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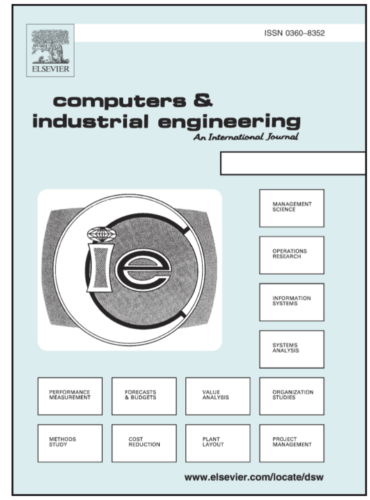

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A novel neutrosophic set based hierarchical challenge analysis approach for servicizing business models: A case study of car share service network

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Abstract

Servicization as a part of circular economy has a prominent role in operations management research by emphasizing the functionality of the products. Servicizing business model is a phenomenon that the products are converted into services for sale, or process of transforming the consumers into users. This newly introduced way of business is defined as a new opportunity for operations management by focusing on; the reliability and durability of the products against the extreme repeatedly use, coordination problems in conducting the business, risk of encountering unknown negative customers, and moral hazard in product usage, operational difficulties, and the degradation of the products. All of the aforementioned issues in implementing the servicizing business models constitute a research question with the high impact of COVID-19 pandemics. Since people avoid using public transportation, car share programs are highly in demand. In addition, there is an obvious research gap in challenge analysis of the car-sharing programs' literature, an overall service network challenge analysis is missing in the field of study. Hence, the purpose of this study is proposing a novel neutrosophic set based hierarchical challenge analysis approach for the servicizing business models with a step by step guidance, and presenting a real world case study addressing a car sharing company's entire service network. A practitioner can understand which challenge should be dealt with first, what is the inter-relationship structure of these challenges in a hierarchy, and what is the expected final result of these interactions. The study also contributes to the theoretical background by using neutrosophic sets to propose a novel interpretive hierarchical challenge analysis. In this research, the evaluation of truth and indeterminacy membership degrees of a neutrosophic set are gathered separately instead of applying the defined linguistic variable schemes. The case study is a contemporary field of study attracting attention of innovative entrepreneurs, since there is an increased demand of individual car driving due to the isolation requirement arisen from COVID-19 pandemics.

Keywords: Servicizing business model, servicization, hierarchical challenge analysis, neutrosophic sets.

1. Introduction

Circular Economy (CE) movement has gained a remarkable importance as a part of sustainable operations management research by transforming the traditional "take-make-dispose" concept to "regenerate-restore-reuse" of the resources and products in a circulating system (Agrawal et al., 2019). In order to create advantage in CE, one should eliminate waste, acknowledge everything having a value, improve collaborations with customers with a "servicizing business model" which is powered by the digital transformation (Accenture, 2015).

Current CE literature emphasizes the barriers and challenges to CE (Suzanne et al., 2020; Bilal et al., 2020), intensions of the organizations towards CE (Khan et al., 2020), servicization (Agrawal et al., 2019; McIntyre & Ortiz, 2015), servicizing business models (Lieder et al, 2020; Hofmann, 2019), product-as-a-service (Patwa et al., 2020), device-as-a-service (HP, 2017; McIntyre & Ortiz, 2015), infrastructure / platform -as-a-service (Amazon Mechanical Turk, 2020; Rackspace, 2020), labor / human resource -as-a-service (Insler, 2018), the potential of Industry 4.0 adoption (Keivanpour, 2021; Bag et al., 2021), green / closed-loop / sustainable supply chains (Dominguez et al., 2020; Ponte et al., 2020; Turken et al., 2020; Atabaki et al., 2020; Frei et al., 2020),.

Agrawal et al. (2019) defines "servicization" as a new opportunity for operations management research. Servicization is the concept of selling the functionality of a product, device, item, infrastructure, platform, labor, human resource, personnel, employee, crew, etc. instead of selling the item itself or instead of hiring the employees permanently. In other words, this is a phenomenon that the products are converted into services for sale (Systems Innovation, 2020), or process of transforming the consumers into users (McIntyre & Ortiz, 2015), or providing human resource as a service. It can be seen in the literature and business reports with "X-as-a-service" phrase such as product / device / infrastructure / platform / data / application / labor / human resource "-as-a-service" by focusing on the functionalization.

"Servicizing" is a transaction through the value provided by a combination of products and services (Systems Innovation, 2016). "Servicizing business models" enable sharing and reuse (Agrawal et al., 2019). Regardless of the scope of the sector, the companies don't transfer the product/service ownership to the customers, instead, they charge the customers in pay-per-use base. The successful examples of the servicizing business models are 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).

Servicizing business models face barriers that needing to be solved. For instance, there is a concern of the customers about whether they can cancel their contract at any time they want. They would not like to feel captive to only one service provider. Hence, for example Bundles' company allows customers for cancellation at any time in order to deal with this obstacle. This flexibility raises the willingness to participate of the customers to the servicization. However, this also brings an uncertainty for the companies with operational costs stemming from removing, transportation, remanufacturing, etc. Especially, in the Bundles' case, the products are bulky and heavy appliances in addition to the customers who living in urban areas. Therefore, fluctuations in revenue, logistic costs and available stock of products is inevitable (Agrawal et al., 2019).

Researches on the challenges in implementing the servicization highlight that regardless of type of the company, servicization introduces a treat due to the transforming the traditional sales model into servicizing (Agrawal and Bellos, 2016). Reliability and durability are the most important properties of the servicized products in this case, since the products are extremely in use repeatedly in contrast with the traditional daily use. Moreover, coordination problems (Corbett and DeCroix, 2001), risk of encountering unknown negative customers, and moral hazard in product usage (Toffel, 2008) are the another challenges discussed in the literature. While the customers who own the item care the operability of the product, servicizing customers perform misuses in many cases. Servicized customers are less cautious in experiencing the function that results in a degradation of the product (Meige, 2018). Furthermore, internal workforce resistance against servicization is an another issue. Since employees receive a certain percentage of commission proportional to the eventuated sales in traditional business models, product-based responsibility is not welcomed (Agrawal and Bellos, 2016).

All of the aforementioned problems in servicizing business model implementation constitute a research question (Meige, 2018). There is an obvious research gap in challenge / risk / disruption / barrier / obstacle analysis of the car-sharing programs' literature. While the related current literature focuses on customer profiles (Pirra and Diana, 2021), modeling the multimodal car-sharing problem (Enzi et al., 2021), sustainability of sharing cars (Harris et al., 2021), environmental impact of mutualized mobility (Sun and Ertz, 2021), the challenges are neglected in the literature. The available car-share challenge papers provide: the challenges for agile algorithms in optimizing car-sharing operations (Martins et al., 2021), mobility implications for government as a disruption (Wilson, and Mason, 2021), risk-based driver authentication scheme for car-sharing platforms (Gupta et al., 2019), the challenges in shared stackable vehicles (Boldrini et al., 2018), and the challenges in electric cars sharing (Illgen and Höck, 2018). An overall service network challenge analysis is missing in the field of study.

Hence, the purpose of this study is proposing a novel neutrosophic set based hierarchical challenge analysis approach for servicizing business models, and presenting a real world case study addressing a car sharing company's entire service network.

The research definition of this study is based on identifying and analyzing the challenges encountered in car-share servicizing business model. The research definition based on three basic challenges as mobile application based problems, vehicle based difficulties, supplier based problems. The research hypothesis defends the opinion that there is a hierarchical cause-and-effect relationship between these defined challenges. The related hypothesis are:

H_1: Mobile application based problems (MA) affects all other challenges since the mobile application is the platform where the business interactions are handled.

H_2: Negative behaviors of the users towards the vehicles (NB) causes a degradation of the vehicles (DoV).

H_3: Coordination problems (CP), operational difficulties (OD) and supplier based problems (S) triggers each other.

Therefore, the proposed methodology presents a novel neutrosophic set based hierarchical challenge analysis approach for the defined indeterminate uncertain factors. The methodology is based on the defined challenges ant their inter-relations in order to find the root cause of these obstacles. By doing so, it is possible to decide on which problematic area to be solved first.

The current neutrosophy literature addresses supplier selection problem (Pamucar et al., 2020), facility location and routing (Mohammadi et al., 2020), production processes (De et al., 2020), linear programming (Khatter, 2020), multi-criteria decision making (Gül, 2020; Liu and Cheng, 2020; Hashmi et al., 2020; Son et al., 2020, Tian et al., 2020; Köseoğlu et al., 2020), time series models (Zhao et al., 2020; Singh and Huang, 2019), sentiment analysis (Kandasamy et al., 2020). However, there are limited number of researches discussing risks / barriers / challenges / difficulties / disruptions / interruptions such as Gul et al. (2021), Fu et al. (2020), Ayber and Erginel (2020), Abdel-Basset et al. (2019) in the neutrosophy. Therefore, this study aims to contribute the neutrosophic theory literature by a novel challenge analysis approach.

The following sections present the preliminaries of neutrosophic sets, the proposed methodology, literature review of challenges in implementing the servicizing business models, case study and conclusion parts.

2. Preliminaries

Neutrosophic sets (NSs) are proposed by Smarandache (1998) as a general form of fuzzy sets and intuitionistic fuzzy sets. 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).

The reason behind why the neutrosophic sets are selected in this paper is based on their advantages. For instance, neutrosophic sets can measure all three truth, falsity, indeterminacy memberships independently, and shows how one effects another in decision making. In case of intuitionistic fuzzy sets, if membership increases, the certainty the sum of other two measure decreases. In the intuitionistic fuzzy sets, the membership and non-membership degrees are dependent, and their sum should be less than or equal to 1. In neutrosophic sets, all sources are independent, and they do not communicate with each other and they do not know the response of each other. (Smarandache, 2021; Smarandache & Pramanik, 2016; Das et al., 2020).

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

$A=\{\langle x, TA(x), IA(x), FA(x), \mid x \in E \rangle\}$ 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).

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

Definition 4. Let A $= \langle T_A, I_A, F_A \rangle$ be a SNN. The score function s(A)= $(2 + T_A - I_A - F_A) / 3$, accuracy function a(A) = $T_A - I_A$, and certainty function c(A) = T_A of a SNN (Broumi et al., 2018). In order to rank two SNN A and B,

- If $s(A) > s(B)$ then $A > B$,
- If $s(A) = s(B)$, and $a(A) > a(B)$ then $A > B$,
- If $s(A) = s(B)$, and $a(A) = a(B)$, and $c(A) > c(B)$ then $A > B$,
- If $s(A) = s(B)$, and $a(A) = a(B)$, and $c(A) = c(B)$ then $A = B$.

It is clear that, if score functions are equal, then accuracy function should be calculated, and certainty function should be checked at last in order to rand the alternatives.
Composition rules enable to evaluate the indirect relationships between different variables.
Definition 5. Max-product composition is $\tilde{R}_1 \overset{\circ}{\cdot} \tilde{R}_2(x,z) = \max_y \ [\mu_{R_1}(x,y) * \mu_{R_2}(y,z) | \ x \in X, \ y \in Y, \ z \in Z]$ which requires a multiplication and selecting the maximum membership degree, while max-min composition is $\tilde{R}_1 \circ \tilde{R}_2(x,z) = \max_y \ [\min \mu_{R_1}(x,y), \ \mu_{R_2}(y,z) | \ x \in X, \ y \in Y, \ z \in Z]$ emphasizing the intersection, and max-average composition is $\tilde{R}_1 \overset{\circ}{_{\text{av}}} \tilde{R}_2(x,z) = \frac{1}{2}\max_y \ [\mu_{R_1}(x,y) + \mu_{R_2}(y,z) | \ x \in X, \ y \in Y, \ z \in Z]$ that needs a summation and taking the average of the membership degrees (Zimmermann, 1991).
All of the above definitions will be applied to the proposed methodology in the following sections.

3. Proposed Methodology

The proposed model is grounded on the interpretive structural modeling decision technique that identifies the relationships between factors / risks / barriers / challenges / contingencies / disruptions in a system. It is possible to determine the root causes of such a problem (Sage, 1977). The steps of the proposed methodology:

1. Define the barriers in implementing the servicizing along the entire supply chain.
2. Apply Delphi technique to obtain a fuzzy reachability matrix which is a consequence of expert opinions. Experts discuss together to determine the relationship between each barrier, and construct a final decision matrix. Table 1 is the basic form of a fuzzy reachability matrix indicating that which barrier has an influence on one another barrier. In other words, it stands for solving barrier i also solves the barrier j.

Table 1. Fuzzy reachability matrix structure.

Evaluations of Experts via Delphi Technique	Barrier 1			Barrier 2			Barrier 3		
	T_A	I_A	F_A	T_A	I_A	F_A	T_A	I_A	F_A
Barrier 1				T_{12}	I_{12}	F_{12}	T_{13}	I_{13}	F_{13}
Barrier 2	T_{21}	I_{21}	F_{21}				T_{23}	I_{23}	F_{23}
Barrier 3	T_{31}	I_{31}	F_{31}	T_{32}	I_{32}	F_{32}			

Pairwise comparisons are gathered as neutrosophic sets, and truth-membership degree T_A, indeterminacy-membership degree I_A, and a falsity-membership degree F_A are asked to experts one by one. Relation strengths are taken with Saxena et al. (1992)'s 0 ± 1 scale. Here, 0 means there is no relation between these barriers, while 0.1 represents the very low directed relationship, 0.3 is low, 0.5 is medium, 0.7 is high, 0.9 is very high, and 1 stands for full relationship, respectively.

3. Calculate the score, accuracy and certainty function values by computing the T_A, I_A and F_A. This step is important for ranking the columns and rows, and bring three values into one. As it is defined in the previous section, there is a ranking rule in order to decide which function value of score, accuracy or certainty should be taken into consideration.
4. Draw an initial visual graph, so that one can easily determine the indirect relationships. The indirect relationship rule says that if there is a relationship directed *x* to *y*, and *y* to *z*, so there is a relation directed *x* to *z*.
5. Write letters IR to the matrix cells for newly-introduced relationships.
6. Calculate each IR value by composition rules, and take the minimum one. Since the indirect relationship implies a possible minor inter-relation, taking the minimum composition value is preferred in the literature commonly such as Karadayi-Usta (2020), Dwivedi et al. (2017), Yenradee and Dangton (1995). In this research, the experts have been asked for the indirect relationship values,
7. Adjust the matrix by changing the rows and columns in order to generate an adjacency matrix as a lower triangular matrix (if possible).
8. Count the zeros in each row, add a new column to the right-hand side of the matrix, place the number of zeros to this column cells. This represents the hierarchical positions of each barrier.
9. Draw the hierarchical visual graph.
10. Adjust the final graph in terms of driving and dependence powers. In case of a large amount of difference in values, change the hierarchical positions.

Here, 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, 2014).

In the following section, the challenges in implementing the servicizing business models in the literature will be introduces in detail, and the proposed methodology will be applied to one of the most important actor's case of servicizing business models.

4. Challenges in Implementing the Servicizing Business Models

The service business model is function-oriented where tangible products and intangible services are combined together (Tukker, 2004), and it encounters obstacles needing to be resolved. For example, customers don't want to be tied down by just one service provider. Therefore, companies allow customers to cancel the contract at any time to handle this obstacle. However, this leads to an uncertainty for the companies with operating costs due to the movement, transportation, and repair, etc. (Agrawal et al., 2019). This situation also brings different pricing strategies / service packages for different kind of customers (Kryvinska et al., 2020), which can be perceived as a personalized / special pricing strategy by some of the customers. Unfortunately, in case there are customers considering that there are another people treated privileged with better pricing alternative, this may introduce a customer loss for the servicizing provider.

Moreover, reliability and durability might be challenging because of the extreme use of the products. Hence, maintenance, repair, operation and spare parts supply are the critical issues in servicization (Cheng and Prabhu, 2012). In addition, coordination problems (Corbett and DeCroix, 2001; Kryvinska et al., 2020), complicated customer demands (Baines & Shi, 2015), negative customer behaviours and moral hazard (Toffel, 2008) are the barriers in implementing the servicization. Although the customers who possess the product itself cares about the reliability and durability, in many cases, the customer could perform misuses resulting in product degradation (Meige, 2018).

There is also another difficulty in executing the servicization concept due to the transforming the conventional sales concept into servicizing. Internal workforce resistance against servicization is one of the most important barriers in the servicization concept (Agrawal and Bellos, 2016). Knowledge and experience may be insufficient for the servicizing, and tools / competent personnel in servicizing may be absent (UNEP, 2002). Hence, the organizational culture (Kryvinska et al., 2020), i.e. resistance in cultural shift (Rothenberg, 2007; Örsdemir et al., 2019) is an important issue.

Servicization could be financially and environmentally inferior because of the products that are sold after a certain leasing / utilization period of time. It can prompt the company to remove the in use products from the market owing to the newly released in demand products. The companies feel compelled to sell their mid-life products so that they can stay up to date to appeal more customers (Agrawal et al., 2012).

A comprehensive literature review defining the challenges of servicization (i.e. servitisation, product-service system) outlines the barriers as customer perspective, interface redefining, revenue / pricing and selling issues, product/service system design, supply network, organizational architecture, performance measurement, and cultural transition (Nudurupati et al., 2016).

As a result, all of the aforementioned problems constitute a research covering the barriers in servicizing business model implementation (Meige, 2018).

5. Car sharing Service Network Case Study

According to the current car sharing literature, Strulak-Wójcikiewicz and Wagner (2021) study presents a suitable business model. They determine the reasons for using sharing platforms as saving money, paying for the service as individual, caring for the environment, opportunity to meet people, learning new lifestyles, obtaining a unique and customized offering, sense of belonging to a group of people. Also, Yun et al. (2020) illustrates a car sharing business model dynamics containing government regulations, taxi industry, public transportation, and automotive industry by specifying the revenue, responsibility and system models.

Car sharing company X is a new brand of Turkey that meets the car rental needs of individuals and institutions. It provides people with hundreds of car options suitable for different needs and tastes by paying as you go. Ones who have at least one-year valid driver license that has not been seized by the authorities within the last one-year, those who have not made an accident more than two times in the last one-year, people having a credit card that has not expired and is open to internet shopping with a sufficient limit, and the owners of smart mobile phones can take the advantage of Car sharing company X application just by clicking the "Rent Now". The customers can see the available nearest cars on the map, can find the car, and use the application so that they can open the car. The application uses GPS signals to control the doors' lock, permits opening the doors by an activation process via the application. The key stands in the glove compartment, and when the customers leave the car, they put the key again to the same place. People can leave the rented cars to the convenient parking places. Finally, the application requires some photographs of the car in order to end the servicizing experience.

It is assumed that the impact of the COVID-19 on the car sharing business is positive in terms of requiring individual transportation in affordable prices instead of public transportation. Also, although the hygiene is a question mark for many people in sharing vehicles, since the Car sharing company X control the cleaning team firmly, it is assumed that the hygenization is not a problem.

In addition to the above listed barriers extracted from the literature, this case study focuses on a Car sharing company X mobile application that provides the fleet leasing with contracted vehicles since 2003. An in-depth interview was held with the company representatives in order to describe the implementation challenges of the servicization.

Step 1. Define the barriers in implementing the servicization.

The company faces,

- (OD) Operational difficulties in enabling the vehicles after some specified amount of usage by the required cleaning, maintenance and repair services.
- (DoV) Degradation of the vehicles due to the extreme and repeated use.
- (S) Supplier based problems (vehicle vendor, car-park provider, automatic vehicle identification based fuel supplier) such as noncompliance with service level agreements, service breakdown.
- (CP) Coordination problems with the suppliers (e.g. lack of communication, unannounced service disruptions), and with the back office (e.g. impatient or slowing down attitude of the employees)
- (NB) Negative behaviors of the users towards the vehicles (e.g. leaving the vehicles dirty, smoking inside, and leaving waste material inside the vehicle).
- (MA) Mobile application based problems (software based or payment system based issues).

Step 2. Obtain a fuzzy reachability matrix.

This kind of interpretive studies requiring expert evaluations have one to six sector representatives and one to three academicians in general (Dwivedi et al., 2017). These papers have at least three experts in total like Yudatama et al. (2018) for the validation. The Delphi techniques has been applied with the participation of the 2 company representatives and an academician having researches in service networks in order to construct the decision matrix.

The experts of the Car sharing company X are responsible for the sales and inventory management. They are only restricted in terms of revealing the company secrets. All of the experts are agree in identifying and analyzing the challenges. The Delphi session was done once for creating the reachability matrix, and the experts were all agreed in the following matrix. By the structure of the Delphi technique, there are no individual matrices or calculations. All experts discuss and have a common idea on a specific issue.

Table 2 addresses the fuzzy reachability matrix indicating that which barrier has an influence on one another barrier. In other words, it stands for solving barrier i also solves the barrier j.

Table 2. Fuzzy reachability matrix.

.......To / From	MA			OD			DoV			S			CP			NB		
	T_A	I_A	F_A	T_A	I_A	F_A	T_A	I_A	F_A	T_A	I_A	F_A	T_A	I_A	F_A	T_A	I_A	F_A
MA				.5	.3	.5	1	0	0	-	-	-	.6	.35	.4	.2	.45	.8
OD	-	-	-				-	-	-	-	-	-	1	0	0	-	-	-
DoV	-	-	-	-	-	-				-	-	-	-	-	-	-	-	-
S	-	-	-	1	.1	0	-	-	-				-	-	-	.7	.2	.3
CP	-	-	-	1	0	0	-	-	-	1	0	0				-	-	-
NB	-	-	-	.7	.2	.3	.6	.2	.4	-	-	-	.7	.2	.3			

Step 3. Calculate the score, accuracy and certainty function values for ranking the columns and rows. The score function values are primarily required, the accuracy and certainty values will be put in use in case of need. The score function values and indirect relationships (IR) is stated in Table 3.

Step 4. Draw an initial visual directed graph, determine the indirect relationships. Dotted lines represent the indirect relationships (see Figure 1).

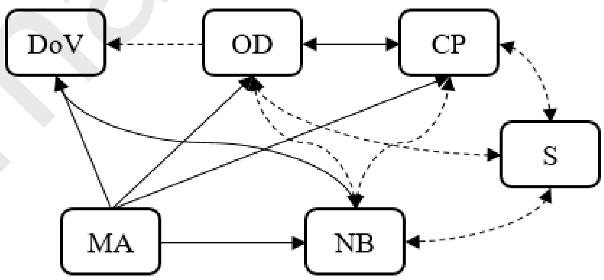

Figure 1. Directed graph of implementation challenges with indirect relationships.

Step 5. Write letters IR to the reachability matrix cells for newly-introduced relationships (see Table 3).

Step 6. Calculate each IR value by composition rules and take the maximum score value. As an example of how to calculate an indirect relationship, Figure 2 is stated.

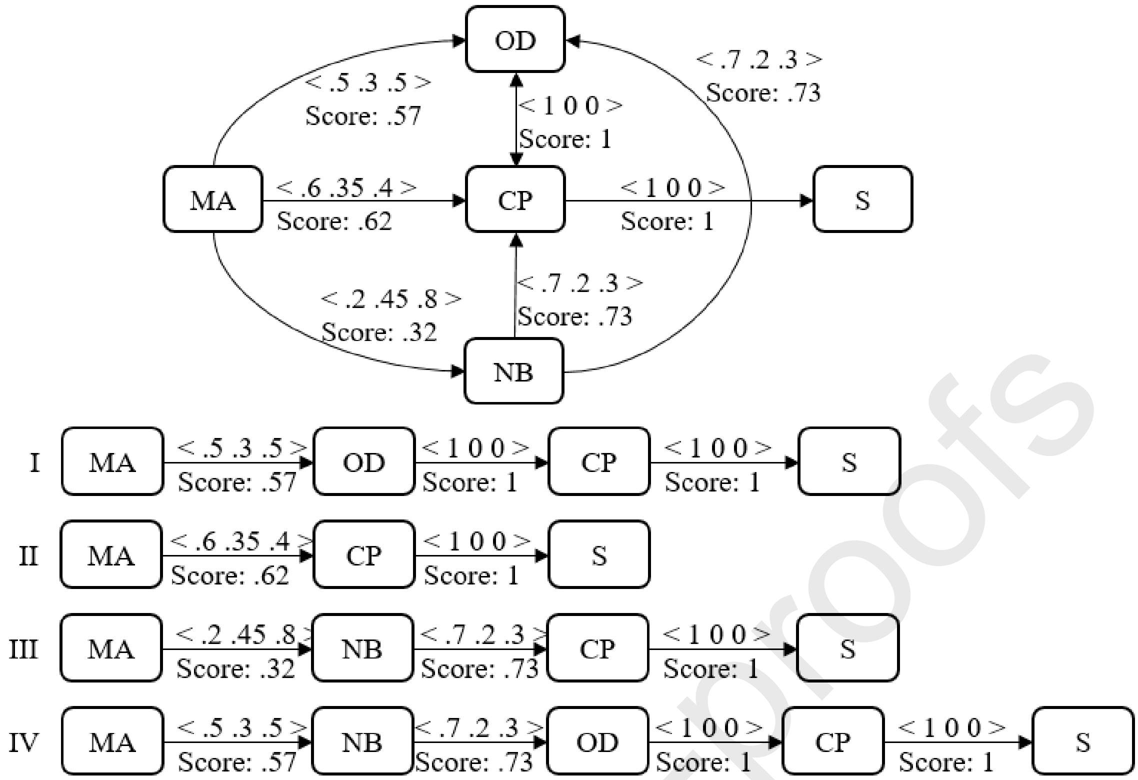

Figure 2. Example of indirect relationship calculation.

Multiplication of the scores – path I: .57, II: .62, III: .23, IV: .41, then the max-product is .62. Minimum scores – path I: .57, II: .62, III: .32, IV: .57, then the max-min product is .62. Averages of the scores – path I: .86, II: 81, III: .68, IV: .83, then the max-average product is .86. By taking the minimum of these composition rules, the indirect relationship strength is .62 from MA to S challenge. Table 3 indicates all of the related calculations.

Table 3. Indirect relationships in terms of score function values.

	MA	OD	DoV	S	CP	NB
MA		.57	1	IR - .62	.62	.32
OD	0		IR - .49	IR - 1	1	IR - .73
DoV	0	0		0	0	0
S	0	.97	IR - .49		IR - .53	.73
CP	0	1	IR - .49	1		IR - .73
NB	0	.73	.67	IR - .73	.73	

Step 7. Adjust the matrix by changing the rows and columns in order to generate an adjacency matrix.

Step 8. Count the zeros in each row, add a new column to the right-hand side of the matrix, place the number of zeros to this column cells (see Table 4). This represents the hierarchical positions of each barrier.

Table 4. Indirect relationships in terms of score function values.

	DoV	OD	S	CP	NB	MA	Number of zeros	Driving power
DoV		0	0	0	0	0	5	0
OD	.49		1	1	.73	0	1	3.22
S	.49	.97		.53	.73	0	1	2.72
CP	.49	1	1		.73	0	1	3.22
NB	.67	.73	.73	.73		0	1	2.86
MA	1	.57	.62	.62	.32		0	3.13
Dependence power	3.14	3.27	3.35	2.88	2.51	0		

Step 9. Draw the hierarchical visual graph (see Figure 3) by taking the number of zeros into consideration.

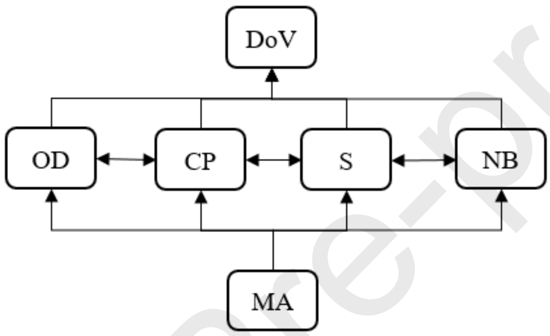

Figure 3. Final model of implementation challenges in servicization case study.

Step 10. Adjust the final graph in terms of driving and dependence powers.

As a result of this case study, mobile application based problems (software based or payment system based issues) are root cause of this challenge network. The operational difficulties, the coordination problems, supplier based problems and negative behaviors of the users towards the vehicles are triggered by MA directly or indirectly, and grounds for the degradation of the vehicles as a final result.

According to the feedbacks of the company representatives, any problem in the mobile application results in negative behaviors of the customers directly. Especially when the suppliers cannot reach the defined car's position because of a MA-based disruption, the cleaning and repairing operations cannot be fulfilled, and the coordination problems with the suppliers arise in general. All of these aforementioned issues cause the degradation of the vehicles. For instance, the customers damage the car on purpose when the servicizing experience cannot be ended and the payment cannot be done since the driving is seen not ended. Moreover, when the photographs that are shot at the end of the servicization and uploaded to the mobile application are not clear, both the next customers and the cleaning personnel cannot identify the car.

6. Discussion

In order to compare the proposed approach with the existing methodologies, at first the fuzzy interpretive structural modeling is applied with the same data. Secondly a form of intuitionistic fuzzy sets was used in the proposed approach. As a result, the findings were similar. However, while the proposed neutrosophic sets based approach present truth, falsity, indeterminacy membership degrees independently, in the case of intuitionistic fuzzy sets application, an increase in membership degrees resulted in a decrease of certainty. Since the membership and non-membership degrees are dependent in intuitionistic fuzzy sets, neutrosophic sets provided better findings with independent membership degrees. In other words, in neutrosophic sets, all sources are independent, and they do not communicate with each other and they do not know the response of each other.

In order to compare the results of this study with other similar studies, the risk / challenge / barrier / obstacle / disruption keywords in car sharing literature were reviewed. Accordingly, Martins et al. (2020), Gupta et al. (2019), Boldrini et al. (2018), and Wilson and Mason (2020) are review papers of challenges with conceptual frameworks, while Illgen and Höck (2018) uses simulation as the methodology. Besides, as a benefit of this proposed research, there is no hierarchical cause-and-effect analysis implementation in car sharing business model that is finding the root causes of the defined challenges.

The implementation phase of this study contains the possibility of subjective judgements of the experts as a constraint. Furthermore, by the COVID-19 outbreak, the changing psychological conditions of the people has become a constraint in terms of considering the customer side. Hence, defining the challenges is the another constraint for the research.

Conclusion

Servicization as a functionality based business model enables the companies do not transfer the product ownership to the customers, instead, charges them in pay-per-use base. This newly introduced way of business is highlighted as a new opportunity for operations management. However, there are significant obstacles in implementing the servicizing such as contract cancellations at any time, uncertain operational difficulties and fluctuations stemming from these cancelations, durability of the products, product misuses, degradation of the products as a result of negative attitudes of the customers towards the products, servicizing company's internal workforce resistance, coordination problems with suppliers, etc. These issues in implementing the servicizing business models constitute a research question. Hence, this study proposes a novel neutrosophic set based hierarchical challenge analysis approach for the servicizing business models with a step by step guidance, and presents a real world case study addressing a car sharing company's entire service network.

The current neutrosophy literature has limited number of researches discussing obstacles in operations management. The proposed methodology contributes to both the neutrosophic theory and the operation management field of study by a novel approach applying neutrosophic sets to the hierarchical interpretive studies of different variables. Moreover, this research gathers the expert evaluations of truth, indeterminacy, and falsity membership degrees separately, in contrast to the general approach of multi-criteria decision making techniques that are applying the defined linguistic variable schemes. Next, it calculates the score, accuracy and certainty functions in order to rank and link the variables, and takes the indirect relationship possibilities into account, computes composition rules to identify the score, accuracy, certainty functions of these indirect relations, and forms a hierarchical visual graph. This process results in a causal relationship structure of the defined challenges, and highlights which obstacles should be dwelt on first.

The case study subjects a present-day servicizing business model arisen from the COVID-19 pandemics' isolation need via using individual cars for the transportation instead of public vehicles. The topic attracts the attention of innovative entrepreneurs that made serious investments to this business, and that reaped the benefit of this financial funding as a result of growing demand for the car share programs. Owing to the economic burden of the COVID-19 pandemics, it became difficult to own a vehicle since the decreased manufacturing volume of the automobile producers and increased prices in second-hand vehicles with increased demand. Hence, the car share programs attracts the users economically with an ease of implementation. As a result of the car share program case study, mobile application based problems (software or payment based problems) affects the other obstacles directly or indirectly in a hierarchical network. The operational difficulties, the coordination problems, supplier based problems and negative behaviors of the users towards the vehicles are led by this root cause, and results in the degradation of the vehicles. The car share company representatives revealed that any problem in the mobile application gives a rise to the negative behaviors of the customers directly. For example, when the suppliers cannot reach the defined car's position because of a mobile application-based interruption, the cleaning and repairing operations cannot be done on time, and the coordination problems with the suppliers occur in many cases. The degradation of the vehicles is the final outcome of the previous challenges' interrelations. For example, the users vandalize the vehicles on purpose when the servicizing experience does not ended well.

As a managerial implication, a practitioner can understand which obstacle should be dealt with first, what is the inter-relationship structure of these challenges in a hierarchy, and what is the expected final result of these interactions. The study also contributes to the theoretical background by using neutrosophic sets to propose a novel interpretive hierarchical challenge analysis.

Limitations of the study stems from the individual evaluations of the experts that can be biased towards the business case. Therefore, this study pays ultimate attention in selecting the experts who are apart from just looking after a benefit in order to elaborate the non-objective attitudes. Additionally, the mathematical background is open to discuss with other preliminary definitions, and other perspectives in generating a relationship based causal hierarchical structures.

Further researches may involve different case studies with different or more experts of the servicizing business field. Also, alternative ranking methodologies can be applied to the same case study bringing about different hierarchical causal relationship networks.

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- Contributing to the theoretical background by using neutrosophic sets
- Gathering membership degrees separately instead of applying the schemes
- Pointing the increased demand of driving need as a result of COVID-19
- Understanding which servicization challenge should be dealt with first
- Structuring the inter-relationship of these challenges in a hierarchy

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Declaration of interests

☒ The author declares that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.