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FUZZY ASSESSMENT MODEL FOR SECTORS PRIORITIES TOWARDS TRANSFORMING NEW CITIES INTO SMART CITIES

"A Case Study of the New Minya City"

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ABSTRACT

Smart technology is a vital key to make cities more efficient in terms of resources usage, which is indispensable to support sustainability and resilience in cities. Nevertheless, limited studies suit the African situation regarding this matter. Also, there are no strategies adopted to define sectors' priorities. This strategy is vital to enable the application of smart technologies and policies of new cities in Upper Egypt. Accordingly, this paper presents a Fuzzy Assessment Model for Sectors Priorities (FAMSP) to distinguish and prioritize sectors in terms of smartness. A focus-group survey was then done to determine the Importance of the sectors (IS) and the low cost of sectors (LS). Results obtained from the survey were applied in the fuzzy model. Fuzzy sectors priorities, FSP is the output of applying the IS and the LS in the model. Finally, this study aims to test the (FSP) through Spearman's and Kendall's tests. Obtained results proved that the proposed model can be used successfully in determining and ordering sectors priorities to be transformed into smart sectors.

Key words: Smart cities, sectors priorities, Fuzzy model.

1. INTRODUCTION

Almost half of the world's urban population resides in urban agglomerations with a population of nearly count of half a million people, while about 13% of them live in major cities with more than ten million inhabitants. Cities such as Tokyo, Delhi, Shanghai, Cairo and Mumbai has a population more than 20 million (United Nations, 2018). As the whole world turns into urbanization; many challenges face the successful management of this urban growth, especially in the low or middle income countries where the rates of urbanization are expected to increase dramatically in 2050 (Eremia, 2017; Service, 2014; Weeks, 2020).

The rapid urbanization and the increasing population may set an overload on the cities' infrastructures and the services they provide with subsequent arise of problems related to health, traffic, pollution, and mismanagement of resources. These problems can hinder the growth of cities if not dealt with in smart and sustainable ways (Joshi, 2016). The current urbanization requires robust strategies and innovative planning to modernize urban life. Many

cities enhance the quality and performance of urban services by adding digital technologies. Thus, governments around the world have started to set the necessary plans to make the existing and emerging cities more smart and sustainable (J. H. Lee, Hancock, M. G., & Hu, M. C., 2014).

Though, in the past ten years, there are a number of researches on smart cities (Beard, Mahendra, & Westphal, 2016), (Angelidou, 2015), however based on authors' knowledge there are few studies in the subject of smart urban progress policies in the African case or how that progress has developed in the African case (Korah, 2021). Also, no strategies were adopted to define sectors priorities for the application of smart technologies and policies that respond to the singular characteristics of new cities in Egypt. As a matter of fact, a latest tendency of "new cities" progress upon the African continent (Van Noorloos & Kloosterboer, 2018) and their agreement of defining the urgent urban sustainability calls,

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reveal some manifestation of smart urban development (Korah, 2021). The degree of execution of smart infrastructure and smart city progress over Africa and the Middle East alters considerably (Sabri, 2021). Developing the assessment's strategies regarding smart city performance, calls for a thorough, multi-regional and flexible paradigm in parallel with regional and national strategic preferences which embraces efficiency, effectiveness and sustainability elements(Sang & Li, 2019). In such embracement, citizens are involved in the process as they are not only users but also performers of smart city strategies. Considering people as the main factor of smart cities implies co-constructing strategies with people all over the policy round(Cities & Growth, 2020). One of the main aspects regarding the comprehension of smart cities is associated with the different forms of cities. Each city is singular in terms of size, built environment, financial resources and numerous other characteristics. Such differences influence the ability of cities to handle smart technologies and catch attention to smart city investment. Various tangible features may also influence the amount of viability of particular smart technologies(Cities & Growth, 2020). Considerable literature on smart cities aims to concentrate on large cities, which makes it hard to convey their experience to smaller cities(Cities & Growth, 2020). The various dimensions of city competitiveness and particularity should be considered (Abusaada & Elshater, 2021). These dimensions vary from the scale of individual homes up to the scale of cities and regions. People and places should be respected in these scales based on the connections built at these various city scales. So far, the recent literature and methods have to be embraced, including digital technologies (Abusaada & Elshater, 2021). A balance between desired strategies and limitations is needed to achieve efficient upscaling. Also, accurately crafted strategic moves are necessary to improve experimental projects at a larger scale (Organization, 2010).

The research aims to establish a mechanism to identify and arrange the priority sectors to be transformed into smart sectors in new Egyptian cities. To achieve this goal, the research depends on achieving a set of interim objectives that are necessary steps to achieve the basic goal. First, this study attempts to provide an explanation of the most important criteria for measuring the smartness of cities and plans for the assessment of global cities to determine the main sectors to be prioritized accordingly. It also develops a new fuzzy model for prioritizing Sectors to be transformed.

2. LITERATURE REVIEW

The smart city model emerged in the twentieth century as an alternative and innovative concept for the city planning. Rapid digital transformation and technological development has led to a rapid trend towards cities that try to achieve the maximum efficiency and quality in the service delivery. With the help of information and communication technologies, new technologies and participatory approaches have emerged (Colding & Barthel, 2017).

The studies and researches on smart cities have diversified. Considerable research and scientific books suggest different definitions, models and methods for developing the concept of a smart city (A., 2019; Li, Fong, Dai, & Li, 2019; Nam & Pardo, 2011). To transform existing cities into smart cities, planners and city managers should survey citizens' opinions and determine local priorities and citizens' requirements (J. Lee & Lee, 2014) . A group of literary researches focused on the use of information, communication technologies and modern technologies as a major driver for the development of smart cities. Other studies confirmed the importance of human resources and city services, and the participation in improving the economic, social and environmental aspects. There are some studies that discuss the means to transform existing cities into smart cities (Kumar, Singh, Gupta, & Madaan, 2020). There are studies that have shown that the use of modern technologies and various smart city applications can improve some indicators of the quality of life by up to 10-30%. Any services that used to be employed in a city can become smart city services.(J. Lee & Lee, 2014). However, global cities that implemented the latest smart technologies are still at the beginning of their journey. Also, the possibilities and priorities need to be determined regarding the implementation of smart city applications (Čukušić, Jadrić, & Mijač, 2019). Numerous previous studies have used the fuzzy logic in setting the priorities. Some studies used the model to determine the priority for the reconstruction of facilities in Syria (Ebrahem, 2016). Other studies have conducted the model to prioritize smart requirements (Ramzan, 2010). On the other hand, some studied have applied the model to help choosing a technique for prioritizing the software (Dhingra, Savithri, Madan, & Manjula, 2016).

2.1. STUDY OF EVALUATION CRITERIA REGARDING SMART CITIES

Many researchers have set different criteria and indicators to evaluate the performance of smart cities, which in turn enhances the abilities of competitiveness of smart cities and contributes to direct the choices of investors. This evaluation is necessary to compare cities and benefit from the best experience - identifying the driving forces of smart cities, identifying points of weaknesses and knowing The needed effort to overcome them - identifying the relative advantages of each city and its strengths, and potential development opportunities, in addition to assessing the current state of development in the city in comparison with other cities - attracts the individuals' attention to the issues related to smart city development, and contributes to educating individuals through which the individuals can identify the foundations of their city, and on its position within the group of cities. There are two main types of indicators; The first type highlights the features of the city by measuring its basic characteristics, and each of these indicators is a composite index, representing a measure that is calculated from several variables. The second type includes a set of city performance indicators, and it is usually organized into 20 topics. It measures a wide range of services of the city, quality of life factors in it, and includes all city services. Each of these indicators is a measure of several variables.(Tok, McSparren, Al Merekhi, Elghaish, & Ali, 2015), Sharifi in 2019 sets a classification of the criteria and indicators for evaluating the smart cities and it studied the points of strength and weakness used in the various evaluation frameworks for smart cities. (Sharifi A, 2019). The study has clarified that most of the standards do not provide specific detailed indicators and data or do not publish all the information needed for in-depth analysis, except for only three standards that provide the necessary details about the indicators (U4SSC - CITYKeys - ITUT). These standards provide details on the indicators and the rationale for each indicator. It improves the objectivity and transparency of the standards, and based on the above, data were collected on the U4SSC initiative standards, which were enumerated and issued in 2017 in the form of a methodology for collecting key performance indicators for smart sustainable cities, which were mainly based on the ITU-T Recommendation issued in 2016. Therefore, it can be based on the initiative of "U4SSC" in applying the dimensions of these standards to the new Egyptian cities.

2.2. STANDARDS OF UNITED FOR SMART SUSTAINABLE CITIES INITIATIVE “U4SSC”

The evaluation process is consisted in setting a list of general standards by which all the physical and intangible components that make up the smart city and the comprehensive management system for all sectors and departments of the city “including the human engine” are measured. Through a hierarchical structure in which each level expresses the level that precedes it, each dimension is represented by number of factors and each factor is represented by number of indicators that were seated in the light of global sustainable development indicators. Each indicator has a weighing factor (relative weight) or degree. It is not important for the indicator to obtain a high score but at least minimum required availability(Huovila, Bosch, & Airaksinen, 2019),The evaluation dimensions are determined in 3 specific sectors with 7 dimensions divided into 26 factors that achieve their performance, and were measured in the light of the performance and descriptive indicators with 93 indicators (Garau & Pavan, 2018) as shown in Table (1) (Abdo, Mohamed, & Orabi, 2021), and when these indicators are combined together in one city, they are achieving a comprehensive view of a sustainable smart city(Sang & Li, 2019).

Table (1) Components of Standards of “U4SSC” Initiative

Number of indicators	Number of factors	Number of dimensions	Number of sectors
93	26	7	3

These indicators are sectioned into two main categories: basic priority indicators and advanced indicators. The first, the priority indicators, are those measures that cities should be willing to apply presently. They are 56 indicators. The second, the advanced indicators, give a more in-depth view of the city. Moreover, advanced procedures can measure progress in more advanced ways. However, implementing advanced indicators may exceed current capabilities of some cities(Sang & Li, 2019). Advanced indicators consist of 37 indicators that were classified into 3 types: indicators with smart actions; indicators with sustainable action; and indicators with structural procedures. Firstly, indicators with smart action are all related to communications and smart applications and are 44 in number. Secondly, indicators with sustainable (environmental) action include 20 indicators. Thirdly, indicators with a structural procedure are all related to construction and basic facilities. They consist of 29 indicators. The sectors that need to be prioritized in new-Minya city “the study area” were drawn from the factors of this initiative and its basic indicators. Figure (1) shows the Structure of smart city indicators according to “U4SSC”.

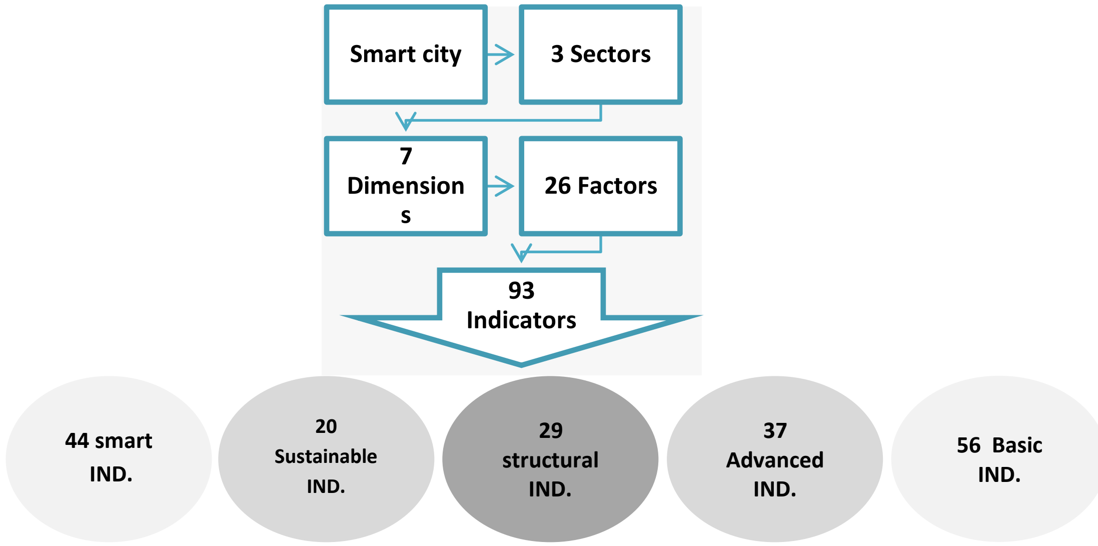

Figure (1) Structure of smart city indicators according to "U4SSC"

3. RESEARCH METHODOLOGY

The goal of transforming new cities into smart cities aims primarily to improve the quality of life through the use of technologies and the provision of appropriate services and content. Within the framework of a sustainable and long-term vision that goal can be attained.

This research is based on the use of qualitative approach and quantitative approach. A focus group survey was conducted. The outputs of the survey were applied to the proposed model. The output of the application was then tested via deductive reasoning. The used methodology consists of 4 steps:

1. The theoretical part:
   This part aims to study the evaluation criteria regarding smart cities. It also aims to classify smart cities indicators and draw a structure according to the initiative "U4SSC", united for smart sustainable cities.

2. A focus group survey:
   This survey was done based on data obtained from the theoretical part with specialists and city officials. It aims to determine the importance of the sectors (IS) and the low cost of sectors (LS). A sample of 70 individuals was selected between specialists and decision makers (city officials in the New Minya City Authority). Specialists who are university professors with experience in the field of city planning represent 64.3% of the sample, which are 45 individuals. City officials and managers from the New Minya City Authority represent the remaining 25 individuals, and 35.7% of the sample. The target sample was asked to give an assessment of each sector of the city. This was done by developing an assessment of the importance of the sector (IS), and another assessment of the low cost of the sector (LS). Likert scale was used through five assessments (very high, high, medium, few, very few). Likert scale is characterized by being easy to build and allowing participants to answer the questionnaire according to the degree of feeling about the statements

3. The fuzzy model for sectors priorities:
   The proposed model was developed to obtain the best results in determining the priorities of the sectors to be transformed in an easy and acceptable way, by linking the "importance of the sector" and the "low cost of the sector". This model is characterized by giving clear results and not relying on the vision of a particular party. The data were analyzed by statistical methods using the computer programs (Matlab v7), (SPSS v20), (Excel v2010).

4. Data concluded from the survey, (IS and LS), were then applied to the proposed fuzzy model to reach fuzzy sectors' priorities (FSP).

5. FSP, fuzzy sectors priorities, were then tested using Spearman's test and Kendall's test.

The research methodology is presented in Figure (2).

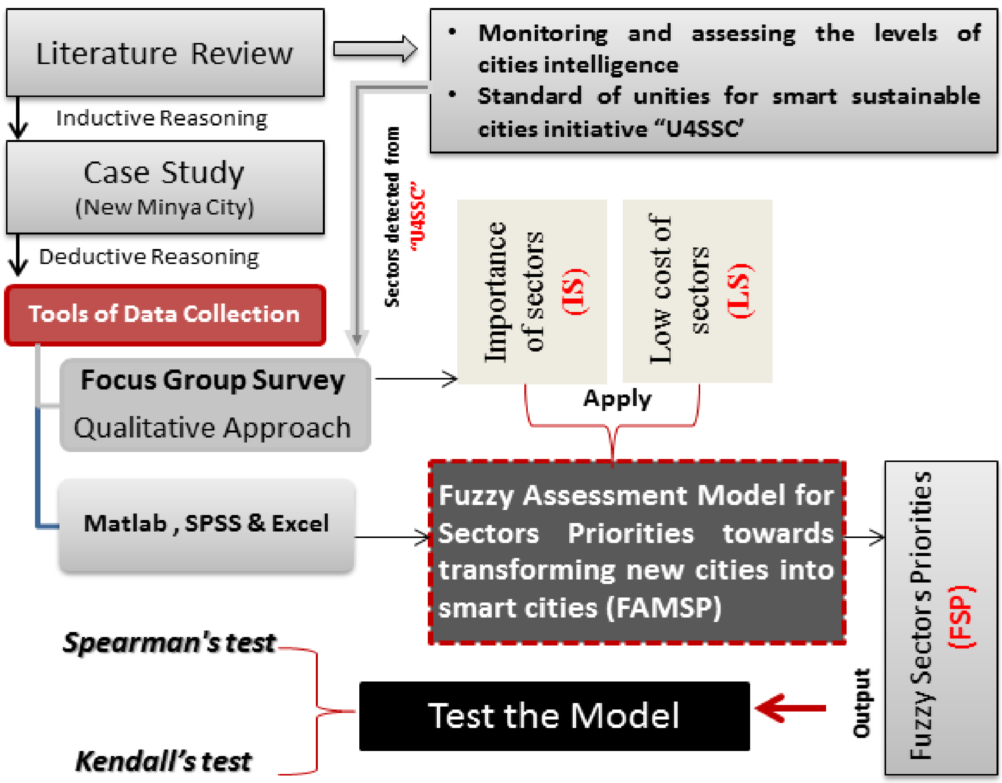

Figure (2) The research methodology

4. CASE STUDY: TRANSFORMING THE NEW CITY OF MINYA INTO A CITY WITH SMART TECHNOLOGIES

New Minya is a city in the Minya Governorate, Egypt. The city is located on the east bank of the Nile from Old Minya and is 250 km away from Cairo. The total area is about 31106.35 acres and the urban block is about 6509 acres. (New Minya City, 2020) Figure (3) shows the Master plan of the new city of Minya.

This area was chosen for several reasons. First, there are considerable similarities between the circumstances of both new Minya city and other new cities in Egypt. For instance, they are similar in terms of the problems, whether they are administrative, environmental, economic, social, constructional, or service problems. They are also comparable in other features such as the urban fabric, and in the level of technology and applications used in their management.

Moreover, the location of New Minya city which is close to the city of Minya, the capital, is distinguished, as it is only 8 km away from the city of Minya and can be reached through different ways, which are connecting to the Nile Miya Bridge. Further, the new city of Minya is close to the researchers 'scope of work. This made it easy to conduct the survey, perform field visits and personal interviews, which resulted in correct and useful results that helped in developing the best strategy for transforming the existing new cities into smart ones. Accordingly, the new city of Minya was chosen as an area for study.

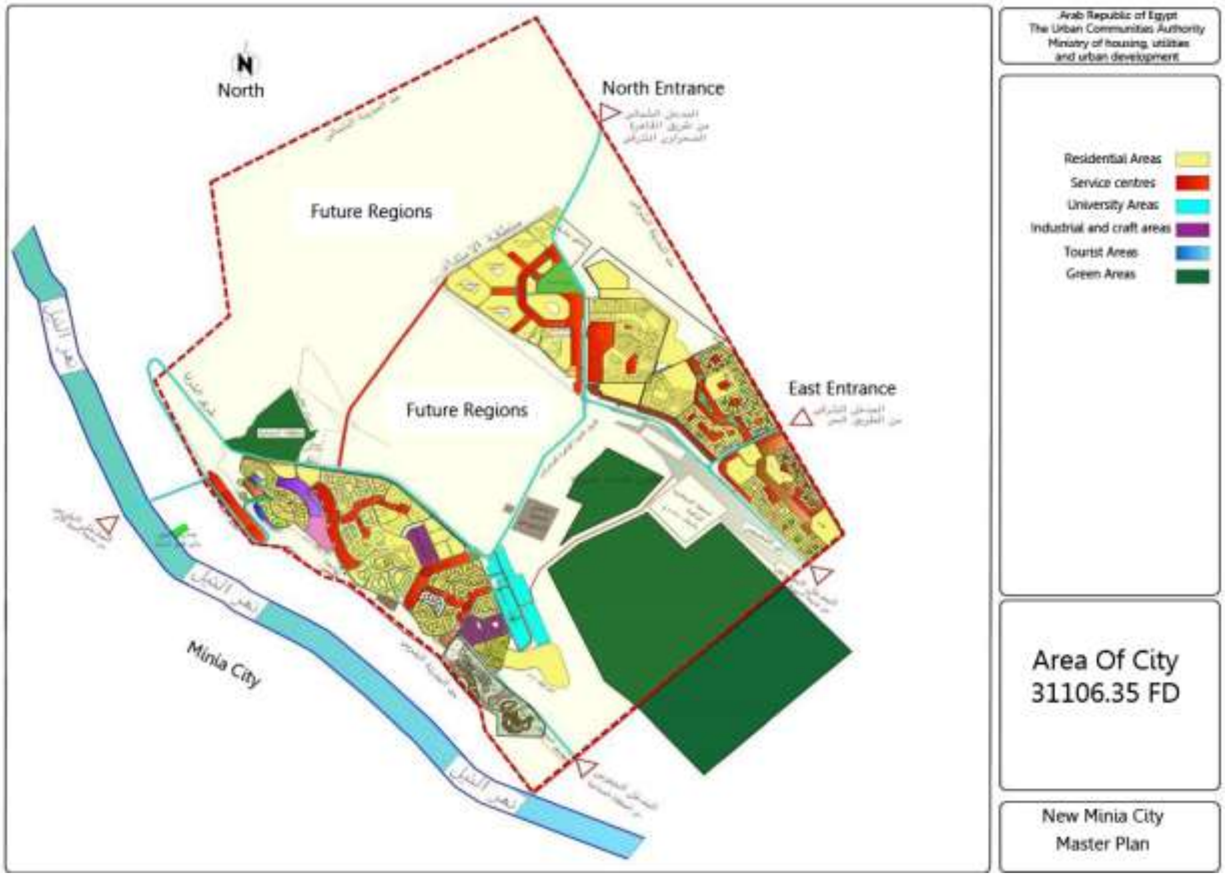

Figure (3) New Minya City Master Plan (New Minya City, 2020)

4.1. THE ANALYSIS AND STRATEGY PHASE TO TRANSFORM THE NEW MINYA CITY INTO A SMART CITY

Where the stages of development and the important variables that must be studied to transform the new city of Minya into a smart city were determined in proportion to the available capabilities in the city, and the priority of each stage according to the priority sectors, where priorities were determined based on a questionnaire distributed to specialists and officials in the city. It was found that there are strategies at the city level that must be taken into account, such as community awareness, where awareness programs are conducted for citizens through various media outlets to educate citizens about technology and its various applications and how to use and adapt to it. This strategy is done when transforming all sectors. As for the rest of the sectors, it is difficult to deal with them at the city level, but they are dealt with step by step. By applying the strategies at the sector level, priority sectors were identified by setting some variables and studying the relationship and correlation of those variables with each other to reach the best results. These variables are (Sector Importance (IS) - Low Cost Sector (LS) - Fuzzy Model for Prioritizing Sectors).

FUZZY ASSESSMENT MODEL FOR SECTORS PRIORITIES (FAMSP)

The point of the proposed model is to distinguish and prioritize segments to be changed into smart ones in new Egyptian cities in a worthy and simple way. It relies on the connections between the Importance of the segment (IS) and the low cost of the division (LS). It ought to be recognized that this model is common and with slight alterations can be effectively adjusted and connected to any other sorts of appraisal. The crisp inputs utilized in this model are two indicators: The importance of the sector (IS) and the low cost of the segment (LS). In arrange to recognize and prioritize sectors, a modern factor list is represented as the output of this model, to be specific Fuzzy Sectors Needs (FSP). FSP shows the significance or the size of a certain factor to prioritize the anticipated sector. Figure (4) shows the inputs and output for the proposed model.

4.2. MEMBERSHIP FUNCTIONS

Participation capacities are recognized to grant a numerical meaning for each phonetic variable (Issa, Mosaad, & Hassan, 2019) . Each participation work distinguishes the extend of input values that compare to each name. Unlike Boolean logic, the participation function of each label does not characterize boundaries, where the label is completely connected to one side of a cutoff and not at all to the other side of the cutoff. Instep, there's a locale, where input values continuously alter from being completely pertinent to totally inapplicable. The membership function utilized within the FAMSP is the triangle shape for all variables inputs and outputs sources as appeared in Figure (5). The comparing fuzzy sets can be characterized as follows:

Very low = (1, 0.67, 0.33, 0, 0, 0, 0, 0, 0, 0, 0)
Low = (0, 0, 0.5, 1, 0.5, 0, 0, 0, 0, 0, 0)
Medium = (0, 0, 0, 0, 0.5, 1, 0.5, 0, 0, 0, 0)
High = (0, 0, 0, 0, 0, 0.5, 1, 0.5, 0, 0, 0)
Very high = (0, 0, 0, 0, 0, 0, 0, 0, 0.33, 0.67, 1)

The labels applied to the field study were planned to fulfill the linguistic factors used within the fuzzy set within the proposed model. For instance, the fuzzy label in the probability of prioritizing a specific division is Trivial, Minor, Moderate, Major, and Extreme. On the other hand, the names (Rare, Impossible, Moderate, Likely, and Very Likely) were utilized to show the degree to which distinctive sectors of the city can impact priority setting. Moreover, the output file (FSP) was spoken to by 5 labels (Very Low (VL), Low (L), Medium (M), High (H), and Very High (VH)). Each label is connected to a fuzzy set as depicted in Figure (5). The overlap ratio and overlap vigor were calculated and checked.

Figure (4) Inputs and outputs for the *FAMSP*

4.3. DEVELOPING A FUZZY MODEL TO DEFINE SECTORS PRIORITIES THAT NEEDS TO BE TRANSFORMED

The Crisp Input that will be used in this model are 2 variables (indicator) which are "Importance of sector index" - IS, "Low sector cost index" - LS. The results will be analyzed depending on the results of the analysis of the proposed fuzzy model. The indicators of the importance of the sector and the low cost of the sector will be arranged and applied to the fuzzy sector priority index to determine the sectors' priorities. Then the results will be compared to each other.

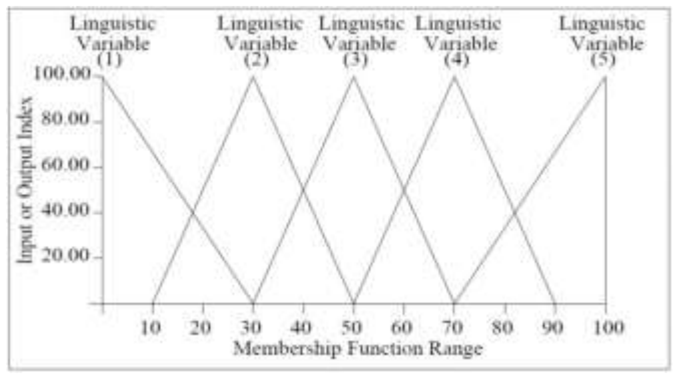

Figure (5) Membership functions used for proposed model

This will also be confirmed by statistical methods using the spearman test, which is used to discover the strength of the association between two sets of data.(Finkelstein & Levin, 2000) described the degree of rank of Spearman's correlation coefficient as (a measure of the linear relationship between two sets of data ranks, and it measures the tightness of the data arranged around a straight line), and the degree of rank for Spearman's correlation coefficient, like all other correlation coefficients, **takes Value between -1, + 1; In a positive relationship**, the ranks of all factors increase together. In the negative relationship, the ranks of one factor increase while the rank of the other factor decreases in turn. Correlation -1 or +1 arises if the relationship between two factors is completely linear, but in the absence of a linear relationship between the ranks, the value of the correlation coefficient is zero.

Sectors' priorities were extracted and arranged in New Minya City, based on numerous studies. These studies are represented in the criteria and schemes for assessing the intelligence of cities and the sectors, dimensions and indicators they contain. It is also represented in the aspects of intelligence in the new city of Minya and the possibilities available in it, which are as in Table (2).

Table (2): The sectors to be prioritized and transformed into smart sectors

The sector to be transformed into a smart sector	ID
Citizen participation	1
Identity and culture	2
Economy and employment	3
Education	4
Health	5
Open spaces	6
Housing	7
Transportation and mobility	8
Ability to walk	9
IT connection	10
Smart government services	11
Energy sources and supply	12
Water supply and sources	13
Wastewater management	14
Waste management	15
Water quality	16
Air quality	17
Energy efficiency	18
Electricity infrastructure and utilities	19
Health facilities	20
Safety	21
Climate change	22

Table (3) Descriptive Statistics of methods used to prioritize sectors

	N	Range	Minimum	Maximum	Mean	Std. Deviation
IS	22	.33	.50	.83	.682	.098
LS	22	.57	.21	.78	.579	.149
FSP	22	.40	.40	.80	.625	.104

Table (3) shows the statistical results of the variables used to determine the priorities of the sectors that need to be transformed or made smart. The table shows that the variable of sector significance (IS) lies between a minimum of 0.5 and a maximum of 0.83 with a mean value of 0.68 and a standard deviation of 0.098. While the variable LS segment falls between a minimum of 0.21 and a maximum of 0.78, with a mean value of 0.57 and a standard deviation of 0.14.The fuzzy logic variable (FSP) is between a minimum of 0.4 and a maximum of 0.8 with a mean value of 0.625 and a standard deviation of 0.1. It is also evident that the standard deviation of the sector cost variable and the fuzzy logic variable are close, which means that the results of the sectors' priorities are converging between the two variables. Figure (6) shows a comparison between the average value of IS, LS, and FSP.

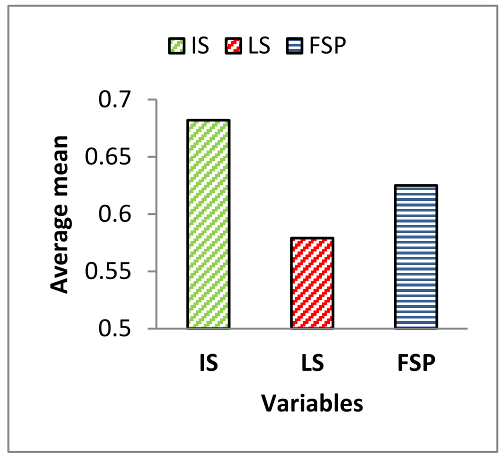

Figure (6) The average mean for the three indices

Through the statistical results in Table (4) for the Kendall's test and Spearman's test, we find that the correlation coefficient between FSP and "LS" is the highest in the two tests. The test factor is 0.732 in the Kendall's test, which is the highest correlation coefficient between two groups, while the Spearman's test factor is 0.859. Therefore, the results of the fuzzy logic model can be taken into account to determine sectors' priorities to be converted into smart sectors in New Minya City.

4.4. SECTORS PRIORITIZATION ACCORDING TO THE FUZZY MODEL

The education sector is of first priority, followed by the smart government services sector, the information technology communication sector, safety and security, waste management, energy efficiency, and cultural spaces. At the end comes the sector of climate change, economy, employment, health and the ability to walk, as shown in table (5).

Table (4) Statistical results of the strength of correlation between two sets of data

	IS	LS	FSP

Table (4) Statistical results of the strength of correlation between two sets of data

Kendall's Test	IS	Correlation Coefficient	1.000	.145	.413*
		Sig. (2-tailed)	.	.350	.011
		N	22	22	22
	LS	Correlation Coefficient	.145	1.000	.732**
		Sig. (2-tailed)	.350	.	.000
		N	22	22	22
	FSP	Correlation Coefficient	.413*	.732**	1.000
		Sig. (2-tailed)	.011	.000	.
		N	22	22	22
Spearman's Test	IS	Correlation Coefficient	1.000	.201	.532*
		Sig. (2-tailed)	.	.369	.011
		N	22	22	22
	LS	Correlation Coefficient	.201	1.000	.859**
		Sig. (2-tailed)	.369	.	.000
		N	22	22	22
	FSP	Correlation Coefficient	.532*	.859**	1.000
		Sig. (2-tailed)	.011	.000	.
		N	22	22	22

Table (5) Prioritizing the sectors according to a fuzzy model resulting from (IS,LS,FSP)

Ranking according to low cost (LS)	Ranking according to importance (IS)	Ranking according to the Fuzzy Logic Model (FSP)	Sectors to be prioritized	Sector No.
3	4	1	Education	4
1	2	2	Smart government services	11
2	1	3	IT connection	10
6	5	4	Safety	21
4	6	5	Waste management	15
8	9	6	Energy efficiency	18
10	7	7	Cultural places	2
12	8	8	Transportation and mobility	8
9	14	9	Water quality	16
11	11	10	Wastewater management	14
13	10	11	Energy sources and supply	12
14	12	12	Citizen participation	1
15	16	13	Health facilities	20
5	20	14	Air quality	17
18	17	15	Water supply and sources	13
22	3	16	Electricity infrastructure and utilities	19
7	18	17	Open spaces	6
17	19	18	Housing	7
21	13	19	Economy and employment	3
19	15	20	the health	5
16	21	21	Ability to walk	9
20	22	22	Climate change	22

5. CONCLUSION

Considering the foregoing about the methodology for transforming the new cities into smart cities, some conclusions were drawn as presented below:

1. This study presented a structure according to "U4SSC". Sectors were included from this initiative. Then, they were surveyed to determine the priority of sectors.
2. Through the focus group survey, this study could determine the (IS) and (LS) in New Minya city.
3. This paper has proposed a new fuzzy model (FAMSP) using the computer programs (Matlab v7), (SPSS v20), (Excel v2010) and based on previously mentioned survey outputs. Accordingly the FSP was designed.
4. This study proved that FSP is important to obtain the best results in determining the priorities of the sectors to be transformed in an easy and acceptable way.
5. FSP applicability was confirmed through Spearman's test and Kendall's test.

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