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Circular Supply Chain Network Design for E-commerce

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Highlights

- This paper focuses on circular supply chain network design for e-commerce.
- A linear programming is proposed to minimize cost in the study.
- A basic knowledge to implement a network design for SME size e-commerce firms in terms of CE.

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Abstract

There is a growing attention to circular economy through researchers, enterprises and governments. The idea of circular economy is to give no harm to environment while using material till the end of its life and keeping it as much as possible in the cycle. From this point of view, to keep the material in cycle might be possible with a well-designed logistics infrastructure. In this study, the small and medium size enterprises (SMEs) that make sales through e-commerce and the way of handling returns are brought forward. A case study is created for footware industry in Istanbul and a circular supply chain network design is proposed. Afterwards, a linear programming is applied to minimize cost. This study gives a clear and simple solution for SMEs to minimize the cost for handling returns while keeping them in the cycle.

1. INTRODUCTION

Circular economy (CE) has been an interesting research field for many researchers, public authorities and businesses due to find a way to minimize the negative environmental effects of production and consumption. Circular economy is an approach against linear economy that is a traditional way of economy. According to circular economy, linear economy works in a take-make-waste system that could not work for long time as earth sources are finite [1]. Therefore circular economy is a system that metarials and produced goods are reused and cause less waste through recycling, refurbishing and extending product life [2]. Additionally, CE aims to take action in production and service processes by consuming less energy such as electricty, water, fossil fuels. It could be said that CE keeps the metarials in the cycle as much as possible by using less energy in order to reduce negative environmental effects. Seroka-Stolka and Ociepa-Kubicka [3] explaine subjects that circular economy covers as;

- From cradle to cradle (C2C)
- 3R (Reduce, Reuse, Recycle)
- LCA
- Cleaner manufacturing
- Industrial ecology
- Sustainable supply chain management
- Green supply chain

Each of those subjects has a significant role in reducing environmental impact of linear economy and also points the value of supply chain. Enterprises need to reimage and redesign their supply chains, in which sourcing, production, logistics, return and disposal are key activities, in order to embrace and implement

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CE [4]. Therefore literature has met a new notion called Circular Supply Chain Management (CSCM) that is defined as "the integration of circular thinking into the management of the supply chain and its surrounding industrial and natural ecosystems. It systematically restores technical materials and regenerates biological materials toward a zero-waste vision through system-wide innovation in business models and supply chain functions from product/service design to end-of-life and waste management, involving all stakeholders in a product/service lifecycle including parts/product manufacturers, service providers, consumers, and users" [5].

Today's economical system is based on more production and more consumption. This causes many logistics movements in supply chains. Although circular economy supports circular movements to achieve the maximum use of resource so that it decreases the environmental impact [6]. Developing technology especially internet lead people to do more shopping. Today consumers could be able to reach any product via internet and buy them over internet and have the product delivered to their door. This type of shopping creates another stop for the products. Beside this, due to the growth of e-commerce business, the frequency of delivery increases. This causes more vehicles to travel in cities by creating pollution and congestion [7]. In e-commerce business, customer expectation is to receive the goods faster and cheaper, authorities consider the well-being of inhabitants above individual needs, transport companies try to minimize the cost by ignoring negative environmental impacts and e-commerce services aim to keep the customer satisfied [8]. It is clearly seen that the ambition of e-commerce stakeholders connects with logistics. In order to create a sustainable logistics in e-commerce business, it is important to evaluate stakeholders' aim all together.

This study focuses on circular economy by eliminating movements of products in e-commerce supply chain network. First section literature review in which green logistics, reverse logistic and closed-loop supply chain will be framed under circular economy and try to identify how e-commerce could fit in. Second section comes up with research questions and a network proposal. Third section is about the method of the study which is linear programming and a case study. Last section is conclusion and earnings of the study. Figure 1 shows the framework of the study.

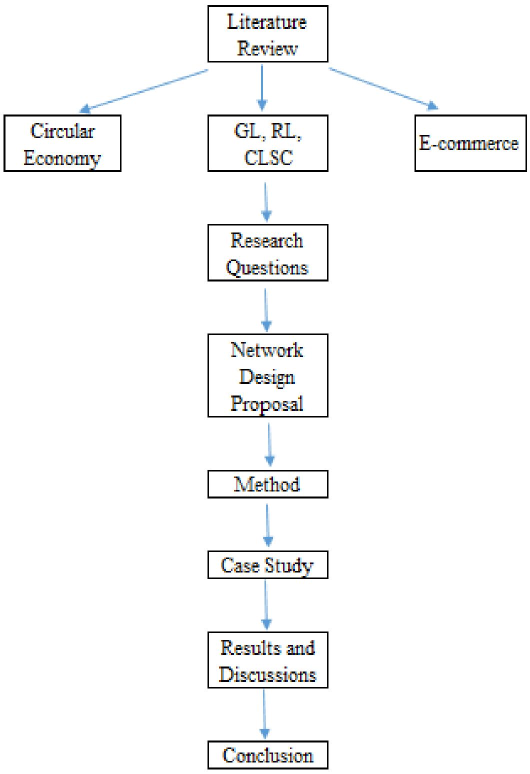

Figure 1. *The Framework of the Study*

2. LITERATURE REVIEW

2.1. Connection of Green Logistics, Reverse Logistics and Closed-Loop Supply Chain with Circular Economy

In order to explain the connection of green logistics, reverse logistics and closed-loop SC with circular economy, it is important to define the notions. Green logistics aims to measure and decrease ecological impact of logistics activities. Green packaging, green transport, storage and flow of processing are crucial activities of green logistics [3]. Green logistics intends to reduce green gas emission, use of fossil energy sources and to make it possible to return of metarials after their end-of-life [9]. According to World Bank [10] transportation which is a logistics activity creates 23% of world's CO_2 emission. At the same time one of the principle of circular economy is reduction of environmental impact of activities such as the ways of reducing gas emission and usage of natural resources. In this manner, green logistics and circular economy supports each others.

Hawks [11] defines reverse logistics as 'the process of planning, implementing and controling the efficient, cost the point of consumption to the point of origin for recapturing value or proper disposal. Remanufacturing and refurbishing activities also may be included in the definition of reverse logistics'. Beside this, Guarnieri, Cerqueira-Streit, and Batista [12] identify reverse logistics processes as;

- Collected
- Transported
- Sorted and
- Then conducted to recycling
- Remanufacturing
- Reconditioning
- Refurbishing

It is clearly seen that reverse logistics and circular economy connect around the same objectives. Reverse logistics supports circular economy by making it possible to return products for remanufacturing, recycling and refurbishing that would reduce the usage of natural sources. Roudbari, Ghomi, and Sajadieh [13] has a similar inference by stating that reverse supply chain networks will reduce the need for natural resources. Beside this, Das, Kumar and Rajak [14] underline that stores motivate customers to bring back their unused, end-of-life and end-of-use goods in order to minimize the environmental negative impact of goods. This will also effect circular economy in a positive manner. On the other hand, traditional supply chain is not responsible for end-of-life merchandise [13].

Closed-loop supply chain is the return of products to original equipment manufacturers and reselling those products in perfect condition to the original markets [15]. Closed-loop supply chain increase usage of materials as much as possible and this also helps to circular economy [16]. As circular economy gets more attention, many enterprises start to consider reverse logistics for closed-loop supply chain [17]. It is crucial to create a cloosed-loop supply chain which enables original equipment manufacturers to recover and resell items as a transition to circular economy [6].

It is becoming the most priority subject to have cleaner and sustainable environment for both stakeholders and owners of the businesses. This could be achieved by implementing sustainable practises such as decreasing amount of waste through process of recycling, recovery, remanufacturing. Also these practises enable minimization in cost and environmental impact [18]. Firms' efforts to take in consideration human and environmental impact of their products while process of supply chain that includes from raw materials to manufacturing, storing to distribution and any movement between them generates supply chain sustainability [6].

2.2. E-Commerce from Logistics Aspects

Dutta, P. and et.al [18] defines e-commerce as ‘it is to share trade information, sustain business relations, doing trade negotiations, making and managing aggrements via telecommunication especially through internet in order to realise business transactions’. E-commerce business provides customers many types of choices, price transparency between retailers, discount offers [17]. Global e-commerce sales in 2021 is 5.2 trillion U.S.dollars world wide and expected to grow by 56% [19]. E-commerce sales are growing rapidly by making supply chains more complicated [11]. Covid-19 pandemic period also caused an increase in e-commerce that bypassed the importance of physical stores [20].

On the other hand there is a growing rate in the return of products that sales through e-commerce. Almost 30% of e- commerce orders are returned as compared to nearly 9% of brick and morter sales [21]. This is nearly three times higher than physical store returns. It is clearly seen that e-commerce returns has a volume of 1.5 trillion U.S.dollars. Global Webindex in 2019 carried out a survey which aims to find out the most frequently returned online product categories. These are 56% clothing/shoes, 30% accessories/jewellery, 42%electronics, 22% health and beauty, 21% entertainment [22]. Therefore E-commerce firms need to design a reverse logistics network that aims to minimize the cost by having in mind the product return categories and their volume and also their collection and disposition in a suitable way [17]. Although firms increase sales via e-commerce, the cost of return increases as compared to physical stores. The reverse logistics cost of Taobao, which is one of the biggest e-commerce platform, is 16% of total logistics cost [23]. In order to minimize the cost of returns firms need a sustainable and efficient network design. In Table 1 some of studies that proposed such network designs.

Table 1. *Articles reviewed in the field of network design of e-commerce*

Authors	Year	Location	Industry	Problem	Echelons	Facilities	Optimization Model	Objective Function
XiaoYan, Q.et.al [24]	2012	China	-	RL network design	factories, online retailers, 3PL,market	-	0-1 Mixed Integrate LP	Cost Minimization
Liu, D. [25]	2014	-	-	Location-allocation optimization RL	collecting points, recycling centers, remanufacturing centers	storing, reprocessing, remanufacturing, new module suppliers	Genetic Algorithm	Cost Minimization
Guo, J., et.al.[26a]	2017	Shangai	Fashion	RL network design	Primary Recycling Centre, Union RC, E-business enterprises, union processing factories, secondary markets, manufacturers, primary markets	recycling, recovery, remanufacturing, disposal	Dynamic joint mathematical model, Particle Swam Optimization (PSO), Genetic Algorithm (GA)	Cost Minimization
Guo, J., et.al.[26b]	2017	Shangai	Fresh Food	Forward and reverse logistics	customers, pick-up points, distribution/r	-	Particle Swam Optimization (PSO),	Cost Minimization with

				network and route planning	ecycling centers, food processing plants, landfills, e-commerce enterprises		Genetic Algorithm (GA)	low carbon emission
Das, D.,et.al [14]	2020	India	Fashion	RL network design	Customer location ICC	-	Mixed Integer LP (MILP)	Cost Minimization
Dutta, P.,et.al. [18]	2020	India	Fashion	Multi objective logistics network design for return products	Customer market, delivery hub, fulfillment center, incinerator, recycling center, landfil	recycling, recovery, remanufacturing	MILP with Weighted Goal Programming	Social, environmental, economic optimization
Roudbari, E.S.et.al.[13]	2021	Iran	Medical Equipment	RL network design	Customer, local collection, centralized collection, market, reuse center, refurbishing center, processing center, disposal, spare market, remanufacturing center, new module from supplier, recycling center	refurbishing, reusing, recycling, remanufacturing,selling spare parts	Genetic Algorithm and branch &cut algorithm	Profit Maximization
Govindan, K.,et.al. [27]	2022	Iran	Medical Waste	RL network design	Hospitals, collection center, treatment center, recycling center, disposal center	-	MILP, queuing theory, stochastic scenario based approach, AUGMECON2	Cost Minimization
Prajapati, D.[6]	2022	India	Electronic Products	Close-loop supply chain (forward & return)	Customer, local distribution center, manufacturing center, refurbishing center, inspection center	-	Mixed Integer Non-LP (MINLP), Sensivity Analysis	Total expected cost, Total expected revenue

Nanayakkara, P.R.,et. al. [17]	2022	Brazil	Electronic and Electrical Equipment	Handling product returns and RL network design	Customer market, Fulfillment center, sellers, ICCs, Formal recyclers, landfills	Reuse, Refurbish, Repair, Recycle, Remanufacture,Resell	Hierarchical Clustering, MILP	Cost Minimization

3. RESEARCH QUESTIONS

After literature review, it has been found that there are studies that covers e-commerce returns from perspective of green logistics, reverse logistics, closed-loop supply chain and circular economy. But we could not come across any study that frames all those notions under the framework of circular economy. Therefore, first question of the study is;

Q1: Is it possible to unite green logistics, closed-loop supply chain, reverse logistics under circular economy approach while designing e-commerce supply chain design?

Additionally, it is found that there are studies which use a couple of echelons while designing a network design to minimize the cost. For some big enterprices it might be useful. On the other hand it might not be sufficient to minimize cost for small and medium size businesses such as home-made products. Therefore second and question of the study is;

Q2: How small and medium size businesses cope with returns in terms of minimizing the cost?

Previous studies by adding echelons increases number of movements of products. In this case transport of return products increases as well. Therefore third question of the study is;

Q3: As there is a rising trend in e-commerce and an increase in volume of returns, is it possible to reduce echelons in SC to minimize cost and respectively environmental damage like gas emission?

There are two crucial points in order to reach circular economy and sustainability. First of them is to determinate optimization models which aim to present an effective business and second one is to involve in reselling, refurbishing and recycling as closed-loop supply chain into that optimization model [6]. While considering small and medium size businesses, a new network design for e-commerce returns is proposed in Figure 2.

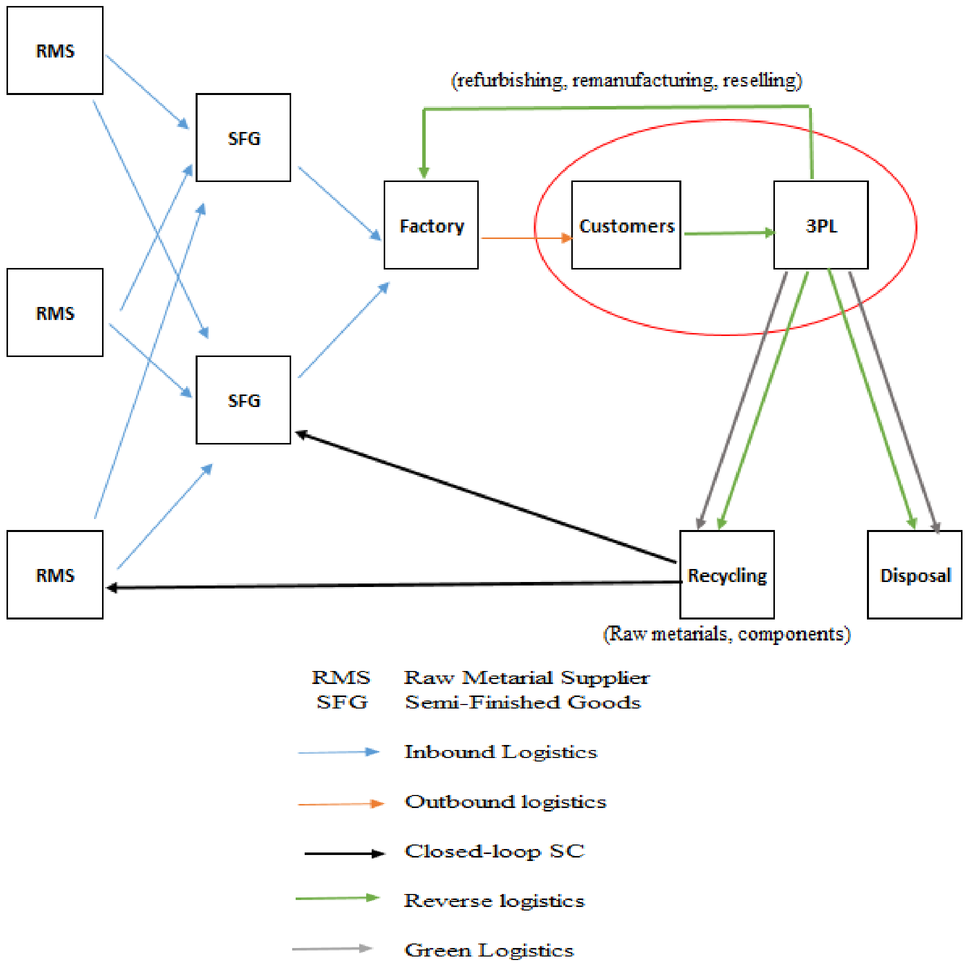

Figure 2. *Circular Supply Chain Desing for E-Commerce*

4. METHOD

As seen in Table 1, there are studies that use mixed interger liner programming to optimize network sites. This study also uses liner programming to minimize the cost. The model is created by considering the cost of returns from customers to 3PLs and the handling cost of PLs for returns.

4.1. Notations

i customer
j 3PL point
Q quantity
K capacity
r return product
Y send/do not send
C transport cost
H order handling cost
Q_{ij} the quantity of returns from i customer to j 3PL point
Q_r the quantity of return product
K_j the capacity of 3PL point
Y_j the indicator sending returs to j 3PL Yj=1, not sending Yj=0
C_{ij} the transport cost of per return from i customer to j 3PL point
H_{ij} order handling cost of per return in j 3PL point

4.2. Decision Variables

Qij the quantity of returns from i customer to j 3PL point
Yj the indicator sending returs to j 3PL Yj=1, not sending Yj=0

4.3. Constraints

$$\sum Q_{ij} = \sum Q_{ir} \tag{1}$$

$$\sum Kj \sum Y_{kj} >= \sum K_i \tag{2}$$

$$Q_{ij} >= 0 \tag{3}$$

4.4. Objective Function

$$\text{Min} \sum Q_{ij} \sum C_{ij} + \sum Q_{ij} \sum H_{ij} \tag{4}$$

5. CASE STUDY

The footware industry has a reasonable part in Turkish economy. The footware industry produces approximately 280 million pair shoes per year and 90% of that production services to local market. The production is done by fully industrial and semi-industrial firms. The semi-industrial firms have a percentage of 33 of total footware industry [28]. Therefore it could be said that semi-industrial firms have a production capacity of 83.160 million pair of shoes.

The case study covers footware sales and their return in Istanbul by small and medium size enterprises via e-commerce. In Turkey, 50% of SMEs are located in Istanbul. Therefore it could be said that 41.580 million pair of shoes produced in Istanbul by SMEs.

The e-commerce part of Istanbul for footware all over Turkey is 10%. Additionally e-commerce sales of clothing and shoes is around 56% [29]. Therefore it could be said that 2.334 million pair of shoes are returned in e-commerce per year. This is a quite big amount of return and handling of them might be a significant issue for SMEs in terms of sorting and cost.

The case study trying to give an answer to SMEs to handle the issue with a third party provider (3PL) by minimizing cost, reducing transport time in order to reduce carbon emission. There are some assumptions in the case study in order to solve the problem. These are;

1- The return amount of 1.507 million pair of shoes spread over the population density of each district. The districts of European side of Istanbul is pointed as customer location
2- Therefore the return of shoes per district is known.
3- Four 3PL points are used and their capacity for footware return are assumed
4- Carrying cost per km is calculated by 3PLs’ tariffs
5- The order handling cost (sorting of returns) in four 3PL points are assumed

6. RESULTS AND DISCUSSIONS

The European side of Istanbul is selected as sample in the case study. The aim of the case study is to find the optimal solution to allocate the returns to 3 PLs by minimizing total transport cost and order handling cost. Therefore, small and medium size enterprises in footware industry could be able to calculate the optimal solution among their purpose.

The Excel Solver is used to minimize the cost. The decision variables are defined as two. The first one is quantity of returns from customer points to 3PL points (Q_{ij}). The second one is binary decision variable that decides to send or not to send returns to each 3PL (Y_j). The aim of using binary is to allocate the returns in the best possible way.

There are four constraint in the case study. First one is the total return amount of each customer points (Qi). Second one is capacity of 3PL points. The third one is to send or not send which is binary (Y_j). The last one is that decision variable equal or bigger than zero.

Excel solver is applied by using above mentioned parameters. The results of solver is shown in Table 2.

Table 2. *Excel Solver Results*

customer points (i)	3PL points (j)				Amount of Retun (Qi)
	K.cekmece	Bayrampasa	Kagithane	Esenyurt	
Arnavutkoy	45983	0	0	0	45983
Avcilar	67493	0	0	0	67493
Bagcilar	109695	0	0	0	109695
Bahcelievler	89203	0	0	0	89203
Bakirkoy	33712	0	0	0	33712
Basaksehir	74163	0	0	0	74163
Bayrampasa	0	40510	0	0	40510
Besiktas	26370	0	0	0	26370
Beylikduzu	58671	0	0	0	58671
Beyoglu	34385	0	0	0	34385
Buyukcekmece	39666	0	0	0	39666
Catalca	11219	0	0	0	11219
Esenler	65891	0	0	0	65891
Esenyurt	0	0	0	144052	144052
Eyup	0	61506	0	0	61506
Fatih	0	56441	0	0	56441
Gaziosmanpasa	72667	0	0	0	72667
Gungoren	41718	0	0	0	41718
Kagıthane	0	0	66987	0	66987
Kucukcekmece	118770	0	0	0	118770
Sariyer	51575	0	0	0	51575
Silivri	30802	0	0	0	30802
Sisli	0	0	41896	0	41896
Sultangazi	80078	0	0	0	80078
Zeytinburnu	43303	0	0	0	43303
Capacity of 3PL (Kj)	1095363	158457	108883	144052	

As seen in Table 2, the four 3PL points are open. It shows that excel solver is considering to spread the returns to four 3PLs as optimum solution. The transport cost is evaluated as per km. Therefore, the distance has a crucial issue to allocate the return to 3PL points. The excel solver is chosen the nearest 3PL point to allocate the return. Therefore 3rd research question of this study ‘to reduce gas emission’ is achieved by choosing nearest 3 PL point.

The handling cost of K.cekmece is less than other three 3PLs. As seen in Table 2, the excel solver allocated significant amount of returns to K.cekmece. Therefore, it could be said that the solver minimize the cost in terms of transport and order handling. Also this is an answer to 2nd research question of this study ‘how small and medium size enterprises cope with returns in terms of cost. SMEs in footware industry that is located in European side of Istanbul could have a cost of app.621.786 $ per year if they prefer to use 3PLs to handle the returns to take a part in circular economy.

7. CONCLUSION

The enterprises need to focus on environmental awareness as much as having profit. The world sources are limited and need to make most use of each source that is over ground either the product that is in the cycle. Therefore enterprises need to adopt and implement circular economy into their businesses. This could be done by eliminating waste and pollution, keeping material in use either product or component during its life-cycle and regenerate nature [30]. Due to implement a circular economy into business it is essential to support it by creating a circular supply chain management. CSCM aims to reduce waste and establish a circular metarial flow [31]. From this point of view reverse logistics, green logistics and closed-loop supply chain become important facilities for circular supply chain management.

The e-commerce is getting more attention due to availability of internet and improvements of softwares and also reducing storage and operational cost for enterprises. On the other hand there is approximately 30% of return from e-commerce sales as compared to store sales [21]. The handling of returns is important issue that e-commerce enterprises should consider. The return of goods also causes more logistics movements on the roads. Beside this a rise in frequency of deliveries causes pollution, congestion, road accidents in terms of urban logistics as well as increase in delivery cost [32]. The product return due to some reasons such as damaged, wrong product, time-out might be hard issue for SMEs to handle. This might be because of lack of operational excellence, lack of resources, lack of knowledge etc. Therefore a return of product could not evaluate enough and carry out with right operation. This could cause waste of product. But according to circular economy, it is necessary to make the most use of a product during its life-cycle. From this point of view, the study proposed a circular supply chain network design that includes reverse logistics, green logistics and closed-loop supply chain for e-commerce firms and analysis footware industry in Istanbul. A model is developed for SMEs to handle e-commerce returns. The handling of return products are done by 3PLs due to collection and delivery centers create more sustainable e-commerce logistics [33]. The mathematical model is created by linear programming in order to keep the cost minimum. The return of shoes collected from customer points by 3PL and taken to 3PL point for sorting. Afterwards they will send either recycling either disposal or factory. In the model, the nearest 3PL is chosen for each customer point as long as 3PLs capacity is available. Therefore emission of carbon is minimized and respectfully the transport cost.

As seen in the network design SMEs could be able to implement circular economy into their supply chains by creating just an echelon that is 3PL. 3PLs provide collection and sorting for return products so that SMEs have a chance to keep the product or its components in the cycle during its life-time by giving less harm to environment such as low emmision of carbon.

The limitation of this study is that mathematical model is based on European side of Istanbul due to excel solver capacity. However, Istanbul has 39 districts that means 39 customer points, excel solver could not work out 39 customer points for allocation. Because of this reason Python could be used in the next studies that has more than 25 customer points.

This study is relevant for SMEs to give an idea how to take a part in circular economy by having advantage of using outsource (3PL). The circular supply chain network design that is proposed in this study could be implemented in other sectors such as furniture manufacturers. Also the next studies might generate network through disposal and recycling points and calculate the cost.

CONFLICTS OF INTEREST

No conflict of interest was declared by the authors.

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