NEUTROSOPHIC ANALYTIC HIERARCHY PROCESS FOR EVALUATING A NEW SERVICIZING BUSINESS MODEL OF TRANSPORTATION

ABSTRACT

The new normal of the world has been shaped by the COVID-19 pandemics. It has made compulsory to avoid public transportation and to provide individual transportation in order to prevent the spread of the disease. Due to the high financial burden of purchasing a car, new business models have been developed in order to make possible of utilizing vehicles to meet the transportation needs in pay-per-use base. The concept called "servicizing business model" or "servicization" is based on presenting a product as a service, and selling the functionality of that product instead of the product itself. In order to meet the increasing demand for individual vehicle use, the existing car rental service providers have provided a new mobile application controlled business model which makes the rental process easier, by determining the location of the available vehicle via the applications, opening the vehicle without a key by GPS signals through the application, and making the payment from the previously defined credit card according to the duration of driving. The aim of this study is to evaluate the customers' preferences of purchasing, renting through an agency, or mobile application supported new pay-as-you-go business model use, in order to determine which criterion is prominent in the decision-making process, and to identify the weights of these criteria. Due to the uncertain and indeterminate attitudes of the customers in decision making, the data were collected as neutrosophic data sets and analyzed with a novel neutrosophic Analytic Hierarchy Process (nAHP) approach. The study provides implications both theoretically and practically in terms of revealing new servicization possibilities and analyzing real user judgments.

Keywords: servicization, servicizing business model, car sharing program, neutrosophic sets, neutrosophic Analytic Hierarchy Process.

1. Introduction

Circular Economy which based upon the reuse, remanufacture and recycling of the products is a well-known and well-accepted movement of sustainable operations management research (Agrawal et al., 2019). The servicizing business models, i.e. servicization or product-as-a-service concept, grounds on selling the functionality of a product / item / device instead of selling the product itself to the customers. This is a phenomenon converting the products into services (Systems Innovation, 2020), or transforming the consumers into users (McIntyre & Ortiz, 2015) by bringing the functionalization into the forefront. In this case, companies don't transfer the product ownership to the customers, instead, they charge the them in pay-per-use base.

Servicizing business models have been drawn attention with its sustainable and environmental side owing to the durability and reliability requirement of these repeatedly in use products, and they have been defined as an "opportunity to research" (Agrawal et al., 2019) in the literature. Besides, the companies have made serious investments for this business model recently (Syncron, 2020). However, the COVID-19 pandemic has caused a serious decrease in individual purchasing power, and the companies have developed a new servicization versions in order to minimize the face-to-face communication and contracting process with an easier way of payment via mobile applications.

This change in the way of business has motivated this research to analyze the customer perception and attitude towards different individual transportation options. Hence, this study aims to develop a decision model for evaluating the customers' decisions on purchasing, renting through an agency (walk-in or using the website of provider or a website comparing all providers), or new mobile application controlled way of renting alternatives of driving in order to determine which criterion is more important in the decision-making process, and to identify the weights of these criteria.

Since the decision criteria have often vague, uncertain, indeterminate or inconsistent information, the data were collected as neutrosophic data sets from the real customers having experiences in both purchasing, renting through an agency and renting through the mobile application alternatives were analyzed with a neutrosophic AHP approach. The fuzzy AHP provides a wide range of application areas and remarkable results for many sectors (Singh et al., 2018; Darbari et al., 2019; Ganguly and Kumar, 2019; Karasan, 2019; Ferrari et al., 2020). The study provides theoretical and practical implications by revealing new servicization alternatives and analyzing real customer attitudes.

The following sections include literature review, objective of the study, methodology, analysis and conclusion parts.

2. Literature Review

Current servicization literature focuses on the intensions of the organizations towards servicizing (Khan et al., 2020; Lieder et al, 2020; Hofmann, 2019), product-as-a-service (Patwa et al., 2020), device-as-a-service (HP, 2017; McIntyre & Ortiz, 2015), the potential of Industry 4.0 adoption in servicizing (Keivanpour, 2021; Bag et al., 2021).

There are successful examples in servicization such as Xerox printing services, Runway car rental, Michelin fleet solutions, Philips' lighting solutions, Rolls-Royce's total care solutions (Agrawal and Bellos, 2016), and Bundles' household appliance services (Agrawal et al., 2019).

Servicization studies implementing AHP discuss construction servicization (Chen et al., 2020), design requirements for plumbing services (Jadhav et al., 2020), prioritization of product-service business model elements at aerospace industry (Salomon et al., 2019), and cloud manufacturing (Cao et al., 2016). Moreover, there are Neutrosophic AHP papers addressing system selection (Radwan et al., 2016; Bilandi et al., 2020), AHP-SWOT analysis for strategic planning and decision-making (Abdel-Basset et al., 2018), AHP and TOPSIS framework (Junaid et al., 2020), AHP and DEA methodology (Kahraman et al., 2019), and performance analysis (Kahraman et al., 2020).

However, the new mobile application driven pay-as-you-go model of servicization research is missing in the literature. Besides, there are limited number of AHP studies applied neutrosophic sets. Therefore, the priorities of the customers having experiences in both purchasing and renting cars will be examined in this study with neutrosophic sets in order to serve as a good example of neutrosophic AHP for servicizing.

3. Methodology

The evaluation criteria that the real customers consider in transportation through driving alternatives have been specified via an in-depth interview with a car rental service provider

X representative. The model is based on the literature review and information provided by the company X representative. The goal, criteria and alternatives are presented in Figure 1.

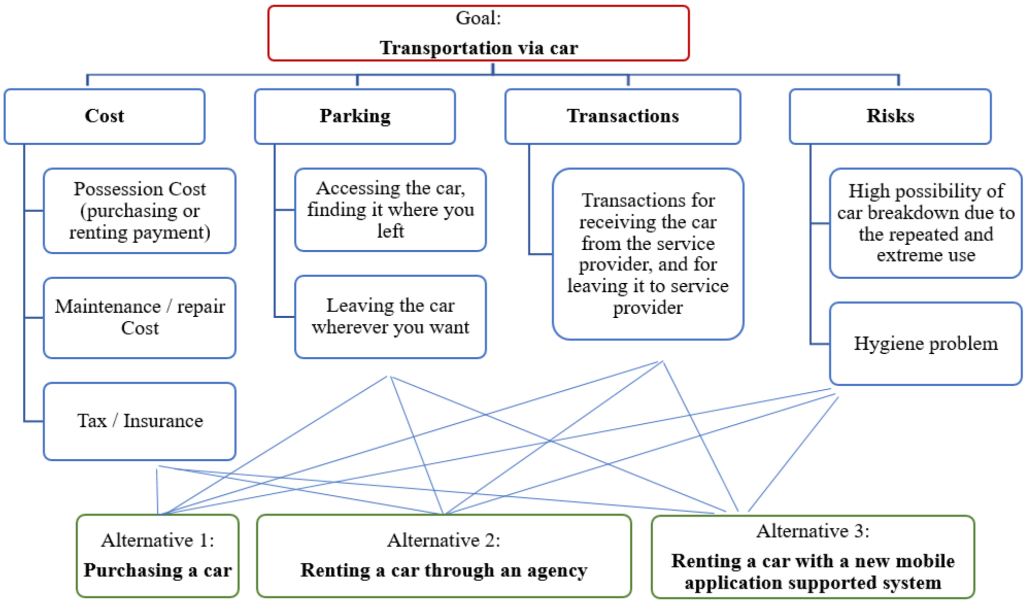

Figure 1. Developed AHP model.

In order to obtain the customer judgements, a user survey has been used, and neutrosophic sets have been used to gather the preferences. The experts were selected from the car rental service provider X's real users who had comments about the mobile application in the website of the company. 36 users were identified as candidate experts, and just 3 of them accepted to state their opinions.

3.1 Preliminaries

Neutrosophic sets (NSs) are proposed by Smarandache (1998) as a general form of fuzzy sets and intuitionistic fuzzy set. This is a powerful technique to handle incomplete, indeterminate and inconsistent information that is valid in the real world applications. Besides, there are many neutrosophic sets: single valued, interval-valued, multi-valued, bipolar, hesitant, refined, simplified, rough and hyper-complex neutrosophic sets (Broumi et al., 2018).

Basic definitions and operations of neutrosophic sets:

Definition 1. A neutrosophic set A in E (let E be a universe) is characterized by a truth-membership function $T_A(x)$, an indeterminacy-membership function $I_A(x)$, and a falsity-membership function $F_A(x)$ where $x \in E$.

A can be defined as $A=\{\langle x, T_A(x), I_A(x), F_A(x), \mid x \in E \rangle\}$

where $T_A(x), I_A(x), F_A(x) \in]0^-,1^+[$ such that $0^- \leq T_A(x), I_A(x), F_A(x) \leq 3^+$.

Definition 2. A single-valued neutrosophic set A is a subclass of NS and is stated as

$A=\{\langle x, T_A(x), I_A(x), F_A(x) \mid x \in E \rangle\}$ where $T_A, I_A, F_A : X \rightarrow [0,1]$

such that $0 \leq T_A(x) + I_A(x) + F_A(x) \leq 3$.

In particular, if E has only 1 element, A is called a simplified neutrosophic number (SNN), which is represented as $A=\langle T_A, I_A, F_A \rangle$ (Wang et al., 2010).

Definition 3. Let A and B be two SNN, and p(A) be the complement of A, the following operations are valid (Wang et al., 2010; Radwan et al., 2016).

$A \oplus B = \langle T_A + T_B - T_A * T_B, I_A * I_B, F_A * F_B \rangle$
$A \otimes B = \langle T_A * T_B, I_A + I_B - I_A * I_B, F_A + F_B - F_A * F_B \rangle$
$A / B = \langle T_A / T_B, I_B - I_A / 1 - I_A, F_B - F_A / 1 - F_A \rangle$
$\alpha A = \langle 1 - (1 - T_A)^{\alpha}, (I_A{}^{\alpha}), (F_A{}^{\alpha}) \rangle, \alpha > 0$
$A / \alpha = \langle 1 - (1 - T_A)^{1/\alpha}, (I_A{}^{1/\alpha}), (F_A{}^{1/\alpha}) \rangle, \alpha > 0$
$p(A) = \langle F_A, 1 - I_A, T_A \rangle$

Definition 4. The score function is defined as s(A)= $(2 + T_A - I_A - F_A) / 3$ for a SNN to deneutrosophicate or rank (Broumi et al., 2018).

Definition 5. Geometric means are defined as (Kahraman et al., 2019):

$T_1 = [1 \times T_{12} \times \ldots \times T_{1n}]^{1/n}, \ldots, T_n = [T_{1n} \times \ldots \times 1]^{1/n}$
$I_{1m} = [1 \times I_{12m} \times \ldots \times I_{1nm}]^{1/n}, \ldots, I_{im} = [I_{n1m} \times \ldots \times 1]^{1/n}$
$F_{1m} = [1 \times F_{12m} \times \ldots \times F_{1nm}]^{1/n}, \ldots, F_{im} = [F_{n1m} \times \ldots \times 1]^{1/n}$

Definition 6. Aggregation formula is (Kahraman et al., 2019):

$F_w(A_1, A_2, \ldots, A_n) = \langle 1 - \prod_{j=1}^{n}\left(1 - T_{A_j}(x)\right)^{w_j}, 1 - \prod_{j=1}^{n}\left(1 - I_{A_j}(x)\right)^{w_j}, 1 - \prod_{j=1}^{n}(1 - F_{A_j}(x))^{w_j} \rangle$ where $W = (w_1, w_2, \ldots, w_n)$ is the weight vector of A_j $(j = 1, 2, \ldots, n)$, $w_j \in [0,1]$ and $\sum_{j=1}^{n} w_j = 1$.

The truth-membership T_A stands for "the possibility in which the statement is true", the indeterminacy-membership I_A is "the degree in which he/she is not sure", and the falsity-membership F_A means that "the statement is false" (Ye, 2018).

All of the above definitions will be applied to the proposed nAHP methodology in the following sections.

3.2 Procedure in gathering and aggregating the individual evaluations

There are different proposed scales for the neutrosophic linguistic variable such as Radwan et al. (2016) and Kahraman et al. (2019). However, there is also a fair criticism for these scales due to the defined structure of them. For example, the aforementioned Radwan et al. (2016) scale defines "extremely highly preferred" as <.9 .1 .1>. The truth-membership can be thought as the reverse of falsity-membership; this is acceptable by definition. However, since the indeterminacy means "the degree in which one is not sure", we cannot define this indeterminacy proportional to the truth-membership value with a scale. Participants should express "the degree in which he/she is not sure". Therefore, this study gathers the truth and indeterminacy values separately from the participants instead of using these defined tables in order to deal with this criticism.

In order to aggregate the individual neutrosophic evaluations into group evaluations, the captured expert opinions have been processed with the proposed formula of Kahraman et al. (2019) (the definition 6). There are nAHP papers use the neutrosophic weighted arithmetic average aggregation operator of Ye (2014), such as Aydın et al. (2018). However, since the average operator is problematic in terms of finding reciprocals, this study prefers to adopt a geometric mean based formulation in aggregating the expert opinions.

3.3 Steps of the methodology

The steps of the nAHP used in this study:

Step 1. Defining the problem, criteria and alternatives with a structured hierarchy.

Step 2. Gathering the expert evaluations by taking truth- and indeterminacy-membership values separately via a survey in order to obtain pairwise comparisons of criteria and alternatives.
Step 3. Checking the consistency of pairwise matrices by Eigenvector solution.
Step 4. Aggregating the individual evaluations into group decision.
Step 5. Obtaining the weights of each criteria. Repeating these steps for the alternatives' pairwise comparisons.
Step 6. Ranking the alternatives with respect to the calculated weights.

4. Analysis

The defined problem with criteria and alternatives in a structured hierarchy is provided in Figure 1 previously by fulfilling the Step 1.
Step 2. The user survey provided real users' judgements on the goal "transportation via car" and the alternative ways of transportation. Table 1 presents the individual judgements of the experts.

Table 1. Pairwise comparison matrix with respect to goal by experts.

	Expert #	Cost	Parking	Transactions	Risks
	1	< .5 .5 .5 >	< .7 .2 .3 >	< .7 .2 .3 >	< .4 .7 .6 >
Cost	2	< .5 .5 .5 >	< .9 .1 .1 >	< .9 .1 .1 >	< .9 .1 .1 >
	3	< .5 .5 .5 >	< .9 .1 .1 >	< .9 .1 .1 >	< .7 .2 .3 >
	1	< .3 .8 .7 >	< .5 .5 .5 >	< .7 .2 .3 >	< .3 .8 .7 >
Parking	2	< .1 .9 .9 >	< .5 .5 .5 >	< .9 .1 .1 >	< .6 .2 .4 >
	3	< .1 .9 .9 >	< .5 .5 .5 >	< .8 .1 .2 >	< .5 .1 .5 >
	1	< .3 .8 .7 >	< .3 .8 .7 >	< .5 .5 .5 >	< .2 .8 .8 >
Transactions	2	< .1 .9 .9 >	< .1 .9 .9 >	< .5 .5 .5 >	< .9 .1 .1 >
	3	< .1 .9 .9 >	< .2 .9 .8 >	< .5 .5 .5 >	< .7 .1 .3 >
	1	< .6 .3 .4 >	< .7 .2 .3 >	< .8 .2 .2 >	< .5 .5 .5 >
Risks	2	< .1 .9 .9 >	< .4 .8 .6 >	< .1 .9 .9 >	< .5 .5 .5 >
	3	< .3 .8 .7 >	< .5 .9 .5 >	< .3 .9 .7 >	< .5 .5 .5 >

Step 3. The consistency was checked with the score function value definition for each participant evaluations via Eigenvector solution procedure (Teknomo, 2006).
The score function was applied to deneutrosophicate the evaluations into crisp values. The sum of each column was taken, next, each element of the matrix was divided into the sum of its columns in order to have normalized relative weights. Then, the normalized principal Eigenvector (also called priority vector) is obtained by averaging across the rows. This calculation provides the experts' priorities with respect to goal. For example, while the risk criterion is the priority of the expert 1, cost criterion is the most important criteria for expert 2 and 3. Besides of the relative weight calculation, this procedure paves the way for checking the consistency of participants' answers. Here, one needs Principal Eigen value (λ_{max}) obtaining from summation of products between each element of Eigen vector and sum of columns of the reciprocal matrix. Table 2 states the score function values, normalization, weights and Principal Eigen value.
The largest Eigen value equals to the size of comparison matrix, or $\lambda_{max} = n$ (Saaty, 1986), which gives a measure of consistency named Consistency Index ($CI = (\lambda_{max} - n) /(n-1)$). The CI values should be compared with Random Consistency Index as a previously defined index of sample size 500, and RI is 0.89 for n=4 (4×4 matrix). The Consistency Ratio CR was calculated (CR = CI / RI), and if the CR is ≤ 10% in comparison with the CI, the

inconsistency is acceptable. Accordingly, while the evaluations of expert 1 and 3 are within the acceptable inconsistency limits, the evaluations of expert 2 cannot be taken into consideration due to the CR = 23%.

Table 2. Score function values, normalization, weights and principal Eigen value.

wrt. Goal		Score function values				x/sum values				w	λ_{max}
		C	P	T	R	C	P	T	R	Row average	
E1	C	0,500	0,733	0,733	0,367	0,300	0,328	0,265	0,275	0,292	3,681
	P	0,267	0,500	0,733	0,267	0,160	0,224	0,265	0,200	0,212	
	T	0,267	0,267	0,500	0,200	0,160	0,119	0,181	0,150	0,153	
	R	0,633	0,733	0,800	0,500	0,380	0,328	0,289	0,375	0,343	
	Sum	1,667	2,233	2,767	1,333	1	1	1	1		
E2	C	0,500	0,900	0,900	0,900	0,313	0,429	0,338	0,303	0,345	4,409
	P	0,367	0,500	0,900	0,667	0,229	0,238	0,338	0,225	0,257	
	T	0,367	0,367	0,500	0,900	0,229	0,175	0,188	0,303	0,224	
	R	0,367	0,333	0,367	0,500	0,229	0,159	0,138	0,169	0,173	
	Sum	1,600	2,100	2,667	2,967	1	1	1	1	1,000	
E3	C	0,500	0,900	0,900	0,733	0,333	0,466	0,365	0,278	0,361	4,002
	P	0,367	0,500	0,833	0,633	0,244	0,259	0,338	0,241	0,270	
	T	0,367	0,167	0,500	0,767	0,244	0,086	0,203	0,291	0,206	
	R	0,267	0,367	0,233	0,500	0,178	0,190	0,095	0,190	0,163	
	Sum	1,500	1,933	2,467	2,633	1	1	1	1	1,000	

Step 4. In order to aggregate the individual evaluations into group decision, the aggregation definition 6 was used (see Table 3).

Table 3. Aggregating the individual evaluations into group decision.

	Cost			Parking			Transactions			Risks		
wrt. Goal	T	I	F	T	I	F	T	I	F	T	I	F
Cost	0,4	0,4	0,4	0,7	0,1	0,1	0,7	0,1	0,1	0,4	0,3	0,3
Parking	0,1	0,3	0,6	0,3	0,3	0,3	0,5	0,1	0,1	0,2	0,3	0,4
Transactions	0,1	0,2	0,5	0,1	0,5	0,4	0,2	0,2	0,2	0,2	0,2	0,3
Risks	0,3	0,3	0,3	0,4	0,4	0,2	0,5	0,4	0,2	0,3	0,3	0,3

Step 5. The weights of each criterion were obtained, ant the step was repeated for the alternatives' and sub-criteria's pairwise comparisons.
Step 6. The alternatives were ranked with respect to the calculated weights.

According to the analysis results, renting through an agency was the most preferred alternative in terms of the cost criterion. Secondly the new system, and then the purchasing option was preferred by the weight values. When the parking criterion was considered, the ranking was purchasing, renting through an agency and new system, respectively. Similarly, in case we had a focus on the transactions, the same ranking was valid. However,

participants addressed the new system as the most risky alternative, next renting through an agency and then the purchasing option, respectively.
The subcriteria analysis revealed that there was a tax/insurance, maintenance / repair cost, and possession cost sequence with respect to cost criterion. Moreover, "hygiene problem" subcriterion had a greater importance than the "high possibility of car breakdown due to the repeated and extreme use" in terms of risks criterion. Besides, the "accessing the car, finding it where you left" subcriterion and the "leaving the car wherever you want" subcriterion had close weights as 0,51 and 0,49.
When the criteria weights and alternatives were combined, this analysis resulted that the effect of alternatives on the goal was identified with the weights as renting through an agency (0.358), purchasing option (0.326), and the new system (0.316).

5. Conclusions

This study introduces a new way of servicizing business model as a contribution to the literature with real customer preferences shaping the decision making process. The analysis results addressed the weights of criteria and alternative ranking by real user preferences.
As a theoretical implication, this study tries to handle the criticism of previously defined linguistic variable tables by a different way of data gathering. In addition, the study adopts the score functions to deneutrosophicate the fuzzy sets in analysis procedure as a new approach.
The practical implications of the paper provide a real world customer preference point of view for the industry representatives. Since the new normal of the world requires new way of business models, this analysis addresses new initiatives to overcome the burden of this hard time. One can infer from these results that the companies can introduce new way servicization by taking the defined significant criteria into consideration.
The number of company representatives, number of participants, and the possibility of biased attitudes of the both these representatives and the participants are the main limitations of this study. Hence, this study tries to select the real participants who have experienced these services previously in order to reflect the real world case. In addition, the participants were asked whether they are willing to participate the survey, or they are feeling obliged at the beginning of the survey questions.
Furthermore, this paper serves both theoretical implications by using the neutrosophic sets to AHP and practical implications by presenting the real user priorities. One can infer from the study to understand which criteria is prominent in contrast with the others, and the theoretical background can be applied to different decision making problems.
Further researches may have a large number of participants and representatives, or different mathematical assumptions can be utilized in the calculations. This study differs from the existing ones by gathering the indeterminacy values of neutrosophic sets by the participants instead of using the defined linguistic variable tables.

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