Article

The Novel Paradigm of Economics Driven for Local Smart Sustain Cities Modeling Using Exploratory Factor Analysis and Planning Technique Using Fuzzy Evaluation Decision Making

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Abstract: The Smart Cities (SCs) models currently widely employed are identical and inconsiderate of Economics Driven (ED), Local Context (LC), and Sustainability (St) factors. These are key factors to driving, constructing, and developing smart cities. This paper presents a process wherein "the Local Smart Sustain Cities Model (LSSCsM)" is combined and modeled with Exploratory Factor Analysis technique (EFA) to design a smart city that fits the local features of a given area. This particular process creates a Smart Cities Model (SCsM) that has unique sustainability and local context factors. This paper also presents the smart cities Priority Action Ranking (PAR) process using Fuzzy Logic Decision Making (FLDM) to evaluate the strengths and weaknesses of each smart city economics driver and characteristic and prioritize the direction planning of each factor and characteristic. The resulting smart cities model can then be used as the foundation of sustainable smart cities that avoid the pitfall of using incompatible smart cities models as the base and consequently failing, thus avoiding the extravagant costs associated with an unsuccessful project of such scale.

Keywords: local context; economics driven; smart cities; sustainability; planning; EFA; fuzzy logic; decision making

1. Introduction

Originally, Smart Cities (SCs), by definition, were most concerned with using technology to develop a given city towards sustainability. The internationally-acknowledged definition of the word [1] gives the same general definition of the concept. The particulars may vary depending on the way each city developer or architect of SCs defines the word to describe the idea of SCs that fits their sensibility, but the theme remains consistent: SCs improve and develop their communities in the pursuit of quality of life and environment betterment by means of employing extensive Information Communication Technologies (ICT) and Internet of Things (IoT) in all the facilities that the city provides [1].

The first mention of SCs were made in The Technopolis Phenomenon—Smart Cities, Fast Systems and Global Networks [2], in which "Tatsuno" described the concept of SCs as a metaphor for intelligent cities and a distribution of globally-networked cities' economic nodes that cooperate and converge, linked though airports, tollways, and communications, all reliant on a "knowledge processor" connected to "rapid information exchanges." Moreover, the book also provides the word "Technopolis," a city of technology, which is a concept closely linked to SCs [2,3]. Expectation has

been set to use the SCs concept to develop and improve the quality of cities and citizens. Kummitha and Crutzen [4] reviewed 211 and studied and concluded that there were only two primary drives of SCs implementation including ICT and IoT technologies [5]. Other studies focused more on the human driven factors, such as convenience and safety [6,7]. Other studies pointed more to the importance of administration and institutions that are critical to a successful SCs [8]. If one were to examine these studies closely, they would find that none of them focused on an important driver, i.e., economics, which is essential to maintaining the well-being of citizens, businesses, and the government. Disregarding economics as a factor potentially brings poverty and social disparity concerns, leading to an imbalanced SCsM [9,10]. Even those studies that mentioned economics failed to address it as anything more than an opportunity that, with the help of technology, can be expanded and capitalized upon [11].

In truth, ED is an important factor of the Sustainability Model (StM), widely lauded as one of the best and most balanced models for multifaceted development that has long been in use [12]. The last two decades saw StM used in developing communities and metropolitans, with the aims to achieve balance in economics, environment, and social condition, as well as developing cities into ones that are attractive and competitive [13,14].

Many studies pointed to the importance of StM to SCsM, as it fills the gaps of SCs, making it more complete. Trindade [12] collected 630 St and SCs related articles from reliable sources (Scopus, Emerald, and Science Direct) and selected 97 of them that are clearly relevant to St and SCs to study on. Twenty-five significant articles were then chosen. Only some of these articles mentioned economics, and mostly in a way that describes economics as an opportunity [7,15–17], but not as the main driver to ensure a sustainable SCs. This research thus presents driving Smart Sustain Cities Model (SSCsM) primarily through ED, as an effort to address this flaw of SCsMs.

Neirotti [7] interestingly commented that "a city's GDP, indicative of a city's economic growth, influences the creation and development of SCs in many ways, most importantly local economic conditions and development rate, which is a significant drive for continued economic expansion. This directly affects the available financial resource of a city, allowing investment in developing public transportations, basic facilities, or education". A city with a well-developed economy is also one with a clear image of striving towards the betterment of citizens' quality of life [18,19].

SCsM has been used in many countries, many times disregarding entirely the regions' LC, or that each country and each city has different characteristics and structure. One of the most popular models is Giffinger's, which consists of six dimensions, namely smart mobility, smart people, smart economy, smart environment, smart government, and smart living [6] (Figure 1), and is a model conceived through surveys and analysis in an effort to rank 70 small- and medium-sized SCs in Europe. Basing future city models in other areas throughout the world on data collected only from European cities may prove impractical. However, Santana [20] concluded that the SCsMs in wide use in different regions are still based on the six dimensions of Giffinger's model (Figure 1).

In Figure 1, it is clear that Giffinger's SCsM has been in wide usage throughout the world, both in its full capacity including the six dimensions of SCs Europe Model, and, in some cases, used partially. Weed, Junkes, and ISO 37122 for example opt to use the model in full. Gramma, Moraes, and Rbeih excluded smart economy from the model. Clark chose only to include the aspects of smart economy, smart people, smart governance, and smart mobility. Intelit chose to include smart governance and smart mobility, while Meijerring chose smart governance, smart mobility, smart environment, and smart living. Guimaraes chose smart people, smart mobility, smart environment, and smart living [20]. The countries selected to be used with Giffinger's SCs Europe model, however, were fundamentally different from European cities, making application of the model and using the model to create SCs that fit with the needs of each of these countries' citizens impractical.

Giffinger et al. (2007)	Smart Economy	Smart People	Smart Governance	Smart Mobility	Smart Environment	Smart Living
Inteli (2012)	Smart Economy	Smart People	Smart Governance	Smart Mobility	Smart Environment	Smart Living
Gamma,Alaro & Peixoto (2012)	Smart Economy	Smart People	Smart Governance	Smart Mobility	Smart Environment	Smart Living
Clarke (2013)	Smart Economy	Smart People	Smart Governance	Smart Mobility	Smart Environment	Smart Living
Weiss (2016)	Smart Economy	Smart People	Smart Governance	Smart Mobility	Smart Environment	Smart Living
Weed (2017)	Smart Economy	Smart People	Smart Governance	Smart Mobility	Smart Environment	Smart Living
Atieda (2017)	Smart Economy	Smart People	Smart Governance	Smart Mobility	Smart Environment	Smart Living
Junkes (2017)	Smart Economy	Smart People	Smart Governance	Smart Mobility	Smart Environment	Smart Living
ISO 37122 (2017)	Smart Economy	Smart People	Smart Governance	Smart Mobility	Smart Environment	Smart Living
Meijeringa,Kern & Tobi, (2018)	Smart Economy	Smart People	Smart Governance	Smart Mobility	Smart Environment	Smart Living
Moraes (2018)	Smart Economy	Smart People	Smart Governance	Smart Mobility	Smart Environment	Smart Living
Rbeih (2018)	Smart Economy	Smart People	Smart Governance	Smart Mobility	Smart Environment	Smart Living
Guimaraes (2018)	Smart Economy	Smart People	Smart Governance	Smart Mobility	Smart Environment	Smart Living

Figure 1. Smart cities model based on the 6 dimensions of Giffinger (blue highlight means using).

The Figure 2; SCs literature review matrix illustrates that only three significant studies took the initiative to consider LC as a factor [6,7,20], and mentioned, although briefly, its importance to a complete SCs and solving issues citizens of SCs may have. The SCsM to be expanded upon thus must be of individual of LC [9,10].

"There is no unique global definition of SCs, and that the current trends and evolution patterns of any individual SCs depend to a great extent on the LC factors" [7]. Santana and Nunes [20] also made an interesting observation on LC and SCs and the evaluation of the model, which fits with this research's modus operandi "to not use the same solution or standard with all regions and areas as each region has its specific characteristics". In assessment of each of the SCs' performance, all characteristics of the SCs must also be classified and evaluated as to produce an accurate and truthful evaluation process, whereupon the best solutions can be had and applied based on each city's true needs.

This paper thus focuses on ED as the primary drive of SCs, as opposed to a growth opportunity or perk that is born of another aspect of SCs. Driving SCs primarily using ED is a largely an unexplored field, as highlighted in the review matrix Figure 2. Moreover, this research also presents the mathematical modeling of LSSCsM, as can be seen in SCs review matrix, showing that only 4 previous studies were conducted mathematically, while the large majority of existing studies were descriptive in nature. The first part of this research presents an indicator set relating to SCs and St used worldwide (ISO 37120, ISO 37122, ESTI-TS 103-463, ITU-TY 4901, ITU-TY 4902, and SCs ranking of Europe medium-sized cities), totaling at 428 relevant indicators. These indicators are then examined through qualitative research methodologies, including processing the indicators through surveys and grading to select only the most relevant indicators for LSSCsM by experts and local stakeholders. The results are then input into statistical EFA calculation programs to finally create LSSCsM that can

serve as a base of a successful and sustainable SCs that truly fits the needs of the local community, while not being prone to failure and the extravagant cost that is to follow.

Author(s)	Title	SCs Core Driven				Sustainability			Research Method			LC	Index	Stat.	Model
		Techno	Human	Institute	Economics	Social	Environ.	Economics	Descriptive	Mat.	Skeptism				
Llacuna (2016)	The intelligent Method (I) for making "smarter" city project and plans								x						
Gibson.(1992)	The technopolis phenomenon: Smart cities, Fast Systems, global networks; 1.Technopolis: Challenges and Issues: A Tale of (at Least) Three Cities ; 2.The Multimedia City of the Future					x			x						
Valentin (2000)	A guide to community sustainability indicators					x							x		
Valentin (2000)	Sustainability and urban policy in Germany—retrospect and prospect					x			x						
Paroutis (2014)	A strategic view on smart city technology: The case of IBM Smarter Cities during a recession	x							x						
DHS (2014)	National Network of Fusion Centers Final Report												x		
Gibson (1992)	The technopolis phenomenon: Smart cities, Fast Systems, global networks														
Giffinger (2007)	Smart Cities Ranking of European medium sized cities											x			x
Santos (2018)	The use of ISO 37122 as standard for assessing the maturity level of a smart city								x			x			x
Calzada (2015)	Unplugging: Deconstructing the Smart City	x	x	x					x		x				
Caragliu (2011)	Smart cities in Europe	x	x						x					x	

Author(s)	Title	SCs Core Driven				Sustainability			Research Method			LC	Index	Stat.	Model
		Techno	Human	Institute	Economics	Social	Environ.	Economics	Descriptive	Mat.	Skeptism				
Richter (2015)	The smart city as an opportunity for entrepreneurship.	x							x						
Datta, (2015a)	A 100 smart cities, a 100 utopias	x							x		x				
Evans (2002)	Smart City more than broadband network		x					x	x						
Holland (2008)	Will the real smart city please stand up?		x						x						
Santangelo (2015)	A (more?) intelligent city	x							x						
Graham (2002)	Bridging Urban Digital Divides? Urban Polarization and Information and Communications Technologies (ICTs)		x					x	x						
Angelidou (2015)	Smart cities: A conjecture of four forces	x	x												
Letaifa (2015)	How to strategize smart cities: Revealing the SMART model	x	x												
Bunnell (2015)	Smart city returns. Dialogues in Human Geography	x	x						x						
Hoornweg (2011)	Smart cities for dummies		x						x						
Hill (2013)	On the smart city; or, a 'manifesto' for smart citizens instead		x						x						
Orlikowski (2000)	Using technology and constituting structures: A practical lens for studying technology inorganisations		x						x						
Toppeta (2010)	The smart city vision: How innovation and ICT can build smart, "livable",sustainable cities.		x			x			x						
Eger (2003)	Smart Communities, Universities, and Globalization: Educating the Workforce for Tomorrow's Economy		x	x					x						
Waart (2015)	A participatory approach for envisioning a smart city		x						x						
Leydesdorff (2011)	The Triple Helix Model and the Meta-Stabilization of Urban Technologies in Smart Cities			x					x					x	x
Rudmann (2008)	Entrepreneurial skills and their role in enhancing the relative independence of farmers,		x						x						
Moser (2015)	New cities: Old wine in new bottles?								x		x				
Hogan (2012)	ViewpointAsian urbanisms and the privatization of cities								x		x				
Huovila (2019)	Comparative analysis of standarddized indicators for Smart sustainable cities: What indicators and standards to use and when?					x							x	x	
Lazaroiu (2012)	Definition methodology for the smart cities model	.	.	.	.	.	.	.	.	x	.	.	x	x	x
Neirotti (2014)	Current trends in Smart City initiatives: Some stylised facts		x					x		x		x	x	x	x
Anand (2017)	Evaluation of sustainablity indicators in smart cities for India using MCDM approach					x	x			x			x	x	x
Dall'O (2017)	Evaluation of cities's smartness by means of indicators for small and medium cities and communities: A methodology for Northen Italy									x			x	x	x

Figure 2. Smart cities article literature review matrix.

Furthermore, this paper also presents the SCs-PAR for planning process using FLDM, wherein strengths and weaknesses of each SCs and characteristic are evaluated and prioritized, with recommendation for the direction each of the factors and characteristics should be taken towards.

2. Smart cities driven

Kummitha and Crutzen [4] collected all studies on SCs from 1999–2016 from reliable sources (the Wiley online library, the Oxford Journal database, Taylor and Francis Springer, Scopus, Sage and Elsevier 's ScienceDirect), totaling at 211 studies. The studies can be separated into two categories, including technology driven studies, and human driven studies. Some outliers focused on additional drives to SCs such as Institution [8]. Mode,Varin and Wanchai [9,10] found some studies made mentions of economics and attempted to link economics with SCsM, but ultimately did so in a way that sees SCs as a driver of economics, when in truth SCsM needs its own ED to remain thriving and sustainable. SSCsM can be summarized hence as shown in Figure 3.

It cannot be denied that StM is an efficient and balanced model that has been in use for a considerable amount of time (three core driven consist of economics, environment and social). SCsM, on the other hand, only began to focus on the driving aspects [4,8] but still did not consider an important core drive that is ED [9]. This research emphasizes ED to complete the core drives of SCs, leading to a model of successful and sustainable SCs as shown in Figure 3. SSCsM, with many studies attempting to consolidate into a single model, lacks the emphasis on the key link that is economic factor. That the aforementioned research was not successful in completely linking SSCsM was due to the complete absence of ED factor in SCs. This resulted in an incomplete linking of the two models.

This research thus focuses on ED, which is an important yet mostly absent driver of SCs found in St, being that a successful SSCsM should be driven by ED. This research gathers 428 SCs and St relevant indicators from various sources (ISO 37120, ISO 37122, ESTI-TS 103-463, ITU-TY 4901, ITU-TY 4902, and SCs ranking of Europe medium-sized cities.) These indicators are then examined by experts and input into statistical calculation programs using EFA method. The results from this process, through calculations of correlation values between the factors and categorization of components using EFA method, are considered important driving factors of LSSCsM. These results are shown in this research.
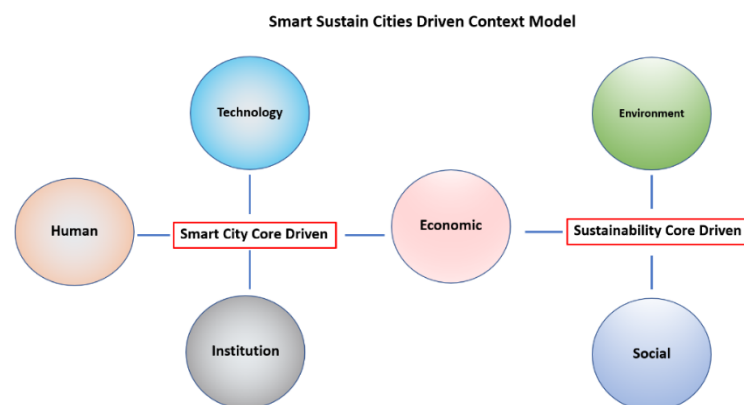

Figure 3. Smart cities and sustainability economics core driven connection.

3. Indicator of Local Smart Sustain Cities and Current Smart Cities Modeling Method

Huovila [21] studied and collected SCs and St relevant indicators in global use and found that the optimal indicator set was one from ISO 37120, ISO 37122, ETSI-TS 103-463, ITU-TY 4901, ITU-TY 4902, (this research does not use ITU-TY 4903 and Sustainable development goal), and one from this research where 74 EU SCs ranking indicators are added, for a total of 428 indicators, 25 duplicated meaning indicators have been found and cut, and the resulting indicator set is complete and optimal

for creation of LSSCs to further drive the model's economy. The below is the area where each indicator set focus on;

- ISO 37120; Sustain development of communities—indicators for city services and quality of life [22]
- ISO 37122; Sustainable development in communities—indicators for smart cities [1]
- ETSI-TS 103-463 Key performance indicators for sustainable digital multi-service cities [23]
- ITU-TY 4901; Key performance indicators related to the use of information and communication technology in smart sustain cities [24]
- ITU-TY 4902; Key performance indicators related to the sustainability impact of information and communication technology in smart sustainable cities [25]
- SCs Ranking of Europe medium-sized cities [26].

Currently, SCsM methods in use are almost exclusively qualitative, with few recent studies employing quantitative method [7,15,27,28]. Using qualitative modeling method means that the results cannot be achieved using statistics or quantification processes, but the resulting qualitative information group can be used as designs or engineering guidelines, rules, or checklists to further develop the model. The trade-off is that results from qualitative modeling method may vary based on the knowledge of the individual using the model [29–31].

Quantitative modeling method, on the other hand, helps identify a critical flaw of a product or process, and can be used to find the best alternative of a process. Results are also easy to decipher, owing to the numerical nature of the method which translates well to graphical display, scoring, or indexing [30,32,33]. This paper looks at the gap in the development of SCsM, and so presents the Factor Analysis (FA) process of LC, St, and SCs, model creation using EFA, model creation using statistical programs, evaluation of decision making for SCs type, and model creation from data of a city's basic economic structure using Fuzzy Logic Evaluation (FLE) and calculating program. The SCsM from this research, as such, are not one based on vague description or baseless assumption, but one conceived through analysis of statistics and economic information. The numbers presented by the SCsM are thus accurate, clear, grounded in reality, and suitable for the actual community the model is based on.

4. Methodology

4.1. Research Design: Quantitative Dominant Crossover Mixed Analysis Solution

This research employs a 2-phases research framework, with crossover mixed methodology research design [34], both quantitative and qualitative evaluation tools are used concurrently, Figure 4 illustrate the framework diagram. The first phase of this research is the qualitative analysis phase, aimed to collect and plan the model, and to extract statistical information that is used in the quantitative phase. Activities include

- collection of relevant indicators collected from reviews
- creation of questionnaires using suitable indicators for LSSCs selected from reviews and by experts
- collection of LSSCs information from model cities, data improvement and testing using statistical programs
- LSSCs modeling with EFA.

In this phase, all 428 SSCs indicators collected and referenced from ISO 37120, ISO 37122, ETSI-TS 103-463, ITU-TY 4902 [21], and EU SCs ranking [26] are examined to find suitable indicators for each work. Experts then select these indicators to create factors, with each factor being defined by 1–6 jointly indicators [6]. The factor sets are then made into a questionnaire using Thailand local expertise, to create LSSCs indicator set that serves as a suitable base to further develop LSSCsM.
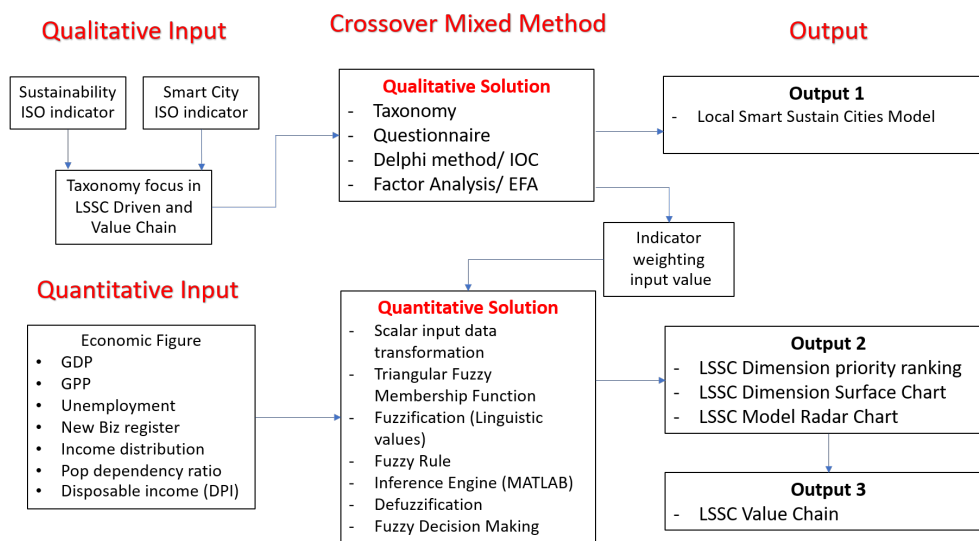
Figure 4. Research framework diagram.

The questionnaire is then used to make survey with the stakeholders, which, for this research, is the population of Rayong province, the testbed of the resulting model of this research statistical values are collected from sample groups including government sector, business sector, citizen sector, and relevant stakeholders of Rayong province. The judges are then provided with surveys to select LSSCsM indicators to trim the indicators down to only those with the highest relevance, being that the end goal is to develop Rayong into a SSC. The judges' input are taken both for consideration of relevant drivers and characteristics.Collected data is then reexamined and shaped into a model using EFA, which is a testing process for indicators' correlation structure and grouping of components/dimensions of LSSCsM.

4.2. Factor Analysis and EFA Method

FA has been used as an analysis instrument for a long time since the work of Pearson and Spearman; the practical application of this approach has been suggested to be in fact of a modern research [35]. Spearman's work has shows the origin of the concept and the theory of EFA process. Even though these processes have been pointed to throughout many decades, in reality they were only expansively applied when the computer and software systems in the area of statistics could employ the analysis technology. FA is usually applied in the fields of psychology and education and in the decision-making process for the interpretation of self-reporting questionnaires. FA is the analysis of the data with many statistical variables which is widely applied with 3 principles

- FA is used to lessen the large quantity of variables or components
- FA generates the structure of the model from measured variables and latent constructs and it also helps the formation and refinement of the theory
- FA is used for the validity of structure of self-reporting scales [36].

EFA is the process for testing the correlation structure and lessening the unnecessary variables of the indicator, and this results in the combination of components namely various dimensions in LSSCsM. After the indicator set was achieved, the data will go through the EFA process by applying statistic program to analyze the correlation of factor.

4.2.1. The Kaiser-Meyer-Olkin (KMO)

Equation (1) is the statistical value that is used as the index of the ratio of variance value in variables that are caused by underlying factors [37].

$$KMO = \frac{\sum r_i^2}{\sum r_i^2 + \sum (partial\ correlation)^2} \tag{1}$$

where *r* = the correlation matrix. The small value of KMO (going to 0) indicates that the factor analysis did not match with the data; the high KMO value (going to 1) means that the factor analysis is appropriate for the data.

4.2.2. Bartlett's Test of Sphericity

The hypothesis testing of correlation matrix which would indicate the variables that are not relevant to and suitable for the structure detection, and the Bartlett's value that is lower than 0.05 is a significant level in FA and is thus acceptable [38].

4.3. Fuzzy Logic Decision Making Method

Apart from shaping the LSSCsM, a developed PAR model also plays a significant role in managing limited time and resources [27]. The Fuzzy Logic (FL) application used in control is widely used in many fields and can solve multiple issues by converting data into Fuzzy Membership Function FMF) whether non-mathematical model, ambiguities, partial quantifications or complex concept. FL can also process the calculation of factors that are in different forms using "Linguistics variable (LV)". Some factors that are significant but cannot be quantified cannot be used in the traditional mathematical models [30]. These include factors that cannot be numerically defined (e.g., those from qualitative studies.) FL, however, can evaluate these factors, making it a suitable tool for the research, as the primary inputs of this research consist of;

- Qualitative data input from phase one
- Quantitative data based on economic information.

With no tools better suited for handling both types of input, FL is the most qualified tool, capable of managing data and knowledge of different natures in mat model, linguistic rules, numerical value or linguistic expressions [30,39,40]. The LSSCs index determine to use in Fuzzy Inference System (FIS) consist of the fuzzification, inference fuzzy learning engine, fuzzy rules and defuzzification.

4.3.1. Determination of LSSCs Index Value Fuzzy Input

Determination of the variables on LSSCsM Index is done through FLE using FIS. The details for each step are as follows (Figure 5):

- Set LV gained from quantitative data e.g., economic information, and qualitative data e.g., environment management priority; poor, ordinary, good (Figure 6). This data will be put into each input/output variable using FMF. This research also uses Triangular Membership Function (TMF).
- Qualitative data value and quantitative data value are then transformed into LV in FLE, which is then processed under fuzzy rule condition, with the "if-then" rule (AND/OR/NOT)", this affects the output results from input value calculation using FIS process (Figure 5).
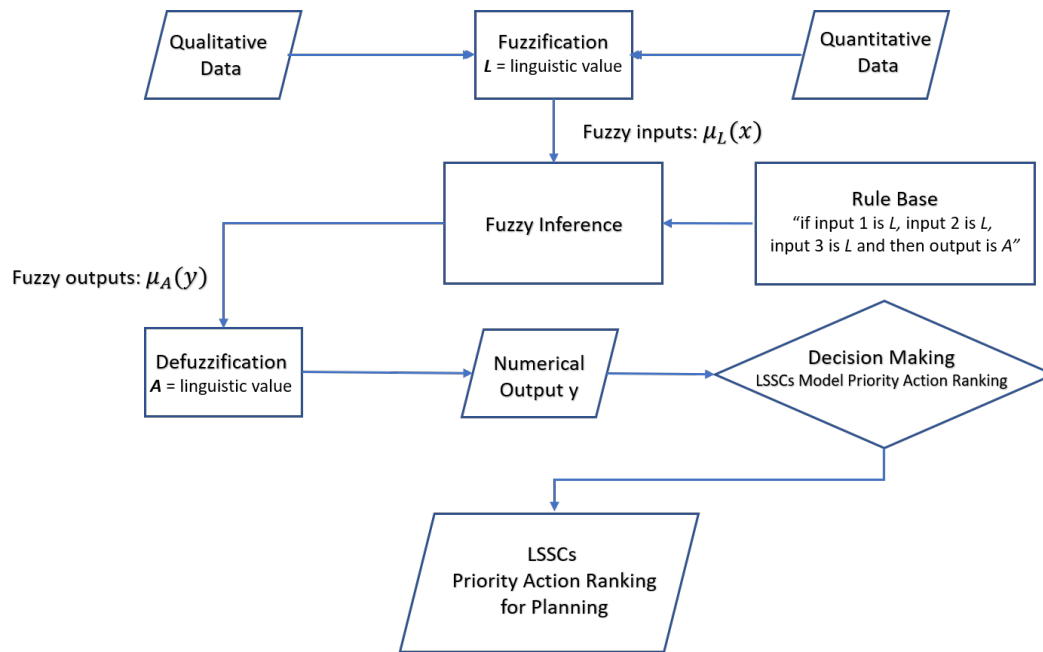- Defuzzification then processes fuzzy output using degree of membership in the form of single numerical value [30].

Figure 5. Fuzzy inference system process flow diagram.

4.3.2. Fuzzy Membership Function

FMF is the key of fuzzy model, critical to transform and set the form of input variables to conform to each other for the sake of calculation regardless of input data's varying original forms. In this research, TMF is applied, as it is the simplest and most commonly used membership function due to the ability to be adapted for various assessments [30,41,42]. TMF equation (Equation (2)) and input/output FMF chart (Figure 6), in this research use three degree of input variables: poor, ordinary, good (Figure 6).

$$
\mu_A(x) = \begin{cases}
0, & if\, x \le a_1 \\[2ex]
\dfrac{(x-a_1)}{(a_2-a_1)}, & if\, a_1 \le x \le a_2 \\[2ex]
\dfrac{(a_3-x)}{(a_3-a_2)}, & if\, a_2 \le x \le a_3 \\[2ex]
0, & if\, x \le a_2
\end{cases}
\tag{2}
$$

where $A = (a_1, a_2, a_3)$, a_1 = minimum, a_3 = maximum and $a_2 = (a_1 + a_3)/2$.
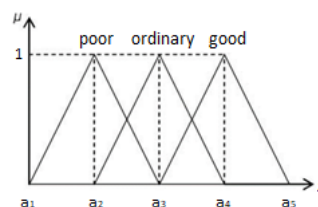

Figure 6. Three-degree of fuzzy membership function.

4.3.3. Fuzzification, Fuzzy Rule and Fuzzy Inference

- Fuzzification is the action of setting degree of membership $u(x)$ of a fuzzy set's input variable (x) using membership function. The resulting value is a membership value that varies from 0 to 1

- Fuzzy rules is the determination of contribution of the input variables to the output responses using linguistic term approaches, separated into two parts. First, a premise (input) is set as part of the "if" rule, then the second part consists of the conclusion, which is a single fact (one output) [30,42]. The number of fuzzy rules depend on the number of variable and degree of input variable (Equation (3)).

$$R = n^v \tag{3}$$

  where n = the number of degree of input variables (triangular = 3), v = the number of input variables.

- Fuzzy inference is the process that consists of two parts. First, the implication process, in which fuzzy conclusions (Ni) of each rule (Ri) is set. Truth value (Tj) for each premise of the proposition in Ri is also set. Premise, in this instance, consists of two or more variables. Truth value is set by logical connectivity operation (fuzzy operator) AND/OR/NOT. Output gained through the implication process is the fuzzy conclusion (Ni) of each rule, as shown in Figure 7, on the horizontal arrow. Next is the aggregation process, which is after the fuzzy conclusion (Ni) is consolidated into a single fuzzy set as shown on Figure 7 on the vertical line [30].

4.3.4. Defuzzification Method

Each fuzzy conclusion from the implication process (horizontal arrow in Figure 7) is then aggregated into a single fuzzy set (downward vertical arrow). A popular and widely accepted defuzzification technique is the Center of Area method (CoA), as it is the most efficient computation process for the multiple output linguistic terms which is to calculate and find the area under the scale of membership function graph which is in range of the output variable (Equation (4)).

$$CoA = \frac{\int_{x_{min}}^{x_{max}} f(x) * x \, dx}{\int_{x_{min}}^{x_{man}} f(x) \, dx} \tag{4}$$

where *CoA* = the Center of Area, *x* = linguistic variable, X_{min} and X_{max} = range of the linguistic variable.
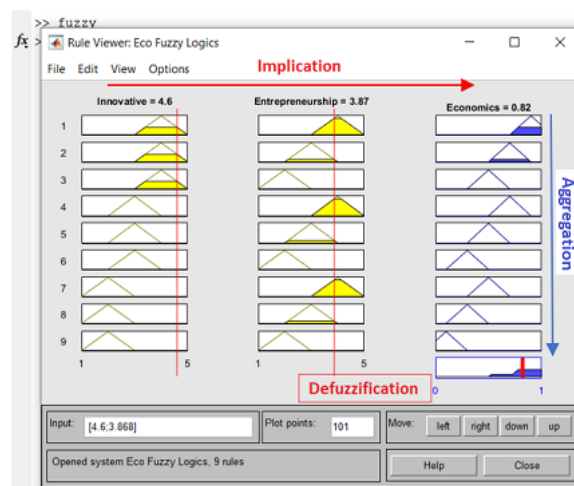

Figure 7. Fuzzy inference system (implication,aggregation and defuzzification processes).

4.4. Case study Rayong Province Thailand

EFA and FLDM are used in this research to shape the LSSCsM and rank priority for action plan for Rayong respectively. This is done through collecting data from sample groups in Rayong, which is a model city for LSSCsM. The raw data comes from two parts: qualitative data collected from expert-approved questionnaires with the proper indicators for Rayong LSSCsM built in, and qualitative data collected from Rayong's central treasury database [43], which is used as an input in conjunction

with the data from the first part in FLDM to rank LSSCs dimension, assessment and prioritizing each dimension as appropriate.

5. Result and Discussion

5.1. LSSCs Indicator Set

In evaluating and creating LSSCsM for Rayong, 428 indicators collected from indicator database referencing ISO 37120, ISO 37122, ESTI-TS 103-463, ITU-TY 4901, ITU-TY 4902, and EU SCs ranking final report are used. Two processes are employed in the selection and categorizing phase, including expertise's selection and literature review. The hierarchical structure development (Figure 8), 248 indicators are selected to describe 61 factors to analyze performance of 13 LSSCs dimensions.
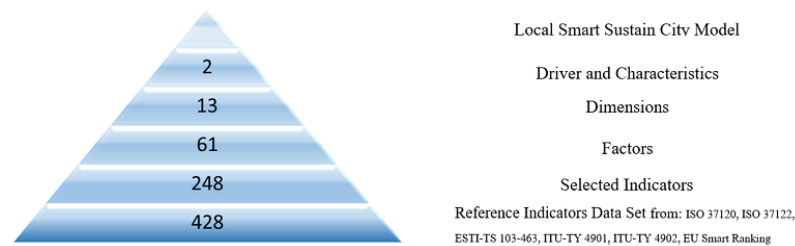

Figure 8. The hierarchical structure of LSSCM factors.

Each dimension will be categorized to LSSCs dimension sets as a driver, which is a set of factors that are critical drives of LSSCs and characteristics that are unique to the LSSCs, consisting of 6 drivers including (Figure 9); ED, environment driver, social driver, technology driver, human driver and governance driver.
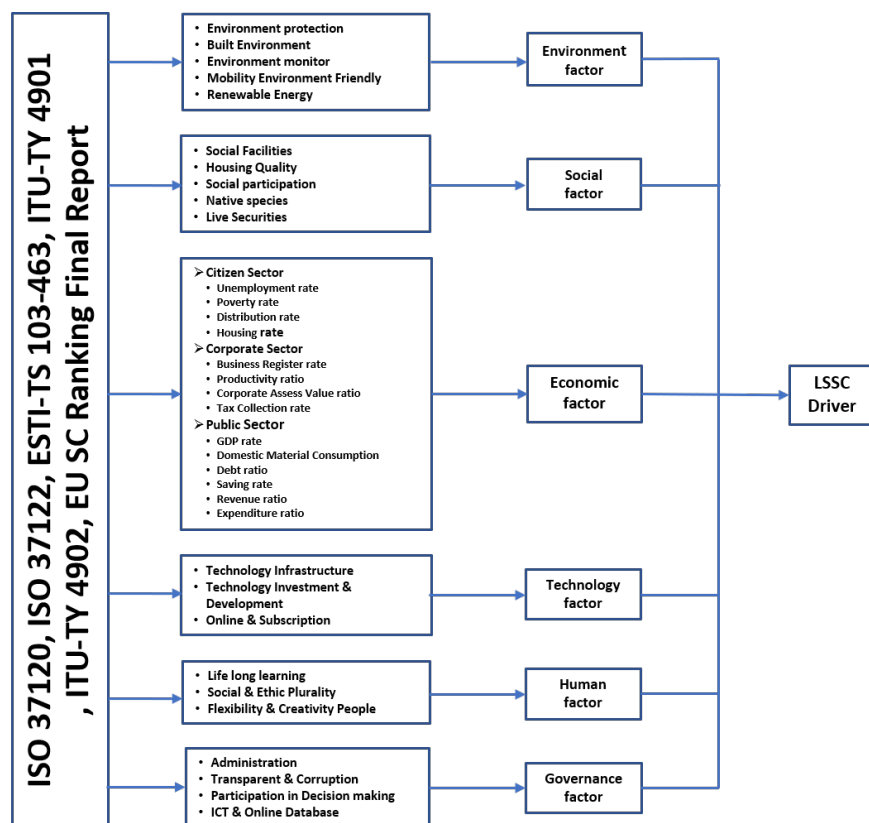

Figure 9. LSSCs driver factor diagram.

And Figure 10 is a set of 7 LSSCs characteristics, including; smart industry, smart logistics, smart education, smart health, smart agriculture, smart business, smart tourist.
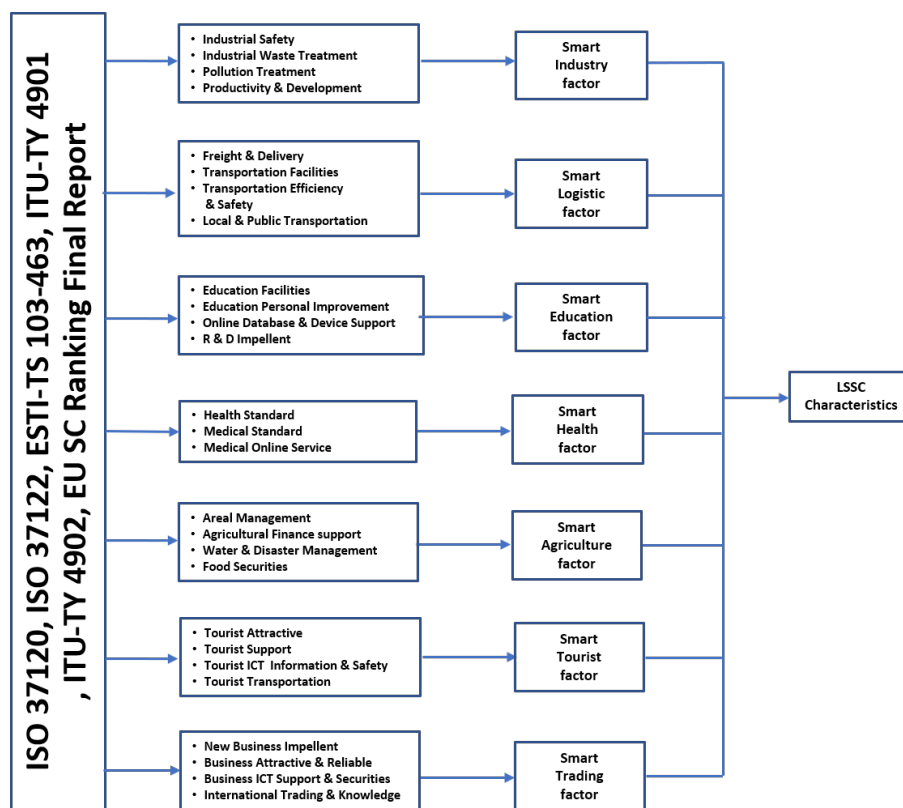

Figure 10. LSSCs characteristics factor diagram.

LSSCs driver and characteristic sets are named as a group using Indicator correlation according to EFA method to set components, as shown on figures 9 and 10. The results are in line with the Twelfth national economic and social development plan of Thailand [44].

5.2. Economic Driven of LSSCs Modeling

LSSCs factor can be separated into two types, including driver and characteristics. For driver, "this research only focuses on economics", LSSCs economics factor set to EFA processing to create ED model, the 14 factors of ED show KMO = 0.772 (higher than 0.5), thereby confirming that the factor analysis technique well suits the data on hand. Bartlett's test of sphericity result is 0.000 (less than 0.5) (Figure 11), which is significant and illustrate that factors used in the test are related and suitable for further testing and creation of LSSCsM. The Principal Component Analysis (PCA) and Varimax Rotation Method (VRM) are employed in this research to create factor structure [36].

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.772
Bartlett's Test of Sphericity	Approx. Chi-Square	302.873
	df	91
	Sig.	.000

Reliability Statistics		
	Cronbach's	
	Alpha Based on	
Cronbach's	Standardized	
Alpha	Items	N of Items
.865	.870	14

Figure 11. LSSCsM economics driven: Kaiser-Meyer-Olkin (KMO), Bartlett's test and reliability statistics from statistics program.

The reliability of the tools used are also tested, with the result being Cronbach's alpha = 0.870 which is higher than 0.800 and should be considered a good value (Figure 11).

Figure 12 the total variance explained, statistical values from before and after factors are extracted are shown. Eigenvalues is the total amount of variance in the variables in the data set that can be explained by the common factor (sum of the squared factor loading). Focus should be given exclusively to components with Eigenvalue higher than 1; for ED, there should only be 4 components.

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings	
	Total	% of Variance	Cumulative %	Total	% of Variance
1	5.519	39.420	39.420	5.519	39.420
2	1.630	11.640	51.061	1.630	11.640
3	1.456	10.400	61.461	1.456	10.400
4	1.121	8.004	69.465	1.121	8.004
5	.925	6.606	76.071		
6	.687	4.904	80.975		
7	.619	4.420	85.394		
8	.482	3.441	88.835		
9	.417	2.977	91.812		
10	.336	2.399	94.211		
11	.281	2.011	96.222		
12	.218	1.559	97.781		
13	.177	1.264	99.045		
14	.134	.955	100.000		

Figure 12. LSSCs economic driven: total variance explained from statistics program.

Then, the numbers are run through the rotated component matrix. The values shown on the matrix are factor loading values subjected to VRM. The resulting values show correlation between factors and components/Economic Driver Sector (EDS). Factor loading for each component or EDS, in this instance, should be higher than 0.400 (Figure 13).

Rotated Component Matrix[a]

	Component			
	1	2	3	4
Revenue ratio	.850			
GDP	.845			
Domestic Material Consumption	.763			
Expenditure ratio	.700			
Debt ratio	.622	.508		
Saving ratio	.606			
Poverty rate		.724		
Disparity rate		.693		
Employment rate		.627		
Housing rate		.589	.524	
Productivity ratio			.805	
Business resgister			.701	
Assess Value ratio				.778
Tax collection				.773

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.[a]
a. Rotation converged in 6 iterations.

Figure 13. LSSCsM economics driven rotated component matrix from statistics program.

- EDS 1 consist of revenue ratio, GDP, domestic material consumption, expenditure ratio, debt ratio, saving ratio

- EDS 2 consist of poverty rate, disparity rate, employment rate, housing rate
- EDS 3 consist of productivity ration and business register
- EDS 4 consist of assess value ration and tax collection.

Since EDS 1 is public sector, EDS 2 is citizen sector, and EDS 3 and 4 are corporate sector, then EDS 3 and 4 can be combined.

The result from EFA method calculations via statistical programs of SCs and St indicator sets' economic factors are collectively considered the ED factor that is SCs and St relevant, and is considered an important driver of LSSCsM.

5.3. Characteristics of LSSCs Modeling

At this stage, LSSCsM is created based on characteristics the data of which is gained from analyzing the correlations between LSSCs factors that are consolidated by the EFA process, with the KMO value being at 0.643 (higher than 0.5) and Bartlett's test of sphericity being at 0.000 (less than 0.5) which is significant, and the reliability test shows Cronbach's alpha value at 0.739. All this indicates that proper factor analysis techniques are used, factors tested are correlated, and that the tools used are reliable (Figure 14).

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.643
Bartlett's Test of Sphericity	Approx. Chi-Square	207.134
	df	91
	Sig.	.000

Reliability Statistics		
Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.731	.739	14

Figure 14. LSSCsM characteristics: KMO, Bartlett's test and reliability statistics from statistics program.

The rotated component matrix of LSSCsM characteristics (Figure 15), subjected to VRM test the correlation between factors and components illustrate as below;

Rotated Component Matrix[a]					
	Component				
	1	2	3	4	5
Productivity	.852				
Industrail waste treatment	.828				
Polution management	.819				
Industrial safety	.648				
Transport Efficientcy&Safety		.784			
Freight & Delivery		.736			
Transport Facilities		.712			
Inter-trading&knowledge			.854		
Business Attractive&Reliable			.683		
Food Securities				.753	
Water&Disaster management				.682	
Agriculture area management				.583	
Tourist Support					.872
Tourist Attractive					.622

Extraction Method: Principal Component Analysis.

Rotation Method: Varimax with Kaiser Normalization.[a]

a. Rotation converged in 8 iterations.

Figure 15. LSSCsM characteristics: rotated component matrix from statistics program.

- Characteristic 1 consist of productivity, industrial waste treatment, pollution management, and industrial safety
- Characteristic 2 consist of transport efficiency and safety, freight and delivery ,and transport facilities
- Characteristic 3 consist of international trading and knowledge business, attractive and reliability
- Characteristic 4 consist of food securities, water and disaster management, and agriculture area management
- Characteristic 5 consist of tourist support, and tourist attractive.

Further analysis on components-characteristics show the characteristics relevant to the model include; characteristic 1; smart industry, characteristic 2; smart logistics, characteristic 3; smart business, characteristic 4; smart agriculture and characteristic 5; smart tourist. Smart Education and smart health characteristics are not reflected on this Rayong-based LSSCsM as qualitative data both gained from experts and sample groups does not prioritize these characteristics. By combining the two parts of the model, namely ED model and characteristics model, Rayong's LSSCsM is made (Figure 16).
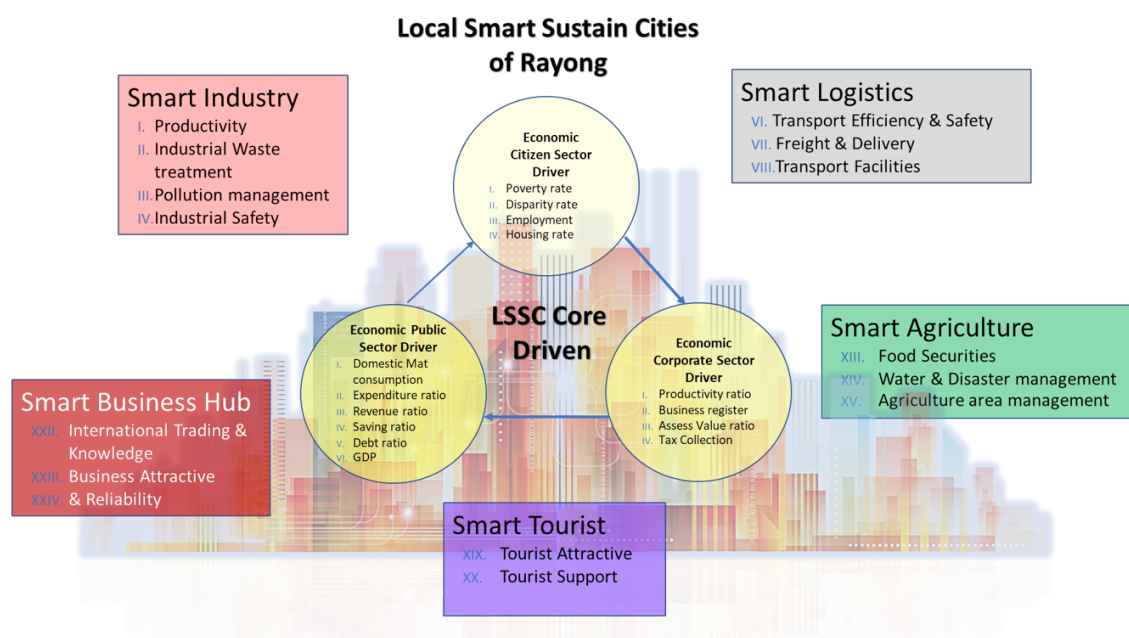

Figure 16. Local smart sustain cities model of Rayong.

5.4. Priority Action Ranking for LSSCs Planning

With LSSCsM comprising of ED and characteristics modeled by EFA complete, the next step is to evaluate the strengths and weaknesses of each driver and characteristic using PAR process for the direction planning, and then rank each driver and characteristic for policy purpose. This allows one to identify which of the characteristics should be expanded upon first in accordance with the city's strengths and weaknesses, and to identify which economic sector most needs expansion or improvement to ensure that a sustainable LSSCsM can be achieved.

FLDM-PAR method for LSSCs is used in evaluating, comparing, and ranking ED 3 sectors and the 5 LSSCs characteristics, the raw data (Figure 17) obtained from Rayong's treasury database [43]. The purpose of evaluating the index using Fuzzy method is to determine the best economic sectors and characteristics of Rayong, doing so by considering the index factor value of each LSSCs characteristic. Ranking by Fuzzy method is done by categorizing input data based on the drivers and characteristics of LSSCsM.Two types of input data are present, including numeric or quantitative data which is obtained from Rayong's treasury database, and quantitative data from evaluating Rayong stakeholders

(as Figure 17). The input data will then be subjected to FIS in sets according to each set's driver or characteristic category, as illustrate in LSSCs factor matrix of FL input data (Figure 17), smart industry has 4 input data; industrial productivity = 9.10, industrial safety = good, Industrial waste treatment = good, pollution treatment = ordinary. By define FMF, FIS can calculate both quantitative and qualitative data.

LSSC Factor	Input data type	Unit	Fuzzy Set Value range			Economic Driver			Smart Sustain Characteristics				
			Min	Med	Max	Citizen Sector	Corporate Sector	Public Sector	Industry	Logistics	Business	Agriculture	Tourist
Unemployment rate	quantitative	%yoy	0.75	1.02	1.28	0.75							
Poverty rate	quantitative	%yoy	0.32	2.35	4.37	4.37							
Disparity rate (Gini coefficiency)	quantitative	%yoy	34.30	36.16	38.01	36.07							
Home-ownership rate	quantitative	%yoy	51.44	56.54	61.64	54.07							
Business Register	quantitative	%yoy	-2.30	1.30	4.90		4.5						
Private Investment	quantitative	%yoy	-2.80	6.60	16.00		15.60						
Productivity ratio (GPP/capita)	quantitative	million bath/person/yr	0.98	1.12	1.25		1.25						
Tax Collection rate	quantitative	%yoy	-21.60	2.00	25.60		25.60						
GPP Growth rate	quantitative	%yoy	-3.20	3.45	10.10			8.60					
Domestic material consumption	quantitative	%yoy	-21.40	2.00	25.40			14.90					
Government Expenditure	quantitative	%yoy	-18.20	13.75	45.70			14.00					
Infration rate	quantitative	%pa	-1.60	0.55	2.70			1.30					
Industrial Productivity (Number of Factory register)	quantitative	number	1928	2507	3086				3002				
Industrial Safety	qualitative	input degree	Poor	Ordinary	Good				Good				
Industrial Waste Treatment	qualitative	input degree	Poor	Ordinary	Good				Good				
Polution Management	qualitative	input degree	Poor	Ordinary	Good				Good				
Transportation Efficiency (new car register rate)	qualitative	%yoy	15.60	-3.70	-23.00					13.90			
Freight & Delivery	qualitative	input degree	Poor	Ordinary	Good					Good			
Transporation Facilities	qualitative	input degree	Poor	Ordinary	Good					Ordinary			
Local & Public Transportation	qualitative	input degree	Poor	Ordinary	Good					Ordinary			
Bussiness Attractive & Reliable (wholesales/retails)	quantitative	%yoy	0.60	5.95	11.30						7.50		
New Bussiness Impellent	qualitative	input degree	Poor	Ordinary	Good						Ordinary		
Bussiness ICT Support & Securities	qualitative	input degree	Poor	Ordinary	Good						Poor		
International Trading & Knowledge	qualitative	input degree	Poor	Ordinary	Good						Good		
Agriculture growth rate	quantitative	%yoy	-9.90	2.80	15.50							8.80	
Agriculture Area Management	qualitative	input degree	Poor	Ordinary	Good							Ordinary	
Water & Disaster Management	qualitative	input degree	Poor	Ordinary	Good							Good	
Food Securities	qualitative	input degree	Poor	Ordinary	Good							Ordinary	
Tourist growth rate	quantitative	%yoy	4.00	7.00	10.00								6.40
Tourist Attractive	qualitative	input degree	Poor	Ordinary	Good								Ordinary
Tourist ICT Information & Safety	qualitative	input degree	Poor	Ordinary	Good								Ordinary
Tourist Transportation	qualitative	input degree	Poor	Ordinary	Good								Poor

Figure 17. LSSCs factor matrix of fuzzy logic input data.

Upon aggregating the input data for each driver and characteristic using FIS, the result illustrate in the Figure 18 that the ED group in Rayong has a very strong corporate sector, valuing at 0.855, with public sector and citizen sector scoring 0.611 and 0.471 respectively. This indicates that Rayong's economic structure is bent towards corporate sector as the driving force behind industry and Business sectors. Rayong's public sector is moderately strong, but the citizen sector needs improvement to achieve better quality of life and income rates for its citizens. Meanwhile, the FIS characteristics evaluation illustrates in Figure 18 that the smart industry characteristic scores 0.869 in index value, while smart logistics, smart agriculture, and smart business are given nearly identical scores at 0.601, 0.601, and 0.581 respectively. smart tourist, on the other hand, is given the score of 0.346.

Economic Driver Sector	Driver Index	Priority Action Ranking	LSSCs Characteristics	Characteristics Index	Priority Action Ranking
			Smart Industry	0.869	1st
Citizen Sector	0.471	3rd	Smart Logistics	0.601	2nd
			Smart Agriculture	0.601	3rd
Corporate Sector	0.855	1st	Smart Business	0.581	4th
			Smart Tourist	0.346	5th
Public Sector	0.611	2nd	Smart Education	N/A	N/A
			Smart Health	N/A	N/A

Figure 18. LSSCsM economics driven and characteristics PAR by FLDM.

This indicates Rayong having a strong infrastructure for industries to thrive, and suitable to be further developed into a smart industrial city. That said, other characteristics including the second and third highest-rated characteristics of smart logistics and smart agriculture can also be expanded upon simultaneously with the industrial side. smart business, as a characteristic, however, requires improvement, and it may be difficult to develop the smart tourist characteristic of Rayong into a notable or strong characteristic.

The research uses radar chart to display the PAR result from FLDM to ensure clarity and that evaluating Rayong's LSSCsM is done with ease. As illustrate in Figure 19, the yellow line illustrate ED, which consists of three sectors, the strongest sector acting as the driving force of Rayong's LSSC being the corporate sector, while also showing the weaknesses in ED, including the citizen sector, which is a sector in need of improvement. The red line shows LSSCs characteristics, and here indicates that Smart Industry is the strongest characteristic of Rayong that should be expanded upon. smart logistics and smart agriculture, meanwhile, can also be expanded upon after some improvement. smart tourist as a characteristic is the weakest one, while education and health characteristics are difficult characteristics to improve and elevate.
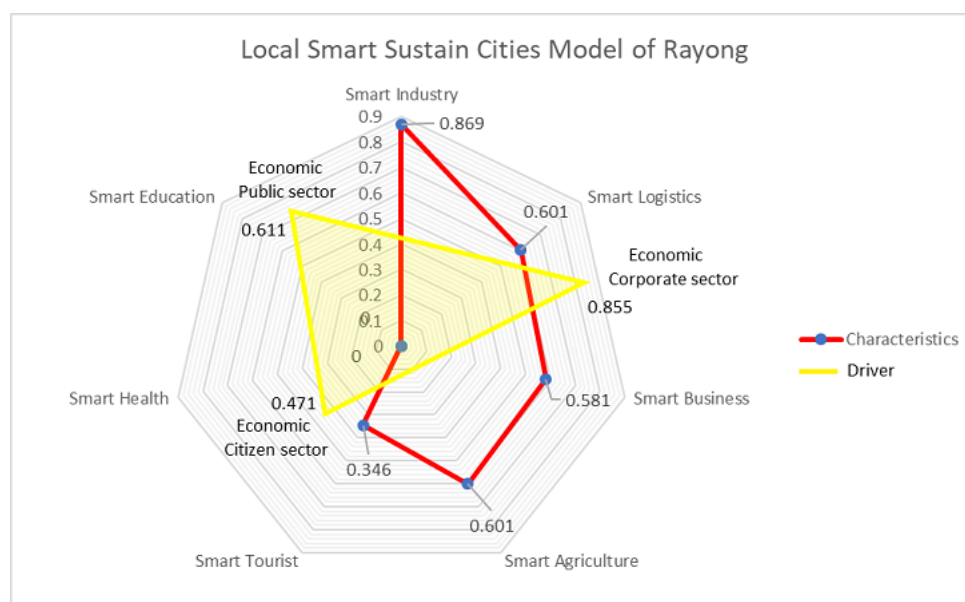

Figure 19. LSSCsM radar chart of Rayong.

6. Conclusions

This research presents a solution and the process through which SCsM that is considerate of LC and thus is suitable to a given city can be produced. This is done through a collection of 428 key indicators for development of SCs and St, referenced from ISO 37120, ISO 37122, ESTI-TS 103-463, ITU-TY 4901, ITU-TY 4902 and EU SCs Ranking Final Report. Selection and categorization procedures for these indicators are handled by local expertise. SCsM and StM are thus connected via selected economic factor set and other factor set chosen based on LC. The resulting indicator set is therefore well-rounded and multifaceted. Apart from the initial indicator selection process, EFA technique is also applied to LSSCs modeling to create LSSCsM. The qualitative input data is then subjected to EFA and calculated using statistical programs to build up LSSCs factor correlation structure, resulting in LSSCsM that recognize and fits with the unique features of a given city. Raw data obtained from Rayong's treasury database is used to determine the best economic sector and characteristic of the province, using the index factor values of each LSSCs in such evaluation. On ranking the factors and characteristics using FLDM-PAR process, input data is separated into various categories based on related drivers and characteristics of LSSCsM. Two types of input data are taken, namely, quantitative data and qualitative data. Results are represented by index values as calculated by FIS, ED, and are

separated into index values for citizen sector, corporate sector, and public sector, with the values being at 0.471, 0.855, and 0.611 respectively. This indicates that Rayong's citizen sector needs improvement if better living condition and income are to be obtained for its citizens, while its corporate sector is already strong and is able to support industrial and business growth. The public sector, while moderately strong, has areas that can be improved upon.

In calculating the FLDM-PAR of Rayong's characteristics using FIS, the resulting values for smart industry, smart logistics, smart agriculture, smart business, and smart tourist are 0.869, 0.601, 0.601, 0.581, and 0.346 respectively. This indicates Rayong having a strong industrial infrastructure and should strive towards becoming a smart industrial city. smart logistics and smart agriculture are the second and third highest-rated characteristics respectively and can be concurrently expanded upon and improved. Smart Business characteristic, however, needs improvement, and Smart Tourist characteristic is not in a position to be easily made into a strength.

LSSCsM solution used in this research was developed to be one that is generic. To reiterate, the solution is made to be flexible, with the indicator set used being interchangeable depending on the city or region the solution is applied to. Input variable and factors used, as well, are flexible and can be tuned to suit the LC of a given city. The goal of a LSSCsM solution is to create a SCsM that is well suited for the city or the region, and that the resulting SCs are those that are sustainable and ones that truly meet the demands of their communities and citizens.

Conflicts of Interest: The authors declare no conflict of interest.

Abbreviations

The following abbreviations are used in this manuscript:

CoA	Centre of Area
ED	Economics Driven
EDS	Economics Driver Sector
EFA	Exploratory Factor Analysis
FA	Factor Analysis
FIS	Fuzzy Inference System
FL	Fuzzy Logic
FLDM	Fuzzy Logic Decision Making
FLE	Fuzzy Logic Evaluation
FMF	Fuzzy Membership Function
LC	Local Context
LSSCs	Local Smart Sustain Cities
LSSCsM	Local Smart Sustain Cities Model
LV	Linguistic Variable
PAR	Priority Action Ranking
SCs	Smart Cities
SCsM	Smart Cities Model
St	Sustainability
StM	Sustainability Model
TMF	Triangular Membership Function
VRM	Varimax Rotation Method

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