REAPPRAISING GIS FROM A TOOL PERSPECTIVE

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ABSTRACT

The past 50 years has seen a rapid development of Geographic Information Systems (GIS) in assisting urban development in multiple fronts. To better release the potentials of GIS as an auxiliary tool for pursuing sustainable built environment, it is necessary to seek a retrospective understanding of GIS' origins, evolution and capabilities that are closely tied to the chronic problems of urban renewal. Built upon a longitudinal study of interdisciplinary literature, this paper represents an initial conceptual exploration to relate GIS' capabilities in facilitating complex urban renewal practices whose efficiency and quality of handling multi-sourced information holds the key to project success. Key findings include the classification of three thematic eras of GIS since the 1960s; and the identification of the 3In capabilities of GIS developed in the three eras respectively - intelligence in data synthesis, interoperability with other ICT tools, and interconnection among stakeholders. It is suggested that GIS' 3In capacities could open a new way of addressing complex urban renewal, but a wider adoption of GIS in this under-developed area will hinge on a number of factors.

Keywords: built environment, capability, Geographic Information Systems (GIS), tool, urban renewal.

AIM AND OBJECTIVES

It is estimated that up to 80% project-related data is geographically referenced (AECOM, 2011). Hence, a thorough understanding of the spatial-temporal context holds the key to the building industry (Brooks & Lestage, 2012), be it selecting sites for new uses, rehabilitating historic places, or repositioning brownfields. Since the 1960s, Geographic Information Systems (GIS) has been rapidly developed to advance the understanding of the industry's impact on human habitats. Despite its progressively broadening scope of applications, the technology is more welcomed by straightforward projects than complex ones. One notably underdeveloped field is urban renewal whose process tends to be intricate due to its multiple-stakeholder project environment. To better release the potentials of GIS as an auxiliary tool for urban renewal, it is necessary to seek a retrospective understanding of GIS in relation to the chronic problems of urban renewal. To this end, this paper presents a review of international literature on the historical evolution and current capacities of GIS with three specific objectives set out below:

- To understand the characteristics and problems of post-industrialized urban renewal.
- To trace the environmental origins of contemporary GIS, and categorize its evolution of the past 50 years into three distinctive eras where three complementary capabilities in relation to addressing urban renewal problems were developed respectively.

- To suggest a combined use of the 3In capabilities of GIS to address the chronic problems of urban renewal.

The rest of this paper will follow the three objectives set out above. Desk research of both online and offline resources were collected and analyzed by using a set of searching techniques including search terms, search engines, web directories, and specialized databases.

CONTEMPORARY URBAN RENEWAL

The end of World War II ushered in an initial wave of urban renewal led by the public sector across western cities. As typified in the USA in the 1950s, urban renewal was predominated by large-scale slum-clearance and urban mega-projects such as central business districts and inter-city highways (Altshuler & Luberoff, 2003). One of the apparent costs to these lineal approaches was further environmental degradation (Roberts & Sykes, 2000), ironically a key slogan for renewing post-war cities. The environmental movements that subsequently peaked in the late 1960s largely put a halt to such unhampered pro-growth projects whose social and environmental losses much outweighed economic gains. Instead, selective demolition and image-enhancing projects were adopted as conflict-avoidance strategies to achieve more balanced outcomes among legal framework, social wellbeing, environmental stewardship, and historic preservation (Keyes, 1968; Yelling, 1990).

Noticeably, the 1970s saw a geographic shift of urban renewal to industrial wastelands or urban fringes, in anticipation of a win-win between providing new economic incentives and causing less social frictions or environmental damages (Couch, 1990). Spurred by the refashioned concept of "entrepreneurial city" in the 1980s, it became a predominant urban agenda for cities to secure a global foothold and draw inward investment (Biddulph, 2011; Hubbard, 1996). While there was a re-emergence of substantial investments in urban mega-infrastructures in developed economies, an increasingly popular trend was urban renewal initiatives with an emphasis on negotiated interests and more balanced results (Kantor et al., 1997; Savitch & Kantor, 2002). With a transforming economic backdrop in the 1990s, most emerging economies began to join the inter-city competition by initiating large-scale urban redevelopment as an antidote to increasing inner-city deterioration (Marshall, 2003). Despite markedly different localities, the tension between the develop mentalism and environmentalism in renewing cities remains largely unresolved if not escalated (Douglass, 2000; Marcotullio, 2003).

Globally, complex urban renewal initiatives have seldom been developed in a concerted manner, because of the complexity and interdependency of various urban systems and stakeholders involved. Urban renewal practices typically span over two decades (Lynch & Hack, 1984) where awaits a substantial amount of work from land assembly to facility management. Whereas there is a need to set priorities by stage, it is important that the objectives and opinions of a wide spectrum of interest groups are to be adequately represented throughout. Regardless of time and territory, it is controversy-prone using legal or financial instruments to take private properties for city-initiated or market-oriented renewal projects. The triple relationships triangulated by the public, private, and community sectors (Carter, 2000) are often laden with misunderstandings and value conflicts. The pluralism of participators may further bring a few negative consequences in practice. One is the inconsistency in project requirements due to information mismatch. This stands as one of the major causes of lowering the efficiency of the delivery process due to intertwined communications loops. This further adds extra costs of agency-wide and cross-agency

communications, due to multi-sourced information and fragmented decision-making (Deng & Poon, 2011).

EVOLUTION OF CONTEMPORARY GIS: 3IN CAPABILITIES

For comprehensive urban renewal, the efficiency and quality of identifying, synthesizing, sharing, and communicating information affects the extent to which participators could remove doubts, lessen misunderstandings, reach consensuses, and ultimately keep integrity over its long timeframe. In the current digital era, the adoption of information and communications technology (ICT) tools is an irreversible trend to assist in handling data of massive quantity, on various scales, and from multiple sources. In this regard, GIS is a strong candidate. The history of GIS has been discussed at length from various disciplinary perspectives, but there are two missing links with regard to urban renewal from a tool perspective: its environmental origins and implications, and a thematic classification of its enhanced capabilities. Hence, the overarching aim of this section is to tease out which major capacity was developed during a specific era, despite the fact that the development of any specific capability of a tool may continue subsequently alongside others.

3In capabilities in three thematic eras

The birth of contemporary GIS was attributed to multiple disciplines from mathematics to medicine (Friendly & Denis, 2001). Two most environmentally-related origins are thematic cartography popular in the 1900s and terrestrial photogrammetry since the beginning of the 20th century (Rogers & Luna, 2004). Another greater pusher was the advent of urban planning in the late 19th century when planners started to use aerial imagery to trace landscape shifts of large geographic regions over time (Friendly, 2008). The comparison between longitudinal and horizontal spatial data is especially useful when a place undergoes tremendous changes after significant natural disasters or man-made transformation such as urban renewal. However, meaningful analysis of the mapped data was not possible until breakthroughs in computing technologies were made in the 1960s. Since then, GIS has gradually become a predominant medium for graphic representation of geospatial data (Rogers & Luna, 2004). The following offers a brief overview by dividing the comp temporary development of GIS into three thematic eras.

The embryonic era: intelligence in data synthesis

Since the late 1950s, the academia in North America spearheaded digital mapping technologies with independent pursuits. They included the Harvard Laboratory for Computer Graphics and Spatial Analysis, the Canada Geographic Information System (CGIS), and the Environmental Systems Research Institute (ESRI). In 1964, Canadian's pilot use of GIS to perform labor-intensive land inventory work was epoch-making that the technology surpassed its paper-based predecessors by accommodating and manipulating a dramatically increased amount of information. In 1968, Roger Tomlinson (1968) coined the term GIS and is widely acknowledged as the father of contemporary GIS. However, the development of GIS was attributed not only to technological breakthroughs in computer technologies but to philosophical rethinking in urban planning.

As a response to environmental degeneration, social split, and economic recession, the 1950s and 1960s was marked by significant capital investments in the burgeoning urban sprawl in the West. As mentioned earlier, the highly disruptive nature of urban renewal triggered an

intensified debate between the widely adopted rational functionalism at that time and its alternatives that would be more nature-respectful and people-centric (Droege, 2006). Among the scholarly work of durable value in this era was *Design with Nature* (McHarg & Mumford, 1969), in which not only the concept of environmental planning was proposed but a pioneering approach was developed that had the far-reaching impact on GIS.

A major reason for the insufficient consideration over environmental impact of urban planning and landscape design was a lack of proper tools to measure and present the environment quality. McHarg developed a classic tool of map overlays – using transparent overlays to make large volumes of spatial information simultaneously visible. This innovation heralded a new era in which composite map overlays have become a common language for professionals to better inform decision makers of a wide spectrum of issues. With the pioneering use of map overlays, physiographic features, environmental attributes, and social traits became precisely quantified and visually articulated for a holistic consideration for optimizing land-use by local residents and regulatory boards.

While a traditional cartographic document and a GIS are both built upon a base map, the difference is more than just the amount of data accommodated. What made this era epoch-making was the unprecedented capability of GIS to describe, classify, and manipulate the complexity of the urban environment through transferring virtually unlimited layers of natural and man-made attributes of a specific area into hybrid representations (Ceccato & Snickars, 2000). With newly formed linkages between various information, conflicts of interests and constraints of conditions become transparent. In this sense, a GIS could significantly reduce and simplify the degree of conflicts among multi-stakeholders, as well as more accurately predicting urban trends and dissolving chronic problems in urban renewal practices.

The commercializing era: interoperability with other ICT tools

The commercialization of GIS is widely accredited to ESRI which has been playing a leading role in the field since its establishment in 1968 (MacDonald, 2001). In 1970, satellite imaging technologies were adopted at the national level in the West mainly as a tool for imaging and distributing digitally formatted geospatial data. A most notable milestone came in 1972 with the launching of the Landsat Program featured by a series of satellite missions to obtain high-resolution data of earth phenomena globally. Similar initiatives have been continuously enhancing the spatial awareness and deepening the understanding of the impact of the built environment on the Earth (Sipes & Lindhult, 2007). By the instrument of satellite imagery, GIS began to walk out of academic centers and benefit everyday business and research. Nevertheless, the commercialization process proved difficult due to several widely noted inhibitors (Ceccato & Snickars, 2000; Nyerges & Jankowski, 2010; Tomlinson, 1987).

- The first is attributed to the intrinsic features of geographic data, namely, multi-sourced data generated by various agencies, incompatibility with other formats of data or hardware components/ software; and incongruence derived from the variation of data accuracy.
- The second is the cost-benefit consideration on which the successful implementation of any technology would ultimately depend. Related factors included low visible return on investment, high implementation costs, slow speed and poor performance qualities, lack of trained personnel, absence of training programs, low awareness, and poor user-interfaces.

- Lastly, interoperability between different geographic tools is another major setback as they follow distinct modeling paradigms for data generation and management. They are either hardly integrated into the urban design process for combining creativity and research, or are time-consuming, data-intensive and expensive to build. The feasibility of communicating geographic information between different systems is often problematic and may therefore hinder the efficient delivery of anticipated outcomes.

Since the 1980s, ceaseless efforts have been made towards the merging of computer-based tools of different purposes (Cowen, 1988; Lee, 1998). With a focus on improving the usability of technology, GIS was advanced to enable the interaction between spatial and temporal data in a three-dimensional virtual environment with significantly reduced costs and increased memory and enhanced processing environment (Friendly, 2008). By linking spatial information with attributive information, GIS offers unlimited possibilities to explore enriched digital data (Jankowski & Nyerges, 2001). The value of GIS does not limit to its infinity of application in various disciplines but its flexibility in combined uses with other ICT tools such as Computer-Aided Design (CAD) and Building Information Modeling (BIM). The gaps between different computer-based technologies are constantly narrowed while the unique advantage of each strengthened through the process of compatibility. With further enhanced spatial-temporal analytic capacities and three-dimensional simulation function to combine multiple datasets, GIS has evolved from an efficient inventory tool into a better planning and management tool for urban (re)development (Aronoff, 1989; Cowen, 1988).

The network era: Interconnection among stakeholders

The 1990s saw a further trickling-down trend in GIS application among more civic groups other than national-level agencies. A major driving force behind this was the releasing of a desktop solution to map generation know as ArcView via the interface of Microsoft Windows (ESRI, 2013). By enabling distributed mapping and spatial analysis over the Internet, ArcView increased data availability among local authorities, neighborhood organizations and community-based agencies; and has gradually been adopted as a defacto industry standard (Sipes & Lindhult, 2007). With the advent of the new millennium, major GIS suppliers began to encourage user organizations to add datasets to the available online map sets. GIS has become a collaborative and communicative tool in the network society (Bots, 2005). Key sectors such as government, non-government organizations and utilities seem to be developing an approach to sharing data and there is evidence of significant sharing of data sets across shared platforms. A number of leading project consultancy firms which offer a full array of interdisciplinary services have adopted GIS as a regular support tool in the technical delivery of services to their clients (Nyerges & Jankowski, 2010).

Many viable uses, especially realistic visualization, are gaining ground in facilitating dialogue among stakeholders and multi-criteria decision making (Malczewski, 2006; Mersey et al., 2002). They range from predicting housing needs (Martínez, 2000) to analyzing urban morphology (Guney et al., 2012), from determining multiple criteria for mixed land use (Gh et al., 2013) to forecasting urban growth patterns (Bell et al., 2000), from assisting urban governance (Lewis & Ogra, 2010) to facilitating online public participation in comprehensive planning (Howard, 2006). GIS allows all parties to work in a more interactive way to address the multi-faceted nature of urban renewal projects, with its upgraded and expanded capacities in relating different types and levels of interventions, evaluating their collective impacts, and integrating individual input (Abbott, 2003; Stevens et al., 2007). This provides a powerful

medium for communicating, promoting, and forwarding new ideas in a transparent and interactive manner (Malczewski, 2006).

DISCUSSIONS AND CONCLUSIONS

This paper presents a brief reappraisal of the past 50-year history of GIS with two initial findings. First, it profiles its leapfrogging development - from simple data digitization for managing inventory in the embryonic era, to intelligent data synthesis for supporting decision-making in the commercializing era, to a user-centric platform for exploring and interacting with a project's lifecycle in the current network era. Secondly, it reveals its highly adaptive nature with the presence of historic evidence on its continuously enhanced and expanded capabilities over time. The 3In capacities are complementary by nature. Intelligence in data synthesis and interoperability with other ICT tools set the stage for infinity in application and interconnection among project stakeholders.

GIS applications are, however, more concentrated on individually-run projects. A less applied field is complex urban renewal developments which demand efficient digital instruments for handling multi-sourced data among stakeholders. In the 21st century, urban renewal has become more than ever participative oriented towards collective decision-making and actions. This demands tapping the infinite potentials of ICT for better engaging various actors at different areas and stages, for which traditional methods would no longer suffice. Given its strong interconnection capability, GIS should play a bigger role for better engaging the local communities and the general public with the government sector and the market forces as the initiators of urban renewal. A combined use of the three capabilities could facilitate the consolidating of multifaceted information as a point of departure towards addressing the complexes of urban renewal.

Nevertheless, the full potentials of GIS have yet to be well released in urban renewal as other sectors, due largely to the time-consuming and knowledge-demanding nature of the application process. A wider adoption of GIS in complicated urban renewal projects will rely on a number of related issues, including stakeholder awareness, perceptions of the benefits, availability of trained staff and training programs, as well as sponsorship in research and development from both the public and private sectors. More studies are in need to overcome these constraints to better utilize GIS as a digital facilitator to nurture a collaboration environment for more sustainable urban renewal.

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