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Providing an Ontology-based Framework to Determine the High-Level Software Classes of a Smart City

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ABSTRACT

In any society, software designed for a smart city in an environment based on the Internet of Things (IoT), provide smart urban models and user requirements for a better life and citizens' interaction with this smart city. However, the existing requirements extracting methods, due to several reasons like integration, interoperability, preventing data redundancy, possible interference and lack of integration and semantic queries, are not suitable and the mentioned problems are usually visible in some of these software systems. This article presents a comprehensive ontology of the smart city at the level of the existing meta-classes along with the way of inheritance and cooperation of these classes to integrate, prevent data redundancy and semantic query capability by using the experts' opinions. The classes required for the construction of this ontology were first collected by the snowball method from the urban target community and then refined and finalized by the Delphi method using the opinions of experts including university professors, industrial and business owners, as well as city officials. For the first time, three major classes are embedded in this model as super classes that all classes can inherit from. Thus, the framework presented in this article, while covering various aspects of a smart city, can be used to determine the software classes of a smart city, including high level classes and most important sub-classes, along with the localization capability for each community based on priorities of that community.

Keywords: *Smart City, Ontology, Software Classes, Software Requirements*

1. Introduction

The software designed for a smart city in every society simulates human, physical and digital systems in an environment based on the Internet of Things (IoT), urban models and user needs, and makes them usable. However, existing integration methods are suitable for island applications. Lack of interoperability, data redundancy, possible interference, lack of integration and lack of semantic queries are visible in all these systems. The existing lack of integration makes it very difficult and sometimes impossible to determine common requirements. The lack of sufficient interaction, clarity of features and services, as well as the required classes, have practically challenged different software architectures and have faced the existing software development methodologies with the problem of determining requirements, including functional and non-functional requirements. All these cases have led to the creation of island systems and integrated intelligent services have faced many problems.

Various factors influence the failure of projects based on information technology systems. About 24% of the reasons for the failure of projects based on information technology are related to the weakness in knowledge, engineering and management of requirements. Extracting these requirements, both functional and non-functional requirements, is a time-consuming and

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costly task, and for various reasons, in many cases at the beginning of the project, these requirements, especially the non-functional requirements, are not clear and it is possible that after spending a lot of time and money, the project fails.

The concept of smart city has become one of the most popular concepts in the world today, and many researchers from all over the world are researching it. Many works have been done on it and many systems have been implemented and used in this regard. The wideness and universality of the smart city structure necessitates the need to understand the structure and connections in the smart city, the absence of which has prevented the creation of a unified structure and replaced island systems with a unified system. In this paper, with a complete understanding of the problems of island systems that lead to data redundancy, unavailability, low reliability and countless other problems, for the first time a comprehensive ontology for the concept of the city Smart is designed which, in addition to its many strengths, for the first time, will use the concept of super classes in a smart city based on the Internet of Things and shows that the smart city should inherit from these super classes to create a more integrated system than before.

2. Research background

When it comes to the smart city and its software requirements, various opinions and experiences are presented by the users and experts of this category. Some of these definitions and experiences are common and others differ from each other depending on culture, needs and even political, economic and geographical conditions. Therefore, in order to understand this paper more and better, some of these definitions should be reviewed and re-stated, and in the following, the concepts of "smart city", "ontology" and "Internet of Things" will be presented.

A. Smart city

In the last thirty years, "smart city" has been defined differently by different people. Based on the needs of communities or existing resources and based on the level of development of that community, the definitions of smart city constantly change from one city to another and between different nationalities. For example, for the first time, the concept of "smart city" was expressed in 1990, at that time due to the emergence of new ICT technology in relation to modern infrastructure, the main attention was focused on the impact of this technology on cities and people's way of life. [1], while in the research [2], the smart city is mentioned as a city that is futuristic in people, economy, transportation, government, environment and way of life based on the smart combination of citizens' activities. It is made autonomously, independently and consciously. Also, in [3], he described the smart city as a smarter city: "A city that uses technology to transform its main systems and optimize the efficiency of many finite resources. In the research [4], the integrated model of this city is based on The basis of six accepted main components and several main sub-components and three essential meta-components were introduced in the form of a graph that showed the cooperation of the components with each other. According to this research and the review of other articles, it can be stated that the concept of a smart city with more than 30 years of age is a developing concept that has taken on a new form with the emergence of the Internet of Things and in such a situation, in order to search and identify smart solutions for everyday urban issues and increase the quality of services provided to citizens requires a close connection between the information and existing knowledge of the city, including open knowledge and hidden knowledge, and sharing them and extracting the services needed by each community from these entities based on the essence of existence and the abilities of each entity.

B. Internet of Things

The Internet of Things (IoT) is a paradigm in which items with actuators, sensors, and processors are connected together to achieve a specific goal. Users will benefit from the advancement of high-speed communication systems in the Internet of Things (IoT)-based intelligent network that includes analytics, scalability, and sustainability. The Internet of Things is a pervasive and global network that connects real-world items to the Internet and allows them to share the data they generate[5].

Recently, the Internet has become a new generation called the Internet of Things, and thus by creating a comprehensive and self-organized network, it makes possible the connection between the physical and digital worlds. A large number of smart objects can now be identified and addressed while being able to communicate with each other. In addition, the integration of cloud infrastructure into the design of the Internet of Things has taken this brand new technology to a new dimension, enabling virtualization and service delivery. Therefore, billions of cloud services with different performance levels, requirements, and functionalities are offered in IoT, raising issues related to their management, discovery, and selection. In the literature, considerable effort has been invested in addressing service discovery and selection in the context of the Internet of Things, despite the lack of standardization that meets the requirements of the Internet of Things [6].

With the emergence of the Internet of Things, the smart city has taken on a new concept and has been able to make the most of the possibilities created by this new generation of the Internet. But still the main problem is the insular systems and countless services that have been created and are being created, without having a constructive and integrated interaction with each other. This is where the relationships between different parts of a smart city should be identified and specified using ontology concepts so that services can work together effectively and seamlessly. The creation and use of ontologies has become increasingly relevant for complex systems in recent years[7]. This is due to the increasing number of use cases that rely on real-world integration of disparate systems. The need for semantic consistency across boundaries and user expectations for conceptual clarity in evolving domains or systems of interest are evident in most research areas involving complex systems[8]. The main challenges in the Internet of Things (IoT) refer to the diverse capabilities of objects, the huge amount of data they generate, the heterogeneity of this data, and the diverse services provided. For each application domain and for each vendor, there is usually a proprietary IoT platform for which no standards are currently found or expected in the near future. Therefore, ensuring the semantic interoperability of things between different types of IoT platforms and applications is one of the major problems in this field[9].

C. Ontology

Ontology plays an essential role in describing the standard and sharing the knowledge of the field with the wide application of ontology [10]. As a philosophical term, the word "ontology" refers to the study of the nature of existence. Etymologically, “Onto" refers to existence and "Logy" is knowledge. Ontology deals with categories and concepts of existence and relationships between them. More generally, beyond philosophy is used as a framework in the study of any complex phenomenon. Providing an ontology means providing a description of the categories and concepts that are involved and specifies the relationships between these categories and concepts [11]. Today, ontologies have become a topic of study in computer science and information theory. By describing a body of knowledge in terms of primitives, classes, and attributes, we have a machine-independent way to characterize knowledge. For example, the Resource Description Framework (RDF) designed by Brickley and Guha and adopted by the World Wide Web Consortium is of this type [12]. Such descriptions are important because the same information may be presented in different formats and different vocabularies, and entities such as autonomous agents must have a way of knowing that they are "looking" at the same object (or related entity). Without this, we would have silos of information instead of an interconnected and integrated knowledge base.

Beyond static repositories of information, ontologies are used in natural language processing for speech understanding and in artificial intelligence and machine learning to help systems understand objects and their relationships. (E.g. Yao et al. used ontologies to build an artificial intelligence model that predicts side effects of traditional Chinese medicines [13].

Taxonomy and lexicon are related to ontology. A taxonomy is a classification of concepts into a hierarchical structure that may be described as linear, while an ontology is multidimensional. When a taxonomy functions in relation to an ontology, the taxonomy's classification can be related to a broader ontological classification among categories and concepts. A lexicon is a set of terms or vocabulary that tries to clearly define the elements being represented. While ontology and lection are related, they also differ from each other, as ontology is language independent while lexicon is language dependent [14].

3. Literature review

There are many approaches in the research literature to enable meaningful communication between different IoT devices in a smart city. These approaches are derived from the ontologies that have been identified and applied so far.

Dey and Dasgupta [15] propose an extension of the OntoSensor ontology in the energy domain to include spatial and temporal concepts of sensor data.

Woznowski et al. [16] has proposed an ontology for semantic labeling of activities of daily living (ADL) for the smart home domain, such as cooking food, brushing teeth, etc. Their ontology is based on dynamic segmentation of sensor data for variable time windows. Identifying simple user activities, these simple activities are then used to infer more complex activities.

In [17], Lee et al. has proposed a University Activity Ontology (UAO) in order to identify activities in a university.

In [18] V. Kumar Murty and Sukarmina Singh Shankar seek to identify a set of categories and objects belonging to the symbol of a smart village. In addition, they sought to express the relationships between objects and categories, which also form a part of ontology.

In defining the concept of "smart city", the work of Ramaprasad, Sanchez-Ortiz and Syn refers to the concept of ontology [19]. Their focus is to set the definition in a way that clarifies the components of a smart city and the relationships between those components. Therefore, it provides the context to describe the functional architecture of the concept. The work of Fox et al. takes a similar approach [20].

The rationale for the rural versus urban debate is explained in Ramaprasad's earlier work on the discovery phase [21] and is also discussed in Visvizi and Lytras [22].

Mehdi Kayseri, et al. [23] presented a three-module framework to solve the problem of heterogeneity, protect private information and provide high-level services, the first module includes an ontology and a data storage model to discover the problem of heterogeneity.

In another research [24], ontology has been used as a knowledge representation technique in various software engineering processes to help develop test strategies for IoT applications.

In another article, an ontology-based approach for modeling Internet of Things design patterns is considered, in which an ontology-based framework for specification and modification of Internet of Things design patterns is presented [25]. In this approach, an analysis of meta-models and ontologies has also been performed to reduce the gap between the high-level design abstraction of Internet of Things patterns based on the Unified Modeling Language (UML) and the formal ontology.

In another article [26], a proposal for a comprehensive community-oriented ontology for the interdependent ecosystem that includes smart cities has been presented. The importance of such an ontology (more broadly: Knowledge Organization System or KOS) is applicable to the integration of many specialized information systems and insights obtained from machine learning, which in turn supports the integration and mutual reinforcement of activities in planning and construction. The use of smart cities and smart buildings to serve the real human needs, improving the quality of life and the efficiency of life activities are the achievements of this system.

In another research [27] conducted and analyzed the existing integration strategies and created an ontology for the integration of Open Spatial Consortium (OGC) data modeling standards CityGML, IndoorGML and SensorThings API.

In a review study [28], using a systematic literature review along with thematic classification and gap mapping analysis to examine the existing solutions to the challenges, typology/classification of challenges facing agile software development in general and In particular, they deal with challenges in requirements engineering and how to find solutions. This study covers from 2009 to 2023.

Many other articles were also reviewed [29..39], each of which dealt with a part of the topic of ontology in a smart city based on IoT, and based on the studies conducted so far by the authors of this article, an integrated ontology for the smart city has not been proposed so far and this article proposes a complete and integrated ontology using the opinion of experts.

4. Methodology and tools

In order to design and draw the ontology, several software are used. Each of them has its own characteristics and its own strengths and weaknesses. For this purpose, the authors of this article used the protégé 5.5.0 software that is more coordinate with other designs, and enables them to design the characteristics and methods of the classes in the future, and to extract the meaning and relationship. SPSS software was used to collect and calculate the statistics of experts' opinions, which is used for statistical and calculation tasks.

The current research is of the "parallel single method" type. It should be noted that the parallel single-method design (like Morse's typology) uses two qualitative methods at the same time, one of which is the basic method and the other is the complementary method, then the results are combined with each other. Therefore, the method of conducting this research includes two steps as follows:

- Qualitative part (first part - basic part) [Meta-composition: to present the initial conceptual model of the smart city,
- Qualitative part (second part - supplementary part) [content analysis]: towards the conceptual structure of the smart city and its ontology.

The data collection method is document study, opinions, definitions and semi-structured individual interviews. The statistical population includes ordinary people as well as experts and, university professors in the fields of computer, urban planning, environment, economics, sociology, and managers and decision makers in urban issues, which are 124 people with a purposeful sampling method and the snowball technique was chosen as a research sample. In order to generate data, a semi-structured interview method was used, which is suitable for qualitative research in terms of flexibility and depth. Each interview lasts from 35 to 50 minutes on average. After conducting 103 interviews, repetition in the received observation information; But to be sure, it continued until the 124th interview and the sufficiency of the data to produce the conceptual model was achieved, and as a result, the data collection process was terminated. Figure 1 shows the main stages of the research.

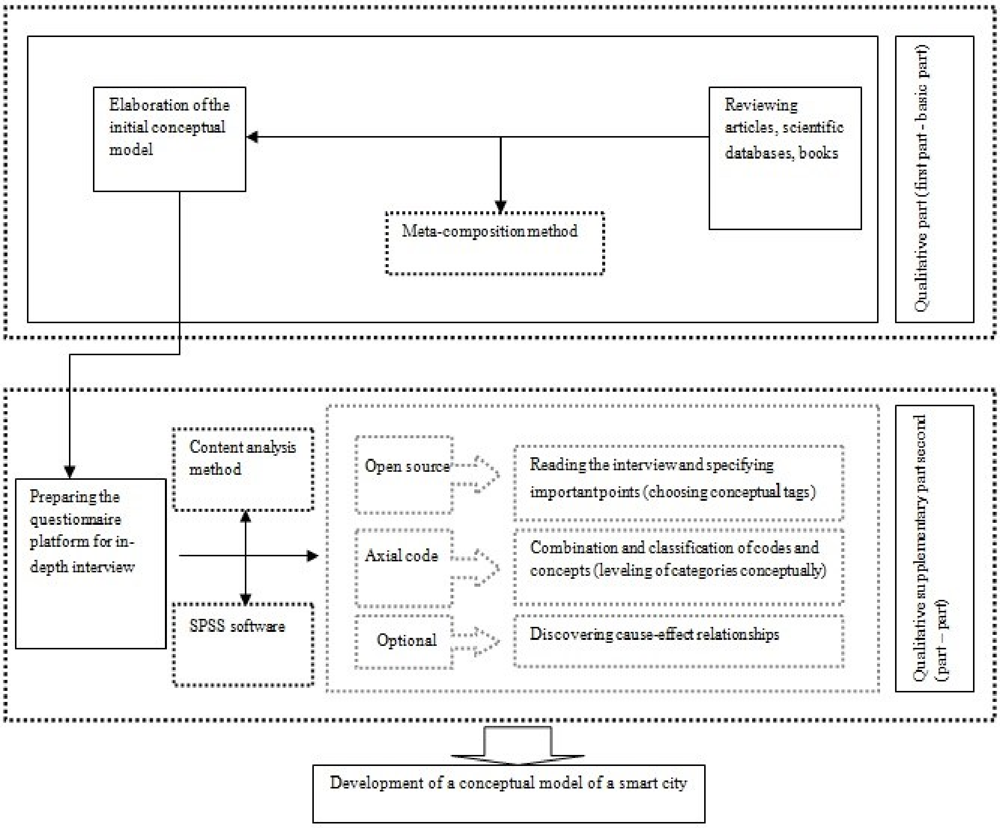

Figure 1. The process of the research method

In order to measure the validity of the extracted components, the opinions of 60 experts and the fuzzy Delphi method were used [40]. In this research, Chang's (1998) fuzzy Delphi method was used in the traditional Delphi method, first developed by Dalkey and Helmer (1963) in a company and then widely used in many management fields. One of the advantages of the Delphi method is its simplicity; because it does not require advanced math skills, implementation and analysis. Rather, it requires a person who is aware of the issues and Delphi technology and creativity in the project. In 1985, the concept of combining the traditional Delphi method and the fuzzy theory was presented in order to improve the ambiguity and inconsistency in the Delphi method. Triangular fuzzy number is used to include expert opinions and therefore, fuzzy Delphi method is established. The maximum and minimum values of expert opinions are used as the two endpoints of triangular fuzzy numbers, and the geometric mean is used as the degree of membership of triangular fuzzy numbers in order to avoid the effect of finite values. The traditional Delphi method requires multiple considerations in order to reach a consistency in expert opinions, but the fuzzy Delphi method only requires one consideration, all opinions can be covered. A five-point scale is used in this research. Fuzzy Delphi method uses the geometric mean as a basis for the decision-making group in order to screen inappropriate factors and avoid the influence of final values. Also, in addition to reducing cost and time consumption, this method enables decision makers to evaluate the fuzziness in the decision-making process and reach a better result in agent selection. In the fuzzy Delphi method, information will be received from experts in the form of written language and analyzed in a fuzzy manner (Chen and Wang, 2012). The implementation pattern of the fuzzy Delphi method is shown in Figure 2.

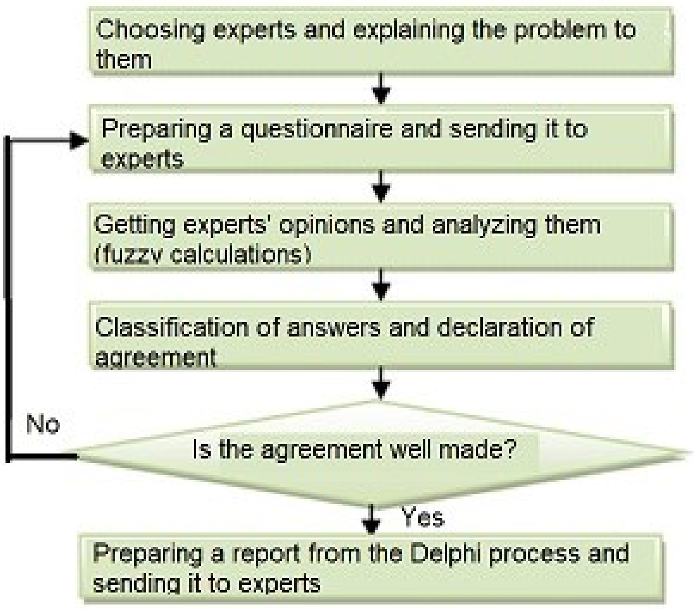

Figure 2. Algorithm for implementing fuzzy Delphi method

In Table 1, the determined fuzzy numbers are extracted from Minkowski's equation as equation 1. The fuzzy average will also be calculated based on relations 1 and 2 shown in table 2.

Table 1. Fuzzy numbers of verbal variables

Verbal variables	Triangular fuzzy number (m, α, β)	determined fuzzy number
very much	(0.75,1,1)	0.75
Much	(0.5.0.75,1)	0.5625
Average	(0.25,0.5,0.75)	0.2125
Low	(0,0.25,0.5)	0.0625
Very Low	(0,0,0.25)	0.0175

$$\chi = m + \frac{\beta - \alpha}{4} \qquad (1)$$

Table 2. Fuzzy average relations

Relation (1)	$(a_1^i, a_2^i, a_3^i) \quad i = 1,2,3,,\ldots, n$
Relation (2)	$A_{ave} = (m_1, m_2, m_3) = (\frac{1}{n}\sum_{i=1}^{n} a_1^i, \frac{1}{n}\sum_{i=1}^{n} a_2^i, \frac{1}{n}\sum_{i=1}^{n} a_3^i)$

5.Evaluation and discussion

As mentioned in the previous section, by reviewing the literature, the components (items) related to the success in the renovation of the urban context were extracted from the literature of the research. In order to verify (validate) the items, a questionnaire was prepared according to the fuzzy Delphi method and it was provided to the experts to screen these components and identify their importance in order to identify the important components for the development of strategies. Be specified at first, the opinions of the decision-making group were collected using a 5-point Likert scale, and then according to the experts' opinions, a triangular fuzzy number was assigned to the factors. Next, using the threshold value suggested in the literature, the status of each factor (confirmation/rejection) was determined. 156 indicators were extracted and used to design the questionnaire. Also, an open-ended question was included at the end of the questionnaire in which the respondents were asked to mention any effective factor that they consider important for the purpose of the research. Second, a questionnaire was used to collect the opinions of experts in the decision-making group in order to obtain the relative importance of the effective factors and their rank. Based on this, information was collected in two stages. In the first stage, the questionnaire was given to the expert group members and they were asked to express their opinion about each criterion in the form of verbal variables included in the questionnaire. According to the average calculation formulas, the fuzzy average and the determined fuzzy number were extracted. According to Cheng Lin and his colleagues, if the difference between two polling stages is less than a very small threshold (0.1), the polling process is stopped.

Table 3. The results obtained from the opinions of experts in the smart government subgroup.

Grouping	Comprehensive subjects	Organizer subjects	Basic subjects	Component status	The difference between the two final stages	Status of the Delphi process
	Smart government services	Smart relief forces		✓	0.086458	end
		Smart fire brigades		✓	0.072917	end
		Smart Red Cross forces		✓	0.0625	end
		Smart government departments		✓	0.072917	end
		Smart military and police forces		✓	0.095833	end
	Smart municipality			✓	0.09375	end
	Smart rules			✓	0.064583	end
	Smart technology infrastructure	ICT centers		✓	0.065625	end
		Network technology		✓	0.051042	end
		Satellite technology		✓	0.044792	end
		Network technologies	Sensors	N.A	-0.04167	end
			Optical fiber	N.A	-0.070833	end

			WiFi	N.A	-0.04375	end
			Mobile connection	N.A	-0.022917	end
	Smart management	internal management		✓	0.083333	end
		External management		✓	0.059375	end
	Smart data transparency			✓	0.036458	end
	Smart integration	Smart interactions		✓	0.078125	end
		Smart services		✓	0.077083	end
	Smart Backup			✓	0.04375	end
	Smart feedback			✓	0.03125	end
	Smart resource management and productivity			✓	0.054167	end

a. Analysis of components and influencing factors

As mentioned earlier, 156 indicators were extracted from the theoretical foundations as influencing factors, which were refined using the fuzzy Delphi process.

Table 4. The results obtained from the opinions of experts in the smart people subgroup.

Grouping	Comprehensive subjects	Organizer subjects	Component status	The difference between the two final stages	Status of the Delphi process
	Smart technical skills		N.A	-0.08958	end
	Smart innovation and creativity		N.A	-0.03646	end
	Smart human resources		✓	0.029167	end
	Smart technological space		✓	-0.00521	end
	Smart education	Smart schools	✓	0.016667	end
		Smart University	✓	0.057292	end
		Smart free education	✓	0.05	end
		Smart public education	✓	0.032292	end
		Smart library	✓	0.051042	end
		Smart learning tool	✓	0.042708	end

	Smart products	Smart kindergarten	✓	0.065625	end
		Smart study	✓	0.06875	end
		Smart learning	✓	0.08125	end
		Smart tool	✓	0.0125	end
		Smart food	N.A	0.014583	end
		Smart clothing	✓	0.088542	end
	Smart lifestyle		✓	0.08125	end
	Smart data analysis and processing		✓	0.080208	end
	Smart art		✓	0.05	end

Table 5. The results obtained from the opinions of experts in the smart living subgroup.

grouping	Comprehensive subjects	Organizer subjects	Component status	The difference between the two final stages	Status of the Delphi process
	Smart advertising		✓	0.038542	End
	Smart cultural facilities	Smart religious places	✓	0.029167	End
		Intelligent ancient sites	✓	0.060417	End
		Smart library	✓	0.036458	End
		Smart culture center	✓	0.014583	End
		Smart sports centers	✓	0.053125	End
		Smart theater and performance	✓	0.04375	End
		Smart entertainment venues	✓	0.01875	End
	Smart correlation		✓	0.075	End
	Smart ethnic relations		N.A	-0.03542	End
	Smart prevention		✓	0.088542	End
	Smart accommodation		✓	0.059375	End

Smart nursing home		✓	0.089583	End
Smart living		✓	0.06875	End
Smart suburbanization		✓	0.091667	End
Smart security	Life safety	✓	0.072917	End
	Family and social security	✓	0.071875	End
	Job and financial security	confirmed	0.125	End
	Psychological security	confirmed	0.146875	End

The final results of this method are presented below.

After gathering the opinions of experts in both stages, the numerical difference between the two stages was measured, and if the difference between the two stages was more than 0.1; we were entering the next stage. After 5 repetitions, considering that the difference of variables in two stages for all components was less than 0.1, as a result, the fuzzy Delphi process ended. Some items were removed based on experts' opinions. The rest of the species were not removed and the experts confirmed the items and these items were confirmed based on the opinions of the experts.

In the smart government subgroup, as shown in Table 3, the network technologies were not approved by the experts due to their inheritability, and other items were approved by the experts.

In the smart people subgroup, as shown in Table 4, Smart technical skills, Smart innovation and creativity and smart food were not approved by the experts due to the lack of evaluability and the special nature of these cases, and other items were approved by the experts.

Table 6. The results obtained from the opinions of experts in the smart transportation subgroup.

Grouping	**Comprehensive subjects**	**Organizer subjects**	**Component status**	**The difference between the two final stages**	**Status of the Delphi process**
Smart transportation	Smart clean transportation	Electric vehicles	✓	0.091667	end
		Bike	✓	0.096875	end
		Hybrid vehicles	✓	0.071875	end
		Drones	✓	0.076042	end
		Hyperloop	✓	0.098958	end
	Smart urban traffic	Smart streets	✓	0.091667	end
		Smart parking lots	✓	0.089583	end
		Smart traffic lights	✓	0.079167	end
		Smart street lighting	✓	0.086458	end
		Smart traffic software	✓	0.0875	end

	Smart boards	✓	0.078125	end
Smart stable transportation	Smart human guide	✓	0.061458	End
ICT integrated traffic infrastructure	Public transportation	✓	0.052083	end
Smart road traffic		✓	0.084375	end
	road maintenance	✓	0.0625	end
	rescue aid	✓	0.095833	end
	Car assistance	✓	0.058333	end
	Road informing	✓	0.060417	end
Smart road traffic Safe transportation	Highways	✓	0.085417	End
	Lighting	✓	0.092708	End
	Air transportation	✓	0.097917	End
	Sea Transportation	✓	0.091667	End
	railroad transportation	✓	0.059375	End
Safe transportation Safety and security in transportation	Smoke and gas warning inside the car	✓	0.065625	End
	Anti-theft of vehicles	✓	0.075	End
Safety and security in transportation Autonomous systems	Fire alarm inside the car	✓	0.045833	End
	Car driver status warning	✓	0.065625	End
	Smart self-driving bus	✓	0.065625	End
	Smart self-driving metro	✓	0.092708	End
	Smart Cars	✓	0.097917	End

In the smart living subgroup, as shown in Table 5, Smart ethnic relations was not approved by the experts due to the lack of evaluability and the special nature of this case, and other items were approved by the experts.

In the smart transportation subgroup, as shown in Table 6, all items were approved by the experts.

In the smart economy subgroup, as shown in Table 7, Smart mines and smart seeds were not approved by the experts due to the lack of evaluability and the special nature of these cases, and other items were approved by the experts.

Table 7. The results obtained from the opinions of experts in the smart economy subgroup.

Grouping	Comprehensive subjects	Organizer subjects	Component status	The difference between the two final stages	Status of the Delphi process
Smart economy	Smart entrepreneurship		Confirmed	0.051042	End
	Smart business model		Confirmed	0.071875	End
	Smart creative production and products		Confirmed	0.061458	End
	e-commerce		Confirmed	0.063542	End
	Creative services based on ICT		Confirmed	0.08125	End
	Smart companies and cooperatives		Confirmed	0.044792	End
	Smart export and import		Confirmed	0.066667	End
	Smart startups		Confirmed	0.059375	End
	Smart research and development		Confirmed	0.073958	End
	Smart light and heavy industries	Domestic manufacturing industries	Confirmed	0.063542	End
		Alternate	Confirmed	0.039583	End
		Packaging Industry	Confirmed	0.054167	End
		Assemble	Confirmed	0.058333	End
		Mines	N.A	-0.04271	End
	Smart tourist industry	Smart location	Confirmed	0.036458	End
		Tourist	Confirmed	0.070833	End
		Health	Confirmed	0.088542	End
		Religious	Confirmed	0.078125	End
	Smart selling	Marketing	Confirmed	0.078125	End
		Market-making	Confirmed	0.038542	End
		Market-place	Confirmed	0.054167	End
		Planting and harvesting	Confirmed	0.085417	End

	Smart agriculture	Smart irrigation	Confirmed	0.082292	End
		Smart pest control	Confirmed	0.023958	End
		Smart seed	N.A	-0.07188	End
		Smart animal husbandry	Confirmed	0.064583	End
	Financial systems	Smart banking	Confirmed	0.082292	End
		Smart investment	Confirmed	0.082292	End
		Smart insurance	Confirmed	0.082292	End

In the smart environment subgroup, as shown in Table 8, biological sensors and connection tools were not approved by the experts due to the lack of evaluability and the special nature of these cases, and other items were approved by the experts.

Table 8. The results obtained from the opinions of experts in the smart environment subgroup.

Grouping	Comprehensive subjects	Organizer subjects	Basic subjects	Component status	The difference between the two final stages	The status of Delphi process
Smart environment	Smart buildings			✓	0.064522	end
	Smart energy distribution			✓	0.07135	end
	Smart waste disposal			✓	0.045762	end
	Smart treatment	Smart clinic		✓	0.056214	End
		Smart software		✓	0.068127	End
		Smart health control tools	Smart wearables	✓	0.033458	End
			Biological sensors	N.A	-0.07218	end
			Connection tools	N.A	-0.06154	end
		Smart clinic and hospital	health centers	✓	0.074458	end
			Smart hospital	✓	0.083917	end
			Smart pharmacy	✓	0.0725	end
			Smart emergency	✓	0.069917	end

		Private centers	✓	0.076833	end
		Smart veterinary medicine	✓	0.09175	end
		Smart doctor	✓	0.071583	end
Environmental monitoring and maintenance	Smart monitoring of pastures		✓	0.081225	end
	Smart monitoring of the desert		✓	0.061342	end
	Smart forest monitoring		✓	0.052392	end
	Smart sea and ocean monitori		✓	0.086458	end
	Smart monitoring of rivers		✓	0.072143	end
	Wildlife environment		✓	0.06941	End
	Domestic and wild animals		✓	0.072138	end
Smart pollution control	Smart waste disposal and		✓	0.08674	End
	Smart control of noise pollution		✓	0.063148	End
	green City	parks	✓	0.074592	End
		green belt	✓	0.068201	End
	Drinking water		✓	0.06392	End
Smart energy	Smart energy consumption		✓	0.053274	End
	Smart distribution of water, electricity		✓	0.054213	End

Smart monitoring of energy		✓	0.058192	End
Renewable energies	Solar Energy	✓	0.067	End
	Wind energy	✓	0.043621	End
	Other clean energy sources	✓	0.06702	End
	nuclear energy	✓	0.05611	End

In the model presented for the integrated smart city in [4], three super classes were proposed, but two of these classes were changed by the experts and three classes specified in Table 9 were unanimously replaced.

Table 9. The super classes obtained from the opinions of experts in the smart city.

grouping	Comprehensive subjects	Component status	The difference between the two final stages	Status of Delphi process
Super classes	Knowledge	Confirmed	0.036458	End
	IOT	Confirmed	0.091667	End
	Reliability	Confirmed	0.082531	End

The final result of fuzzy Delphi indicated that 156 components were examined and 12 components were removed from the stated components based on experts' opinions, and 144 components were identified as effective factors that can be the basis of ontology production. Due to obtained results, smart city could be considered and recognized and used as the main classes of this framework.

As mentioned in the previous sections, the 6-part structure of the smart city is currently approved by the majority of users [4], and therefore, in the first step, according to Figure 3, the class of the smart city can be considered as the main class, and the 6 approved parts can be inherited from it. According to experts, this main class will undergo major changes in the future.

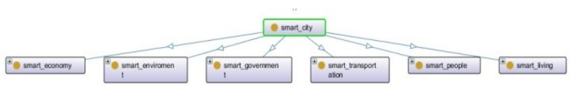

Figure 3. Inheritance of the 6-part smart city model

i. Smart economy

Smart economy refers to a set of factors that give the economy growth and competitiveness. These sets include e-commerce, creative services based on ICT, smart cooperative companies, smart exports and imports, smart startups, research and smart development, smart light and heavy industry, smart tourism industry, smart sales, smart agriculture and financial systems. Based on the division and results mentioned in Table 3, the smart economy can be considered as the root of the tree and other subclasses can be inherited from it as shown in Figure 4.

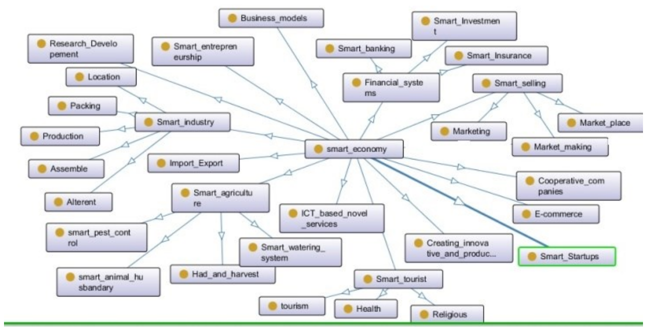

Figure 4. How to inherit sub-classes from the smart economy

The specified subclasses for smart economy are divided into other subclasses according to experts, and the inheritance hierarchy in Figure 4 is clearly visible. Certainly, in any society or country, based on the economic needs and priorities of that society or country, new classes can be defined, classes can be merged or separated, or a part of it can be ignored. In other words, the drawn inheritance tree can be localized for any society.

i. Smart environment

Perhaps, the smart environment can be called one of the most important components of the smart city, which has attracted many researchers to provide efficient models to improve the living environment. The intelligent environment brings broad concepts including health and healthy living conditions. The most important factors involved in the smart environment can be considered as increasing the quality of natural resources, health, pollution control and monitoring, smart advertising, energy distribution networks, smart energy and smart buildings. Again, based on the opinion of experts, the inheritance tree can be drawn according to Figure 5.

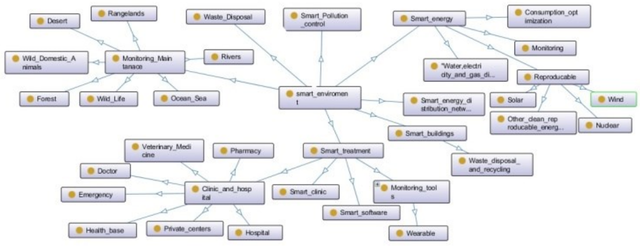

Figure 5. How to inherit the components of the smart environment

As shown in Figure 5, the most important components of the smart environment are placed at level 1 of the inheritance tree, and each one is divided into other subclasses based on the amount of use and the number of factors, and inheritance continues to lower levels. Again, other researchers can localize the inheritance form and the tree based on their preferences.

ii. Smart government

Today, the smart government, which is used in place of the electronic government, as well as the digital government, has its own definitions. Conceptually and functionally, the smart government is at a higher level of abstraction, just as the digital government is at a higher level of abstraction than It is located in the electronic government. If the government and digital governance pursue the lofty goal of reforming the process, the governments and smart governance of the future will definitely seek to improve democratic processes and public services through emerging technologies, and this is where the position of digital policy is to achieve these goals. It becomes bold. In digital policy, the main goals should be, first of all, the discussion of clearing thoughts to create new principles and rational attitudes in order to understand digital developments, and also the identification of beneficiaries, both at the national level and at the regional and world level, should be considered with priority and the principles of preserving national interests, and at the end, policy making following the retrospective method to create a new world should express an institutional mapping or the digital road map of the society. For this purpose, the most important elements that can be mentioned are smart municipality, smart laws, technology infrastructure and decision-making based on wisdom and collective knowledge, smart government services, smart management, data transparency, as well as integration and avoiding isolated services. Figure 6 depicts the classes and their inheritance.

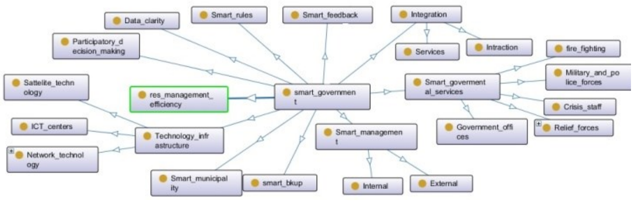

Figure 6. How to inherit sub-classes from smart government classes

As seen in Figure 6, the related main classes or smart government are located at level 1 of the tree and each has its own subclasses, which clearly shows the way of inheritance. Different governments can localize and use the suggested inheritance tree in their government based on their policies and thinking principles and short-term, medium-term and long-term policies.

iii. Smart transportation

Transportation in big cities is a growing challenge for travelers and city officials. With the benefit of new technologies, intelligent transportation systems provide proper management and response to traffic conditions. The intelligent transportation system can make a significant difference in the way passengers travel in dense urban areas and provide better and safer services to city residents, and also save money for municipalities. With smart shipping. Municipalities have new opportunities to incentivize green and efficient modes of transportation, reduce congestion, and improve quality of life. Help in saving costs, providing better services to citizens and better management of safety and security. Therefore, this system becomes an essential element among people. Using technologies such as electronic devices, wireless, and the Internet, smart urban transportation provides access to more accurate, safer, and faster travel between two points in a large city, with richer information and greater control. It provides traffic flow for city authorities. Smart transport infrastructure is often recommended as the first step towards becoming a smart city.

The intelligent transportation system achieves traffic efficiency by minimizing traffic problems. Having prior information about traffic, a user can easily get real-time information, seat availability, etc., which reduces the travel time of passengers as well as their safety and comfort.

Smart transportation is one of the most important components of a smart city to improve the quality of life of citizens and improve sustainability, and the movement of cities towards smartness often begins with the establishment of smart transportation infrastructure in the form of a smart transportation network. Among the important benefits of smart transportation, we can mention things such as quality of life, reduction of pollution, safety and security of public transportation. For this purpose, Figure 7, considering smart transportation as the main class, draws the required components and subclasses and shows how to inherit them.

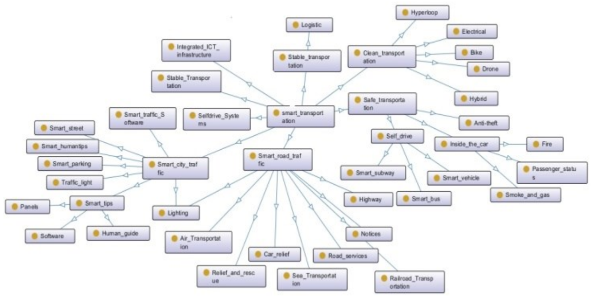

Figure 7. Classes and their inheritance in smart transportation

As seen in Figure 7, the considered main classes are divided into several subclasses and inherited according to experts' opinion. It can also be said that different communities can localize these classes based on their requirements.

iv. Smart people

The goal of Smart People in the Smart City is to transform the way citizens interact – through information or service delivery – with the public and private sectors as individuals or businesses. Creating social and digital equality through education is an important precondition for more efficient provision of information and services based on new technologies. Smart People includes smart forms of education to facilitate career choices, job opportunities, vocational training as well as lifelong learning for all age groups and demographics. Cultivating talents is also an important aspect from the point of view of economic development. Smart people solutions support the creation of an accessible and inclusive environment to increase prosperity and innovation in a city or community. Participation, open mind and creativity are aspects that are possible or cultivated by implementing the solutions of smart people in a smart city. Citizens of smart cities should know how the data obtained from them will be used. People should know what the advantages of these cities are and how they can make the best use of them. In other words, citizens' digital literacy should be increased and people should become "smart". In this way, according to Figure 8, the most important classes and their subclasses can be displayed for smart people.

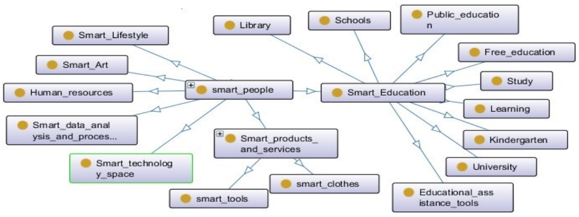

Figure 8. Classes and their inheritance in smart people

As can be seen in Figure 8, the most important subclasses for smart people are placed at level one according to the opinion of experts, and each of these classes is divided and inherited into many other subclasses, depending on its importance and extend. The people of each society can localize these classes and their inheritance method based on their culture and requirements.

v. Smart life

Smart life does not mean living with wise robots or equipment that do their work by themselves, but smart life is a vital solution for optimal use of modern technologies. The concept of smart life seeks to realize three principles in people's lives: facilitating people's way of life, maintaining their health and at the same time protecting the environment. There are many technologies whose potential losses have been fully proven in long-term applications or in uncontrolled conditions. In the concept of smart life, different aspects of using a technology are fully considered and it will be used in the safest possible way to minimize the possibility of creating risks for people's health. Undoubtedly, computers and computer networks play a very important role in the realization of intelligent life, but these components themselves have undergone many changes so that they can be placed in a position where their destructive effects on human life are minimized. In this way, you can draw the subtree of smart life as figure 9 and specify the classes and their inheritance.

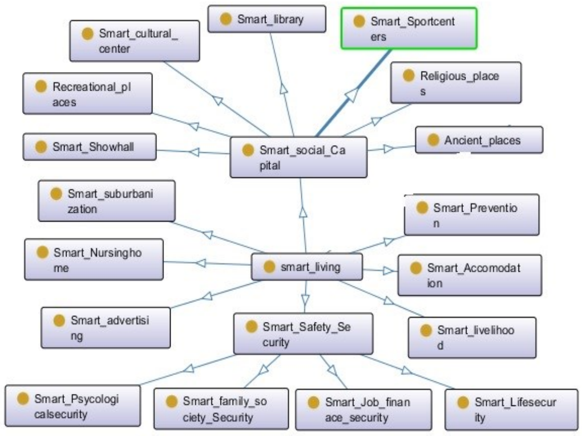

Figure 9. Classes and their inheritance in smart life

As can be seen in Figure 9, the main classes are drawn based on experts' opinions and other classes are subclasses and are inherited from the main classes. Based on the social, cultural needs and expectations of each society, subclasses can be localized and used for that society.

vi. General super classes of the smart city

In a smart city based on the Internet of Things, several components appear in common in all models. These components include dependability and all its concepts, internet of things and all its concepts, and finally, knowledge with all concepts in it. Since these three components are used as three main classes in the entire structure of the smart city, they should be considered as three super classes that the main class of the smart city inherits from all of them and in each of the subclasses of the smart city, Depending on the needs of the subclass, appropriate properties and methods should be added to it. This inheritance can be seen as multiple inheritance in Figure 10.

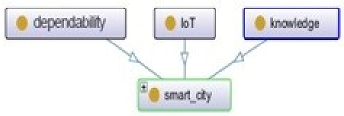

Figure 10. Multiple inheritance of smart city from super classes

As seen in Figure 10, the smart city has multiple inheritance from the three mentioned super classes. Each super class includes several main subclasses. Reliability, availability, safety, integrity, confidentiality, and maintainability are considered for dependability. Internet of Things includes subclasses of hardware architecture, data processing and analysis, and data transmission. For knowledge, knowledge engineering and knowledge management subclasses are included. Therefore, the overall overview of the smart city can be shown in Figure 11.

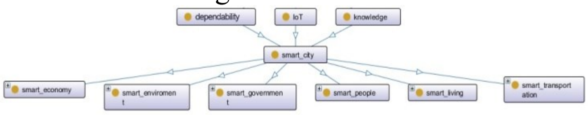

Figure 11. General header of Smart City

As can be seen in Figure 11, the three super classes of reliability, Internet of Things and knowledge are placed at the top, and the smart city class has multiple inheritance from all of them, and it is the main subclasses of the smart city, which are the same 6 main components. , inherits. In this way, by putting all the classes together, the proposed ontology of the smart city can be presented as shown in Figure 12.

As can be seen in Figure 12, the general structure, classes and their inheritance method are given in the whole structure of the smart city, thus forming a comprehensive integrated system. It is noteworthy to mention that the structure of the presented ontology is based on the results of the consensus of experts' opinions and other researchers of any society can use it as a basic reference model and based on social, cultural, economic needs and current policies to localize it in their community.

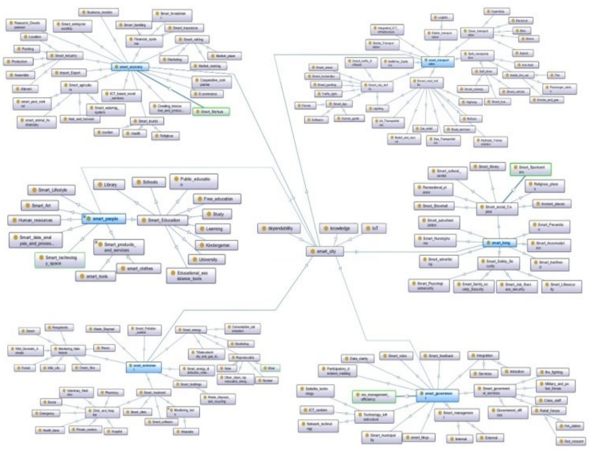

Figure 12. Proposed ontology of smart city

vii. CONCLUSION AND FUTURE WORKS

The concept of smart city has become one of the most popular concepts in the world today, and many researchers from all over the world are engaged in research on it. Many works have been done on it and many systems have been implemented and used in this direction. The breadth and universality of the smart city structure necessitates the need to understand the structure and connections in the smart city, the absence of which has prevented the creation of a unified structure and has replaced island systems with a unified system. The authors of this article, with a complete understanding of the problems of island systems that lead to data redundancy, complete unavailability, low reliability and countless other such problems, for the first time, using collective wisdom and expert opinion, a comprehensive ontology designed for the concept of a smart city, which, in addition to its great strength, for the first time used the concept of super classes in a smart city based on the Internet of Things and showed that the smart city must be inherited from these super classes to make the system more integrated than before.

Considering the ontology presented in this article, there is an urgent need to create and present appropriate proposals to complete the structure, create new classes, merge or break up classes. Also, the important features proposed for each class along with their main methods should be designed and suggested, and the interaction and cooperation of the classes should be investigated.

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