

Evaluation of Transition Barriers to Circular Economy: A Case from the Tourism Industry

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Abstract

Current economic system exhibits a linear path by using resources to produce goods and disposing of waste after their consumption. Circular economy (CE) turns this linear pattern into a circular one by using waste as a resource for another process. It focuses on environmental responsibility, efficiency, renewable resources, preventing wastage, and, minimizing consumption. CE helps the sustainability of the economy by restructuring the production processes to use fewer resources and extending the lifetime of the products. Although there are powerful drivers for transition to CE firms often face significant barriers while implementing their plans. This study aims to evaluate the barriers that the tourism industry would face during the transition process and put them in order according to their importance. We used the Interval Type-2 Fuzzy Analytical Hierarchy Process (FAHP) method which is based on a pairwise comparison of relevant criteria to calculate the weights of importance of these barriers. We conducted semi-structured interviews with four experts from the tourism industry. According to our results, the most important barrier is organizational structure/infrastructure that creates inconvenience with the supply chain. The results are expected to be a guide for the firms in the tourism industry for their transition to CE applications.

Keywords- Circular economy, Interval type-2 fuzzy AHP, Sustainable tourism, Barriers to circular economy.

1. Introduction

The world has been facing a paradigm shift from linear economy (LE) to circular economy (CE) in recent years (Vargas-Sanchez, 2018). Conventional industrial economy shows a linear pattern that consists of take-make-dispose steps. In this linear model, the resources are used to produce goods which are sold to the consumers; however, these products become waste and get discarded when the consumers do not need them anymore (The Ellen MacArthur Foundation, 2013). When a product's waste is used as a resource for another product, the economy can be defined as a CE since this step transforms the linear system into a loop or circular system (Andersen, 2007). CE is a system that restores and regenerates resources by promoting renewable energy, decreasing the use of hazardous chemicals, and designing products and manufacturing systems that eliminate waste (The Ellen MacArthur Foundation, 2013). The basis of CE can be expressed as the 3R (reduce – reuse – recycle) principle, which refers to reducing the amount of materials in the production

process, reusing the products for an extended time by repairing or fixing, and, recycling the components of the products when they reach the end of their economic lives (Jiang and Zhou, 2012).

Scholars argue that CE encourages reducing the use of resources, limits the amount of waste production, and carries a potential for economic prosperity (Zink and Geyer, 2017). CE has important drivers like “government support”, “company culture”, “consumer demand”, “social recognition”, “economic attractiveness”, and “information to practitioners” (Gue et al., 2020). However, transition from LE to CE is not an effortless process for companies. On the contrary, the companies must face and overcome a wide range of barriers and challenges in their transition processes. The barriers to CE can be grouped as “outsourcing barriers”, “technology barriers”, “knowledge barriers”, “financial barriers”, “involvement and support barriers” (Govindan et al., 2014) or “government-related barriers”, “economic barriers”, “technological barriers”, “knowledge and skill related barriers”, “management-related barriers”, “CE framework related barriers”, “cultural & social barriers”, and “market-related barriers” (Govindan and Hasanagic, 2018).

The tourism industry faces difficulties in this transition process like other industries that have to overcome the obstacles and take advantage of CE applications' potential gains to prosper in the new era (Vargas-Sanchez, 2018). The industry is a fast-growing industry, and it has close links with the consumption of resources and the generation of waste (Pamfilie et al., 2018). Although it creates value and helps countries develop their economies, it also damages the environment and produces high amounts of waste and pollution (Girard and Nocca, 2017). Creating new processes according to CE, which reduces resource extraction and creates value from waste, is one of the most important principles for establishing a sustainable tourism environment (Pan et al., 2018).

This paper aims to evaluate the barriers that the tourism industry would face during the transition process from LE to CE and put these barriers in an order according to their weights determined by the evaluation of relevant literature and expert opinions. Even though the numbers of research about the barriers to CE transition have been increasing in recent years, tourism-specific research on the topic has not reached a satisfactory level yet. The existing research papers mainly offer a literature review and do not have case studies or applications. The number of researches that compare and rank the barriers to CE in a hierarchy is also extremely limited. Therefore, the study also aims to fill these gaps in the literature. Following the publication of the results of the study, the companies will have an opportunity to allocate their resources and efforts with respect to the weights of importance of these barriers. The weights were calculated by using the Interval Type-2 Fuzzy Analytical Hierarchy Process method. This method is based on a pairwise comparison of relevant criteria. The following parts of the study include a detailed literature review on CE, an introduction of the methodology used, the application, and the results and discussion parts.

2. Literature Review

The current LE model, which exhibits a one-way take-make-dispose system, was born with the industrial revolution that did not take the overuse of resources and its long-term effects into consideration (Prieto-Sandoval et al., 2018). The growing world population, increasing purchasing power, and tendency to consume cause higher demand on the limited resources (Andrews, 2015). The combination of the increasing demand and one-way path of the LE model creates a substantial challenge on establishing sustainable development throughout the world according to many scholars (Andrews, 2015; Korhonen et al., 2018). CE framework was born as an alternative to one-way LE model, and it promotes reexamining the current relationship of humanity with the resources

and waste to support the efficient use of resources and prevent the loss of value (Blomsma and Tennant, 2020). CE is encouraged by the European Union (EU), numerous private companies, and various governments like China, Japan, Canada, France, Sweden, Finland, and, The Netherlands (Korhonen et al., 2018).

It has been increasing the popularity of CE as a study subject in the last decade; however, there is no commonly accepted definition for the concept. One of the most universally accepted definitions of CE is presented by Ellen MacArthur Foundation:

“The circular economy refers to an industrial economy that is restorative by intention; aims to rely on renewable energy; minimizes, tracks, and eliminates the use of toxic chemicals; and eradicates waste through careful design” (The Ellen MacArthur Foundation, 2013).

CE is defined by Wu et al. (2014) as a system that targets to reach the optimum production level by minimizing the use of natural resources and pollution at the same time and minimizing wastage by encouraging reusing, recycling, and restoration of the waste. An analysis of 114 definitions in the literature was conducted by Kirchherr et al. (2017), and the study shows that CE is predominantly defined by the activities of reducing, reusing, and recycling while the scholars usually forget to mention the need for a systemic transition. CE concepts are mentioned alongside other environment-related concepts like sustainable development, green economy, or ecological economy from time to time. The study of Schoggl et al. (2020) affirms a subset relationship between CE and sustainable development, which was broadly advocated in the previous research. Arguing that the line between the CE and sustainability concepts is not drawn clearly in the academic or industrial literature, Geissdoerfer et al. (2017) aimed to distinguish the similarities, differences, and the relationship between these two popular concepts by reviewing the existing literature and conducting bibliometric analysis.

Various scholars link different concepts with the CE framework. Ezzat (2016) specified the concepts related with the CE model as “greening the economy”, “natural capitalism”, “fundamental economy”, “lifecycle thinking”, “creating shared value principle”, “resource and energy efficiency gap”, and “ecological transition” in his comparative work. Geisendorf and Pietrulla (2018) also listed the concepts related with CE model as “cradle-to-cradle”, “blue economy”, “regenerative design”, “closed supply chains”, “natural capitalism”, “industrial ecology”, “performance economy”, “biomimicry”, and “reverse logistics” in the study that they conducted to reach an updated CE definition by analyzing and comparing the existing literature. According to their observation, CE is mainly related to the “cradle-to-cradle” concept and even though all of the abovementioned concepts are interconnected, they differ in their main focuses, aims, and characteristics (Geisendorf and Pietrulla, 2018). Korhonen et al. (2018) listed these concepts with the help of a detailed review on the existing literature as “industrial ecology”, “industrial ecosystems”, “industrial symbiosis”, “cleaner production”, “circular material flows”, “product-service systems”, “eco-efficiency”, “cradle-to-cradle”, “biomimicry”, “resilience of social-ecological systems”, “performance economy”, “natural capitalism”, and “zero emissions”. Morseletto (2020) examined the importance of two other concepts, “restoration”, and “regeneration” in his study. He argues that restoration can be accepted as an essential concept for CE applications, while regeneration might be ignored as an essential principle due to its lack of applicability.

Producing goods with easier disassembling processes, improving the reverse cycle, leasing certain products instead of selling, and clearing landfills from organic food waste represent some possible CE solutions that add value to our environment and economy. These CE solutions provide various benefits and advantages to economies, companies, and consumers. CE implementation helps economies by saving materials, reducing price volatility, creating new employment opportunities by shifting industries, decreasing externalities, and building a more robust economic environment. The companies may benefit from the CE practices in reducing material costs and risks, enhancing customer interaction, improving customer loyalty, reducing the complexity of the goods, and, managing their lifecycles more efficiently. The consumers would have smaller ownership costs for the products; they would have more options and secondary benefits while purchasing a new product with the widespread implementation of CE practices in manufacturing processes (The Ellen MacArthur Foundation, 2013).

CE model proposes a significant contribution to the sustainability of the planet; however, there are certain limitations for applying the CE practices. According to Korhonen et al. (2018), the limitations can be categorized under six main groups, namely “thermodynamic limits”, “system boundary limits”, “limits posed by the physical scale of the economy”, “limits posed by path-dependency and lock-in”, “limits of governance and management”, and “limits of social and cultural definitions”. Moreau et al. (2017) argue that recycling strategies of CE model are weak in the aspects of having an exhaustive understanding of biophysical limitations and involvement of social and institutional participants and these weaknesses prevent handling the productivity of material and energy in the economic system.

Barriers to the implementation of CE practices is another important topic in the CE literature. Govindan et al. (2014) grouped barriers to CE implementation as “outsourcing barriers”, “technology barriers”, “knowledge barriers”, “financial barriers”, and “involvement and support barriers” and then rank them according to their importance. Ritzen and Sandstrom (2017) classified the barriers for moving towards CE under 5 main groups as “financial”, “structural”, “operational”, “attitudinal”, and “technological” barriers while Galvao et al. (2018) specified 7 barriers as “technological”, “policy and regulatory”, “financial and economic”, “managerial”, “performance indicators”, “customer”, and “social” barriers. Farooque et al. (2019) listed the barriers to CE as “lack of financial resources”, “limited expertise, technology and information”, “organizational culture and management”, “uncertainty about benefits”, “lack of economies of scale”, “weak environmental regulations and enforcement”, “lack of market preference or pressure”, and “lack of collaboration/support from supply chain actors”. Govindan and Hasanagic (2018) conducted a comprehensive study about the barriers that slow down the transition from LE to CE and listed 39 individual barriers under 8 clusters such as “governmental issues”, “economic issues”, “technological issues”, “knowledge and skill issues”, “management issues”, “CE framework issues”, “culture and social issues”, and finally “market issues”. They evaluated these barriers according to their relevance with internal or external environment and also their link with consumers, government, society, and organizations (Govindan and Hasanagic, 2018). Kirchherr et al. (2018) covered the same topic by conducting a survey with 208 participants and interviewing with 47 experts, and they listed 15 individual barriers under 4 main groups, namely “cultural”, “market”, “regulatory”, and “technological” barriers. According to the results of their study, the most constraining barriers to the implementation of CE practices are cultural barriers, specifically “lacking consumer interest and awareness” and “hesitant company culture” (Kirchherr et al., 2018). According to de Jesus and Mendonca (2018), technical, economic, financial, and market barriers

can be defined as “hard barriers” while institutional, regulatory, social, and cultural barriers can be defined as “soft barriers”.

Rizos et al. (2016) conducted a research in order to understand the barriers and enablers for a CE transition for small and medium-sized enterprises (SME) in Europe. According to the results of this research, the most mentioned barriers by the SMEs were “lack of support supply and demand network”, “lack of capital”, “lack of government support”, “administrative burden”, “lack of technical know-how”, “lack of information”, and “company environmental culture”, respectively. In comparison, the most mentioned enablers were “company environmental culture”, “networking”, “support from the demand network”, “being financially attractive”, “recognition”, “personal knowledge”, and “government support”, again, respectively.

Goyal et al. (2018) examined the CE practices in India in the aspects of reduce, recycle, and reuse concepts in their research which was conducted to understand the implementation of CE business model in developing countries. According to the results of their study, the main challenges on CE implementation can be categorized under four main groups; “infrastructure-level barriers and challenges” like the inefficiency of recycling processes, incompatible infrastructure, lack of industry-level abilities; “technology barriers and challenges” like lack of awareness about technologies for collection, dissociation, and extraction of metals from wastes; “ineffective policy and social barriers and challenges” like lack of social perception and government focus on the industry; “traditional approaches for processing of e-waste in developing countries” which cause severe environmental and health-related problems (Goyal et al., 2018).

Transition from a LE to a circular one is a complex process and requires a comprehensive redesign of the existing system (Vargas-Sanchez, 2018). Therefore, it must be supported by the dedication of all stakeholders. These required changes are important research topics in both academic and organizational environments. Various studies were conducted to investigate the requirements and success factors for the application of CE frameworks in different industries. Lieder and Rashid (2016) conducted a research to create a comprehensive framework that plays a role as a strategical guide for a successful CE transition process. Their proposed framework lists the economic benefits, resource scarcity, and environmental impact of the CE concept as its three main perspectives, and the research also emphasizes the need for the complete dedication of all stakeholders in the transition process. Smol et al. (2020) aimed to develop and propose a CE model framework for the European waste and wastewater industry in their study by conducting extensive research on the existing literature on CE principles and waste management practices. According to their proposed framework, “reduction”, “reclamation”, “reuse”, “recycling”, “recovery”, and “rethink” are the six actions that help a successful implementation of CE principles in the water and wastewater industry (Smol et al., 2020). Lebre et al. (2017) investigated the compatibility of the CE framework within the mining industry, and they suggested that by applying CE principles, organizations can manage mining waste in a better form and produce added environmental value to the industry. Yadav et al. (2020) developed a framework by combining Industry 4.0 and CE principles to propose a solution to the challenge of sustainable supply chain management in the automotive industry. Adams et al. (2017) questioned the current position, awareness, drivers, and limitations of CE practices comprehensively in the construction industry.

Tourism industry would provide a wide range of possibilities to create value by implementing CE principles, however, the number of academic works have been conducted remains very limited compared to other industries, especially to the manufacturing industry (Rodriguez et al., 2020). A

project, namely CIRTOINNO, was developed by seven organizations from four South Baltic Region countries in 2016 to encourage the use of innovation in small and medium-sized touristic companies with the help of implementation of CE practices in their operations. The possible CE applications within the accommodation, hotel, restaurant, and spa & wellness areas are examined in a very detailed manner in the handbook published by the initiative. The handbook defines the increasing amount of traveling and hedonic consumption of the tourists as the main challenges to CE implementation in the tourism industry. As the tourism industry grows, new destinations and new flight routes come into the picture. The increase in traveling poses a significant threat to environmental sustainability due to increasing carbon emissions coming from fuel consumption. Hedonic consumption of the tourists is a challenge for a successful implementation of CE principles in the tourism industry because people tend to use more in holidays and prefer to use the water and energy in a more unconcerned way (Manniche et al., 2017). Pamfilie et al. (2018) examined the applicability of CE practices in the Romanian hotel industry, and they suggest that the industry is not ready to adopt this new economic model. Sorensen and Baerenholdt (2020) approached the relationship between CE practices and the tourism industry from a different perspective. They aimed to determine the required practices of tourists instead of determining those of the tourism companies or institutions that accelerate the transition of the tourism industry to a CE model.

3. Methodology

This study aims to rank the importance of the barriers to transition to CE that are faced by the tourism industry. In line with this target, the related barriers we used in our analysis were determined by literature review and expert opinions. Then, the pairwise comparison survey form was conducted by a group of experts consisting of industry representatives. Interval Type 2 Fuzzy AHP method was used for the evaluation of the collected data. Fuzzy sets were used in this study since it delivers healthier results in decision making in the environment of uncertainty. Conventional mathematical modeling techniques use absolute data based on numbers. However, in practice, the phenomenon of uncertainty can be faced in any stage of the problem-solving process. People make decisions in uncertain environments of an uncertain world. Uncertainty can reveal itself in the data when verbal expressions have different meanings for different people or when people's perceptions are different (Dereli and Altun, 2013; Kahraman et al., 2014). Uncertainty increases from numbers to words and from word to perceptions (John and Coupland, 2009). Fuzzy sets were first proposed by Zadeh (1965) in order to reduce the uncertainty by modeling verbal expressions or words, while Type 2 fuzzy sets were proposed by Zadeh (1975) again in order to model perceptions (Dereli and Altun, 2013).

In the process of solving a decision-making problem, fuzzy sets are used in order to deal with the uncertainty. Lately, researchers have started to use type-2 fuzzy sets to overcome different kinds of uncertainty, such as the impossibility of defining membership functions, linguistic differences among people, ambiguity, and lack of information. We can present a type-2 fuzzy set as below (Cebi and Otay, 2015):

$$\begin{aligned} \tilde{\tilde{A}}_i &= (\tilde{A}_i^U, \tilde{A}_i^L) \\ \tilde{A}_i^U &= (a_{i1}^U, a_{i2}^U, a_{i3}^U, a_{i4}^U; H_1(\tilde{A}_i^U), H_2(\tilde{A}_i^U)), \\ \tilde{A}_i^L &= (a_{i1}^L, a_{i2}^L, a_{i3}^L, a_{i4}^L; H_1(\tilde{A}_i^L), H_2(\tilde{A}_i^L)), \\ H_1(\tilde{A}_i^U), H_2(\tilde{A}_i^U), H_1(\tilde{A}_i^L), H_2(\tilde{A}_i^L) &\in [0,1]. \end{aligned}$$

In the above equation, \tilde{A}_i^U and \tilde{A}_i^L represent upper and lower trapezoidal membership functions as in type-1 and $a_{i1}^U, a_{i2}^U, a_{i3}^U, a_{i4}^U, a_{i1}^L, a_{i2}^L, a_{i3}^L, a_{i4}^L$ represent the reference points of type-2 fuzzy numbers. $H_j(\tilde{A}_i^U)$ and $H_j(\tilde{A}_i^L)$ are the membership values of $a_{i(j+1)}^U$ and $a_{i(j+1)}^L$. Figure 1 in the figures section exhibits the membership function of a type-2 fuzzy set $\tilde{\tilde{A}}$ (Cebi and Otay, 2015; Lee and Chen, 2008).

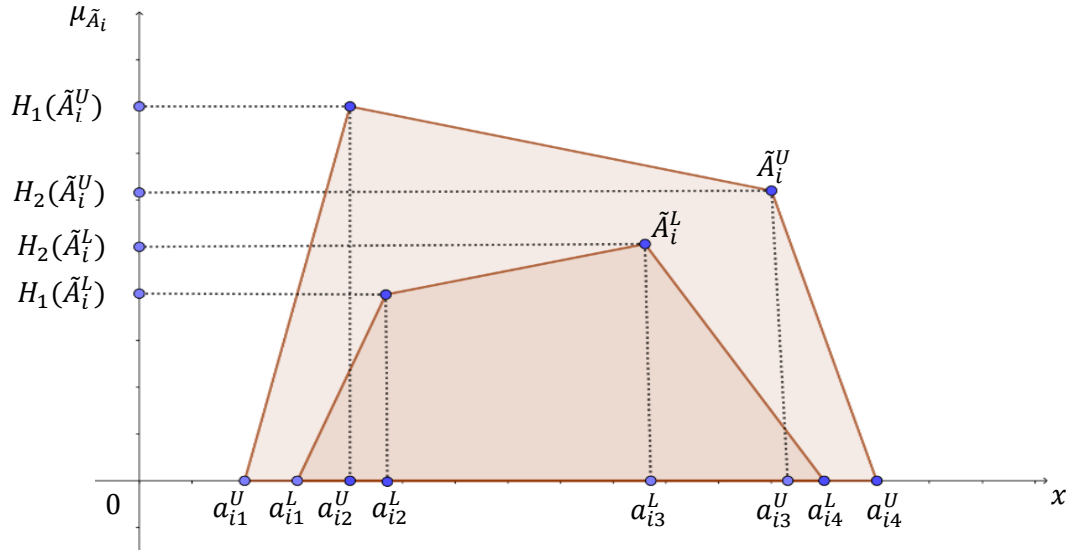


Figure 1. Interval type-2 fuzzy set $\tilde{\tilde{A}}$.

The membership functions in type-1 fuzzy sets are two dimensional, while they are three dimensional in type-2 fuzzy sets. The third dimension in type-2 fuzzy sets plays a vital role in overcoming uncertainty with the degree of freedom it provides.

Interval type-2 fuzzy sets are the most common version of type-2 fuzzy sets. Its most typical characteristics are its simplicity and lower amount of mathematical calculations (Kahraman et al., 2014). Before starting the application, it is necessary to summarize some of the arithmetic operations in interval type-2 fuzzy sets in order to provide a better understanding of the process. When the relevant literature is reviewed, it is seen that the arithmetic operations are summarized before the application part (Ayvaz and Kusakci, 2017; Cebi and Otay, 2015; Chen and Lee, 2010; Deveci et al., 2017; Lee and Chen, 2008). In the next part of the study, first, the arithmetic operations in interval trapezoidal type-2 fuzzy sets and then the processing steps for interval type 2 fuzzy AHP model will be explained.

3.1 Arithmetic Operations in Interval Trapezoidal Type 2 Fuzzy Sets

Definition 3.1.1 Addition operation between two interval trapezoidal type-2 fuzzy sets, $\tilde{\tilde{A}}_1$ and $\tilde{\tilde{A}}_2$, is defined as;

$$\tilde{A}_1 \oplus \tilde{A}_2 = \left(\left(\begin{array}{l} a_{11}^U + a_{21}^U, a_{12}^U + a_{22}^U, a_{13}^U + a_{23}^U, a_{14}^U + a_{24}^U; \\ \min(H_1(\tilde{A}_1^U), H_1(\tilde{A}_2^U)), \min(H_2(\tilde{A}_1^U), H_2(\tilde{A}_2^U)) \end{array} \right), \right. \\ \left. \left(\begin{array}{l} a_{11}^L + a_{21}^L, a_{12}^L + a_{22}^L, a_{13}^L + a_{23}^L, a_{14}^L + a_{24}^L; \\ \min(H_1(\tilde{A}_1^L), H_1(\tilde{A}_2^L)), \min(H_2(\tilde{A}_1^L), H_2(\tilde{A}_2^L)) \end{array} \right) \right) \quad (1)$$

where

$$\tilde{A}_1 = (a_{11}^U, a_{12}^U, a_{13}^U, a_{14}^U; H_1(\tilde{A}_1^U), H_2(\tilde{A}_1^U)), (a_{11}^L, a_{12}^L, a_{13}^L, a_{14}^L; H_1(\tilde{A}_1^L), H_2(\tilde{A}_1^L)).$$

and

$$\tilde{A}_2 = (a_{21}^U, a_{22}^U, a_{23}^U, a_{24}^U; H_1(\tilde{A}_2^U), H_2(\tilde{A}_2^U)), (a_{21}^L, a_{22}^L, a_{23}^L, a_{24}^L; H_1(\tilde{A}_2^L), H_2(\tilde{A}_2^L)).$$

Definition 3.1.2 Subtraction operation between two interval trapezoidal type-2 fuzzy sets, \tilde{A}_1 and \tilde{A}_2 , is defined as;

$$\tilde{A}_1 - \tilde{A}_2 = \left(\left(\begin{array}{l} a_{11}^U - a_{24}^U, a_{12}^U - a_{23}^U, a_{13}^U - a_{22}^U, a_{14}^U - a_{21}^U; \\ \min(H_1(\tilde{A}_1^U), H_1(\tilde{A}_2^U)), \min(H_2(\tilde{A}_1^U), H_2(\tilde{A}_2^U)) \end{array} \right), \right) \\ \left(\begin{array}{l} a_{11}^L - a_{24}^L, a_{12}^L - a_{23}^L, a_{13}^L - a_{22}^L, a_{14}^L - a_{21}^L; \\ \min(H_1(\tilde{A}_1^L), H_1(\tilde{A}_2^L)), \min(H_2(\tilde{A}_1^L), H_2(\tilde{A}_2^L)) \end{array} \right) \right) \quad (2)$$

where

$$\tilde{A}_1 = (a_{11}^U, a_{12}^U, a_{13}^U, a_{14}^U; H_1(\tilde{A}_1^U), H_2(\tilde{A}_1^U)), (a_{11}^L, a_{12}^L, a_{13}^L, a_{14}^L; H_1(\tilde{A}_1^L), H_2(\tilde{A}_1^L)).$$

and

$$\tilde{A}_2 = (a_{21}^U, a_{22}^U, a_{23}^U, a_{24}^U; H_1(\tilde{A}_2^U), H_2(\tilde{A}_2^U)), (a_{21}^L, a_{22}^L, a_{23}^L, a_{24}^L; H_1(\tilde{A}_2^L), H_2(\tilde{A}_2^L)).$$

Definition 3.1.3 Multiplication operation between two interval trapezoidal type-2 fuzzy sets, \tilde{A}_1 and \tilde{A}_2 , is defined as;

$$\tilde{A}_1 \otimes \tilde{A}_2 = \left(\left(\begin{array}{l} a_{11}^U \times a_{21}^U, a_{12}^U \times a_{22}^U, a_{13}^U \times a_{23}^U, a_{14}^U \times a_{24}^U; \\ \min(H_1(\tilde{A}_1^U), H_1(\tilde{A}_2^U)), \min(H_2(\tilde{A}_1^U), H_2(\tilde{A}_2^U)) \end{array} \right), \right) \\ \left(\begin{array}{l} a_{11}^L \times a_{21}^L, a_{12}^L \times a_{22}^L, a_{13}^L \times a_{23}^L, a_{14}^L \times a_{24}^L; \\ \min(H_1(\tilde{A}_1^L), H_1(\tilde{A}_2^L)), \min(H_2(\tilde{A}_1^L), H_2(\tilde{A}_2^L)) \end{array} \right) \right) \quad (3)$$

where

$$\tilde{A}_1 = \left(a_{11}^U, a_{12}^U, a_{13}^U, a_{14}^U; H_1(\tilde{A}_1^U), H_2(\tilde{A}_1^U) \right), \left(a_{11}^L, a_{12}^L, a_{13}^L, a_{14}^L; H_1(\tilde{A}_1^L), H_2(\tilde{A}_1^L) \right). \text{ and}$$

$$\tilde{A}_2 = \left(a_{21}^U, a_{22}^U, a_{23}^U, a_{24}^U; H_1(\tilde{A}_2^U), H_2(\tilde{A}_2^U) \right), \left(a_{21}^L, a_{22}^L, a_{23}^L, a_{24}^L; H_1(\tilde{A}_2^L), H_2(\tilde{A}_2^L) \right).$$

Definition 3.1.4 Multiplication and division of an interval trapezoidal type-2 fuzzy set, \tilde{A}_1 , with a crisp number k are defined as follows:

$$k \times \tilde{A}_1 = \left(\left(k \times a_{11}^U, k \times a_{12}^U, k \times a_{13}^U, k \times a_{14}^U; H_1(\tilde{A}_1^U), H_2(\tilde{A}_1^U) \right) \right. \\ \left. \left(k \times a_{11}^L, k \times a_{12}^L, k \times a_{13}^L, k \times a_{14}^L; H_1(\tilde{A}_1^L), H_2(\tilde{A}_1^L) \right) \right) \quad (4)$$

$$\frac{\tilde{A}_1}{k} = \left(\left(\frac{1}{k} \times a_{11}^U, \frac{1}{k} \times a_{12}^U, \frac{1}{k} \times a_{13}^U, \frac{1}{k} \times a_{14}^U; H_1(\tilde{A}_1^U), H_2(\tilde{A}_1^U) \right) \right) \\ \left(\frac{1}{k} \times a_{11}^L, \frac{1}{k} \times a_{12}^L, \frac{1}{k} \times a_{13}^L, \frac{1}{k} \times a_{14}^L; H_1(\tilde{A}_1^L), H_2(\tilde{A}_1^L) \right) \quad (5)$$

where $\tilde{A}_1 = \left(a_{11}^U, a_{12}^U, a_{13}^U, a_{14}^U; H_1(\tilde{A}_1^U), H_2(\tilde{A}_1^U) \right), \left(a_{11}^L, a_{12}^L, a_{13}^L, a_{14}^L; H_1(\tilde{A}_1^L), H_2(\tilde{A}_1^L) \right)$ and $k > 0$.

Definition 3.1.5 Ranking value of a type-2 fuzzy number, \tilde{A}_i , is as follows where

$$\tilde{A}_i = (\tilde{A}_i^U, \tilde{A}_i^L) = \left(\left(a_{i1}^U, a_{i2}^U, a_{i3}^U, a_{i4}^U; H_1(\tilde{A}_i^U), H_2(\tilde{A}_i^U) \right), \right. \\ \left. \left(a_{i1}^L, a_{i2}^L, a_{i3}^L, a_{i4}^L; H_1(\tilde{A}_i^L), H_2(\tilde{A}_i^L) \right) \right)$$

$$\text{Rank}(\tilde{A}_i) = M_1(\tilde{A}_i^U) + M_1(\tilde{A}_i^L) + M_2(\tilde{A}_i^U) + M_2(\tilde{A}_i^L) + M_3(\tilde{A}_i^U) + M_3(\tilde{A}_i^L) - \\ \frac{1}{4} \left(S_1(\tilde{A}_i^U) + S_1(\tilde{A}_i^L) + S_2(\tilde{A}_i^U) + S_2(\tilde{A}_i^L) + S_3(\tilde{A}_i^U) + S_4(\tilde{A}_i^L) \right) + H_1(\tilde{A}_i^U) + H_1(\tilde{A}_i^L) + \\ H_2(\tilde{A}_i^U) + H_2(\tilde{A}_i^L) \quad (6)$$

In the equation, $M_p(\tilde{A}_i^j)$ indicates the average of the elements a_{ip}^j and $a_{i(p+1)}^j$,

$$M_p(\tilde{A}_i^j) = \left(a_{ip}^j + a_{i(p+1)}^j \right) / 2, \quad 1 \leq p \leq 3.$$

$S_q(\tilde{A}_i^j)$, on the other hand, denotes the standard deviations of the elements a_{iq}^j and $a_{i(q+1)}^j$.

$$S_q(\tilde{A}_i^j) = \sqrt{\frac{1}{2} \sum_{k=q}^{q+1} \left(a_{ik}^j - \frac{1}{2} \sum_{k=q}^{q+1} a_{ik}^j \right)^2}, \quad 1 \leq q \leq 3.$$

$S_4(\tilde{A}_i^j)$, gives the standard deviations of the elements $a_{i1}^j, a_{i2}^j, a_{i3}^j$, and a_{i4}^j .

$$S_4(\tilde{A}_i^j) = \sqrt{\frac{1}{4} \sum_{k=1}^4 \left(a_{ik}^j - \frac{1}{4} \sum_{k=1}^4 a_{ik}^j \right)^2}$$

$H_p(\tilde{A}_i^j)$ gives the membership value of the element $a_{i(p+1)}^j$ of \tilde{A}_i^j isosceles trapezoid membership function and there, $1 \leq p \leq 2$, $j \in \{U, L\}$, and $1 \leq i \leq n$.

Interval type-2 fuzzy AHP method is used in this study to determine the importance of the criteria. Kahraman et al. (2014) modified Buckley's (1985) type-2 fuzzy AHP model and it is used in this study. The steps of the method are as follows:

Step 1: Fuzzy pairwise comparison matrices for all criteria are set up as shown below:

$$\tilde{A} = \begin{bmatrix} 1 & \tilde{a}_{12} & \dots & \tilde{a}_{1n} \\ \tilde{a}_{21} & 1 & \dots & \tilde{a}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{a}_{n1} & \tilde{a}_{n2} & \dots & 1 \end{bmatrix} = \begin{bmatrix} 1 & \tilde{a}_{12} & \dots & \tilde{a}_{1n} \\ 1/\tilde{a}_{21} & 1 & \dots & \tilde{a}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ 1/\tilde{a}_{n1} & 1/\tilde{a}_{n2} & \dots & 1 \end{bmatrix}, \quad \text{where}$$

$$\frac{1}{\tilde{a}} = \left(\left(\frac{1}{a_{14}^U}, \frac{1}{a_{13}^U}, \frac{1}{a_{12}^U}, \frac{1}{a_{11}^U}; H_1(a_{12}^U), H_2(a_{13}^U) \right), \left(\frac{1}{a_{24}^L}, \frac{1}{a_{23}^L}, \frac{1}{a_{22}^L}, \frac{1}{a_{21}^L}; H_1(a_{22}^L), H_2(a_{23}^L) \right) \right)$$

Fuzzy pairwise comparison matrices are set up with the help of linguistic variables of expert opinions. The interval type-2 fuzzy scale (Kahraman et al., 2014) which was used by the experts on pairwise comparisons is shown in Table 1.

Table 1. Definition and interval type-2 fuzzy scales of the linguistic variables.

Linguistic Variables	Triangular interval type-2 fuzzy scales	Trapezoidal interval type-2 fuzzy scales
Absolutely Strong (AS)	(7.5,9,10.5;1) (8.5,9,9.5;0.9)	(7,8,9,9;1,1) (7,2,8,2,8,8,9;0,8,0,8)
Very Strong (VS)	(5.5,7,8.5;1) (6.5,7,7.5;0.9)	(5,6,8,9;1,1) (5,2,6,2,7,8,8,8;0,8,0,8)
Fairly Strong (FS)	(3.5,5,6.5;1) (4.5,5,5.5;0.9)	(3,4,6,7;1,1) (3,2,4,2,5,8,6,8;0,8,0,8)
Slightly Strong (SS)	(1.5,3,4.5;1) (2.5,3,3.5;0.9)	(1,2,4,5;1,1) (1,2,2,2,3,8,4,8;0,8,0,8)
Exactly Equal (E)	(1,1,1;1) (1,1,1;1)	(1,1,1,1;1,1) (1,1,1,1;1,1)
If factor i has one of the above linguistic variables assigned to it when compared with factor j, then j has the reciprocal value when compared with i	Reciprocals of above	Reciprocals of above

Step 2: The consistency of the fuzzy pairwise comparison matrices are investigated. If they are not consistent, the experts are asked to make pairwise comparisons again. In order to perform consistency evaluation, the fuzzy matrix must be defuzzified first. In the defuzzification process, the DTrAT model which was suggested by Kahraman et al. (2014) is applied.

$$DTrAT = \frac{\left[\frac{(u_U - l_U) + (\beta_U \cdot m_{1U} - l_U) + (\alpha_U \cdot m_{2U} - l_U)}{4} + l_U \right] + \left[\frac{(u_L - l_L) + (\beta_L \cdot m_{1L} - l_L) + (\alpha_L \cdot m_{2L} - l_L)}{4} + l_L \right]}{2} \quad (7)$$

where α and β denote the maximum membership degrees of the lower membership function of the type-2 fuzzy set; u_U denotes the largest possible value of the upper membership function; l_U denotes the least possible value of the upper membership function; m_{1U} and m_{2U} denote the second and third parameters of the upper membership function; u_L denotes the largest possible value of the lower membership function; l_L denotes the least possible value of the lower membership function; m_{1L} and m_{2L} denote the second and third parameters of the lower membership function, respectively.

After completing the defuzzification process with the DTraT method, the consistency procedure used in the classical AHP method is performed. According to the model suggested by Saaty and Vargas (2012), the steps for the consistency test of a given pairwise comparison matrix A is given

below where $A = \begin{vmatrix} 1 & a_{12} & \dots & a_{1n} \\ 1/a_{12} & 1 & \dots & a_{2n} \\ \vdots & \vdots & 1 & \vdots \\ 1/a_{1n} & 1/a_{2n} & \dots & 1 \end{vmatrix}$ and n is the number of criteria.

First, normalized decision matrix B is determined by normalizing A, where $b_{ij} = \frac{a_{ij}}{\sum_{i=1}^n a_{ij}}$. Then, the arithmetic mean of the elements of each row in the normalized decision matrix B is calculated, and it gives the weight vector, W:

$$W = \frac{\sum_{i=1}^n b_{ij}}{n} \tag{8}$$

After finding the weight vector W, the cross product of A and W is calculated, and each row of the calculated (A x W) column vector is divided by the corresponding row of W. The arithmetic mean is called as λ_{max} .

The following step for the consistency test is the calculation of consistency index (CI) and consistency ratio (CR):

$$CI = \frac{\lambda_{max} - n}{n - 1} \tag{9}$$

$$CR = \frac{CI}{RI} \tag{10}$$

where RI denotes random index which is derived by using 1/9, 1/8, ..., 1, ..., 8, 9 scale. Random Index table for the first 10 criteria is exhibited in Table 2. A CR value that is less than 0.10 means the pairwise comparison matrix is consistent and can be used for the analysis.

Table 2. Random index table.

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

Step 3: Geometric mean of each row is calculated by using the equation 11:

$$\tilde{r}_i = [\tilde{a}_{i1} \otimes \dots \otimes \tilde{a}_{in}]^{1/n} \quad (11)$$

where

$$\begin{aligned} \sqrt[n]{\tilde{a}_{ij}} = & \left(\left(\sqrt[n]{a_{ij1}^u}, \sqrt[n]{a_{ij2}^u}, \sqrt[n]{a_{ij3}^u}, \sqrt[n]{a_{ij4}^u}; H_1^u(a_{ij}), H_2^u(a_{ij}) \right), \right. \\ & \left. \left(\sqrt[n]{a_{ij1}^l}, \sqrt[n]{a_{ij2}^l}, \sqrt[n]{a_{ij3}^l}, \sqrt[n]{a_{ij4}^l}; H_1^l(a_{ij}), H_2^l(a_{ij}) \right) \right). \end{aligned}$$

Step 4: Fuzzy weights of each criterion is calculated by using the equation 12:

$$\tilde{w}_i = \tilde{r} \otimes [\tilde{r} \oplus \dots \oplus \tilde{r}_i \oplus \dots \oplus \tilde{r}_n]^{-1} \quad (12)$$

where

$$\begin{aligned} \frac{\tilde{a}_{ij}}{\tilde{b}_{ij}} = & \left(\frac{a_1^u}{b_4^u}, \frac{a_2^u}{b_3^u}, \frac{a_3^u}{b_2^u}, \frac{a_4^u}{b_1^u}; \min(H_1^u(a), H_1^u(b)), \min(H_2^u(a), H_2^u(b)) \right), \\ & \left(\frac{a_1^l}{b_4^l}, \frac{a_2^l}{b_3^l}, \frac{a_3^l}{b_2^l}, \frac{a_4^l}{b_1^l}; \min(H_1^l(a), H_1^l(b)), \min(H_2^l(a), H_2^l(b)) \right). \end{aligned}$$

Step 5: Fuzzy performance score is calculated by using the equation 13

$$\tilde{U}_i = \sum_{j=1}^n \tilde{w}_j \tilde{r}_{ij}, \quad \forall i \quad (13)$$

where \tilde{U}_i denotes the fuzzy utility of alternative i ; \tilde{w}_j denotes the weight of the criterion j , and \tilde{r}_{ij} denotes the performance score of alternative i with respect to criterion j .

Step 6: Fuzzy numbers are defuzzified in order to determine the rank of alternatives, and then the ranking is decided.

4. Application

In this study, the barriers to the transition to CE in the tourism industry are evaluated. Transition to CE is considered as an unavoidable transformation for manufacturing companies in order to reach a sustainable economic environment (Kazancoglu et al., 2020). The tourism industry acts as an essential driver for the growth and prosperity of the countries, yet, it also creates serious negative environmental issues since it uses lands, consumes water, food, and energy resources, creates waste, and pollutes the environment (Rodriguez et al., 2020). We chose the tourism industry because of its importance on the economy and the lack of studies covering the relationship between CE and the industry.

The barriers used in the application were determined by reviewing the existing literature and interviewing experts from the industry. The evaluation of the barriers was conducted by the expert opinions. The aim of this study is to evaluate and rank the barriers to transition to CE in the tourism industry hierarchically according to their importance. With the help of this study, the industry will be able to determine its primary study areas for transition to CE. The Interval Type 2 Fuzzy AHP method was used, and the survey was conducted with 4 experts working as general managers at different 5-star hotels in the Mediterranean region of Turkey. The conceptual framework of the study is exhibited in Figure 2.

An extensive set of barriers to transition to CE was put together after a comprehensive literature review for the application stage. Then, the most relevant barriers for the tourism industry were determined with the help of experts from the industry and ten of them were selected. These barriers are “lack of governmental support (B1)” (Farooque et al., 2019; Govindan et al., 2014; Rizos et al., 2016), “complexity of CE friendly product designs (B2)” (Govindan et al., 2014; Ritzen & Sandstrom, 2017), “lack of new technologies, materials and processes (B3)” (Farooque et al., 2019; Govindan et al., 2014; Rizos et al., 2016), “high initial investment costs and/or low returns (B4)” (Agyemang et al., 2019; Farooque et al., 2019; Govindan et al., 2014; Kirchherr et al., 2018; Masi et al., 2018; Ritzen & Sandstrom, 2017), “cost of environmental friendly packaging(B5)” (Govindan et al., 2014), “additional human resource needs (B6)” (Govindan et al., 2014), “lack of knowledge and training possibilities (B7)” (Govindan et al., 2014), “lack of awareness/preference/pressure of the consumers (B8)” (Farooque et al., 2019; Galvao et al., 2018; Govindan et al., 2014; Govindan and Hasanagic, 2018; Kirchherr et al., 2018), “lack of corporate social responsibility (B9)” (Govindan et al., 2014), and “organizational structure/infrastructure that creates inconvenience with supply chain on transition to CE (B10)” (Farooque et al., 2019; Govindan and Hasanagic, 2018; Ritzen and Sandstrom, 2017).

In the first step of the application, the experts were asked to fill a pairwise comparison survey consisting of linguistic variables. Their linguistic expressions were transformed into fuzzy variables using the interval type-2 fuzzy scale mentioned earlier in Table 1, and these fuzzy variables constructed the pairwise comparison matrix exhibited in Table 3.

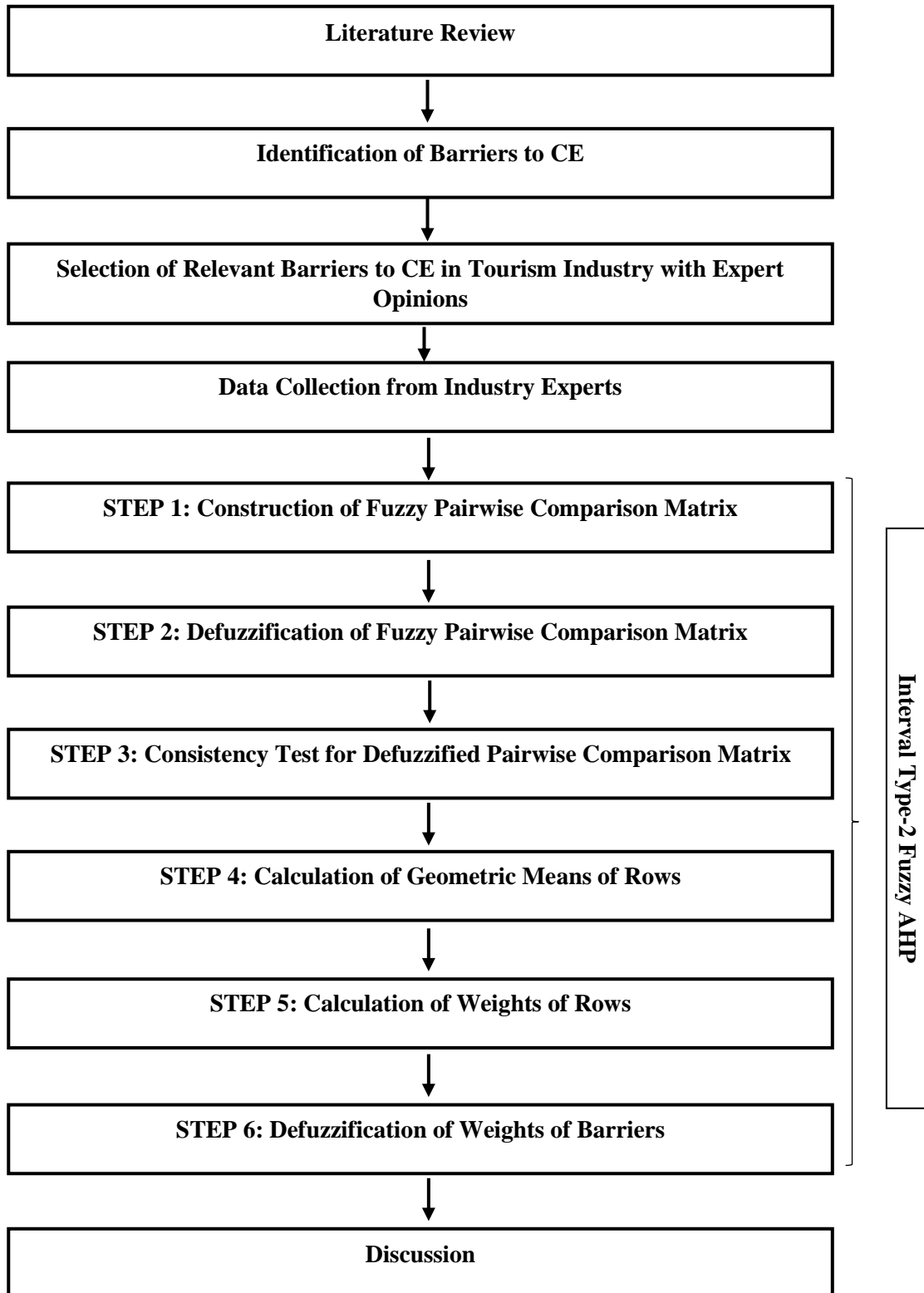


Figure 2. Conceptual framework.

1
2

Table 3. Fuzzy pairwise comparison matrix.

B_{10}	B_9	B_8	B_7	B_6	B_5	B_4	B_3	B_2	B_1
(1.1,1.19,1.41,1.51,1) 6.2,43;1,1) (0.95,1.25,1.7,1.48;0.8,0.8) (3.87,4.9,6.93,7.94;1,1) (4.08,5.1,6.73,1.1,79;0.8,0.8)	(0.88,1.19,1.8,6.2,43;1,1) (0.95,1.25,1.7,8.2,28;0.8,0.8) (1.16,1.68,2.9,1.3,96;1,1) (1.26,1.79,2.7,6.3,69;0.8,0.8)	(1.43,1.68,2,28,2,82;1,1) (1.48,1.74,2,19,2,67;0.8,0.8) (1.21,1.41,1,86,2,14;1,1) (1.25,1.46,1,81,2,08;0.8,0.8)	(0.39,0.50,0.7,6,1;1,1) (0.41,0.52,0.7,3,0,94;0.8,0.8) (1.1,32,2,2,59,1,1) (0.67,0.84,1,1,9,1,5;1,1) (0.71,0.87,1,1,5,1,41;0.8,0.8)	(0.88,1.19,1.8,6,2,43;1,1) (0.95,1.25,1.7,8,2,28;0.8,0.8) (0.45,0.59,1,1,5,1,1) (0.48,0.62,0.9,4,1,35;0.8,0.8)	(1.1,32,2,2,5,9,1,1) (1.07,1.38,1,9,3,1,49;0.8,0.8) (0.41,0.45,0,59,0,7,6;1,1) (0.42,0.46,0,57,0,7,1;0.8,0.8)	(1.97,2.63,3,72,4,21;1,1) (2.11,2.75,3,62,4,12;0.8,0.8) (1.32,1.68,2,45,2,88;1,1) (1.39,1.76,2,37,2,79;0.8,0.8)	(1.97,2.63,3,72,4,21;1,1) (2.11,2.75,3,62,4,12;0.8,0.8) (0.66,0.78,1,07,1,26;1,1) (0.68,0.81,1,04,1,22;0.8,0.8)	(0.22,0.24,0.3,2,0,41;1,1) (0.23,0.25,0.3,1,0,39;0.8,0.8) (1.1,1,1,1,1,1,1) (1.1,1,1,1,1,1,1)	(1.1,1,1,1,1,1,1) (1.1,1,1,1,1,1,1) (2.43,3.13,4,12,4,49;1,1) (2.59,3.25,4,02,4,42;0.8,0.8)
(0.81,1.07,1.5,7,1,85;1,1) (0.87,1.12,1.5,1,1,79;0.8,0.8) (0.61,0.76,1,1,14;1,1) (2.1,85;1,1) (0.59,0.8,1,24,8,1,11;0.8,0.8)	(1.06,1.28,1.7,3,2,01;1,1) (1.1,1,1,32,1,6,8,1,95;0.8,0.8)	(0.86,1.32,2,15,2,59;1,1) (0.96,1.4,2,0,9,6,1,42,0,8,2,5;0.8,0.8)	(0.67,0.84,1,1,9,1,1,1,5;1,1) (0.71,0.87,1,1,5,1,41;0.8,0.8)	(0.54,0.64,0.9,3,1,24;1,1) (0.56,0.66,0.8,9,1,15;0.8,0.8)	(0.58,0.59,0,64,0,67;1,1) (0.58,0.6,0.6,3,0,66;0.8,0.8)	(1.1,1,1,1,1,1,1) (1.1,1,1,1,1,1,1) (1.5,1,57,1,6,8,1,73;1,1) (1.51,1,58,1,67,1,72;0.8,0.8)	(1.1,1,1,1,1,1,1) (1.1,1,1,1,1,1,1) (1.32,1.68,2,2,1,2,43;1,1) (0.61,0.73,0,61,0,73,0,88,0,98;0.8,0.8)	(0.35,0.41,0.5,9,0,76;1,1) (0.36,0.42,0.5,7,0,72;0.8,0.8)	(0.24,0.27,0,38,0,51;1,1) (0.24,0.28,0,36,0,47;0.8,0.8)
(1.32,2.3,13.3,64;1,1) (1.47,2.12,3,0,3,3,54;0.8,0.8) (0.67,1.1,68,2,4;1,1) (0.74,1.06,1.6,2,09;0.8,0.8)	(0.61,0.9,1,41,1,7;1,1) (0.68,0.96,1.3,6,1,64;0.8,0.8)	(0.54,0.76,1,32,1,85;1,1) (0.59,0.8,1,2,4,1,71;0.8,0.8)	(0.45,0.59,1,1,5,1,1) (0.48,0.62,0.9,4,1,35;0.8,0.8)	(0.45,0.59,1,1,5,1,1) (0.48,0.62,0.9,4,1,35;0.8,0.8)	(1.1,1,1,1,1,1,1) (1.1,1,1,1,1,1,1) (0.81,1,07,1,1,8,4,1;1,1) (0.81,1,07,1,1,8,4,1;1,1)	(1.5,1,57,1,6,8,1,73;1,1) (1.51,1,58,1,67,1,72;0.8,0.8)	(1.32,1.68,2,2,1,2,43;1,1) (0.61,0.73,0,61,0,73,0,88,0,98;0.8,0.8)	(0.63,0.84,1,3,2,1,73;1,1) (0.67,0.88,1,2,5,1,62;0.8,0.8)	(0.39,0.5,0.7,6,1;1,1) (0.41,0.52,0,73,0,94;0.8,0.8)
(0.81,1.68,2,9,1,3,96;1,1) (1.26,1.79,2,7,6,3,69;0.8,0.8)	(1.73,2.38,3,4,6,3,96;1,1) (1.87,2.5,3,36,3,86;0.8,0.8)	(0.92,1.19,1,68,1,197;1,1) (0.98,1.24,1,63,1,91;0.8,0.8)	(1.1,1,1,1,1,1,1) (1.1,1,1,1,1,1,1)	(0.51,0.59,0.8,4,1,09;1,1) (0.52,0.61,0.8,1,1,02;0.8,0.8)	(0.67,1.1,68,2,24;1,1) (0.74,1.06,1,6,2,09;0.8,0.8)	(0.92,1.1,19,1,32,1,1) (0.94,1,02,1,17,1,29;0.8,0.8)	(0.67,0.84,1,19,1,5,1,1) (0.71,0.87,1,15,1,41;0.8,0.8)	(0.39,0.5,0.76,1,1,1) (0.41,0.52,0.7,3,0,94;0.8,0.8)	(1.1,32,2,2,5,9,1,1) (1.07,1.38,1,9,2,2,44;0.8,0.8)
(0.81,0.97,1.3,6,1,63;1,1) (0.84,1.01,1.3,1,56;0.8,0.8)	(0.58,0.66,0.9,1,16;1,1) (0.59,0.68,0.8,7,1,09;0.8,0.8)	(1.1,1,1,1,1,1,1) (1.1,1,1,1,1,1,1)	(0.51,0.59,0.8,4,1,09;1,1) (0.52,0.61,0.8,1,1,02;0.8,0.8)	(0.54,0.76,1,65;1,1) (0.59,0.8,1,2,4,1,71;0.8,0.8)	(0.67,1.1,68,2,24;1,1) (0.74,1.06,1,6,2,09;0.8,0.8)	(0.57,0.76,1,19,1,5,1,1) (0.61,0.8,1,1,4,1,43;0.8,0.8)	(0.39,0.47,0,61,0,83;1,1) (0.48,0.55,0.6,9,0,8,0.8,0.8)	(0.47,0.54,0.7,1,0,83;1,1) (0.48,0.55,0.6,9,0,8,0.8,0.8)	(0.35,0.44,0,59,0,7,1,1) (0.37,0.46,0,58,0,68;0.8,0.8)
(0.92,1.19,1.6,8,1,97;1,1) (0.98,1.24,1.6,3,1,91;0.8,0.8)	(1.1,1,1,1,1,1,1) (1.1,1,1,1,1,1,1)	(0.86,1,11,1,52,1,73;1,1) (0.92,1,15,1,48,1,69;0.8,0.8)	(0.25,0.29,0.4,2,0,58;1,1) (0.26,0.3,0.4,0,53,0,8,0.8)	(0.59,0.71,1,11,1,63;1,1) (0.61,0.73,1,05,1,47;0.8,0.8)	(0.59,0.71,1,11,1,63,1,1) (0.61,0.73,1,05,1,47;0.8,0.8)	(0.54,0.76,1,32,1,85;1,1) (0.59,0.8,1,2,4,1,71;0.8,0.8)	(0.5,0.58,0.7,8,0,94;1,1) (0.51,0.59,0,76,0,9,0.8,0.8)	(0.25,0.34,0.5,9,0,86;1,1) (0.27,0.36,0.5,6,0,79;0.8,0.8)	(0.41,0.54,0,84,1,14;1,1) (0.44,0.56,0,81,0,66;0.8,0.8)
(1.1,1,1,1,1,1,1) (1.1,1,1,1,1,1,1)	(0.51,0.59,0.8,4,1,09;1,1) (0.52,0.61,0.8,1,1,02;0.8,0.8)	(0.61,0.74,1,03,1,24;1,1) (0.64,0.77,0,99,1,19;0.8,0.8)	(0.25,0.34,0.5,9,0,86;1,1) (0.27,0.36,0.5,6,0,79;0.8,0.8)	(0.27,0.32,0,5,0,76;1,1) (0.28,0.33,0,7,1,54;0.8,0.8)	(0.27,0.32,0,5,0,76;1,1) (0.28,0.33,0,7,1,54;0.8,0.8)	(0.88,1,1,32,1,63;1,1) (0.9,1,03,1,2,7,1,54;0.8,0.8)	(0.54,0.64,0,93,1,24;1,1) (0.56,0.66,0,89,1,15;0.8,0.8)	(0.13,0.14,0.2,0,26;1,1) (0.13,0.15,0.2,0,25;0.8,0.8)	(0.67,0.71,0,84,1,1,1,1) (0.68,0.72,0,82,0,96;0.8,0.8)

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In the next step, the pairwise comparison matrix was defuzzified by DTraT method to make it ready for the consistency test. The defuzzified matrix of the pairwise comparison matrix is exhibited in Table 4.

Table 4. Defuzzified pairwise comparison matrix.

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10
B1	1.00	3.37	0.33	0.33	0.62	0.69	1.63	0.50	0.69	0.76
B2	0.30	1.00	1.07	0.50	1.06	1.32	0.62	0.60	0.48	0.17
B3	3.05	0.93	1.00	0.76	1.82	0.71	0.99	0.65	0.66	0.79
B4	3.05	2.01	1.32	1.00	1.54	1.26	1.05	0.95	1.05	1.14
B5	1.60	0.94	0.55	0.65	1.00	0.76	1.32	1.05	0.94	0.43
B6	1.45	0.76	1.42	0.80	1.32	1.00	2.29	1.44	1.27	0.83
B7	0.61	1.60	1.01	0.95	0.76	0.44	1.00	0.71	0.36	0.48
B8	2.02	1.66	1.55	1.05	0.95	0.70	1.40	1.00	1.24	0.86
B9	1.45	2.08	1.51	0.95	1.06	0.79	2.77	0.81	1.00	0.71
B10	1.32	5.79	1.27	0.88	2.31	1.21	2.08	1.17	1.40	1.00

After the defuzzification process, consistency test of the defuzzified matrix was conducted, and the consistency ratio (CR) was found to be 0.05, which means that the pairwise comparison matrix is consistent. Table 5 exhibits the related calculations.

Table 5. Consistency test.

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	W	A*W	(A*W)/W	CI	CR
B1	0.06	0.17	0.03	0.04	0.05	0.08	0.11	0.06	0.08	0.11	0.08	0.86	11.05	0.08	0.05
B2	0.02	0.05	0.10	0.06	0.09	0.15	0.04	0.07	0.05	0.02	0.06	0.68	10.49		
B3	0.19	0.05	0.09	0.10	0.15	0.08	0.07	0.07	0.07	0.11	0.10	1.05	10.78		
B4	0.19	0.10	0.12	0.13	0.12	0.14	0.07	0.11	0.12	0.16	0.13	1.35	10.78		
B5	0.10	0.05	0.05	0.08	0.08	0.09	0.09	0.12	0.10	0.06	0.08	0.86	10.60		
B6	0.09	0.04	0.13	0.10	0.11	0.11	0.15	0.16	0.14	0.12	0.11	1.20	10.49		
B7	0.04	0.08	0.09	0.12	0.06	0.05	0.07	0.08	0.04	0.07	0.07	0.74	10.66		
B8	0.13	0.08	0.14	0.13	0.08	0.08	0.09	0.11	0.14	0.12	0.11	1.18	10.69		
B9	0.09	0.10	0.14	0.12	0.09	0.09	0.18	0.09	0.11	0.10	0.11	1.19	10.70		
B10	0.08	0.29	0.12	0.11	0.19	0.14	0.14	0.13	0.15	0.14	0.15	1.61	10.90		
													$\lambda_{max} =$ 10.72		

After checking the consistency of the pairwise comparison matrix, the geometric means of each row of the matrix were calculated, which are exhibited in Table 6, and then the weights of each barrier were calculated which are also exhibited in Table 7.

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Table 6. Geometric means of rows.

\tilde{r}_i	Values
\tilde{r}_1	(0.54,0.65,0.89,1.1;1,1) (0.56,0.67,0.86,1.05;0.8,0.8)
\tilde{r}_2	(0.41,0.5,0.72,0.9;1,1) (0.43,0.52,0.69,0.85;0.8,0.8)
\tilde{r}_3	(0.68,0.83,1.16,1.44;1,1) (0.71,0.86,1.12,1.37;0.8,0.8)
\tilde{r}_4	(0.97,1.17,1.56,1.82;1,1) (1.02,1.21,1.51,1.76;0.8,0.8)
\tilde{r}_5	(0.59,0.71,0.99,1.27;1,1) (0.62,0.73,0.96,1.19;0.8,0.8)
\tilde{r}_6	(0.75,0.97,1.45,1.9;1,1) (0.8,1.01,1.39,1.78;0.8,0.8)
\tilde{r}_7	(0.5,0.6,0.84,1.06;1,1) (0.52,0.62,0.81,1;0.8,0.8)
\tilde{r}_8	(0.79,1.01,1.45,1.76;1,1) (0.84,1.05,1.4,1.68;0.8,0.8)
\tilde{r}_9	(0.77,1.1,1.49,1.87;1,1) (0.82,1.05,1.43,1.77;0.8,0.8)
\tilde{r}_{10}	(1.04,1.34,1.87,2.19;1,1) (1.1,1.39,1.82,2.12;0.8,0.8)

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Table 7. Weights of rows.

\tilde{w}_i	Values
\tilde{w}_1	(0.04,0.05,0.1,0.16;1,1) (0.04,0.06,0.09,0.14;0.8,0.8)
\tilde{w}_2	(0.03,0.04,0.08,0.13;1,1) (0.03,0.04,0.08,0.11;0.8,0.8)
\tilde{w}_3	(0.04,0.07,0.13,0.2;1,1) (0.05,0.07,0.12,0.18;0.8,0.8)
\tilde{w}_4	(0.06,0.09,0.18,0.26;1,1) (0.07,0.1,0.17,0.24;0.8,0.8)
\tilde{w}_5	(0.04,0.06,0.11,0.18;1,1) (0.04,0.06,0.1,0.16;0.8,0.8)
\tilde{w}_6	(0.05,0.08,0.17,0.27;1,1) (0.05,0.08,0.15,0.24;0.8,0.8)
\tilde{w}_7	(0.03,0.05,0.1,0.15;1,1) (0.04,0.05,0.09,0.13;0.8,0.8)
\tilde{w}_8	(0.05,0.08,0.17,0.25;1,1) (0.06,0.09,0.15,0.23;0.8,0.8)
\tilde{w}_9	(0.05,0.08,0.17,0.26;1,1) (0.06,0.09,0.16,0.24;0.8,0.8)
\tilde{w}_{10}	(0.07,0.11,0.21,0.31;1,1) (0.08,0.12,0.2,0.29;0.8,0.8)

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In the final step, the weights of each barrier were defuzzified to put them in an order according to their scores, as in Table 8.

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Table 8. Scores of barriers.

Barrier	Score
B1	8.08%
B2	6.45%
B3	10.45%
B4	13.91%
B5	9.06%
B6	13.06%
B7	7.62%
B8	12.81%
B9	13.21%
B10	16.42%

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50 **5. Results and Discussion**

51 According to the results of the study, the most important barrier to transition to CE in the tourism
52 industry is “organizational structure/infrastructure that creates inconvenience with supply chain on
53 transition to CE”. This barrier has the highest weight amongst all ten barriers, with a weight of
54 16.4%. A successful transition to CE requires the participation and engagement of every actor in a
55 supply chain (de Jesus and Mendonca, 2018). As De Angelis et al. (2018) state, existing supply
56 chains are mostly in linear shape with the spread of globalization that makes it possible to use
57 resources from different regions of the world. Therefore, when a company changes its process
58 designs to a more compatible structure with CE principles, it may face certain incompatibility
59 problems with the existing supply chain if the other actors are not involved in the process
60 sufficiently. This probability seems leading tourism companies to turn a blind eye to CE transition,
61 according to the results. Overcoming this barrier might require increasing the awareness and
62 participation of the actors of the supply chain in the tourism industry.

63
64 The second most important barrier to the transition to CE according to the result of the study is
65 “high initial investment costs and/or low returns” with a 13.9% weight. It can be inferred that the
66 industry experts think the changes for a CE transition require a big budget for the companies, and
67 they also think the potential benefits of this transition are not lucrative enough compared to the
68 money invested in at the moment. This result also supports the findings of Agyemang et al. (2019),
69 suggesting that the firms think the up-front investment for the transition to CE would be high since
70 it means reshaping a built facility when the CE practices were not even existing.

71
72 “Lack of corporate social responsibility” showed up as the third most important barrier with a
73 weight of 13.2%. Corporate social responsibility is a popular concept among private sector
74 companies which helps them to be accountable in social aspects. It is considered an important factor
75 for companies to find their places in society and embrace social and ethical standards in their
76 operations. The adoption of corporate social responsibility principles by the companies increases
77 every year, yet, many companies still have a long way to go for a serious action towards the concept
78 (Lindgreen and Swaen, 2010). Corporate social responsibility is related to the transition to CE in
79 tourism because it supports the responsible tourism concept and encourages actions like saving
80 water, producing lower CO₂ emissions, and decreasing energy consumption (Vargas-Sanchez,
81 2018). The expert opinions show that the adoption of corporate social responsibility practices is not
82 at a sufficient level in the tourism industry to successfully support a transition to CE and other
83 environment-friendly practices.

84
85 The fourth most important barrier is “additional human resource needs” for the transition process
86 with a weight of 13.1%. Govindan et al. (2014) argue that companies will need extra human
87 resources to implement a transition to green supply chain management practices. Agyemang et al.
88 (2019) suggest that the companies find it expensive to hire qualified employees, which helps the
89 companies to support CE transition. The result of our study supports these claims since we can
90 infer that the experts from the tourism industry think they would need additional workers if they
91 adopt CE practices, and the difficulty of recruitment and the cost of additional employees push
92 them away from implementing CE principles.

93
94 “Lack of awareness/preference/pressure of the consumers” is the fifth most important barrier to CE
95 transition in the tourism industry, with a weight of 12.8%. CE transition needs efforts and
96 participation of all possible actors of the existing supply chain, and consumers are an important
97 part of it (Lieder and Rashid, 2016; Rizos et al., 2016). It is seen that the industry experts think the

98 low awareness level of consumers about CE principles makes it difficult to implement CE
99 principles in the tourism industry.

100
101 “Lack of new technologies, materials and processes”, “cost of environmental friendly packaging”,
102 “lack of governmental support”, “lack of knowledge and training possibilities”, “complexity of CE
103 friendly product designs” are the sixth, seventh, eighth, ninth and tenth important barriers with
104 weights of 10.4%, 9.1%, 8.1%, 7.6%, 6.4% respectively.

105 106 **6. Conclusion**

107 Transition to CE is of growing interest in the academic environment in recent years, yet, the studies
108 about the barriers to CE implementation in the service industry and, more specifically, in the
109 tourism industry are not sufficient. We intended to understand and present the challenges of the CE
110 transition in the tourism industry to display the current situation and help the stakeholders and the
111 actors in the industry in their actions towards a more circular tourism environment. Positive
112 externalities coming from the application of CE practices would create a significant competitive
113 advantage in the levels of industries and countries. We think that the results will help all the
114 stakeholders within the industrial environment allocate their resources and efforts more efficiently,
115 in line with the aim of establishing a more circular and more sustainable tourism industry.

116
117 We believe that relating the CE exclusively with the manufacturing industry limits the benefits of
118 this novel economic model. We hope this study will raise the interest in the possible contributions
119 of CE practices in the service industry and specifically the tourism industry. The drivers and
120 enablers of the CE transition in the service business and the tourism industry can be the main
121 subjects for future research. The relationship of the other industries under the service business can
122 also be examined in a more detailed approach in the following studies. Transition to CE in the
123 tourism industry would be examined in detail by breaking down the tourism industry into
124 accommodation, food, and spa & wellness industries. As the number of organizations that adopt
125 CE practices on their business processes increase, performance evaluations of these organizations
126 would open a new field of research in the not-too-far future.

127
128 In our study, we faced certain limitations. Since the CE is a novel model and is not yet a known
129 concept in the Turkish tourism industry, finding industry experts who have sufficient knowledge
130 about the CE was difficult. Therefore, we were able to conduct our study with only four industry
131 experts. As the understanding of CE expands in the tourism industry, we will be able to work with
132 a higher number and experts and the accuracy of the findings would increase.

133 134 135 **Conflict of Interest**

136 The authors confirm that there is no conflict of interest to declare for this publication.

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