Quality and Usability Assessment of Smart City Mobile Applications by Using a DEMATEL Approach

Musab Talha Akpinar[a], Semih Ceyhan[a]

[a] *Ankara Yildirim Beyazit University Ankara, Turkey*

Abstract

Nowadays, there are many municipalities have provided mobile services related to their smart city implementations. Therefore, citizens can use mobile services at anytime and anywhere [1]. The object of our research is to understand what criteria affect consumers' tendency to use smart city mobile services. We focused on three measurement dimensions for quality: system quality, information quality, and service quality and five dimensions for usability: effectiveness, efficiency, satisfaction, learnability, and security to assess consumers' attitudes. In addition, for usability assessment focalize as a combination of effectiveness, efficiency, satisfaction, learnability, and security. This paper combined the DEMATEL approach to cope with the problem of interdependence exists among criteria, and to select an optimal portfolio of smart city mobile consumers' attitude.

Keywords

Smart City, Mobile Application, DEMATEL, Quality, Usability

1. Introduction

To make a good decision, the ability to forecast the outcome of the available options is very important. The original decision support systems (DSS) concept was clearly defined by Gorry and Scott Morton, as "is the system that supports any managerial activity in semi structured or unstructured decisions". They also defined that characteristics of information requirements and decision models differ in a decision support systems environment. The reason of the difference is that DSS is defined in terms of the addressed task structure. Most study on DSS focuses on the adaptive processes about design strategy, decision research and implementation strategy.

Strategy implementation is the conversion of selected tactics into organizationasl activity so as to acquire strategic targets and objectives [2]. Decision-making needs to deal with complex problems, with a limited information, in order to reach the organizational goals and objectives. Numerical programming models like business investigation devices are significant tools to solve the problems in a dynamic way, as they help decision models to provide well rounded solutions. These applications provide businesses with support on their decisions and processes based on computer based systems. Lately, new innovations have expanded the matter of information examination and have broadened the capability of utilizing information driven instruments through dynamic procedures. Business analytics, as an emerging research area, strives to bring different fields and disciplines together overlaying diverse aspects in terms of technological innovations, quantitative/numerical methods, and decision-making.

Data analytics refers to the information technologies that are grounded mostly in three main types which are descriptive, predictive and prescriptive. Descriptive analytics examine data in detail to reveal the frequency of cases, the cost of processes, and the base cause of collapse. It ensures meaningful insight into activity performance and facilitate users to better follow up and operate their work processes. Predictive analytics use models and techniques to estimate forthcoming results based on historical and streamed data. In predictive forming, the statistical model is prepared, forecast is made, and the pattern is confirmed as supplementary data becomes existing [3, 4]. The final stage in understanding a business which can be called prescriptive analysis, offers suggestions on how to act and take advantage of forecast. The last stage of the analytics uses a variety of algorithms and data modelling practices to get a complete understanding of the environment and build up activity's performances.

The aim of the prescriptive analytics is to define set of alternatives which is the best appropriate by the group of decision makers as a whole. The main objective would be one where all the decision makers could convey their options on the alternatives in a certain way by means of prescriptive, unlike descriptive analysis which include fundamental analytical component

IVUS 2020: Information Society and University Studies, 23 April 2020, KTU Santaka Valley, Kaunas, Lithuania
takpinar@ybu.edu.tr (M.T. Akpinar); sceyhan@ybu.edu.tr (S. Ceyhan)

such as tables or even multidimensional tables. Research shows that the nature and content of business decision making has hardly changed and that managers operate by a majority descriptive analytics, some predictive analytics, and a few of prescriptive analytics. There is a lack of prescriptive studies in the field and this study will provide inspiration for further studies and contribute in to that gap.

In this respect, a novel business analytics approach is proposed in this paper for smart city administration and getting a grip on three quality dimensions; system, information and service quality and five dimensions for usability; effectiveness, efficiency, satisfaction, learnability, and security with addressing an important research method; DEMATEL. The decision-making trial and evaluation laboratory method (DEMATEL) was aimed at the fragmented and oppositional fact of societies and searched for combined resolutions. This study investigates the DEMATEL to determine the information importance's as prescriptive analytics foreseeing quality and usability of smart city mobile application (SCMA) with expert feedbacks are then used to construct new evaluation and assessment system.

DEMATEL methodology have been applied in many contexts such as mobile banking [5], waste management [6, 7], maintenance management [8], knowledge management [9], supply chain management [10], service quality [11], business process management, brand marketing [12]

Mobile application frameworks have found their way into regular day to day existence, and with an extensive client base [13, 14]. Subsequently, organizations are seeing the advantages of structuring and building up their items with client arranged strategies rather than innovation situated techniques, and are attempting to comprehend both client and item, by examining the cooperation between them. This huge and expanding number of versatile applications in the market has moved designers to create applications of better quality all together than contend. Functionality and prevalence of smart phones have enabled online applications to solve many problems people face in their daily lives and make the life easier. Nowadays, municipalities also use smart city mobile applications in order to facilitate the city life by achieving the sustainability standards. Health, transportation, energy, education is some of the important services provided by SCMA leading to more comfort of their citizens. In this sense, investigating SCMA's quality and usability will contribute both in theory and practice.

2. Methodology

The main research question of this study is how can impact-relations map help us to determine important parameters in quality and usability assessment of smart city mobile applications? The aim of this study is to find out which of the many meaningful attributes revealed in the smart city mobile applications are influential. Furthermore, the concept of prescriptive analytics in decision support systems in the smart city context is introduced. In the smart city mobile applications, system quality is a very significant factor to assess the extent of the all system resources [12]. High system, information and service quality are critical factors to ensure end-users trust due to SCMA unable to involve face-to-face contact customers.

It is important to consider the following 3 aspects of usability for all types of software:

- To use more efficiently: it takes less time to complete a given task.
- Easier to learn: operations can be learned by looking at the object.
- More user satisfaction: satisfy user expectations. On the other hand, ISO 9241 defines usability as "the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use".

On the other hand, ISO 9241 defines usability as "the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use". consolidate the ISO 9241, IOS 9126, ISO 13407, usability models, and propose an enhanced one, referred to as the Consolidated Usability Model (2003). This model describes usability as all combination of effectiveness, efficiency, satisfaction, learnability, and security, along with a recommended set of related measures. This enhanced model, referred to as the Consolidated Usability Model, is presented in Figure 1.

There are 5 experts who are software developers were invited to identify various criteria and elements for quality and usability factors. Base on experts' discussion and literatures review, this study listed three measurement dimensions for quality: system quality, information quality, and service quality and five dimensions for usability: effectiveness, efficiency, satisfaction, learnability, and security. This study used the DEMATEL method to establish the network relationship among eight dimensions. When a user decides

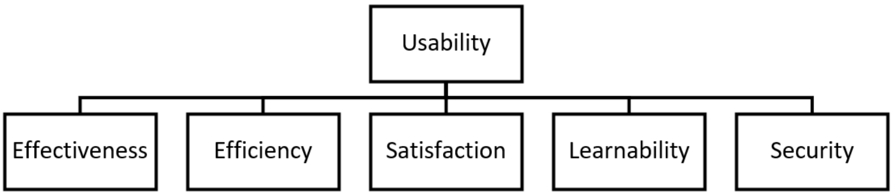

Figure 1: Consolidated Usability Model

Table 1
The assessment data of the experts, average matrix

Conditional Attributes	A1	A2	A3	A4	A5	A6	A7	A8
A1. System Quality	0	2,63	2,88	2	1,33	2,66	0,33	2
A2. Information Quality	3,33	0	2,88	3,33	3,67	3,1	3	2,88
A3. Service Quality	2,63	2	0	2	2,25	2,63	1,66	3,66
A4. Effectiveness	2,88	3,66	3,66	0	2,88	2,66	2	1,66
A5. Efficiency	1	1,33	2,66	2	0	1,33	0,5	0,66
S6. Satisfaction	1,66	2,66	3	1,88	3	0	0,75	1,25
A7. Learnability	1	2,75	3,33	3,33	2,88	2	0	0,75
A8. Security	3	1,88	3,33	1,33	2	2,75	1,66	0

using SCMA may consider many criteria. The most common problem is determining the mutual effects of criteria. In order to improve the overall performance and the quality and efficiency of users using SCMA, it is therefore necessary to identify the criterion that has the greatest impact on other criteria before the evaluation. To explain DEMATEL steps briefly, attributes impact values have already asked to several different experts working in this field. The impact value which is from 0 to 4 (0 means that there are not any affect and 4 means that there are dramatically effective relations with those attributes) has collected from each different specialist. Finally, these 10 experts are asked to identify the degree of influence between the factors or parameters (criteria) to calculate the average matrix of influence matrix in Tab. 1.

The proposed method has the four-step procedure. First, the decision goals for segmenting the eight conditional attributes were established to determine the significance of the factors affecting fragmentary end-user usage. DEMATEL technique can convert the interrelations between criteria into an intelligible structural model of the system and divide them into a cause group and an effect group [15]. DEMATEL is a practicable and beneficial tool to analyze the interdependent relationships among elements in a complex framework and grade them for decision making. Thus, this technique can be used in prescriptive analysis. The formulating steps of the classical DEMATEL [16] can be summarized as follows;

Step 1: Generating the direct-relation matrix. For example, five scales for measuring the relationship among different criteria are used: 0 (no influence), 1 (low influence), 2 (normal influence), 3 (high influence) and 4 (very high influence). Decision makers prepare sets of pair-wise comparisons in terms of effects and direction between criteria. The initial data can be obtained as the direct-relation matrix which is a n × n matrix A where each element of a_{ij} is denoted as the degree in which the criterion i affects the criterion j.

Step 2: Normalizing the direct-relation matrix. Normalization is performed using the Eq. 1

$$X = k \times A \tag{1}$$
$$k = \frac{1}{max_{1 \leqslant i \leqslant} \Sigma_{j=1}^{n} a_{i,j}} \quad i, j = 1, 2, \dots, n$$

Step 3: Attaining the total-relation matrix. Once the normalized direct-relation matrix X is obtained, the total relation matrix T can be acquired by using Eq. 2 , where I is denoted as the identity matrix,

$$T = X \cdot (I - X) - 1 \tag{2}$$

Step 4: Producing a causal diagram. The sum of rows and columns are separately denoted as vector D and vector R through equations in Eq. 3. The horizontal axis vector (D + R) named as “prominence” is

Table 2
The initial direct-relation matrix

C.A.	A1	A2	A3	A4	A5	A6	A7	A8
A1	0,000	0,119	0,130	0,090	0,060	0,120	0,015	0,090
A2	0,150	0,000	0,130	0,150	0,165	0,140	0,135	0,130
A3	0,119	0,090	0,000	0,090	0,101	0,119	0,075	0,165
A4	0,130	0,165	0,165	0,000	0,130	0,120	0,090	0,075
A5	0,045	0,060	0,120	0,090	0,000	0,060	0,023	0,030
A6	0,075	0,120	0,135	0,085	0,135	0,000	0,034	0,056
A7	0,045	0,124	0,150	0,150	0,130	0,090	0,000	0,034
A8	0,135	0,085	0,150	0,060	0,090	0,124	0,075	0,000

made by adding D to R, which reveals the relative importance of each criterion. Similarly, the vertical axis (D - R) called as "relevance" is made by subtracting D from R, which may divide criteria into a cause and effect groups. Generally, when (D - R) is positive, the criterion belongs to the cause group, (D - R) is negative, the criterion represents the effect group. Therefore, the causal diagram can be obtained by mapping the dataset of the (D + R, D - R), providing some insight for making decisions.

$$\begin{aligned} T &= [t_{i,j}]_{n\times n} \quad i,j = 1,2,\dots,n \\ D &= \left[\Sigma_{j=1}^{n} t_{i,j}\right]_{n\times 1} = [t_i]_{n\times 1} \\ R &= \left[\Sigma_{i=1}^{n} t_{i,j}\right]_{1\times n} = [t_j]_{1\times n} \end{aligned} \quad (3)$$

where vector$D$ and vector R denote the sum of rows and columns in total-relation matrix T.

Step 5: Obtaining the inner dependence matrix. In this step, the sum of each column in total-relation matrix is equal to 1 by the normalization method, and then the inner dependence matrix can be acquired. At first step of DEMATEL, attributes impact values have already asked to 5 different experts on working this field. The impact value which is from 0 to 4 (0 means that there are not any affect and 4 means that there are relations with those attributes a very dramatically effective) has collected each different software developer. 5 experts are asked to identify the degree of influence between the factors or elements (criteria) to calculate the average matrix of influence matrix. In step 2, the experts adopted the eight attributes as evaluation factors. In step 3, once the relationships between those attributes were measured by the experts through the use of the scale, the data from each individual assessment could be obtained. Then, using the CFCS method to aggregate these assessment data, the initial direct-relation matrix (Tab. 2) was produced.

In step 4, based on the initial direct-relation matrix, the normalized direct-relation matrix (Tab. 3) was obtained. Next, the total-relation matrix (Tab. 4) was acquired. Following the step of DEMATEL method is created the total influence matrix. There shows the sum of the direct and indirect effects that factor has received from the other factors. The total influence matrix is defined the sum of the rows and the sum of the columns separately which can be denoted as vector r and s

Let i=j and i,j ∈ { 1,2,...n }; the horizontal axis vector (r_i + s_i) is then made by adding r_i to s_i , which illustrates the importance of the criterion. Similarly, the vertical axis vector (r_i - s_i) is made by deducting r_i from s_i , which may separate criteria into a cause group and an affected group. In general, when (r_i - s_i) is positive, the criterion is part of the cause group. On the contrary, if (r_i - s_i) is negative, the criterion is part of the affected group. Therefore, a causal graph can be achieved by mapping the dataset of (r_i + s_i,r_i - s_i), providing a valuable approach for decision-making. The sum of influences is given and received on criteria will be shown in Tab 5. The direction of influence between dimensions and criteria can be visualized in Fig. 2. After all those analytics, the Integrated Natural Resource Management (INRM) indicates that A2. Information Quality and A3. Service Quality are the most effective attributes can be understood from Fig. 2. Moreover, A5. Efficiency factor also may be one of the most affected ones. As a result of the DEMATEL methods, the conditional attributes' degrees of impacts have been identified.

Moreover, descriptive analytics results (multidimensional reports) have been supported with DEMATEL technique. All those outcomes would give advices for decision makers with meaningful results.

3. Conclusion

Nowadays, lot of cities have supplied mobile device as a smart city application. In mobile application, mar-

Table 3
The normalized direct-relation matrix

C.A.	A1	A2	A3	A4	A5	A6	A7	A8
A1	1,000	-0,119	-0,130	-0,090	-0,060	-0,120	-0,015	-0,090
A2	-0,150	1,000	-0,130	-0,150	-0,165	-0,140	-0,135	-0,130
A3	-0,119	-0,090	1,000	-0,090	-0,101	-0,119	-0,075	-0,165
A4	-0,130	-0,165	-0,165	1,000	-0,130	-0,120	-0,090	-0,075
A5	-0,045	-0,060	-0,120	-0,090	1,000	-0,060	-0,023	-0,030
A6	-0,075	-0,120	-0,135	-0,085	-0,135	1,000	-0,034	-0,056
A7	-0,045	-0,124	-0,150	-0,150	-0,130	-0,090	1,000	-0,034
A8	-0,135	-0,085	-0,150	-0,060	-0,090	-0,124	-0,075	1,000

Table 4
The total-relation matrix

C.A.	A1	A2	A3	A4	A5	A6	A7	A8
A1	0,216	0,328	0,393	0,289	0,295	0,338	0,156	0,272
A2	0,444	0,331	0,532	0,443	0,497	0,462	0,322	0,385
A3	0,353	0,339	0,325	0,322	0,365	0,372	0,227	0,358
A4	0,4	0,442	0,517	0,283	0,436	0,415	0,268	0,32
A5	0,193	0,212	0,302	0,228	0,167	0,217	0,121	0,163
A6	0,281	0,327	0,397	0,287	0,358	0,227	0,171	0,24
A7	0,285	0,365	0,45	0,374	0,39	0,342	0,16	0,245
A8	0,353	0,321	0,438	0,286	0,342	0,363	0,217	0,205

Table 5
The total influence matrix

Conditional Attributes	D	R	D+R	D-R
A1. System Quality	2,288	2,524818	4,813	-0,237
A2. Information Quality	3,416	2,665346	6,082	0,751
A3. Service Quality	2,661	3,353749	6,014	-0,693
A4. Effectiveness	3,080	2,511152	5,591	0,569
A5. Efficiency	1,603	2,84989	4,453	-1,247
S6. Satisfaction	2,288	2,735482	5,024	-0,447
A7. Learnability	2,610	1,641643	4,252	0,969
A8. Security	2,525	2,188399	4,713	0,336

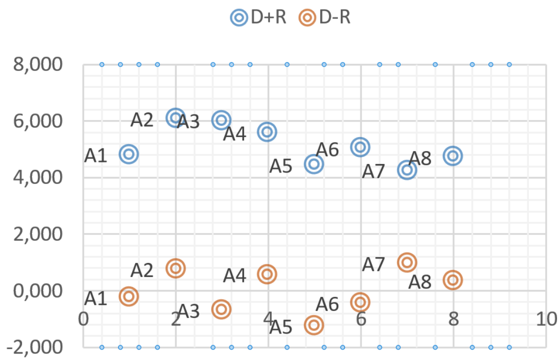

Figure 2: The Causal Diagram

ket mobile devices and technology has continued to expand. Internet technology continues to grow that widely used mergers and action for mobile devices, has a channel operation trade in services, particularly in the rapidly. DEMATEL approach to cope with the problem of interdependence exists among the criteria, and to select an optimal portfolio of consumers' inclination. This study the DEMATEL approach to consider the interdependencies among criteria and to obtain a priority of inclinations. Then, the DEMATEL provide a decision model for determining the final ranking of alternatives using the weights of each criterion of SCMA. So, the result of the priority for end user' inclination first is "Information and Service Quality", after that is "effectiveness". Hope these results can help governors and city managers to evaluate how well each sourcing decision is able to approximate the expected maximum benefit.

References

[1] R. Giuliano, G. Cardarilli, C. Cesarini, L. Di Nunzio, F. Fallucchi, R. Fazzolari, F. Mazzenga, M. Re, A. Vizzarri, Indoor localization system based on bluetooth low energy for museum applications, Electronics (Switzerland) 9 (2020) 1–20.

[2] M. Gagné, From strategy to action: transforming organizational goals into organizational be-

havior, International Journal of Management Reviews 20 (2018) 83–104.

[3] F. Fassnacht, F. Hartig, H. Latifi, C. B. J. Hernández, B. K. P. Corvalán, Importance of sample size, data type and prediction method for remote sensing-based estimations of aboveground forest biomass, Remote Sensing of Environment 20 (2014) 102–114.

[4] F. Beritelli, G. Capizzi, G. Lo Sciuto, C. Napoli, F. Scaglione, Rainfall estimation based on the intensity of the received signal in a lte/4g mobile terminal by using a probabilistic neural network, IEEE Access 6 (2018).

[5] W. Lin, Y. Wang, T. Hung, Selecting mobile banking system service for consumers by using a combined dematel and anp approach, Journal of Accounting, Finance & Management Strategy 1 (2012).

[6] M.-L. Tseng, Y. Lin, Application of fuzzy dematel to develop a cause and effect model of municipal solid waste management in metro manila, Environmental Monitoring and Assessment 158 (2009) 519–533.

[7] G. Capizzi, G. Lo Sciuto, C. Napoli, G. Susi, M. Woźniak, A spiking neural network-based long-term prediction system for biogas production, Neural Networks 129 (2020) 271–279.

[8] D. Vujanovic, V. Momilcovic, N. Bojovic, V. Papic, Evaluation of vehicle fleet maintenance management indicators by application of dematel and anp, Expert Systems with Applications 39 (2012) 10552–10563.

[9] W.-W. Wu, Choosing knowledge management strategies by using a combined anp and dematel approach, Expert Systems with Applications 35 (2008) 828–835.

[10] B. Chang, C.-W. Chang, C.-H. Wu, Fuzzy dematel method for developing supplier selection criteria, Expert Systems with Applications 38 (2011) 1850–1858.

[11] M.-L. Tseng, Y. Lin, Application of fuzzy dematel to develop a cause and effect model of municipal solid waste management in metro manila, Environmental Monitoring and Assessment 158 (2009) 519–533.

[12] W.-R. Lin, Y.-H. Wang, T.-E. Hung, Selecting mobile banking system service for consumers by using a combined dematel and anp approach, 2012.

[13] C. Shin, J.-H. Hong, A. Dey, Understanding and prediction of mobile application usage for smart phones, 2012, pp. 173–182.

[14] G. Capizzi, C. Napoli, S. Russo, M. Woźniak, Lessening stress and anxiety-related behaviors by means of ai-driven drones for aromatherapy, in: CEUR Workshop Proceedings, volume 2594, 2020, pp. 7–12.

[15] J.-I. Shieh, H.-H. Wu, K.-K. Huang, A dematel method in identifying key success factors of hospital service quality, Knowledge-Based Systems 23 (2010) 277–282.

[16] E. Fontela, A. Gabus, The dematel observer, dematel 1976 report, Battelle Geneva Research Center, Geneva (1976).