capitals, a balance of focus is required because no single one can achieve sustainability by itself.

3. Sustainability indicators and indices

3.1Definition of sustainability indicators and indices

Sustainability indicators are generally defined as a set of parameters or integrated associated parameters to quantify the attributes (e.g., dynamics, status, performance) of a target system (Gallpoin, 1997). Numeric values extracted from surveys or monitoring for those parameters are used to assessthe development towards, maintain, or away from the direction of sustainability. Also, quantified indicators can be used to investigate the interaction of human-environmental systems, taking urban quality, flows, and patterns together into measurements. Indicator development is highly dependent upon the specifiedcircumstances, policy focus, geographical scale, time, and limiting factors. Sustainability indices are aggregated indicators based on mathematical combination. The essential difference between indicator and indices lies in what level the aggregation is. Wu and Wu (2012) emphasized that there is little significance of distinguishing indictors and indices because indices belong to indicators from a broad interpretation.

3.2Criteria of sustainability indicator (or indices) selection

Potential sustainability indicators can be selected directly from relevant literature which has similar research backgrounds or evaluation goals. Also, they can be developed according to the widely acknowledged methodologies established for previous studies (Patrick, 2002). The identified USIs are supposed to follow a series of standard criteria.

One of the commonly used sets of indicator selection criteria is the "Bellagio Principles" which was approved by a worldwide team of scholars and practitioners at the Bellagio international conference in 1996 (Handy and Zdan, 1997). The ten Bellagio principles can be summarized into eight key points namely explicit definition, integrity and inclusiveness, spatial-temporal dynamics, simplicity, accessibility, engagement, continuity, and adaption. In addition, Alberti (1996) generalized four fundamentalguidelines of USI selection as"policy-relevant, scientifically-founded, readily-implementable, and usable for planning".A more detail set of standards was recommended by Maclaren (1996) who listed twelve principles based on a wide range of previous studies and practices. In particular, Maclaren (1996) emphasized that an effective set of indicators requires a relatively small size for efficient management. Other similar principles can be found in Keirstead and Leach (2008)who underlinedsome basic characteristics of USIs such as "clearly defined", "data availability and measurability", "compartmentalization", "consensual and participatory processes", and so on.Based on those criteria, Shen et al. (2013) summarized a set of more general standard for selecting sustainability indicators namely "clearly defined and scientifically representable", "responsive to target goals and audience", "data available", "numerically measurable", "spatially and temporally comparable", and "cost-effective".Thoseaforementioned sets of indicator selection criteria are essentially consistent with each other.

4. Sustainability indicator frameworks (or models)

Sustainability indicator frameworksare also known as conceptual models which can provide a comprehensive understanding of what sustainability to evaluate and how to measure it through incorporating the definition, key dimensions, potential indicator sets, and the linkages between indicators into a synthetic system (Wu and Wu, 2012).

A number of conceptual frameworks have been found in existing studies and practices. In the report of Canadian experience in developing urban sustainability indicators, Maclaren (1996) summarized five primary types of USI models including "domain-based frameworks, goal-based frameworks, sectoral frameworks, issue-based (or theme-based) frameworks, and causal frameworks".

In the same document she also pointed out the characteristics of each framework type. The domain-based framework has the capability to encompassmost dimensions of sustainable development (socioeconomy, environment, and well-being) which is more readily for providingan integrated interpretation of urban sustainability. The goal-based framework that is more specific to certain emphasized topics related to urban sustainability allows for development process monitoring. The sectoral framework can best serve as a tool for the formulation of public regulations due to its explicit identification of policy-associated issues. On the other hand, sectoral frameworkscompromiseto some extent the integration of different aspects in urban sustainability. The same limitations also exist in issue-based framework. Although the causal framework is able to demonstrate the linkages between different dimensions or indicators, still it is considered the most complex and difficult type in identifying the explicit stressors and conditions. Further discussion on sustainability indicator models can also be found in Wu and Wu (2012) who listed another five types of commonly used sustainability indicator modelshighly similar to Maclaren's work.

5. Discuss on characteristics of good sustainability indicators or indices

Based on our literature review of existing research theories and practices, four general characteristics of 'good' sustainability indicators can be extracted as: 1) reflective of an integrated definition of sustainability; 2) responsive to the community capital approach; 4) Developed within an integrated conceptual framework; 3) satisfying the commonly accepted indicator selection criteria.

5.1 Reflective of appropriate interpretations of sustainability

Good sustainability indicators should firstreflect the coexistence of weak and strong sustainability by making use of their respective advantages.This means that those indicators aresupposed to cover all the relevant dimensions of sustainability and guarantee the ecological priority at the same time.

There is not absolutely right or wrong for "weak" or "strong" sustainability because both philosophies are applicable in different aspects. Strong sustainability emphasizes the ecological priority and weak sustainability underlines the development balance. Since the growing consumption of natural resources and the huge stress caused by dramatic population growth, it does make sense to adopt the philology of strong sustainability. This is especially for some fundamental ecosystem functions which are prerequisites for the regular maintenance of human survival and socioeconomic activities in terms of delivering raw materials, assimilating waste output, and providing operational environments.Most of the environmental resources or services cannot be substituted by the manufactured products or facilities. Thus, it should come as no surprise that in most research environmental sustainability is recognized as the key of the overall sustainability.

Therefore, indicators for environmental protection must be included and conflicts should not exist between environmental indicators and those in other dimensions. If such violation occurs, indicators in non-environmental dimensions should be changed or deleted to ensure the ecological priority. This is also consistent with the fourth principledelivered in *Agenda 21* by United Nations Conference Environment and Development in 1992"in order to achieve sustainable development, environmental protection shall constitute an integral part of the development process and cannot be isolated from it" (UNCED, 1992).

On the other hand, to achieve a balanced and harmonious development between multiple considerations, this sustainability indicator model will also incorporate social and economic domains as necessary components in accordance withthe definition of the triple bottom line. Several reasons accounts for this inclusion. First, as a complex system formed by the natural power and anthropogenic transformation, target regions cannot be separated from multiple socioeconomic interactions such as commercial activities, manufacturing production, cultural communication, public administration, and political involvement. If socioeconomic dimensions are not encompassed, the potential indicator model will not be a comprehensive one to reflect the overall sustainable status. Second, the urban or community ecological system is not purely the natural environment and in fact it is impacting and being impacted by the disturbances from socioeconomic activities. Thus, the balance idea of weak sustainability should be used to guarantee a comprehensive set of sustainability indicators. Three pillars should be connected and integrated dimensions instead of separated aspects towards a sustainable goal. Environmental quality needs to be ensured by making appropriate economic regulations. Social equality should be implemented from both intra-generation and inter-generation perspectives. Economic development should be advanced on both qualitative and quantitative improvement.

5.2 Responsive to the community capital approach

Effective sustainability indicators also should be responsive to the community capital approach. The community capital framework is recognized as a useful tool to regulate the content of the proposed sustainability indicator model by promoting the six types of community capital. The advantages of community capital framework can be threefold in practical sustainability assessment. First, it allows for an efficient incorporation of sustainability relevant dimensions, standards, priorities to provide a comprehensive understanding of balanced community development. Second, this framework can deliver explicit goals and guidelines to narrow the input (time, money, energy, labor) for establishing an appropriate indicator framework. Third, from a long-term planning perspective, the capital framework approach also benefits public participation (NGOs, residents, administrators, researchers, and so on) for forming consensus and strategies to cope with the sustainability issues.

Meadow (1998) listed two practical examples of sustainability indicators identified for social capital based on the community capital approach. These two projectswererespectively conducted by U.S. Interagency working group on sustainable development indicators (1998) and The World Bank (1997). Indicators within the social capital category can clearly characterize the social issues of poverty, disparity, and inequity in a quantitative manner.

In addition, sustainability indicator identified following the idea of community capital framework can also help recognize the relationships between different forms of capitals. For instance, how does increasing natural capital influence the change of human capital or physical capital? What is the impact of social capital on cultural capital? Or more specific questions can be raised such as “is there any relationship between increasing commercial area and the neighborhood’s crime rate?”or “How can the transformed industrial area from crop land impact the local air temperature? Indicators defines using capital framework approach can help address more similar concerns.

5.3 Developed within an integrated conceptual framework

Helpful sustainability indicators should also be developed within an integrated conceptual framework. Only by establishing an integrated indicator model, can full coverage of relevant dimensions be accomplished by identifying potential indicators within such a conceptual framework. Even for the same type of framework, there are diverse practical models in various ways of categorizing and calculating indicators based on different sustainability interpretations under specific circumstances and goals. Therefore, the combined framework is strongly recommended by Maclaren (1996) to minimize the disadvantages of each single framework and to incorporate multiple advantages into one integrated system.

A Practical example in existing literature can be found in Shen et al. (2013) who have proposed adomain-based conceptual framework of the integrated multiple sustainability indicators. This USI framework encompasses three fundamentaldomains (environmental, socioeconomic, and well-being) based on an appropriate urban sustainability concept. Hierarchical themes ranging from broad to specific levels were further developed with reference from substantial literature. However, we have improved this sustainability indicator model by condensing the three domains into two *urbanization* and *quality of life*. We also incorporated more indicators relevant to smart growth such as *the mixed land use*, *supermarket access* (reflective of food desert), and *sustainable traveling index* (promoting non-automobile lifestyle). Figure 1 shows the definition adopted for suburban sustainable growth. Figure2 illustrates the hierarchical system of indicators or indices at different aggregated level. Figure 3 is the indicator conceptual framework. The quantification of this indicator model will be based both spatial data (satellite imagery, vector data) and censuses data incorporated a subjective information weighting based on social surveys. Compared to the previously established urban sustainability indicator model in Shen et al., (2013), this newly developed one is more suitable for assessing suburban development due to the implement of the ideas of smart growth.

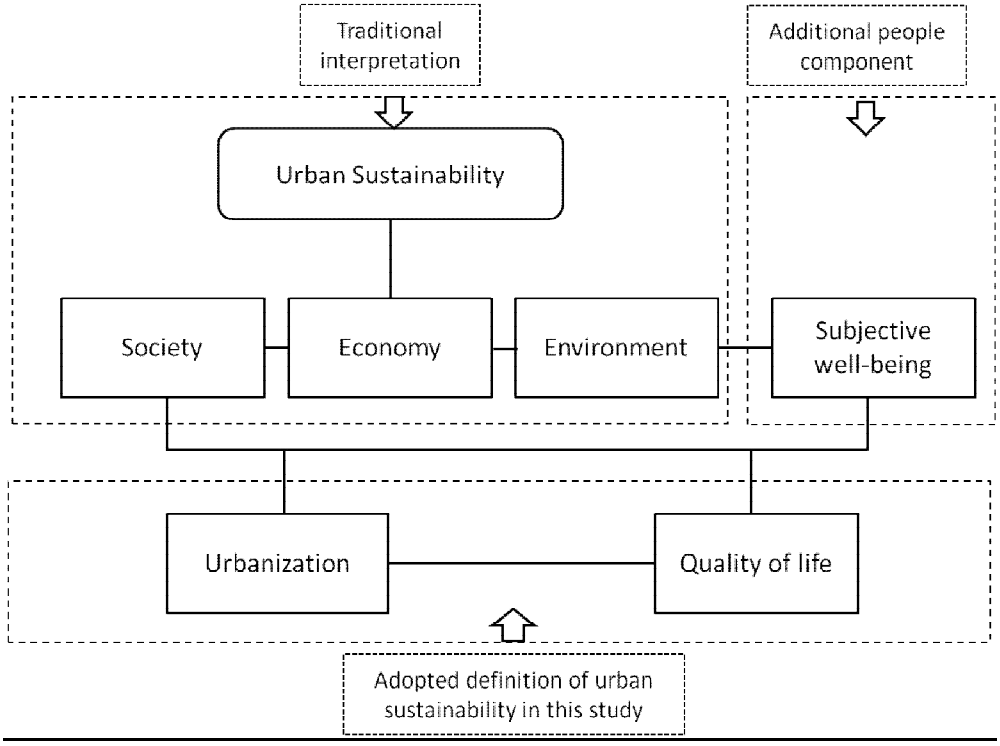

Figure 1. The definition adopted for suburban sustainable growth

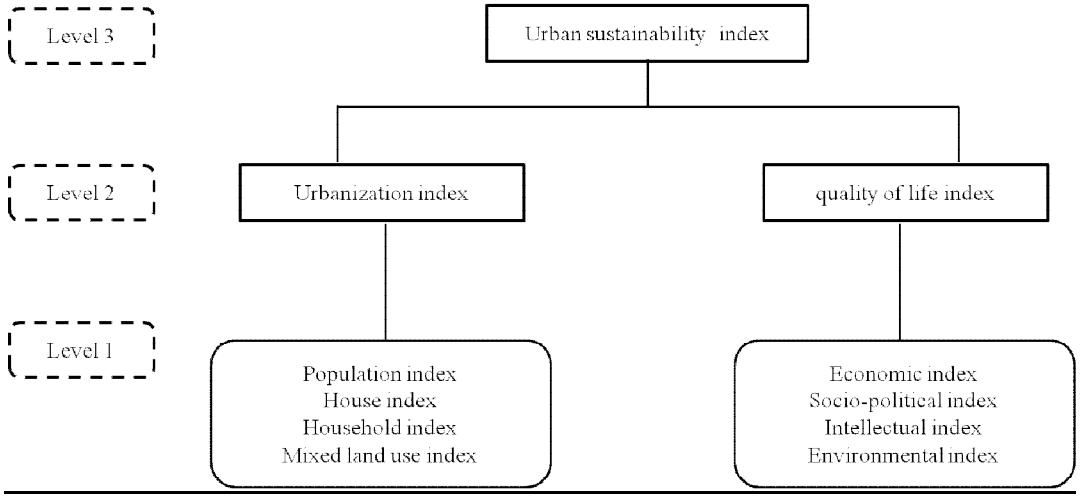

Figure2.The hierarchical system of indicators or indices at different aggregated level

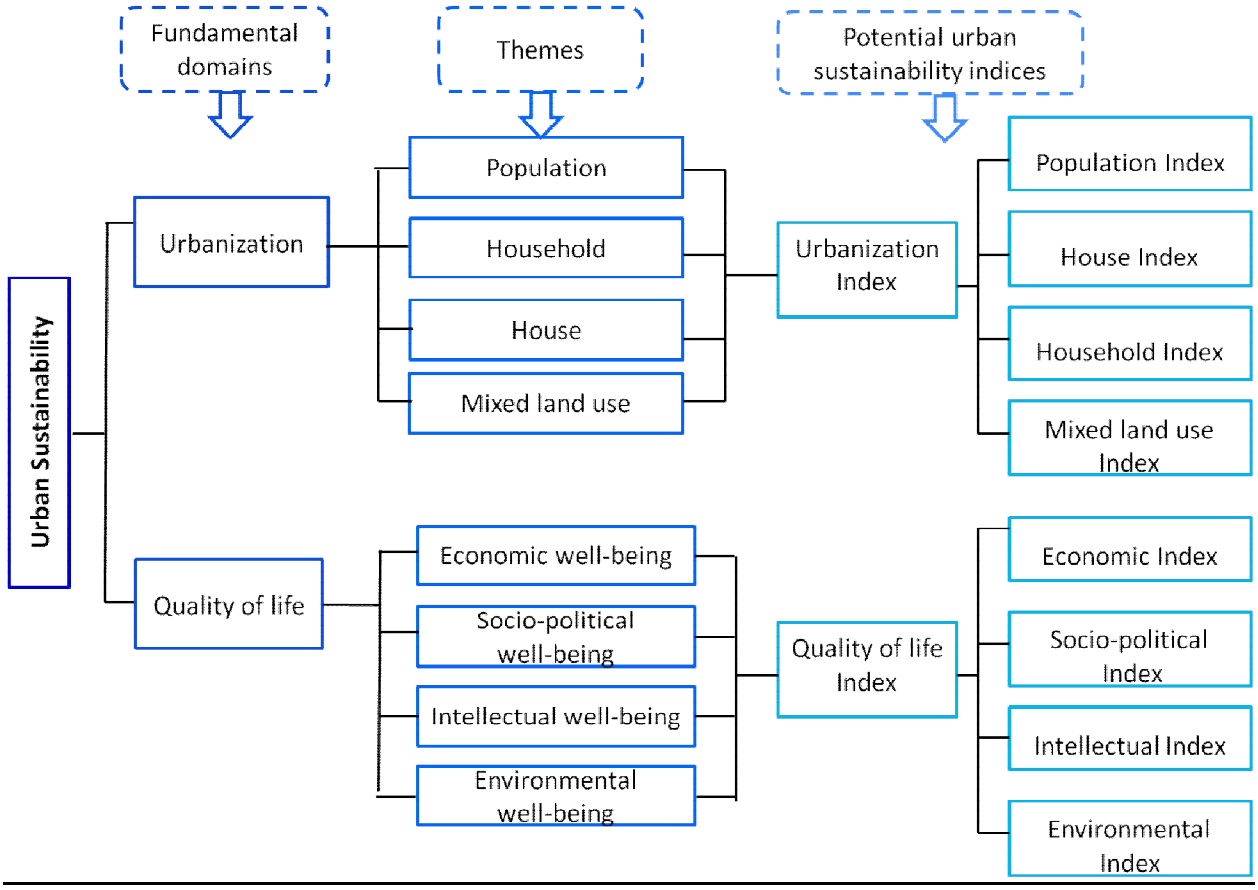

Figure 3.The improved indicator conceptual framework

5.4Consistent with commonly accepted indicator selection criteria

Last but not least, a set of quality sustainability indicators should be well gauged by commonly accepted indicator selection criteria. This helps to build trust and reliability of the proposed sustainability indicators.Before the application of indicator selection criteria, the preliminary sustainability indicators should be selected based on the specialized knowledge as well as the suggestions from different stakeholders (general public, researchers, or policy makers). Then the initial indicator set can be evaluated based on the selection criteria of different weights. It is also dependent upon the local development plans to add, reduce, or modify the initial indicators. The last step is to test the indicator set in real studies for practical urban sustainability evolution(Carruthers, 1994).

In particular, the spatial-temporal characteristic of sustainability indicators should be satisfied. In fact, this criterion is ignored in most of previous practices. Similar emphasis was also pointed out by other researchers. In 1980s, Rossi and Gilmartin(1980) stressed that repeatable measures during a long temporal period should be an indispensable feature of USIs for detecting the dynamic changes of specific urban phenomena.Likewise, the expert group at the 1996 Bellagio Conference also agreed that USIs should be characterized by the capability of indicating the dynamic spatial-temporal pattern of the targeted sustainable variables. The same attention was also paid by and Maclaren (1996) who at the same time pointed out that it is allowable to modify the USI selection criteria according to the specific goal and interpretation of sustainability.

6. Conclusions

This paper addressed bout how to define the characteristics of useful indicators for practical sustainability evaluation based on a discussion of the interpretation of sustainability, the capital framework approach, sustainability indicators and indices, and conceptual models. Good sustainability indicators should be Reflective of appropriate interpretations of sustainability, responsive to the community capital approach, developed within an integrated conceptual framework, and consistent with commonly accepted indicator selection criteria.

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