

## UNIVERSITY-LED SMART CITY RESEARCH COOPERATION IN EUROPE

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*Abstract: With the development of Information and Communications Technology (ICT), the smart city has increasingly become one of the urban planning research focuses in recent years. Universities and other higher education institutions have become the major research organizations for smart cities. This paper investigated higher education institutions in 15 European countries and a total of 122 university-led smart city research organizations or alliances. Classifying and analyzing the research cooperation patterns of these research organizations or alliances, the paper summarizes four types of cooperation patterns, which are research project, research group, research institution and research platform respectively. Then the paper introduces Fuzzy Consistent Matrix to evaluate the performances of four types of cooperation patterns with five factors, including internal factors and external factors. The results show that the platform pattern is the most preferred pattern of smart city research cooperation, followed by research institution, research group and research project. The research platform can maximize the integration and collaboration of research resources and people, thus it should be applied to future smart city research.*

Keywords: smart cities, research cooperation, European universities

### 1. Introduction

In the past few decades, European cities and policy makers have been engaged in initiatives aimed at improving cities environment, infrastructures and services to provide better economic, social and living conditions for the citizens and to enhance the competitiveness and attractiveness of the cities (Neirotti et al., 2014; de Jong et al., 2015). The concept of smart cities brings more effective means in responding to these requirements, especially with the widely use of Information and Communications Technologies. In European context, smart city strategies have been greatly valued. For example, European Union s strategy of Europe 2020 has clearly wanted the EU to become a smart, sustainable and inclusive economy ((Caragliu, Del Bo and Nijkamp, 2011; Lazaroiu and Roscia, 2012; Caragliu, 2013). Smart cities are sustainable, ecological, intelligent and harmonious (de Jong et al., 2015), thus the concept and the best practice of smart cities could effectively assist with the implementation of EU s strategies.

Meanwhile, the level of scientific research cooperation has been growing worldwide, with no exception in Europe, therefore the level of international research cooperation, intra-EU cooperation and inter-organizational collaboration have been increasing rapidly in Europe (Hoekman, Frenken and Tijssen, 2010). The EU has been committed to promote collaborations across universities, enterprises

and governments to transfer knowledge and technologies, and to establish connections among researchers and scholars in different cooperation countries (Cummings and Kiesler, 2007). For instance, European Framework Programmes are the most significant research instruments and funding in Europe, which constitute a pool of research-related initiatives of EU (Hoekman, Frenken and Tijssen, 2010). Most of smart city-related research are based on collaboration research, and many of them are supported by European research programmes and fund.

This paper aims at studying smart city-related research cooperation which is led by European universities in 15 countries. Summarizing different patterns of cooperation, analyzing and comparing which kind or kinds of patterns are preferred by smart city research.

## **2. Data collection and methodology**

### *2.1 Definition and classification of smart cities*

Before collecting the data of university-led smart city research cooperation in Europe, the notion of smart cities should be defined. Despite the extensive discussion, there is no general consensus on the definition and classification of smart cities at global scale (Angelidou, 2014; (Jucevičius, Pataien and Pataius, 2014); Neirotti et al., 2014; Ben Letaifa, 2015). Even the improper use of smart cities in superficial ways may mislead the meaning of smart cities. The main reason is that the needs of smart cities are highly depend on the contextual condition of different countries and cities, such as natural resources, technology development, government etc. So there is no one-size-fits-all exists for smart cities (Ben Letaifa, 2015, pp.1415).

However, there is a wide agreement that smart cities are characterized by the widely use of Information and Communications Technologies (ICT) in different domains of urban system (e.g. traffic control system, security cameras, power grid, waters, etc.), in which ICT system plays the central role (Neirotti et al., 2014). ICT help cities make better use of urban and natural resources, enhance the efficiency of urban systems, and prevent the cities from hazards and disasters. In other words, the technology-based approaches and solutions endow cities with digital nervous systems plus the abilities to sense and react.

On the other hand, although ICT-based solutions are considered as one of the most special features of smart cities, a growing number of scholars have realized that smart cities contain not only technological capital but also human and organizational capital. Social, economic, political and cultural context shape the ways of cities to become smarter and information technologies are complementary tools, depending on the cities backgrounds and needs. In that way, smart cities initiatives can be fostered by education, innovation industry, social welfare system and city liveability.

Based on the understanding above, smart cities contents could be divided into two categories, one is tangible, including smart infrastructure, transportation, energy and nature resources etc., the other is intangible, including social capital, innovation economy, public administration, intellectual capital etc. (Neirotti et al., 2014). Similarly, the classification could also be expressed as hard domains and soft domains of smart cities initiatives.

Some other scholars think that ICT-based smart cities solutions emphasize top-down monitoring of city systems. The other aspect of smart cities is bottom-up approaches in which the public could get access to the data and make their own decisions, and the authorities are fair and transparent enough when making decisions (Ben Letaifa, 2015).

### 2.2 Data collection

ICT-based solutions are not the only way to evaluate smart cities has become widespread awareness, this paper explains the notion of smart cities from both research and practice aspects.

In the research aspect of smart cities, the paper retrieved and extracted the data from published scientific articles of the Web of Science . The Web of Science is a bibliographic database by Thomson Reuters, which is considered as one of the most comprehensive and reliable research database worldwide (Hoekman, Frenken and Tijssen, 2010). The paper retrieved smart city as the theme of literature and the search period was limited between 2000 and present. The retrieval date is 13th March, 2015 and total of 1253 eligible articles are selected.

Statistics showed that since 2011, the number of publications regarding smart cities has considerably increased (Figure 1), thus selecting publications from 2000 could represent the research of smart cities. And the results covered 15 European countries the paper studies, as well as United States, China, etc. (Figure 2).

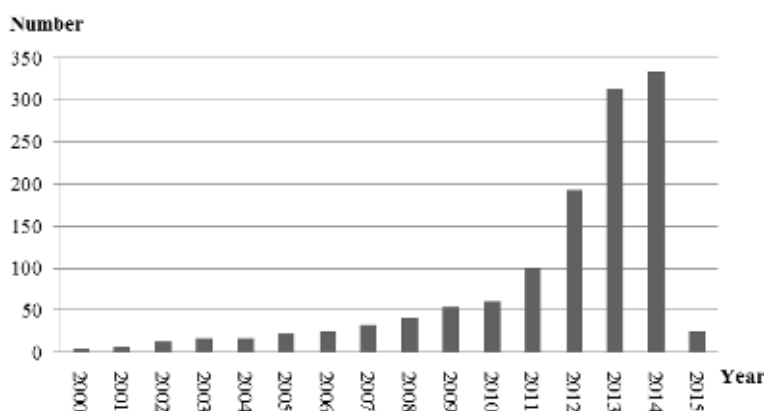


Figure 1. The number of smart cities publications in Web of Science (2000-2015)

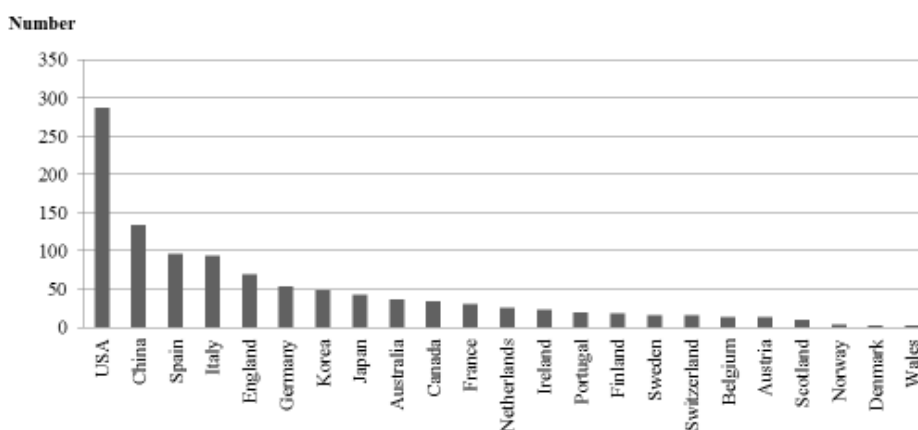


Figure 2. The number of smart cities publications by countries/regions

Analyzing the retrieval results, ten categories of smart cities research topics are classified according to the Web of Science categories and listed by the number of publications (Table 1). The 12 categories include Computer Science/ICT, Engineering, Environment/Ecology/Energy, Urban Planning, Science, Traffic Engineering, Geology, Administration/Management/Political Science, Economics, Biology/Medicine/Health, Sociology/Culture/Education and Architecture.

Table 1. Classification of smart cities research categories

Categories	Web of Science categories	Publications
Computer Science /ICT	Computer science information systems, Computer science artificial intelligence, Computer science interdisciplinary applications, Telecommunications etc. (10 items)	905
Engineering	Engineering electrical electronic, Automation control systems, Engineering civil, Engineering mechanical, Engineering manufacturing etc. (11 items)	540
Environment/ Ecology/Energy	Environmental studies, Energy fuels, Environmental sciences, Ecology, Water resources etc. (7 items)	310
Urban Planning	Urban studies, Planning development (2 items)	201
Science	Physics applied, Thermodynamics, Mathematics applied, Mechanics, Physics multidisciplinary etc. (15 items)	146
Traffic Engineering	Transportation science technology, Transportation (2 items)	104
Geology	Geography, Remote sensing, Geography physical etc. (5 items)	92
Administration/ Management/ Political Science	Management, Operations research management science, Political science, Public administration, International relations, Law (6 items)	65
Economics	Economics, Business, Business finance (3 items)	48

Biology/Medicine / Health	Public environmental occupational health, Infectious diseases, Plant sciences, Social sciences biomedical etc. (11 items)	48
Sociology/Culture/ Education	Sociology, Education educational research, Social work, Art, Criminology penology, Cultural studies etc. (10 items)	46
Architecture	Construction building technology, Architecture (2 items)	33
Sum		25381

As for the practice aspect of smart cities, the paper selected 15 smart cities evaluation index system around the world to classify smart cities practice, including European medium-sized smart cities rankings (Giffinger et al. 2007), Smart City Evaluation System by The World Economic Forum, and by International Data Corporation etc. Calculating the frequency of sub-index of those evaluation systems, the results contain 10 categories of smart cities practice in Table 2.

Table 2. Classification of smart cities practice categories

Categories	Contents	Frequency
Computer/ICT/Internet	Ubiquitous network, Internet popularity, Information and communication facilities, Computer, Radio etc.	90%
Society/People	ICT social foundation, Social justice, Social security, Social inclusion, Smart people etc.	82%
Culture/Education	Knowledge-based labor, Education, E-learning, Culture and Entertainment, Cultural heritage protection etc.	30%
Government/Management /Public Services	E-government, Smart urban management, Public platform database, Democracy, Government transparency etc.	65%
Environment/Ecology/ Energy	Ecological conservation, Renewable energy, Urban waste management, Food and agriculture etc.	78%
Traffic	Transportation information, Smart logistics, Automatic toll road, Urban convenience etc.	60%
Infrastructure	Municipal facilities, Smart grid etc.	40%
Planning/Buildings	Smart planning, Compact land use, Green building etc.	45%
Economic/Business	Smart industry, Economic information service, Enterprise innovation etc.	35%
Medicine/Health care	Medical information system, Home health services etc.	20%

Combine the analysis of smart cities research and practice above (Table 1 and 2), the paper determined 8 domains of smart cities: Information and Technology, Environment and Energy, Society and People, Government and Management, Transportation and Infrastructure, Economy and Innovation, Medicine and Health, Planning and Architecture (Table 3). This classification is consistent with the literature review about smart cities (can be divided into hard and soft domains).

Table 3. Final classification of smart cities domains

Categories	Contents
Information and Technology	ICT, Computer science and technology, Remote sensing, Geographic information technology, Internet of things etc.
Environment and Energy,	Environmental monitoring, Ecological protection, Renewable energy, Energy efficiency, Water management, Atmospheric research etc.
Society and People	Social justice, Social inclusion, Social security, Education level, Recreational activities, Heritage protection, Public space management etc.
Government and Management	E-government, Public platform, Government transparency, Smart city management etc.
Transportation and Infrastructure	Traffic information, Smart traffic management, Green transportation, Smart municipal facilities, Smart grid etc.
Economy and Innovation	Information economy development, High-tech Industry, Enterprise information innovation etc.
Medicine and Health	Public health, Medical information system, Food and agriculture etc.
Planning and Architecture	Smart planning method, Smart buildings, Green buildings, Building services etc.

According to the classification of smart cities domains, the paper screened 122 smart city research cooperation institutions or organizations which were led by universities in 15 major Europe countries. They are listed by countries in Table 4.

Table 4. Screening results of university-led smart city research cooperation

Regions	Countries	Numbers
Northern Europe (4)	Finland	6
	Sweden	9
	Norway	5
	Denmark	6
Central Europe (3)	Germany	20
	Austria	6
	Switzerland	4
Western Europe (5)	UK	21
	Ireland	5
	Netherlands	7
	Belgium	2
	France	13

Southern Europe (3)	Italy	7
	Spain	7
	Portugal	4
Total		122

Those collaborative institutions are mainly located in western and central Europe, around the North Sea, English Channel and Cantabrian Sea. They are distributed more in countries like UK, Germany and Netherlands etc.(Figure 3).

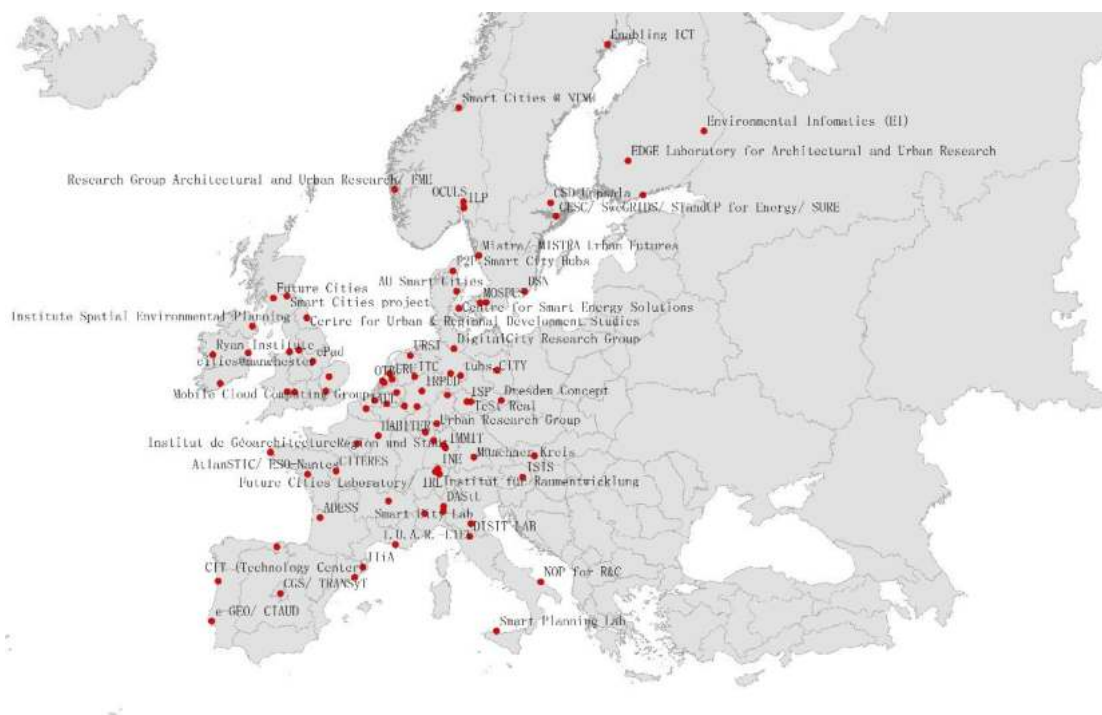


Figure 3. The distribution of university-led smart city research cooperation

2.3 Methodology

This paper attempts to analyze and compare different patterns of smart city research cooperation led by universities, involving in several qualitative factors which are difficult to quantify. Therefore, the paper introduces Fuzzy Consistent Matrix for cooperation pattern performance assessment. The method and procedures are as follows:

Suppose there are N decision-making alternatives, then  $a_i$  ( $i=1, 2, \dots, n$ ) constitutes preferred alternatives set. And suppose there are M evaluation factors, then  $e_k$  ( $k=1, 2, \dots, m$ ) constitutes factors set. The corresponding weight of each factor is  $w_k$  ( $k=1, 2, \dots, m$ ), and

$$\sum_{k=1}^m w_k = 1 \tag{1}$$

Step I: Constitute preferred relationship matrixes. According to the supposes, there are  $N$  decision-making alternatives under  $M$  evaluation factors, therefore  $M$  single-factor fuzzy preferred relationship matrixes are established, named  $B_k$ ,

$$B_k = (b_{ij}^k)_{n \times n} \quad (k=1, 2, \dots, m) \tag{2}$$

where  $b_{ij}^k$  represents when evaluation factor is  $e_k$ , the priority relationship between  $a_i$  and  $a_j$ , and values are as follows:

$$b_{ij}^k = \begin{cases} 0 & \text{when evaluation factor is } e_k, a_j \text{ is superior to } a_i \\ 0.5 & \text{when evaluation factor is } e_k, a_i \text{ equals } a_j \\ 1 & \text{when evaluation factor is } e_k, a_i \text{ is superior to } a_j \end{cases}$$

Step II: Transform matrixes  $B_k$  (2) into fuzzy consistent matrixes  $R_k$ ,

$$R_k = (r_{ij}^k)_{n \times n} \quad (k=1, 2, \dots, m)$$

where  $r_{ij}^k = \frac{r_i^k + r_j^k}{2n} \in [0.5, 1]$ ,  $(r_{i1}^k, r_{i2}^k, \dots, r_{in}^k)$  (4)

Because  $i, j = 1, 2, \dots, n$ , are

$$\begin{aligned} r_{il}^k - r_{jl}^k &\leq 0.5 - \frac{r_i^k + r_l^k}{2n} \leq 0.5 - \left( \frac{r_j^k + r_l^k}{2n} - 0.5 \right) = 0.5 \\ &\leq \frac{r_i^k + r_j^k}{2n} - 0.5 = r_{ij}^k - 0.5 \end{aligned} \tag{5}$$

Through (5) to verify  $R_k$  is fuzzy consistent matrix.

Step III: Calculate univariate priority.  $s_i^k$  represents the priority of decision-making alternative  $a_i$  ( $i=1, 2, \dots, n$ ) under the evaluation factor  $e_k$  ( $k=1, 2, \dots, m$ ),

$$s_i^k = \frac{\bar{s}_i}{\sum_{i=1}^n \bar{s}_i} \tag{6}$$

where  $\bar{s}_i = \sqrt[n]{\prod_{j=1}^n r_{ij}^k}$  (7)

Step IV: Calculate multivariate priority.  $S_i$  ( $i=1, 2, \dots, n$ ) represents the comprehensive priority of

decision-making alternative  $a_i$  ( $i=1, 2, \dots, n$ ),

$$S_i = \sum_{k=1}^m w_k s_i^k \quad (i=1, 2, \dots, n) \tag{8}$$

Finally, the most preferred alternative among  $N$  alternatives under  $M$  evaluation factors is selected.

### 3. Results

#### 3.1 Patterns of University-led smart city research cooperation

By analyzing 122 university-led research cooperation engaging smart cities research, the paper summarizes four types of cooperation patterns, named research project, research group, research institute, and research platform respectively (Table 5, Figure 4).

Table 5. Patterns of University-led smart city research cooperation by countries

Countries	Research Project	Research Group	Research Institute	Research Platform	Total
Germany	0	4	13	3	20
Austria	0	1	4	1	6
Switzerland	0	0	3	1	4
Finland	1	2	2	1	6
Sweden	0	2	5	2	9
Norway	0	2	3	0	5
Denmark	1	1	3	1	6
UK	1	4	14	2	21
Ireland	0	1	3	1	5
Netherlands	0	0	6	1	7
Belgium	0	0	1	1	2
France	0	1	11	1	13
Italy	1	2	4	0	7
Spain	0	1	5	1	7
Portugal	0	0	4	0	4
Sum	4	21	81	16	122

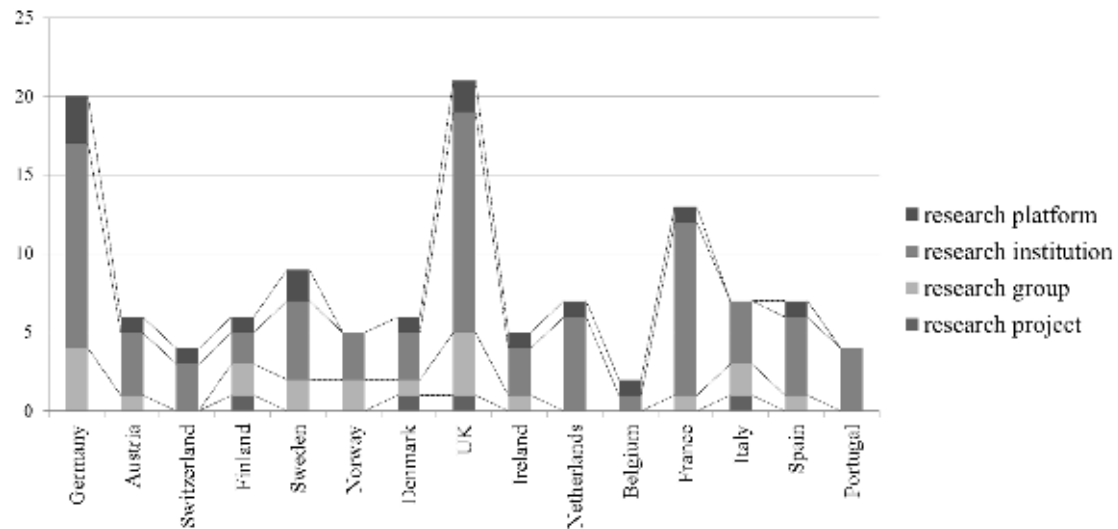


Figure 4. Patterns of University-led smart city research cooperation by countries

### 1) Research project

Research project pattern is research collaboration that based on one single research project related to smart cities, which is the most basic and simple cooperation pattern. Many of those cooperation projects are initiated by European Union research programmes. Some of them are sponsored by national research institutions, enterprises or local governments. Such kind of cooperation last for relatively short time, generally for the period of 3 to 5 years with loose organization structure. Smart cities research requires multidisciplinary and cross-regional researchers, those people and research resources join together to form temporary research collaboration.

### 2) Research group

Research group pattern is collaboration based on common research contents. Compare with research project pattern, this pattern forms a relatively long-term and stable research alliance. Those research groups are not joined because of one single research project, but joined to conduct a series research projects related to smart cities which are led by universities. The team size of research groups are small, there are rarely more than 50 people in the research group. And the organizational structure is simple, consisting of a team leader or co-leader, several professors and research staffs to form a close cooperation relationships.

### 3) Research institution

Research institutions are the most common type of collaborative research pattern, accounting for more than 65% of European universities-led smart city research cooperation. It is the most stable form of

cooperation. As the name implies, research institutions refer to the research entities that are long-term exist and conduct multiple smart cities research. These institutes could be established by a single school or department, by multiple schools and departments in the university as an interdisciplinary research organization, by one or more universities and by the government or EU. They could also be funded by enterprises to conduct joint research and technology transfer regarding smart cities. All these research institutions highly rely on universities taking charge of research and training programme, but they are individual institution.

The organizational structure of research institutions is much more complex than the former two research patterns. They have a clear division of responsibilities including teaching, researching and managing, especially for institutions having the task of teaching and training. Many institutions are origin from research groups or even research projects, after years of development they grow up as research institution, which is a more advanced research cooperation pattern.

#### 4) Research platform

Research platform pattern is a more complex and sophisticated form of cooperation because they set a relatively virtual cooperation platform compare with institutions. On the platform, partners from universities, governments and business work together. This pattern of cooperation is relatively new and not as common as research institutions. Research platform pattern has the highest potential to organize and form a wide national and international cooperation.

The core of the platform is managed by one university or multiple universities who are taking charge of arranging scientific research projects, conferences and seminars. Another important work for those people is recruiting different researchers from other institutions, universities, companies etc. based on research needs. Therefore, after each time of research cooperation, the collaborative network will be expanded. Research platforms integrate more potential research resources include the talent, technologies and facilities in order to form a greater cooperation network. This kind of cooperation also attracts universities and governments attention financial supports.

However, this pattern of research cooperation also has disadvantages. The platforms are not entities, whose researchers and research places are unstable for the most of research platforms, which increases the difficulty of cooperation. There are less research results made by the platforms than stable research institutes, and many of research results are conferences articles and working papers. They need more practical research results like technologies, planning methods, books etc. But it is undeniable that research platform is an innovative pattern of research cooperation, especially with the rapid development of ICT. The platform partners can cooperate by teleconference and the internet, there is no need to do research face to face in a fixed place, thus the research platform will better adapt to

these changes. In summary, the similarities and differences of four types of research cooperation patterns are listed below (Table 6).

Table 6. Comparison of university-led smart city research cooperation patterns

Items	Research Project	Research Group	Research Institute	Research Platform
Research projects	Single	Multiple	Multiple	Multiple
Team size	Various	Majority small size	Majority middle, large size	Various
Cooperation partners	Multiple	Multiple	Single or Multiple	Multiple
Cooperation methods	Interdisciplinary	Interdisciplinary	Interdisciplinary	Interdisciplinary
Organization	Simple	Simple	Complex	Complex
Stability	Short-time, unstable	Short-time or long-time	Long-time, most stable	Various, unstable

### 3.2 Preferred cooperation selection

Suppose there are 4 cooperation alternatives, respectively research projects ( $a_1$ ), research groups ( $a_2$ ), research institutions ( $a_3$ ) and research platforms ( $a_4$ ). And suppose there are 5 aspects of evaluation factors, considering both internal factors and external environmental factors, respectively smart cities research fitness ( $e_1$ ), operational or management difficulty ( $e_2$ ), research mainstream adaptation ( $e_3$ ), economic benefits potential ( $e_4$ ) and European policies compliance ( $e_5$ ). See Table 7.

Table 7. Evaluation factors of university-led smart city research cooperation

Categories	Factors	Name
Internal factors	Smart cities research fitness	$e_1$
	Operational or management difficulty	$e_2$
External factors	Research mainstream adaptation	$e_3$
	Economic benefits potential	$e_4$
	European policies compliance	$e_5$

1) Smart cities research fitness means whether the research cooperation pattern are suitable for conducting smart cities research because smart cities research need interdisciplinary researchers and inter-regional or international collaborations. The more partnerships in the research, the more ideas and intellectual benefits generate during the cooperation. From this point of view, research institution and platform patterns are superior to research project and group patterns because they have larger cooperation network.

2) Operational or management difficulty means whether the research cooperation demands more inputs of personnel, facilities, funds and time. Although the institution and platform pattern will attract more partnership, multi-institution and inter-regional cooperation tend to have less frequent and effective collaboration but more often diverging interests, free-riding and conflicts (Adams et al., 2005; Cummings and Kiesler, 2007). That is, they will experience more difficulties and complexities during the cooperation research processes.

3) Research mainstream adaptation means whether the research cooperation is common and effective cooperation pattern that is required by urban planning research and innovation development. The extensive research cooperation provides more shared resources and expertise, which are required by smart cities research in the field of urban planning.

4) Economic benefits potential means whether the research cooperation will contribute to generating more economic benefits and attract research funding and contracts. Despite the fact that research institution and platform patterns have more potential partnerships, multilateral cooperation foster more coordination cost because of geographical distance and institutional differences (Cummings and Kiesler, 2007; Hoekman, Frenken and Tijssen, 2010). Further study shows that research organizations and project teams within one institution is more effective in integrating research resources and expertise and more likely to be successful.

5) European policies compliance means whether the research cooperation is encouraged in European context (e.g. the research projects under the research framework of European Union), and whether the cooperation supported by national or local governments. Since more significant public funding are used to foster inter-regional and transnational research collaborations in Europe, perhaps research platform is more preferred by the policies.

Adopting Fuzzy Consistent Matrix to select the most preferred cooperation pattern for university-led smart city research. First, constitute preferred relationship matrixes as below:

	0.5	0.5	0	0		0.5	0.5	1	1		0.5	0.5	0.5	0
B <sub>1</sub>	0.5	0.5	0.5	0	B <sub>2</sub>	0.5	0.5	0.5	1	B <sub>3</sub>	0.5	0.5	0	1
	1	0.5	0.5	0		0	0.5	0.5	0.5		0.5	1	0.5	0.5
	1	1	1	0.5		0	0	0.5	0.5		1	0	0.5	0.5
	0.5	0	0	0.5		0.5	0.5	0.5	0					
B <sub>4</sub>	1	0.5	0	0.5	B <sub>5</sub>	0.5	0.5	0	0					
	1	1	0.5	1		0.5	1	0.5	0.5					
	0.5	0.5	0	0.5		1	1	0.5	0.5					

Second, transform 5 matrixes  $B_k$  ( $k=1, 2, 3, 4, 5$ ) into fuzzy consistent matrixes  $R_k$  ( $k=1, 2, 3, 4, 5$ ):

	0.5	0.4375	0.375	0.1875		0.5	0.5625	0.6875	0.75
$R_1$	0.5625	0.5	0.4375	0.25	$R_2$	0.4375	0.5	0.625	0.6875
	0.625	0.5625	0.5	0.3125		0.3125	0.375	0.5	0.5625
	0.8125	0.75	0.6875	0.5		0.25	0.3125	0.4375	0.5
	0.5	0.4375	0.375	0.4375		0.5	0.375	0.1875	0.4375
$R_3$	0.5625	0.5	0.4375	0.5	$R_4$	0.625	0.5	0.3125	0.5625
	0.625	0.5625	0.5	0.5625		0.8125	0.6875	0.5	0.75
	0.5625	0.5	0.4375	0.5		0.5625	0.4375	0.25	0.5
	0.5	0.5625	0.375	0.3125		0.5	0.375	0.1875	0.4375
$R_5$	0.4375	0.5	0.3125	0.25		0.625	0.5	0.3125	0.5625
	0.625	0.6875	0.5	0.4375		0.8125	0.6875	0.5	0.75
	0.6875	0.75	0.5625	0.5		0.5625	0.4375	0.25	0.5

Third, calculate univariate priority according to the formula (6,7):

$$s_1^1=0.1823, s_1^2=0.3151, s_1^3=0.2185, s_1^4=0.1823, s_1^5=0.2176;$$

$$s_2^1=0.2168, s_2^2=0.2827, s_2^3=0.2500, s_2^4=0.2506, s_2^5=0.1846;$$

$$s_3^1=0.2506, s_3^2=0.2176, s_3^3=0.2814, s_3^4=0.3502, s_3^5=0.2827;$$

$$s_4^1=0.3502, s_4^2=0.1846, s_4^3=0.2500, s_4^4=0.2168, s_4^5=0.3151;$$

Finally, calculate multivariate priority  $S_i$  ( $i=1, 2, 3, 4$ ) according to the factors weights below (8):

Table 8. Weights of evaluation factors

$W_1$	$W_2$	$W_3$	$W_4$	$W_5$
0.27	0.18	0.13	0.17	0.25

The comprehensive priority of cooperation patterns are  $S_1=0.2197$   $S_2=0.2307$   $S_3=0.2736$   $S_4=0.2759$ , and  $S_1 < S_2 < S_3 < S_4$ . The results indicate that considering these five factors or criteria, research group pattern is superior to research project pattern, and the research institution and platform patterns are superior to the former two. But the difference between institution and platform pattern is extremely small. It should be noted that the four types of cooperation patterns have no absolute priority, but have preferred solutions under different conditions.

#### 4. Conclusion

European university-led smart city research has a range of cooperation patterns which are innovative and have deep insights of smart city research. A growing number of urban research institutions join in the research of smart cities, and more smart city research platforms will be set up in the future.

For large-scale smart city research institutions, which have better research projects and networks, the pattern of research platform will help them move one step further. By multi-disciplinary partnership participation and interaction, the research platform expands the collaborative network of institutions and organizations. As for smaller smart city research groups, whose strength is the flexible and weakness is lack of enough research projects and funds. The platform pattern will help them attract more partnerships and to be better involved in collaborative research. And the platform pattern would not spend too much organization and management cost, only a small group of people could take charge of the daily works.

However, despite the high potential to become the most promising research cooperation pattern, the research platform also has its own flaws. For example, the organizational structure is looser compare with research institutions, which makes it difficult to function efficiently and have substantial research results. In order to deal with the situation, the platforms need to set up management teams for taking charge of publishing working paper, contacting with their research members regularly, publicizing the collaborative research results through internet and other advanced technologies. Research platforms should cooperate with institutions who already have good research foundation and extensive research cooperation network, and making full use of those advantages. Moreover, the universities and local governments should encourage this kind of research pattern and involve in the research network, thus help promote further development of smart city research.

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