AN ANALYTIC NETWORK MODEL FOR SMART CITIES

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ABSTRACT

This paper aims to offer a profound analysis of the interrelations between smart cities components connecting the cornerstones of the triple helix. The triple helix model has emerged as a reference framework for the analysis of knowledge-based innovation systems, and relates the multiple and reciprocal relationships between the three main agencies in the process of knowledge creation and capitalization: university, industry and government (Etzkowitz, 2008). This analysis of the triple helix will be augmented using the Analytic Network Process to model, cluster and begin measuring the performance of smart cities. The model obtained allows interactions and feedbacks within and between clusters, providing a process to derive ratio scales priorities from elements (Saaty, 2005). This offers a more truthful and realistic representation for supporting policy making. The application of this model is still to be developed but a full list of indicators, available at urban level, has been identified and selected from literature review.
Keywords: Analytic Network Process, Smart Cities components, Triple Helix Approach.

1. Introduction

Traditional neoclassical theories of urban and regional growth are often inadequate in analyzing the urban transformations of the 21st century. Theories of regional competitiveness try to fill this gap by focusing not only on the city's endowment of hard infrastructures (physical capital), but also, and increasingly, on the availability and quality of knowledge communication, social and environmental infrastructures (intellectual, social and environmental capital).
The application of information technology (ICT) in the context of future cities is often indicated by the notion of Smart City. This concept has been quite fashionable in the policy arena in recent years.

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Compared with the concept of digital city or intelligent city (Lombardi et al., 2009), the main focus is not limited to the role of ICT infrastructure but mainly on the role of human capital/education, social and relational capital and environmental issues. These are considered important drivers of urban growth.

In order to explore the concept of smart city, a revised triple helix model has been recently proposed by Lombardi et al. (2011) focusing on the production of knowledge by Universities and Government and the production of innovation which are patented by industry and university as an index of intellectual capital (Etzkowitz, 2008; Caragliu et al, 2009; Deakin, 2010). This model presupposes that the three helices operate in a complex urban environment, where market demand, governance, civic involvement and citizens' characteristics, along with cultural and social capital endowments shape the relationships between the traditional helices of university, industry and government.
The results of the above study has shown the analysis to baseline the development of smart cities in terms of their dual roles as generators of intellectual capital, creators of wealth and regulator of standards (University, Industry, Civil Society and Government), as well as supporting the social learning and knowledge-transfer abilities which are needed to meet the requirements of their regional innovation systems.
Although this analysis has been a useful start for understanding the main "governance" component of smart cities, it does not consider the other recognized aspects related to ecological sustainability. In addition, it does not recognize the number of relationships and feed backs between categories which are dependant upon the interconnected and systemic nature of the aspects involved.
The paper proposes a different model which involves the civil society as one of the main key actors, alongside the university, the industry and the government (Etzkowitz and Zhou,2006). This new framework has been used as a "control hierarcy" in a analytical network process (ANP) with the aim to identify and evaluate the performances of a smart city. The following section illustrates both the adopted model and the performance indicators used for this exercise.

2. Modelling the Smartcity' performances

Although there is no agreement on the exact definition of a smart city, a number of main dimensions of a smart city has been identified through a literature review exercise (Giffinger et al., 2007; Van Soom, 2009; Fusco Girard et al., 2009) and includes: smart economy; smart mobility; smart environment; smart people; smart living; and smart governance.
Based on the above components and on the triple helix approach (Etzkowitz and Zhou, 2006), a novel framework for classifying smart city performance indicators has been developed as shown in Table (1). As one can notice, both the main components/activities and the main actors/helices of a Smart city are represented. The identified clusters are: Smart *Governance* (related to participation)*; Smart Human Capital* (related to people)*; Smart Environment* (related to natural resources)*; Smart Living* (related to the quality of life) and *Smart Economy* (related to competitiveness).
The source of data for this table are both literature review including EU projects' reports and Urban Audit dataset and indicators selected from statistics of European commission, European green city index, TIS-SUE, Trends and Indicators for Monitoring the EU Thematic Strategy on Sustainable Development of Urban Environment and smart cities ranking of European medium-sized cities. This includes more than 60 indicators classified in the five aforesaid clusters.
Furthermore, the authors of this study have identified the relations between the Smart Cities components by way of an Analytic Network Process (ANP). The ANP model consists of clusters (i.e. groups of homogeneous elements of a decision problem), elements (i.e. nodes of the network), interrelationship between clusters, and interrelationship between elements. It allows interactions and feedback within and between clusters and provides a process to derive ratio scales priorities from the elements (Saaty, 2005).
More specifically, a complex model was developed using the axes of the adopted Triple Helix, i.e. university, industry, government and civil society as a control hierarchy for structuring the sub-networks as shown in Figure 1. Each axe is organised by a sub-network consisting of:

- the five clusters representing the above mentioned smart cities component/activities including the relative selected indicators;
- a cluster of alternatives made by four policy visions (or prototypes) of smart cities as derived from the "Urban Europe" Joint Programme Initiatives (see report by: P. Nijkamp, K. Kourtik, 2011): *Connected*

City (smart logistic & sustainable mobility), *Entrepreneurial City* (economic vitality), *Liveable City* (ecological sustainability) and the *Pioneer City* (social participation & social capital).

Table (1) Smart Cities components and indicators

Clusters / Revised Triple Helix	SMART Governence	SMART Economy	SMART Human	SMART Living	SMART Environment
	INDICATORS				
UNIVERSITY	No of universities, research centres in the city	Public expenditure on R&D - % of GDP per head of city	% of population aged 15-64 with secondary level education living in Urban Audit	% of proffessors & researchers involved in international projects and exchange	An assessment of the ambitiousness of CO2 emissions reduction strategy
	No. courses entirely downloadable from the internet / Total No. Courses	Public expenditure on education - % of GDP per head of city	% of population aged 15-64 with high education living in Urban Audit	Number of grants for international mobility per year	An assessment the extensiveness of city energy efficiency standards for buildings
		Number of research grants funded by international projects	% of inhabitants working in education and in research & development sector	% of accescable courses for PWD	
GOVERNEMENT	E-government on-line availability (% of the 20 basic services which are fully available online)	Gross Domestic Product per head of city	Voter turnout in national and EU parliamentary elections	Proportion of the area in recreational sports and leisure use	Total annual energy consumption, in gigajoules per head
		Debt of municipal authority per resident	Share of female city representatives	Green space (m2) to which the public has access, per capita	Efficient use of electricity (use per GDP)
	Percentage of households with computers	Median or average disposable annual household income	City representatives per resident	Number of public libraries	Total annual water consumption, in cubic metres per head
		Unemployment rate		Number of theaters & cinemas	Efficient use of water (use per GDP)
	Percentage of households with Internet access at home	Energy intensity of the economy - Gross inland consumption of energy divided by GDP		Health care expenditure - % of GDP per head of city	Area in green space (m2)
					Geenhouse gas emissions intensity of energy consumption
				Tourist overnight stays in registered accommodation in per year per resident	An assessment of the comprehensiveness of policies to contain the urban sprawl and to improve and monitor environmental performance
					Urban population exposure to air pollution by particulate matter - micrograms per cubic metre
CIVIL SOCIETY	E-government usage by individuals (% individuals aged 16 to 74 who have used the Internet, in the last 3 months, for interaction with public authorities)	% of projects funded by civil society	Foreign language skills	Total book loans and other media per resident	The total percentage of the working population travelling to work on public transport, by
			Participation in Life-long learning (%)	Museums visits per inhabitant	An assessment of the extent to which citizens may participate in environmental decision-making
			Individuals' level of computer skills	Theatre & cinema attendance per inhabitant	An assessment of the extensiveness of efforts to increase the use of cleaner transport
			Individuals' level of internet skills		% of citzens engaged in environmental and sustainability oriented activity
INDUSTRY	Number of research grants funded by companies, foundations, institutes / No annual scholarships	Employment rate in: - High Tech & creative industries - Renewable energy & energy efficieny systems - Financial intermediation and business activities - culture & entertainment industry - commercial services - transport and communication - hotels and restaurants	Patent applications per inhabitant	Number of enterprises adopting ISO 14000 standards	The percentage of total energy derived from renewable sources, as a share of the city's total energy consumption, in terajoules
					Combined heat and power generation - % of gross electricity generation
		All companies (total number)	Employment rate in knowledge-intensive sectors	Rate of people undertaking industry based training	Rate of rycycled waste per total kg of waste produced
		Number of local units manufacturing High Tech & ICT products			

		Companies with HQ in the city quoted on national stock market			Total CO2 emissions, in tonnes per head (2)
		Components of domestic material consumption			% of new buildings and renevoation which were assesed

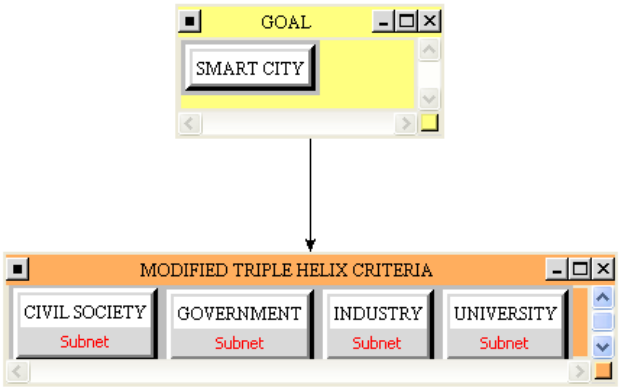

Figure (1) The main network

As an example, Figure 2 shows the Civil Society sub-network where both Smart Governance and the Smart Economy clusters include only one element, respectively: "*E-gov usage by individuals*" and "*Percentage of projects funded by civil society*". This nodes' organisation allows inner connections in the other clusters as in the Smart Human Capital, where the "*Foreign language skills*" influence other nodes, such as "*Individuals level of computer skills" and "Individuals level of internet skills*".
Bidirectional relationships are identified as follows:

- Smart Economy and Smart Environment, where the "*Percentage of projects funded by civil society*" is the direct cause of the "*Relationship to percentage of citizens engaged in environmental and sustainability oriented activities*";
- Smart Human Capital and Smart Living, where the "*Participation in life-long learning*" is connected by all smart living nodes ("*Museums visit per inhabitant*", "*Theatre & cinema attendance per inhabitant*" and "*Total book loans and other media per resident*").

Additional mono-directional connections can be identified between the other clusters.

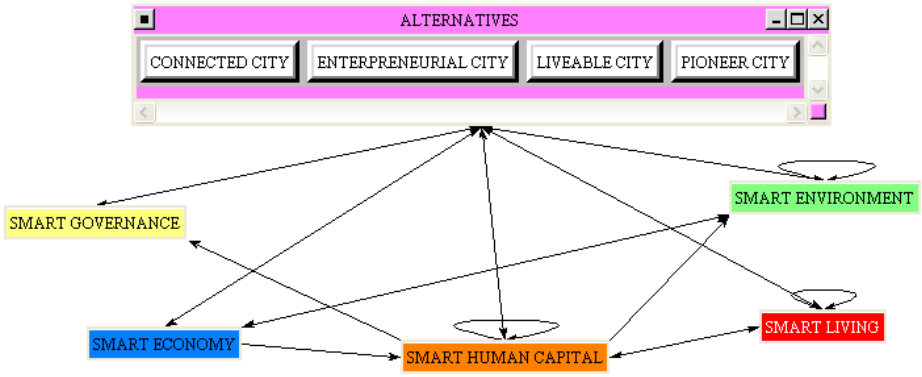

Figure (2) The Civil Society sub-network

This model will be used for investigating the interrelations between smart cities components and actors and finally for verifying whether: the cities are "smart"; if not, whether they are moving in the right direction.

3. Conclusions and further steps

This paper has illustrated an on-going study in the field of Smart cities' evaluation. The analysis has started from a revised notion of triple helix considering that civil society usually plays a prominent role toward the realization of sustainable development in cities (Etzkowitz and Zhou, 2006).
In order to assess the connections between Smart city development and this institutionalization of the Triple Helix, a ANP model has been developed. This allows the capture both the triple helix components of a smart urban development and the recognized components of a smart city.
The assessment exercise still requires all the following steps: a) Developing pairwise comparison of both elements and clusters to establish relations within the structure; b) Achievement of the final priorities. The development of the above methodological steps entails the participation of main city stakeholders, offering a reflexive learning opportunity for the cities to measure what options exist to improve their performances. It will be the tasks of authors' future activities.

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