TRANSITIONING TO A CIRCULAR ECONOMY IN THE CONSTRUCTION INDUSTRY: BARRIERS AND ENABLERS FROM STAKEHOLDERS' PERSPECTIVES

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ABSTRACT

TRANSITIONING TO A CIRCULAR ECONOMY IN THE CONSTRUCTION INDUSTRY: BARRIERS AND ENABLERS FROM STAKEHOLDERS' PERSPECTIVES

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As the global population increases and the need for buildings expands, the construction industry has emerged as a primary driver of waste production and resource utilization. As a result, the influence of sector on the economy and environment is growing as well. By reducing the environmental impact of the sector and the natural resources consumption, preferring a circular economy model in contrast to the traditional linear economy approach can help address these problems. Circular economy (CE) has recently gained attention due to the need to recycle, with the goal of minimizing carbon emissions and material consumption. Although much research has been conducted to understand the awareness on CE principles and their promotion, there are still some challenges for the construction industry to make a transition towards a circular economy model. The barriers and enablers that will assist the construction sector towards circular economy need to be known, and the perspectives of various stakeholders on their roles should be explored. The objective of this study is to identify the perspectives of construction stakeholders on their roles for transitioning to CE. Accordingly, a systematic literature review for determining

the impact of barriers and enablers on the construction industry and the involvement of stakeholders in the implementation of these enablers is performed. Perspectives of various stakeholders are acquired through a survey, and results are assessed using Social Network Analysis (SNA). The similarities and differences in the reflections of stakeholders are discussed. This thesis contributes to the construction management literature by reflecting the perspectives of construction stakeholders on the barriers and enablers of CE and the roles of the stakeholders in supporting the adoption of CE in construction projects.

Keywords: Circular Economy (CE), Stakeholders' Perspective, Barriers, Enablers

ÖZ

İNŞAAT SEKTÖRÜNDE DÖNGÜSEL EKONOMİYE GEÇİŞ: PAYDAŞLARIN PERSPEKTİFLERİNDEN ENGELLER VE KOLAYLAŞTIRICILAR

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Artan nüfus ve inşaat talebi göz önüne alındığında, inşaat sektörü atık üretimi ve kaynak tüketiminin başlıca nedenlerinden biri haline gelmiştir. Bunun sonucunda sektörün ekonomi ve çevre üzerindeki etkisi de artmaktadır. İnşaatın çevresel etkilerini ve doğal kaynak tüketimini azaltarak, geleneksel doğrusal ekonominin aksine döngüsel ekonomi modelinin benimsenmesi bu sorunların ele alınmasına yardımcı olabilir. Döngüsel ekonomi (DE), karbon emisyonlarını ve malzeme tüketimini en aza indirmek hedefiyle birlikte geri dönüşüm ihtiyacı ile son zamanlarda dikkat çekmeye başlamıştır. DE ilkelerine ilişkin farkındalığı ve bunların teşvik edilmesini anlamak için çok sayıda araştırma yapılmış olmasına rağmen, inşaat sektörünün döngüsel ekonomi modeline geçiş yapabilmesi için hala bazı zorluklar bulunmaktadır. İnşaat sektörünün döngüsel ekonomiye geçişine yardımcı olacak engellerin ve kolaylaştırıcıların bilinmesi ve çeşitli paydaşların rollerine ilişkin bakış açılarının araştırılması gerekmektedir. Bu çalışmanın amacı, inşaat paydaşlarının döngüsel ekonomiye geçişteki rollerine ilişkin bakış açılarını belirlemektir. Bu doğrultuda, engellerin ve kolaylaştırıcıların inşaat sektörü üzerindeki etkisini ve paydaşların bu kolaylaştırıcıların uygulanmasına katılımını

belirlemek için sistematik bir literatür taraması yapılmıştır. Çeşitli paydaşların bakış açıları bir anket aracılığıyla elde edilmiş ve sonuçlar Sosyal Ağ Analizi kullanılarak değerlendirilmiştir. Paydaşların görüşlerindeki benzerlikler ve farklılıklar tartışılmıştır. Bu tez, inşaat paydaşlarının DE'nin engelleri ve kolaylaştırıcıları hakkındaki bakış açılarını ve paydaşların inşaat projelerinde DE'nin benimsenmesini desteklemedeki rollerini yansıtarak inşaat yönetimi literatürüne katkıda bulunmaktadır.

Anahtar Kelimeler: Döngüsel Ekonomi (DE), Paydaşların Perspektifi, Bariyerler, Kolaylaştırıcılar



To my family,

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LIST OF ABBREVIATIONS

ABBREVIATIONS

AEC: Architecture, Engineering, and Construction

CDW: Construction and Demolition Waste

CE: Circular Economy

CI: Construction Industry

DfD: Design for Disassembly

GDP: Gross Domestic Product

IQR: Interquartile Range

SNA: Social Network Analysis

CHAPTER 1

INTRODUCTION

This chapter provides an assessment of the present condition of the construction industry in the context of the circular economy and presents the problem statement. Additionally, it outlines the thesis's objectives, scope, and structure.

In developing countries, the demand for the construction sector and the consumption of materials and raw materials, in parallel with the demand, is increasing daily with the development of technology and sector conditions, population growth, and the resulting infrastructure needs. Given the growing needs, the construction industry stands as a significant consumer of raw materials and a prominent generator of waste on a global scale. Years of economic growth and various development activities that ignore natural ecosystems and additional environmental elements have been associated with resource exploitation. The extensive extraction of raw materials leads to biological degradation and the release of pollutants, undeniably increasing existing environmental pressures; therefore, it has become inevitable to address these barriers to ensure sustainability in the construction sector (Ababio & Lu, 2023).

The linear economy model, characterized by extensive utilization of natural resources and disregard for resource recovery, has been questioned due to the growing problems with climate change and resource scarcity (Cruz Rios et al., 2021). By employing diverse end-of-life strategies like material reduction, reuse, and recycling throughout production, distribution, and consumption, the circular economy (CE) presents a chance to decrease reliance on primary materials and mitigate the resulting environmental consequences. The adoption of the circular economy (CE) model has recently gained attention due to the rising need for global recycling in the industry and the aim to minimize carbon emissions and material

consumption. Adopting CE is a profitable and sustainable alternative that promotes resource efficiency and offers socio-economic benefits, such as increasing gross domestic product and job opportunities (Munaro & Tavares, 2023).

While considering the materials used in the construction industry and cash flow in the sector, in the economic system, the construction industry has an essential significance in the economy. Considering the significant amount of construction and demolition waste (CDW) generated, it is also one of the highest waste generators; therefore, it is a sector targeted to be prioritized in the transition to a circular economy (Giorgi et al., 2022). The transitioning to the CE in the construction industry encourages a more sustainable and resource-efficient approach than the traditional linear "take, make, waste" model. This transformation aims to reduce waste, conserve resources, reduce carbon emissions, and create more durable and sustainable construction.

1.1 Aim and Scope of the Thesis

The circular economy requires collaborative and interdisciplinary work for better consumption and waste management strategies (Tirado et al., 2022). Therefore, the transition of the CE to the construction industry requires some practices that require the intervention of different stakeholders.

Stakeholders involved in construction projects may include contractors, engineers, designers, material suppliers, local community members, government agencies, financial institutions, and many others. Each stakeholder's contribution, expectations, concerns, and impact on the project may differ. Although decision-makers in the project can often have a more significant influence, a range of factors and stakeholders are involved that affect the project's outcome. Therefore, understanding stakeholders' needs, expectations, and perceptions facilitates more successful projects through improved communication and collaboration.

Understanding the role of stakeholders and the main indicators, barriers, and enablers for implementing circular economy strategies within construction projects can facilitate effective management and long-term sustainability of the process (Guerra & Leite, 2021). Much research has been conducted to assess the comprehension and awareness of CE principles to ensure CE adoption in the construction industry. Many studies identified the barriers and enablers of CE. However, limited studies identified the barriers and enablers of CE strategies that can be used in the construction sector (Cruz Rios et al., 2021). Existing studies focusing on different regions and cultures show variations in their findings, which may affect the CE transition. No studies have been found exploring Turkish construction stakeholders' perspectives on CE. Moreover, existing studies in the international literature mainly rely on the previously published articles in identifying the barriers, enablers, and the stakeholders' roles. However, it is essential to explore the awareness level and perspectives of construction stakeholders in practice regarding the transition into CE for better situation awareness.

This study aims to identify the perspectives of different stakeholders on the barriers to CE and the roles of stakeholders in supporting the integration of CE into the Turkish construction industry. The approach is to examine the barriers and enablers from the perspective of stakeholders in the sector through a survey and establish a relationship between the enablers of CE and the roles of stakeholders through the Social Network Analysis (SNA). Different stakeholders' perceptions of the enablers necessary for adopting circular economy principles in construction projects are also compared to assess the similarities and differences in their reflections. This thesis contributes to the construction management literature by reflecting the construction stakeholders' perspectives on the barriers and enablers of CE and the roles of the stakeholders in supporting the adoption of CE in construction projects.

In line with the aim of the thesis, the following research questions were answered;

- What are the perceptions of Turkish construction stakeholders on the barriers and enablers for transitioning the construction industry towards a circular economy?
- How to map the interrelationship between CE enablers and relative stakeholders to determine the role of each stakeholder in transitioning the construction industry toward a circular economy?

1.2 Organization of the Thesis

This thesis examines the construction industry's adoption and implementation of a circular economy. This study includes the following chapters;

The first chapter presents introductory information on CE and the construction industry. The introduction chapter emphasizes the motivation and importance of the research by focusing on the key concepts of circular economy and the construction industry.

The second chapter includes a literature review on the barriers to the applicability of CE in the construction sector, enablers, and stakeholders in the sector. The literature review examines the relationship between these two fields, barriers, and potential enablers in the sector. This thesis aims to identify why the circular economy has not been adopted in the construction sector and the factors that hinder its adoption.

The third chapter contains the methodology used for the study. The methodology details the research methodology and data collection process used to achieve the thesis's objective, including the survey and Social Network Analysis.

The fourth chapter presents the findings and discussions of the study.

The last chapter presents the conclusions and recommendations. The findings and conclusions obtained assess the current state of circular economy implementation in the construction sector and possible future steps. This thesis provides a broad overview of the role of the circular economy in the construction sector.

CHAPTER 2

LITERATURE REVIEW

Assessing the awareness of the Circular Economy (CE) and exploring the employed and well-known strategies are trending research topics (Torgautov et al., 2021). This chapter presents the CE concept, barriers and enablers of integrating CE into the construction sector, and the role of the stakeholders in such a transformation.

2.1 Circular Economy (CE) Concept

The basic logic of CE is the evolution of systems that aim to go beyond linear " take-make-dispose" economic models and aim to close material and energy loops that preserve the value of resources; however, the CE concept started to receive more attention after 2015, when the Ellen MacArthur Foundation promoted its use (Osei-Tutu et al., 2023).

The Ellen MacArthur Foundation defines the circular economy as follows: “A circular economy is an industrial system that is restorative or regenerative by intention and design. It replaces the ‘end-of-life’ concept with restoration, shifts towards the use of renewable energy, eliminates the use of toxic chemicals, which impair reuse, and aims for the elimination of waste through the superior design of materials, products, systems, and, within this, business models.” (Macarthur, 2013.)

CE is an emerging concept within the construction industry, an innovative business model that has arisen out of a growing concern to preserve and recover the value of construction materials and structures and minimize construction and demolition waste (C&DW) (Torgautov et al., 2021). CE aims to produce increased business value and economic opportunities while consuming less resources that, together with waste management, can be reused for a long time to come (Cruz Rios et al., 2021).

CE offers a chance to diminish the consumption of primary resources and their environmental repercussions. Several CE definitions evolved, often derived from a set of interconnected underpinnings of thought. Similar elements include waste elimination and the value of materials optimization (Adams et al., 2017). Various strategies within CE include material reduction, reuse, recycling, and replacing traditional end-of-life practices. Embracing CE is not only an ecologically responsible choice but also a financially profitable one. It encourages the efficient utilization of resources and delivers socio-economic advantages, including heightened Gross Domestic Product (GDP) and expanded employment opportunities (Munaro & Tavares, 2023). CE strategies frequently serve as a means to achieve sustainability by enhancing resource efficiency. They are anticipated to offer economic benefits by raising net material savings, GDP, and employment opportunities while reducing the risks associated with material price fluctuations and supply chain disruptions (Ababio & Lu, 2023).

Diverse end-of-life (EOL) approaches, including recycling, reuse, and material reduction throughout production, distribution, and consumption, constitute integral components of the circular economy (CE) (Munaro & Tavares, 2023). These strategies encourage the use of primary materials while minimizing their adverse environmental effects. With these advantages, CE adoption can be positioned as a profitable and sustainable alternative promoting resource efficiency and socio-economic benefits, such as increasing GDP and job opportunities. CE plays a critical role not only in the efficient use of resources but also in ensuring economic resilience and stability. Such benefits explain why CE has become one of the topics that is increasingly being emphasized and paid attention to.

The circular economy considers a holistic approach to achieving zero waste generation. It ensures that the environment is protected from the negative impacts of construction-related activities by reducing and eliminating waste generated (Osei-Tutu et al., 2023). When contemplating the incorporation of circular economy principles into the construction sector, practices such as establishing reuse and incorporating salvaged materials can be recognized as Circular Economy (CE)

strategies (Cruz Rios et al., 2021). Strategies applicable in the built environment encompass design for disassembly (DfD) and adaptability, the reuse of building components, adaptive reuse, and the utilization of biodegradable building materials. Charef et al. (2021) conducted an assessment of sustainable asset lifecycle management and the adoption of CE in the Architecture, Engineering, and Construction (AEC) sector. They recognized and categorized barriers associated with strategies such as design for demolition, waste management, prefabrication, and closed-loop systems. On a parallel note, Giorgi et al. (2022) clustered CE implementation strategies at the building level into three key domains: business networks and stakeholder engagement, resource and waste management, and reversible architectural design.

Furthermore, waste management is one of the strategies that significantly influence the advancement of the circular economy. The inability to establish an effective and sustainable solution often arises due to unclear regulations and guidelines governing waste management, making it a critical issue that demands attention and consideration. Additionally, it's essential to acknowledge that alongside the required policy measures, the practice of disposing of waste in landfills, which is currently the norm, isn't something that companies are eager to forsake as it can increase their expenses. Besides, it is possible to say that the construction and demolition waste management could not develop due to the poor performance of the contractors and the lack of appropriate infrastructure and facilities (Torgautov et al., 2021).

While circular economy strategies are evolving, they are not yet widely implemented. The reliance on the traditional linear economy model affects the transformation to a circular economy. This transformation requires economic and operational changes and may face several obstacles before widespread industry-wide adoption.

Among the reasons why CE strategies are not widespread are a lack of understanding of barriers and enablers and a lack of understanding of stakeholder responsibilities. The recent literature primarily focuses on two aspects of CE: investigating suggested

and used strategies and highlighting the awareness level of the CE concept (Torgautov et al., 2021). Literature on identifying barriers and enablers to CE strategies which can be used in the buildings and construction sector is limited (Cruz Rios et al., 2021). The interaction between Circular Economy (CE) barriers and their impact on CE strategies and indicators can play a role in identifying key barriers (Bilal et al., 2020). Also, the identification of key barriers is based on the relationship between barriers within the circular economy (CE) and the impact of CE enablers on stakeholders in the sector.

2.2 Circular Economy Barriers

While Circular Economy (CE) holds immense potential and numerous advantages, its implementation in the construction industry (CI) has encountered numerous obstacles. Construction firms and other significant stakeholders encounter challenges in adopting methodologies that facilitate the shift towards CE. The literature highlights various areas where difficulties arise in CE implementation, encompassing design and construction processes, supply chain management, policy formulation, end-of-life principles, waste management, and the exchange of information and analytics (Ababio & Lu, 2023).

Previous studies relied on a literature review to identify barriers and cover a wide range of geographical areas, including Hong Kong, the USA, Kazakhstan, and Europe (Ababio & Lu, 2023; Charef et al., 2021; Munaro & Tavares, 2023; Osei-Tutu et al., 2023; Wuni, 2022). For example, Hossain et al. (2020) suggest a forward-looking, integrated framework for CE adoption and assessment methodology by analyzing current issues in Hong Kong and Canada (Hossain et al., 2020). Many conducted small-scale interviews (e.g., Bilal et al., 2020; Charef & Lu, 2021; Liu et al., 2021; Morel et al., 2021; Tirado et al., 2022; Torgautov et al., 2021). Charef & Lu, Morel et al., and Tirado et al. have studies on Europe, while Liu et al. (2021) conducted China-specific research. Torgautov conducted a study specific to the construction sector in Kazakhstan in terms of the potential for implementation of

circular economy principles by local stakeholders (Torgautov et al., 2021). Bilal took a more general approach and targeted developing countries (Bilal et al., 2020). Some other studies have investigated stakeholders' perspectives by targeting certain practitioners, including architects and consultants (Cruz Rios et al., 2021; Kanters, 2020).

The literature includes survey studies that have been conducted more extensively (e.g., Adams et al., 2017; Al Hosni et al., 2020; Guerra & Leite, 2021). In the United Kingdom, Adams (2017) conducted a survey with 110 participants, 7% of whom were designers, and a follow-up workshop with 97 construction stakeholders, 9% of whom were designers. Although there is an industry-wide awareness of the concept, the survey results show that clients, designers, and subcontractors are the least knowledgeable, and this is a significant challenge for further adoption of the circular economy (Adams et al., 2017). Al Hosni (2020) evaluated 80 responses of the survey conducted in Oman, highlighting the lack of government support and regulation of CE and the need for a government-led initiative to improve CE momentum (Al Hosni et al., 2020). Guerra & Leite (2021) conducted 130 online surveys and more than 14 interviews with United States stakeholders to stimulate a much-needed conversation about circular construction and its challenges and to expand the limited knowledge available. While the quantitative data from the survey was used to measure stakeholders' awareness and adoption of circular strategies, the qualitative data from the general interview was used to assess current construction practices, factors hindering the adoption of circular strategies, and elements supporting the circular economy (Guerra & Leite, 2021).

This study determines barriers through a review of the existing literature. They are examined in the following sections under four separate headings: social and behavioral, economic, political and legal, and technical.

2.2.1 Social and Behavioral Barriers

The social and behavioral barriers (see Table 2.1.) are generally related to stakeholders' knowledge, awareness, and behaviors. Also, they include sector resistance to change, dependence on other sectors, high labor costs, lack of access to materials that can be adapted to CE, and lack of CE-specific regulations (Kanters, 2020). Also, Guerra & Leite (2021) emphasized that budget and costs, deficiencies in project planning, implementation, and regulations, lack of awareness in the sector, sector resistance to change, and the current construction business model are the main barriers to circularity. In the literature, Munaro & Tavares (2023) handled this group in their study as informational and institutional barriers. There is a general lack of knowledge and awareness within the sector about the circular economy and how it can be used for what purpose (Al Hosni et al., 2020; Munaro & Tavares, 2023). Hossain's (2020) research highlights an important issue, particularly the lack of understanding of the Circular Economy (CE) concept among various stakeholders in the social and institutional spheres. There is a clear emphasis on increasing CE awareness and understanding among different participants to transform citizens' attitudes and behaviors toward adopting remanufactured products.

The absence of a comprehensive global strategy for waste reduction can be attributed directly to a linear, rather than circular, mindset and a general neglect of life cycle considerations, as noted by Ghisellini et al. (2018). Reluctance to embrace Circular Economy (CE) integration, including related business models, can be attributed to the underdeveloped market for recovered materials and the associated high costs. These are recognized as social and behavioral barriers.

Cultural barriers within the construction industry and among stakeholders are the deeply ingrained ideas, traditions, and attitudes that hinder the adoption of Circular Economy (CE) practices (Wuni, 2022). These cultural barriers can significantly influence the pace and success of CE adoption in the construction industry.

Key knowledge barriers in this context encompass the lack of CE knowledge, technical capabilities, and expertise in construction. Additionally, limited awareness among stakeholders regarding circular materials, products, services, and strategies, as well as a restricted understanding of CE principles across the construction supply chain network, contribute to these barriers. Moreover, the absence of suitable CE training, development programs, and technical support for supply chain members further hinders the integration of CE practices in the construction industry (Wuni, 2022). Social and behavioral barriers are listed in Table 2.1 according to the literature review prepared by taking all these studies into account.

Table 2.1: Social & Behavioral Barriers[1]

No	Social & Behavioral Barriers	*A1*	*A2*	*A3*	*A4*	*A5*	*A6*	*A7*	*A8*	*A10*	*A11*	*A12*	*A13*	*A14*	*A15*	*A17*	*A18*	*A19*	*A20*
1	Lack of knowledge and awareness of stakeholders about CE strategies and benefits	*		*			*			*	*		*			*	*	*	*
2	Uncertainty about the specifics of CE principles and concepts	*					*				*		*				*		*
3	Lack of experience and skills of stakeholders in the construction sector			*	*		*				*		*				*		*
4	Lack and irregularity of information exchange between stakeholders			*	*					*	*		*	*					
5	Lack of public awareness of the benefits of CE and social pressure	*		*		*	*		*				*			*	*		*
6	Lack of literature and appropriate training-development programs on CE barriers			*	*		*					*		*		*	*	*	*
7	Lack of knowledge about circular design	*	*		*	*			*	*		*		*		*	*		
8	The competitive environment within the construction industry						*												
9	The sector is traditionally characterized by an unwillingness to take risks and resistance to embracing change				*	*	*		*				*	*		*	*	*	*
10	Lack of stakeholder interest		*			*	*		*						*		*	*	*
11	Lack of awareness of production responsibility											*	*	*		*			*

[1] ***Note1:*** A1: (Adams et al., 2017), A2: (Al Hosni et al., 2020), A3: (Bilal et al., 2020), A4: (Charef & Lu, 2021), A5: (Charef et al., 2021), A6: (Cruz Rios et al., 2021), A7: (Giorgi et al., 2022), A8: (Guerra & Leite, 2021), A10: (Hossain et al., 2020), A11: (Kanters, 2020), A12: (Liu et al., 2021) A13: (Morel et al., 2021), A14: (Tirado et al., 2022), A15: (Torgautov et al., 2021) A17: (Munaro & Tavares, 2023), A18: (Ababio & Lu, 2023), A19: (Osei-Tutu et al., 2023), A20: (Wuni, 2022)

2.2.2 Economic Barriers

Budget and schedule constraints are common in construction projects. In addition to the fact that the construction sector requires high investments and budgets, the economic constraints increase when circular economy practices are included in the sector. Many studies in the literature on this topic have adopted many different approaches. The importance of the economic advantage is highlighted when it comes to the utilization of environment-friendly technologies and the reuse of construction materials, as was noticed during the literature review (Torgautov et al., 2021). Companies are usually not willing to take risks that affect profits. In the case of the circular economy, the companies keep construction materials for reuse or landfill instead of taking risks and using more environmentally friendly technologies (Torgautov et al., 2021).

Economic and market barriers within the construction sector pertain to the dynamics of supply and demand, and barriers in the construction sector encompass challenges related to financing, investment limitations, and financial disincentives that obstruct the adoption of Circular Economy (CE) practices (Wuni, 2022). The primary market barriers to CE adoption in the construction industry comprise market pressures and a lack of competition, uncertain market demand for refurbished, remanufactured, and recycled products, market immaturity and related technologies, and the restricted availability of recycled materials and reused products (Wuni, 2022). As identified in the literature, several economic barriers include high initial investment costs, insufficient financing for circular business models, a scarcity of financial resources, low short-term economic advantages, low prices of virgin materials, unpredictable financial returns and economic savings, the elevated cost of environmentally friendly materials and products, and an uncertain financial business case for CE in construction. These economic barriers can significantly impede the widespread implementation of CE principles in the industry. The compiled economic barriers for CE are shown in Table 2.2, along with the relevant stakeholders from earlier studies.

Table 2.2: Economic Barriers[2]

Code	Economic Barriers	*A1*	*A2*	*A3*	*A4*	*A5*	*A6*	*A7*	*A8*	*A10*	*A11*	*A12*	*A13*	*A14*	*A15*	*A17*	*A18*	*A19*	*A20*
E1	Lack or underdevelopment of the market mechanism for recovery	*	*			*	*									*	*	*	
E2	Schedule constraints					*	*	*	*	*	*	*			*			*	
E3	Cost constraints			*		*	*	*	*	*	*	*	*		*	*	*	*	*
E4	Limited applicability of circular business management for the construction industry						*										*		
E5	Uncertain financial situation for CE /High financial risk	*	*				*		*			*	*				*		*
E6	The customer's willingness or readiness to pay for the new concept / Competition			*			*			*	*		*		*		*		
E7	Insufficient research funds											*					*		*
E8	Lower costs of virgin materials/ Higher costs of recycled materials		*	*		*	*	*				*				*	*	*	*
E9	More investment requirement (Quick investment expectation of the customer)		*	*		*	*	*	*				*			*	*		*
E10	Dependence of markets on imports/ established market issues and rapid changes in the market		*				*						*				*		

[2] ***Note1:*** A1: (Adams et al., 2017), A2: (Al Hosni et al., 2020), A3: (Bilal et al., 2020), A4: (Charef & Lu, 2021), A5: (Charef et al., 2021), A6: (Cruz Rios et al., 2021), A7: (Giorgi et al., 2022), A8: (Guerra & Leite, 2021), A10: (Hossain et al., 2020), A11: (Kanters, 2020), A12: (Liu et al., 2021) A13: (Morel et al., 2021), A14: (Tirado et al., 2022), A15: (Torgautov et al., 2021) A17: (Munaro & Tavares, 2023), A18: (Ababio & Lu, 2023), A19: (Osei-Tutu et al., 2023), A20: (Wuni, 2022)

Table 2.2: Economic Barriers (continued)

Code	Economic Barriers	*A1*	*A2*	*A3*	*A4*	*A5*	*A6*	*A7*	*A8*	*A10*	*A11*	*A12*	*A13*	*A14*	*A15*	*A17*	*A18*	*A19*	*A20*
E11	Unreasonably high cost of careful removal of components and parts			*				*				*				*	*	*	*
E12	Cost of disposal				*	*							*				*	*	*
E13	Dependence of the construction industry on other industries										*				*				
E14	Low-profit margins & long payback periods		*						*				*						*

2.2.3 Political and Legislative Barriers

Political and legislative barriers in the construction sector represent regulatory measures or mechanisms that prevent the transition to Circular Economy (CE) practices in the construction industry. Moreover, the failure to revise current standards and methodologies is perceived as an obstacle to the progress of increasingly sustainable and circular technologies. Governmental hindrances in the form of local regulations represent a key political barrier to the execution of circular strategies (as depicted in Table 2.3). In regions with less strict and environmentally attuned regulations, the industry finds allocating resources for strategy implementation more feasible, fostering a greater sense of security and diminished hesitance toward risk-taking (Guerra & Leite, 2021).

One of the key barriers that emerged in the literature is the lack of supporting regulations. According to Al Hosni et al. (2020), since the concept of CE is relatively new in many parts of the world, many studies have mentioned the absence of policies, frameworks, and regulations to support the transition to CE as the most critical challenge for implementation.

The research by Cruz Rios et al. (2021) cites examples of existing regulations that act as barriers to reuse. For example, this study implies the inadequacies of existing building codes when considering reuse. It was also noted that because the buildings are built to code, which makes it very difficult to reuse things, as codes do not take into account the circular economy strategies. Key regulatory barriers in this context include the absence of a regulatory framework, appropriate policies, and sound legislation for CE in construction (Wuni, 2022). This also encompasses the lack of government financial support mechanisms and tax incentives for circular business models, as well as the deficiency of regulatory pressure and strict regulations. Furthermore, the lack of clearly defined goals, visions, and a solid infrastructure for CE in the construction sector prevents the principles of CE from being widely adopted in the construction sector.

Table 2.3: Political Barriers[3]

Code	Political Barriers	*A1*	*A2*	*A3*	*A4*	*A5*	*A6*	*A7*	*A8*	*A10*	*A11*	*A12*	*A13*	*A14*	*A15*	*A17*	*A18*	*A19*	*A20*
P1	Lack of specific regulations, legislations, and laws		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
P2	Inadequate incentive and support policies for EOL and CE		*		*		*					*	*			*	*	*	*
P3	Ignoring circularity policies						*							*			*		
P4	Warranty and quality issues of using reused/recycled products		*				*			*		*		*	*				
P5	Lack of commitment, financial incentives, and regulatory support for advancing CE initiatives		*	*	*	*	*	*				*	*			*	*		*
P6	Absence of established guidelines for reused and recycled building materials				*	*	*	*				*		*		*	*		*
P7	Lack of awareness of the meaning of reversible building							*					*						
P8	Lack of use of building sustainability certification and building codes					*		*								*			
P9	Lack of control and punishment for illegal dumping of waste											*	*			*			

[3] ***Note1:*** A1: (Adams et al., 2017), A2: (Al Hosni et al., 2020), A3: (Bilal et al., 2020), A4: (Charef & Lu, 2021), A5: (Charef et al., 2021), A6: (Cruz Rios et al., 2021), A7: (Giorgi et al., 2022), A8: (Guerra & Leite, 2021), A10: (Hossain et al., 2020), A11: (Kanters, 2020), A12: (Liu et al., 2021) A13: (Morel et al., 2021), A14: (Tirado et al., 2022), A15: (Torgautov et al., 2021) A17: (Munaro & Tavares, 2023), A18: (Ababio & Lu, 2023), A19: (Osei-Tutu et al., 2023), A20: (Wuni, 2022)

2.2.4 Technical Barriers

Technical barriers are constraints associated with limited access to appropriate technologies and tools for CE adoption in the construction sector. By considering the political and legislative barriers, the study of Munaro & Tavares (2023) considered the government's challenges in promoting integrated resource management and DfD. This means that the government's regulatory system may limit its capacity to support such practices.

While promoting efficient use of resources, current resource policies are not focused on reducing resource demand. While this encourages more efficient use of resources, it is not sufficient to cope with the increase in demand (Hossain et al., 2020). Adapting reused materials to existing regulations is a barrier to energy performance requirements (Kanters, 2020).

The high level of risk and limited profitability commonly associated with construction endeavors presents a challenge when it comes to experimenting with and embracing novel technological approaches (Guerra and Leite, 2021). Various technical hindrances emerge from intricate architectural designs, the absence of uniform protocols, challenges in data administration, insufficient technology incorporation, and an insufficient understanding of forthcoming requirements, affecting different parties involved (as outlined in Table 2.4). The ability of stakeholders to recognize the value of tools they might require in the future is complicated, and this stands as a primary obstruction to comprehending the necessity of transitioning to a Circular Economy (CE) model.

According to Wuni (2022), several technological barriers include a lack of technology, infrastructure, and equipment, a lack of robust information systems to track recycled materials, and a lack of digital technologies and solutions.

Therefore, it cannot be ignored that both a strategy and stakeholders are needed to implement the circular economy and that these shortcomings can hinder such sustainability efforts (Al Hosni et al., 2020).

Table 2.4: Technical Barriers[4]

Code	Technical Barriers	*A1*	*A2*	*A3*	*A4*	*A5*	*A6*	*A7*	*A8*	*A10*	*A11*	*A12*	*A13*	*A14*	*A15*	*A17*	*A18*	*A19*	*A20*
T1	Uncertain product content of CE materials, lack of material components, and problems in material classification				*	*	*			*	*	*				*	*		
T2	Lack of uniformity and portability of building elements					*	*	*	*		*	*	*			*	*		
T3	Uncertainty and lack of awareness about future spatial needs/demands, end-of-life and recycling of building materials	*	*		*		*			*	*	*	*	*					
T4	Complexity of building design & design phase / Lack of circularity in design	*	*		*	*	*	*	*			*		*	*	*	*	*	*
T5	Existing buildings are not designed for dismantling, and the potential for damage during demolition (Improper management of site demolition)					*	*	*	*			*		*					
T6	Lack of space to store disassembled materials					*		*			*	*	*						
T7	Challenges in locating readily detachable building products within the market							*				*					*	*	*

[4] ***Note1:*** A1: (Adams et al., 2017), A2: (Al Hosni et al., 2020), A3: (Bilal et al., 2020), A4: (Charef & Lu, 2021), A5: (Charef et al., 2021), A6: (Cruz Rios et al., 2021), A7: (Giorgi et al., 2022), A8: (Guerra & Leite, 2021), A10: (Hossain et al., 2020), A11: (Kanters, 2020), A12: (Liu et al., 2021) A13: (Morel et al., 2021), A14: (Tirado et al., 2022), A15: (Torgautov et al., 2021) A17: (Munaro & Tavares, 2023), A18: (Ababio & Lu, 2023), A19: (Osei-Tutu et al., 2023), A20: (Wuni, 2022)

Table 2.4: Technical Barriers (continued)

Code	Technical Barriers	*A1*	*A2*	*A3*	*A4*	*A5*	*A6*	*A7*	*A8*	*A10*	*A11*	*A12*	*A13*	*A14*	*A15*	*A17*	*A18*	*A19*	*A20*
T8	Challenges of take-back from other companies			*		*													
T9	Lack of standard systems for performance indicators and legislation regulating tests on reused products			*		*		*						*			*		
T10	Lack of data and data management		*		*	*	*			*			*	*	*	*	*	*	*
T11	Undesirable use of second-hand materials and industrialization of natural materials						*					*	*	*	*				
T12	Lack of necessary technology and infrastructure for salvaged components		*		*		*	*				*	*			*	*		*
T13	Fragmented and complex supply chain	*	*							*						*	*		*
T14	Lack of tools and information to identify circularity metrics		*			*	*			*				*	*	*	*	*	*
T15	Lack of adequate technology			*	*	*		*	*				*		*		*		*
T16	Lack of integration between digital design technologies and tools for assessing environmental sustainability				*	*		*					*	*		*	*		*
T17	Limited visualization capability for circularity						*								*	*			

Understanding barriers is critical to facilitating the transition to a circular economy. There are some key enablers to overcome the barriers to circular economy adoption in the construction sector and ensure the successful implementation of the circular economy in the construction sector. These enablers are elements that facilitate the adaptation of the construction sector to the circular economy and help it become more sustainable and efficient. They can play a key role in overcoming barriers and mainstreaming circular economy principles in the construction sector.

2.3 Circular Economy Enablers

The previous section discussed the barriers that make it difficult to adopt circular economy principles in the construction sector. These barriers can hinder the sector's transition to the circular economy and limit the diffusion of more sustainable practices. However, specific sets of enablers are needed to overcome these barriers and align the construction sector more closely with circular economy principles. The enablers found in the literature represent various ways to accelerate this transformation. The enablers were identified by reviewing this study. Numerous enablers linked to various stakeholders have been outlined in existing literature to enhance or eradicate these prevailing barriers (as depicted in Table 2.5). Acknowledging the drawbacks of the construction industry's linear economic paradigm and implementing corrective actions can pave the way for embracing a Circular Economy (CE) framework within the constructed environment. Some studies relied on a literature review on barrier and enabler identification (Hentges et al., 2022; Munaro & Tavares, 2023). Hentges's study focused on the Brazilian construction industry. Cruz Rios et al. (2021) have investigated architectures' perspectives for identifying barriers and commented on the role of different stakeholders on enablers. The literature includes survey studies on enables (Adams et al., 2017; Al Hosni et al., 2020; Guerra & Leite, 2021; Munaro & Tavares, 2023; Wuni & Shen, 2022). In addition to the content discussed in the barrier section of this thesis, Wuni and Shen (2022) focused on CE for modular construction projects

in Hong Kong through survey data with 117 responses. Overall, the research consisted of a focused literature review, consultation with subject matter experts, a survey of industry practitioners, mean score ranking, factor analysis, and fuzzy synthetic evaluation (Wuni & Shen, 2022).

This study determines enablers through a review of the existing literature. They are examined in the following sections under four separate headings: social and behavioral, economic, political and legal, and technical. Some of the enablers found in the literature to facilitate the transition to a circular economy in the construction sector are listed in Table 2.5.

Table 2.5: Enablers for Transitioning to the Circular Economy[5]

Code	Enablers	*A1*	*A2*	*A6*	*A8*	*A9*	*A15*	*A16*	*A17*	*S**
X1	Ensuring the recovery of materials logistically and commercially	*		*		*	*			C, M
X2	Developing markets and enabling technologies	*	*				*			R, M
X3	Raising awareness on circularity	*		*		*	*		*	R, G
X4	Enactment of a CE-specific legislation	*		*						G
X5	Making necessary practices to raise awareness and knowledge	*		*		*		*	*	G, R, O
X6	Introducing a level of accountability for manufacturers of construction products	*	*	*						G, M, D
X7	Optimizing the lifetime of buildings to extend their life	*					*			G, R, O
X8	Setting and using standards to develop strategies	*	*	*		*	*	*		R, G
X9	Financial incentives development for utilizing secondary materials and for collaboration between companies	*	*	*				*	*	G
X10	Making sure secondary materials are of the correct quality and reusable	*						*	*	C

[5] Note1: A1: (Adams et al., 2017), A2: (Al Hosni et al., 2020), A6:(Cruz Rios et al., 2021), A8: (Guerra & Leite, 2021), A9: (Hentges et al., 2021), A15: (Torgautov et al., 2021), A16: (Wuni & Shen, 2022), A17: (Munaro, M. R., & Tavares, S. F., 2023))
Note2: Contractor (C), Owner (O), Designer (D), Manufacturer (M), Supplier (S), Customer (Cu), Researcher ®, Government (G)

Table 2.5: Enablers for Transitioning to the Circular Economy (continued)

Code	Enablers	*A1*	*A2*	*A6*	*A8*	*A9*	*A15*	*A16*	*A17*	*S**
X11	Adequate experience and knowledge of stakeholders about the performance of the lifecycle	*	*					*	*	G, R, O, C, D
X12	Collaboration within supply and supply chain management activities and information-sharing capabilities	*		*		*	*	*		R, O, C, M
X13	Promoting the use of more prefabricated, organic, environmentally friendly, and renewable materials			*		*	*			G, R, O, C
X14	Preparing the robust and new regulations/policies by taking into account construction standards			*			*		*	G, O
X15	Reasonable and competitive prices for materials						*			C, M
X16	Using lean principles for minimizing waste		*		*	*	*			C, O
X17	Developing and using new technologies and construction methods		*	*			*		*	C, O, R
X18	Integrating CE into contract requirements for design			*						D, C, O
X19	Creating and enlarging database for circular economy		*	*	*				*	R, O, C, M
X20	Dissemination of new volunteer management programs				*					G, R
X21	Changing people's perception and perspective on circular economy / Encourage the stakeholders for CE	*		*	*		*		*	G, R
X22	Ensuring that buildings receive the necessary maintenance						*			O, C
X23	Establishment and implementation of zero waste policies		*	*		*			*	G, M, O, C, D
X24	Developing CE action plans at both national and regional levels		*	*				*	*	G
X25	Establishing tax deductions for design, labor, or material expenses related to CE strategies		*	*		*			*	G, O
X26	Developing designs that consider manufacturing, assembly, and the principles of the CE							*		D, C, O
X27	Incorporating collaboration, cooperative work, and knowledge exchange among project teams and stakeholders		*					*	*	ALL

2.3.1 Social and Behavioral Enablers

CE represents an important paradigm that aims to break free from traditional consumption habits (Munaro & Tavares, 2023).But the transition to CE requires a fundamental change, not only at the industry level but also in the mindset of society and consumers. Aligning consumer behavior with the principles of the CE is a key step in successfully adopting this paradigm. Furthermore, effective implementation of CE requires research, development, and awareness-raising in this area.

Education and raising awareness among stakeholders at every phase of a project's lifecycle are pivotal in motivating them to consider the challenges and opportunities CE presents. This entails transforming mindsets and practices, both in the immediate and long-term contexts. It involves reevaluating how projects are designed, conducting diagnostics, coordinating networks and sectors, and integrating reuse into construction projects. Presently, only a handful of professions are dedicated entirely to the circular economy. Instead, the emphasis is on adapting the skills of professionals in other fields to align with CE principles (Tirado et al., 2022).

Lack of awareness and knowledge of CE among construction stakeholders is seen as a significant barrier to CE adoption (Adams et al., 2017; Al Hosni et al., 2020; Bilal et al., 2020). This problem is exacerbated by customers' lack of interest in product reuse. According to Al Hosni et al. (2020), economic reasons may also be associated with low interest and demand for reusing or recycling products. These awareness gaps can also include limited consideration of the environment during construction activities. Lack of public interest in environmental issues was also categorized as a major people-based challenge.

Collaboration and networks across sectors can provide platforms for sharing knowledge, experience, and best practices. Furthermore, there is a need for case studies to contextualize work models and provide credibility and confidence in circular approaches (Munaro & Tavares, 2023).

2.3.2 Economic Enablers

One of the most significant barriers to the adoption of circularity in the built environment is the unclear financial situation, and the most critical enabler to overcome this is to have a clear state of business (Adams et al., 2017).

The economic enabler category emphasizes creating a market for secondary materials. To achieve this, it's essential to establish markets with inventory control systems, product tracking, monitoring protocols, and the dissemination of information about available or forthcoming used materials. This approach is crucial for transforming buildings into materials banks facilitating the reuse and circulation of materials within the construction industry (Munaro & Tavares, 2023).

Promoting projects in line with sustainability and circular economy principles promotes more environmentally friendly and efficient practices. For this purpose, it is important to establish legislation to reduce or eliminate costs for such projects (Hentges et al., 2022). Such legislation can incentivize construction projects to achieve environmental sustainability goals and adopt circular economy principles. Other recommendations, such as tax benefits for projects with prefabricated modules, staff for waste segregation, removal and disposal, and projects utilizing C&D waste, are also discussed in the study by Hentges et al. (2022).

It emphasizes the importance of the ability to measure the value of products or materials throughout their life cycle to express the value aspects of the circular economy (Adams et al., 2017). This ability makes it easier for project stakeholders to adopt sustainability and circular economy principles.

2.3.3 Political and Legislative Enablers

Political enablers should provide political instruments to promote implementing the circular economy in buildings. It is also important to set a long-term holistic vision and goals, and this vision should help to develop a flexible, experimental, and concrete development agenda (Munaro & Tavares, 2023).

According to Charef & Lu (2021), specific political and procedural enablers are discussed, which encompass elements such as contractual agreements, tendering processes, and procurement procedures. Within this category, there is an emphasis on the identification and specification of clients' and builders' requirements, as well as those of facility managers and end-users, regarding data, classification, and expectations for updates.

It has been suggested in the literature that the local government should comprehensively investigate the operational status and actual needs of various enterprises before formulating policies (Liu et al., 2021). The government should establish a legal framework for the sector to manage C&DW with CE and use legal constraints to promote CE development.

In Ghisellini et al.'s (2018) study, the Chinese government has developed policies to regulate and control the behavior of stakeholders, supporting regulations that encourage the involvement of construction companies through economic incentives and the removal of barriers to the adoption of technological innovations, specific regulations such as improving the environmental and energy quality of buildings.

The political and legislative enabler group emphasizes the need for political rules to reduce construction and demolition waste production (Munaro & Tavares, 2023). The circular economy could be promoted through laws, policies, risk mitigation, and strict management.

2.3.4 Technical Enablers

The design and implementation of circular buildings require the use of technological tools and guidelines (Munaro & Tavares, 2023). These tools and guidelines provide guidance for constructing and managing buildings in accordance with circular economy principles. Technological enablers can be used to make construction projects more sustainable and ensure more efficient use of resources.

In order to increase the circularity of materials to the highest possible value, technical barriers need to be overcome, which can present themselves at the material, product, and/or building level. Given that the existing building stock belongs to structures designed without considering circularity, this creates a material problem. To overcome this, design, adaptability, flexibility, and deconstruction at the end of the life cycle should be considered to enable circularity and the longevity of buildings (Adams et al., 2017).

The study of Cruz Rios et al. (2021) discusses matching the old with the new when trying to use salvaged components in new construction. The use of salvaged components in construction projects in accordance with circular economy principles is important for sustainability and more efficient use of resources. However, it can sometimes be challenging to find and use these components. Therefore, an important factor among potential enablers is the development of material tracking technologies and databases for urban material stocks to make it easier for architects to find salvaged components in sufficient quantities and sizes (Cruz Rios et al., 2021).

By transitioning to circular economy principles, the construction industry aims to use resources more efficiently, reduce waste, and increase environmental sustainability. To achieve this transition, several groups of 'enablers' and some of their approaches have been mentioned above to encourage the construction sector to adopt circular economy principles more closely. These groups represent enablers that facilitate the adoption of circular economy principles and aim to accelerate the sector's transition to a circular economy.

Adopting circular economy principles is important for an environmentally friendly and sustainable economy. However, a vision and strategy is necessary to implement these principles. Government funding is necessary to encourage sustainable practices and support research, innovation, and investment. However, even if this funding is provided, it is not enough to implement circular economy principles. In order to put circular economy principles into practice, role models or leadership figures are essential. These people or models can inspire others and effectively spread circular economy practices. In this sense, it is important that stakeholders in the sector take an active role in the process.

It is important to inform and raise awareness among stakeholders in the construction sector about the advantages of the circular economy. This can encourage the transition of the sector towards more sustainable practices. Different stakeholders in the construction sector can collaborate to implement the circular economy. Managers, government, clients, suppliers/manufacturers, designers, contractors, and recyclers can come together to promote sustainable practices.

Few articles in the literature map stakeholders to barriers (Cruz Rios et al., 2021; Munaro & Tavares, 2023). In the study of Munaro & Tavares (2023), the stakeholders of the construction value chain are categorized as internal and external stakeholders according to the literature. Members of the project community or financing stakeholders are referred to as internal stakeholders, while those significantly affected by the project are referred to as external stakeholders (Munaro & Tavares, 2023). However, Munaro & Tavares's (2023) study does not aim to understand the relationships between an organization and its stakeholders but rather to reveal the diversity of stakeholders. Cruz Rios et al. (2021) performed interviews with architects, and then, based on their point of view (the authors'), they mapped enablers and barriers to each other and assigned stakeholders to these enablers. The mapping of enablers to stakeholders from Cruz Rios et al. (2021) perspective is shown in Table 2.5, but none are based on stakeholders' views.

Although many studies examine the impact of stakeholders on identified barriers and enablers, they are based on existing literature, and none of the mappings are based on stakeholders' perspectives. After the enablers are identified, it is important to identify the stakeholders associated with these enablers in order to integrate the circular economy into the sector. This study aims to present an enabler-stakeholder relationship by considering the stakeholders' perspective.

2.4 Stakeholders in the Construction Sector

Analysis of CE transition at the macro level requires an understanding of how the adaptation of individual sectors takes place. Therefore, to understand the internal relationships of a macro-level system, it is necessary to consider sector perception (Gue et al., 2020). Considering the research efforts made in the CE adaptation process and the fact that most construction projects have not fully adopted CE principles, it is necessary to investigate the stakeholders' perceptions on whether these CE principles can be adopted in construction projects.

In the global economy, stakeholder engagement is increasingly becoming part of construction projects to achieve excellent project outcomes. Stakeholders have their interests in the project, often with different priorities, which can cause conflicts and significantly increase the projects' complexity. A well-managed stakeholder engagement process helps project stakeholders work together to improve comfort and quality of life while reducing negative environmental impacts and increasing the projects' sustainability (Bal et al., 2013).

The participation of stakeholders and the implementation of enabling strategies are necessary for the successful and efficient implementation of CE to remove barriers (Ababio et al., 2023). According to Ababio et al. (2023), the transition to a CE in the construction industry depends on stakeholder involvement and influence in the process of circular projects. Different types of barriers demand different enablers and stakeholder roles to deal with them. Cruz Rios et al. (2021) identified barriers and

enablers in the sector by involving stakeholders through a survey. After presenting lists of enablers and barriers from literature and surveys, the authors discussed the responsibilities of various stakeholders, including government entities, manufacturers, researchers, consultants, contractors, designers, building owners, and sector associations, in fostering the creation of enablers for a "circular built environment" (Cruz Rios et al., 2021). Ababio & Lu (2023) presented a comprehensive framework that combines the contributions of various stakeholders to overcome CE barriers in construction. This framework reveals that each stakeholder in the construction sector has a distinct responsibility in addressing "socio-cultural, technological, political and financial barriers.

Although previous studies have attempted to assess the circular economy by considering the interdependence between enablers and stakeholders, these studies have analyzed by aggregating information from the literature and have the following limitations: the assessment index is limited to measuring the level of awareness of a company or a sector on the circular economy, as the studies were conducted without consulting stakeholders working in the sector, and cannot assess the importance of CE enablers and the role of stakeholders in the sector. This prevents accurate analysis in the process of adapting the CE to the construction industry.

Over the last decades, the influence of stakeholders on construction projects has been analyzed using many methods such as stakeholder circle, stakeholder map, stakeholder-relationship matrix, strategic needs analysis, and social network analysis (SNA), where SNA has been widely adopted in construction management (Yuan et al., 2018). The stakeholder approach is concerned with the groups and individuals that can influence the organizations and the managerial actions taken in response to these groups and individuals (Yuan et al., 2018). Several stakeholder models have been proposed to improve stakeholder management, including the Stakeholder Strategy Formulation Model, the Stakeholder Salience Model, and the Social Network Model (Yuan et al., 2018). The stakeholder salience model developed by Mitchell, Agle, and Wood (1997) has become one of the most widely accepted and applied perspectives on stakeholder relationship analysis and organizational

governance. According to the MAW (Mitchell, Agle, and Wood) model, stakeholder salience is defined as the extent to which managers give priority and attention to competing stakeholder demands (Raha et al., 2021).

Stakeholder management in construction projects usually or partially consists of identifying stakeholders, gathering information about stakeholders, identifying stakeholder missions, identifying stakeholder strengths and weaknesses, identifying stakeholder strategies, predicting stakeholder behavior, and implementing stakeholder management strategies (Yuan et al., 2018).

There are some studies in the literature on identification (Lahane et al., 2022; Manoharan et al., 2022), prioritization (Mahpour, 2018; Singh et al., 2020; Thomas & Khanduja, 2022; Zhang et al., 2019), and cause-effect (Ayçin & Kayapinar Kaya, 2021; Govindan & Hasanagic, 2018; Yadav et al., 2023), addressing barriers and enablers in the adaptation of circular economy to the construction sector. However, none of these studies have mapped stakeholders - enablers in the construction sector.

It is observed that previous studies on relating enablers to stakeholders did not include the perspectives of stakeholders in the sector. Moreover, the enablers and the roles of stakeholders are predominantly listed without considering their interaction. One exception is Liu et al. (2021). Liu et al. (2021) used social network analysis (SNA) to investigate the potential barriers, scope, and milestones of the transition to CE in Guangzhou, China. Liu et al. (2021) considered the stakeholders' perspective and constructed a network to illustrate the relationship between potential barriers, considering each node as a barrier for a particular stakeholder. Their study is limited in terms of specifically focusing on C&DW recycling.

SNA assumes that actors and their relationships are not independent and form a mutually interactive network. In the stakeholder management field, SNA has been included in stakeholder analysis, and it has been noted that SNA can provide a mechanism to identify the effect of multiple stakeholders simultaneously and estimate the responses of companies (Yuan et al., 2018).

SNA examines the connections and interactions among entities in a network. It offers an understanding of dynamics, structure, and the characterization of social systems. SNA is used to define the roles of stakeholders, map the relationships between stakeholders, and analyze their roles (Ghinoi et al., 2020). The role of stakeholders within each network can be determined using scales, including degree centrality, and betweenness centrality. Degree centrality is a metric that measures the 'popularity' of each stakeholder within the network by determining the number of connections (Ghinoi et al., 2020). This indicates how connected stakeholders are to other stakeholders and can reflect their level of interaction within the network. Betweenness centrality is a measure used to assess the strategic importance of a stakeholder in the network (Ghinoi et al., 2020). It shows how often a stakeholder interacts with other stakeholders as part of the shortest pathways within the network. This provides an essential tool for understanding the position of stakeholders within the network and assessing their interactions.

A group of participants and the interrelationships between groups define cooperation networks. Single-mode networks exclusively account for nodes that share similar characteristics, which might not be comprehensive enough to represent the intricate connections inherent in collaboration networks accurately. Consequently, this leads to two-mode network analysis, a distinctive form of complex network analysis in which nodes can be categorized into two different clusters, and connections only occur between nodes in other clusters (Gan et al., 2018).

While SNA is powerful, it has never been used within the context of stakeholder perspectives to understand relationship assessment between stakeholders and enablers of CE in the construction sector.

2.5 Gap in the Literature

While many studies in the existing literature focus on circular economy, these approaches often do not consider the stakeholder perspective. In most cases, the enablers and barriers identified based on literature reviews are not assessed based on the experiences and perspectives of sector participants themselves. The studies that explored stakeholders' perspectives consist of a range of geographies, including the USA and Europe. The results of these studies show variations, and no study reflects the point of view of Turkish stakeholders. As a result, there is a lack of knowledge and understanding of Turkish stakeholders' experiences and perspectives on the barriers and enablers of transitioning CE into the construction industry.

Moreover, while it is essential to identify the roles of stakeholders in CE transition, existing studies often rely on the authors' own interpretation of stakeholder roles or assumptions based on the literature. Building upon the significance of stakeholder engagement, the stakeholders' interaction and roles in enabling CE should be known. However, the literature lacks information on the stakeholder-enabler interaction based on the reflections and experiences of industry practitioners. By providing a more participatory perspective, this study aims to understand factors affecting the Circular Economy in the construction sector and the roles of various stakeholders from the perspectives of stakeholders.

CHAPTER 3

METHODOLOGY

The previous chapter provided a comprehensive literature review on circular economy-related barriers, enablers, and their use in construction. The need to identify the enablers and barriers of CE in the construction sector and assess stakeholders' perceptions in addressing the barriers and enablers is discussed in detail. This chapter outlines this study's methodology, including the literature review, questionnaire survey, and Social Network Analysis (SNA).

3.1 Overview of the Methodology

A detailed literature review is performed using the Web of Science database to identify the factors, specifically the barriers and enablers, during the transitioning of CE into the construction sector. Twenty articles on barriers and enablers of CE in the construction industry were used to identify these factors. After the identification, similar concepts were synthesized, and lists of barriers and enablers were acquired. Following this, a survey is designed to gather input from practitioners on the level of these factors and the roles of stakeholders. Afterward, the survey results are analyzed through descriptive statistics and SNA.

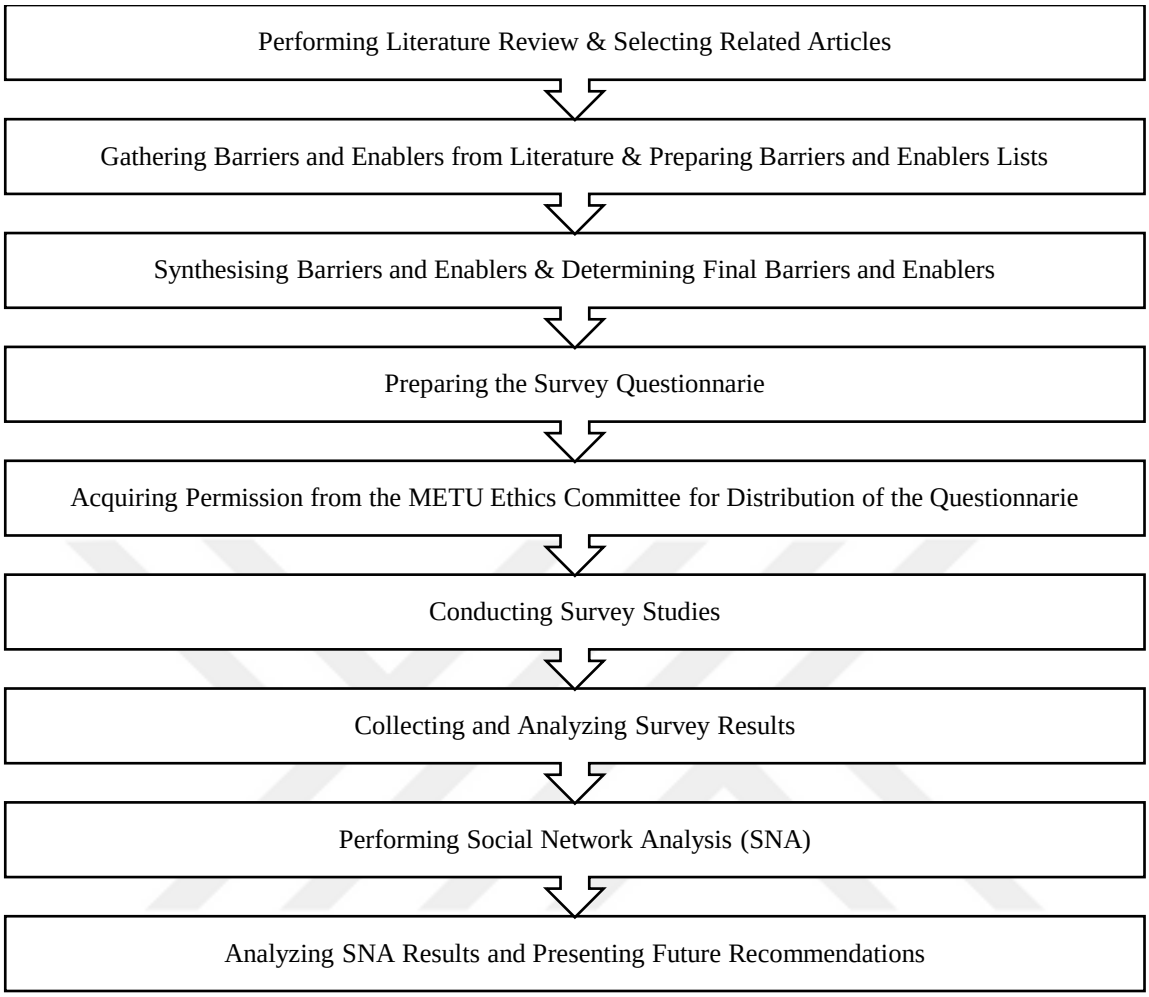


Figure 3.1: Research Methodology

3.2 Identification of Barriers and Enablers

First, a literature review was conducted on the circular economy in the construction sector to identify the barriers that prevent the transition to the circular economy in the sector and the enablers that can help overcome these barriers. The barriers and enablers collected from the literature are listed. The listed barriers and enablers were categorized into sub-groups, and similar factors expressed with the same or similar terms were synthesized under a single factor. Consequently, the lists of enablers and barriers to be presented to the practitioners are finalized.

3.2.1 Systematic Literature Review

This study employed a systematic literature review approach to identify barriers and enablers related to integrating CE into the construction industry. A systematic review is a comprehensive and reliable process of searching the available literature to address a specific research question (Rakhshan et al., 2020). The Web of Science was the primary database in this article to ensure accurate and relevant data acquisition. The keywords searched for the search are mentioned below:

TI= (("circular economy" OR circular*) AND (construction OR build* OR "built environment") AND (barrier OR challenge OR benefit OR enabler OR factor OR strategy OR indicator))

Certain filters were applied to streamline the research process and focus on the core literature. Initially, the research was confined to articles published in English. Given the recent surge in research on the subject, the aim was to stay up-to-date by encompassing the most recent publications. Therefore, articles, including literature review papers, published between 2020 and 2023 were considered in this study. Research in the field of circular economy covers a variety of topics. When these topics are examined closely, the literature reveals a variety of methodologies for assessing relevant barriers and enablers. However, in the broader context of the circular economy, relatively few studies do not focus on a specific topic (e.g., waste management, design for deconstruction). The scope was narrowed by selecting articles focusing on general attitudes instead of particular issues. Studies on the identification and prioritization of barriers were identified and grouped. In addition to these most recent studies, Adams' research was included due to its high number of citations, although it did not fit the set limitations (Adams et al., 2017).

Twenty articles were utilized to identify and compile the list of barriers and enablers. Subsequently, the factors from each source were compared, matched, and synthesized. The list of references and identified factors can be found in Table-1, in the "Findings" section.

During this literature review, the main stakeholders that can be part of the transition to a CE in the construction industry were determined. Similarly, previous studies that indicate the role of stakeholders in CE are also identified.

3.2.2 Survey

The survey was conducted to determine the significance of the identified barriers and enablers and to assess the relationship between enablers and stakeholders from the stakeholders' perspective. Overall, this survey aims to serve as a valuable tool for decision-makers and researchers to understand the dynamics of the circular economy in the construction sector, helping them make informed decisions and implement targeted strategies to overcome barriers and effectively leverage enablers. The survey was designed in accordance with the main objectives of this study.

1. Perception of Stakeholders: The survey systematically assesses the stakeholders' perception of the barriers and enablers identified from the literature. Stakeholders provide feedback on the perceived level of each barrier and enabler, shedding light on which barriers are more critical to resolve and which enablers are essential for success.
2. Relationship Assessment: The SNA explores the relationships between enablers and stakeholders. Gathering input from relevant practitioners explores stakeholder engagement and the need for collaboration on specific enablers.

After the survey was designed, a pilot study was conducted with experts in the field to check the context, content, language, and comprehensibility of the survey questions and to make necessary improvements. The survey was finalized according to the feedback acquired at this stage. It should be noted that the METU Human Research Ethics Committee granted permission to survey the permission protocol number 0401-ODTÜİAEK-2023. Following the acquisition of these necessary

permissions, the survey was distributed to the pertinent stakeholders through email, LinkedIn, and WhatsApp platforms as a link.

The targeted participants included practitioners experienced in the construction industry, such as academics, engineers, architects, and consultants. In the first phase of the questionnaire, respondents were asked about their perception of the importance of each previously identified barrier and enabler related to transitioning the circular economy to the construction sector, scoring them based on their perspectives. The scoring ranges from 1 to 7 for each barrier and enabler. In the second phase, respondents were presented with the enablers and asked to rate the influence of each listed stakeholder on these enablers on a scale of 0 to 5.

The primary target group of the survey is experts on Circular Economy and decision-makers in the sector. For this purpose, the survey was delivered to such experts and decision makers in the field, and then the network was expanded by snowballing. Snowballing is a method based on finding new participants by getting referrals from existing participants. In this way, it is aimed to expand the network and obtain different perspectives. There were 41 participants who responded to the survey.

Once the data is collected, statistical techniques and network analysis are used to obtain valuable insights. Specifically, the results of the first stage of the questionnaire are presented using descriptive statistics, and the results of the second stage are presented using the SNA method.

3.1 Analysis of Results

Box Plots were used to show the distribution and statistical summaries of the values in the data set from survey scoring. In this case, it is shown as a box plot of the scores of the barriers perceived by "stakeholders." Tukey proposed the Box Plot method in 1977 (Constantin, 2017). The method considers quartiles instead of median and sample mean as indicators of central tendency. The box plot contains a box bounded at the bottom by the first quarter (Q1) and at the top by the third quarter (Q3) (Hubert

et al., 2006). A line is drawn inside this box for the median (Q2). Points outside this box are considered potential outliers and are drawn as boundary lines (whiskers) on either side of the box. This graph shows how the barriers are distributed according to stakeholders' perceptions.

The perceptions of respondents were explored and interpreted in groups. First, all results were evaluated together, and a general understanding was achieved. Then, to investigate whether there are differences in the views of stakeholders, the participants' perceptions were explored according to their experience levels, stakeholders' companies' fields of activity, and knowledge levels.

Social Network Analysis (SNA) captures complex network structures and their relationships. The node and edge properties of SNA are used as working principles. Each node represents an enabler or a stakeholder. Edges represent the relationships between these nodes. The strength of these relationships, whether directed or undirected, characterizes the network. Different centrality metrics are used to measure the importance of nodes in the network. Measures, such as degree centrality, betweenness centrality, closeness centrality, eigenvector centrality, and eigenvalue centrality, help determine the importance and influence of nodes. This study analyzes network structures and relationships using SNA principles and analysis methods. Applying the basic principles of SNA, such as graphical representations and centrality measures, the relationships between nodes are visualized, and important stakeholders and enablers in the network are identified.

A social network is formally referred to as a set of social actors or nodes, members connected by one or more types of relationships. To understand networks and their participants, the position of actors in the network must be assessed. The concept of centrality and other related concepts should be used to measure the position of each node. Through empirical measurement of a network, various roles and groupings in a network will be found (Zhang, M., 2010).

In this study, enablers and relevant stakeholders are treated as a two-mode social network analysis is used for data analysis. Two-mode social network analysis is a

powerful tool for understanding complex interactions and relationships, and this method of analysis was used to understand the influence of stakeholders on enablers. Three steps were applied in data analysis to investigate the impact of stakeholders on these enablers. The first step describes the relationships between enablers and relevant stakeholders in a network structure. This network structure shows who interacts with whom and the nature of these interactions. In the second step, the network structure is analyzed to quantitatively measure and understand stakeholders' influence on enablers. In the third step, the obtained results obtained were interpreted. These interpretations help formulate strategies for developing and improving circular economy practices.

This study used UCINet for SNA (Social Network Analysis) analysis. UCINet is a widely used software tool for analyzing social network data and studying network structure. Social network analysis is an essential tool for understanding the interactions and relationships of stakeholders. UCINet provides tools and methods to perform such analysis and can present results visually. UCINET was developed by Steve Borgatti, Martin Everett, and Lin Freeman, and the program is distributed by Analytic Technologies (Zhang, M., 2010). It runs on a free program called NETDRAW to visualize networks. Centrality metrics, subgroup identification, role analysis, basic graph theory, permutation-based statistical analysis, and other SNA metrics can be performed on the software.

In the survey, respondents were asked to indicate the impact of stakeholders on enablers on a scale of 0 to 5. Such data is generally normalized to use it for the SNA. In the process of creating the network relationship map, which uses important interactions between criteria to inform decision-makers about optimal solutions, a threshold should be set to filter out important relationships between key concepts and reduce complexity; this threshold can be obtained by averaging all entries in the total relationship matrix (Dehdasht et al., 2022).

Subsequently, data were reduced to a binary form, 0 and 1 values, to be analyzed with UCInet. To carry out this normalization, an average was taken for all of the

impact values identified by stakeholders, and this average was used as the threshold value. Then, values below this threshold value were assigned 0, and values above this threshold value were assigned 1, and matrices were obtained to be used for 2-mode analysis. These matrices provide the baseline data for SNA analysis to better understand stakeholder influences and relationships. This approach represents an essential step in data preparation for SNA analysis and helps the analysis to produce more robust and meaningful results. The following chapter presents the results of the literature review and the findings from the survey and provides a comprehensive discussion of these findings.

CHAPTER 4

FINDINGS

This chapter presents the study's outcomes, including the literature review, the questionnaire survey, and the SNA focusing on integrating circular economy principles within the construction sector. First, barriers and enablers of the circular economy within the construction sector are identified and grouped in this chapter based on insights from previous research. Then, these barriers and enablers are investigated based on the perspectives of the stakeholders working in different areas of the construction sector. In addition to this assessment, the roles of stakeholders in enabling CE, according to stakeholders' reflections, are discussed.

4.1 Barriers and Enablers of CE in the Construction Sector

4.1.1 Barriers

The barriers related to CE transitioning in the construction sector were gathered during the literature review process. The identified barriers were grouped under four main categories: behavioral and social, economic, political and legislative, and technical. Although some sources presented environmental barriers as a category, they were listed under other categories in most studies. Hence, in this chapter, environmental barriers are listed under four main categories of barriers.

Under the behavioral and social barriers group, 11 different sub-barriers have been gathered and synthesized into five factors:

- B1 – Lack of stakeholders’ knowledge, awareness, interest, and experiences of circular design, CE, and end-of-life strategies and benefits

- B2 – Lack of public awareness of life cycle costs and benefits (Social pressure, negative perception)
- B3 – Lack of literature and appropriate training-development programs on CE barriers
- B4 – Lack of trust and communication
- B5 - Conservative sector; risk aversion/resistance to change.

Secondly, under the economic barriers group, 14 sub-barriers have been gathered from the literature. By combining sub-barriers, five economic barriers are listed below:

- E1 – Lack or underdevelopment of the market mechanism and business management for recovery.
- E2 – Cost and Schedule constraints, including project constraints, low-profit margins (Uncertain financial situation for CE /High financial risk)
- E3 – The customer's unwillingness or un-readiness to pay for the new concept / Competition.
- E4 – Lower costs of virgin materials/ Higher costs of recycled materials and disposal
- E5 – More investment requirements (Quick investment expectation of the customer)

Thirdly, under the political and legislative barriers group, nine sub-barriers have been gathered from the literature. By combining sub-barriers, four political and legislative barriers are listed below:

- P1 – Lack of specific regulations, legislations, and laws for CE implementation in the sector
- P2 – Inadequate incentive and support policies for end-of-life and CE
- P3 – Warranty and quality issues of using reused/recycled products.
- P4 – Lack of technical specifications and standards for reused and recycled building products

Fourthly, under the technical barriers group, 17 sub-barriers have been gathered from the literature. By combining sub-barriers, six technical barriers are listed below:

- T1 – Uncertain product content of CE materials, lack of material alternatives, and problems in material classification
- T2 – Lack of standardization and transportability of building components
- T3 – Uncertainty and lack of awareness about future spatial needs/demands, end-of-life, and recycling of building materials
- T4 – Complexity of building design & design phase / Lack of circularity in design
- T5 – Lack of data, data management, and visualization / Lack of tools and information to identify circularity metrics.
- T6 – Lack of necessary technology and infrastructure for salvaged components / Lack of connection between digital design technologies and environmental sustainability tools

4.1.2 Enablers

The enablers related to CE transitioning in the construction sector are grouped into four categories: behavioral and social, economic, political and legislative, and technical enablers. Firstly, four sub-enablers of social and behavioral enablers are listed below:

- E-B1 – Making necessary practices to raise awareness and knowledge
- E-B2 – Having some form of manufacturer responsibility for construction products
- E-B3 – Adequate experience and knowledge of stakeholders about the performance of the lifecycle
- E-B4 – Changing people's perception and perspective on the circular economy

Secondly, five sub-enablers of economic enablers are listed below:

- E-E1 – Ensuring the recovery of materials logistically and commercially
- E-E2 – Developing markets and enabling technologies
- E-E3 – Development of financial incentives to use secondary materials and for collaboration between companies
- E-E4 – Promoting the use of more prefabricated, organic, environmentally friendly, and renewable materials
- E-E5 – Creating tax deductions for CE design strategies

Thirdly, four sub-enablers of political and legislative enablers are listed below:

- E-P1 – Setting legislation and using standards to develop strategies
- E-P2 – Establishment and implementation of zero waste policies
- E-P3 – Creating national and regional CE action plans
- E-P4 – Setting contract requirements and control mechanisms for material and product quality, assigning responsibility to manufacturers and users

Finally, four sub-enablers of technical enablers are listed below:

- E-T1 – Collaboration within supply and supply chain management activities and information-sharing capabilities
- E-T2 – Apply lean principles to reduce waste
- E-T3 – Developing and using new design strategies, technologies, and construction methods
- E-T4 – Creating and enlarging database for circular economy

4.2 Perceptions of Stakeholders on Barriers, Enablers, and Roles

The study has resulted in a substantive report highlighting barriers and enablers in the construction industry from a stakeholder perspective and providing actionable insights for decision-makers. The findings from this research are intended to empower organizations to make informed decisions and create positive change by addressing barriers and optimizing enablers.

4.2.1 Demographics of the Participants

According to the survey results, the Pie Chart showing the professional background of the respondents is as follows:

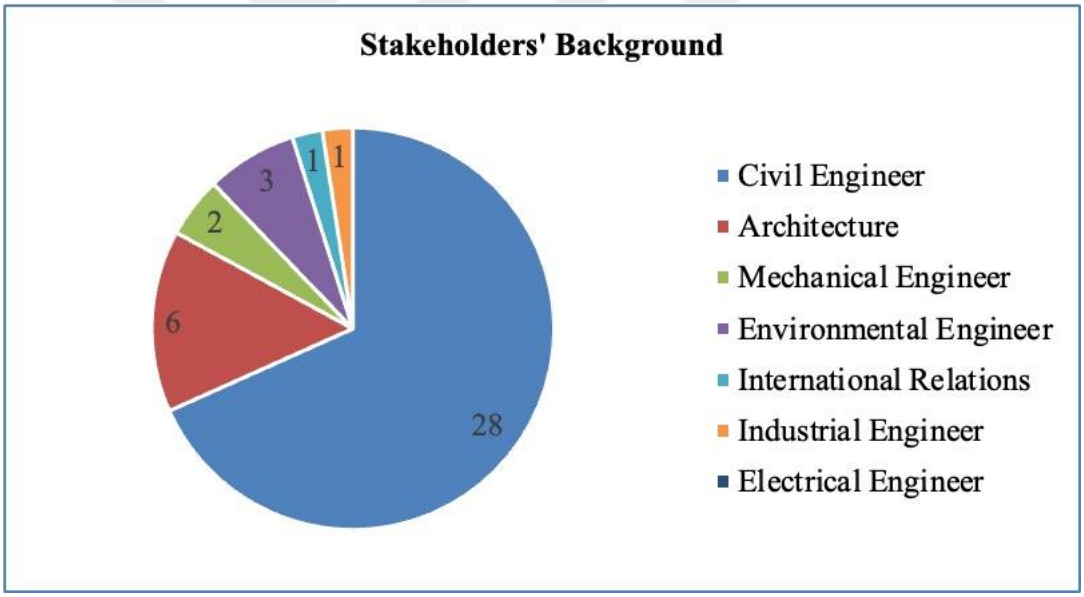


Figure 4.1: The Pie Chart Showing the Professional Background of the Respondents

The survey results show that most respondents are civil engineers, representing the largest group of respondents, with 68.3%. Civil engineers are essential to the transition to a circular economy. Civil engineers are followed by architects, who account for 14.6% of the respondents. The architectural perspective can highlight how a circular economy can be implemented in the design and construction phases.

Survey distribution and snowballing usually takes place through existing networks and communication channels. The fact that the majority of the survey participants were civil engineers may be attributed to the dissemination channels of the questionnaire and the people reached in the beginning stage consisted of civil engineers. The dominance of civil engineers in the survey results should be noted when interpreting the results of the survey.

The experience level of the participants is presented in Figure 4.2.

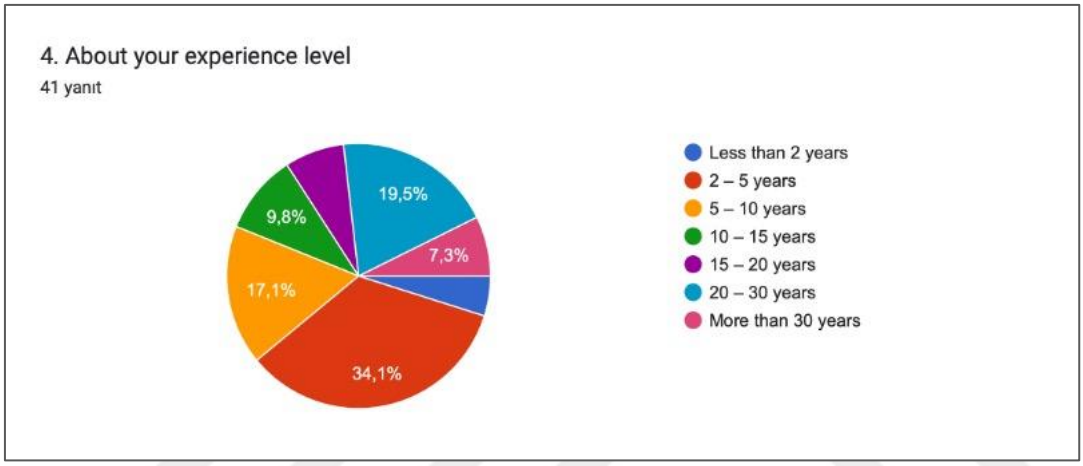


Figure 4.2: The Pie Chart Showing the Experience Level of the Respondents

The stakeholders' perspectives are also assessed based on their field of activity, including contractor, design/engineer or management consultant, government, recycler /supplier /manufacturer, and university.

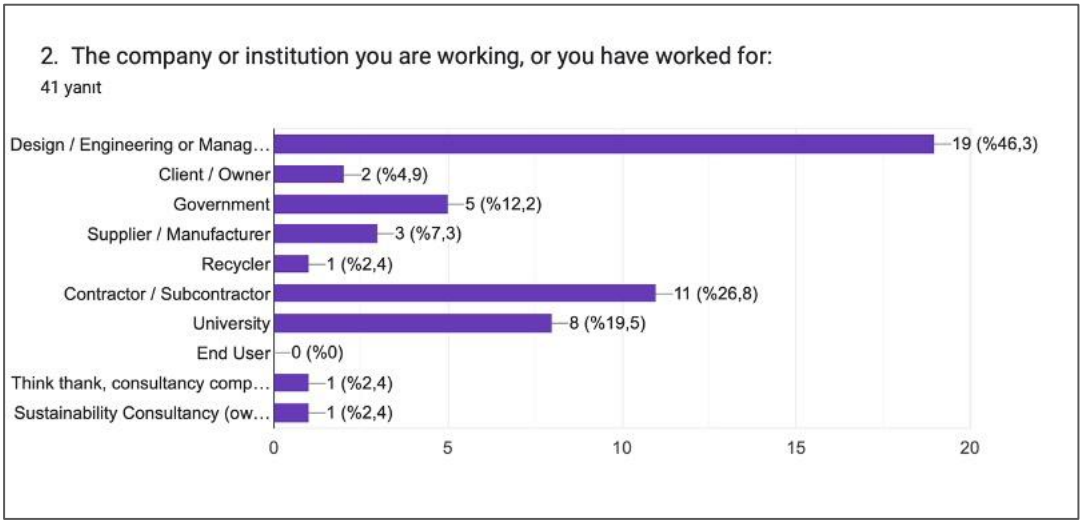


Figure 4.3: The Bar Chart that shows Stakeholders' Companies' Fields of Activity

The knowledge level of the participants is presented in Figure 4.4.

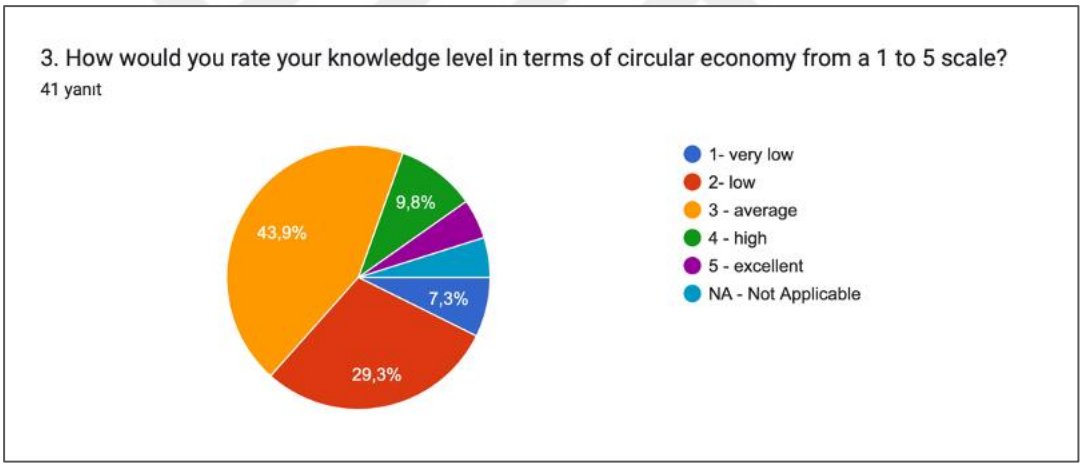


Figure 4.4: The Pie Chart Showing the Knowledge Level of the Respondents

Based on the survey data, the participants' exposure to a circular practice in construction projects and industry was also evaluated. While 20 respondents stated that they have been involved in such processes, 21 respondents stated that they have not been involved in circular economy practices. This may indicate that circular economy in the construction sector is not yet widely adopted. Examples of circular economy principles practiced in the sector includes reuse and cleaning of water through wastewater treatment systems, and the use of excavated materials as

aggregates for road construction or the processing of ballast material from old railway lines for the construction of high-speed rail lines. Such practices reduce environmental impact through efficient use of resources.

4.2.2 Perception of Stakeholders

4.2.2.1 Barriers

The scores given by stakeholders for the barriers were averaged, and stakeholders' overall perceptions were determined. These scores reflect how the stakeholders perceive the level of the barriers. Barriers with higher average scores represent a more significant concern or challenge for most stakeholders. This survey results can be used to develop strategies to overcome or mitigate barriers. Focusing specifically on barriers with higher average scores can create a strategic roadmap to increase stakeholder satisfaction and ensure the successful implementation of circular economy strategies. In this section, the scores of stakeholders on all barriers are shown as box plots.

Figure 4.5 shows that B1 and B5 received slightly higher average scores for social and behavioral barriers than B2, B3, and B4. Hence, lack of knowledge, awareness, interest, and experience (B1) and conservative sector (B5) are perceived as more challenging. It is worth noting that B5 scores are less dispersed than the others, showing more consistency among participants. Since the lower quartile for both B1 and B5 is 5, it can be concluded that most participants share a similar concern. Finally, B2 has wider ranges, indicating a wider distribution of perceptions of social pressure. The average results for Social and Behavioral Barriers are tabulated in Appendix B.

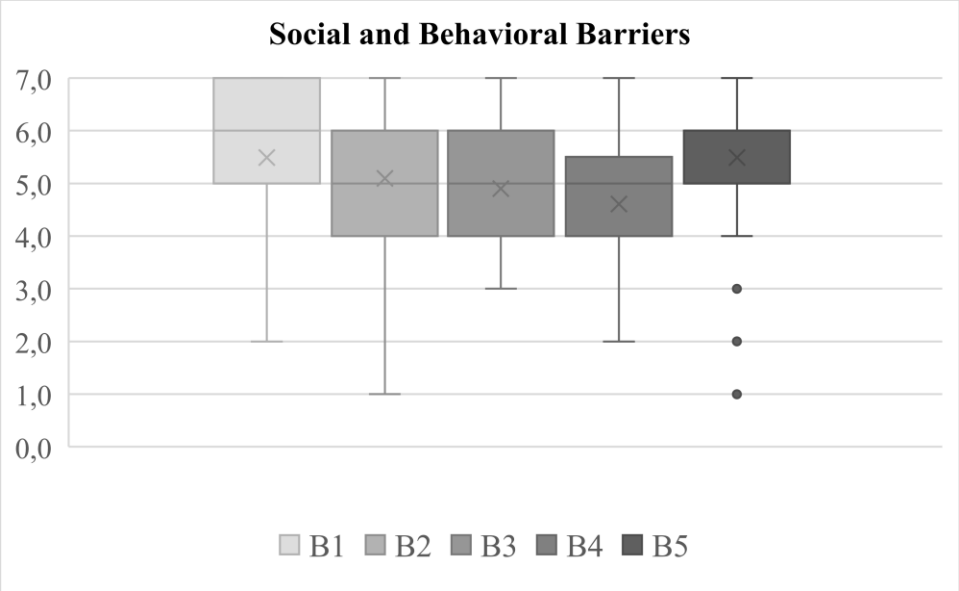


Figure 4.5: Box Plot of the scores of social and behavioral barriers from stakeholders' perceptions (B1: lack of stakeholders' knowledge, B2: lack of public awareness, B3: lack of literature, B4: lack of communication, B5: conservative sector)

Figure 4.6 shows stakeholders' perceptions of economic barriers and average scores. For all economic barriers, the mean value has the same range based on scores.

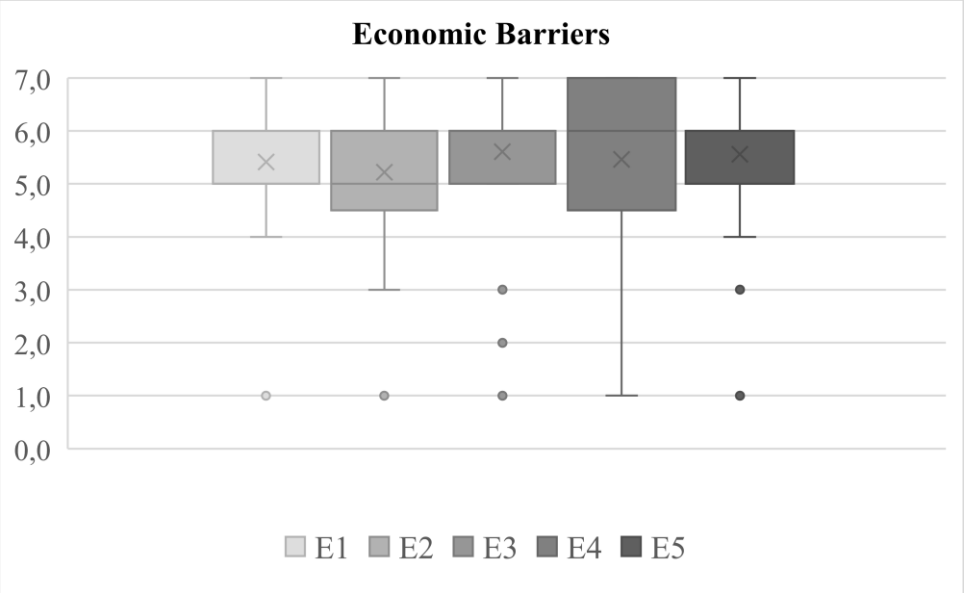


Figure 4.6: Box Plot of the scores of economic barriers from stakeholders' perceptions (E1: lack of market mechanism, E2: cost constraint, E3: unwillingness, E4: the high cost of recycled materials, E5: more investment requirement)

In this data, what stands out is that the E4 barrier has a wider range in the box plot. In a box plot, values above the interquartile range (IQR) and higher than the median (median value) show that the upper part of the data set has a broader distribution (Constantin, 2017). A wider range indicates more variation or distribution in stakeholders' perceptions or ratings of these barriers. Accordingly, the customer's unwillingness to pay for the new concept was more prominent among stakeholders than other economic barriers. Other significant economic barriers were competition and the expectation of more/faster investment. It indicates that competition and investment expectations in the sector are factors that make it challenging to implement circular economy strategies.

The averages of all economic barriers are close, indicating that overall economic barriers are perceived similarly. However, if specific barriers are more prominent than others, strategies may need to be designed more effectively by focusing on these prominent barriers. Such a perception process can be an essential tool to understand

how economic barriers are perceived among stakeholders and to guide strategic planning processes based on these perceptions.

Thirdly, the scores of political and legislative barriers perceived by "stakeholders" are shown as a box plot. These scores reflect stakeholders' perceptions of political and legislative barriers and highlight policy-level challenges. The average scores for Political and Legislative Barriers are shown in Appendix B.

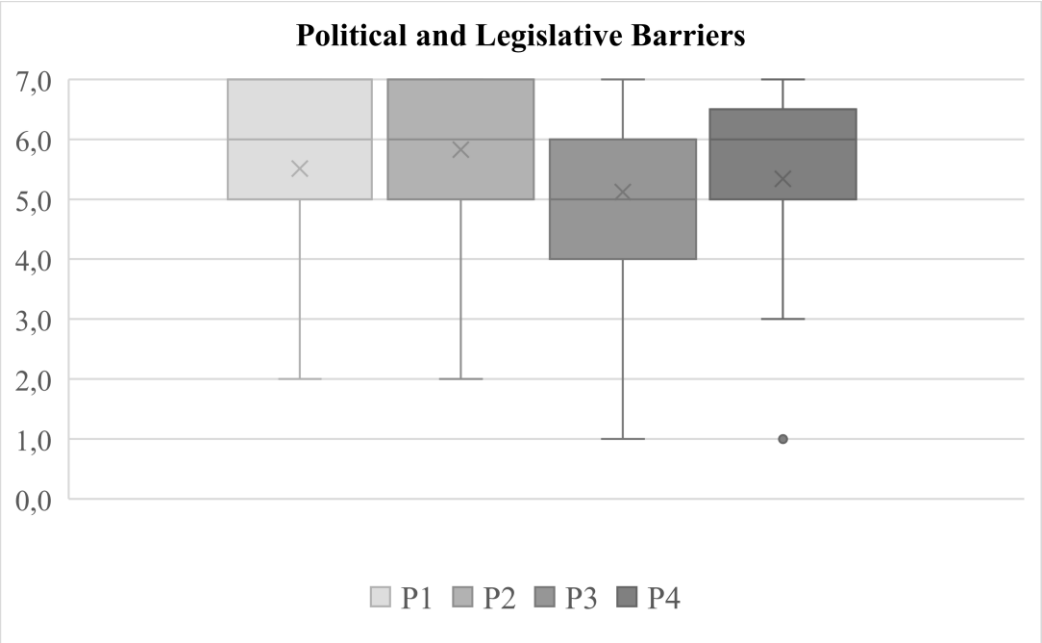


Figure 4.7: Box Plot of the scores of political and legislative barriers from stakeholders' perceptions (P1: lack of regulation, P2: inadequate policies, P3: warranty, P4: lack of specification)

Regarding this plot, it is seen that the mean values for all political and legislative barriers are in the same range. However, the distribution of the data set for barrier P3 is in a range with lower data set values than the others. The fact that the dataset shows lower values for this barrier may reflect the general perception of the participants that this barrier presents relatively less of a challenge for CE practices or circular economy approaches than other barriers. In this case, it could be argued that stakeholders focus on all difficulties at the policy level. Still, concerns about product quality and warranty have a lower influence within this group.

Finally, regarding all survey results, stakeholders' perceptions were determined to reflect how technical barriers are perceived and prioritized. The scores of the technical barriers are shown as a box plot. The average values for this barrier group are shown in Appendix B.

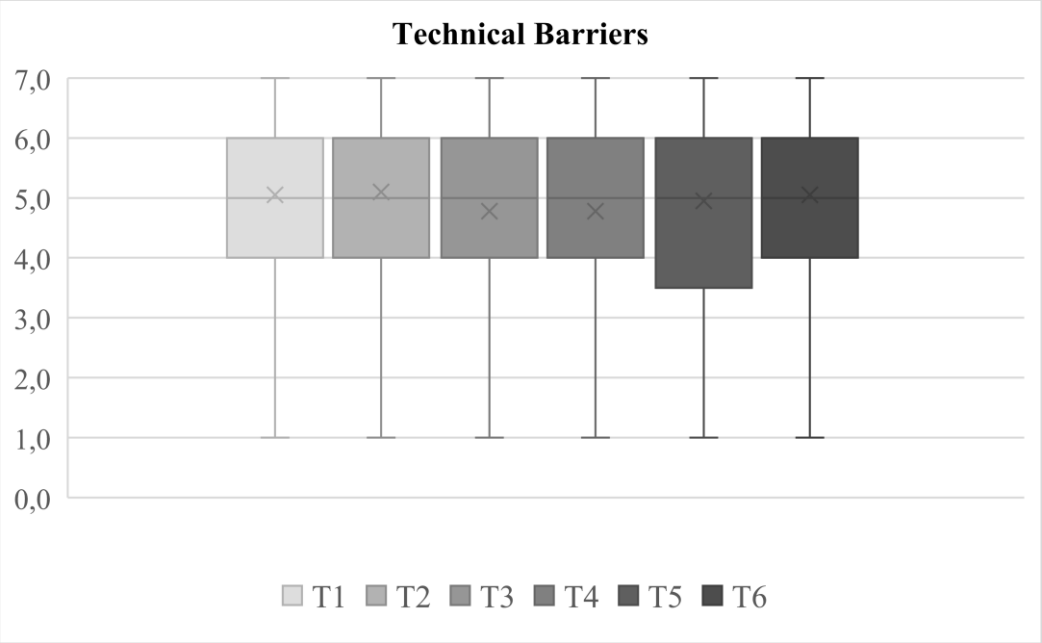


Figure 4.8: Box Plot of the scores of technical barriers from stakeholders' perceptions (T1: uncertain product, T2: lack of standardization, T3: uncertainty for future needs, T4: complex design, T5: lack of data, T6: lack of technology)

Considering this box plot, stakeholders' perspectives are similar for each technical barrier. The interquartile ranges (IQR) and median values are very close. The Boxplot analysis also shows that the maximum and minimum values and the lower and upper quartiles (Q1, Q3) are the same. It may indicate that the dataset has a homogeneous distribution for these barrier scores. This assessment can guide which issues to focus on in strategic planning to identify and address technical barriers.

When each barrier group is evaluated with the mean values of the individual barriers, the assessment according to the stakeholders' perceptions is shown in the box plot. These results guide which areas to focus on when developing strategic solutions for adopting a circular economy in the construction sector.

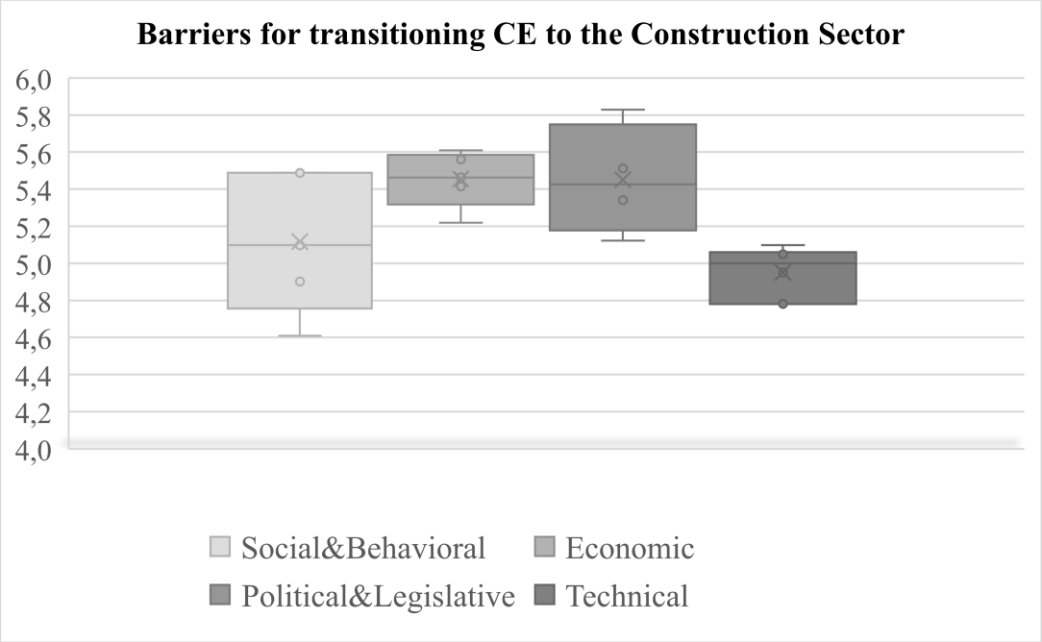


Figure 4.9: Box Plot for each barrier group

Figure 4.9 shows that all average scores of the four categories are higher than 4.8. According to the stakeholder assessment, economic, political, and legislative barriers have higher mean values. This highlights the importance of strategic solutions, including financial incentives, cost-effectiveness, and economic motivations. The need for policymakers to develop more effective policy measures to support the sector with appropriate incentives and regulations is also highlighted. According to stakeholders' assessments, technical barriers are perceived to have less impact than other barriers.

It can be concluded that mostly similar scores were acquired for all barriers, albeit with slight differences. This might suggest no clear gap between the significance of barriers. Accordingly, there is a general view that all barriers are essential. Such a view emphasizes the need to consider all barriers, suggesting that progress in the sector requires a holistic approach.

4.2.2.2 Enablers

The significance of enablers is assessed from the perspectives of the participants. Enablers with higher average scores are considered more essential. They may be prioritized in strategic planning and implementation processes as stakeholders widely accept them. This can help use resources more effectively, concentrate effort and energy on specific enablers, and focus efforts on adopting a circular economy. Understanding stakeholders' perspectives on each enabler is vital to determine which stakeholder groups should focus on and work on which enabler in light of the stakeholder relationships identified in the next step.

The survey results for social and behavioral enablers are shown in the box pilot. The average values are very close and are given in Appendix B.

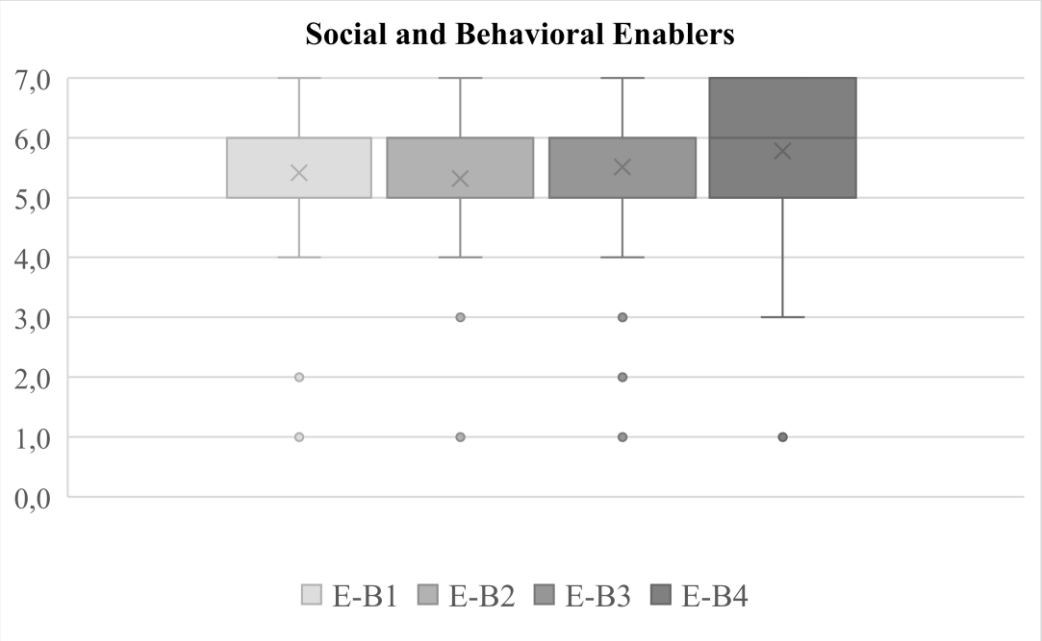


Figure 4.10: Box Plot of the scores of social and behavioral enablers from stakeholders' perceptions (E-B1: raise awareness, E-B2: manufacturer responsibility, E-B3: adequate experience, E-B4: change in perception)

According to the perspective approaches obtained for social and behavioral enablers, the mean values of the scores obtained as a result of the scores given by the

stakeholders are almost equal, while the interquartile range of these enablers is the same in the box plot graph for E-B1, E-B2, and E-B3. This means stakeholders may have perceived these enablers as similarly essential or influential.

In addition, although the E-B4 enabler has a similar mean value, the wide interquartile range indicates that this enabler is rated differently among stakeholders. This suggests that this issue may be necessary to varying degrees among different stakeholders. The E-B4, changing people's perception and perspective on the circular economy, was more prominent than other social and behavioral enablers. It may play a key role in the adoption of the circular economy.

The average scores obtained from the evaluation of the economic enabler were calculated, and the average values are given in Appendix B. Stakeholders' perceptions towards economic enablers are shown as box plots.

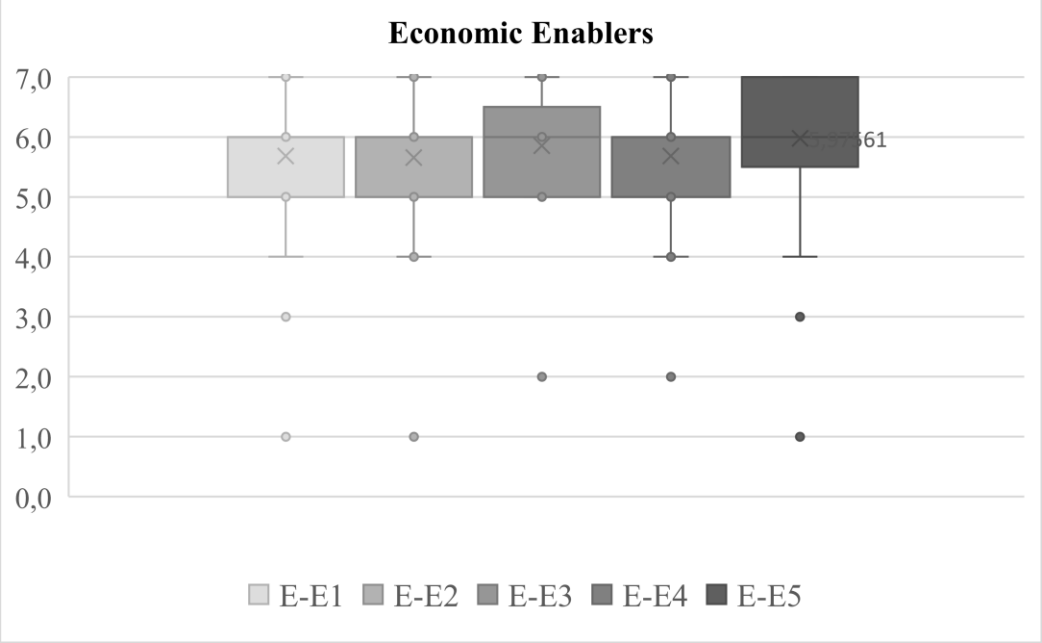


Figure 4.11: Box Plot of the scores of economic enablers from stakeholders' perceptions (E-E1: recovery of materials, E-E2: new markets and enabling technologies, E-E3: financial incentives, E-E4: promoting renewable materials, E-E5: tax deduction)

When economic enablers are analyzed, the perspective insights obtained for recovery of materials (E-E1), new market and enabling technologies (E-E2), and promotion of renewable materials (E-E4) are almost equal. The boxplot representation of these enablers in the analysis shows a similar distribution. The boxplot analysis also indicates that the maximum and minimum values and the lower and upper quartiles are the same, which may suggest that the score distributions of these enablers are similar and similarly significant overall. This indicates that stakeholders may have a similar perception regarding recovery materials, the market and enabling technologies, and the promotion of renewable materials.

In addition, there is a high distribution of values lower than the median for financial incentives to use secondary materials and companies' collaboration (E-E3) and a high distribution of values higher than the median for the tax deduction for CE plans (E-E5). However, the E-E5 enabler's mean values are similar since outliers affect the mean value. The distribution of values higher than the median may indicate that stakeholders generally give higher scores and positively evaluate, care about, or focus on the tax deduction (E-E5). Nevertheless, when outliers are considered, it is possible to say that there are different opinions. On the other hand, a distribution of values lower than the median may indicate that stakeholders generally give lower scores in relation to that enabler. These situations indicate differences in how a particular enabler is perceived or its importance assessed, which can inform how it should be addressed in strategic planning or targeted objectives.

The scores and box plot range were obtained based on the survey results for political and legislative enablers to indicate the stakeholders' perceptions. The average scores are given in Appendix B.

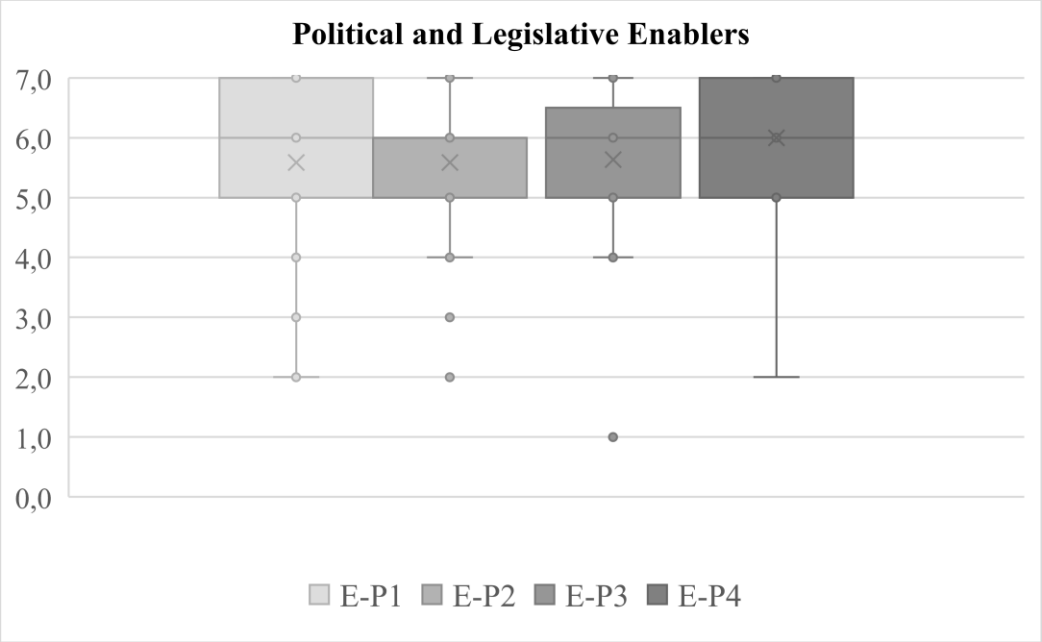


Figure 4.12: Box Plot of the scores of economic enablers from stakeholders' perceptions (E-P1: legislation and standards, E-P2: zero waste policy, E-P3: CE action plan, E-P4: contract requirements and control mechanism)

As a result of stakeholders' perception, it can be said that stakeholders consider it important to set contractual requirements and control mechanisms for material and product quality and to assign responsibility to producers and users. This assessment suggests that political enablers are often related to policy formulation, standards, and quality control and that regulation in these areas can play an essential role in achieving circular economy goals.

For technical enablers, the mean values obtained when the scores given by stakeholders are evaluated are shown as boxplots. The mean values are given in Appendix B. As a result of this analysis, it is possible to suggest that new design strategies, technologies, and construction methods should be developed and used.

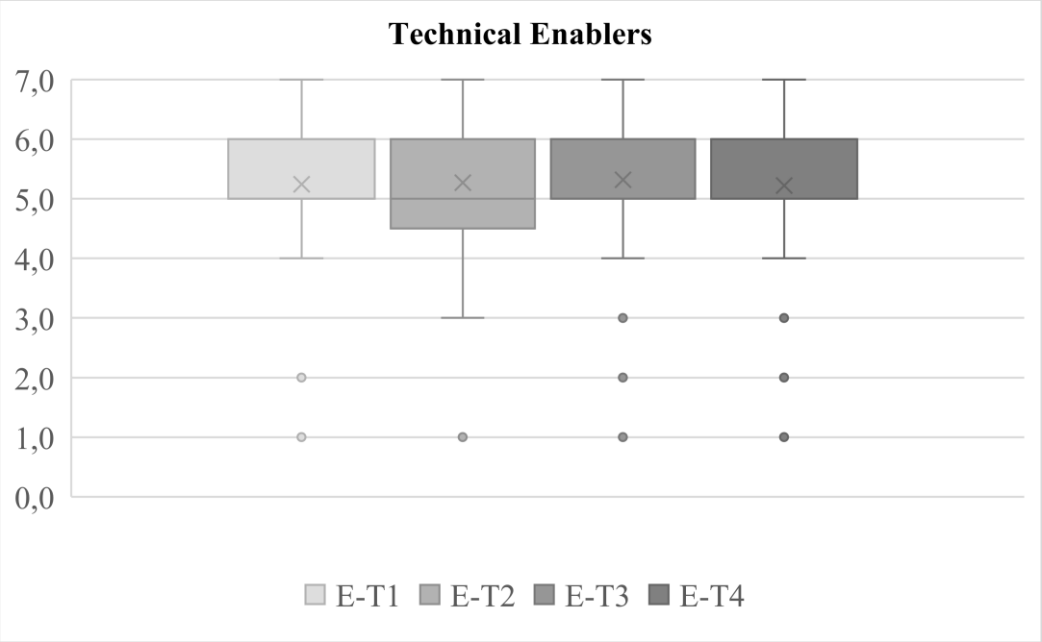


Figure 4.13: Box Plot of the scores of economic enablers from stakeholders' perceptions (E-T1: supply chain management, E-T2: lean principles, E-T3: new design strategies and technologies, E-T4: providing database)

The technical enablers scored very close to each other. This indicates that all enablers are perceived as equally important by stakeholders. It is possible to say that the stakeholders' perspectives are similar in general terms, but different views also emerged. This perception shows that a focus on the technical challenges of the circular economy, combined with innovation and collaboration, can support adopting more sustainable practices in the sector.

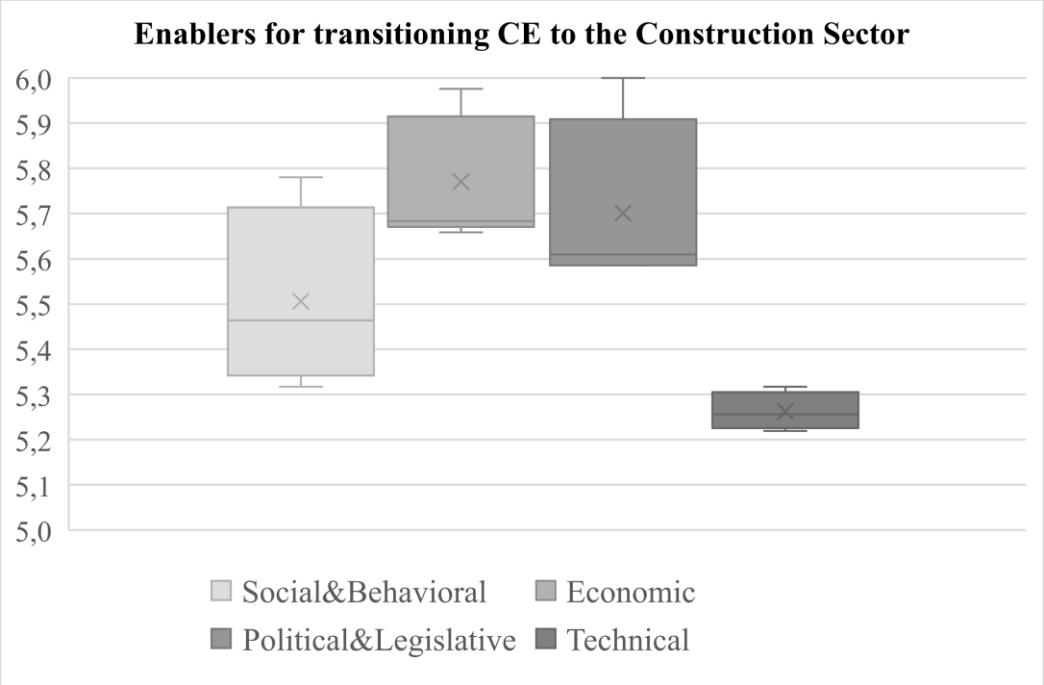


Figure 4.14: Box Plot for each enabler group

The figure shows that enablers generally score in the range of 5-6; in other words, they are considered highly important. However, slight differences may make specific enablers more prominent for some stakeholders.

Following the general picture, this study explored whether differences exist in the perceptions of stakeholders based on characteristics such as years of experience in the profession, level of knowledge about the circular economy, and sector of the organization in which the stakeholders work or differences in the evaluation of enablers.

4.2.2.3 Perception of Stakeholders Based on the Stakeholders' Demographics

The survey is a crucial research tool to assess the construction sector's transition to the circular economy. This study analyzes, assesses, and interprets the enablers and barriers that may affect the construction sector's adoption of circular economy

principles based on some demographics. Such an exploration and comparison could allow for a better understanding of the construction sector's transition to the circular economy and the development of specific strategies and action plans for different stakeholder groups.

4.2.2.3.1 Perception of Stakeholders Based on the Stakeholders' Experience Level

One of the analysis methods is grouping participants according to their experience level. Participants are divided into three groups according to their level of experience in the sector: experienced (10-20 years), less experienced (less than 10 years), and well-experienced (more than 20 years). These groupings provide an understanding of how professionals with different levels of experience in the sector approach the circular economy. Experienced professionals may focus more on the viability of projects and economic sustainability due to their long experience in the sector. In contrast, those with less experience may be more innovative and emphasize environmental impacts. On the other hand, very experienced professionals, with their long experience, can offer essential insights on how to keep up with changes in the sector and integrate circular economy principles. Reflecting on the perception of the circular economy among professionals at different experience levels of this analysis can help develop more detailed and targeted strategies to achieve a circular economy transition in the sector.

Within the experience levels created by considering the survey results, average values were found by evaluating the scores given for each barrier. These scores reflect each barrier's perceived relative importance or impact within the specified experience levels. The higher the average score, the greater the perceived importance of the barriers by stakeholders at that experience level. Comparison between stakeholders with different experience levels can provide insight into how they perceive these barriers in the context of the length of experience and specializations.

The average scores for each barrier were evaluated within their groups, and a boxplot was created for each experience level.

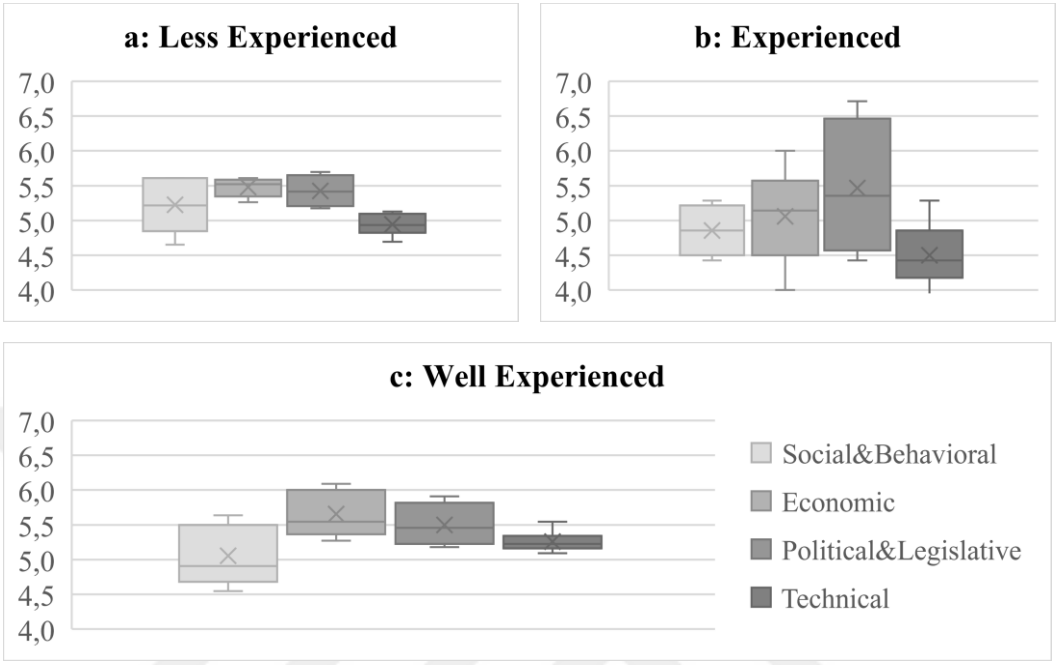


Figure 4.15: Box Plot for CE Barriers according to experience levels, a: less experienced, b: experienced, c: more experienced

According to the box plot from the perspectives of less experienced stakeholders:

- Social and behavioral barriers have a larger interquartile range. It can be said that stakeholders' views on these barriers have a wider distribution.
- Economic barriers have maximum mean value. This may indicate that stakeholders assign a higher importance or give more attention to economic barriers.
- Technical barriers have minimum mean value. This may indicate that technical barriers generally receive less attention among stakeholders than others.

According to the box plot from the perspectives of experienced stakeholders:

- Political and legislative barriers have a larger interquartile range and maximum mean value.

- Social and behavioral, and technical barriers have more homogenous perspectives because of the smaller interquartile range.
- Technical barriers have minimum mean value.
- Economic barriers from the perspectives of experienced stakeholders have a larger score range than those from less experienced stakeholders' perceptions.

According to the box plot from the perspectives of well-experienced stakeholders:

- Social and behavioral barriers have smaller interquartile range and minimum mean value.
- Economic barriers have maximum mean value.
- Technical barriers have a more homogenous perspective because of the smaller interquartile range.

When the results are analyzed, it is seen that the perceptions of the less and well-experienced stakeholders towards barriers are similar; however, the results of the intermediate-level experienced stakeholders are different from the others. This may be because respondents with an intermediate level of experience may not have encountered as many circular practices in construction projects as the others. Although these participants stated a certain level of knowledge of CE, they may lack practice or experience specific to CE. This may differentiate their perception or appreciation of specific barriers. Therefore, stakeholders with intermediate experience levels reflected more diverse perspectives on particular barriers. This emphasizes the importance of training or knowledge sharing on the circular economy.

Enablers are also explored according to the experience levels of the stakeholders. The comparison between stakeholders with different levels of experience can provide insight into how they perceive these enablers regarding their level of experience and specialization. The average scores for each enabler were evaluated within their respective groups, and a boxplot was created for each experience level.

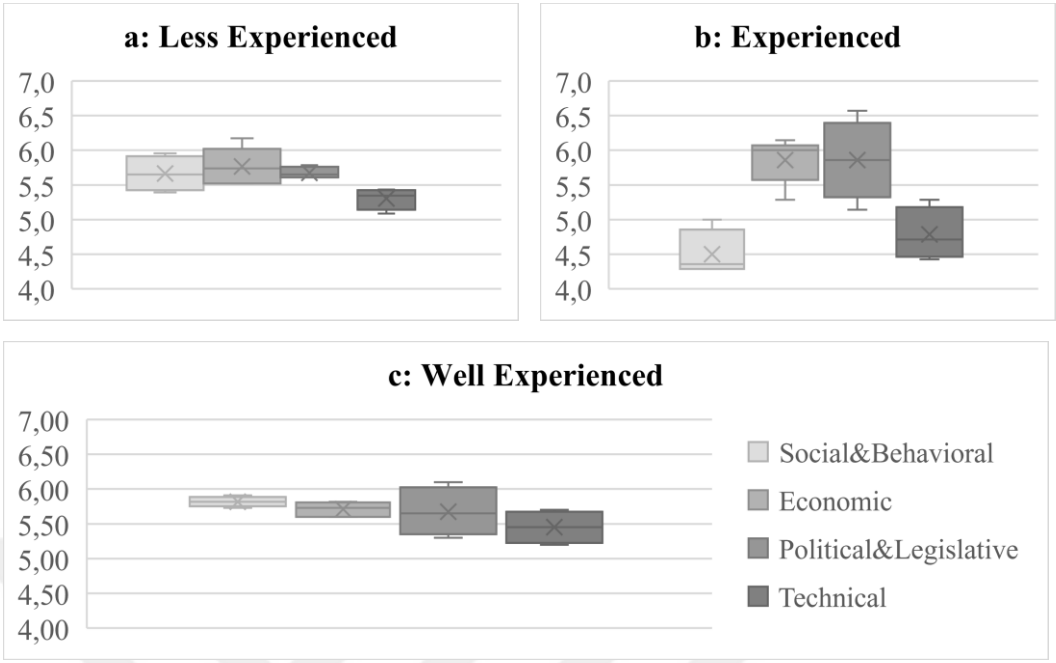


Figure 4.16: Box Plot for CE Enablers- Less Experienced a: less experienced, b: experienced, c: more experienced

According to the box plot from the perspectives of less experienced stakeholders:

- Social and behavioral enablers and economic enablers have the same interquartile range.
- Political and legislative enablers have a minimum interquartile range and more homogenous scores.
- Technical enablers have a minimum mean value.

According to the box plot from the perspectives of experienced stakeholders:

- Social and behavioral enablers have a minimum mean value.
- Political and legislative enablers have a larger interquartile range, so it can be said that they have different perspectives.
- Economic, and political and legislative enablers have similar average values.
- Technical enablers provide a more moderate approximation.

According to the box plot from the perspectives of well-experienced stakeholders:

- Social and behavioral enablers have the maximum mean value, and they are more homogenous separation.
- Political and legislative enablers have a larger interquartile range.
- Technical enablers present minimum average value.

The trend in the result resembles the variations in barriers. While the stakeholders with low and high levels of experience show similar results, the stakeholders with intermediate levels of experience are different than the others. Participants at the intermediate experience level ranked social and behavioral enablers as less critical than others. This is also a significant difference across experience levels. One of the reasons why intermediate-experienced participants rated social and behavioral enablers as less critical than others may be that they have different priorities in their work processes or project planning.

According to the results of the boxplot analysis according to experience level, it is seen that experience levels do not have a significant impact on CE barriers and enablers, albeit with noticeable slight differences. For this reason, it was concluded that the level of experience does not correlate with stakeholders' perceptions on the significance of barriers and enablers.

4.2.2.3.2 Perception of Stakeholders Based on the Stakeholders' Companies' Fields of Activity

The stakeholders' perspectives are also assessed based on their field of activity, including contractor, design/engineer or management consultant, government, recycler/supplier/manufacturer, and university. Contractors have more specialization and experience in the feasibility of physical projects and site conditions. Therefore, they can focus more on project feasibility, cost-effectiveness, and suitability for site conditions. Design and engineering consultants are specialized in technical issues. They have an important perspective on the technical aspects of projects, such as

sustainability, circular design, and material selection. The government is often concerned with regulations, policies, and sectoral changes. They may have a broad perspective, such as general policies in the sector, legal regulations, and environmental impacts. The recycler, supplier, and manufacturer focus on material sourcing, recycling processes, and the supply chain. Recycling, reuse, material quality, and supply chain impacts can be prioritized. Universities are research and innovation-oriented and can work on innovative technologies, the discovery of new materials, and circular economy models. Hence, it was hypothesized that the barriers and enablers could be explored according to the field of activities, allowing projects and strategies to be better customized to the needs and expectations of these different stakeholders.

Box plots and calculations were made to determine stakeholders' perceptions of barriers according to different fields of activity.

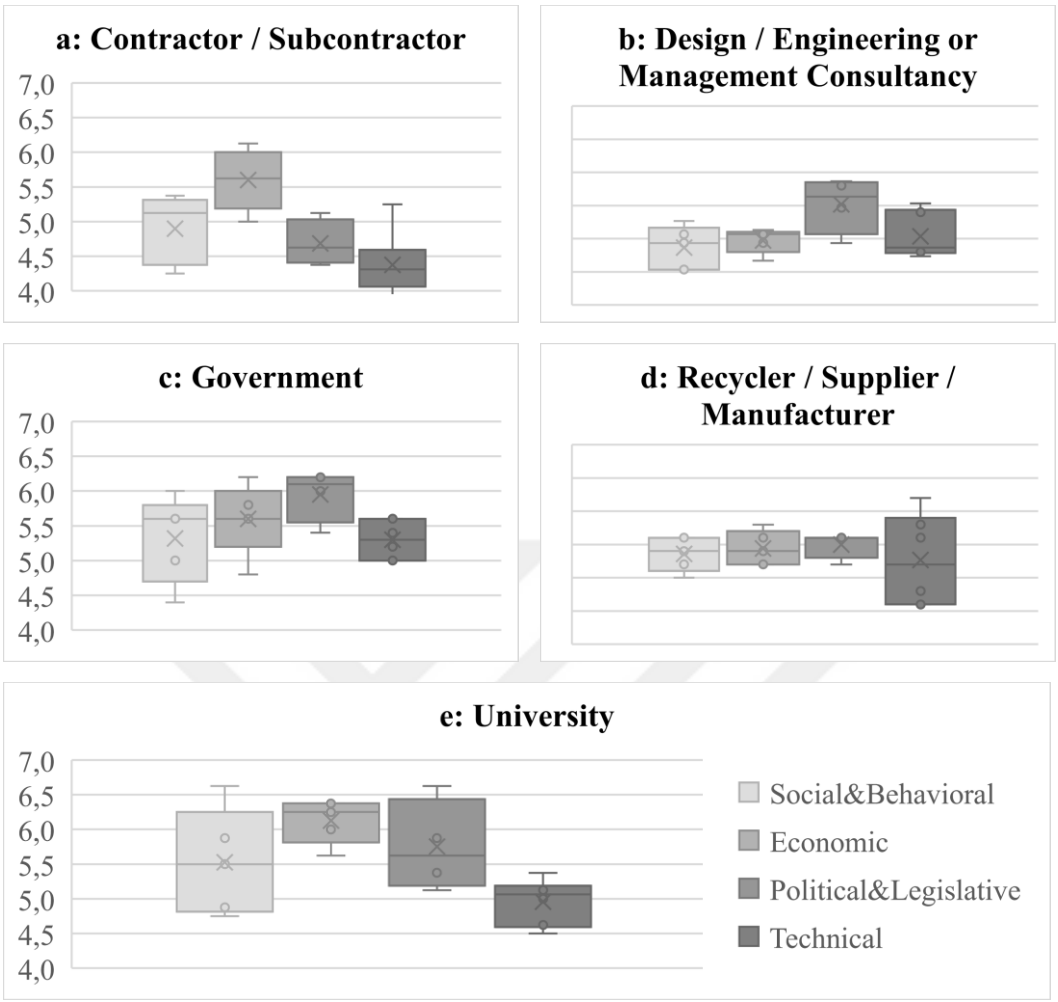


Figure 4.17: Box Plot for CE Barriers - a: contractor/subcontractor, b: design/engineering or management consultancy, c: government, d: recycler /supplier/manufacturer, e: university

According to the box plot from the perspectives of participants working as contractor/subcontractor:

- Economic barriers have maximum mean value.
- Technical barriers present a minimum average value.

According to the box plot from the perspectives of participants who work in design/engineering or management consultancy:

- Political and legislative barriers have a larger interquartile range, so it can be said that they have different perspectives, and also, they have maximum mean value.
- Social and behavioral, economic, and technical barriers have similar average values.
- Technical barriers provide a more moderate approximation.

According to the box plot from the perspectives of participants who work in government:

- Political and legislative barriers have a larger mean value.
- Social and behavioral have a larger interquartile range, meaning stakeholders present different perspectives.
- Economic barriers have a similar approach but are more consistent and have a higher average.

According to the box plot from the perspectives of participants who work as recycler/supplier/manufacturer:

- Social and behavioral, economic, and political and legislative barriers present similar averages.
- Technical barriers show a more extensive interquartile range, meaning stakeholders present different perspectives.

According to the box plot from the perspectives of participants who working in the university:

- Social and behavioral, and political and legislative barriers present a wide range for survey results.
- Economic barriers have maximum mean value.
- Technical barriers belong to the minimum average.

These observations provide insights into how stakeholders from various professional backgrounds perceive the barriers to the transition to a circular economy.

From the contractor/subcontractor perspective, the high emphasis on economic barriers indicates a significant concern with financial issues. There may be less emphasis on technical enablers in this group, indicating potential difficulties in implementing technical solutions.

In the design/engineering or management consulting perspective, different views on political and legal barriers suggest different perceptions or experiences within this group. Similar average scores for social, economic, and technical barriers may mean that there is a balanced concern between these elements. The moderate level of technical barriers may indicate a balanced approach.

For government employees, a greater emphasis on political and legal barriers indicates the importance of legal frameworks and regulations for the public sector. The different perspectives on social and behavioral barriers suggest various concerns or experiences within the stakeholder group.

Similar mean scores for recyclers/suppliers/manufacturers on social, economic, political and legislative barriers emphasize the balance between these elements. Different perspectives on technical barriers imply different views or experiences within this stakeholder group.

The wide range of scores for social and political barriers from the perspective of university-based researchers may indicate that respondents have different views, experiences, and research interests. The minimum mean for technical barriers may suggest that this group sees fewer technical barriers or perceives them as less critical.

Box plots and statistical calculations were used to assess stakeholders' perceptions of circular economy enablers in various fields of activity.

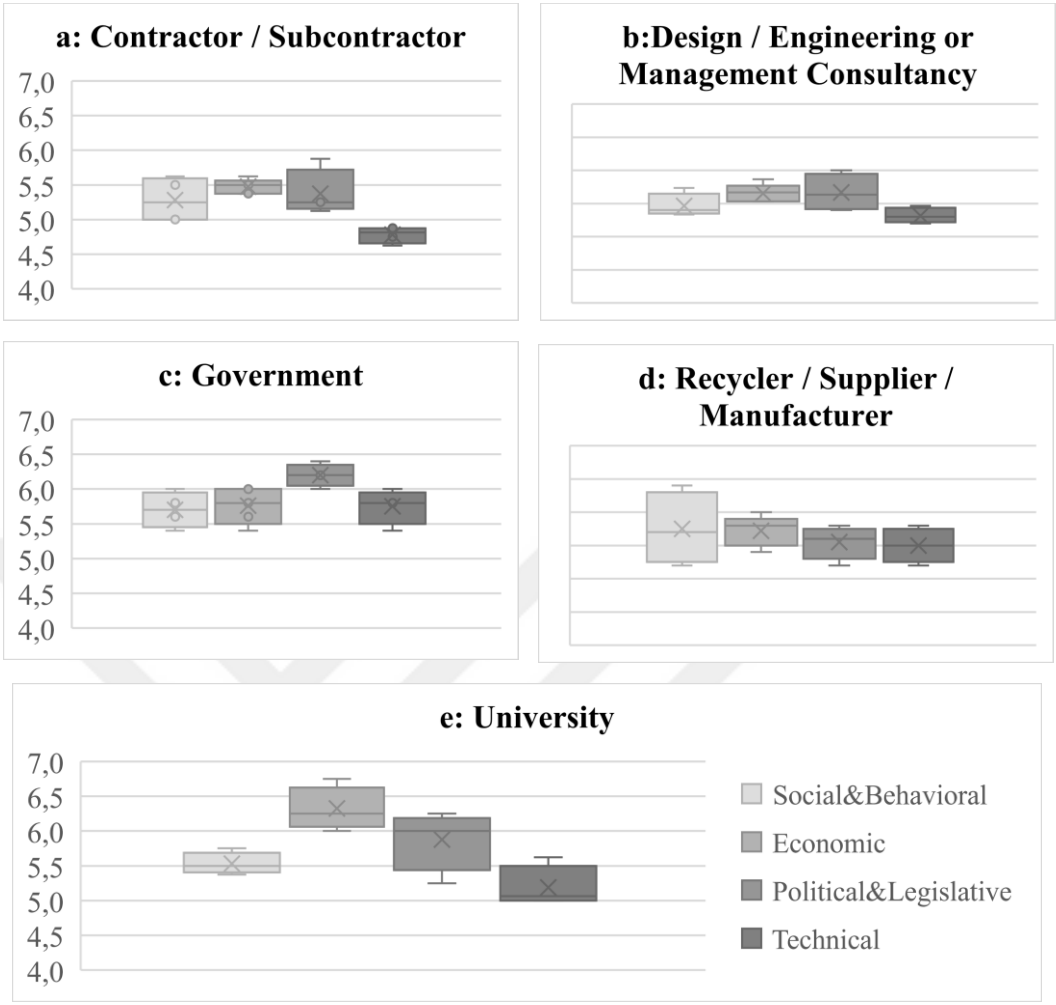


Figure 4.18: Box Plot for CE Enablers – a: contractor/subcontractor, b: design/engineering or management consultancy, c: government, d: recycler /supplier/manufacturer, e: university

According to the box plot from the perspectives of participants working as contractor/subcontractor:

- Economic enablers have the maximum mean value.
- Technical enablers present minimum average value.

According to the box plot from the perspectives of participants who work in design/engineering or management consultancy:

- Political and legislative enablers have a larger interquartile range, meaning stakeholders present different perspectives.
- Technical enablers present minimum average value.

According to the box plot from the perspectives of government workers:

- Political and legislative enablers have a bigger average value than others.
- Social and behavioral, economic, and technical enablers have similar average values.

According to the box plot from the perspectives of participants who work as recycler/supplier/manufacturer:

- Social and behavioral enablers show a more extensive interquartile range.
- All enabler groups present similar averages.

According to the box plot from the perspectives of participants who working in the university:

- Economic barriers have maximum mean value.
- Technical barriers belong to the minimum average.

According to these analyses, from the perspectives of respondents working in different professional fields, enablers are evaluated differently. For example, contractors or subcontractors assign more importance to economic enablers. At the same time, for design/engineering and management consultants, the impact of political and legal factors is more emphasized. Government employees may highlight political and legal barriers more, while recyclers and university employees may set different priorities. These differences may indicate that stakeholders in different sectors and professional positions may prioritize certain enablers differently.

These results suggest that, in general, stakeholders are consistent across barrier and enabler groups. A stakeholder group that placed high importance on a particular barrier group similarly assigned high importance to enablers for the same group. For

example, a stakeholder group that ranked economic barriers highly also rated economic enablers highly. This suggests stakeholders seek opportunities in the same area to solve challenges in a particular site. This consistency may also indicate that a certain balance is maintained for interventions or solutions in specific areas.

4.2.2.3.3 Perception of Stakeholders Based on the Stakeholders' Knowledge Level

Another analysis is conducted by dividing the respondents into three groups, low knowledge, average knowledge, and high knowledge, to reflect their level of knowledge on circular economy.

Respondents with low knowledge may have limited knowledge of the circular economy and therefore may have a different perspective. Respondents with an average level of knowledge may have a basic understanding of the topic and, thus, focus on more detailed issues. Participants with a high level of knowledge may have an in-depth understanding of the topic and, therefore, be able to conduct more advanced analyses. These analyses help us understand the different needs and priorities of respondents with different levels of knowledge on the transition to a circular economy.

Stakeholders' scores for each barrier according to their level of knowledge were evaluated, and then average values were calculated. These scores are considered indicators of how each barrier is perceived at different levels of knowledge. Higher mean scores indicate an increase in the perceived importance of barriers at the relevant levels of knowledge among stakeholders. Analyzing the differences between stakeholders with different levels of circular economy knowledge provides insights into their perceptions of these barriers in line with their understanding of circular economy concepts. Assessing average scores within knowledge-based groups facilitated the creation of custom box plots for each level of knowledge,

visually representing how these barriers are perceived at different levels of expertise on circular economy.

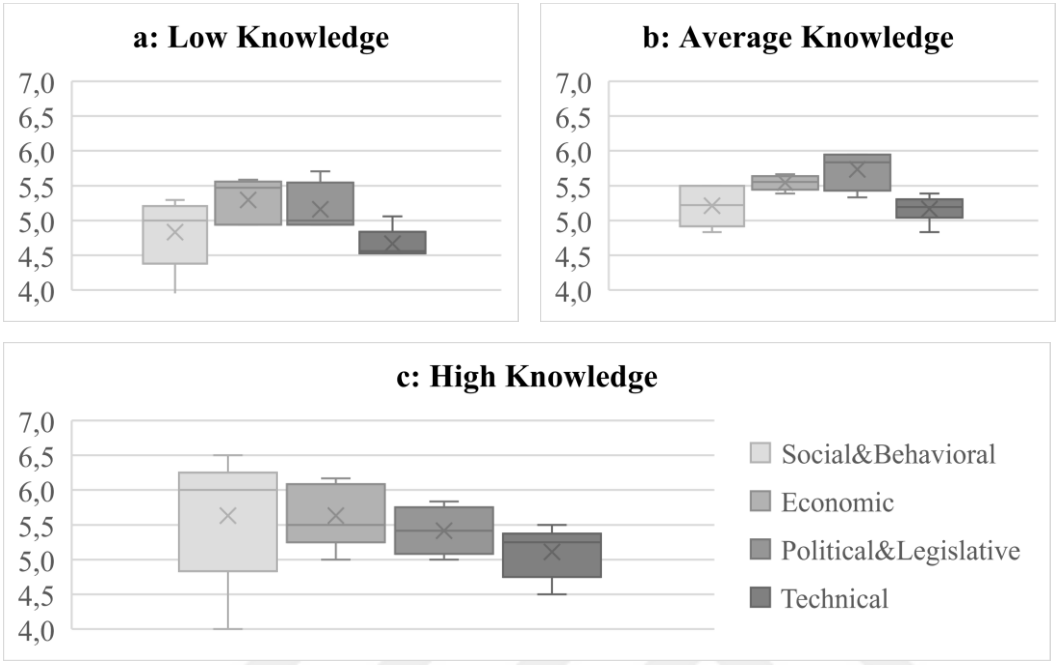


Figure 4.19: Box Plot for CE Barriers – a: low knowledge, b: average knowledge, c: high knowledge

According to the box plot from the perspectives of low-knowledge stakeholders:

- Social and behavioral barriers have a larger interquartile range.
- Technical barriers have a minimum interquartile range and more homogenous scores.
- Although the mean values for all barrier groups are close, technical barriers have a smaller mean value.

According to the box plot from the perspectives of average knowledge stakeholders:

- Political and legislative barriers have the maximum mean value.
- Technical barriers have a smaller average value.

According to the box plot from the perspectives of high-knowledge stakeholders:

- Social and behavioral barriers have a larger interquartile range, meaning stakeholders present different perspectives.
- High-knowledge stakeholders' perspectives show different views in their groups because the barrier groups have larger interquartile ranges when compared to other stakeholder groups.
- All mean values are greater than 5.

It was observed that as the level of knowledge increases, the average scores given by stakeholders to the barriers also increase. This suggests that stakeholders' perceptions of circular economy barriers may change in parallel with their level of knowledge. Although all stakeholders gave generally high scores, there were small differences in these scores with increasing knowledge. This suggests that the perception and assessment of circular economy barriers may vary according to the level of knowledge of stakeholders.

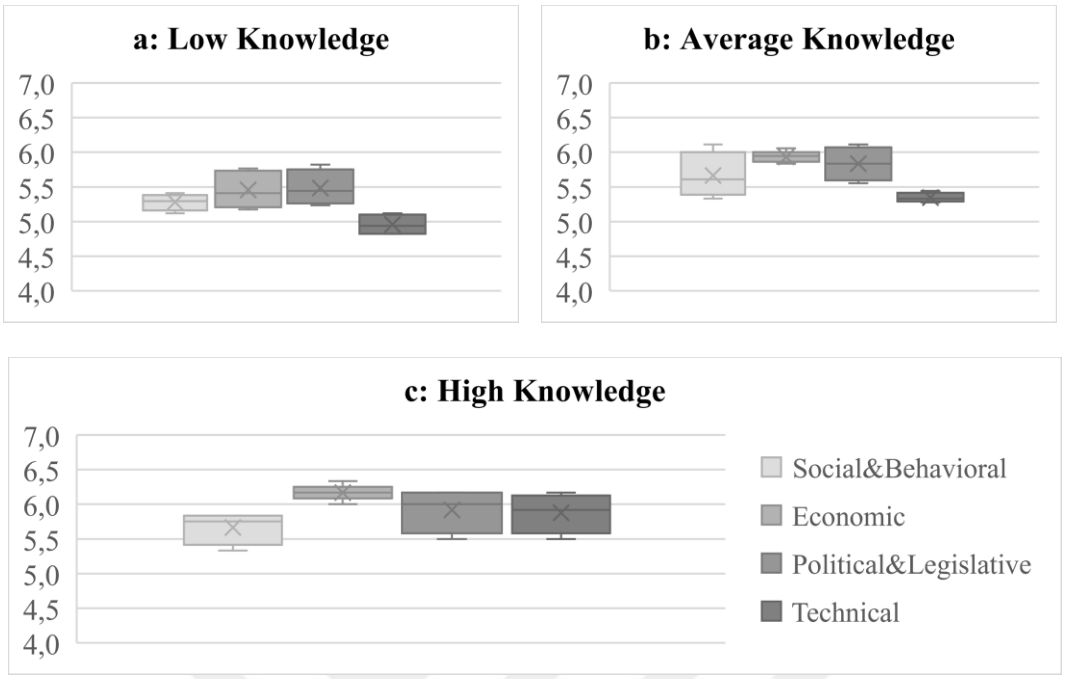


Figure 4.20: Box Plot for CE Enablers – a: low knowledge, b: average knowledge, c: high knowledge

According to the box plot from the perspectives of low-knowledge stakeholders:

- Economic, and Political and Legislative enablers have similar approaches.
- Although the mean values for all enabler groups are close, technical enablers have the smaller mean value.

According to the box plot from the perspectives of average knowledge stakeholders:

- All mean values are close to each other.
- Technical enablers have a smaller average.

According to the box plot from the perspectives of high-knowledge stakeholders:

- Economic barriers have a smaller interquartile range, meaning stakeholders present homogenous perspectives.
- All mean values are greater than 5.5.

4.2.3 Relationship Assessment

The relationship assessment helps examine the interactions and influences of stakeholders in the circular economy. When analyzing the results, 2-mode centrality measures were used to assess the centrality or importance between two types of data (e.g., stakeholders and circular economy enablers). This analysis portrays the relationship of different stakeholders (e.g., contractor, designer, consultant, government, supplier) with each other and circular economy strategies. This analysis helps identify which stakeholders play a central role in circular economy interactions and which have more connections.

Following the analysis with UCINet, 2-mode centrality measures, specifically degree centrality, local, closeness, betweenness, and eigenvector, were obtained. These values were calculated for each row and column in the matrices. Degree centrality shows how much a stakeholder has a relationship with other stakeholders. This measure can be used to assess how often a stakeholder interacts with circular economy practices or other stakeholders. A high degree of centrality may indicate that a stakeholder occupies a central position within the circular economy network. Closeness centrality indicates how close a stakeholder is to other stakeholders. This measure can be used to assess how quickly a stakeholder has access to other stakeholders within the circular economy network. High betweenness centrality means that a stakeholder can reach others faster. Betweenness centrality shows how important a stakeholder is as a bridge or intermediary between other stakeholders. This measure can indicate that a stakeholder facilitates communication between different groups within the circular economy network or plays an important role. All respondents' answers were used to provide an overview at the beginning of the analyses. This overview aims to identify the general trends of views on the circular economy and the main approaches. Based on this overview, network analysis was carried out to understand stakeholder interactions and relationships better. Network analysis revealed how stakeholders are interconnected in the circular economy and how these connections are shaped.

Using the data from the survey results, matrices were created for the four groups of enablers that support the transition to a circular economy. These matrices are presented below in Tables 4.1, 4.2, 4.3, and 4.4. These matrices were then subjected to detailed network analysis using UCINet. The results of the analysis are summarized in Table 4.5 and Table 4.6. These tables show how interactions and relationships are shaped in the transition to a circular economy, particularly the relationships between identified enablers and stakeholders.

Table 4.1: 2-Mode Matrix for Social & Behavioral Enablers

Stakeholders	***E-B1***	***E-B2***	***E-B3***	***E-B4***
Contractor	0	1	1	0
Designer	0	1	1	1
Manager	0	1	1	0
Supplier / Manufacturer	1	1	1	1
Recycler	1	1	1	1
Government	1	1	1	1
Consultant	1	0	1	1
Client / Owner	1	1	1	1

Table 4.2: 2-Mode Matrix for Economic Enablers

Stakeholders	***E-E1***	***E-E2***	***E-E3***	***E-E4***	***E-E5***
Contractor	0	0	0	0	0
Designer	0	0	0	1	0
Manager	0	0	0	0	0
Supplier / Manufacturer	1	1	0	1	0
Recycler	1	1	1	1	0
Government	1	1	1	1	1
Consultant	0	0	0	1	0
Client / Owner	0	0	1	1	0

Table 4.3: 2-Mode Matrix for Political and Legislative Enablers

Stakeholders	***E-P1***	***E-P2***	***E-P3***	***E-P4***
Contractor	0	0	0	0
Designer	0	0	0	0
Manager	0	0	0	0
Supplier / Manufacturer	0	0	0	0
Recycler	0	1	0	0
Government	1	1	1	1
Consultant	0	0	0	1
Client / Owner	0	1	0	1

Table 4.4: 2-Mode Matrix for Technical Enablers

Stakeholders	***E-T1***	***E-T2***	***E-T3***	***E-T4***
Contractor	1	1	0	0
Designer	0	1	1	0
Manager	1	1	1	0
Supplier / Manufacturer	1	1	1	1
Recycler	1	1	1	1
Government	1	1	1	1
Consultant	0	1	1	0
Client / Owner	0	1	0	0

Enablers with higher closeness values may play a more central role in circular economy strategies. However, this ranking alone is insufficient for the analysis; it is important to make a more comprehensive assessment, considering other centrality measures and network analysis metrics.

Regarding the survey results, providing stakeholders adequate experience and knowledge about lifecycle performance (E-B3) and applying lean principles to reduce waste (E-T2) have the highest closeness values: 1. After these enablers, having some form of manufacturer responsibility for construction products (E-B2) has the second-ranking. Changing people's perception and perspective on circular economy (E-B4), promoting the use of more prefabricated, organic, environmentally

friendly, and renewable materials (E-E4), and developing and using new design strategies, technologies, and construction methods (E-T3) have a more central role than other enablers; these three enablers have same closeness centrality values which is 0.909. Equal closeness values indicate that these enablers have a similar level of "closeness" within the network. That is, equal closeness values suggest that both enablers are similarly close to other nodes in the network and, therefore, interact with other nodes at a similar level.

Creating tax deductions for CE design strategies (E-E5), setting legislation, using standards to develop strategies (E-P1), and creating national and regional CE action plans (E-P3) have the lowest closeness value when all enablers are taken into account. This ranking indicates that E-B3 interacts more closely with other enablers and stakeholders within the network, while E-P3 has a lower level of closeness.

Table 4.5: 2-Mode Centrality Measures for Columns

		Degree	Local	Closeness	Betweenness	Eigenvector
1	E-B1	0.625	0.419	0.87	0.018	-0.275
2	E-B2	0.875	0.478	0.952	0.054	-0.326
3	E-B3	1	0.529	1	0.07	-0.365
4	E-B4	0.75	0.463	0.909	0.03	-0.311
5	E-E1	0.375	0.301	0.8	0.004	-0.19
6	E-E2	0.375	0.301	0.8	0.004	-0.19
7	E-E3	0.375	0.287	0.8	0.005	-0.179
8	E-E4	0.75	0.463	0.909	0.03	-0.311
9	E-E5	0.125	0.125	0.741	0	-0.07
10	E-P1	0.125	0.125	0.741	0	-0.07
11	E-P2	0.375	0.287	0.8	0.005	-0.179
12	E-P3	0.125	0.125	0.741	0	-0.07
13	E-P4	0.375	0.243	0.8	0.007	-0.154
14	E-T1	0.625	0.368	0.87	0.029	-0.244
15	E-T2	1	0.529	1	0.07	-0.365
16	E-T3	0.75	0.434	0.909	0.035	-0.295
17	E-T4	0.375	0.301	0.8	0.004	-0.19

The higher ranking of social and behavioral enablers may indicate that stakeholders see these enablers as central elements of circular economy strategies. The lower ranking of political and legislative enablers may suggest that stakeholders view the

interactions of policy regulations or legislation with circular economy strategies as a slightly lower priority. This could suggest that, according to stakeholders, political enablers have a lower level of importance than other enablers in developing CE strategies. Conducting this analysis can be used to understand stakeholders' preferences in this ranking, to shape the CE strategies better, and to gain broader acceptance in society.

After the analysis of the values of the enablers, a comprehensive perspective was obtained by looking at the stakeholders' SNA (Social Network Analysis) values. This type of analysis is crucial for understanding the interactions and relationships between stakeholders in circular economy strategies and practices. It is important to assess which enablers interact with which stakeholders more frequently to understand whether strategy needs to focus more on certain stakeholder groups or whether certain enablers need to be integrated more effectively.

The stakeholder ranking based on closeness values is given in descending order: government, recycler, supplier/manufacturer, client/owner, consultant, designer, manager, and contractor. The government was identified as the stakeholder with the highest closeness value within the network. This indicates that the government interacts more closely and intensively with other stakeholders. This may suggest that the government plays a central role in shaping and implementing circular economy strategies. Recycler has the second highest closeness value within the network, indicating that recycling activities are closely coordinated with other stakeholders. It can be identified as an important player in recycling processes. It shows suppliers, customers, and owners are effectively involved in these strategies. Consultants, designers, managers, and contractors are ranked lower overall. This may indicate that these stakeholders are slightly less engaged in the strategies.

Table 4.6: 2-Mode Centrality for Rows

		Degree	Local	Closeness	Betweenness	Eigenvector
1	Contractor	0.235	0.206	0.544	0.005	-0.177
2	Designer	0.353	0.301	0.585	0.013	-0.269
3	Manager	0.294	0.25	0.564	0.009	-0.217
4	Supplier/ Manufacturer	0.647	0.441	0.721	0.082	-0.417
5	Recycler	0.765	0.485	0.795	0.132	-0.466
6	Government	1	0.529	1	0.416	-0.516
7	Consultant	0.412	0.309	0.608	0.027	-0.283
8	Client / Owner	0.529	0.36	0.66	0.058	-0.336

The SNA results showed that the same ranking result was obtained for all network analysis values (closeness, degree, betweenness, etc.) according to the stakeholders' analysis. A similar ranking of criteria such as closeness, degree, and betweenness may indicate that stakeholders are similarly positioned within the network or have identical patterns of interaction. It may suggest that certain stakeholders play a central role in the network or significantly influence other stakeholders. These identifications provide guidance on how the results of the stakeholder social network analysis can be interpreted.

For example, considering the values given in Table 4.6, the prominence of the government reflects the fact that among stakeholders, the government occupies a central position in the network among actors in this group and significantly influences other stakeholders. Consequently, according to stakeholders, the government needs to play an influential role in setting policy, providing incentives, or making regulations.

Other stakeholder groups, such as recyclers and suppliers/manufacturers, are also prominent, indicating that material cycle and supply chain management are critical in implementing the circular economy. Effective management of recycling processes and material procurement can result in these stakeholders playing a significant role in circular economy implementation.

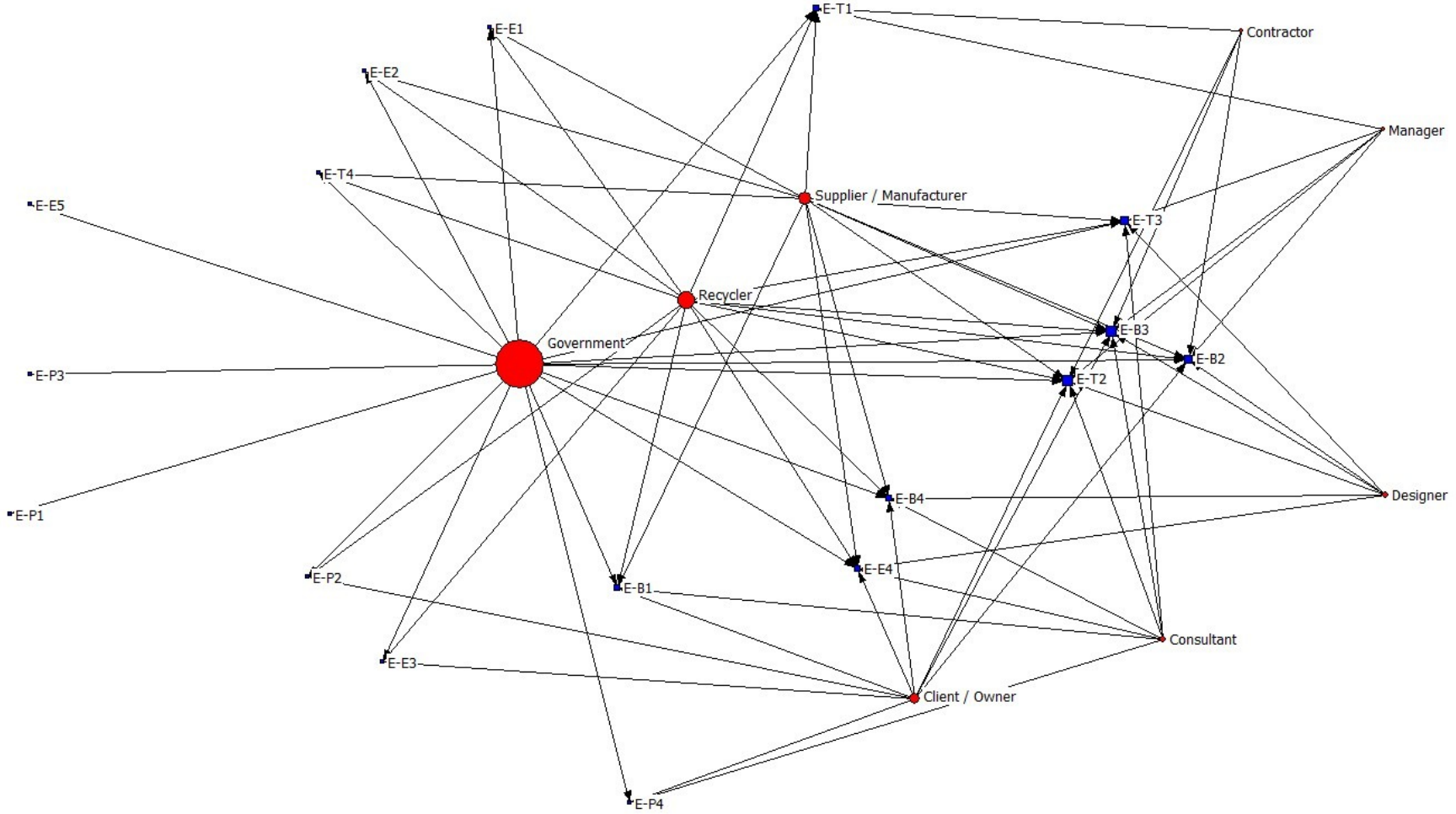


Figure 4.21: Node Centrality Measures for Stakeholders and Enablers (Set Node Size by Degree

These observations may indicate that the government and stakeholders involved in the material cycle and supply chain management are particularly critical in adopting a circular economy in the construction sector. These stakeholders can lead on strategic solutions and policy changes and significantly contribute to the circular economy's development. Stakeholders and their roles in the network can be better understood.

The network visualizations showing the node centrality metrics show that the relevant stakeholder nodes are centralized and strongly connected to other nodes. It indicates that government nodes heavily direct communication within the network and significantly influence other stakeholders in the network.

A general relationship assessment was first made by assessing each survey result together. Then, SNA is performed on divided datasets based on participants' level of experience, their activity fields, and knowledge level. The results of SNA are shown in Appendix C.

4.2.3.1 SNA Results Based on the Stakeholders' Companies' Fields of Activity

Looking at the assessments of the Contractor/Subcontractor group, the distribution of enablers is more balanced for centrally positioned stakeholders. The design/engineers and management consultants group is only centrally positioned by Contractors. Respondents emphasized that consultants should have more influence in the process of CE integration. According to the SNA results, the betweenness value of contractors was found to be 0. This is a remarkable point for this study. The contractor group excluded themselves from the map when making their assessments and only held themselves responsible for implementing lean principles to reduce waste. Considering that the contractor group participating in the survey has an average and low level of knowledge about the circular economy, it can be said that this situation is due to the lack of understanding of the circular economy.

Stakeholders may avoid taking responsibility because they do not know how and who to cooperate with on certain issues.

After the SNA study based on the insights of design/engineers and management consultants, it is seen that a group of stakeholders (government, supplier /manufacturer, recycler, client/owner) is mapped with more enablers in a more centralized position. However, it is interesting to note that according to the assessment of the stakeholder group that made the assessment, the location of these stakeholders on the map is not centralized, and they are only mapped to a group of enablers. It can be said that design/engineers and management consultants hold themselves responsible for social and behavioral, and technical enablers. In this sense, the contractor has been subjected to a similar approach. While the enablers are generally homogeneously distributed, the enablers for which the design/engineers and management consultants group is also responsible stand out and have higher centrality values. Within this analysis, ensure an adequate level of experience and knowledge (E-B3) is associated with all stakeholders. Following this, participants emphasized that the scope of manufacturer responsibility (E-B2) requires collaboration in terms of CE applicability.

The analysis for the government group shows a more dispersed distribution compared to centrally located stakeholders. The enablers that come to the fore are more centralized, and the need for cooperation is emphasized to achieve success in terms of the circular economy. In this sense, technical enablers are centralized and prominent, while the need for adequate experience and knowledge is also highlighted. It can be said that the participants in the Government do not avoid taking responsibility, as they seem to assign maximum betweenness and closeness values to themselves. In fact, since political and legislative enablers are usually associated only with the government, they are considered to play a key role in this sense.

As a result of the assessment of the recycler and supplier/manufacturer groups; a centralized approach was adopted for recycler, supplier/manufacturer, and government. The assessment's stakeholder group has associated all enabler groups

with their own. For enablers, some enablers stand out by being more centrally located. To promote renewable materials (E-E4), general cooperation and sharing of responsibility is envisaged.

Researchers at the university examined the sector as an outside observer. Universities were not included in the map in order to provide a more objective perspective on the direction in which the studies should evolve. When the stakeholders were evaluated after the analysis,

The stakeholder groups in the center of the map show similarity with the other evaluations as a result of the university researchers' assessments. Enablers are generally distributed more specifically. In other words, it can be said that there is an expectation to provide more problem-oriented solutions in general by associating a specific enabler with a specific group of stakeholders.

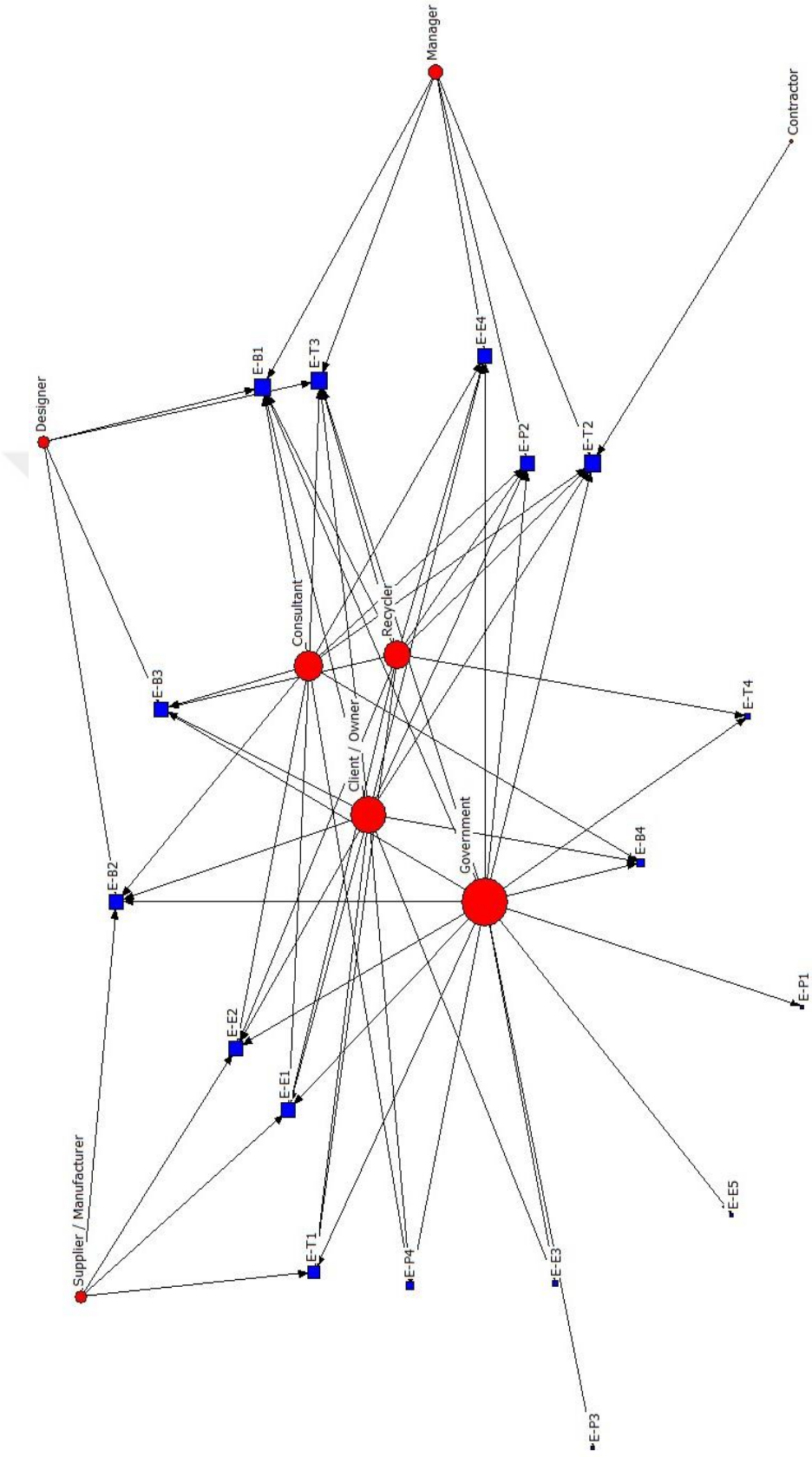


Figure 4.22: Network Analysis Based on Perceptions of Contractor/Subcontractor

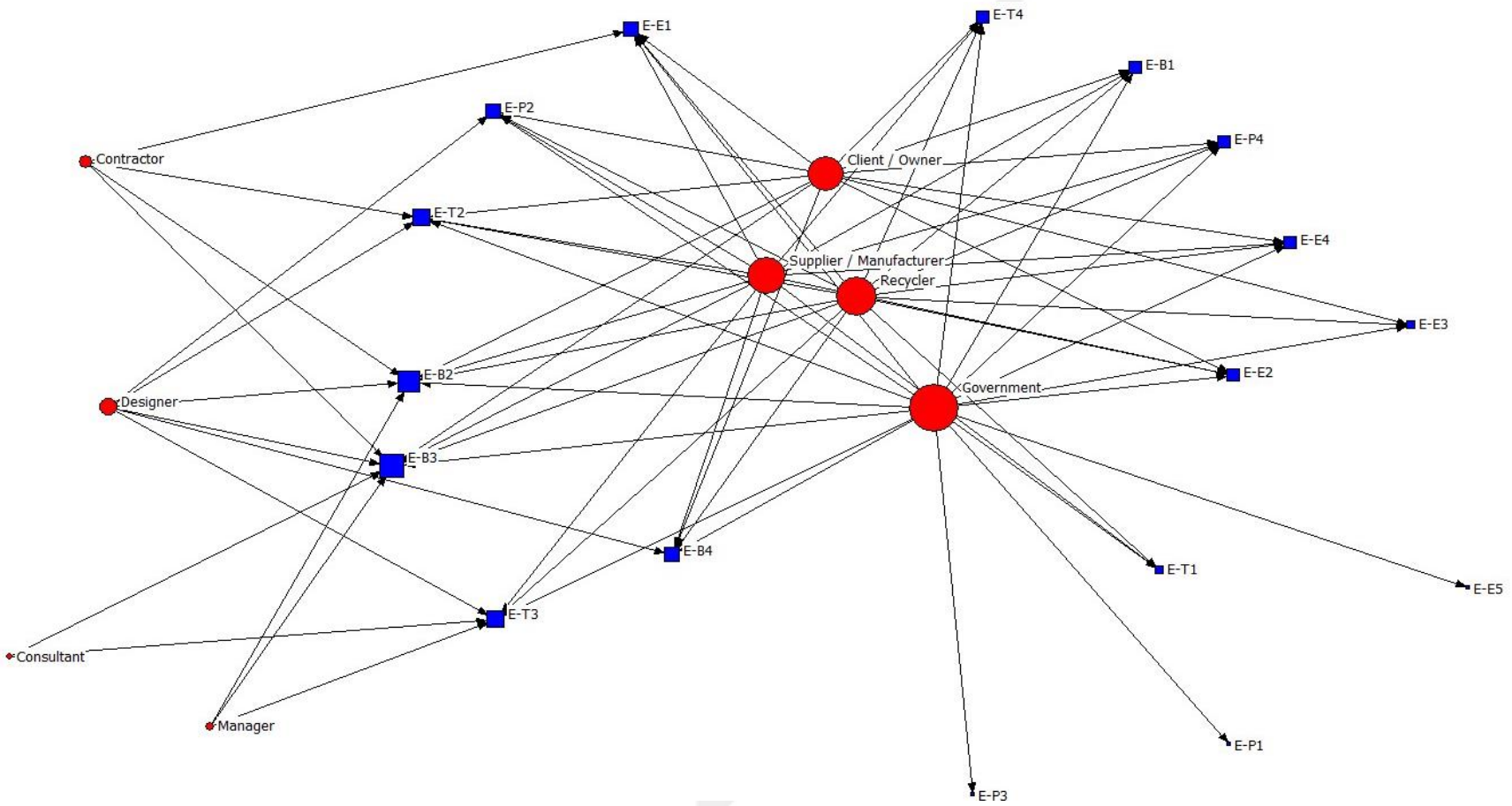


Figure 4.23: Network Analysis Based on Perceptions of Design/Engineering or Management Consultancy

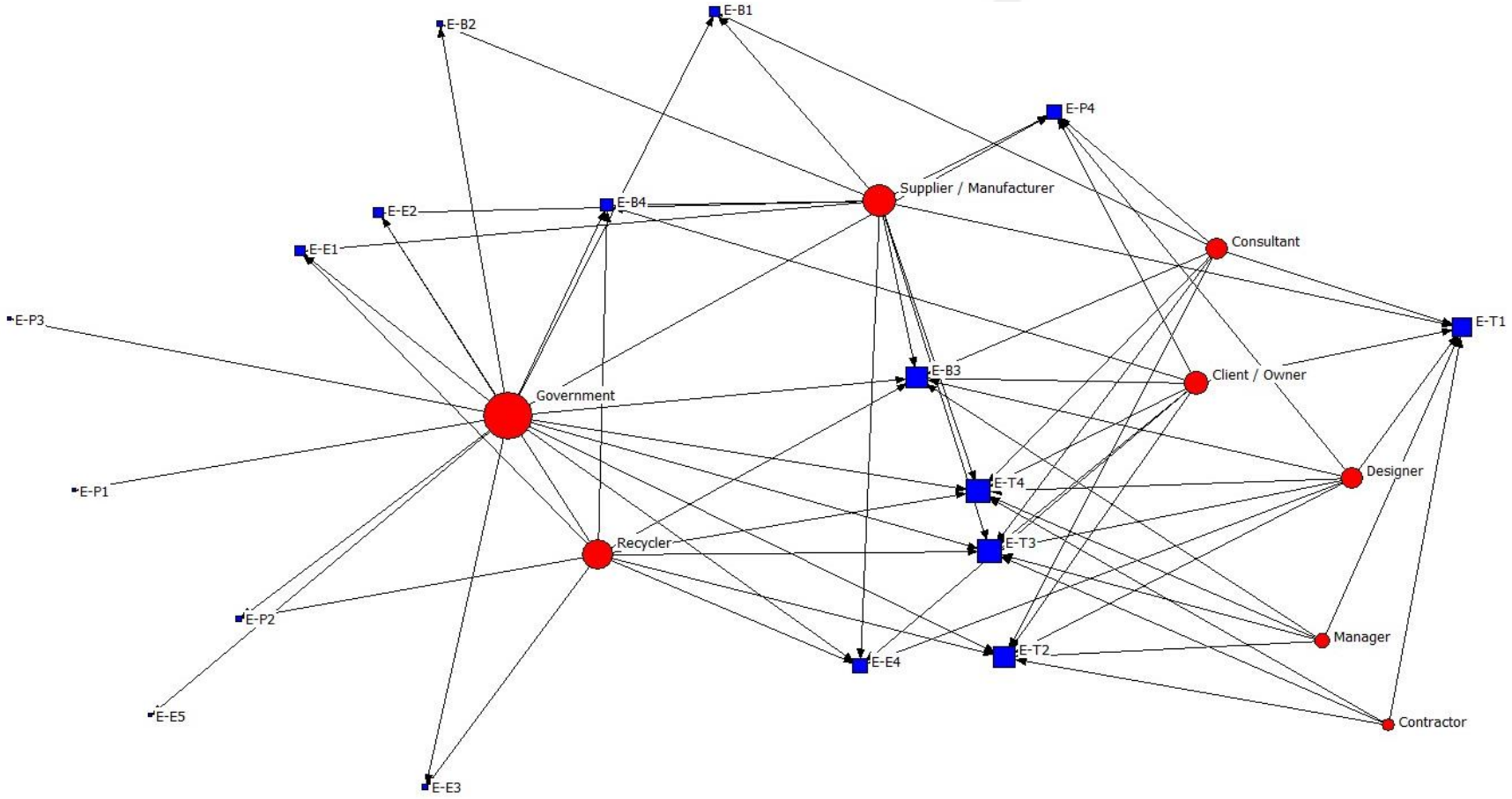


Figure 4.24: Network Analysis Based on Perceptions of Government

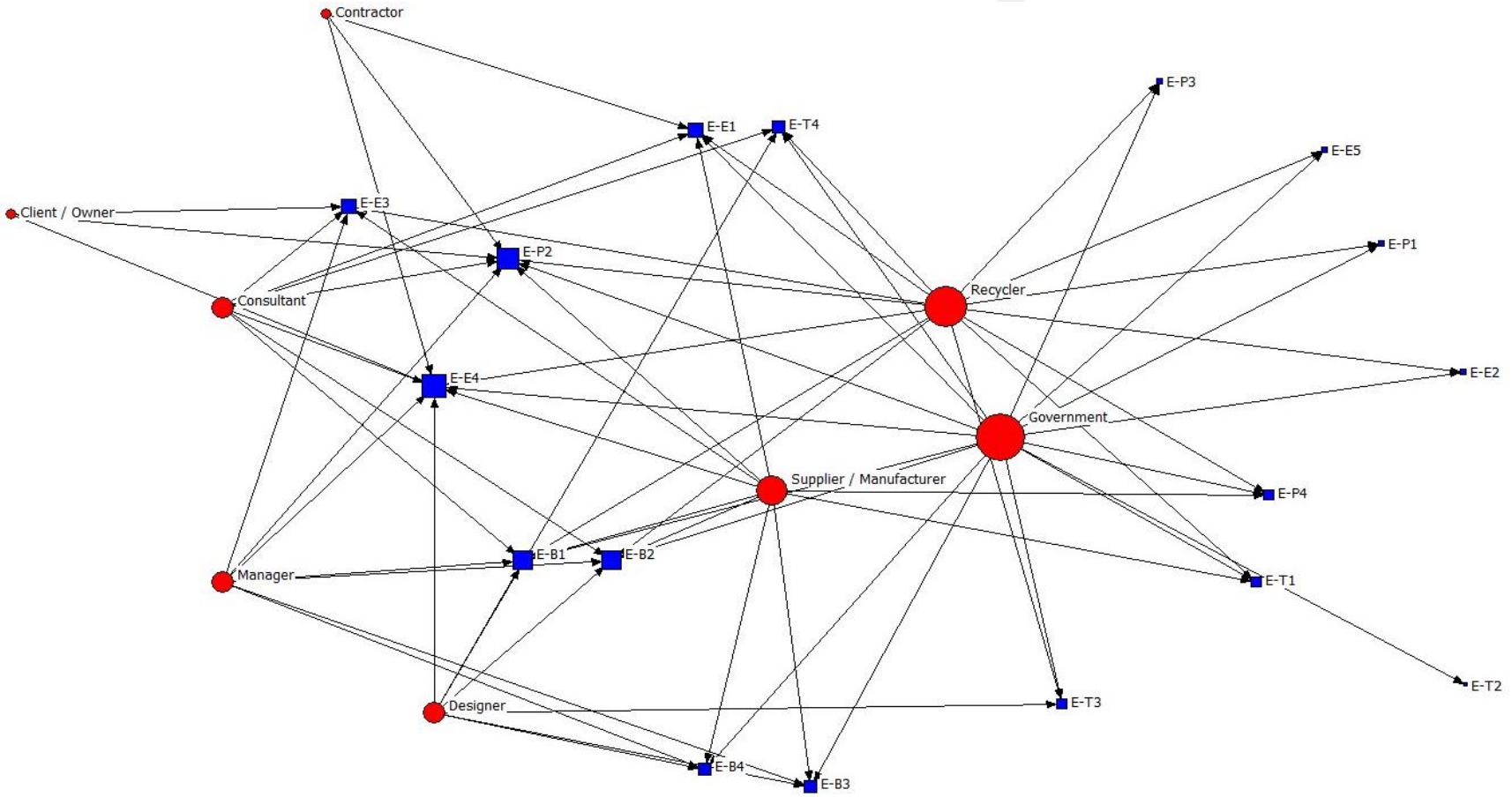


Figure 4.25: Network Analysis Based on Perceptions of Recycler / Supplier / Manufacturer

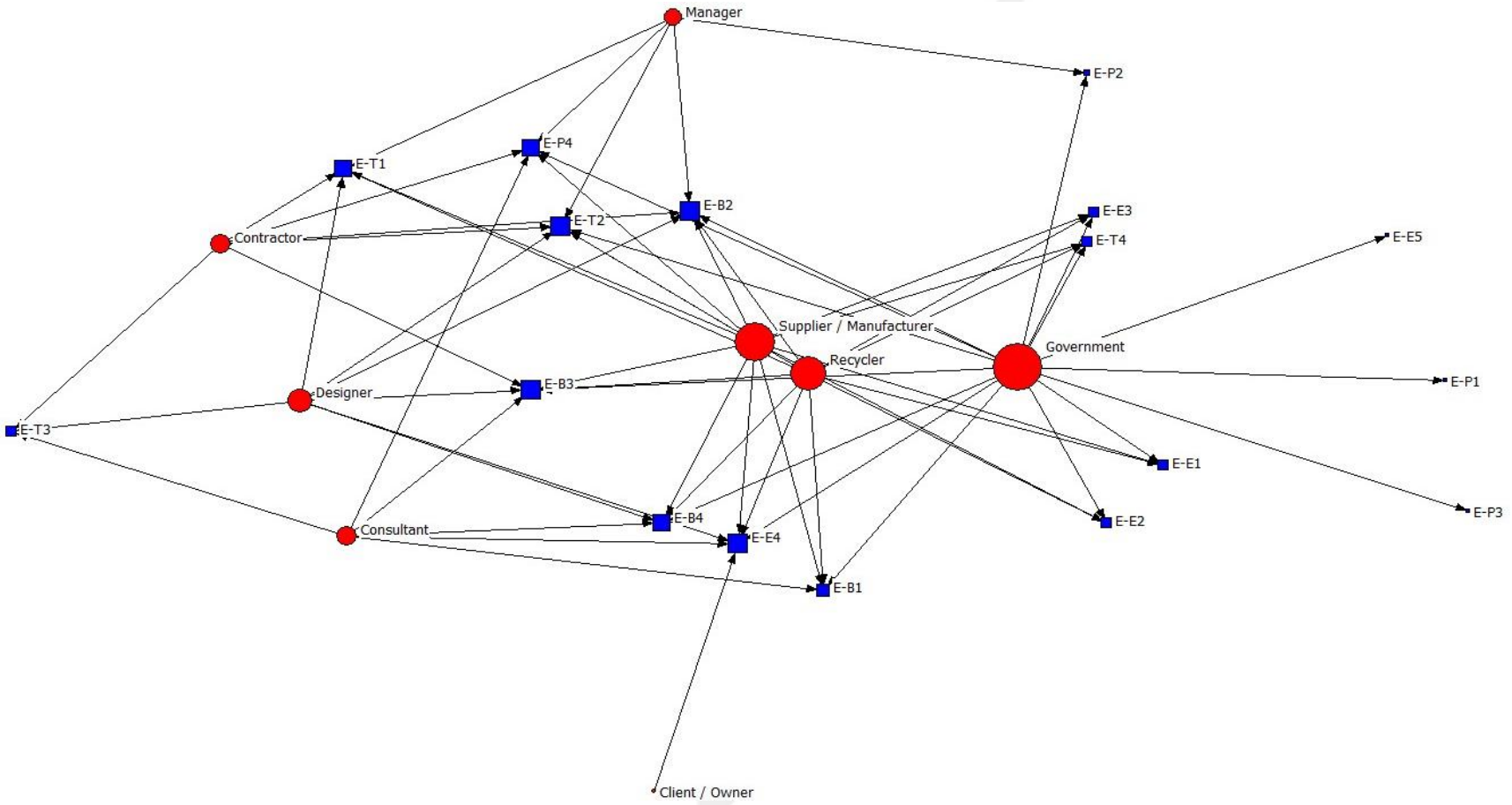


Figure 4.26: Network Analysis Based on Perceptions of University Researcher

4.2.3.2 SNA Results Based on the Stakeholders' Knowledge Level

As the knowledge level increases, a more centralized approach was adopted for stakeholders, and the importance of cooperation was emphasized. With progress towards a more balanced distribution, it can be said that the roles of stakeholders in the sector are better understood in direct proportion to the level of knowledge. It may also indicate that with a broader perspective, they may be able to steer changes in the sector more effectively. This could be a promising sign that stakeholders are able to fulfill their role in the industry more effectively and efficiently as their level of knowledge increases.

For stakeholders with low levels of knowledge, changing people's attitudes towards CE (E-B4) was more prominent. In addition, the high centrality of the need to gain experience and awareness (E-B1) can be interpreted as the stakeholders in this group wanting to increase their level of knowledge in terms of CE. The choice of materials used (E-E4) and the need to apply lean principles (E-T2) were also revealed. The general approach of stakeholders with an average level of knowledge emphasizes the importance of social and behavioral enablers. Highly experienced stakeholders showed a more homogeneous relationship assessment in terms of enablers. The lack of zero waste policies (E-P2) was emphasized, and the responsibilities of manufacturers (E-B2) were highlighted. Stakeholders in this group also mentioned the need for practices to raise awareness and knowledge (E-B1).

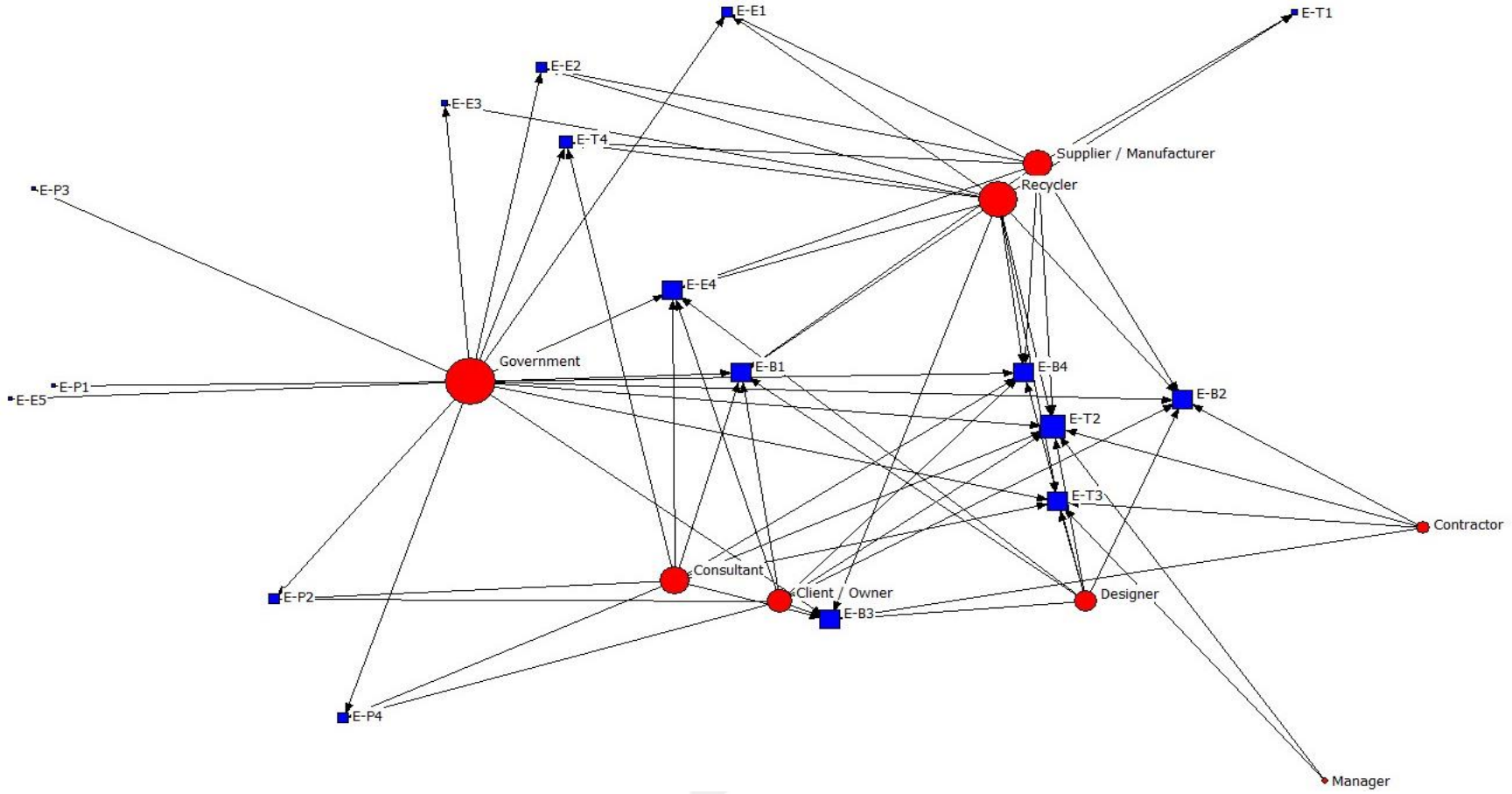


Figure 4.27: Network Analysis Based on Perceptions of Low Knowledge Stakeholders

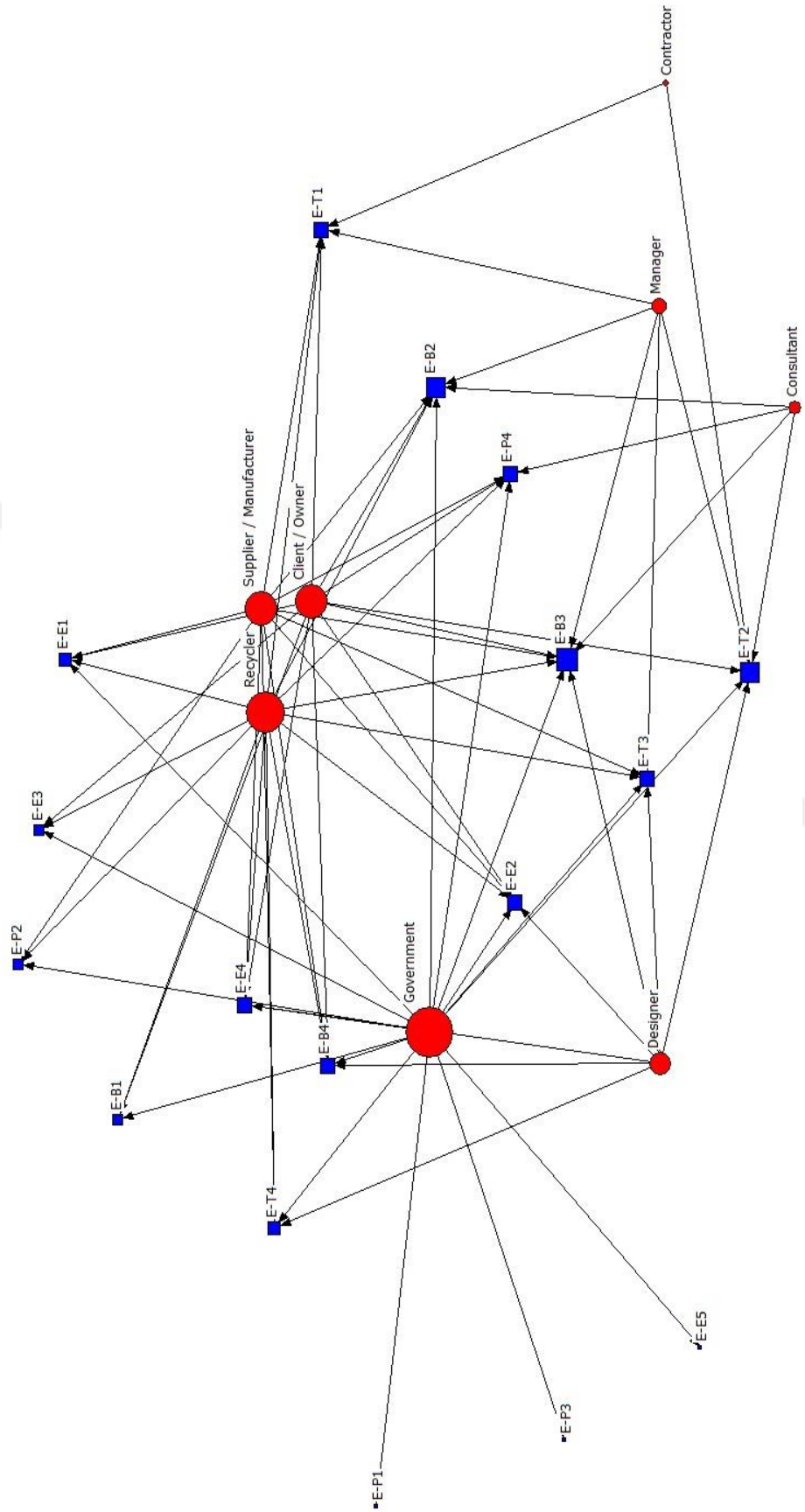


Figure 4.28: Network Analysis Based on Perceptions of Average Knowledge Stakeholders

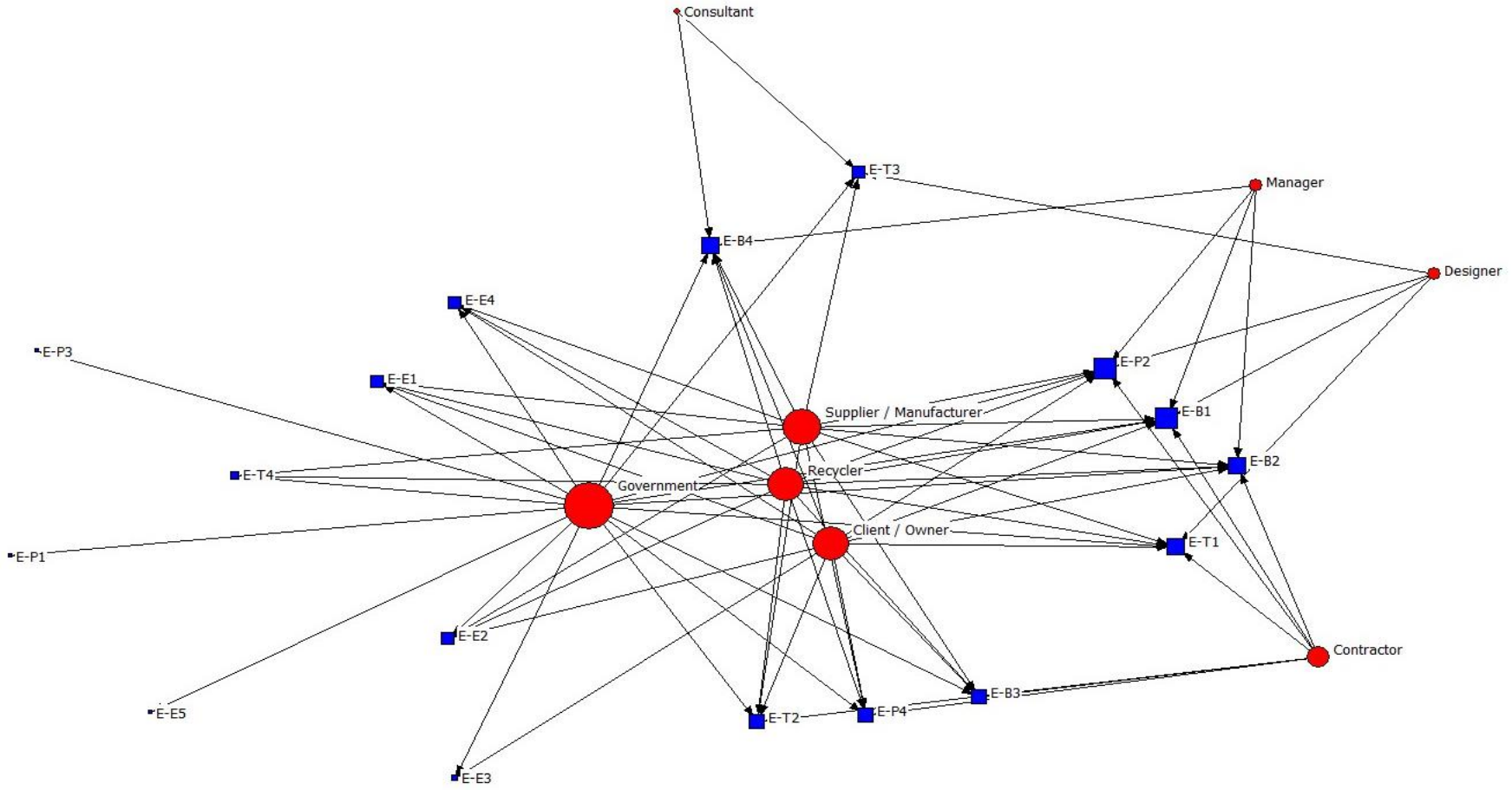


Figure 4.29: Network Analysis Based on Perceptions of High Knowledge Stakeholders

4.3 Discussions

The results of this study were compared within itself (scores of barriers, enablers, roles of stakeholders) and with the literature to check whether the intended outcomes were achieved. The results of the studies revealed a number of different approaches from the literature. The barriers highlighted in the literature based on the region were examined and compared with this study. After determining barriers, the impact of stakeholder perception was examined within the scope of the stakeholder-enabler relationship assessment. Finally, the consistency of stakeholder assessment scores and SNA results was evaluated.

Differences across regions may indicate that there may be variations in the barriers and priorities faced in the transition to a circular economy in the construction sector. While Guerra and Leite's (2021) US-based study emphasized more technical and operational barriers, such as lack of budget, timelines and regulations, the study of Kanters (2020) covering European countries highlighted broader political barriers, such as lack of political priorities and industry conservatism. Focusing on the construction sector in Turkiye, this study reflected on the challenges to circular economy implementation, particularly highlighting local-level factors such as inadequate incentive policies, client reluctance, investment requirements, and missing legislation. Regional analysis can reveal that different geographical and cultural contexts, sectoral barriers, and requirements in the transition to the circular economy may vary. These differences may require varying approaches to proposed solutions and policies.

One of the study's goals was to obtain the stakeholder-enabler map by taking into account the stakeholders' perceptions. The results of this approach were also compared with the literature to understand the results of this approach. When comparing the studies based on the literature and this study based on the stakeholder approach, similarities were observed regarding the stakeholder-enabler map, but some notable differences were also seen. For example, for setting up contract

requirements and control mechanisms in the circular economy (E-P4), this enabler is paired with project professionals such as designers and contractors in the literature (Cruz Rios et al., 2021; Munaro & Tavares, 2023). However, the government was also included in this map when the stakeholder perspective was included in the assessment. Another difference is that there are different approaches in the literature for social and behavioral enablers based on awareness and knowledge. Cruz Rios et al. (2021) map the enabler with politicians, while Munaro and Tavares (2023) present a relationship assessment with project professionals. The result of this study can be presented as an intersection of both studies. Stakeholders with sufficient experience and knowledge about the lifecycle performance (E-B3) was prominent in the assessment and was associated with all stakeholders on the map. According to the SNA result, many different stakeholders (designer, consultant, client/owner, government, recyclers, and supplier/manufacturer) are identified as responsible for promoting the use of prefabricated and renewable materials (E-E4); however, in the literature, other enablers that can be mapped to E-E4 are associated with contractor and manufacturers groups as stakeholders. The results show that the stakeholder approach brings a different perspective to the literature. Assessing specific enablers in the literature from a stakeholder perspective reveals unexpected differences and priorities. For example, while certain enablers of the circular economy are associated with a particular stakeholder group in the literature, this study has shown the influence of a wide range of stakeholders on these factors. This kind of stakeholder-driven analysis can offer a more comprehensive and diversified perspective on the circular economy, which can inspire future work and open new directions for research.

According to the survey results, the order in which participants score enablers differs from the primary enablers that emerge in the stakeholder-enabler map due to the SNA analysis. For example, the creation of a tax deduction for CE-specific design strategies (E-E5) has the 2nd highest score among the enablers from the stakeholder perspective; however, when looking at the SNA results, it was only linked to the government, having lower centrality scales and less prominence. In addition,

applying lean principles to reduce waste (E-T2) was one of the lowest-ranked enablers according to the scoring results, despite having the highest centrality degrees in relation to all stakeholders according to the SNA results. While the SNA analysis derives the network structure based on the explicit preferences or statements expressed by the participants, the survey results usually include evaluations based on a certain structure or predetermined options. The Stakeholder-Enabler Map focuses on visualizing connections and interactions, while the survey ranking can provide a more structured prioritization. The difference between these two methodologies affects how respondents express their opinions and preferences.

These differences may be due to stakeholders' experience, specialization, and responsibilities. Some stakeholders may score specific enablers, while others may assess the importance of these enablers differently. One of the underlying reasons for this may be that stakeholders do not know enough about the circular economy. In this case, there may be uncertainty or mistrust in setting priorities. Another reason is stakeholders' willingness to take on roles or responsibilities. Some enablers or barriers may not be under a stakeholder group's control or responsibility. There may be a reluctance to prioritize or effectively address these enablers in this case. This can lead to differences in prioritization between different stakeholder groups. Finally, stakeholders' experience, knowledge, and areas of role/influence may lead to differences in the relative importance of certain enablers. Therefore, observing the diversity and different perspectives among different stakeholder groups is also essential.

Social Network Analysis (SNA) provides a critical guide for the transition to a circular economy in the construction sector. This analysis is a key tool for understanding the relationships, collaborations and communication networks of stakeholders in the sector. The data revealed by the SNA provides important guidance for strengthening strategic collaborations, addressing communication gaps and overcoming barriers. The results form the basis for identifying critical stakeholders in the sector and developing deeper collaborations between them. By identifying strategies to strengthen communication networks and address gaps,

information flow and cooperation can be enhanced. Furthermore, strategies to overcome the barriers identified by the SNA can guide policy changes, the development of new projects and the promotion of innovation in the sector.

SNA results also provide important guidance for policy makers and regulators. Changes to existing policies and regulations provide an important opportunity to support the transition to a circular economy and reduce barriers in the sector. However, this process requires continuous monitoring and evaluation, as strategies and policies need to be flexible to adapt to changing dynamics.

Removing barriers for the development of the circular economy should be approached from a broad perspective. This process requires a multi-pronged approach, including regulatory changes, economic incentives, education and adaptation of businesses to the transformation process. The convergence of actions in these different areas will play a critical role in advancing the circular economy and building a more sustainable future.

Existing regulations that limit the progress of the circular economy can make it difficult to set up recycling facilities or prevent the use of reusable materials. To remove these barriers, it is important for policymakers and regulators to put in place regulations and economic incentives that encourage recycling. For example, providing tax breaks for the installation of recycling facilities or economic incentives that encourage recycling can facilitate the sector's adaptation.

Education and awareness play a critical role for circular economy adoption. Community education programs and internal awareness campaigns can highlight the benefits of the circular economy and make people more willing to support the transition to this model. However, businesses in the sector need to adapt to the transformation process. For example, it is important for businesses to revise their existing business models and processes for waste reduction or recycling-oriented production. Guiding and supporting companies through this transformation process can accelerate the adoption of the circular economy.

In conclusion, removing existing barriers for the circular economy to move forward requires strategic steps in several areas, such as policy changes, economic incentives, education and adaptation of businesses to the transformation process. A combination of these steps is important for the circular economy to become mainstream and move towards a sustainable future.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

This chapter presents the summary and conclusion of the study. First, an overview of the study is presented. Second, the contribution of the study is discussed. Finally, it presents the limitations of the study and concludes with research recommendations.

5.1 Summary of the Study

The construction sector is one of the largest sectors that produces a large amount of waste and has a negative impact on the environment. Waste generated during the production of building materials, during the construction of buildings and after their demolition can cause serious problems in terms of environmental impacts. Circular economy is an important sustainability approach for the construction sector. Circular economy promotes sustainable practices in the construction sector to reduce these negative impacts, minimize waste generation and use resources more efficiently. While the traditional linear economy model takes resources and pushes them out as waste after use, the circular economy aims to reuse, recycle and conserve their value. Furthermore, the economic benefits of the circular economy in the construction industry cannot be overlooked; longer-lasting structures, reduced waste management costs, new markets and business opportunities can offer significant advantages for stakeholders in the industry.

There are some significant barriers to the transition of the circular economy to the construction sector. These barriers include lack of technological innovation, existing designs are not suitable for circular practices, lack of awareness about the circular economy, inadequate legislation and regulations, and economic models are not

conducive to promoting sustainable practices. Various enablers are proposed to overcome these barriers. Technologically more efficient and sustainable building materials need to be developed, waste management systems need to be improved and recycling processes need to be enhanced. It is also important that legislation is more inclusive and supportive, that economic incentives reward circular practices and that awareness of sustainability is raised. Overcoming these barriers can lead to more effective adoption and implementation of the circular economy in the construction sector. The gap of the literature is the lack of understanding of the roles of stakeholders from the stakeholders' perspective.

In order to better understand the status of the circular economy in the sector, a survey was conducted. It was aimed to distribute the questionnaire to stakeholders in different fields of work in the construction sector in Turkiye. Forty-one participants responded to the questionnaire and evaluations were made accordingly. Having participants from different stakeholder groups (designer, public official, contractor, researcher, consultant, etc.) provides the opportunity to evaluate barriers and enablers from different perspectives.

To understand these perspectives, a network of stakeholders and enablers is presented to map the relationship between them. Scores from the survey results help to understand which barriers or enablers are prominent, while Social Network Analysis (SNA) was used to collect the necessary data for mapping the relationships between stakeholders.

This mapping are essential step in understanding the relationships and interactions of stakeholders and enablers in the construction industry, as the approach of stakeholders in the sector is taken into account. The network map visualizes the relationships of different stakeholders and enablers with each other and their importance in these relationships. This type of visualization clarifies the positions and interactions of stakeholders and enablers within the network. In particular, it has the potential to show which stakeholders play a more central role. This data can

support the potential for collaboration in the sector, resource management and the development of strategies in the transformation process.

5.2 Contributions of the Study

A literature review was conducted to identify barriers and enablers to CE concepts. Barriers and enablers were interpreted by evaluating the scores obtained from the survey. As a result of the evaluations made in the range of 1 - 7, it was seen that the scores of all barriers were greater than 4.5. Although there is no direct prominence as all scores are close to each other, inadequate incentive and support policies (P2), unwillingness to pay for a new concept / competition (E3), more investment requirements (E5) and lack of regulations and laws (P1) received higher scores. This shows that political and economic barriers are more important for stakeholders in the construction sector in Turkiye. Likewise, the scores for enablers were also higher than 5. The enablers of establishing contractual requirements and control mechanisms (E-P4), creating tax deduction (E-E5), developing financial incentives for the use of secondary materials and cooperation between companies (E-E3) and changing people's perspectives on circular economy (E-B4) were given higher scores by stakeholders. Comparisons with articles in the literature highlighted results from different countries. Focusing on the construction sector in Turkiye, this study reflected on the barriers to the implementation of the circular economy, particularly highlighting local level factors such as inadequate incentive policies, customer reluctance, investment requirements and missing legislation.

The SNA method was used to identify the role of stakeholders on enablers from the stakeholders' perspective. The results obtained from the survey were analyzed with Social Network and stakeholder-enabler maps were created. Although the results are consistent with the literature, when the stakeholder perspective is included, the analysis also included stakeholders that may have been ignored and linked them to the enablers. Due to the use of SNA, a network map is presented, which clearly shows the interrelationship between stakeholders and enablers. Also the

collaborations and networks that need to be created between stakeholders in order to adapt the circular economy to the construction sector are clearly presented. In this sense, it is seen that the study has a broader perspective in general. Government is the most frequently mapped stakeholder with enablers, while recycler and supplier/manufacturer groups also have high centrality values.

The results of the analysis were evaluated by taking into account the experience and knowledge level of the stakeholders and their fields of work. In this sense, as there are no significant differences between the scores when the experience levels are considered, SNA was not evaluated for this group. For knowledge level, it was observed that stakeholders exhibited a more centralized approach as the level increased. In terms of professional backgrounds, it was found that the contractor/subcontractor and design / engineering and management consultant groups did not include themselves much in the relationship assessment and did not prioritize themselves in terms of taking responsibility.

5.3 Limitations and Recommendations of the Study

The limitations of the study are that the surveys have been conducted with a number of respondents in Turkiye.

As the survey respondents reflect the Turkish perspective, a broader study may be useful to understand and interpret different views.

When the perspective of Turkish stakeholders is evaluated, the priorities also showed different results from the literature, indicating that there is a difference in perception with the respondents of other studies. However, the overall high scores suggest that stakeholders in Turkiye are not very different in their awareness of the circular economy.

In this study, although participants from each stakeholder group were invited, there was not a balanced participation. As some stakeholder groups (government, recycler

etc.) participated in smaller numbers, the results may not be as comprehensive as desired. Future research could include a more balanced and well attended survey.

There are respondents who are experienced in the sector but not sufficiently knowledgeable about the circular economy. A larger study with a more informed participant profile may yield more efficient results.

Researchers at the university were not included in the relationship map, observing the sector as an outside observer. In the future, it is suggested that this stakeholder group be included in the relationship assessment. However, universities are thought to provide a more objective perspective on the development of circular economy strategies, so it is not thought to make a big difference in the results.

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APPENDICES

A. Survey

TRANSITIONING TO A CIRCULAR ECONOMY IN THE CONSTRUCTION INDUSTRY

Explanation

My name is Zelal Köksal. I am currently working on my Master's Thesis with my advisor Dr. Güzide ATASOY ÖZCAN, in the field of Construction Engineering and Management at Middle East Technical University.

This is an opinion survey based on voluntary participation; connectedly, no confidential information about yourself or your company is required for this study. The responses will be used anonymously.

This study aims to collect information and data about the awareness of the construction and relate sector professionals regarding the barriers and enablers of the circular economy concept for transitioning to the construction sector.

The collected information will be used to prioritize the barriers and enablers of the circular economy through the construction sector.

The survey consists of two sections. The first section of the survey includes demographical questions, including profession, experience level, and department. In the second section of the survey, brief information is provided regarding the circular economy and construction sector. Then, comparison matrices are asked to understand participants' perspectives on the importance of circular economy related barriers and enablers.

This questionnaire consists of 22 main questions and arguments for your returns, and the expected duration is no longer than 20 minutes.

This survey is conducted with the approval of the METU (ODTÜ IAEK) Ethics Committee.

Thank you for your valuable time and participation.

* Zorunlu soruyu belirtir

Demographics

1. 1. Your background: *

Yalnızca bir şıkkı işaretleyin.

- ◯ Civil Engineer
- ◯ Architecture
- ◯ Mechanical Engineer
- ◯ Environmental Engineer
- ◯ Electrical Engineer
- ◯ Diğer: _____

2. 2. The company or institution you are working, or you have worked for: *

Uygun olanların tümünü işaretleyin.

- ☐ Design / Engineering or Management Consultancy
- ☐ Client / Owner
- ☐ Government
- ☐ Supplier / Manufacturer
- ☐ Recycler
- ☐ Contractor / Subcontractor
- ☐ University
- ☐ End User
- ☐ Diğer: _____

3. 3. Your department in the company/institution: *

Uygun olanların tümünü işaretleyin.

- ☐ Procurement
- ☐ Tendering
- ☐ Marketing
- ☐ Design
- ☐ Recycling
- ☐ Site
- ☐ Progress Payment
- ☐ Planning
- ☐ Researching
- ☐ End User
- ☐ Diğer: _____

4. 4. About your experience level *

Yalnızca bir şıkkı işaretleyin.

- ◯ Less than 2 years
- ◯ 2 – 5 years
- ◯ 5 – 10 years
- ◯ 10 – 15 years
- ◯ 15 – 20 years
- ◯ 20 – 30 years
- ◯ More than 30 years

Brief Explanation About Circular Economy in Construction Sector

In the construction sector, raw material demand and consumption are increasing. The increase in population and infrastructure needs affect these with the development of conditions and technology Construction is one of the world's largest consumers of raw materials and producers of waste, given the escalating needs. In the construction industry, resource use and waste management are approached from two different perspectives: the linear economy and the circular economy. The linea economy model, which is based on high natural resource consumption and ignores resource recovery, has been questioned due to the growing problems with climate change and resource scarcity. As a result, a new practice is required to reduce this consumption and the amount of waste Linear economy usually focuses on raw material extraction and product manufacturing, and disposing of the materials as waste after their intended use. The circular economy, on the other hand, aims to minimize resource consumption by encouraging the reuse, recycling, and recovery of materials throughout their life cycle. It seeks to close/narrow the resource cycle by keeping material in use for as long as possible. The use of the circular economy (CE) model has gained attention and has been studied in recent years due to the rise in recycling demand within the sector globally, as well as the desire to reduce carbon emissions and material consumption.

The stakeholders in the construction sector generally prioritize cost efficiency and durability during the design and construction in the linear economy. A more holistic approach considering the entire lifecycle is encouraged by circular economy principles. The linear economy frequently involves siloe operations and little cross-sector cooperation. The circular economy, on the other hand, necessitate cooperation between designers, builders, suppliers, waste management organizations, and other stakeholders in order to optimize material flows, share resources, and create novel solutions. Due to the need for collaborative, interdisciplinary work in terms of better consumption and waste management strategies, certain practices requiring the involvement of various stakeholders are necessary for transitioning into the circular economy.

5. 1. Have you ever encountered a circular practice (for instance, design for deconstruction zero waste, recycling, reusing) in construction projects or the sector?
(If your answer is yes, and you think that the topic is not confidential, please mention it briefly.)

Yalnızca bir şıkkı işaretleyin.

- ◯ Yes
- ◯ No
- ◯ Diğer: _____

6. 2. Which stakeholders should you collaborate with for adapting the circular economy to the construction sector?

Uygun olanların tümünü işaretleyin.

- [ ] Design / Engineering or Management Consultancy
- [ ] Client / Owner
- [ ] Government
- [ ] Supplier / Manufacturer
- [ ] Recycler
- [ ] Contractor / Subcontractor
- [ ] University
- [ ] End User
- [ ] Diğer: _____

7. 3. How would you rate your knowledge level in terms of circular economy from a 1 to 5 scale?

(Please select the number. (NA – not applicable, 1- very low, 2 – low, 3 – average, 4 – high, 5 – excellent)

Yalnızca bir şıkkı işaretleyin.

- ◯ 1- very low
- ◯ 2- low
- ◯ 3 - average
- ◯ 4 - high
- ◯ 5 - excellent
- ◯ NA - Not Applicable

8. 4. On a scale of 1 to 5, please indicate your level of influence in the decision-making process during the adaptation of the circular economy.

(Please select the number.) (0 – not applicable, 1- very low, 2 – low, 3 – average, 4 – high, 5 – excellent)

Yalnızca bir şıkkı işaretleyin.

- ◯ 1 - very low
- ◯ 2 - low
- ◯ 3 - average
- ◯ 4 - high
- ◯ 5 - excellent
- ◯ NA - Not Applicable

9. 5. How would you rate your willingness to follow circular economy practices from a 1 to 5 scale?

(Please select the number. (0 – not applicable, 1- unwilling, 2 – maybe not, 3 – neutral, 4 – interested, 5 – definitely)

Yalnızca bir şıkkı işaretleyin.

- ◯ 1 - unwilling
- ◯ 2 - maybe not
- ◯ 3 - neutral
- ◯ 4 - interested
- ◯ 5 - definetely
- ◯ NA - Not Applicable

10. 6. Please indicate how frequently implement the circular economy in your organization's work and/or projects.

(Please select the number.) (0 – not applicable, 1- very seldom, 2 – seldom, 3 – sometimes, 4 – often, 5 – very often)

Yalnızca bir şıkkı işaretleyin.

- ◯ 1 - very seldom
- ◯ 2 - seldom
- ◯ 3 - sometimes
- ◯ 4 - often
- ◯ 5 - very often
- ◯ NA - Not Applicable

Barriers to Adopting Circular Economy in the Construction Sector

The circular economy cannot widely practiced. According to literature, there are many barriers for a successful CE implementation. We would like to get your input in terms of severity of these barriers.

Please give the score for each barrier within the given groups for the next 5 questions.

We expect you to give a score for each barrier starting from 1 to 7 according to its priority. (1 will represent the least important barrier and the importance of the barriers will increase with increasing number of rows).

(1 - not a priority, 2 - low priority, 3 - somewhat a priority, 4 - neutral, 5 - moderate priority, 6 - high priority, 7 - essential priority)

1. Social and Behavioral Barriers

You should score the given social and behavioral barrier according to prioritization. The number chosen will describe the importance of the barriers to you. We expect you to give a score for eac barrier starting from 1 to 7 according to its priority.

List of Sub-barriers of Social and Behavioral barriers

Þ **B1** Lack of stakeholders' knowledge, awareness, interest and experiences of circular design, CE, and end-of-life strategies and benefits

Þ **B2** Lack of public awareness of life cycle costs and benefits (Social pressure, negative perception)

Þ **B3** Lack of literature and appropriate training-development programs on CE barriers

Þ **B4** Lack of trust and communication

Þ **B5** Conservative sector; risk aversion / resistance to change

11. 1.1. Please give a score for the level of importance of the given "***Lack of stakeholders' knowledge, awareness, interest and experiences of circular design, CE, and end-of-life strategies and benefits (B1)***" barrier for circular economy implementation in the construction sector using the value concepts given.
(1 - not a priority, 2 - low priority, 3 - somewhat a priority, 4 - neutral, 5 - moderate priority, - high priority, 7 - essential priority)

Yalnızca bir şıkkı işaretleyin.

1	2	3	4	5	6	7
◯	◯	◯	◯	◯	◯	◯

12. 1.2. Please give a score for the level of importance of the given "***Lack of public awareness of life cycle costs and benefits (Social pressure, negative perception) (B2)***" barrier for circular economy implementation in the construction sector using the value concepts given.
(1 - not a priority, 2 - low priority, 3 - somewhat a priority, 4 - neutral, 5 - moderate priority, - high priority, 7 - essential priority)

Yalnızca bir şıkkı işaretleyin.

1	2	3	4	5	6	7
◯	◯	◯	◯	◯	◯	◯

13. 1.3. Please give a score for the level of importance of the given "***Lack of literature and appropriate training-development programs on CE barriers (B3)***" barrier for circular economy implementation in the construction sector using the value concepts given.
(1 - not a priority, 2 - low priority, 3 - somewhat a priority, 4 - neutral, 5 - moderate priority, 6 - high priority, 7 - essential priority)

Yalnızca bir şıkkı işaretleyin.

1	2	3	4	5	6	7
◯	◯	◯	◯	◯	◯	◯

14. 1.4. Please give a score for the level of importance of the given "***Lack of trust and communication (B4)***" barrier for circular economy implementation in the construction sector using the value concepts given.
(1 - not a priority, 2 - low priority, 3 - somewhat a priority, 4 - neutral, 5 - moderate priority, 6 - high priority, 7 - essential priority)

Yalnızca bir şıkkı işaretleyin.

1	2	3	4	5	6	7
◯	◯	◯	◯	◯	◯	◯

15. 1.5. Please give a score for the level of importance of the given "***Conservative sector; risk aversion / resistance to change (B5)***" barrier for circular economy implementation in the construction sector using the value concepts given.
(1 - not a priority, 2 - low priority, 3 - somewhat a priority, 4 - neutral, 5 - moderate priority, 6 - high priority, 7 - essential priority)

Yalnızca bir şıkkı işaretleyin.

1	2	3	4	5	6	7
◯	◯	◯	◯	◯	◯	◯

2. Economic Barriers

You should score the given economic barriers according to prioritization. The numbers chosen w describe the importance of the barriers to you. We expect you to give a score for each barrier starting from 1 to 7 according to its priority.

List of Sub-barriers of Economic barriers

Þ **E1** Lack or underdevelopment of the market mechanism and business management for recovery

Þ **E2** Cost and Schedule constraints, including project constraints, low profit margins (Uncertain financial situation for CE /High financial risk)

Þ **E3** The customer's unwillingness or un-readiness to pay for the new concept / Competiti

Þ **E4** Lower costs of virgin materials/ Higher costs of recycled materials and disposal

Þ **E5** More investment requirement (Quick investment expectation of the customer)

16. 2.1. Please give a score for the level of importance of the given "***Lack or underdevelopment of the market mechanism and business management for recovery (E1)***" barrier for circular economy implementation in the construction sector usin the value concepts given.
(1 - not a priority, 2 - low priority, 3 - somewhat a priority, 4 - neutral, 5 - moderate priority, - high priority, 7 - essential priority)

Yalnızca bir şıkkı işaretleyin.

1	2	3	4	5	6	7
◯	◯	◯	◯	◯	◯	◯

17. 2.2. Please give a score for the level of importance of the given "***Cost and Schedule constraints, including project constraints, low profit margins (Uncertain financial situation for CE /High financial risk) (E2)***" barrier for circular economy implementation in the construction sector using the value concepts given.
(1 - not a priority, 2 - low priority, 3 - somewhat a priority, 4 - neutral, 5 - moderate priority, - high priority, 7 - essential priority)

Yalnızca bir şıkkı işaretleyin.

1	2	3	4	5	6	7
◯	◯	◯	◯	◯	◯	◯

18. 2.3. Please give a score for the level of importance of the given "***The customer's unwillingness or un-readiness to pay for the new concept / Competition (E3)***" barrier for circular economy implementation in the construction sector using the value concepts given.
(1 - not a priority, 2 - low priority, 3 - somewhat a priority, 4 - neutral, 5 - moderate priority, 6 - high priority, 7 - essential priority)

Yalnızca bir şıkkı işaretleyin.

1	2	3	4	5	6	7
◯	◯	◯	◯	◯	◯	◯

19. 2.4. Please give a score for the level of importance of the given "***Lower costs of virgin materials/ Higher costs of recycled materials and disposal (E4)***" barrier for circular economy implementation in the construction sector using the value concepts given.
(1 - not a priority, 2 - low priority, 3 - somewhat a priority, 4 - neutral, 5 - moderate priority, 6 - high priority, 7 - essential priority)

Yalnızca bir şıkkı işaretleyin.

1	2	3	4	5	6	7
◯	◯	◯	◯	◯	◯	◯

20. 2.5. Please give a score for the level of importance of the given "***More investment requirement (Quick investment expectation of the customer) (E5)***" barrier for circular economy implementation in the construction sector using the value concepts given.
(1 - not a priority, 2 - low priority, 3 - somewhat a priority, 4 - neutral, 5 - moderate priority, 6 - high priority, 7 - essential priority)

Yalnızca bir şıkkı işaretleyin.

1	2	3	4	5	6	7
◯	◯	◯	◯	◯	◯	◯

3. Political and Legislative Barriers

You should score the given political and legislative barriers according to prioritization. The numbers chosen will describe the importance of the barriers to you. We expect you to give a scc for each barrier starting from 1 to 7 according to its priority.

List of Sub-barriers of Political and Legislative barriers

Þ **P1** Lack of specific regulations, legislations and laws for CE implementation in the secto

Þ **P2** Inadequate incentive and support policies for end-of-life and CE

Þ **P3** Warranty and quality issues of using reused/recycled products.

Þ **P4** Lack of technical specifications and standards for reused and recycled building products

21. 3.1. Please give a score for the level of importance of the given "***Lack of specific regulations, legislations and laws for CE implementation in the sector (P1)***" barrier fo circular economy implementation in the construction sector using the value concepts given.
(1 - not a priority, 2 - low priority, 3 - somewhat a priority, 4 - neutral, 5 - moderate priority, - high priority, 7 - essential priority)

Yalnızca bir şıkkı işaretleyin.

1	2	3	4	5	6	7
◯	◯	◯	◯	◯	◯	◯

22. 3.2. Please give a score for the level of importance of the given "***Inadequate incentive and support policies for end-of-life and CE (P2)***" barrier for circular economy implementation in the construction sector using the value concepts given.
(1 - not a priority, 2 - low priority, 3 - somewhat a priority, 4 - neutral, 5 - moderate priority, - high priority, 7 - essential priority)

Yalnızca bir şıkkı işaretleyin.

1	2	3	4	5	6	7
◯	◯	◯	◯	◯	◯	◯

23. 3.3. Please give a score for the level of importance of the given "***Warranty and quality issues of using reused/recycled products (P3)***" barrier for circular economy implementation in the construction sector using the value concepts given.
(1 - not a priority, 2 - low priority, 3 - somewhat a priority, 4 - neutral, 5 - moderate priority, - high priority, 7 - essential priority)

Yalnızca bir şıkkı işaretleyin.

1	2	3	4	5	6	7
◯	◯	◯	◯	◯	◯	◯

24. 3.4. Please give a score for the level of importance of the given "***Lack of technical specifications and standards for reused and recycled building products (P4)***" barrier for circular economy implementation in the construction sector using the value concepts given.
(1 - not a priority, 2 - low priority, 3 - somewhat a priority, 4 - neutral, 5 - moderate priority, - high priority, 7 - essential priority)

Yalnızca bir şıkkı işaretleyin.

1	2	3	4	5	6	7
◯	◯	◯	◯	◯	◯	◯

4. Technical Barriers

You should score the given technical barriers according to prioritization. The numbers chosen w describe the importance of the barriers to you. We expect you to give a score for each barrier starting from 1 to 7 according to its priority.
List of Sub-barriers of technical barriers

Þ **T1** Uncertain product content of CE materials, lack of material alternatives, and problem in material classification

Þ **T2** Lack of standardization and transportability of building components

Þ **T3** Uncertainty and lack of awareness about future spatial needs/demands, end-of-life, a recycling of building materials

Þ **T4** Complexity of building design & design phase / Lack of circularity in design

Þ **T5** Lack of data, data management, and visualization / Lack of tools and information to identify circularity metrics

Þ **T6** Lack of necessary technology and infrastructure for salvaged components / Lack of connection between digital design technologies and environmental sustainability tools

25. 4.1. Please give a score for the level of importance of the given "***Uncertain product content of CE materials, lack of material alternatives, and problems in material classification (T1)***" barrier for circular economy implementation in the construction sector using the value concepts given.
(1 - not a priority, 2 - low priority, 3 - somewhat a priority, 4 - neutral, 5 - moderate priority, - high priority, 7 - essential priority)

Yalnızca bir şıkkı işaretleyin.

1	2	3	4	5	6	7
◯	◯	◯	◯	◯	◯	◯

26. 4.2. Please give a score for the level of importance of the given "***Lack of standardization and transportability of building components (T2)***" barrier for circular economy implementation in the construction sector using the value concepts given.
(1 - not a priority, 2 - low priority, 3 - somewhat a priority, 4 - neutral, 5 - moderate priority, - high priority, 7 - essential priority)

Yalnızca bir şıkkı işaretleyin.

1	2	3	4	5	6	7
◯	◯	◯	◯	◯	◯	◯

27. 4.3. Please give a score for the level of importance of the given "***Uncertainty and lack of awareness about future spatial needs/demands, end-of-life, and recycling of buildin materials (T3)***" barrier for circular economy implementation in the construction sector using the value concepts given.
(1 - not a priority, 2 - low priority, 3 - somewhat a priority, 4 - neutral, 5 - moderate priority, - high priority, 7 - essential priority)

Yalnızca bir şıkkı işaretleyin.

1	2	3	4	5	6	7
◯	◯	◯	◯	◯	◯	◯

28. 4.4. Please give a score for the level of importance of the given "***Complexity of building design & design phase / Lack of circularity in design (T4)***" barrier for circular economy implementation in the construction sector using the value concepts given.
(1 - not a priority, 2 - low priority, 3 - somewhat a priority, 4 - neutral, 5 - moderate priority, - high priority, 7 - essential priority)

Yalnızca bir şıkkı işaretleyin.

1	2	3	4	5	6	7
◯	◯	◯	◯	◯	◯	◯

29. 4.5. Please give a score for the level of importance of the given "***Lack of data, data management, and visualization / Lack of tools and information to identify circularity metrics (T5)***" barrier for circular economy implementation in the construction sector using the value concepts given.
(1 - not a priority, 2 - low priority, 3 - somewhat a priority, 4 - neutral, 5 - moderate priority, - high priority, 7 - essential priority)

Yalnızca bir şıkkı işaretleyin.

1	2	3	4	5	6	7
◯	◯	◯	◯	◯	◯	◯

30. 4.6. Please give a score for the level of importance of the given "***Lack of necessary technology and infrastructure for salvaged components / Lack of connection between digital design technologies and environmental sustainability tools (T6)***" barrier for circular economy implementation in the construction sector using the value concepts given.
(1 - not a priority, 2 - low priority, 3 - somewhat a priority, 4 - neutral, 5 - moderate priority, - high priority, 7 - essential priority)

Yalnızca bir şıkkı işaretleyin.

1	2	3	4	5	6	7
◯	◯	◯	◯	◯	◯	◯

Comparisons of Enablers of Circular Economy for transitioning to the Construction Sector

Please give the score for each enabler within the given groups for the next 5 questions.

We expect you to give a score for each enabler starting from 1 to 7 according to its priority. (1 will represent the least important enabler and the importance of the enablers will increase with increasing number of rows).

(1 - not a priority, 2 - low priority, 3 - somewhat a priority, 4 - neutral, 5 - moderate priority, 6 - high priority, 7 - essential priority)

1. Social and Behavioral Enablers

You should score the given social and behavioral enablers according to prioritization. The numb chosen will describe the importance of the enablers to you. We expect you to give a score for ea enabler starting from 1 to 7 according to its priority.

List of Sub-Enablers of social and behavioral enablers

Þ **E-B1** Making necessary practices to raise awareness and knowledge

Þ **E-B2** Having some form of manufacturer responsibility for construction products

Þ **E-B3** Adequate experience and knowledge of stakeholders about the performance of the lifecycle

Þ **E-B4** Changing people's perception and perspective on circular economy

31. 1.1. Please give a score for the level of importance of the given "***Making necessary practices to raise awareness and knowledge (E-B1)***" enabler for circular economy implementation in the construction sector using the value concepts given.
(1 - not a priority, 2 - low priority, 3 - somewhat a priority, 4 - neutral, 5 - moderate priority, - high priority, 7 - essential priority)

Yalnızca bir şıkkı işaretleyin.

1	2	3	4	5	6	7
◯	◯	◯	◯	◯	◯	◯

32. 1.2. Please give a score for the level of importance of the given "***Having some form of manufacturer responsibility for construction products (E-B2)***" enabler for circular economy implementation in the construction sector using the value concepts given.
(1 - not a priority, 2 - low priority, 3 - somewhat a priority, 4 - neutral, 5 - moderate priority, 6 - high priority, 7 - essential priority)

Yalnızca bir şıkkı işaretleyin.

1	2	3	4	5	6	7
◯	◯	◯	◯	◯	◯	◯

33. 1.3. Please give a score for the level of importance of the given "***Adequate experience and knowledge of stakeholders about the performance of the lifecycle (E-B3)***" enabler for circular economy implementation in the construction sector using the value concepts given.
(1 - not a priority, 2 - low priority, 3 - somewhat a priority, 4 - neutral, 5 - moderate priority, 6 - high priority, 7 - essential priority)

Yalnızca bir şıkkı işaretleyin.

1	2	3	4	5	6	7
◯	◯	◯	◯	◯	◯	◯

34. 1.4. Please give a score for the level of importance of the given "***Changing people's perception and perspective on circular economy (E-B4)***" enabler for circular economy implementation in the construction sector using the value concepts given.
(1 - not a priority, 2 - low priority, 3 - somewhat a priority, 4 - neutral, 5 - moderate priority, 6 - high priority, 7 - essential priority)

Yalnızca bir şıkkı işaretleyin.

1	2	3	4	5	6	7
◯	◯	◯	◯	◯	◯	◯

2. Economic Enablers

You should score the given economic enablers according to prioritization. The numbers chosen describe the importance of the enablers to you. We expect you to give a score for each enabler starting from 1 to 7 according to its priority.

List of Sub-Enablers of economic enablers

Þ **E-E1** Ensuring the recovery of materials logistically and commercially

Þ **E-E2** Developing markets and enabling technologies

Þ **E-E3** Development of financial incentives to use secondary materials and for collaboration between companies

Þ **E-E4** Promoting the use of more prefabricated, organic, environmentally friendly and renewable materials

Þ **E-E5** Creating tax deductions for CE design strategies

35. 2.1. Please give a score for the level of importance of the given "***Ensuring the recovery o materials logistically and commercially (E-E1)***" enabler for circular economy implementation in the construction sector using the value concepts given.
(1 - not a priority, 2 - low priority, 3 - somewhat a priority, 4 - neutral, 5 - moderate priority, - high priority, 7 - essential priority)

Yalnızca bir şıkkı işaretleyin.

1	2	3	4	5	6	7
◯	◯	◯	◯	◯	◯	◯

36. 2.2. Please give a score for the level of importance of the given "***Developing markets an enabling technologies (E-E2)***" enabler for circular economy implementation in the construction sector using the value concepts given.
(1 - not a priority, 2 - low priority, 3 - somewhat a priority, 4 - neutral, 5 - moderate priority, - high priority, 7 - essential priority)

Yalnızca bir şıkkı işaretleyin.

1	2	3	4	5	6	7
◯	◯	◯	◯	◯	◯	◯

37. 2.3. Please give a score for the level of importance of the given "***Development of financial incentives to use secondary materials and for collaboration between companies (E-E3)***" enabler for circular economy implementation in the construction secto using the value concepts given.
(1 - not a priority, 2 - low priority, 3 - somewhat a priority, 4 - neutral, 5 - moderate priority, - high priority, 7 - essential priority)

Yalnızca bir şıkkı işaretleyin.

1	2	3	4	5	6	7
◯	◯	◯	◯	◯	◯	◯

38. 2.4. Please give a score for the level of importance of the given "***Promoting the use of more prefabricated, organic, environmentally friendly and renewable materials (E-E4)***" enabler for circular economy implementation in the construction sector using the valu concepts given.
(1 - not a priority, 2 - low priority, 3 - somewhat a priority, 4 - neutral, 5 - moderate priority, - high priority, 7 - essential priority)

Yalnızca bir şıkkı işaretleyin.

1	2	3	4	5	6	7
◯	◯	◯	◯	◯	◯	◯

39. 2.5. Please give a score for the level of importance of the given "***Creating tax deductions for CE design strategies (E-E5)***" enabler for circular economy implementation in the construction sector using the value concepts given.
(1 - not a priority, 2 - low priority, 3 - somewhat a priority, 4 - neutral, 5 - moderate priority, 6 - high priority, 7 - essential priority)

Yalnızca bir şıkkı işaretleyin.

1	2	3	4	5	6	7
◯	◯	◯	◯	◯	◯	◯

3. Political and Legislative Enablers

You should score the given political and legislative enablers according to prioritization. The numbers chosen will describe the importance of the enablers to you. We expect you to give a score for each enabler starting from 1 to 7 according to its priority.
List of Sub-Enablers of political and legislative enablers

Þ **E-P1** Setting legislation and using standards to develop strategies

Þ **E-P2** Establishment and implementation of zero waste policies

Þ **E-P3** Creating national and regional CE action plans

Þ **E-P4** Setting contract requirements and control mechanisms for material and product qual assigning responsibility to manufacturers and users

40. 3.1. Please give a score for the level of importance of the given "***Setting legislation and using standards to develop strategies (E-P1)***" enabler for circular economy implementation in the construction sector using the value concepts given.
(1 - not a priority, 2 - low priority, 3 - somewhat a priority, 4 - neutral, 5 - moderate priority, 6 - high priority, 7 - essential priority)

Yalnızca bir şıkkı işaretleyin.

1	2	3	4	5	6	7
◯	◯	◯	◯	◯	◯	◯

41. 3.2. Please give a score for the level of importance of the given "***Establishment and implementation of zero waste policies (E-P2)***" enabler for circular economy implementation in the construction sector using the value concepts given.
(1 - not a priority, 2 - low priority, 3 - somewhat a priority, 4 - neutral, 5 - moderate priority, 6 - high priority, 7 - essential priority)

Yalnızca bir şıkkı işaretleyin.

1	2	3	4	5	6	7
◯	◯	◯	◯	◯	◯	◯

42. 3.3. Please give a score for the level of importance of the given "***Creating national and regional CE action plans (E-P3)***" enabler for circular economy implementation in the construction sector using the value concepts given.
(1 - not a priority, 2 - low priority, 3 - somewhat a priority, 4 - neutral, 5 - moderate priority, 6 - high priority, 7 - essential priority)

Yalnızca bir şıkkı işaretleyin.

1	2	3	4	5	6	7
◯	◯	◯	◯	◯	◯	◯

43. 3.4. Please give a score for the level of importance of the given "***Setting contract requirements and control mechanisms for material and product quality, assigning responsibility to manufacturers and users (E-P4)***" enabler for circular economy implementation in the construction sector using the value concepts given.
(1 - not a priority, 2 - low priority, 3 - somewhat a priority, 4 - neutral, 5 - moderate priority, 6 - high priority, 7 - essential priority)

Yalnızca bir şıkkı işaretleyin.

1	2	3	4	5	6	7
◯	◯	◯	◯	◯	◯	◯

4. Technical Enablers

You should score the given technical enablers according to prioritization. The numbers chosen v describe the importance of the enablers to you. We expect you to give a score for each enabler starting from 1 to 7 according to its priority.

List of Sub-Enablers of technical enablers

Þ **E-T1** Collaboration within supply and supply chain management activities and information sharing capabilities

Þ **E-T2** Apply lean principles to reduce waste

Þ **E-T3** Developing and using new design strategies, technologies and construction methods

Þ **E-T4** Creating and enlarging database for circular economy

44. 4.1. Please give a score for the level of importance of the given "***Collaboration within supply and supply chain management activities and information sharing capabilities (E-T1)***" enabler for circular economy implementation in the construction sect using the value concepts given.
(1 - not a priority, 2 - low priority, 3 - somewhat a priority, 4 - neutral, 5 - moderate priority, - high priority, 7 - essential priority)

Yalnızca bir şıkkı işaretleyin.

1	2	3	4	5	6	7
◯	◯	◯	◯	◯	◯	◯

45. 4.2. Please give a score for the level of importance of the given "***Apply lean principles to reduce waste (E-T2)***" enabler for circular economy implementation in the construction sector using the value concepts given.
(1 - not a priority, 2 - low priority, 3 - somewhat a priority, 4 - neutral, 5 - moderate priority, - high priority, 7 - essential priority)

Yalnızca bir şıkkı işaretleyin.

1	2	3	4	5	6	7
◯	◯	◯	◯	◯	◯	◯

46. 4.3. Please give a score for the level of importance of the given "***Developing and using new design strategies, technologies and construction methods (E-T3)***" enabler for circular economy implementation in the construction sector using the value concepts given.
(1 - not a priority, 2 - low priority, 3 - somewhat a priority, 4 - neutral, 5 - moderate priority, 6 - high priority, 7 - essential priority)

Yalnızca bir şıkkı işaretleyin.

1	2	3	4	5	6	7
◯	◯	◯	◯	◯	◯	◯

47. 4.4. Please give a score for the level of importance of the given "***Creating and enlarging database for circular economy (E-T4)***" enabler for circular economy implementation in the construction sector using the value concepts given.
(1 - not a priority, 2 - low priority, 3 - somewhat a priority, 4 - neutral, 5 - moderate priority, 6 - high priority, 7 - essential priority)

Yalnızca bir şıkkı işaretleyin.

1	2	3	4	5	6	7
◯	◯	◯	◯	◯	◯	◯

Exploring the Influence of Stakeholders on Barriers of Circular Economy for transitioning to the Construction Sector

The 2-mode network will be developed to investigate the influence of stakeholders on barriers to the adaptation of the circular economy in the construction sector. It will consist of two sets of nodes, including stakeholders and CE enablers, where the influence of stakeholders on CE enablers is represented by weighted links.

We expect you to identify the impact of each stakeholder listed in the questions on the given enablers.
When determining these impacts, you should use numbers from "1" to "5". "1" will be used for the stakeholder that has the least impact and "5" for the stakeholder that has the most impact. Each value can be used for more than one stakeholder. If you think that a stakeholder has no relation with the given enabler, you should select "0".

Social and Behavioral Enablers

1. Please indicate the impact of the following stakeholders on social and behavioral enablers the construction sector using the value concepts given. Please write only one number by using following scale:

It is assumed that the ranges from 0 to 5.

· If the value is selected as 0 (zero), the stakeholder does not impact the barrier.

· If the value is selected between 1 and 5, the stakeholder impacts the barrier.

48. 1.1. Please indicate the impact of the following stakeholders on ***Making necessary practices to raise awareness and knowledge (E-B1)*** in the construction sector using th value concepts given.

Her satırda yalnızca bir şıkkı işaretleyin.

	0	1	2	3	4	5
Contractor	◯	◯	◯	◯	◯	◯
Designer	◯	◯	◯	◯	◯	◯
Manager	◯	◯	◯	◯	◯	◯
Supplier / Manufacturer	◯	◯	◯	◯	◯	◯
Recycler	◯	◯	◯	◯	◯	◯
Government	◯	◯	◯	◯	◯	◯
Consultant	◯	◯	◯	◯	◯	◯
Client / Owner	◯	◯	◯	◯	◯	◯

49. 1.2. Please indicate the impact of the following stakeholders on ***Having some form of manufacturer responsibility for construction products (E-B2)*** in the construction sector using the value concepts given.

Her satırda yalnızca bir şıkkı işaretleyin.

	0	1	2	3	4	5
Contractor	◯	◯	◯	◯	◯	◯
Designer	◯	◯	◯	◯	◯	◯
Manager	◯	◯	◯	◯	◯	◯
Supplier / Manufacturer	◯	◯	◯	◯	◯	◯
Recycler	◯	◯	◯	◯	◯	◯
Government	◯	◯	◯	◯	◯	◯
Consultant	◯	◯	◯	◯	◯	◯
Client / Owner	◯	◯	◯	◯	◯	◯

50. 1.3. Please indicate the impact of the following stakeholders on ***Adequate experience an knowledge of stakeholders about the performance of the lifecycle (E-B3)*** in the construction sector using the value concepts given.

Her satırda yalnızca bir şıkkı işaretleyin.

	0	1	2	3	4	5
Contractor	◯	◯	◯	◯	◯	◯
Designer	◯	◯	◯	◯	◯	◯
Manager	◯	◯	◯	◯	◯	◯
Supplier / Manufacturer	◯	◯	◯	◯	◯	◯
Recycler	◯	◯	◯	◯	◯	◯
Government	◯	◯	◯	◯	◯	◯
Consultant	◯	◯	◯	◯	◯	◯
Client / Owner	◯	◯	◯	◯	◯	◯

51. 1.4. Please indicate the impact of the following stakeholders on ***Changing people's perception and perspective on circular economy (E-B4)*** in the construction sector using the value concepts given.

Her satırda yalnızca bir şıkkı işaretleyin.

	0	1	2	3	4	5
Contractor	◯	◯	◯	◯	◯	◯
Designer	◯	◯	◯	◯	◯	◯
Manager	◯	◯	◯	◯	◯	◯
Supplier / Manufacturer	◯	◯	◯	◯	◯	◯
Recycler	◯	◯	◯	◯	◯	◯
Government	◯	◯	◯	◯	◯	◯
Consultant	◯	◯	◯	◯	◯	◯
Client / Owner	◯	◯	◯	◯	◯	◯

Economic Enablers

2. Please indicate the impact of the following stakeholders on economic enablers in the construction sector using the value concepts given. Please write only one number by using following scale:

It is assumed that the ranges from 0 to 5.

· If the value is selected as 0 (zero), the stakeholder does not impact the barrier.

· If the value is selected between 1 and 5, the stakeholder impacts the barrier.

52. 2.1. Please indicate the impact of the following stakeholders on ***Ensuring the recovery o materials logistically and commercially (E-E1)*** in the construction sector using the value concepts given.

Her satırda yalnızca bir şıkkı işaretleyin.

	0	1	2	3	4	5
Contractor	◯	◯	◯	◯	◯	◯
Designer	◯	◯	◯	◯	◯	◯
Manager	◯	◯	◯	◯	◯	◯
Supplier / Manufacturer	◯	◯	◯	◯	◯	◯
Recycler	◯	◯	◯	◯	◯	◯
Government	◯	◯	◯	◯	◯	◯
Consultant	◯	◯	◯	◯	◯	◯
Client / Owner	◯	◯	◯	◯	◯	◯

53. 2.2. Please indicate the impact of the following stakeholders on ***Developing markets ana enabling technologies (E-E2)*** in the construction sector using the value concepts given.

Her satırda yalnızca bir şıkkı işaretleyin.

	0	1	2	3	4	5
Contractor	◯	◯	◯	◯	◯	◯
Designer	◯	◯	◯	◯	◯	◯
Manager	◯	◯	◯	◯	◯	◯
Supplier / Manufacturer	◯	◯	◯	◯	◯	◯
Recycler	◯	◯	◯	◯	◯	◯
Government	◯	◯	◯	◯	◯	◯
Consultant	◯	◯	◯	◯	◯	◯
Client / Owner	◯	◯	◯	◯	◯	◯

54. 2.3. Please indicate the impact of the following stakeholders on ***Development of financia incentives to use secondary materials and for collaboration between companies (E-E3)*** in the construction sector using the value concepts given.

Her satırda yalnızca bir şıkkı işaretleyin.

	0	1	2	3	4	5
Contractor	◯	◯	◯	◯	◯	◯
Designer	◯	◯	◯	◯	◯	◯
Manager	◯	◯	◯	◯	◯	◯
Supplier / Manufacturer	◯	◯	◯	◯	◯	◯
Recycler	◯	◯	◯	◯	◯	◯
Government	◯	◯	◯	◯	◯	◯
Consultant	◯	◯	◯	◯	◯	◯
Client / Owner	◯	◯	◯	◯	◯	◯

55. 2.4. Please indicate the impact of the following stakeholders on ***Promoting the use of more prefabricated, organic, environmentally friendly and renewable materials (E-E4)*** in the construction sector using the value concepts given.

Her satırda yalnızca bir şıkkı işaretleyin.

	0	1	2	3	4	5
Contractor	◯	◯	◯	◯	◯	◯
Designer	◯	◯	◯	◯	◯	◯
Manager	◯	◯	◯	◯	◯	◯
Supplier / Manufacturer	◯	◯	◯	◯	◯	◯
Recycler	◯	◯	◯	◯	◯	◯
Government	◯	◯	◯	◯	◯	◯
Consultant	◯	◯	◯	◯	◯	◯
Client / Owner	◯	◯	◯	◯	◯	◯

56. 2.5. Please indicate the impact of the following stakeholders on ***Creating tax deductions for CE design strategies (E-E5)*** in the construction sector using the value concepts given.

Her satırda yalnızca bir şıkkı işaretleyin.

	0	1	2	3	4	5
Contractor	◯	◯	◯	◯	◯	◯
Designer	◯	◯	◯	◯	◯	◯
Manager	◯	◯	◯	◯	◯	◯
Supplier / Manufacturer	◯	◯	◯	◯	◯	◯
Recycler	◯	◯	◯	◯	◯	◯
Government	◯	◯	◯	◯	◯	◯
Consultant	◯	◯	◯	◯	◯	◯
Client / Owner	◯	◯	◯	◯	◯	◯

Political and Legislative Enablers

3. Please indicate the impact of the following stakeholders on political and legislative enablers the construction sector using the value concepts given. Please write only one number by using following scale:

It is assumed that the ranges from 0 to 5.

· If the value is selected as 0 (zero), the stakeholder does not impact the barrier.

· If the value is selected between 1 and 5, the stakeholder impacts the barrier.

57. 3.1. Please indicate the impact of the following stakeholders on ***Setting legislation and using standards to develop strategies (E-P1)*** of circular economy in the construction sector using the value concepts given.

Her satırda yalnızca bir şıkkı işaretleyin.

	0	1	2	3	4	5
Contractor	◯	◯	◯	◯	◯	◯
Designer	◯	◯	◯	◯	◯	◯
Manager	◯	◯	◯	◯	◯	◯
Supplier / Manufacturer	◯	◯	◯	◯	◯	◯
Recycler	◯	◯	◯	◯	◯	◯
Government	◯	◯	◯	◯	◯	◯
Consultant	◯	◯	◯	◯	◯	◯
Client / Owner	◯	◯	◯	◯	◯	◯

58. 3.2. Please indicate the impact of the following stakeholders on ***Establishment and implementation of zero waste policies (E-P2)*** of circular economy in the construction sector using the value concepts given.

Her satırda yalnızca bir şıkkı işaretleyin.

	0	1	2	3	4	5
Contractor	◯	◯	◯	◯	◯	◯
Designer	◯	◯	◯	◯	◯	◯
Manager	◯	◯	◯	◯	◯	◯
Supplier / Manufacturer	◯	◯	◯	◯	◯	◯
Recycler	◯	◯	◯	◯	◯	◯
Government	◯	◯	◯	◯	◯	◯
Consultant	◯	◯	◯	◯	◯	◯
Client / Owner	◯	◯	◯	◯	◯	◯

59. 3.3. Please indicate the impact of the following stakeholders on ***Creating national and regional CE action plans (E-P3)*** of circular economy in the construction sector using the value concepts given.

Her satırda yalnızca bir şıkkı işaretleyin.

	0	1	2	3	4	5
Contractor	◯	◯	◯	◯	◯	◯
Designer	◯	◯	◯	◯	◯	◯
Manager	◯	◯	◯	◯	◯	◯
Supplier / Manufacturer	◯	◯	◯	◯	◯	◯
Recycler	◯	◯	◯	◯	◯	◯
Government	◯	◯	◯	◯	◯	◯
Consultant	◯	◯	◯	◯	◯	◯
Client / Owner	◯	◯	◯	◯	◯	◯

60. 3.4. Please indicate the impact of the following stakeholders on ***Setting contract requirements and control mechanisms for material and product quality, assigning responsibility to manufacturers and users (E-P4)*** of circular economy in the construction sector using the value concepts given.

Her satırda yalnızca bir şıkkı işaretleyin.

	0	1	2	3	4	5
Contractor	◯	◯	◯	◯	◯	◯
Designer	◯	◯	◯	◯	◯	◯
Manager	◯	◯	◯	◯	◯	◯
Supplier / Manufacturer	◯	◯	◯	◯	◯	◯
Recycler	◯	◯	◯	◯	◯	◯
Government	◯	◯	◯	◯	◯	◯
Consultant	◯	◯	◯	◯	◯	◯
Client / Owner	◯	◯	◯	◯	◯	◯

Technical Enablers

4. Please indicate the impact of the following stakeholders on technical enablers in the construction sector using the value concepts given. Please write only one number by using following scale:

It is assumed that the ranges from 0 to 5.

· If the value is selected as 0 (zero), the stakeholder does not impact the barrier.

· If the value is selected between 1 and 5, the stakeholder impacts the barrier.

61. 4.1. Please indicate the impact of the following stakeholders on ***Collaboration within supply and supply chain management activities and information sharing capabilities (E-T1)*** of circular economy in the construction sector using the value concept given.

Her satırda yalnızca bir şıkkı işaretleyin.

	0	1	2	3	4	5
Contractor	◯	◯	◯	◯	◯	◯
Designer	◯	◯	◯	◯	◯	◯
Manager	◯	◯	◯	◯	◯	◯
Supplier / Manufacturer	◯	◯	◯	◯	◯	◯
Recycler	◯	◯	◯	◯	◯	◯
Government	◯	◯	◯	◯	◯	◯
Consultant	◯	◯	◯	◯	◯	◯
Client / Owner	◯	◯	◯	◯	◯	◯

62. 4.2. Please indicate the impact of the following stakeholders on ***Apply lean principles to reduce waste (E-T2)*** of circular economy in the construction sector using the value concepts given.

Her satırda yalnızca bir şıkkı işaretleyin.

	0	1	2	3	4	5
Contractor	◯	◯	◯	◯	◯	◯
Designer	◯	◯	◯	◯	◯	◯
Manager	◯	◯	◯	◯	◯	◯
Supplier / Manufacturer	◯	◯	◯	◯	◯	◯
Recycler	◯	◯	◯	◯	◯	◯
Government	◯	◯	◯	◯	◯	◯
Consultant	◯	◯	◯	◯	◯	◯
Client / Owner	◯	◯	◯	◯	◯	◯

63. 4.3. Please indicate the impact of the following stakeholders on ***Developing and using new design strategies, technologies and construction methods (E-T3)*** of circular economy in the construction sector using the value concepts given.

Her satırda yalnızca bir şıkkı işaretleyin.

	0	1	2	3	4	5
Contractor	◯	◯	◯	◯	◯	◯
Designer	◯	◯	◯	◯	◯	◯
Manager	◯	◯	◯	◯	◯	◯
Supplier / Manufacturer	◯	◯	◯	◯	◯	◯
Recycler	◯	◯	◯	◯	◯	◯
Government	◯	◯	◯	◯	◯	◯
Consultant	◯	◯	◯	◯	◯	◯
Client / Owner	◯	◯	◯	◯	◯	◯

64. 4.4. Please indicate the impact of the following stakeholders on ***Creating and enlargin database for circular economy (E-T4)*** of circular economy in the construction sector using the value concepts given.

Her satırda yalnızca bir şıkkı işaretleyin.

	0	1	2	3	4	5
Contractor	◯	◯	◯	◯	◯	◯
Designer	◯	◯	◯	◯	◯	◯
Manager	◯	◯	◯	◯	◯	◯
Supplier / Manufacturer	◯	◯	◯	◯	◯	◯
Recycler	◯	◯	◯	◯	◯	◯
Government	◯	◯	◯	◯	◯	◯
Consultant	◯	◯	◯	◯	◯	◯
Client / Owner	◯	◯	◯	◯	◯	◯

Bu içerik Google tarafından oluşturulmamış veya onaylanmamıştır.

Google Formlar

B. Stakeholders' Perceptions

a. Barriers

i. Based on all survey results

Table B.1: Average score for prioritization of Social and Behavioral Barriers for all results

Social and Behavioral Barriers	B1	B2	B3	B4	B5	**AVR.**
Average scores	5.488	5.098	4.902	4.610	5.488	**5.117**

Table B.2: Average scores for prioritization of Economic Barriers for all results

Economic Barriers	E1	E2	E3	E4	E5	**AVR.**
Average scores	5.415	5.220	5.610	5.463	5.561	**5.454**

Table B.3: Average scores for prioritization of Political and Legislative Barriers for all results

Political and Legislative Barriers	P1	P2	P3	P4	**AVR.**
Average scores	5.512	5.829	5.122	5.341	**5.451**

Table B.4: Average scores for prioritization of Technical Barriers for all results

Technical Barriers	T1	T2	T3	T4	T5	T6	**AVR.**
Average scores	5.049	5.098	4.780	4.780	4.951	5.049	**4.951**

ii. Based on stakeholders' experience level

Table B.5: Average Scores for prioritization of Social and Behavioral Barriers based on stakeholders' experience level

Participant Profile		B1	B2	B3	B4	B5	**AVR.**
Average Score	Less Experienced	5.609	5.217	5.043	4.652	5.609	**5.226**
	Experienced	5.286	5.143	4.429	4.571	4.857	**4.857**
	Well Experienced	5.364	4.818	4.909	4.545	5.636	**5.055**

Table B.6: Average Scores for prioritization of Economic Barriers based on stakeholders' experience level

Participant Profile		E1	E2	E3	E4	E5	**AVR.**
Average Score	Less Experienced	5.435	5.261	5.522	5.609	5.565	**5.478**
	Experienced	5.143	4.000	5.143	5.000	6.000	**5.057**
	Well Experienced	5.545	5.909	6.091	5.455	5.273	**5.655**

Table B.7: Average Scores for prioritization of Political and Legislative Barriers based on stakeholders' experience level

Participant Profile		P1	P2	P3	P4	**AVR.**
Average Score	Less Experienced	5.522	5.696	5.304	5.174	**5.424**
	Experienced	5.714	6.714	4.429	5.000	**5.464**
	Well Experienced	5.364	5.545	5.182	5.909	**5.500**

Table B.8: Average Scores for prioritization of Technical Barriers based on stakeholders' experience level

Participant Profile		T1	T2	T3	T4	T5	T6	**AVR.**
Average Score	Less Experienced	4.870	5.000	4.696	4.870	5.087	5.130	**4.942**
	Experienced	5.286	4.714	4.286	3.857	4.286	4.571	**4.500**
	Well Experienced	5.273	5.545	5.273	5.182	5.091	5.182	**5.258**

iii. Based on stakeholders' companies' fields of activity

Table B.9: Average Scores for prioritization of Social and Behavioral Barriers based on stakeholders' companies' fields of activity

Participant Profile		B1	B2	B3	B4	B5	**AVR.**
Average Score	Contractor	5.125	4.500	5.375	4.250	5.250	**4.900**
	Consultant	5.267	5.067	4.533	4.533	4.933	**4.867**
	Government	6.000	5.600	5.000	4.400	5.600	**5.320**
	Recycler/supplier	5.600	5.000	5.200	5.400	5.600	**5.360**
	University	5.875	5.500	4.875	4.750	6.625	**5.525**

Table B.10: Average Scores for prioritization of Economic Barriers based on stakeholders' companies' fields of activity

Participant Profile		E1	E2	E3	E4	E5	**AVR.**
Average Score	Contractor	5.375	5.000	5.875	6.125	5.625	**5.600**
	Consultant	5.067	4.933	5.067	4.667	5.133	**4.973**
	Government	5.800	4.800	6.200	5.600	5.600	**5.600**
	Recycler/supplier	5.800	5.600	5.200	5.200	5.400	**5.440**
	University	5.625	6.000	6.250	6.375	6.375	**6.125**

Table B.11: Average Scores for prioritization of Political and Legislative Barriers based on stakeholders' companies' fields of activity

Participant Profile		P1	P2	P3	P4	**AVR.**
Average Score	Contractor	4.750	5.125	4.500	4.375	**4.688**
	Consultant	5.867	5.800	4.933	5.467	**5.517**
	Government	6.200	6.000	5.400	6.200	**5.950**
	Recycler/supplier	5.600	5.600	5.200	5.600	**5.500**
	University	5.125	6.625	5.875	5.375	**5.750**

Table B.12: Average Scores for prioritization of Technical Barriers based on stakeholders' companies' fields of activity

Participant Profile		T1	T2	T3	T4	T5	T6	**AVR.**
Average Score	Contractor	4.125	4.375	4.375	3.875	4.250	5.250	**4.375**
	Consultant	5.400	5.533	4.800	4.733	4.867	4.867	**5.033**
	Government	5.600	5.000	5.000	5.200	5.600	5.400	**5.300**
	Recycler/supplier	4.800	4.600	4.600	5.600	6.200	5.800	**5.267**
	University	5.125	5.375	5.125	5.000	4.625	4.500	**4.958**

iv. Based on stakeholders' knowledge level

Table B.13: Average Scores for prioritization of Social and Behavioral Barriers based on stakeholders' knowledge level

Participant Profile		B1	B2	B3	B4	B5	**AVR.**
Average Score	Low Knowledge	5.118	5.000	4.882	3.882	5.294	**4.835**
	Average	5.500	5.000	5.222	4.833	5.500	**5.211**
	High Knowledge	6.500	5.667	4.000	6.000	6.000	**5.633**

Table B.14: Average Scores for prioritization of Economic Barriers based on stakeholders' knowledge level

Participant Profile		E1	E2	E3	E4	E5	**AVR.**
Average Score	Low Knowledge	4.941	4.941	5.529	5.588	5.471	**5.294**
	Average	5.611	5.389	5.556	5.500	5.667	**5.544**
	High Knowledge	6.167	5.500	6.000	5.000	5.500	**5.633**

Table B.15: Average Scores for prioritization of Political and Legislative Barriers based on stakeholders' knowledge level

Participant Profile		P1	P2	P3	P4	**AVR.**
Average Score	Low Knowledge	5.059	5.706	4.941	4.941	**5.162**
	Average	5.944	5.944	5.333	5.722	**5.736**
	High Knowledge	5.500	5.833	5.000	5.333	**5.417**

Table B.16: Average Scores for prioritization of Technical Barriers based on stakeholders' knowledge level

Participant Profile		T1	T2	T3	T4	T5	T6	**AVR.**
Average Score	Low Knowledge	4.765	5.059	4.529	4.529	4.529	4.588	**4.667**
	Average	5.278	5.222	5.111	4.833	5.167	5.389	**5.167**
	High Knowledge	5.167	4.833	4.500	5.333	5.500	5.333	**5.111**

b. Enablers

i. Based on all survey results

Table B.17: Average scores of social and behavioral enablers for all results

Social and behavioral enablers	E-B1	E-B2	E-B3	E-B4	**AVR.**
Average scores	5.415	5.317	5.512	5.780	**5.506**

Table B.18: Average scores of economic enablers for all results

Economic enablers	E-B1	E-B2	E-B3	E-B4	E-E5	**AVR.**
Average scores	5.683	5.659	5.854	5.683	5.976	**5.771**

Table B.19: Average scores of political and legislative enablers for all results

Political and Legislative	E-P1	E-P2	E-P3	E-P4	**AVR.**
Average scores	5.585	5.585	5.634	6.000	**5.701**

Table B.20: Average scores of technical enablers for all results

Technical enablers	E-T1	E-T2	E-T3	E-T4	**AVR.**
Average scores	5.244	5.268	5.317	5.220	**5.262**

ii. Based on stakeholders' experience level

Table B.21: Average Scores of Social and Behavioral Enablers based on stakeholders' experience level

Participant Profile		E-B1	E-B2	E-B3	E-B4	**AVR.**
Average Score	Less Experienced	5.522	5.391	5.783	5.957	**5.663**
	Experienced	4.429	4.286	4.286	5.000	**4.500**
	Well Experienced	5.818	5.818	5.727	5.909	**5.818**

Table B.22: Average Scores of Economic Enablers based on stakeholders' experience level

Participant Profile		E-E1	E-E2	E-E3	E-E4	E-E5	**AVR.**
Average Score	Less Experienced	5.522	5.522	5.870	5.739	6.174	**5.765**
	Experienced	6.000	6.000	6.143	5.286	5.857	**5.857**
	Well Experienced	5.818	5.727	5.636	5.818	5.636	**5.727**

Table B.23: Average Scores of Political and Legislative Enablers based on stakeholders' experience level

Participant Profile		E-P1	E-P2	E-P3	E-P4	**AVR.**
Average Score	Less Experienced	5.609	5.609	5.696	5.783	**5.674**
	Experienced	5.143	5.857	5.857	6.571	**5.857**
	Well Experienced	5.818	5.364	5.364	6.091	**5.659**

Table B.24: Average Scores of Technical Enablers based on stakeholders' experience level

Participant Profile		E-T1	E-T2	E-T3	E-T4	**AVR.**
Average Score	Less Experienced	5.304	5.087	5.391	5.435	**5.304**
	Experienced	4.857	5.286	4.429	4.571	**4.786**
	Well Experienced	5.364	5.636	5.727	5.182	**5.477**

iii. Based on stakeholders' companies' fields of activity

Table B.25: Average Scores of Social and Behavioral Enablers based on stakeholders' companies' fields of activity

Participant Profile		E-B1	E-B2	E-B3	E-B4	**AVR.**
Average Score	Contractor	5.500	5.000	5.000	5.625	**5.281**
	Consultant	5.400	5.333	5.400	5.733	**5.467**
	Government	5.600	5.400	5.800	6.000	**5.700**
	Recycler/supplier	5.200	5.400	6.000	6.400	**5.750**
	University	5.375	5.500	5.750	5.500	**5.531**

Table B.26: Average Scores of Economic Enablers based on stakeholders' companies' fields of activity

Participant Profile		E-E1	E-E2	E-E3	E-E4	E-E5	**AVR.**
Average Score	Contractor	5.500	5.500	5.625	5.375	5.375	**5.475**
	Consultant	5.533	5.533	5.667	5.667	5.867	**5.653**
	Government	5.800	5.400	6.000	5.600	6.000	**5.760**
	Recycler/supplier	5.400	5.800	5.600	5.800	6.000	**5.720**
	University	6.250	6.125	6.500	6.000	6.750	**6.325**

Table B.27: Average Scores of Political and Legislative Enablers based on stakeholders' companies' fields of activity

Participant Profile		E-P1	E-P2	E-P3	E-P4	**AVR.**
Average Score	Contractor	5.250	5.250	5.125	5.875	**5.375**
	Consultant	5.800	5.400	5.467	6.000	**5.667**
	Government	6.400	6.000	6.200	6.200	**6.200**
	Recycler/supplier	5.200	5.600	5.800	5.600	**5.550**
	University	5.250	6.000	6.000	6.250	**5.875**

Table B.28: Average Scores of Technical Enablers based on stakeholders' companies' fields of activity

Participant Profile		E-T1	E-T2	E-T3	E-T4	**AVR.**
Average Score	Contractor	4.625	4.875	4.875	4.750	**4.781**
	Consultant	5.200	5.267	5.467	5.333	**5.317**
	Government	5.800	6.000	5.800	5.400	**5.750**
	Recycler/supplier	5.200	5.400	5.600	5.800	**5.500**
	University	5.625	5.125	5.000	5.000	**5.188**

iv. Based on stakeholders' knowledge level

Table B.29: Average Scores of Social and Behavioral Enablers based on stakeholders' knowledge level

Participant Profile		E-B1	E-B2	E-B3	E-B4	**AVR.**
Average Score	Low Knowledge	5.294	5.118	5.294	5.412	**5.279**
	Average	5.556	5.333	5.667	6.111	**5.667**
	High Knowledge	5.333	5.833	5.667	5.833	**5.667**

Table B.30: Average Scores of Economic Enablers based on stakeholders' knowledge level

Participant Profile		E-E1	E-E2	E-E3	E-E4	E-E5	**AVR.**
Average Score	Low Knowledge	5.412	5.176	5.706	5.235	5.765	**5.459**
	Average	5.833	5.944	5.889	5.944	6.056	**5.933**
	High Knowledge	6.000	6.167	6.167	6.167	6.333	**6.167**

Table B.31: Average Scores of Political and Legislative Enablers based on stakeholders' knowledge level

Participant Profile		E-P1	E-P2	E-P3	E-P4	**AVR.**
Average Score	Low Knowledge	5.235	5.529	5.353	5.824	**5.485**
	Average	5.944	5.556	5.722	6.111	**5.833**
	High Knowledge	5.500	5.833	6.167	6.167	**5.917**

Table B.32: Average Scores of Technical Enablers based on stakeholders' knowledge level

Participant Profile		E-T1	E-T2	E-T3	E-T4	**AVR.**
Average Score	Low Knowledge	4.824	5.059	5.118	4.824	**4.956**
	Average	5.333	5.278	5.444	5.333	**5.347**
	High Knowledge	6.167	5.833	5.500	6.000	**5.875**

C. Social Network Analysis Results by UCINET

a. Perception of Stakeholders Based on the Stakeholders' Companies' Fields of Activity

i. Contractor / Subcontractor

- ***Social and Behavioral Enablers from the Perception of Contractor / Subcontractor***

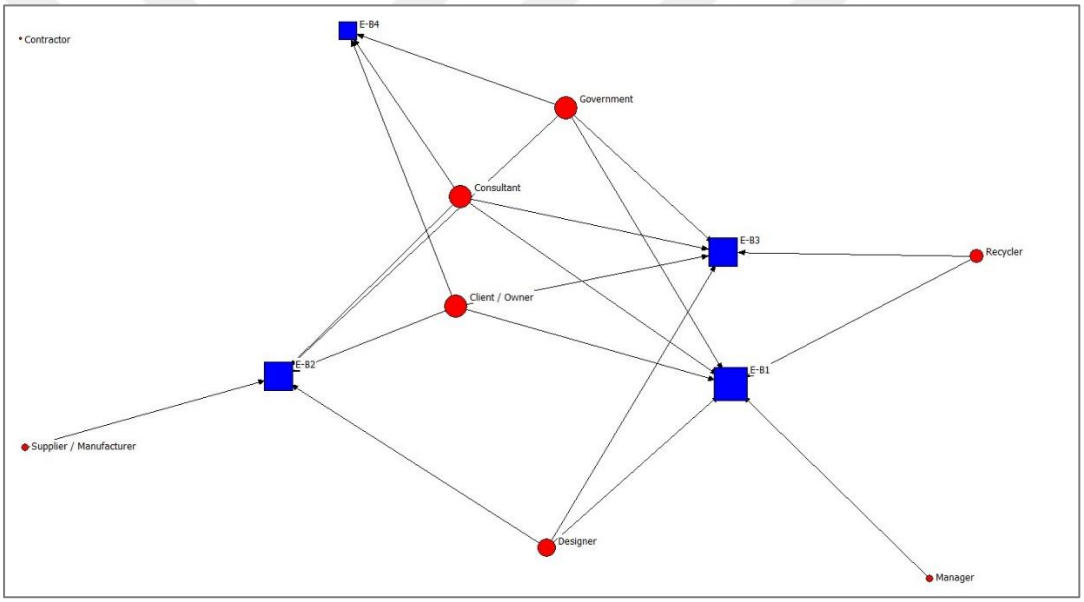


Figure C.1: Node Centrality Measures – Social and Behavioral Enablers –Contractor / Subcontractor (Set Node Size by Degree)

- ***Economic Enablers from the Perception of Contractor / Subcontractor***

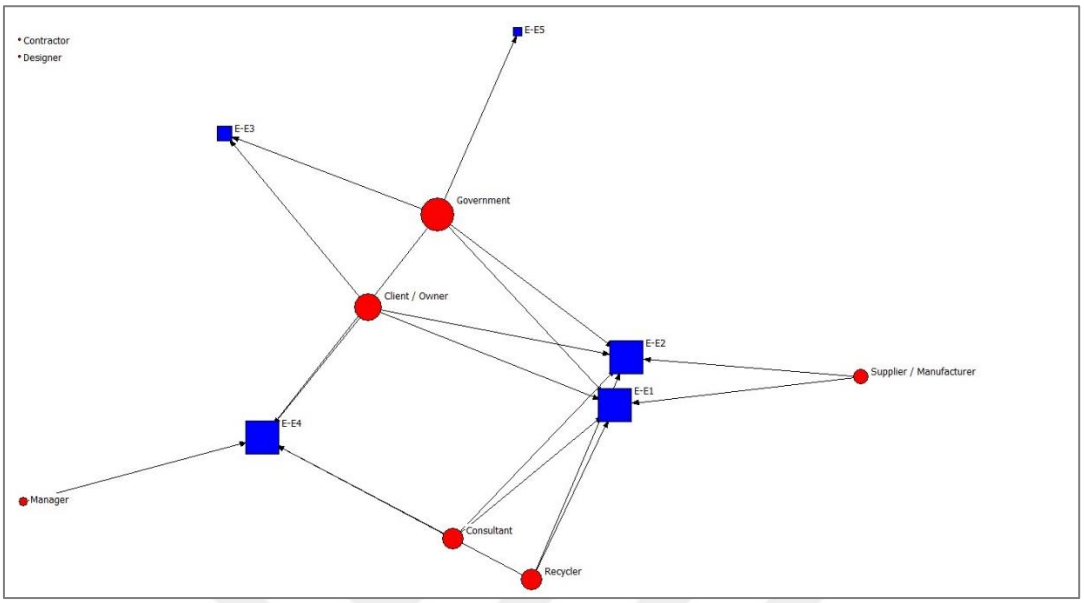


Figure C.2: Node Centrality Measures – Economic Enablers – Contractor / Subcontractor (Set Node Size by Degree)

- ***Political and Legislative Enablers from the Perception of Contractor / Subcontractor***

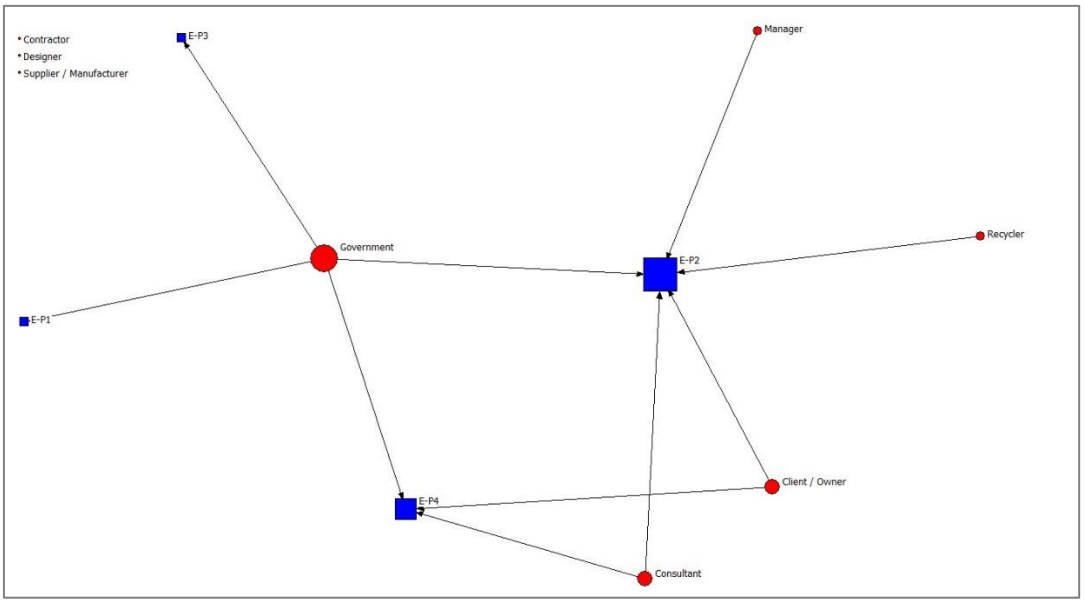


Figure C.3: Node Centrality Measures – Political and Legislative Enablers – Contractor / Subcontractor (Set Node Size by Degree)

- ***Technical Enablers from the Perception of Contractor / Subcontractor***

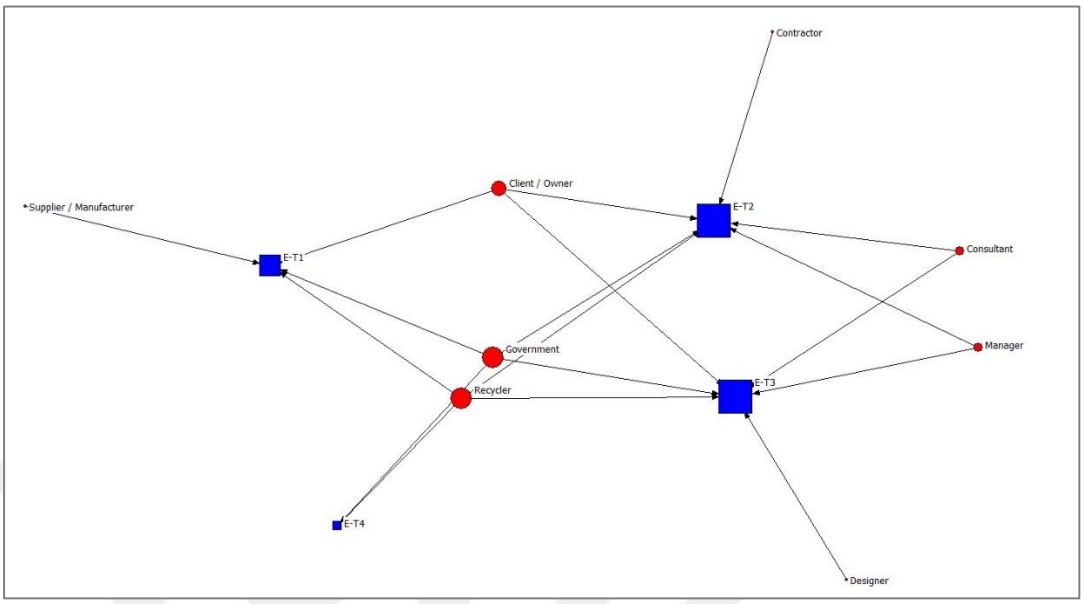


Figure C.4: Node Centrality Measures – Technical Enablers – Contractor / Subcontractor (Set Node Size by Degree)

ii. Design / Engineering and Management Consultant

- ***Social and Behavioral Enablers from the Perception of Consultant***

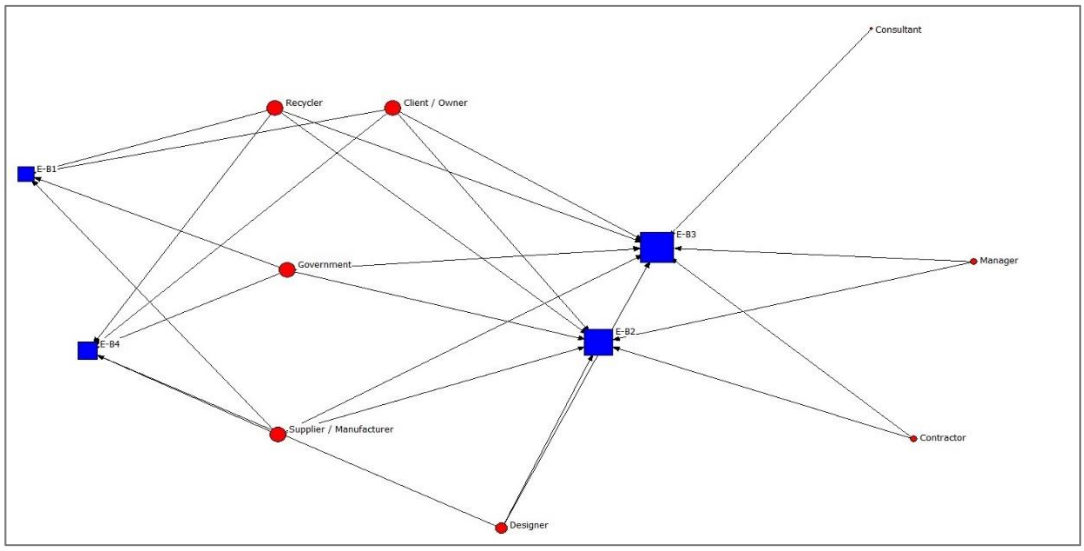


Figure C.5: Node Centrality Measures – Social and Behavioral Enablers – Consultant (Set Node Size by Degree)

- ***Economic Enablers from the Perception of Consultant***

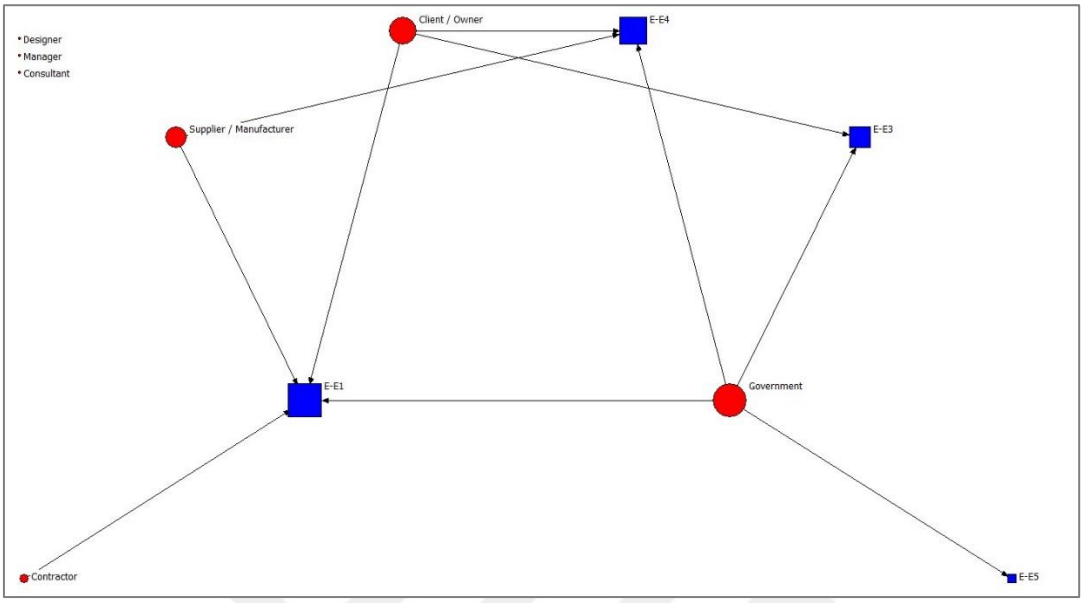


Figure C.6: Node Centrality Measures – Economic Enablers – Consultant (Set Node Size by Degree)

- ***Political and Legislative Enablers from the Perception of Consultant***

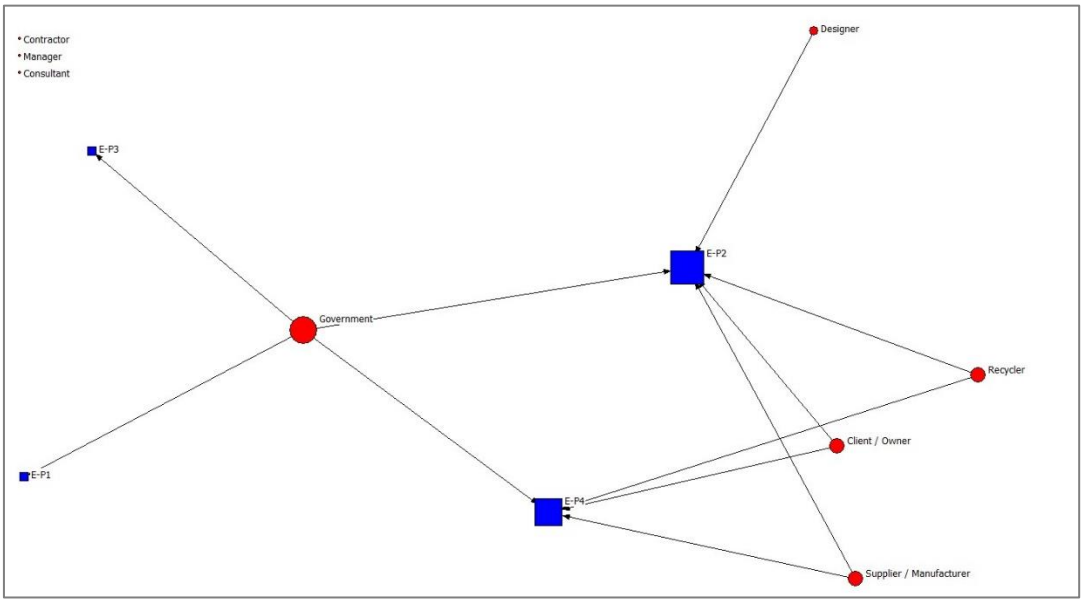


Figure C.7: Node Centrality Measures – Political and Legislative Enablers – Consultant (Set Node Size by Degree)

- ***Technical Enablers from the Perception of Consultant***

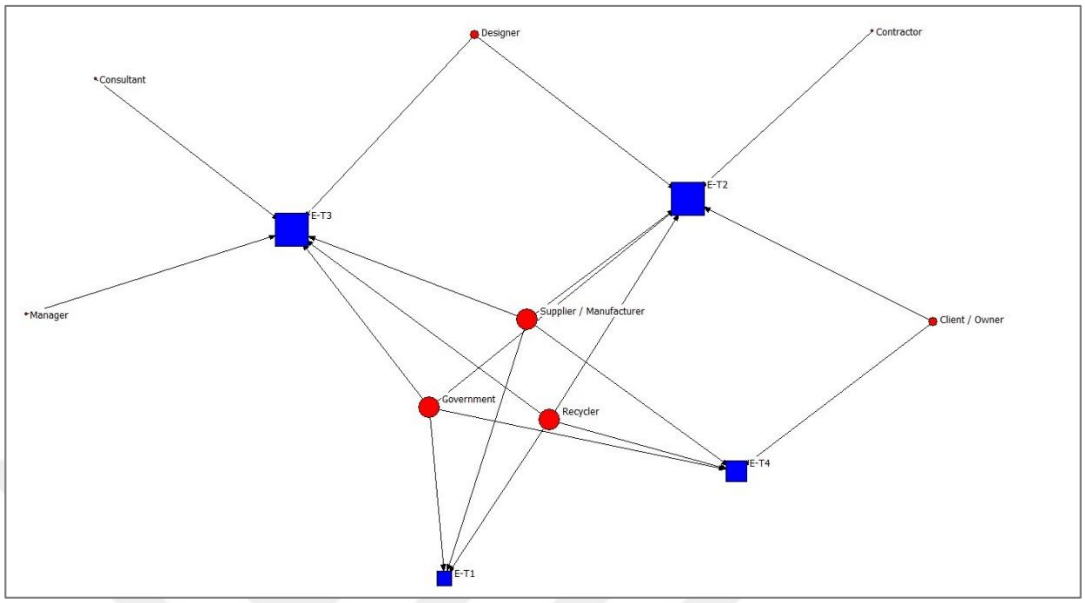


Figure C.8: Node Centrality Measures – Technical Enablers – Consultant (Set Node Size by Degree)

iii. Government

- ***Social and Behavioral Enablers from the Perception of Government***

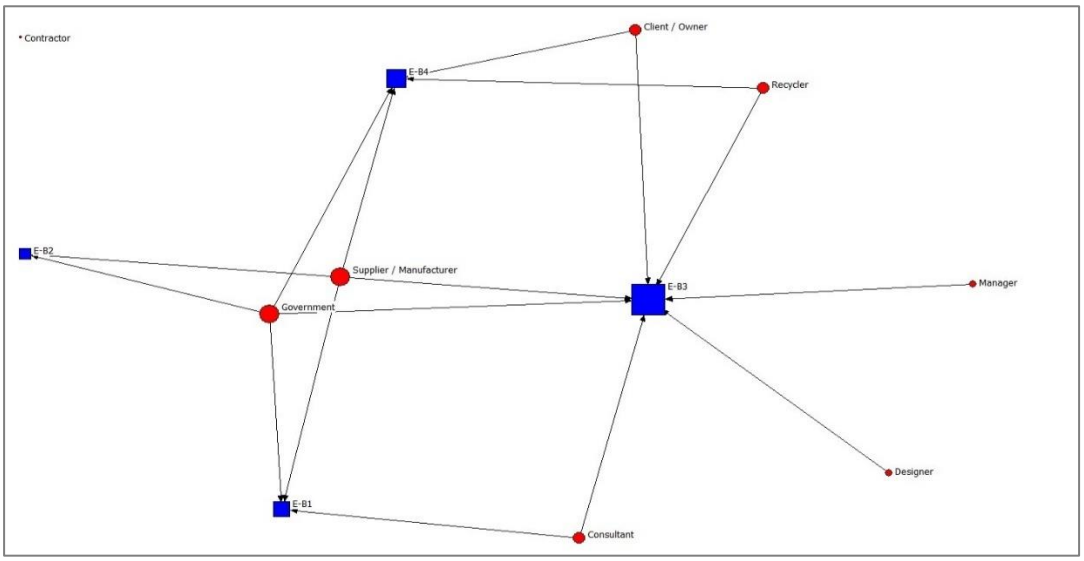


Figure C.9: Node Centrality Measures – Social and Behavioral Enablers – Government (Set Node Size by Degree)

- ***Economic Enablers from the Perception of Government***

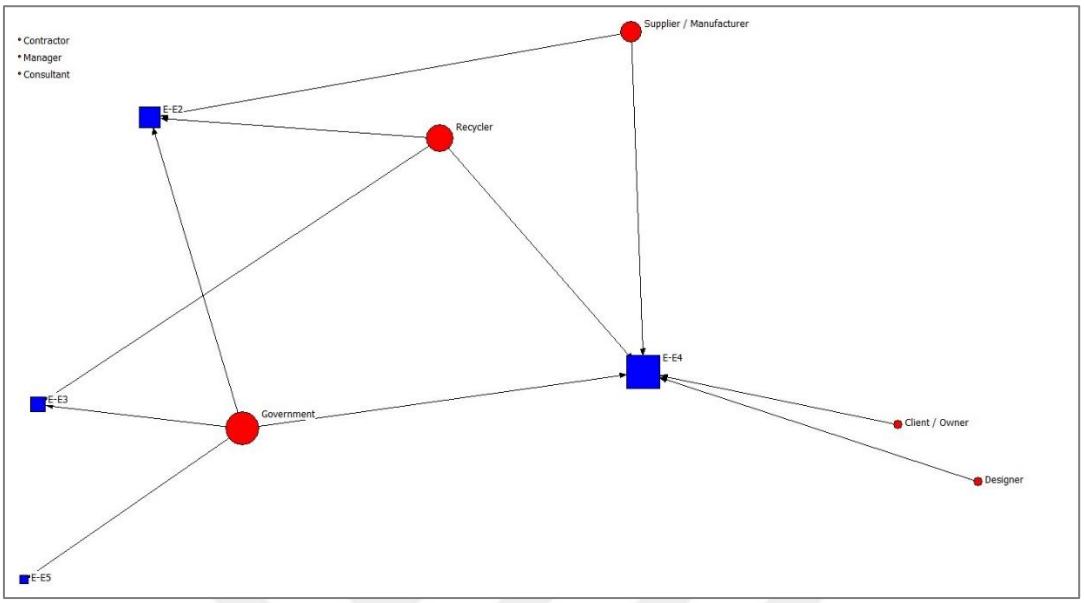


Figure 10: Node Centrality Measures – Economic Enablers – Government (Set Node Size by Degree)

- ***Political and Legislative Enablers from the Perception of Government***

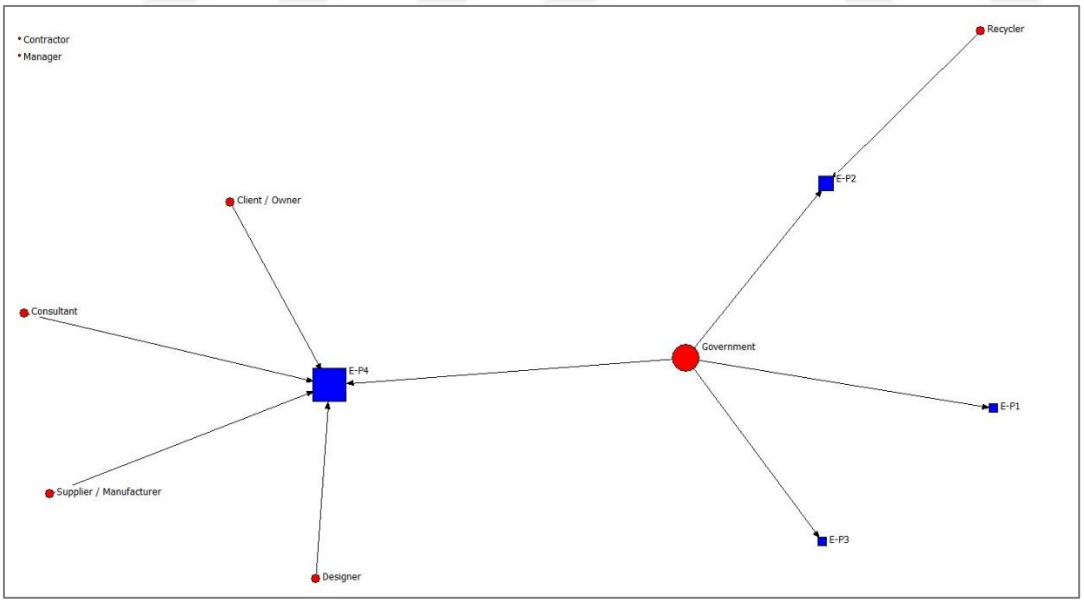


Figure C.11: Node Centrality Measures – Political and Legislative Enablers – Government (Set Node Size by Degree)

- ***Technical Enablers from the Perception of Government***

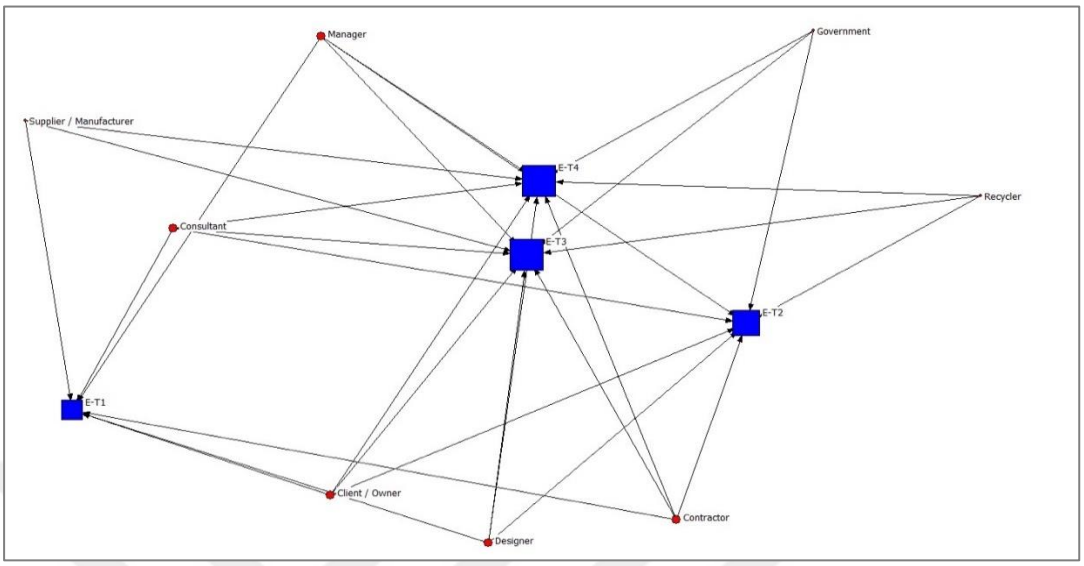


Figure C.12: Node Centrality Measures – Technical Enablers – Government (Set Node Size by Degree)

iv. Recycler / Supplier / Manufacturer

- ***Social and Behavioral Enablers from the Perception of Recycler / Supplier / Manufacturer***

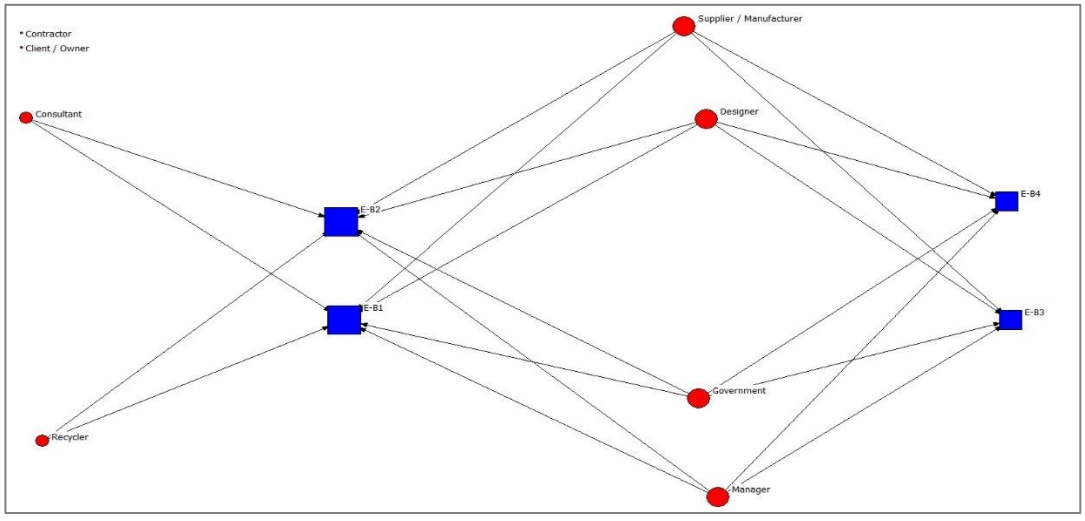


Figure C.13: Node Centrality Measures – Social and Behavioral Enablers – Recycler / Supplier / Manufacturer (Set Node Size by Degree)

- ***Economic Enablers from the Perception of Recycler / Supplier / Manufacturer***

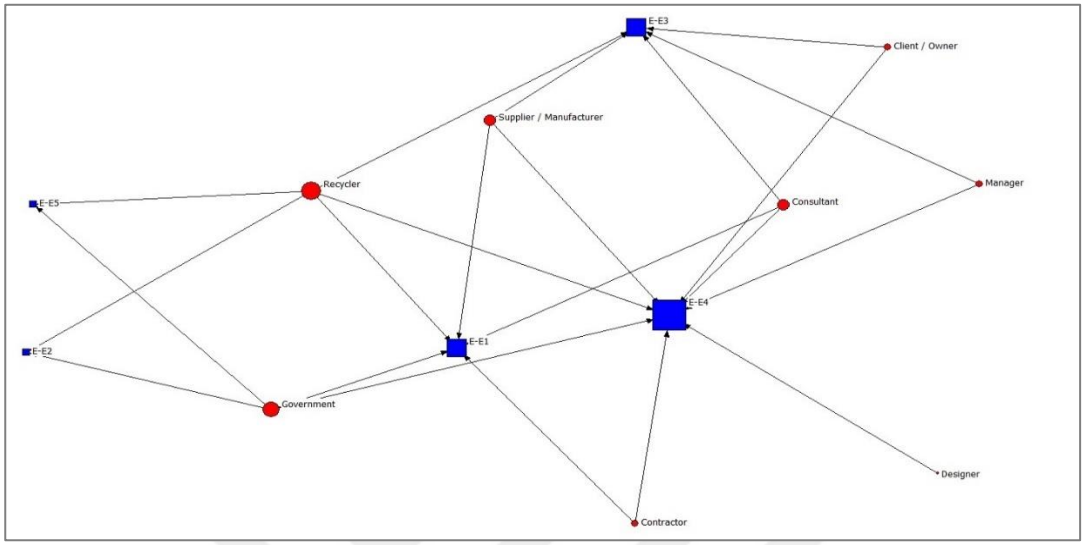


Figure C.14: Node Centrality Measures – Economic Enablers – Recycler / Supplier / Manufacturer (Set Node Size by Degree)

- ***Political and Legislative Enablers from the Perception of Recycler / Supplier / Manufacturer***

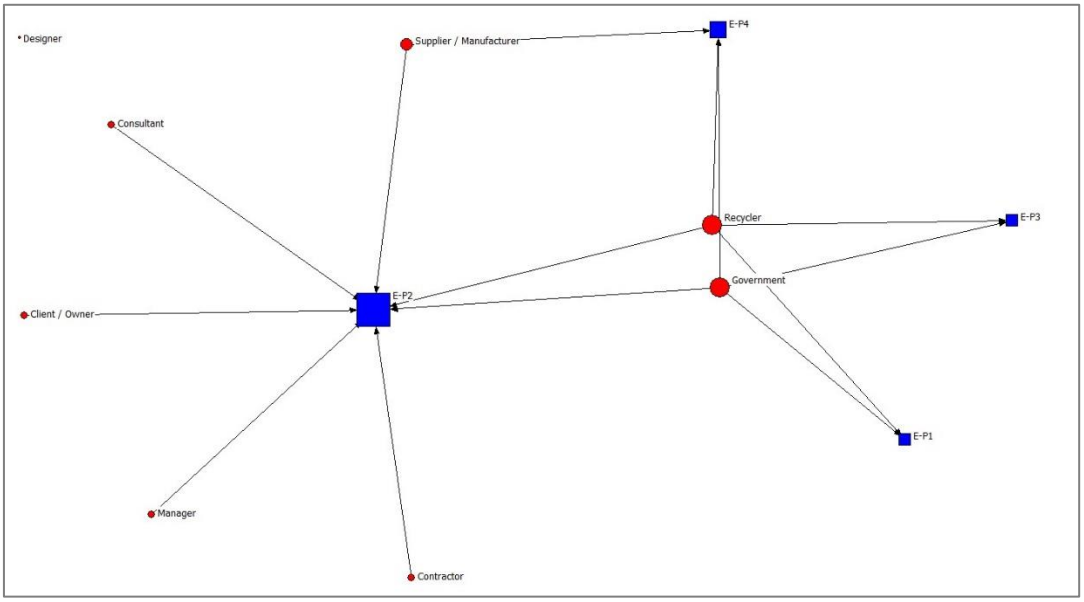


Figure C.15: Node Centrality Measures – Political and Legislative Enablers – Recycler / Supplier / Manufacturer (Set Node Size by Degree)

- ***Technical Enablers from the Perception of Recycler / Supplier / Manufacturer***

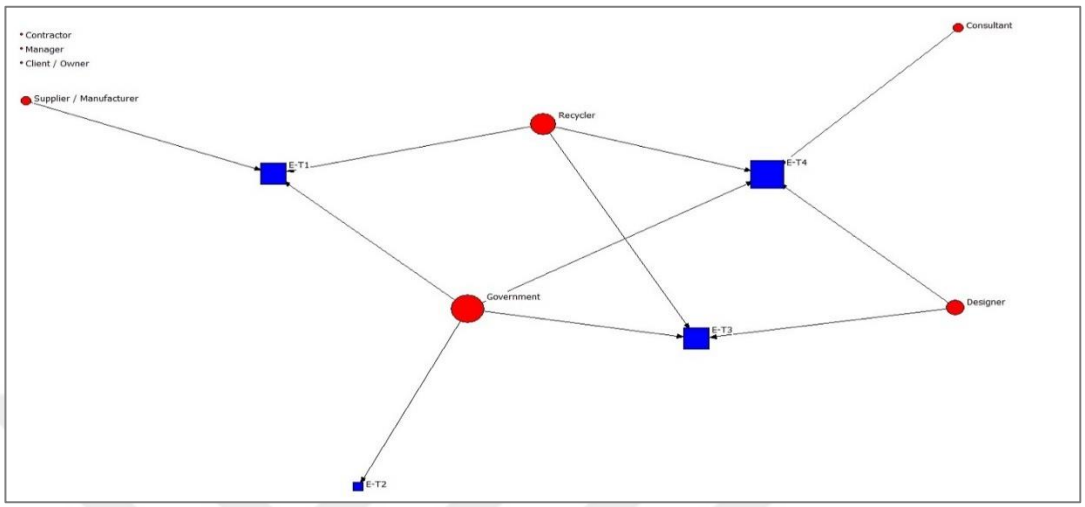


Figure C.16: Node Centrality Measures – Technical Enablers – Recycler / Supplier / Manufacturer (Set Node Size by Degree)

v. University

- ***Social and Behavioral Enablers from the Perception of University Researchers***

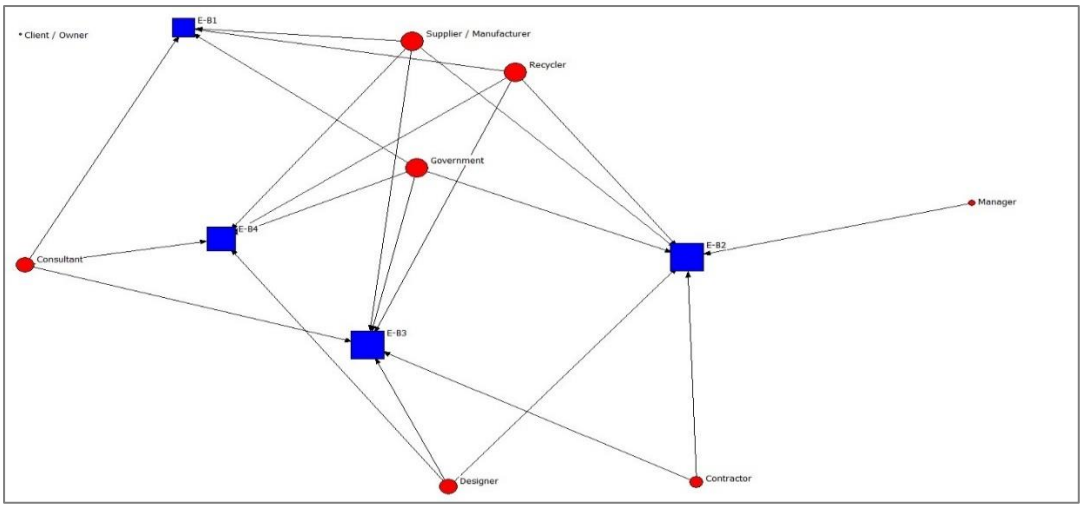


Figure C.17: Node Centrality Measures – Social and Behavioral Enablers – University Researchers (Set Node Size by Degree)

- ***Economic Enablers from the Perception of University Researchers***

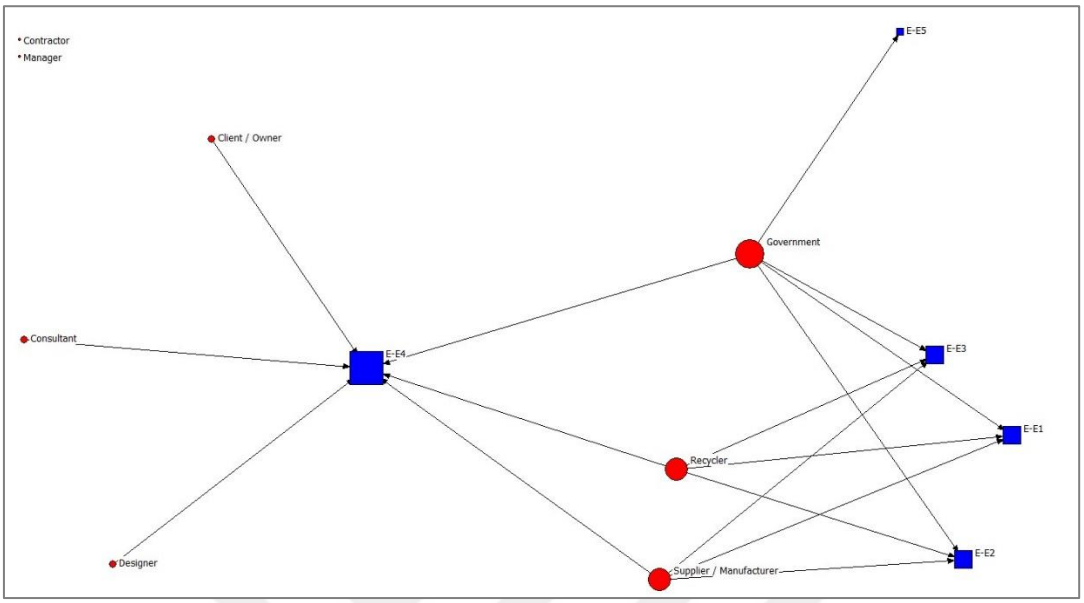


Figure C.18: Node Centrality Measures – Economic Enablers – University Researchers (Set Node Size by Degree)

- ***Political and Legislative Enablers from the Perception of University Researcher***

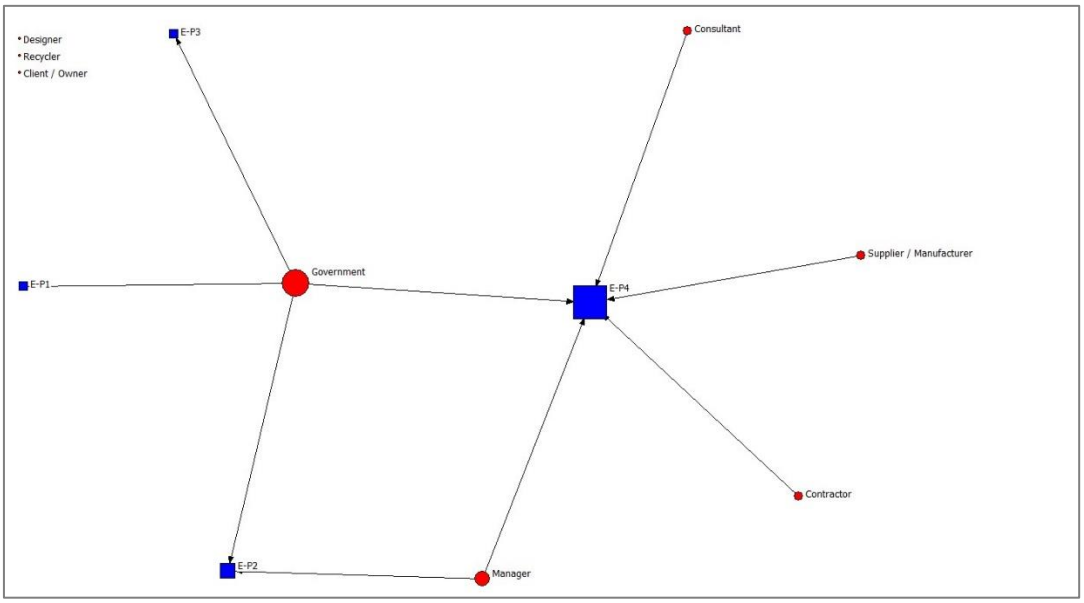


Figure C.19: Node Centrality Measures – Political and Legislative Enablers – University Researchers (Set Node Size by Degree)

- ***Technical Enablers from the Perception of University Researcher***

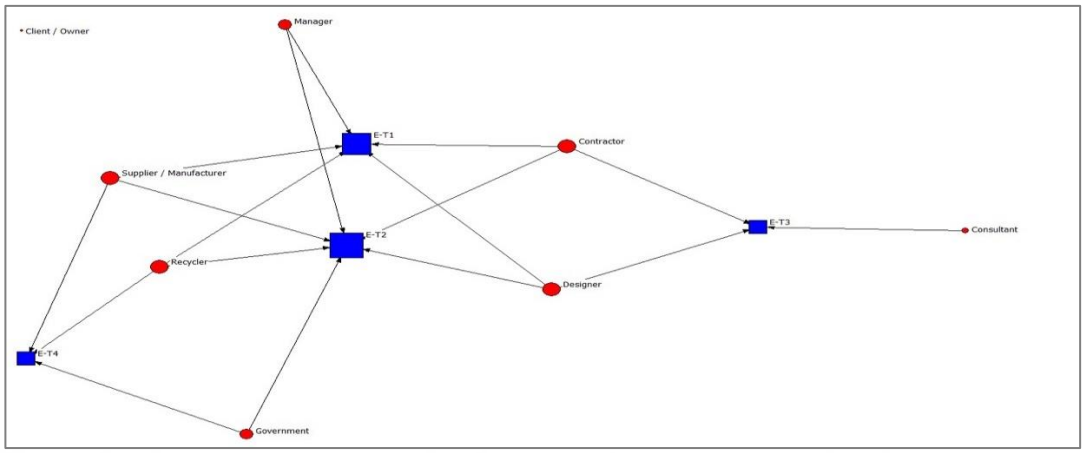


Figure C.20: Node Centrality Measures – Technical Enablers – University Researchers (Set Node Size by Degree)

b. Perception of Stakeholders Based on the Stakeholders' Knowledge Level

i. Low Knowledge Stakeholders

- ***Social and Behavioral Enablers from the Perception of Low Knowledge Stakeholders***

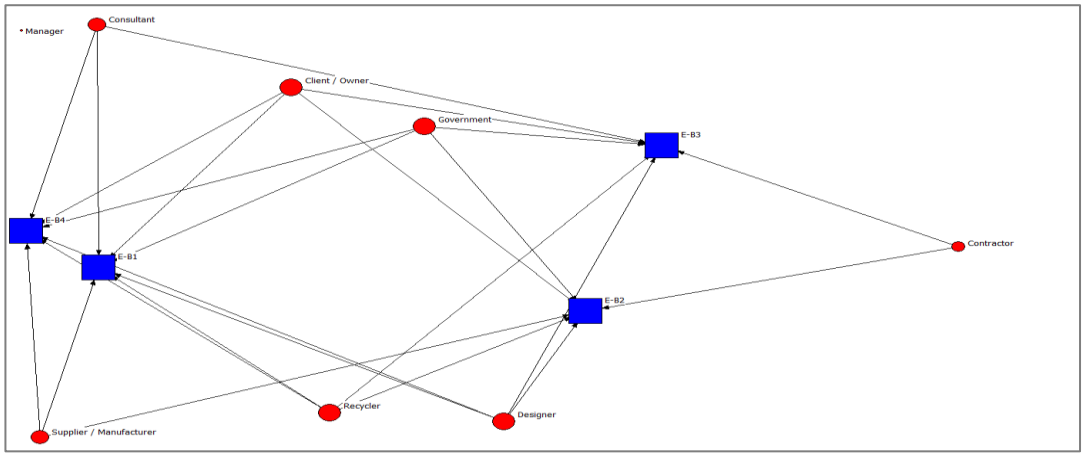


Figure C.21: Node Centrality Measures – Social and Behavioral Enablers – Low Knowledge (Set Node Size by Degree)

- ***Economic Enablers from the Perception of Low Knowledge Stakeholders***

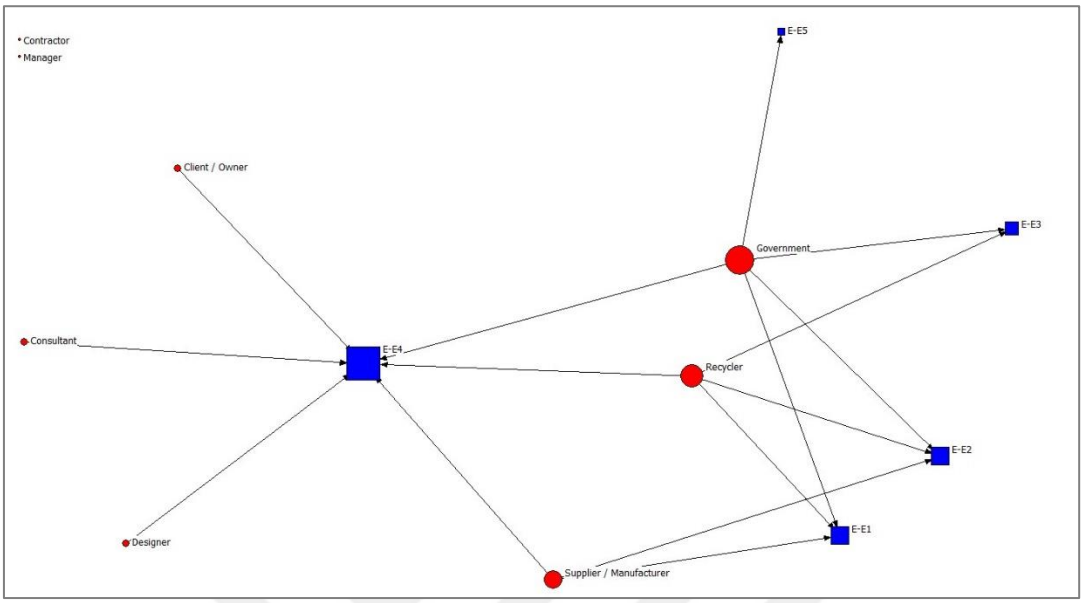


Figure C.22: Node Centrality Measures – Economic Enablers – Low Knowledge (Set Node Size by Degree)

- ***Political and Legislative Enablers from the Perception of Low Knowledge Stakeholders***

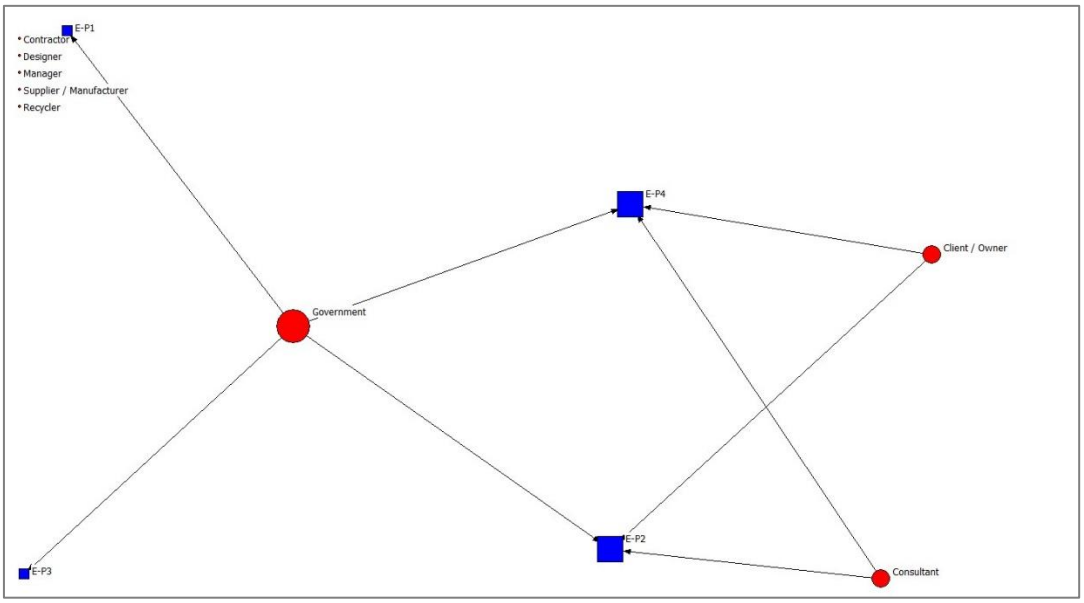


Figure C.23: Node Centrality Measures – Political and Legislative Enablers – Low Knowledge (Set Node Size by Degree)

- ***Technical Enablers from the Perception of Low Knowledge Experienced Stakeholders***

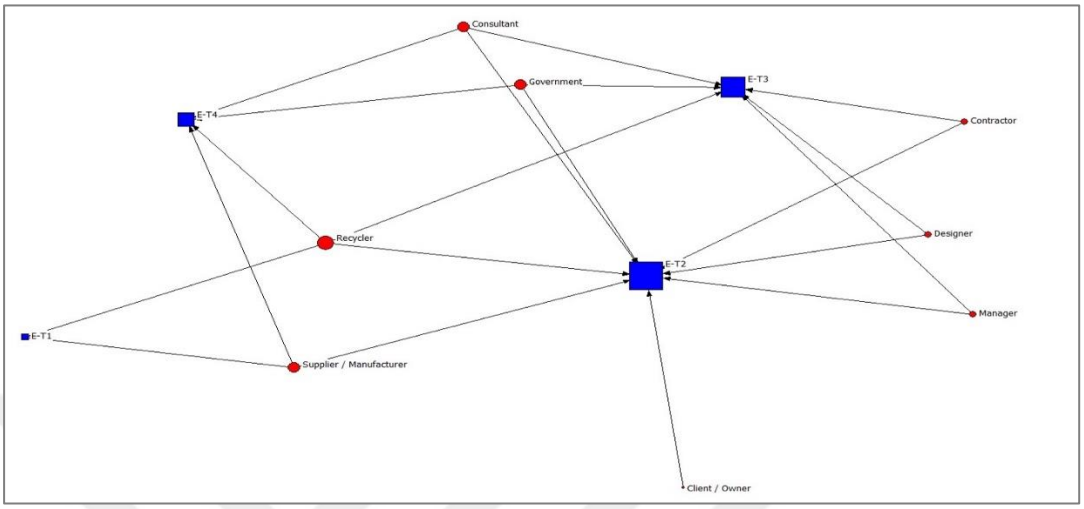


Figure C.24: Node Centrality Measures – Technical Enablers – Low Knowledge (Set Node Size by Degree)

ii. Average Knowledge Stakeholders

- ***Social and Behavioral Enablers from the Perception of Average Knowledge Stakeholders***

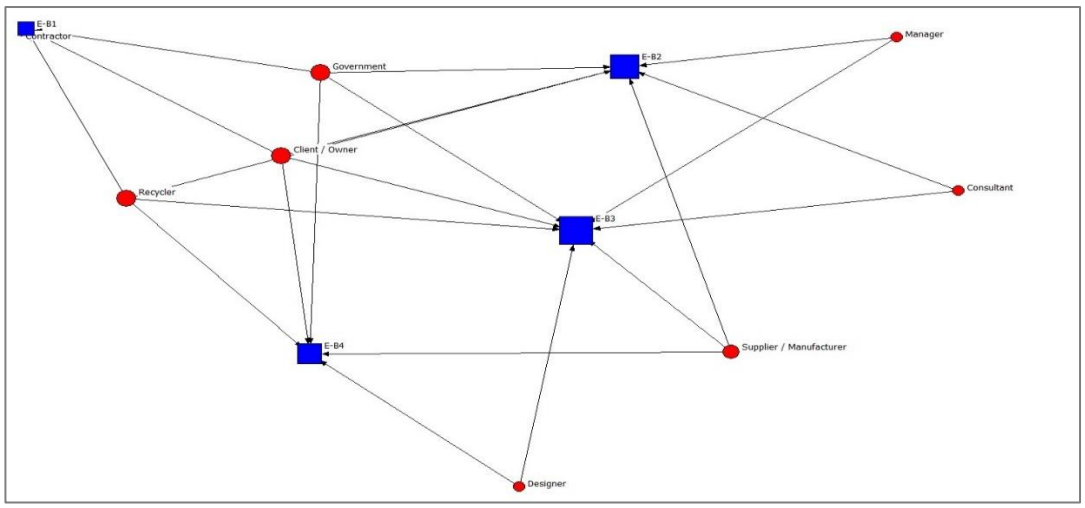


Figure C.25: Node Centrality Measures – Social and Behavioral Enablers – Average Knowledge (Set Node Size by Degree)

- ***Economic Enablers from the Perception of Average Knowledge Stakeholders***

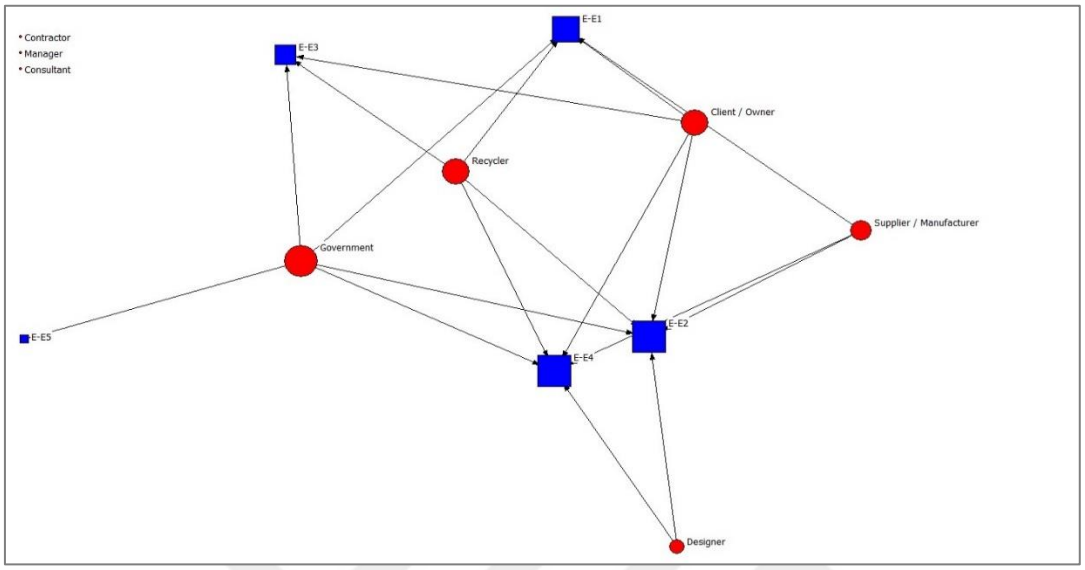


Figure C.26: Node Centrality Measures – Economic Enablers – Average Knowledge (Set Node Size by Degree)

- ***Political and Legislative Enablers from the Perception of Average Knowledge Stakeholders***

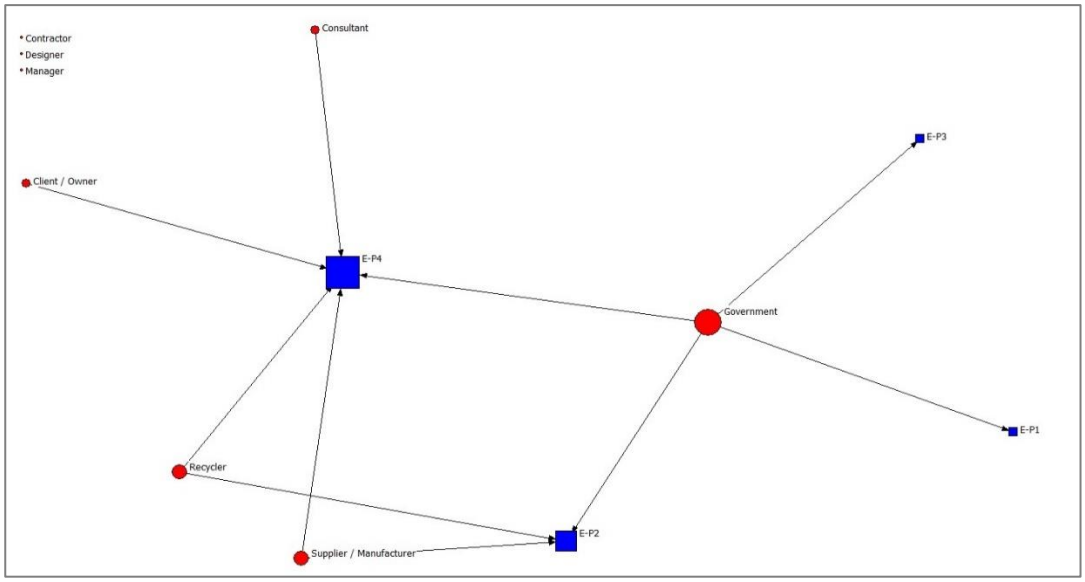


Figure C.27: Node Centrality Measures – Political and Legislative Enablers – Average Knowledge (Set Node Size by Degree)

- ***Technical Enablers from the Perception of Average Knowledge Experienced Stakeholders***

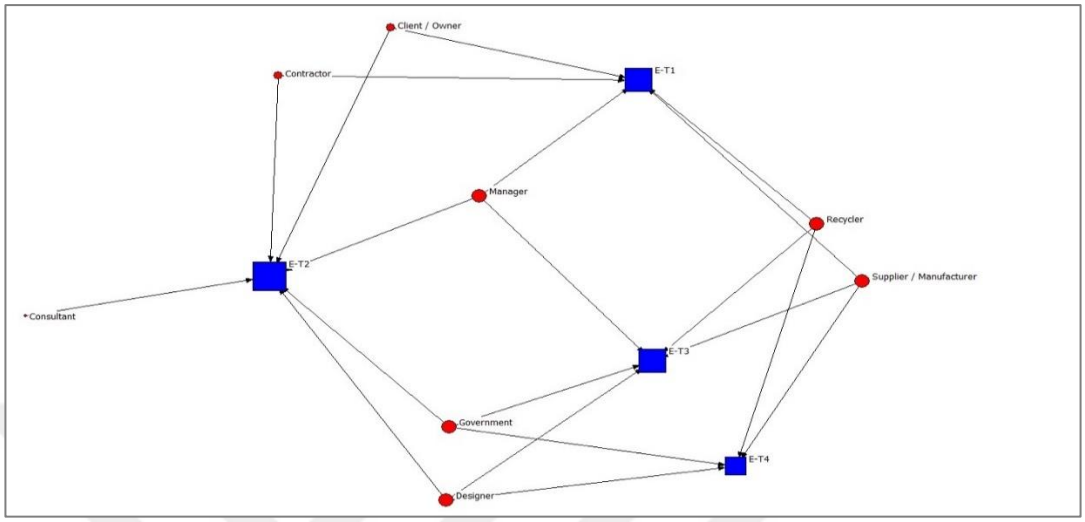


Figure C.28: Node Centrality Measures – Technical Enablers – Average Knowledge (Set Node Size by Degree)

iii. High Knowledge Stakeholders

- ***Social and Behavioral Enablers from the Perception of High Knowledge Stakeholders***

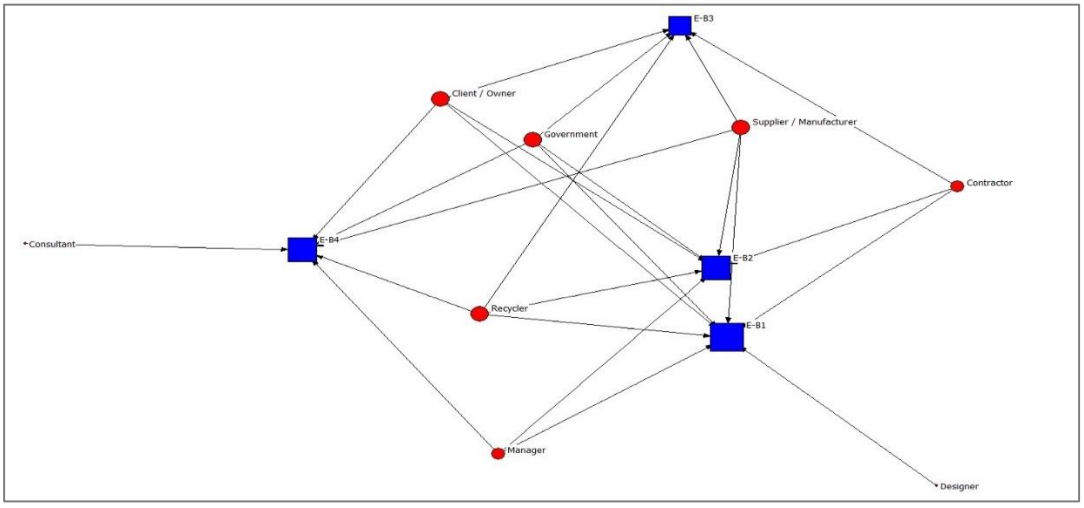


Figure C.29: Node Centrality Measures – Social and Behavioral Enablers – High Knowledge (Set Node Size by Degree)

- ***Economic Enablers from the Perception of High Knowledge Stakeholders***

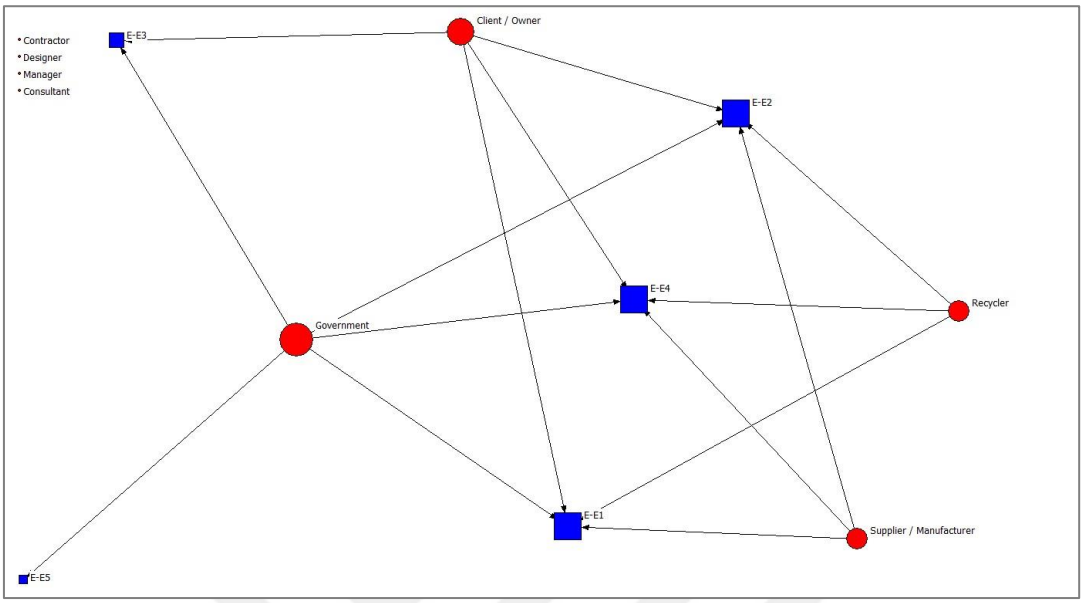


Figure C.30: Node Centrality Measures – Economic Enablers – High Knowledge (Set Node Size by Degree)

- ***Political and Legislative Enablers from the Perception of High Knowledge Stakeholders***

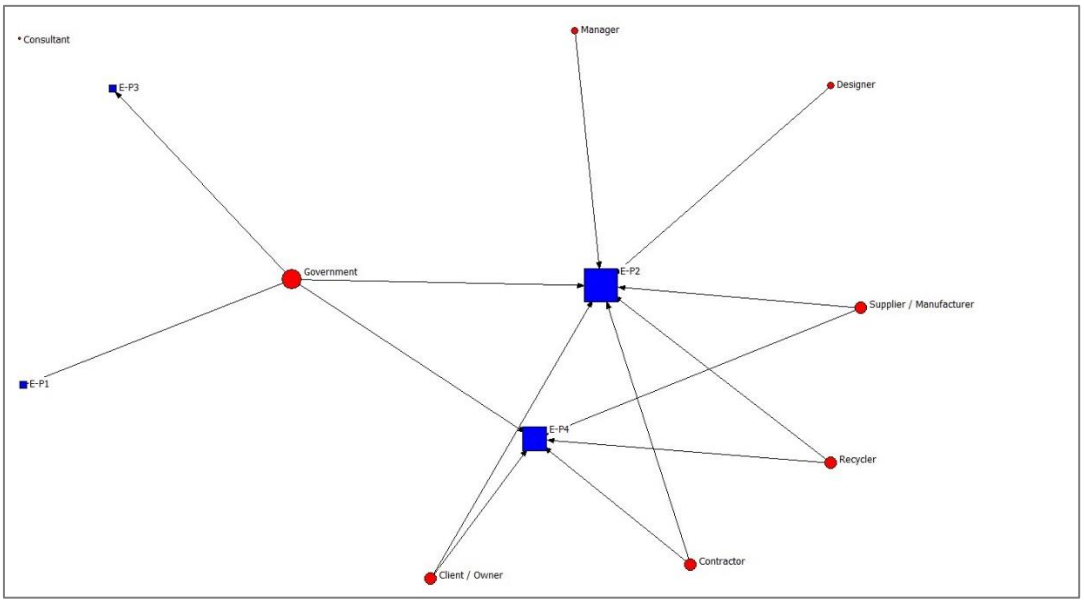


Figure C.31: Node Centrality Measures – Political and Legislative Enablers – High Knowledge (Set Node Size by Degree)

- ***Technical Enablers from the Perception of High Knowledge Experienced Stakeholders***

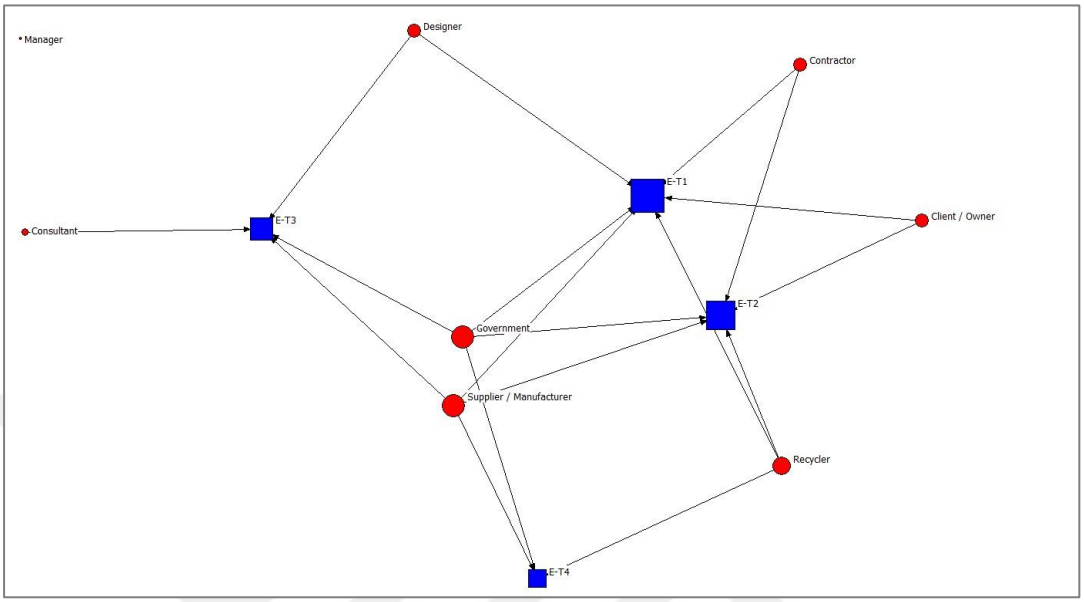


Figure C.32: Node Centrality Measures – Technical Enablers – High Knowledge (Set Node Size by Degree)