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Research Paper

Urban agglomeration: An evolving concept of an emerging phenomenon

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HIGHLIGHTS

- 32,231 urban agglomeration related literature identified.
- Major viewpoints of urban agglomeration definitions summarized.
- Tentative theoretical framework for defining urban agglomeration proposed.
- Empirical examples of China's urban agglomeration presented.

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ABSTRACT

Urban agglomeration is a highly developed spatial form of integrated cities. It occurs when the relationships among cities shift from mainly competition to both competition and cooperation. Cities are highly integrated within an urban agglomeration, which renders the agglomeration one of the most important carriers for global economic development. Studies on urban agglomerations have increased in recent decades. In the research community, a consensus with regard to what an urban agglomeration is, how an urban agglomeration is delineated in geographic space, what efficient models for urban agglomeration management are, etc. is not reached. The current review examines 32,231 urban agglomeration-related works from the past 120 years in an attempt to provide a theoretically supported and practically based definition of urban agglomeration. In addition, through this extensive literature review and fieldwork in China, the current research identifies the four stages of an urban agglomeration's spatial expansion and further proposes operable approaches and standards to define urban agglomerations. The study aims to provide a scientifically sound basis for the healthy and sustainable development of urban agglomerations.
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1. Introduction

Cities are the central locations for capital, labor and information. They have long attracted the attention of researchers from a wide variety of disciplines. The development, spatial evolution and spatial organization of urban forms are major research themes in the urban studies and human geography communities. Studies on the spatial clustering of cities began as early as the 1920s, with various terms used to describe this particular urban spatial organization. These terms include megalopolis, urban agglomeration, city group, and city cluster. Studies on urban agglomeration have increased over the past three decades (Fig. 1). A detailed search with these terms (megalopolis, urban agglomeration, city group, and city cluster) in the Web of Science database (up until July 8, 2015) renders 32,231 academic entries that are related to this specific urban spatial organization. Chronologically, there is only 1 study found in 1922; this number increased to 10 in 1952, 72 in 1980, and 146 in 1990, and the number exploded to an astonishing 5488 in 2000, 20,278 in 2010, and 32,231 as of 2015. Using an extensive literature review and cross-referencing, this study attempts to explore the central themes of studies on the spatial clustering of cities (this study specifically terms it "urban agglomeration" to indicate the inherently integrated characteristics of this city cluster), hence proposing a both scientifically sound and manageable approach to sufficiently define and effectively identify urban agglomerations.

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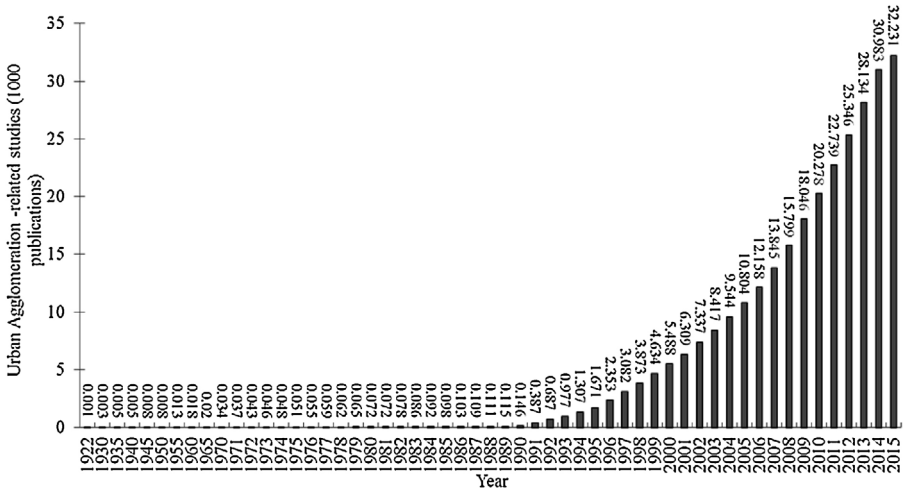
Urban Agglomeration -related studies (1000 publications)
Year
0
5
10
15
20
25
30
35
0.000
0.000
0.000

with a much higher concentration of complete industrial chains. Gottmann used the Greek term "megalopolis," which means large urban nation, to describe the so-called *BosWash* corridor (Kahn & Wiener, 1967), which included the largest cities of Boston, New York, Providence, Hartford, New Haven, Philadelphia, Baltimore and Washington, Gottmann (1957) further proposed that a megalopolis must satisfy the following conditions: 1) a megalopolis should have densely distributed cities that maintain close socioeconomic connections with their peripheral regions; 2) a megalopolis should have at least 25 million people with a population density of 250/km^2 or more; 3) a megalopolis should have a highly developed and efficient urban infrastructure (especially transportation and communication systems) so that the core cities are inherently interconnected; and 4) a megalopolis should be one of the central regions of the nation and serve as an international node. In other words, a megalopolis is an enormous agglomerated urban area with a clear hierarchy centered on multiple cores (large cities) that are geographically close to one another and socioeconomically interconnected. From this study onward, research investigations on megalopolis/conurbation/urban agglomeration have attracted increased scholarly attention (Doxiadis, 1968; Kanemoto & Tokuoka, 2002; Lang & Knox, 2009; Lewis, 1983; Morrill, Cromartie, & Hart, 1999).

In 1964, based on Rostow's theory of economic development stages, Friedman (1973) developed a model that described economic development and its corresponding spatial manifestation. The model was well suited to investigating different stages and processes of urban agglomeration development.

In 1968, a Swedish scholar, Hagerstrand (1968), proposed the modern spatial expansion theory, which lent power to an understanding of the spatial expansion process of urban agglomerations. Two years later, the Greek scholar Doxiadis (1970) predicted that all urban areas would eventually evolve into a huge "ecumenopolis."

In China in 1980, Song (1980) also proposed the concept of the "city-region" in his *Research Method on Regional Economic-Geographic Foundation of City Development*. Conceptually, a city-region is an economic region with multiple economic centers. Subsequently, Zhou (1988) proposed the *Metropolitan Inter-locking Region* (*MIR*) concept, which was similar to the concept of a megalopolis. Zhou (1988) noted that the MIR was a large, integrated, urban-rural region with multiple core cities, had strong socioeconomic connectivity between the cores and peripheries, and was often located along one or more major transportation corridors. McGee (1991) proposed another similar concept, the desakota (desa means rural region and kota cities), following his study on the urbanization of developing nations in southeastern Asia. Lynch (1980) constructed the concept of the dispersed metropolis. In 1983, Yu and Ning (1983) introduced Gottmann's work with the term "metropolis" in the Chinese context and formally set the theme and context for urban agglomeration studies in China. All of these concepts closely followed Gottmann's megalopolis design from a theoretical perspective, though they were derived from a variety of different geographical/regional settings. The growth in various versions of the megalopolis concept clearly reveals a trend in the spatial organization and structures of urbanization toward more concentrated, highly connected, and larger-scaled urban forms.

Rondinelli (1985) summarized 7 types of connections within city-regions. McLoughlin (1969) stressed the importance of rational planning for the sustainable and balanced development of megalopolises. The United Nations' Center for Human Cluster coined the term "urban agglomeration" to summarize all concepts that originated from, or were similar to, Gottmann's megalopolis and noted that the development of economic globalization and information technology had greatly promoted the formation of various urban agglomerations. This article follows the UN's convention and uses urban agglomeration to represent this emerging spatial organization of clusters of cities.

J. Friedman investigated in detail the hierarchy and network within any urban system (Friedman, 1986). Multinational corporations often design their longitudinal division of production areas based on the hierarchical structure of urban systems. In 1989, McGee (1989) and Ginsburg, Koppel, and McGee (1991) further explored the desakota concept based on their studies on southeastern Asian countries. Although both desakota and megalopolis refer to a form of urban clusters, desakota, according to the study by McGee et al., specifically refers to an integrated urban-rural region that contains two or more core cities linked with highly developed transportation systems and all the peripheral regions that are commutable within the same day. Dong (1989) applied similar concepts in *Initial Exploration of China's Urbanization* and defined the term urban agglomeration as follows: an "urban agglomeration, or urban cluster region, is a clustered urban system with different hierarchies and types of cities that often appear in highly developed, commercialized and urbanized regions."

In 1991, Pyrgiotis (1991) and Kunzmann and Wegener (1991) studied the networked urban system under economic globalization and regional integration. They contended that the megalopolis was a product of spatial industrial integration and would evolve to be the core for the global economy.

In 1992, Cui (1992), in his *Studies on China's Urban Development*, proposed that "an urban agglomeration is essentially different from regular clusters of densely populated urban regions. Urban agglomerations are an ordered urban system evolved along industrialization and city-centered regional development. Cities within an urban agglomeration are ordered and have clear hierarchy and division of functions. Clusters of densely populated urban regions are often not related with industrialization. The interactions among various cities are often spontaneous, not ordered, and lack inherent connectivity." Cui further proposed the three stages of urban agglomeration development, namely, the city-region stage, the urban cluster stage and the megalopolis stage. Yao, Chen, and Zhu (2006), in their book *China's Urban Agglomeration*, defined urban agglomeration as an "aggregate" of cities within certain geographic areas. These cities often vary in size, function and characteristics. There are one or two large cities acting as the core and connecting to the other peripheral cities via highly developed transportation and information networks to form an integrated "aggregate," or urban agglomeration.

In 1995, Tomita (1995) extended Gottmann's megalopolis and further proposed that the cities' servicing radii should define the border of a megalopolis after extensive planning and field work. According to this definition, not only cities but also rural areas were part of the megalopolis.

In 1997, Kipnis (1997) further advanced the concept of megalopolis, stating that urban agglomerations were supposed to be the primary cores for post-industrialization, post-modernization development and lifestyles. Urban agglomerations also provide the most encouraging regional environment for innovation and entrepreneurship. Qi and Duan (1997) noted that, in recent decades, urbanization showed a clear spatial clustering trend. Therefore, adequately understanding urbanization and urban development requires more attention to this emerging urban spatial form instead of individual cities. This city-region spatial form of urbanization focuses more on the financial, material and information flows within the larger spatial extent and the impact that such flows have on the spatial organization and hierarchical structures of urban systems. Based on the strength of interaction, the authors proposed a three-layer, semi-concentric structure for the urban agglomeration (using the Shanghai urban agglomeration as a case study in their research).

In 1999, Gu, Chai, and Cai (1999) provided an alternative definition for urban agglomeration. They specifically advocated for the term "agglomeration," in that the cluster of cities within a certain area is often centered on one or two large/super cities (population over 5 million) but is hierarchically interconnected via a highly developed and comprehensive modern transportation and information network. An urban agglomeration is often characterized by its dynamic development process, hierarchical network-like spatial structure, continuity and openness, and strong attraction, clustering, expansion and radiation among the cities within the region. Wu (1999) also provided a similar definition and clearly stated that an urban agglomeration is a "complete (in terms of function, spatial structure, interconnectivity, etc.) urban regional organization."

In 2000, Hu, Zhou, and Gu (2000) distinguished urban cluster and urban agglomeration in their study on the spatial clustering and expansion of China's coastal concentrated urban areas. They argued that an urban cluster stresses the interaction and integration among urban and rural regions, whereas an urban agglomeration is more of a union and integration of cities.

Portnov and Erell (2001) also suggested that an urban agglomeration refers to interconnected cities that are within a commutable distance from one or two large/core cities. These large, or core, cities are densely populated and highly urbanized. Scott (2001) proposed the "global city-region" concept. He discussed the developmental trend, theories and policies of global city-regions and applied the concept to the study of the economic development dynamics of cities in the Americas and Asia. He found that such global city-regions were similar to urban agglomerations, though they aimed at the economic and developmental dynamics at the global level.

Wang (2002) investigated the developmental trajectory of various urban forms and suggested that urban spatial forms often follow a path from individual cities to metropolitan areas, urban clusters, urban agglomerations, greater metropolitan areas, MIRs, and eventually a megalopolis. He coined the term "metropolitanization" to describe this process. Subsequently, Fang et al. (2005) provided another definition for urban agglomeration from a more quantitative perspective. Their research suggested that an urban agglomeration is centered on one large city, with 3 or more metropolitan areas or large cities as the foundation. The cities and in-between areas are closely interconnected via a highly developed transportation and telecommunication infrastructure, which forms a spatially compact, economically related, and regionally integrated urban entity. In a series of works, Fang et al. (Fang, 2011, 2012, 2014, 2015; Fang & Guan, 2011; Fang & Mao, 2015; Fang, Qi, & Song, 2008; Fang, Song, & Lin, 2010; Fang, Song, Zhang, & Li, 2005) contended that urban agglomerations are very different from the simple clustering of similar administrative units. Instead, the urban agglomeration is an emerging urban spatial form that is driven by concentrated industries and populations, a highly connected transportation network, an enhanced central city and favorable regional incentive policies. Urban agglomerations are evidently a product of the late stages of metropolitan development. In 2015, Fang (2015) further developed his understanding of urban agglomeration and argued that urban agglomeration enables the integration of industrial distribution, infrastructure construction, regional market establishment, urban and rural planning and build-up, environmental protection and ecological construction, and social development and social security systems. Therefore, an urban agglomeration is both an economic and an interest community. It also synchronizes master planning, industrial chains, urban and rural planning, transportation networks, information sharing, financial concentration, marketization, science and technological development, environmental protection and remediation, and ecological construction among all of the entities within the spatial extent of the agglomeration. Similarly, Ni (2008) also defined an urban agglomeration as an area of concentrated population and economic activities that are closely connected via a convenient transportation network and other infrastructures.

Teaford (2006) suggested that the interconnectivity among various cities was increasing dramatically due to highly developed social productivity and a market economy. Such increased interconnectivity blurred the boundaries between cities and peripheral regions. This interconnectivity also made traditional city boundaries, often imposed by administrative needs, essentially obsolete. Within such regions, traditional means of describing the differences among cities and rural areas, or the concentration of cities within the region, fall short of fully appreciating the newly emerged urban spatial form. New theories for studying and better understanding this new urban spatial form require further development.

2.2. Summary of the conception of urban agglomeration

The above review examines over 100 years of scholarly research and the evolution of the concept of urban agglomeration. The previously reviewed studies illustrate that various terms have been used for "urban agglomeration" by scholars at different stages of socioeconomic and human development. These terms include urban regions, urban clusters, urban and township cluster, township agglomeration, clustered cities, concentrated urban areas, metropolitan areas, urban economic zones, expanded metropolitan areas, urban-rural integrated regions, metropolitan regions, mega metropolitan regions, megalopolis, MIRs, new urban cluster belt, city assembly, city-region organization, city community, and others (Table 1).

Although there are some similarities among these definitions, an agreed-upon definition for urban agglomeration is hardly within reach. Summarizing the previously reviewed definitions and descriptions, this study proposes that urban agglomerations can generally be defined and described from six specific perspectives. First, from an ecological perspective, the urban agglomeration results from the evolution of urban spatial forms. The development of urban agglomerations is a self-organizing process, and the external morphology of the urban agglomeration is the product of a symbiotic growth among all elements. Second, from a statistical/quantitative perspective, a specific spatial size is identified first and its properties analyzed. Identifying criteria include the population density, urban/township functions, and continuity of the spatial landscape. If these quantities meet the criteria, an urban agglomeration is identified. Third, an urban agglomeration is defined based on functional interconnectivity and accessibility. Functional interconnectivity is mainly defined based on the so-called "urban field" and "urban functional economic zones" concepts, such as the commuting rate and urbanization rate of the peripheral regions within the agglomeration. Accessibility is basically a spatial term that defines the maximum reachable areas within an agglomeration. Normally, the maximum reachable areas should be within daily commutes. Fourth, an urban agglomeration is identified if certain minimum population counts of the core city/cities are reached. Fifth, an urban agglomeration is defined if specific minimum population and residential locations in the peripheral areas are reached. Sixth, an urban agglomeration is identified if the distance from the core city/cities to the most peripheral areas (another form of "urban field") meets certain criteria, such as a four-hour commuting distance.

Undoubtedly, the above definitions and descriptions of an urban agglomeration point to the essence of the concept and will most likely be useful for deriving a scientific definition. On the other hand, all of these definitions and descriptions reference the urban agglomeration based on the metropolitan area, with one or two cores, and multiple peripheral cities and townships that are closely associated economically, socially, or both. The various terms for the urban agglomeration reflect either the original spatial form

Table 1
General views of urban agglomeration studies and corresponding representative scholars from 1898 – 2015.

Year	Basic opinions of urban agglomeration definition	Representative scholars
1898	Equivalent to town cluster	Ebenezer Howard
1915	Equivalent to conurbation	Patrick Geddes
1918	Is an urban organism	E. Saarinen
1920	Is an urban economic zone	Bograd
1931	Is a concentrated urban area, and aggregates of Local administrative areas	Fawcett
1933	Is a city cluster	W. Christaller
1939	Is a city cluster	M. Jefferson
1942	Is an aggregate of cities	R. Vining
1957	Megalopolis (clusters of megacities)	J. Gottmann
1964	Megalopolis is the newly evolved urban forms	J. Friedman
1968	Is urban expansion area	T. Hagerstrand
1970	Equivalent to Ecumunopolis	C.A. Doxiadis
1980	Is a multi-economic-center urban area	J. Song
1980	Equivalent to Metropolitan Inter-locking Region, MIR	Y. Zhou
1980	Equivalent to Desakota (integrated urban-rural area)	T.G. McGee
1980	Equivalent to Dispersed Metropolis	K. Lynch
1983	Equivalent to Metropolis Belt	H. Yu and Y. Ning
1985	Megalopolis and integrated core-peripherals	D.A. Rondinelli
1985	Comprehensive and integrated urban spatial organization	J.B. Mcloughlin
1986	Fundamental spatial units for transnational companies' longitudinal division of labor	J. Friedman
1989	New form of integrated urban-rural (Desakota) combination	T.G. McGee
1989	A concentrated urban area with clear systematic hierachy	L. Dong
1991	Metropolitan belt	N. Pyrgiotis and K.R. Kunzmann
1992	Systematic hierarchical combination	G. Cui
1992	Integrated urban cluster	S. Yao
1995	Metropolitan belt	K. Tomita
1997	A spatial manifestation of regional post-industrialization and post-modernization production and life styles	Kipnis
1997	Integrated groups of cities	K. Qi and J. Duan
1999	Integrated cluster of cities	C. Gu
1999	A new regional integrated form	Q. Wu
2000	Concentrated city and township area	X. Hu
2001	Urbanized areas that are within daily commutable radius	Portnov and Erell
2001	Global city-region	Allen J. Scott
2002	Result from rapid urbanization and mid-point to megalopolis	X. Wang
2005	Highly integrated groups of cities, and a new economic unit for global division of labor	C. Fang
2007	A concentrated region of population and economy	P. Ni
2015	Highly integrated groups of cities that share common interest and fate	C. Fang

of urban agglomerations (such as urban clusters) or a formation of a truly evolved and integrated new urban spatial organization. As Friedman (1986) notes, in a globalizing era, the importance (hence, identification) of urban agglomerations does not necessarily depend on their population size but more on their ability to participate in global socioeconomic activities and to possess, process, and allocate capital and information. All things considered, the organizational structure of future urban agglomerations will be based on hierarchical transportation and ecological networks. Their purposes are centered on the coordinated development of the population, resources, environments, societies and economies of the individual cities within. Urban agglomerations can be treated as semi-organic systems that both attract and diffuse capital and information, thus having potential for development and expansion.

3. The delineation of the urban agglomeration

3.1. A brief history of the parameters and metrics delineating the urban agglomeration

Regardless of how urban agglomerations are defined, it is generally agreed upon that urban agglomerations are complex, dynamic and huge systems. Such systems are typically characterized by fuzzy boundaries and staged diffusing capacity, which makes identifying an urban agglomeration quantitatively a somewhat daunting task. However, numerous studies still attempt to tackle the spatial (albeit fuzzy) boundaries of urban agglomerations from a variety of aspects. Approaches such as the urban field gravity model, urban economic regionalization, and adaptation of administrative boundaries have been attempted (Table 2). We briefly walk through these approaches in chronological order.

In 1910, the United States Census Bureau coined the concept of a Metropolitan District (MD) (Li & Stough, 2007). An MD must have at least one core city with more than 200,000 people. The population density of the smallest administrative unit within a 10 km (6 mile) radius from the core city must be between 150 and 200 people per square mile.

In 1957, when Gottmann (1957) presented his concept of the megalopolis, he also provided the following five criteria for such a megalopolis: 1) there will be densely clustered cities within the megalopolis; 2) there will be a few metropolitan areas that are socioeconomically related to their peripherals; 3) there will be a convenient transportation network among the core metropolitan areas to enable seamless interconnectivity; 4) the total population will be greater than 2.5 million people; and 5) it will serve as an international exchange hub. Based on these five criteria, Gottmann (1957) identified six urban agglomerations globally. They were the *BosWash* agglomeration in the northeastern US, the Great Lakes agglomeration in the Midwestern US, the Pacific Coast agglomeration in Japan, the European Northwestern agglomeration, the Greater London agglomeration and the Yangtze Delta agglomeration centered on Shanghai.

In 1960, the Japan Department of Administrative Management proposed a quantitative definition for the "Greater Metropolitan Belt" concept (Zhang, 2003). Within a Greater Metropolitan Belt, the core city is either designated by the government or has more than 1 million people. In addition, there are peripheral cities that have at least 500,000 people and in which more than 15% of the total population of any peripherals commute to the core. Freight

Table 2
Various approaches to define urban agglomeration quantitatively.

Time period	Individuals or Agencies	Definition summary
1910	US Census Bureau	Defined by population count and density
1957	Gottmann	Defined by five criteria covering population, trade, transportation, and internationalization
1960	Japan Department of Administrative Management	Defined by population/administration and commuting pattern
1990	US Census Bureau	Defined by population count, density, structure, growth and commuting pattern
1995	Zhou and Shi	Defined by five criteria covering population, globalization, spatial structure and commuting pattern
2001	Yao et al.	Defined by ten standards covering population, population structure, spatial structure and interaction, transportation network, population movement and industrialization
2005	Miao and Wang	Defined by six criteria covering population, commuting pattern, spatial extent and common recognition
2009–2011	Fang et al.	Defined by ten criteria covering population, size of city, economic development, industrialization, transportation network and commuting pattern. Concept of concentric spatial organization was proposed based on commuting time
2015	Ning	Defined by six criteria covering population, transportation, size of the cities, and historical coherence and common identity
2015	Wu et al.	Defined by extracting features from remote sensing images

traffic among the Greater Metropolitan Belt will be below 25% of the total freight traffic.

In 1990, the United States revised the MD to the Metropolitan Area (MA). The revision suggests that, for any MA, there will be an urbanized location with no less than 50,000 people as the core. The county within which the city is located is the central county. Other counties within the MA must meet the following requirements: the non-agricultural population must be more than 75%; the population density must be over 50 people per square mile; decennial population growth must be greater than 15%; at least 15% of non-agricultural workers commute to the central county; or the mutual commuting ratio must be over 20% (Li & Stough, 2007).

Zhou and Shi (1995) also proposed a five-criterion standard for the so-called MIRs (another variation on urban agglomerations) based on their intensive studies of Chinese cities and metropolitan areas. First, there must be 2 or more core cities with populations of over 1 million. One of the cores must have the main characteristics of a global city. Second, the MIR must have a highly advanced and developed seaport. This criterion includes an annual cargo throughput of over 100 million tons and an airport with multiple regular international airline operations. Third, the MIR possesses convenient transportation corridors with multiple transportation modes. Cities and the transportation corridors are conveniently connected via land transportation. Fourth, the MIR also includes large numbers of medium and small-sized cities that are connected to the cores via transportation corridors and networks. The total population will be greater than 25 million, with a population density of over 700 people per square kilometer. Fifth, there is clear socioeconomic integration among the cores, peripheral cities and in-between rural areas.

On the other hand, in their book, *China's Urban Agglomeration*, Yao, Zhu, and Chen (2001) proposed a 10-standard approach to judge whether a specific cluster of cities could be identified as an urban agglomeration. This approach includes the following: 1) the total population must be 15–30 million; 2) there are at least two large cities (with a population of more than 1 million); 3) the urban population must be over 35% of the total; 4) the non-agricultural population must be greater than 40% of the total; 5) the non-agricultural population of any areas within the agglomeration must be over 55% of their respective intersected provinces; 6) there must be a complete five-hierarchical urban system structure (megacity, large city, medium-sized city, small city and township); 7) the railway density must be between 250 and 350 km/10,000 km^2 and the road density between 2000 and 2500 km/10,000 km^2; 8) the total retail sales of social consumer goods of any areas within the agglomeration must be above 45% of their respective intersected provinces; 9) the number of migrants of any areas within the agglomeration must be over 65% of their respective intersected provinces; and 10) the total industrial outputs of any areas within the agglomeration must be greater than 70% of their respective intersected provinces.

Miao and Wang (2005) also proposed a six-criterion standard to define urban agglomerations from a functional perspective for China's urban systems. These criteria include the following: 1) there must be at least one large city with over 2 million people, one prefecture or above administrative-level city, or two cities with over 1 million people each; 2) the commuting time from the core to the periphery must be under 4 h; 3) the total area will be at least 20,000 square kilometers; 4) there must be at least 5 formally established municipalities (from an administrative perspective); 5) all of the counties that are under the same prefecture's administration will be counted for census purposes; and 6) regions or areas that are commonly recognized as urban agglomerations by the government or the scholarly community. Fang (2009) and Fang et al. (2011) summarized multiple definitions based on previous studies' classifications of metropolitan areas, metropolitan belts, urban agglomerations and MIRs. As a result, Fang (2009) and Fang et al. (2011) further proposed a nine-criterion standard for defining urban agglomerations. These criteria include the following: 1) there will be at least 3 large cities or metropolitan areas but no more than 20, with at least one core city with over 1 million urban residents; 2) the total population of an urban agglomeration will be no less than 20 million, with at least a 50% non-agricultural population; 3) the per capita GDP of an urban agglomeration will be higher than $3000, with a highly developed industrialization level (in the mature stage); 4) the urban agglomeration's economic density must be more than 5 million RMB/km^2, with over 30% of its economy based on exports; 5) the urban agglomeration must have a highly developed comprehensive transportation network, with a 250–350 km/10,000 km^2 railway density and a 2000 to 2500 km/10,000 km^2 road density; 6) the regional urbanization level within the urban agglomeration will be greater than 50%;

7) the GDP centrality of the core cities must be above 45% and radiate across provincial boundaries; 8) at least 15% of the peripheral population must commute to the core city/cities; and 9) there will be three concentric peripheral regions that are defined by the public transportation total travel time. These three concentric peripheral regions include the immediate peripheral or half-hour peripheral, with a 10-min public transportation frequency and an approximately 30-min traveling time, the medium peripheral, with a 20-min public transportation frequency and an approximately 1-h traveling time, and the outer peripheral, with a 30-min public transportation frequency and an approximately 2-h traveling time.

Ning (2015) proposed another six-criterion standard for urban agglomerations in China. First, counties (primarily rural regions) are the fundamental building units for urban agglomerations. Their census coverages will be included in the urban agglomeration. Second, there must be two core cities with over 1 million people, and one of them must have over 2 million people and serve as the growth pole of the urban agglomeration. Third, the total population must be over 10 million. Fourth, the urban agglomeration must have a high level of urbanization. Fifth, there must be (a) convenient transportation corridor(s) that closely link(s) the core(s) and the peripherals to form an integrated socioeconomic community. Sixth, the areas within the urban agglomeration must have strong historical connections and, hence, a sense of integration and common regional identity.

Based on Ning's (2015) review, in the US, the Metropolitan Institute of the Virginia Institute of Technology proposed a 10-criterion standard for urban agglomerations in the US. Ning (2015) summarized and condensed the 10 criteria to 7 standards. First, there must be at least two metropolitan areas, with these areas being interlocking and continuously located. Second, the population will reach 10 million by 2040. Third, the areas within the urban agglomeration must have a unique historical, cultural and cognitive common identity. Fourth, the areas share roughly similar natural landscapes. Fifth, the metropolitan areas and cities are linked by major highways or interstates. Sixth, there are noticeable urban networks of cargo and service flows. Seventh, counties are the fundamental building blocks for urban agglomerations. The Metropolitan Institute projected that there will be 10 urban agglomerations by 2050 with a population of more than 10 million each in the US.

Over the past three decades, Wu, Zhao, Zhu, and Jiang (2015) have studied the spatiotemporal dynamics of the Beijing-Tianjin-Shijiazhuang urban agglomeration via remote sensing image analysis. However, no specific indicators were provided to define the location of the urban agglomeration. The image analysis provides an alternative approach to examining the spatial extent of urban agglomeration from a land use perspective. A similar approach is also adopted by Huang, Lu, and Sellers (2007), who debate whether the spatial form of urban agglomeration is a true result of urban development or only a form of urban sprawl. Huang et al. (2007) suggest that urban agglomerations, at least in developing nations, were more compact and dense than what urban sprawl might be and, hence, more likely a result of advanced urban development.

3.2. Summary of quantitative delineation

All of the above quantitative criteria, though similar in many respects, differ in significant ways. Such differences reveal that the identification and delineation of urban agglomerations, from a spatial perspective, are more complex than any one-size-fits-all approach could hope to accomplish. Strictly speaking, since an urban agglomeration is supposed to be a dynamic concept, a fuzzy boundary is most likely more appropriate. Any criteria or standards for urban agglomerations must be dynamic and relative to the when and the where. That said, standard methods of identifying urban agglomerations remain necessary for their efficient management, planning and further development purposes. As a summary of the above criteria/standards, we find some common themes.

First, all delineations agree that an urban agglomeration must have a specific number of cities and population size (Forstall, Greene, & Pick, 2009; Polyan, 1982). In fact, nearly all of the surveyed studies identify an urban agglomeration as a continuously urbanized region that is centered on one or more highly urbanized and commercialized large cities that attract population and industries and are densely populated. For instance, in the US, recognizable urban agglomerations include the New York Metropolitan Area (centered on New York City), the Greater Chicago Metropolitan Area (centered on Chicago), the Greater Los Angeles Metropolitan Area (centered on Los Angeles), and the Greater Seattle Metropolitan Area (centered on Seattle). In Japan, the Tokaido urban agglomeration is centered on Tokyo, Osaka, and Nagoya. In China, the Yangtze Delta urban agglomeration is centered on the global city Shanghai (Forstall et al., 2009). A certain population size is also important for delineating an urban agglomeration. Papaioannou (1970) suggested that any reasonably defined megalopolis must have a population of between 35 and 250 million. Gottmann (1976) further argued that 25 million is the minimum population size for a megalopolis.

Second, any urban agglomeration is centered on closely integrated socioeconomic relationships. All delineations agree that an urban agglomeration is not only a geographically continuous entity but also a closely integrated spatial existence of networks (people, cargo, capital and information) and nodes (central and peripheral cities) (Portnov & Schwartz, 2009). The integration of all participants is the key to delineating an urban agglomeration. A simple clustering of various cities in a particular area does not automatically form an urban agglomeration. One can only claim that there is an urban agglomeration when the networks grow in strength and frequency and the socioeconomic ties among the central and peripheral cities become more integrated.

Third, an urban agglomeration is often a complete urban system with a reasonable self-sustaining hierarchical structure. Within any urban agglomeration, scholars observe that there are a variety of medium and small-sized cities and townships in addition to the central city/cities (Portnov, 2006). Each city serves a unique function. For instance, cities in the *BosWash* Megalopolis have unique functions individually. Boston is the intellectual, technological, ideological and political center. New York is the commercial and financial center. Philadelphia is the manufacturing center. Baltimore is an important seaport. Washington, D.C., is not only the political and administrative center but also a site bearing historical and cultural heritage. Therefore, the functional structure of the *BosWash* megalopolis is very clear. Although cities within an urban agglomeration integrate closely with one another, geographically, they are reasonably separated. Each city maintains its own production, lifestyle and ecological pattern.

Fourth, there must be strong driving forces for the formation and future development of urban agglomerations. The driving forces come from a variety of sources. For instance, Vaidyanathan (1977) studies urban agglomerations in Arabic nations and concludes that urban agglomerations often developed the fastest in oil-rich economies. However, the limited availability of usable land could impede the development of urban agglomerations. In addition, the size of the population and the number of immigrants have a significant impact on the development of urban agglomerations. Scott (2001) regards economic globalization as the fundamental driving force for global city-regions. Glazer, Gradstein, and Ranjan (2003) further suggest that diversity of consumption is an important driving force for forming urban agglomerations. Webster and Lai (2003) argue that an urban agglomeration is the result of spontaneous growth in the institutional network of governments

and market economies and serves to cut trade costs. Matsumoto (2004) also regards the international air flow as the primary driving force for global airport urban agglomerations. Bertinelli and Black (2004) argue that the essence of an urban agglomeration is the concentration of production, consumption and trade among various cities. This concentration not only provides markets for various producers and facilitates economic specialization and the production of specialized manufacturers but also provides convenience for consumers and trade among different manufacturers. The concentration of production also promotes the sharing, transfer and exchange of knowledge and information. In this regard, Bertinelli and Black (2004) suggest that the division of labor, economic specialization, efficient trade, and diverse consumer preferences are the primary driving forces for urban agglomerations. Mata, Deichmann, Henderson, Lall, and Wang (2007) also observe that factors such as decreased rural income opportunities, the increased market potential of products, improved labor quality, and reduced inter-city transportation would significantly promote urban growth and, hence, the formation of urban agglomerations.

4. Emerging studies on urban agglomeration

In the dual processes of global urbanization and economic globalization, the formation, growth and expansion of urban agglomerations are clearly the next major area of study in urban spatial organization. With a sufficient industrial concentration and economy of scale, urban agglomerations will actively engage in the global re-division of labor; global competition; exchange of capital, information and labor; and cooperation among all parties to create a win–win economy and common-fate community. Based on the United Nations' forecast, by 2050, 75% of the world's total population will be living in cities. In the meantime, the largest 40 megalopolises or urban agglomerations will have 18% of the total population, 66% of global economic activities and approximately 85% of technological innovations but occupy very small land areas. From the most recent *World Cities Report 2015* by the United Nation Habitat, the megalopolises of the world have begun merging toward "super-megalopolises" or "super-urban agglomerations." Such trends clearly indicate that urban agglomerations are becoming one of the most important geographic units for nations to effectively participate in global competition and the international division of labor. Apparently, focusing on the efficient planning, effective management and sustainable development of urban agglomerations will become crucial for national competitiveness and potentially have an impact on the new global economic order. Summarizing from previous studies, we hope to present a clearer view of urban agglomerations below.

4.1. An urban agglomeration is a highly integrated cluster of cities

Although, to date, a consensus on how to define the urban agglomeration has not been reached, scholars agree that an urban agglomeration comprises multiple cities that are highly integrated. This integrated "urban cluster" has a profound impact on, and even determines, regional development. The urban agglomeration is an inevitable urban development status of regional economic concentration and an advanced regional spatial organization resulting from highly developed industrialization and urbanization. The formation of an urban agglomeration often signifies a highly developed economic and modernization level in a region, which can bring enormous benefits because of economies of scale. Based on the above literature review and empirical studies (Fang, 2012; Fang & Guan, 2011; Fang & Yu, 2016; Fang et al., 2010; Fang, Yao, & Liu, 2011), the present study defines an urban agglomeration as a spatially compact, economically highly integrated cluster of cities. Within that cluster, there is one mega-city at the center, with three or more metropolitan areas or large cities forming the core region. The core region is connected to daily commutable peripherals with highly developed transportation and other infrastructure networks. The urban agglomeration will evolve into an integrated community of economies, interests and common fates with integrated regional industrial distribution, infrastructure construction, regional market establishment, urban and rural planning and construction, environmental protection and ecological construction, and social development and basic public services. To achieve this high level of integration, the core, the peripherals, and all of the in-between areas will share joined master plans, industrial chains, urban and rural development, transportation networks, information flows, financial organizations, marketization, science and technology development, environmental protection and remediation, and ecological construction.

4.2. The spatial extent of an urban agglomeration experiences four expansions

The evolution of an urban agglomeration under the current driving forces of economic globalization, informatization, new industrialization, fast transportation, policy support and the knowledge economy theoretically follows a spatiotemporal path from cluster of cities to metropolitan areas, metropolitan area belts, large metropolitan belts, and a megalopolis (MIR) (Fig. 2). Such a path is a clear representation of the gradient evolution and multilayer structure of urban agglomerations. The characteristics of each expansion are summarized in Table 3. Evidently, each expansion enables the urban agglomerations to become increasingly radiating regional, national, and eventually international growth centers.

5. The urban agglomeration as an evolving concept – our definition and delineation of urban agglomeration

Although studies on urban agglomerations have expanded during the past two and half decades, the concept itself is still evolving. Apart from our extensive review of the literature, we have also worked closely on urban agglomeration cases in China. From our field experiences, we contend that it is imperative to clearly define urban agglomerations for better management and research. In addition, we also argue that an urban agglomeration will be treated as a scientific concept instead of a loosely used term so that a general sense of this geographic entity can be established and specific policies can be devised for sustainable, coherent and coordinated planning and better management. We hence present our own definition and delineation of urban agglomeration based on our working experiences in China.

5.1. Seven criteria for defining an urban agglomeration

One of the practical rationales for defining an urban agglomeration is to recognize an urban agglomeration when it is formed, thus allowing for better implementation and integration of policies, plans and infrastructure construction. Therefore, this study suggests defining an area as an urban agglomeration when it has 1) more than 3 large cities with populations exceeding 20 million (and one of the three large cities – the core – has over 5 million urbanites); 2) a per capita GDP of more than $10,000; 3) a non-agricultural population greater than 50%; 4) non-agricultural industries above 70% of the GDP (in the middle to late stages of industrialization and urbanization); 5) a GDP centrality of the core exceeding 45%; 6) a ratio of dependency on exports over 30%; 7) an economic density of more than 15 million RMB ($2.5 million)/square kilometer; and 8) clear evidence of the half-hour, one-hour and two-hour transportation radii economic belts. We derive these eight criteria mainly

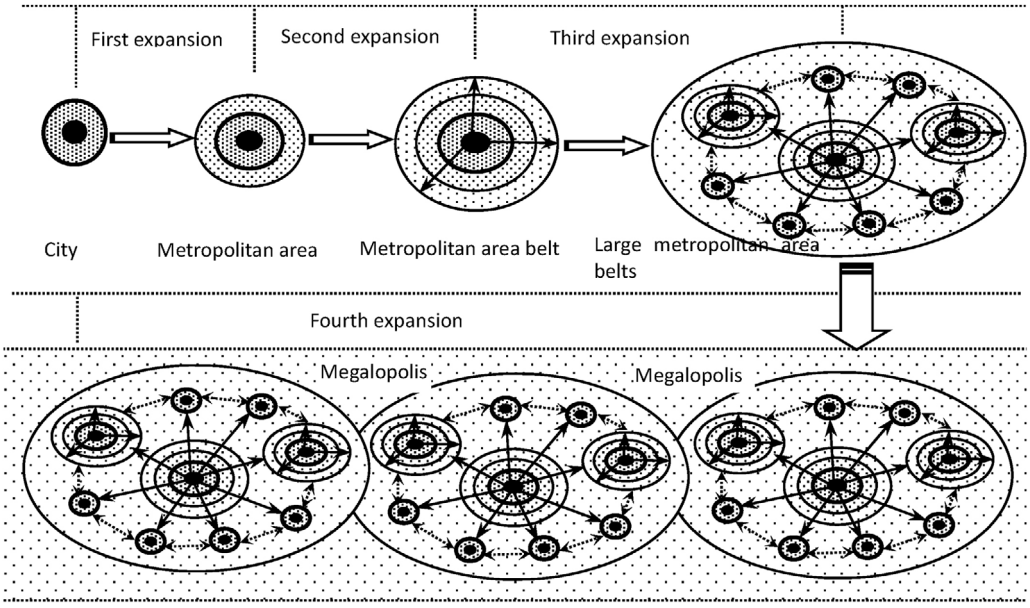

Fig. 2. The four expansion stages of urban agglomeration development.

Table 3
Comparison among the four stages of urban agglomerations.

Stages of urban agglomeration development		First expansion	Second expansion	Third expansion	Fourth expansion
Name	City	Metropolitan area	Metropolitan area belt	Large metropolitan area belt	Megalopolis
Spatial scope	Small	Sub-regional	Regional	Cross-regional	National/international
Radius	Municipal	Metropolitan	Inter-metropolitan	Sub-national	National/international
Number of cities	1	1	1	Three or more	3 cores with multiple peripherals
Population	5–10 million	5–10 million	10–15 million	More than 20 million	More than 30 million
Spatial structure	1 city	1 city and its immediate peripherals	1 city and influencing peripherals	3 or more cities and their peripherals	At least 2 large metropolitan area belts and all the cities
Transportation network	Inner city network, weak inter-city connectivity	Stronger inter-city connectivity	Complete inter-city connectivity	Complete inter-metropolitan connectivity	Extensive connectivity within and among metropolitan areas
Industrial integration	Very weak inter-city integration	Weak inter-city integration	Some inter-city integration	Strong inter-city integration	Fully integrated industrial systems
Regional structure	Single core	Single core layered structure	Single core radiating layered structure	Single or multi-core axis-layered network structure	Multi-core nebula highly interconnected network structure
Expansion mode	Point expansion	Point-circle expansion	Point-axis expansion	Axis-belt expansion	Beaded network radiating expansion
Development stages	Infancy stage	Initial stage	Medium stage	Mature stage	Ultimate stage
Function	Municipal growth center	Sub-regional growth center	Regional growth center	National growth center	International growth center

from our field work in China. Although the implied socioeconomic intensity and integration of cities within an urban agglomeration in these criteria have global applicability, we also acknowledge that the actual standards should be adjustable depending on where an urban agglomeration is defined. Once an urban agglomeration is defined and identified, plans, policies and infrastructure construction can be coordinated from a macro level to ensure smooth long-term integration and sustainable development.

5.2. Differences between urban agglomeration and town agglomeration

Based on more recent empirical investigations (Fang, Mao, & Ni, 2015; Fang & Yu, 2016), this study finds that practitioners, local planners, and local governments often confuse the concepts and presence of urban agglomerations and town agglomerations. This study, however, suggests that these two concepts are different in their respective cluster structures, scales of development, total numbers of agglomerations, competitiveness, interactions, and spatial distributions. Specifically, the cluster structure of an urban agglomeration requires a hierarchical structure with large, medium, and small-sized cities and towns, whereas a town agglomeration is essentially a cluster of small towns that does not necessarily have any meaningful hierarchical structure (Fang & Yu, 2016). The scales of development for an urban agglomeration must meet strict population and economic requirements, whereas a town agglomeration is formed when three or more small towns are economically and technologically related. The total number of urban agglomerations, by definition, will gradually shrink due to expansion and the merging of different urban agglomerations within or across national boundaries. The number of town agglomerations, however, will increase, which is a result of strengthening the integration of regional economies and urban-rural development. Urban agglomerations strive for national and international

competitiveness. These are the core growth poles of a nation. Conversely, town agglomerations focus on regional or even sub-regional competitiveness and might not necessarily serve as growth poles. Apparently, an urban agglomeration also contains multiple town agglomerations. By definition, urban agglomerations can only appear in nations with a sufficient level of economic development and population size, whereas town agglomerations can literally be observed anywhere. Although the differences between these two concepts are salient, it is worth noting that both spatial organizations are important spatial forms for new types of urbanization in the 21 st century that focus on economic structure adjustment and rapid population urbanization, especially for developing nations such as China.

5.3. China's urban agglomerations will become global economic cores, especially under the current national "Belt and Road" strategy

China has invested both financially and academically to facilitate the formation and growth of urban agglomerations (Fang & Yu, 2016). The urban agglomeration is the ultimate urban spatial form for China's New Urbanization. The nation is gradually building its urban agglomerations to become global economic cores. This becomes evident, as the current administration has announced "the Silk Road Economic Belt and the 21st-Century Maritime Silk Road", more commonly referred to as the "Belt and Road" strategy. In particular, China has proposed building a hierarchical urban agglomeration system with five national-level large urban agglomerations, nine regional-level medium-sized urban agglomerations and six sub-regional-level small-sized urban agglomerations. The five large urban agglomerations are the current foci of China's New Urbanization strategy. They include the Yangtze Delta urban agglomeration, Pearl River Delta urban agglomeration, (Bei)Jing-(Tian)Jin-(Hebei)Ji urban agglomeration, Yangtze River Middle-Reach urban agglomeration, and Cheng (Du)-Yu (Chongqing) urban agglomeration. The nine regional urban agglomerations require steady promotion. These include the Harbin-Changchun urban agglomeration, Shandong Peninsula urban agglomeration, Middle and South Liaoning urban agglomeration, West of Taiwan Strait urban agglomeration, Central Plain urban agglomeration, Central Shaanxi urban agglomeration, Jianghuai urban agglomeration, Southern Guangxi urban agglomeration, and Northern Slope of Tianshan Mountain urban agglomeration. The six sub-regional-level urban agglomerations require careful planning and guidance for efficient management and future growth. They are the Central Shanxi urban agglomeration, Hohhot-Baotou-Erdos-Yulin urban agglomeration, Central Yunnan urban agglomeration, Central Guizhou urban agglomeration, Lanzhou-Xining-Baiyin urban agglomeration, and Ningxia-Yellow River urban agglomeration (Fang & Yu, 2016). Over the past five years, this new spatial urbanization structure and urban agglomeration plan have been discussed in a variety of academic and governmental documents (for a detailed review, see Fang & Yu, 2016). The realization of the strong economic development driving capability of urban agglomerations further encourages the Chinese government to engage in very active research on, and involvement in the formation and development of urban agglomerations. As the world's second largest economy and most populous nation, a national strategy of actively promoting and developing urban agglomerations sends a clear message that the urban agglomeration is likely to be the viable future spatial organization of cities and urban development in China.

6. Conclusion

After reviewing over 30,000 research works related to the concept of urban agglomeration, this review summarizes the studies on urban agglomerations from both concept and measurement perspectives. Although a consensus on what constitutes an urban agglomeration, or even regarding a term to name such a spatial organization of cities, is hardly within reach, this emerging phenomenon is clearly on the horizon. Numerous studies across the globe, specifically in China over the past two decades, suggest that it is essential to better understand, scientifically define, efficiently manage, and sustainably plan urban agglomerations. Our involvement in urban agglomeration planning and management in China enables us to clearly understand this importance. We contend that the urban agglomeration will become the primary carrier for the socioeconomic development of China and other regions in the foreseeable future. Studies on the subject are likely to continue to increase. We will closely monitor what comes next on the agenda of studying urban agglomerations and report the new findings in a timely manner.

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