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A Study on Priority in Application of Smart City Elements

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Background/Objectives: The application of a smart city system in old cities requires massive financial input. Accordingly, it is necessary to apply in sequence highly efficient smart city elements preferred by consumers. The present study aimed to propose ways for the efficient application of a smart city by conducting a survey among smart city consumers. **Methods/Statistical analysis**: This study employed Analytic Hierarchy Process (AHP), a tool of identifying knowledge, experiences and intuitive of evaluating participants by ways of judgment resulting from pairwise comparison of elements that constitute the hierarchical structure of decision-making. In the first phase, the elements were classified into a hierarchy by means of brainstorming by eight experts in the field of smart city and from this a decision hierarchy was established. In the second phase, judgment data was collected by means of pairwise comparison of smart city elements on the basis of nine-score scale among 30 those who want to reside in smart cities. In the final phase, the author used an eigenvalue method by which relative weights of decision-making elements were estimated and results were obtained. **Findings:** An analysis of large classification revealed that consumers preferred smart life convenience facilities the most. An analysis of complex significance showed that consumers preferred smart CCTV followed by real-time parking information and public transportation services, smart logistics and delivery system, smart traffic control system, car sharing and public electric bicycle, smart waste sorting system, automatic home clean-net system and waste-turning-resources system. In other words, the results showed that those who want to live in smart cities highly preferred systems capable of saving time as well as the use of efficient and low-cost transportation services. Furthermore, with the significance of smart life environment being considered important, consumers showed high preference for environmental smart elements that can directly affect health amid rising attention to the issue of health.

Improvements/Applications: In order to turn existing cities into smart ones, it is necessary to identify preferential elements of smart cities by urban residents such as safety and environment that may vary depending on the characteristics of such cities in advance and then establish long-term and efficient plans and system.

Key words: *Ubiquitous, Smart city, AHP(Analytic Hierarchy Process), Big data, ICT, Brainstorming.*

Introduction

According to data set released by the United Nations (UN), the percentage of urbanization in the world by 2050 is estimated to be at 70% and this suggests that urbanization is rapidly progressing. Modern cities are composed of interconnected citizens, companies, a variety of transportations and telecommunication networks. The expansion of urbanization causes diverse subsequent problems not only in the socio-economic framework such as traffic jam, air pollution and social inequality, but in terms of environment. Advanced countries with higher percentage of urbanization face new challenges such as the enlarged construction of physical urban infrastructure, a new demand of consumers in the era of the fourth industrial revolution (Vieira and Alvaro, 2018). The construction of smart cities is thus on the rise around the globe in order to enhance urban competitiveness as well as the quality of life of citizens. In particular, smart city emerges as a future city model to achieve balance and harmony in terms of society, economics and environment as the development of information and communication technology (ICT) increased the possibility of building smart cities and the general awareness of the need of sustainable urban development becomes universal.

In South Korea regarded as a country with strong capacity in the field of information technology (IT), ubiquitous city had been implemented since the early 2000s prior to the emergence of smart city. U-city was an urban development model for integrating ubiquitous computing with urban construction technical skills based on the IT development, a project of building national geographic information system and urban information systems. For example, Songdo City is being built by applying a range of ubiquitous elements (Mullins, 2017). Yet, a number of problems in the U-city were identified due to skill-centered and supplier-led development methods. As ICT was developed, its business content was revised to smart city. The South Korean government planned and is building smart cities in Sejong city and Busan city. Most existing cities are preparing for turning into smart cities. Contrary to planned smart cities, the most significant problem in the matter of turning existing cities into smart ones is that massive financial inputs are needed, yet budget is limited since various smart elements must be constituted such as infrastructure. Therefore, highly efficient smart elements preferred by consumers are needed to be applied in sequence. Based on this awareness, this study aims to draw smart elements highly preferred by consumers who are willing to live in smart cities by utilizing the AHP, a multi-criteria hierarchical decision-making tool and then propose efficient ways to apply urban smart cities.

Materials and Methods

Concept and review of smart city

"Smart" originally referred to smart, intelligent or even witty person. Although smart city encompasses elements that constitute people as well as cities, there is no universally or academically concurred view on this concept while this concept is rapidly emerging and applied into cities in recent days (Stone et al., 2018). Smart city was proposed as a concept in the 1980s and has begun since Wireless Sensor Networks (WSNs) were applied in various fields due to the development of ICT. However, this new concept has been initially applied in both newly-planned cities and existing ones as better services were provided with lower costs than WSNs (Routray et al., 2018). In general, smart city is broadly defined as a place where the direction of improving the quality of life of residents is established in a way that elements are efficiently operated by ICT due to the IT development. In addition, it entails an issue of pollutant emissions by efficiently taking advantage of resources and sensors (Siano et al., 2018); (Parikka, 2017). Accordingly, there are numerous elements that constitute smart cities. More importantly, smart cities need to standardize indices promoting smart investment in order to efficiently utilize all resources in such cities (Glasmeier and Nebiolo, 2016).

In addition, some smart city-oriented cities are controlling and managing every sector and element of smart city by using virtual reality driven by the development of the fourth industrial revolution such as artificial intelligence (Jamei et al., 2017). For instance, data connection in both facilities are essential for parking facility information and EV charging in the field of smart traffic environment, which is one of important elements in smart city (Karpenko et al., 2018). In other words, smart city is operated by analyzing big data in the market where suppliers and consumers work. For instance, potential traffic danger is typically operated by learning patterns by means of big data such as device to device (D2D)[10]. Various elements should be and combined to grant the name of smart city (Serrano, 2018). In this sense, a variety of environmental, safety and economic problems facing contemporary cities can be resolved by introducing such smart city elements. For example, the number of automobiles increased 3.7% every year despite enough parking space once cities were initially planned. However, this problem could be addressed by applying ICT as such effects are verified in South Korea and Japan (Lam and Yang, 2019).

Furthermore, one of its biggest advantages is that the supply system producing and distributing resources promotes the optimal output by means of optimal manufacturing process and network communication (Kumar et al., 2016); (Mohammadi and Ala, 2018). According to input and output results of smart city in South Korea titled as a country specialized in the IT industry, the development of smart city industry serves as an important position not only in sustainable cities, but in national economic growth (Kim et al., 2016). Figure 1 presents the concept map in which a number of smart city elements are combined (Silva et al., 2018).

Furthermore, such elements should be applied based on a strategic blueprint reflecting socio-economic and environmentally unique characteristics of such cities rather than being unilaterally applied in all cities. In other words, smart cities need to be planned in a way that characteristics and preference requested by consumers are reflected in the blueprint (Prakash, 2019). With Barcelona being recognized as an exemplary case of smart city, the municipal government has built e-government and e-governance since 2011 and its smart city elements are being regularly updated and newly applied. That is, choice and concentration are required in the process of applying smart city in existing cities where infrastructures for smart cities are absent, as long periods and massive capital inputs are needed (MILA, 2018).

The Principle and Process of the Method

Principle of AHP

AHP is a multi-criteria decision-making method. In other words, it refers to a decision-making method aimed at capturing knowledge, experiences and intuitive of subjects by means of pairwise comparison of elements that constitute a decision-making hierarchy. If people use AHP to address problems related to decision-making, the following four-phase constitution process is generally underway (Saaty, 2005).

In the first phase, decision-making problems are classified into a hierarchy of interconnected decision-making issues and then decision hierarchy is built. A hierarchical tree is established and a whole decision-making framework is created in this phase, which is the most significant phase in applying AHP.

In the second phase, judgment data is collected by means of pairwise comparison of decision-making elements. This phase is a process by which such elements are converted into eigenvalues by means of pairwise comparison among criteria depending on drawn frameworks. Elements in the direct descendant structure contributing to achieving the goal of elements on the top are pairwisely compared and then matrix is written. The significance is typically granted to the degree of contributing to top elements as nine-point scale. If the direct descendant structure is composed of n elements, n(n-1)/2 comparisons are thus needed.

In the third phase, an eigenvalue method is used to estimate the relative weight of decision-making elements. It should be noted that the weight refers to either relative significance or preference for the elements. If the relative significance of n elements considered as comparison targets in a single layer is wi(i = 1, · · · ·, n), aij on the pairwise comparison matrix is estimated to wj(i = 1, ·, ·, ·, ·, n). formula 1 below shows all elements on the matrix.

$$\sum_j^n aij \cdot wi = n \cdot wi(i, j = 1, \cdots, n) \qquad (1)$$

In this phase, the fact that how consistently evaluators assessed evaluating items is monitored and the ratio of consistency is calculated. Consistency measures the logical paradox in the process of judgment made by the evaluators. Consistency Ratio (CR), outcome calculated by dividing Consistency Index (CI) by Random index (RI), is used to test consistency.

Representing it as a formula, it can be expressed as CR = (CI/RI)×100%.
RI with the CR formula refers to Random Index, which writes inverse matrix by randomly setting numbers ranging from 1 to 9, while referring to a tolerance limit as the calculated average consistency index of this matrix. [Table 1] shows random numbers when n varies from 1 to 10.

Table 1: Random number index

N	1 2 3 4 5 6 7 8 9 10
Random number index	0 0 0.58 0.90 1.12 1.24 1.32 1.41 1.45 1.49

Hypothesis and tested statistics on consistency are shown as follows.
Null hypothesis (Ho) : random evaluation by decision-makers
Alternative hypothesis ((H_1) : no random evaluation by decision-makers
Test statistics (CR) : Consistency Ratio = CI/RI
If CR is less than 0.1, Ho is rejected. In other words, CR with 0 indicates that respondents remain completely consistent and conducted pairwise comparison.
In the fourth phase, the relative weights of decision-making elements are summed up to obtain a rank on a number of alternatives considered as evaluation targets. The total significance can be calculated in accordance with the formula 2 below.

$$c[1, k] = \prod_{i=2}^{k} B_i \qquad (2)$$

C[1 , k] : aggregate weight of *k*th hierarchical elements on the first hierarchy

Bi : ni-1 · ni matrix containing a line constituting estimated w vector
ni : the number of elements in the *I*th hierarchy

Through weights determined during the above phase, the relative significance of each assessment category is judged and priority in alternative decision-making is determined.

Analytic phase and model design

This study underwent the following process. First, application elements were drawn by reviewing and reading books, journals and previous studies related to smart city in order to obtain smart city elements. By conducting brainstorming with experts, preliminary evaluation criteria of such elements were prepared. [Table 2] shows the phase of model design.

Table 2: Phase of model design

1st phase	Reference and earlier studies	Preparation for evaluation criteria	Technical exploration
2nd phase	Expert survey for preliminary survey, process of brainstorming	Drawing and obtaining evaluation criteria	The first face-to-face discussion with experts and interview, improve evaluation criteria for main survey
3rd phase	Main survey	Draw evaluation criteria weights and priority through expert survey	AHP Analysis

Second, face-to-face interview were conducted with eight experts in smart city and the first expert survey was carried out as part of individual discussion, leading to obtaining the final evaluation criteria by means of preliminary evaluation criteria and improvement on what smart city elements are. The model composed of five hierarchical classification categories and 22 small classification categories. [Table 3] shows the features of first expert survey.

Table 3: First expert survey

Population	Experts in smart city	
Sample	Experts in Sejong smart city	4
	Professors in smart city-related department	4
	Total	8
Survey method	Free discussion	
Survey period	May 7, 2019	

Third, survey was carried out among 30 participants by using AHP Program (Expert choice) based on the given model during the first expert survey, tested consistency on evaluation criteria on respective drawn categories and assessed significance weights. With placing evaluation results as weights, significance and priority were drawn. The final conclusion was drawn by evaluating and comparing significance with priority based on total evaluation results. [Table 4] presents the characteristic of respondents.

Table 4: Characteristic of Respondents in this Study

Population	Consumers who are willing to live in smart cities	
Sample	Women	18
	Men	12
	Total	30
Survey method	Survey by using structured questionnaires	
Survey period	From May 20, 2019 to June 23, 2019	

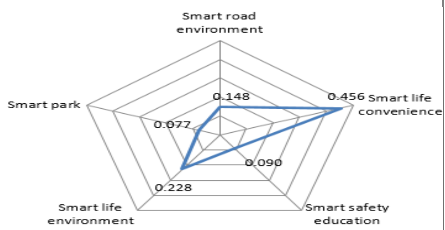
Results and Discussion

Significance of major classification

The Result of major classification in [Table 5] showed that the average percentage of consistency was 0.056% and it is most likely to see CR(Consistency Ratio) with less than 10%. The relative significance among major classification categories showed that smart life convenience was the highest (0.456), followed by smart life environment (0.228), smart road environment (0.148), smart safety and education (0.09) and smart park (0.077).

Table 5: Significance of hierarchical classification categories

Category	Significance	Consistency
Smart road environment	0.148	0.056
Smart life convenience	0.456	
Smart safety education	0.090	
Smart life environment	0.228	
Smart park	0.077	



The result showed that the significance of smart life convenience facilities including smart logistics and delivery system, parking information, car sharing, smart CCTV was the highest. It can be said that

The above result suggests that consumers who want to live in smart cities show high preference for using time-saving system as well as efficient and low-cost transportation. In addition, as smart life environment such as home clean-net, smart waste sorting and waste-turning-resources were highly significant, it is assumed that they prefer environmental elements that may directly affect health amid rising attention to health in recent days. On the contrary, smart safety and education as well as smart park showed lower preference. This suggests that due to a number of surveillance camera compared to population and already-implemented modernization school projects in South Korea, these are not on the list. In addition, other categories are relatively better than other countries except for road environment and traffic jam.

Significance of sub-classification

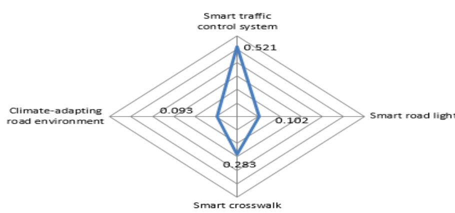
The evaluation on sub-classification revealed that the percentage of consistency in 22 categories was 5% in average with CR(Consistency Ratio) being consistent less than 10%. The following result presents the significance of sub-categories included in four major classification categories by the same categories.

Smart road environment

[Table 6] shows the relative significance of sub-categories in smart road environment. The result showed that smart traffic control system is considered the most important (0.521), followed by smart crosswalk (0.283), smart road light (0.102) and climate-adapting road environment (0.093).

Table 6: Smart road environment

Category	Significance	Consistency
Smart traffic control system	0.521	0.030
Smart road light	0.102	
Smart crosswalk	0.283	
Climate-adapting road environment	0.093	



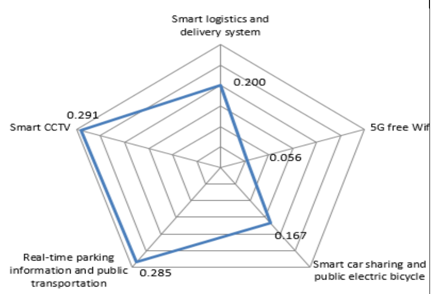
The above result showed that consumers showed the highest preference for mitigating traffic jam by the efficient traffic control system and thereby reducing travel time and highly interested in safety while walking on the road. This may reflect the situation in South Korea where traffic jame is a serious problem and moderately frequent traffic accidents. By contrast, they were not highly interested in improving existing road environment such as smart road light and climate-adapting road environment.

Smart life convenience

[Table 7] shows the relative significance of sub-categories in smart life convenience, which was assessed as the most significant. Smart CCTV was regarded as the most significant (0.291), followed by real-time parking information and public transportation (0.285), smart logistics and delivery system (0.200), smart car sharing and public electric bicycle (0.167) and 5G free Wifi (0.056). The result suggested that consumers preferred using smart CCTV lately recognized as an essential element for safety in residential areas, efficient smart public transportation that help save travel time and parking information. In addition, they showed high preference for environment such as smart logistics and delivery system that promotes easy shopping in the busy contemporary society, smart car sharing and public electric bicycle, as well as comfortable and low-cost transportation. However, public free Wifi gained low attention under the circumstances in South Korea where 5G became universal for the first time in the world and high-speed Internet can be used in most areas including even rural areas.

Table 7: Smart life convenience

Category	Significance	Consistency
Smart logistics and delivery system	0.200	0.050
5G free Wifi	0.056	
Smart car sharing and public electric bicycle	0.167	
Real-time parking information and public transportation	0.285	
Smart CCTV	0.291	

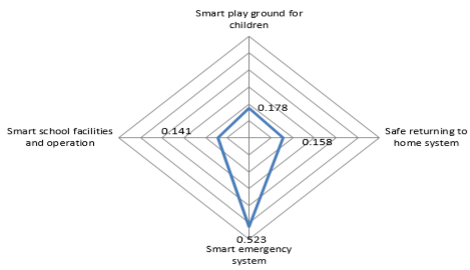


Smart safety and education

[Table 8] shows the relative significance of sub-categories in smart safety and education, which showed the lowest significance. The result showed that smart emergency system was regarded as the most important (0.523), followed by smart play ground for children (0.178), safe returning to home system (0.158) as well as smart school facilities and operation (0.141).

Table 8: Smart safety education

Category	Significance	Consistency
Smart play ground for children	0.178	0.038
Safe returning to home system	0.158	
Smart emergency system	0.523	
Smart school facilities and operation	0.141	



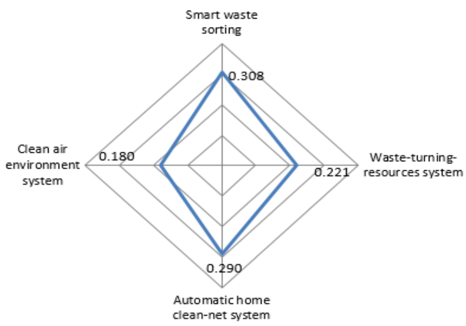
The above table shows that smart emergency system is the most significant among four categories. It can be assumed that consumers think that health and rapid response to emergency are considerably needed and South Koreans had many experiences due to well-established emergency system. In addition to this, the significance of other categories shows no great difference. It can be said that these elements have been to a great extent improved in the process of developing new towns driven by rapid economic development in South Korea.

Smart life environment

[Table 9] presents the relative significance of sub-category in smart life environment, the second higher significance among other hierarchical classification categories. The results showed that smart waste sorting was the most important (0.308), followed by automatic home clean-net system (0.290), waste-turning-resources system (0.221) and clean air environment system (0.180).

Table 9: Smart life environment

Category	Significance	Consistency
Smart waste sorting	0.308	0.028
Waste-turning-resources system	0.221	
Automatic home clean-net system	0.290	
Clean air environment system	0.180	



The above analysis shows that the significance of four categories in smart life environment did not considerably differ. It can be assumed that amid growing interests in environment along with increased income, many consumers are less comfortable with passive waste sorting, which has begun since 2000s and they prefer the complementary home clean-net system. It can be also said that due to recently growing concern over environmental conservation and environmental pollution such as fine dust, they are more or less interested in the application of waste-turning-resources system as well as clean air environment system.

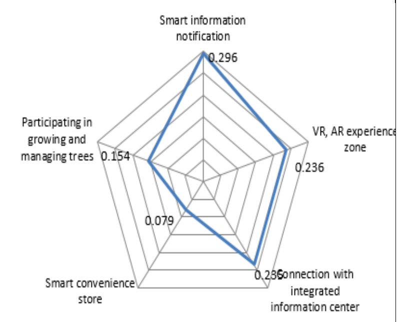
Smart park

[Table 10] shows the relative significance of individual sub-category in smart parks whose significance is low among major classification categories. The table indicates that smart information notification is the most significant shown as 0.296, followed by VR·AR experience zone (0.236), connection with integrated information center (0.235), participating in growing and managing trees and in parks (0.154) and convenience stores in parks (0.079). The table shows the relative significance of sub-categories in smart park, which presented the lowest significance among major classification categories. Smart information notification was considered the most important (0.296), followed by VR·AR experience zone (0.236), connection with an integrated information center (0.235), participating in growing and managing trees in parks (0.154) and smart convenience store (0.079).

The above result reveals that while consumers used to utilize parks merely for exercise or repose, now they recognize the importance of parks as a place to gather and use necessary general information along with the aforementioned purposes. In addition, they show preference for smart information notification as well as play and experience facilities such as VR and AR. In addition, they are more or less interested in growing and managing trees to serve as a connection with an integrated control center and personal repose space for the safe use of parks.

Table 10: Smart Park

Category	Significance	Consistency
Smart information notification	0.296	0.054
VR, AR experience zone	0.236	
Connection with integrated information center	0.235	
Smart convenience store	0.079	
Participating in growing and managing trees	0.154	



Complex Significance

[Table 11] shows the complex significance of 22 sub-categories included in five major categories. The result suggested that smart CCTV as one of sub-categories was the highest (0.133), followed by real-time parking information and public transportation (0.130), smart logistics and delivery system (0.091), smart traffic control system (0.077), smart car sharing and public electric bicycle (0.076), smart waste sorting system (0.070), automatic home clean-net system (0.060) and waste-turning-resources system (0.05). However, smart convenience store, participating in growing and managing trees in parks, smart school facilities and operation were less significant.

Table 11: Complex significance

Main classificaiton	Sub-classification	Complex significance	Rank
Smart road environment	Smart traffic control system	0.077	4
	Smart road light	0.015	17
	Smart crosswalk	0.042	10
	Climate-adapting road environment	0.014	18
Smart life convenience	Smart logistics and delivery system	0.091	3
	5G free Wifi	0.026	12
	Smart car sharing and public electric bicycle	0.076	5
	Real-time parking information and public transportation	0.130	2
	Smart CCTV	0.133	1
Smart safety education	Smart play ground for children	0.016	16
	Safe returning to home system	0.014	18
	Smart emergency system	0.047	9
	Smart school facilities and operation	0.013	20
Smart life environment	Smart waste sorting	0.070	6
	Waste-turning-resources system	0.050	8
	Automatic home clean-net system	0.066	7
	Clean air environment system	0.041	11
Smart park	Smart information notification	0.023	13
	VR, AR experience zone	0.018	14
	Connection with integrated information center	0.018	14
	Smart convenience store	0.006	22
	Participating in growing and managing trees in parks	0.012	21

To summarize results of complex significance exhibiting the significance of all smart elements used in this study, people who want to live in smart cities are highly aware of the importance of safety, life environment and saving time. To examine more specifically, they considered the necessity of using smart CCTV lately recognized as an essential element for safety in residential areas, efficient smart public transportation that help save travel time and parking information. In addition, they preferred using not only the smart logistics and delivery system that promotes easy shopping in the busy contemporary society, smart car sharing and public electric bicycle, but using comfortable and low-cost transportation. Above all, mitigating traffic jame and reducing travel time by the efficient traffic control system are recognized as significant smart city elements under the circumstances in major cities in South Korea where people experience chronic traffic jam. Amid rising attention to the environment due to increased income and improved health, many consumers are less comfortable with passive waste sorting that has begun in 2000s. They showed high preference for the complementary home clean-net system. They were highly interested in applying the waste-turning-resources system and the clean air environment system due to heightened concern over environmental pollution such as the environmental conservation and fine dust in recent days.

Conclusion

Most new cities around the word set smart cities as milestones. In South Korea, some smart cities are planned and under construction. Even existing cities are preparing to turn into smart ones. However, the biggest problem for existing cities in this process is that massive financial inputs are needed as various smart elements such as changing the existing infrastructure should be applied. Therefore, it is necessary to apply efficient smart elements preferred by consumers in sequence. This study aimed to propose methods to make efficient smart cities by building an AHP model by means of expert brainstorming and by conducting a survey among consumers who are willing to reside in such cities.

The major classifications that showed the highest preference for smart life convenient facilities included smart logistics and delivery systems, parking information, car sharing and Smart CCTV. The complex significance showed that they preferred Smart CCTV the most, followed by real-time parking information and public transportation, smart logistics and delivery system, smart traffic control system, smart car sharing and public electric bicycle, smart waste sorting system, automatic home clean-net system and waste-turning-resources system.

These results suggest that consumers who want to live in smart cities show high preference for using time-saving systems as well as efficient and low-cost transportation. In addition, they preferred environmental smart elements that may directly affect health amid rising interests in health, as smart life environment including home clean-net, smart waste sorting and waste-turning-resources became significant. Accordingly, it is necessary to establish the process of launching a plan considering such elements in advance and creating a project in the process of turning existing South Korean cities into smart ones. The implications of the results lie in identifying smart preferential elements of urban residents that may vary according to urban characteristics in advance and thereby proposing the necessity of setting a long-term and efficient plan and building the system.

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