

## **Minimizing losses at red meat supply chain with circular and central slaughterhouse model**

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## Minimizing Losses at Red Meat Supply Chain with Circular and Central Slaughterhouse Model

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## MINIMIZING LOSSES AT RED MEAT SUPPLY CHAIN WITH CIRCULAR AND CENTRAL SLAUGHTERHOUSE MODEL

### Abstract

**Purpose:** The aim of this paper is to find solutions to improve the red meat sector in an emerging economy, Turkey, from the circular economy point of view, and taking sustainability approach. The need for circular management within the red meat sector in Turkey is emphasized by using Grey method. As theoretical contribution of this study, the investigation of the causes of losses at the slaughter stages of the red meat supply chain leads to proposals for sustainable and circular solutions.

**Design/methodology/approach:** Grey Method is used to predict the number of slaughtered cattle and the amount of bone and blood waste in the slaughtering process between 2018-2020.

**Findings:** It is revealed that according to Grey prediction calculations, although the amount of slaughtered cattle, bone and blood waste seem have decreased between 2018-2020, there are still significant losses in Turkish red meat sector. For bone waste, this is expected to be 56,581,200 kg in 2018, 48,235,840 kg in 2019 and 41,121,380 kg in 2020. For blood waste, it is expected to be 24,754,275 kg in 2018, 21,103,180 kg in 2019 and 17,990,604 kg in 2020.

**Originality/value:** This paper represents policymakers with a proposal for triple bottom line based circular and central slaughterhouse model, based on triple bottom line, which brings social, economic and environmental benefits for the red meat sector in Turkey.

**Key Words:** Circular Economy, Emerging Country, Red Meat Loss, Food Supply Chain, Sustainability, Grey Prediction

### 1. Introduction

In recent years, combating food loss and waste has become a major societal challenge throughout the world. Especially, the implementation of circular business models and policies can make sustainable contributions to this initiative in a sustainable way by conserving limited natural resources, and by reducing greenhouse gas emissions (GHGe) (Sharma et al., 2019; Ali et al., 2019). Food loss and waste refers to the decrease in the amount of edible food from plants and animals that are harvested or produced for human consumption across all stages of the food

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3 supply chain (Lipinski et al., 2013; Sawaya, 2017; Verma et al., 2019). Food loss and food  
4 waste occur at different stages in the food supply chain (Salihoglu et al., 2018). These terms  
5 have different meanings: food loss is defined as the reduction in quantity or quality of food at  
6 the pre-consumer stages in production, postharvest and processing, whereas food waste is the  
7 removal from the food supply chain of food which is appropriate for human consumption, or  
8 which has spoiled or expired for various reasons, mainly due to economic behavior, poor stock  
9 management, or neglect at the consumer stages in food services and household (Parfitt et al.,  
10 2010; Grimm et al., 2014; Aktas, et al., 2018; Mangla et al., 2018). From this point of view,  
11 both food loss and waste have a serious impact on the sustainable development in terms of  
12 environmental, economic and societal aspects (FAO, 2013a). According to the U.N. Food and  
13 Agriculture Organization (FAO), one-third of the edible parts of food production lost or wasted,  
14 approximately 1.3 billion tons worldwide annually; furthermore, almost half of all fruit and  
15 vegetable production wasted before reaching consumers (FAO, 2011). Moreover, many food  
16 issues including safety, hygiene, temperature control, and trace & tracking seriously impact  
17 human health, and cause economic loss for farmers and businesses, and consequently, restrict  
18 food access to the poor in both develop and developing countries (Verma et al., 2019). Food is  
19 wasted at all stages of the food supply chain, between initial agricultural production, and final  
20 household consumption; during transportation and distribution, in production, postharvest,  
21 processing, in storage, at restaurants, and in markets. This waste costs around \$680 billion in  
22 developed countries and \$310 billion in developing countries (FAO, 2011). The most  
23 significant food loss and waste from farm to fork occurs in early and middle stages of the food  
24 supply chain (close to the farm) in developing countries, whereas mainly at later stages at the  
25 retail and consumption (close to the fork) in developed countries (Parfitt et al., 2010). In Europe  
26 and the US, a greater amount of food loss and waste at the consumer and pre-consumer stage  
27 than in the rest of the world. Global quantitative food loss and waste is raising (FAO, 2011) and  
28 account for roughly 30% for cereals, 40-50% for root crops, and fruit and vegetables, 20% for  
29 oil seeds, meat and dairy, and 35% for fish per year. Also, this waste and loss causes about 4.4  
30 gigatons of GHGe annually (FAO, 2011), almost four times greater than generated in aviation  
31 industry, and is comparable to emissions from all road transport. The challenges in each stage  
32 of food supply chain need to be measured to ensure appropriate interventions as part of overall  
33 food security practices. From this perspective, food loss and waste not only create a distortion  
34 in food availability and exacerbates rising food prices, but also puts excessive pressure on the  
35 environment. Avoiding food loss and waste would therefore avoid unnecessary GHGe and help  
36 mitigate climate change.  
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3 It is essential to focus on sustainability to reduce losses in the food supply chain (Ali et al.,  
4 2019). In this study, losses in the red meat supply chain are investigated, since this is an  
5 important area in an emerging economy, like Turkey, in which agriculture and livestock are  
6 major sectors (FAO, 2013b). The red meat sector has structural problems in Turkey, including  
7 the informal nature of slaughterhouses, lack of knowledge about slaughtering processes,  
8 uneducated employees, unhygienic conditions, and inadequate governmental policies (Us,  
9 2010). Previously implemented governmental policies were not effective in the long term  
10 because they did not consider the structural problems and were limited to import regulations.  
11 The governmental regulations were based on linear economy and provided no long-term  
12 benefits in terms of sustainability, leaving a problematic environment in the red meat sector.  
13 Thus, the problematic structure of the red meat sector in Turkey, continues to cause social,  
14 environmental and economic impacts.  
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25 Hence, this study stands on the research question of how to improve the red meat sector from  
26 circular economy perspective and sustainability approach. The study proposes models to find  
27 sustainable solutions by investigating the causes of losses at the initial stages of the red meat  
28 supply chain, and specifically, the slaughtering process. **By considering the related literature,**  
29 **although there are many studies about prevention of food loss, these studies are either limited**  
30 **with current state analysis or focusing solely on environmental solutions (Gobel et al., 2015;**  
31 **Kummu et al., 2012; Parfitt et al., 2010; Verghese et al., 2015). In addition to that, a food supply**  
32 **chain needs to meet sustainability concerns based on TBL to reduce food losses, energy**  
33 **consumption while to increase social and economic welfare (Foran et al., 2005; Fritz and**  
34 **Schiefer, 2008; Kucukvar et al., 2019; Miemczyk and Luzzine, 2019; Tsolakis et al., 2018).**  
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43 Moreover, according to Sgarbossa and Russo (2017), waste should be reused as raw material to  
44 prevent disposal of valuable wastes. In addition, circular economy is not only about reducing  
45 the waste which damage on environment, but also about reusing of waste as new input in food  
46 supply chain (Genovese et al., 2017; Secondi et al., 2019).  
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51 Furthermore, the sustainability of a food supply chain involves being circular such as reusing  
52 wastes as resource (Jurgilevich et al., 2016). In addition, the sustainability of food supply chain  
53 depends on the recycling operations and the circularity of waste management (Borrello et al.,  
54 2017; Ciulli et al., 2019; Cristobal et al., 2018).  
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3 Therefore, the purpose of the study is trying to find the best solution to avoid food loss with the  
4 help of a new model on slaughterhouse which is sustainable and meeting circular concerns. To  
5 sum up, with this study, the gap in practical solutions for food waste in food supply chain is  
6 tried to be filled by proposing a sustainable and circular slaughterhouse model. Therefore, in  
7 this study, after a prediction of the amount of slaughtered cattle and bone and blood waste  
8 caused by slaughtering process, and a new model is proposed based on sustainability for the  
9 Turkish red meat sector to decrease supply chain losses.

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11 In this study, Grey prediction is used to forecast the number of slaughtered cattle, and the  
12 amount of bone and blood waste caused by slaughters. Grey prediction method is practical in  
13 case of limited data and uncertain environment. In other words, grey prediction is based on  
14 uncertainty and limited data set, and not past observations like fuzzy time series method (Tien,  
15 2009). When there is problematic environment and information inaccuracy, grey prediction  
16 method is more appropriate than fuzzy time series (Tien, 2009). Thus, Grey method is better  
17 suited for predicting potential losses due to the problematic environment of the meat sector in  
18 Turkey, and this forecast can be a basis for solutions that reduce potential losses.

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20 Moreover, the traditional forecasting methods for time series are based on accessible and  
21 practical data (Song and Li, 2008; Wen, 2004), and is therefore unviable for limited data and  
22 problematic environment (Wen, 2004). Grey Prediction is more suitable than traditional  
23 methods for predicting values that emphasizes the rapidly increasing losses in slaughtered cattle  
24 and by products i.e. bone and blood.

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26 Therefore, based on the expected number of slaughtered cattle, and losses, calculated by the  
27 Grey Prediction method, we may arrive at permanent and sustainable solutions essential for the  
28 red meat sector in Turkey.

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30 Before explaining methodology, literature review about sustainable supply chain management,  
31 sustainable food supply chain and meat supply chain are explained in detail in the following  
32 section.

## 33 **2. Literature Review**

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35 In this study, literature review focuses on sustainable supply chains, food supply chains and  
36 meat supply chains.

### 37 **2.1. Sustainable Meat Supply Chain Management**

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3 Sustainability and sustainable supply chain management has increased in importance due to  
4 concerns about the environment. Sustainability has become an important concept for  
5 developing country, confronting overpopulation, health issues, political issues, and meeting  
6 growing needs with limited resources (Mensah and Castro, 2004). These problems affect the  
7 countries economically, socially and environmentally, and it is crucial to consider sustainable  
8 solutions to avoid serious adverse consequences.  
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12 “Sustainability is defined as maintaining the ability to be permanent while ensuring the  
13 continuity of diversity and productivity as a term” (Business Dictionary, 2018). According to  
14 Brundtland Report which is published by the World Commission on Environment and  
15 Development (WCED) in 1987, sustainable development is defined as “the desire to develop  
16 the environmental and social performance of the current generation without ignoring the ability  
17 of the next generation to meet the social and environmental needs” (WCED, 1987). Sustainable  
18 supply chain management is a specific approach that seeks to provide the requirements of  
19 social, environmental and economic dimensions in the flow of materials and services between  
20 the supplier, the producer and the client, by focusing on creating value for all stakeholders (Ince  
21 and Ozkan, 2015). Moreover, sustainable supply chain considers not only economic, but also  
22 social and environmental effects on supply chain operations, i.e. the “triple bottom line” (TBL),  
23 in sustainable point of view.  
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26 According to Elkington (1997), environmental sustainability covers “planet” issues, such as  
27 reducing air pollution, avoiding waste, considering emissions and hazardous materials;  
28 economic sustainability covers “profit” issues such as market share, profit maximization,  
29 financial conditions; and social sustainability covers “people” issues, such as living conditions,  
30 job opportunities, educational and healthy working conditions.  
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33 In this study, meat losses in supply chain are mentioned. Therefore, food supply chain is crucial  
34 issue for this study.  
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37 A food supply chain includes processes from food production to consumer (Bendeković et al.,  
38 2015), and comprises various products and firms selling food products or operating in the  
39 markets (European Commission, 2014). Food supply chain, from production to consumption,  
40 is facilitated by logistics and transport companies (Dani, 2015). The most important duty of  
41 logistics and transportation companies is to deliver the food to the consumers in a timely and  
42 accurate manner. Food supply chain includes food producers, food processors, i.e. food  
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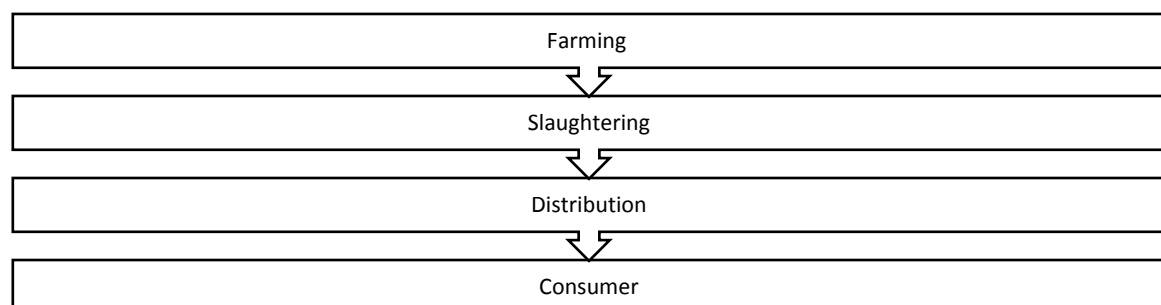
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3 manufacturers, retailers and distributors as well as hospitality sectors, which create links  
4 between producer and consumer (Dani, 2015).  
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7 It is crucial for food supply chains to be sustainable in current world conditions (Smith, 2008).  
8 Sustainability and quality can be achieved by “Triple Bottom Line (TBL)”; in other words,  
9 sustainable in terms of social, environmental and economic factors.  
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13 There are many studies about sustainable food supply chain in the literature. For instance,  
14 Pullman et al. (2009) studied sustainable food supply chain from the environmental and social  
15 point of view, Zanoni and Zavanella (2012), focused sustainable supply chain based on decision  
16 strategies. In 2008, Fritz and Schiefer studied sustainable food chain management, and Darkow  
17 et al. (2015), the sustainable food service supply chain. In 2010, Akkerman et al. studied  
18 sustainability in food distributions. Sgarbossa and Russo (2017) suggested a Closed-Loop  
19 Supply Chain model for sustainability in food sector. Becker and Ellis (2017) focused on  
20 sustainability in food supply chain. Additionally, Parfitt et al. (2010) analyzed waste in the food  
21 supply chain, particularly losses in the meat supply chain which is important for the current  
22 study.  
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26 Red meat and products, which have an important place in human nutrition and health, are  
27 among the basic foods to meet the need for animal protein (FAO, 1992). Red meats are obtained  
28 from butchery animals such as cattle, sheep, goats and pigs worldwide. Since red meat products  
29 are perishable, the management of supply chain process is critical. The red meat supply chain  
30 consists of farming, slaughtering, distribution and consumer stages. In Figure 1, the meat supply  
31 chain is shown.  
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43 **Figure 1 Meat Supply Chain (USDA, 2015)**



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56 The meat supply chain begins with breeding, and in farming process, the animal is fed and  
57 raised to be sent to the slaughterhouse. After feeding and growing by the producer, carcass meat  
58 production starts with the purchase of live animals from the producer, and it is the health of the  
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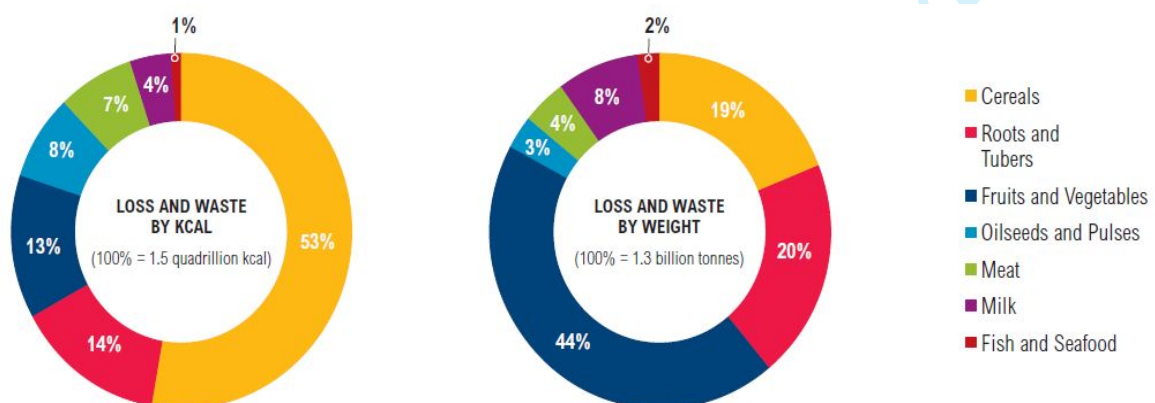
animal and its quality of meat is checked by veterinary control (USDA, 2015). The slaughtering process includes cutting, packaging and storage in cold depots. Then the head and feet of the animal is separated from its body by cutting process, and blood is poured. The skin of the carcass is stored at 4-6 ° C in cold storage depots (USDA, 2015). Products such as bone, cartilage and blood, which appear as residues from meat production, are referred to the rendering process for evaluation in the feed industry (USDA, 2015). After the manufacturing process, carcass meat is sent to retailers or food services and eventually reaches the consumer on food.

In the following part, meat loss and animal waste are explained by considering circular economy.

### 3. Preventing Meat Loss by Circular Economy

Not all food loss or waste is equally wasteful. Different types of food waste cause various degrees of adverse externalities to society, economy and the environment. Particularly, livestock production is relatively natural resource, as well as the most carbon intensive industry, according to emission intensity factor, with 2.58 kg CO<sub>2</sub>eq/\$, higher than the direct production of all other foods for humans (Borello et al., 2016, Boehm et al, 2018). Therefore, it has greater negative environmental impacts associated with fueling climate change, polluting landscapes and waterways (Abecassis et al., 2018). This energy intensity, combined with the high production cost of meat, may indicate that reducing meat loss and waste should receive at least as much attention as other commodities, despite its relatively small share of food loss and waste (Searchinger et al., 2013; Sawaya, 2017). Although meat waste, only 7 percent, to relatively lower than fruit and vegetables, seen in Figure 2 (Lipinski et al., 2013), meat waste causes by far the most CO<sub>2</sub>e.

**Figure 2 Shares of Global Losses and Waste by Commodity (Lipinski et al., 2013)**



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3 In the case of meat and meat products, consumption rates and waste proportions per capita are  
4 highest in industrialized countries. This waste at the consumption level account for  
5 approximately half of total meat loss and waste (FAO, 2011). However, the amount of energy  
6 required for meat production is significantly higher than for plant-based food production  
7 because farms use a lot of diesel fuel and other utilities from fossil fuels in order to feed and  
8 maintain livestock, and plant and harvest animal feed crops. If meat and meat products are  
9 wasted during purchasing and preparing stages, these fuels as well as fertilizers are also wasted.  
10 Avoiding consumption of meat would significantly reduce associated GHGe in food system  
11 (Boehm et al, 2018; Xue et al., 2019). Consequently, not only the amount, but the types of food  
12 being wasted is an important consideration.  
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21 Meat is generally subject to a long production and distribution chain, and as a product it can be  
22 adulterated with other animal meats, and easily contaminated with bacteria. As a relatively  
23 sensitive product, meat is highlighted by major food crises and safety scandals, such as the BSE  
24 (or commonly called mad cow disease), Escherichia coli contamination, avian flu, and replacing  
25 beef with horsemeat, or pork meat contained halal products (Maruchek, et al., 2011, Stamatis  
26 et al., 2015). Meat can quickly become wasted, unless properly processed in the system with  
27 proper storage, handling and distribution of the meat product. Above mentioned inefficiencies  
28 of meat the economy cost trillions of dollars globally, and even more if social and  
29 environmental cost are added. On the other hand, there is increased public awareness about the  
30 origin and quality of meat. Therefore, establishing transparency in meat supply chain is  
31 necessary to guarantee the safety, quality and consumer faith in meat products (Kassahun, et  
32 al., 2014). Furthermore, implementing circular economy in food supply chain can be a solution  
33 to tackle the meat waste problem. The circular economy briefly means reuse, repair,  
34 refurbishing and recycling of the existing materials and products, so that wastes, become a  
35 resource (Jurgilevich et al., 2016; Jakhar et al., 2018). The goal of circular economy is to  
36 generate more value and economic opportunity with less material and energy consumption  
37 (Jakhar et al., 2018; Sharma et al., 2019). More specifically, progress towards circular economy  
38 in food production system means waste prevention, better recycling, and sustainable  
39 management of nutrients. The circular food economy aims at the efficient use of resources, as  
40 well as creativity in inventing uses for food waste and food surplus (Jurgilevich et al., 2016).  
41 Meat waste at the pre-consumer and consumer stages can be evaluated in the frame of circular  
42 economy, although some regulations and laws prohibit meat waste processing, which can limit  
43 the possibility of achieving a fully circular system in the meat supply chain (Borello, 2016).  
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In the following section, animal waste based on byproducts is explained in detail.

### 3.1. Animal Waste

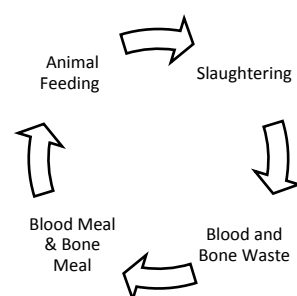
Disposal of waste in the food processing industry or by-product management causes problems in terms of sustainability (Russ and Pittroff, 2004). For a sustainable environment, a waste management system should be established to provide economic benefits to individuals and countries, helping to minimize the harmful effects of degraded materials on the environment and human health. It is important to classify waste according to its source, composition and properties; to design, install and operate collection, transportation and disposal systems; to integrate recoverable substances into the economy, and to produce energy from these wastes.

Animals can play an important role in the meat supply chain, by turning food waste into edible proteins. Animal wastes consist of feces of animals such as cattle, horses, sheep and chickens, dead animals, slaughterhouse losses and waste generated during processing of animal products (Jayathilakan et al., 2012). Although there are wastes caused by animal deaths, most of the animal wastes occur during slaughter in the meat industry (Jayathilakan et al., 2012).

Slaughterhouse waste consists of inedible parts of animals obtained from meat and blood, bone, and other animal by-products (Franke-Whittle and Insam, 2013). Inedible animal tissues (tendons, organs, blood vessels, integuments, bone, feathers, ligaments) correspond to almost 50% of the slaughtered animal (Franke-Whittle and Insam, 2013). The two main uses of traditional waste as fertilizer or animal feed (Russ and Pittroff, 2004). However, many slaughterhouse wastes are generated worldwide, and these wastes are improperly disposed of because they are too costly to utilize in the sector. Such practices cause environmental problems (Arvanitoyannis and Ladas, 2008). Instead of other wastes of by-products, blood and bone are crucial resource for animal husbandry in terms of feed, including protein and iron (Jedrejek et al., 2016). The share of blood and bone by-products is 3,5% and 8% respectively (FAO,1992).

In addition, blood and bone from animal wastes arising in slaughterhouses are important in terms of their potential as raw material for fertilizer, animal feed, biodiesels or raw material for other sectors, such as medicinal, furniture, pharmaceutical (Jedrejek et al., 2016). In Figure 2, the cyclical nature of blood and bone wastes is shown. Blood and bone wastes from animals can be converted into animal feed or fertilizer.

**Figure 3. Circular and Bone Waste**



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Animal blood contains high levels of iron and protein and is an important edible by-product for animals (Jedrejek et al., 2016). On the other hand, when compared with other slaughtering process wastes blood has the highest pollution load (FAO,1992). Blood can be used as fertilizer and feed. Blood is used as blood meal in animal feed (Jayathilakan et al., 2012). Protein supplementation is used as a milk substitute, vitamin stabilizer etc. (Jayathilakan et al., 2012). Moreover, blood can be used in other sectors, such as medicinal, biodiesels and pharmaceutical.

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Furthermore, bone is another slaughterhouse animal waste. Bone meal is a source of minerals, amino acids, and vitamin B12 in animal nutrition. Bone meal-processed protein products have the potential to be used to make cutlery handles, and collagen i.e. uses other than animal feed, and is also used as poultry feed (Auvermann et al., 2004; Irshad et al., 2015). In addition, bone is a raw material for other sectors, such as furniture and medicine.

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In the following section, meat loss in Turkey is explained in detail as problem definition.

#### 4. Problem Definition

In this part of the study, general information about meat sector in Turkey is given and the meat sector in Turkey is analyzed in detail.

##### 4.1. Meat Sector in Turkey

Turkey is an agricultural country, which has valuable agricultural resources, and the food industry is the major sector (Ministry of Food, Agriculture and Livestock, 2018), and essential for the economy. Animal husbandry has a prime position within Turkey's economy for two reasons. It provides a balanced diet and its outputs can be used as raw materials in many sectors (Ministry of Food, Agriculture and Livestock, 2018).

Livestock, i.e. animals raised on farms for commercial sale, includes cattle, sheep, goats, cows, and chickens (Thorntons, 2010). The products that are required for human health and nutrition are animal products. Especially, red meat is a common source of protein, iron, zinc and contains

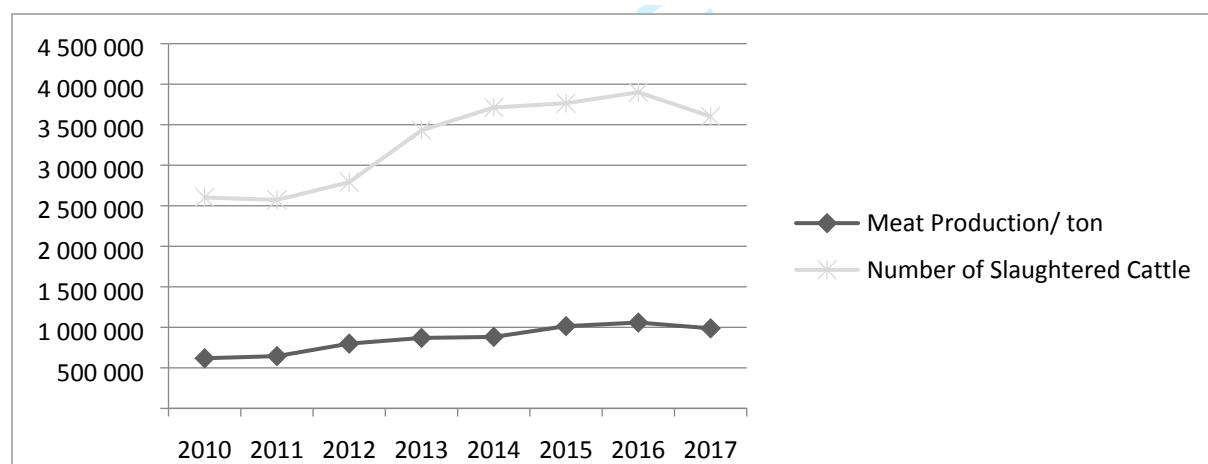
B group vitamins (Sharma et al., 2013). It helps to decrease the nutritional deficiencies and is the most valuable source of animal protein. Moreover, it is often consumed because its benefits are known in Turkey. Red meat are cattle, sheep, buffalo in Turkey (Us, 2010).

Cattle accounts for 88% of the total red meat production in Turkey. Moreover, according to FAO statistics, Turkey accounts for 12% of the EU cattle population with only France and Germany having greater number (FAO, 2017). For this purpose, the article is focused on importance of cattle for Turkey.

Cattle has the benefits such as year-round milk production, its suitability to different climatic zones, and economic value of its meat. To these reasons, cattle is more important than buffalo and sheep for Turkey. In addition, according to FAO data, cattle raising provides 83% of world milk production and 21% of meat production in 2016, and it has a large share in nutrient production (FAO, 2017).

According to TUIK (2018) data, the meat production (tons) and the number of slaughtered cattle in Turkey is shown in Figure 4.

**Figure 4. The meat production (tons) and the number of slaughtered cattle in Turkey (TUIK, 2018)**

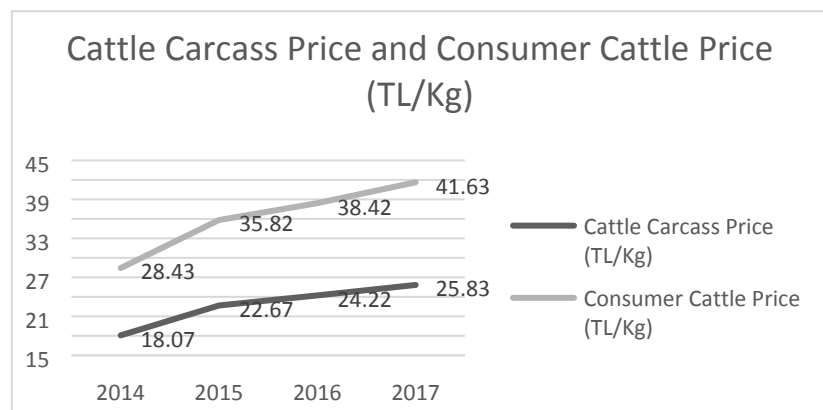


As seen in Figure 4, the number of slaughtered cattle increased between 2010 and 2014. Due to the livestock import regulation applied by the government in 2010 to meet increasing red meat demand in Turkey. However, the import regulation failed to meet demand in Turkey, since the slaughtered animals could not be replaced due to increased input costs, such as feed, medicine, fuel. Moreover, in addition to domestic animals, imported livestock are also slaughtered. However, this regulation was insufficient due to the relatively increasing demand. After that, in

order to decrease red meat prices in Turkey and to meet customer demand from consumers, carcass meat import regulation was permitted by the government on August 2014. Import regulation temporarily increased the amount of meat available and reduced prices, but after 2014, the number of slaughtered cattle stabilized, and meat production decreased. In 2017, total amount of red meat production decreased to 982.487 tons, and the number of slaughtered cattle decreased to 3,602,115 (TUIK, 2018). According to TUIK (2018) data, countries that imported carcass meat to Turkey are as follows: Poland (83%), France (14%) and others (3%).

Import regulation failed to reduce meat prices, its main aim. Cattle carcass meat prices and consumer cattle prices are shown in Figure 5.

**Figure 5. Cattle Carcass Meat Prices and Consumer Cattle Prices (TUIK, 2018)**



As shown in the Figure 5, for 2014, 2015, 2016 and 2017, cattle carcass prices are calculated as 18.07 TL/kg, 22.67 TL/kg, 24.22 TL/kg and 25.83 TL/kg respectively. Moreover, consumer cattle prices are calculated as 28.43 TL/kg, 35.82 TL/kg, 38.42 TL/kg and 41.63 TL/kg (TUIK, 2018).

As seen in the figures, the Turkish red meat sector has structural problems that cannot be resolved by just establishing import regulations. The red meat sector in Turkey based on local farmers and local producers; fluctuations in the production of local farmer and producers cause structural problems and, problematic environment. Although the governmental subsidies and support for livestock has increased, untrained the uneducated employees and the continuation of migration to the city are the obstacles to the sector (Aydogdu and Kucuk, 2018). In addition, after import regulations, dependency on other countries, and the lack of enthusiasm of local farmers and producers cause problematic environment in Turkey. Two major regulations

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2  
3 regarding Turkey's red meat sector, have added to difficulties for local farmers and producers  
4 in Turkey. One was livestock import in 2010 and the other was carcass red meat import in 2014.  
5  
6 Important fact for Turkey's red meat sector are animal deaths resulting from the disease,  
7  
8 inadequate governmental controls, lack of attention to hygiene, the informal nature of  
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10 slaughterhouses, lack of knowledge about technology and slaughtering processes, and the losses  
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12 and wastes due to the absence of regulation (Ministry of Food, Agriculture and Livestock,  
13  
14 2018). Furthermore, by-products i.e. skin, blood, bone, feet, fatty issues are disposed of in  
15  
16 Turkey, although most can be used as raw material in other sectors, e.g. production of biodiesel  
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18 or feed for animals. Especially, bone and blood waste can be transferred to feed, fertilizer or  
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20 raw material in other sectors (Jayathilakan, 2012). For all these reasons, the number of animals  
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22 decreased, and losses in the meat sector increased due to improper cutting procedures,  
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24 unhygienic conditions, informal slaughterhouses, and lack of trained labor. Turkey's  
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26 competitive advantage is low in the sector since cause a confused environment. To sum up,  
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28 chaos in Turkey's red meat sector in Turkey was caused by structural problems that were not  
29  
30 adequately addressed by the livestock import in 2010 and carcass red meat import in 2014  
31  
32 legislation. These solutions were part of the linear economy, and did not consider sustainability,  
33  
34 and eventually did not work out. Therefore, local farmers and local producers lost their source  
35  
36 of income. According to FAO Turkey (2013b), the biggest meat loss occurs in the initial stages  
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38 of meat supply chain at the level of farmer, slaughterhouse and meat processor in Turkey, and  
39  
40 this loss accounts for about 10%. Small and fragmented farms, and lack of cooperation culture  
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42 are generally indicated as the most important reasons for food losses. Nonetheless, new  
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44 production systems for sustainable agriculture are much more knowledge intensive, requiring  
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46 farmers to learn to use additional technologies, management methods, risk avoidance plans,  
47  
48 financial literate and familiar with environment protection practices (Jöhr, 2012). Most farmers  
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50 use still traditional methods with outdated farming practices, and avoid using new agricultural  
51  
52 system and technologies (Salihoglu et al., 2018). Furthermore, the aging of Turkish farmers is  
53  
54 an important issue since the young generation tends give up farming and move to cities,  
55  
56 likewise, many developing countries suffer the same phenomenon: a massive brain drain from  
57  
58 rural to urban areas (Jöhr, 2012, FAO, 2013b).  
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54 As mentioned before, the structural problems of the sector, and temporary solutions such as  
55 import regulations, not only made the country dependent on imports, but also failed to stop the  
56 increase of consumer meat prices. This damaged farmers' income sources and decreased  
57 productivity in meat production. In this study, it is aimed to find solutions for the structural

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3 problems in the sector and to provide additional income sources via circular and sustainable  
4 approaches. From the point of circular view, bone and blood waste, discussed in the Animal  
5 Waste Section, will be examined here.  
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9 To do so, firstly, it is crucial to predict the number of slaughtered cattle, and secondly, the  
10 amount of bone and blood waste caused by slaughtering process, to create a roadmap for  
11 eliminating meat sector losses, and benefit from byproducts based on sustainability goals.  
12  
13

14 This study is an investigation of the effect of irregularities and problems in the red meat sector.  
15 In the literature, there are studies about consumption of the red meat in Turkey (Adisen, 1999;  
16 Atay et al., 2004, Yaylak et al., 2010), consumer perception in red meat sector (Tosun and  
17 Hatırlı, 2009; Saçlı, 2018), analysis of red meat prices based on regions in Turkey (Kan and  
18 Direk, 2004). However, here is a notable lack of forecasting-based studies relating to the red  
19 meat sector in Turkey. For this purpose, the losses from structural problems, inappropriately  
20 trained cutters, lack of technology, and loss of byproducts (blood and bone) is revealed with  
21 numeric data.  
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29 Therefore, in this study, Grey method is used for the prediction of the amount of slaughtered  
30 cattle, and bone and blood waste, to emphasize the growing problems in red meat sector in  
31 Turkey. Grey method is expedient method for explaining the potential problems from losses  
32 due to the fluctuating environment in the sector in Turkey. Grey System Theory (GST) is  
33 appropriate for discrete data and uncertain systems, since GST is related with incomplete  
34 information in the research area (Song and Li, 2008; Liu et al., 2012). Moreover, grey prediction  
35 method is practical for dealing with inaccuracy and partial knowledge, as in the real world  
36 (Wen, 2004; Liu and Forrest, 2007).  
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44 Moreover, traditional estimation methods include Box Jenkins methods, regression analysis, or  
45 neural networks. In order to get correct results these methods require large scale statistical data  
46 (Chiang, 1997; Song and Li, 2008). However, the mixed and problematic structure in the  
47 Turkish red meat sector makes it difficult to predict the actual losses in by-products, preventing  
48 the use of traditional statistical methods. In addition, the method is appropriate for the study  
49 since the analysis includes analysis of error, which is low in this study, to indicate the reliability  
50 of the method, as mentioned in Grey Prediction Section.  
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57 Furthermore, other alternative methods for example system dynamics modelling can be used  
58 for problematic problems in uncertain environment (Sterman, 2000). Dynamics system  
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3 modelling is similar to Grey Prediction in that it is more reliable (Lyneis, 2000). It was designed  
4 to understand the behavior of the systems (Aiguer et al., 2013). “Dynamics” refers to “changing  
5 over time” (Barlas, 2002) and can be used in many different fields, e.g. social science,  
6 engineering and economics when there is problematic environment with interrelations can  
7 haven many elements (Saraji and Sharifabadi, 2017). The three main steps of system dynamics  
8 modelling forecast are defining the problem, designing dynamic hypothesis to describe the  
9 causes of the problem, and developing a problem formulation which is used as a simulation to  
10 analyze different scenarios (Aiguer, 2013; Nair and Rodrigues, 2013; Saraji and Sharifabadi,  
11 2017). System dynamics modelling includes feedbacks, causal relationships, analysis,  
12 simulation and different scenarios to understand fluctuations across different data (Aiguer et  
13 al., 2013). However, system dynamics modelling has some drawbacks: it needs other tools to  
14 forecast, and requires expert modelers (Suryani, 2012). Furthermore, discontinuities are not  
15 calculated in the system (Barlas, 2002; Suryani et al., 2012).

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26 Compared to Grey Prediction, system dynamics modelling requires more data to analyze  
27 interrelations between elements of the problematic environment. System dynamics modelling  
28 is more suitable when there are many parameters, and understands their interrelations is  
29 essential for forecasting (Lyneis, 2000; Aiguer et al., 2013; Saraji and Sharifabadi, 2017). In  
30 addition, although used in a short-term forecast, system dynamics modelling is more useful for  
31 long-term forecasts (Lyneis, 2000). Although both grey prediction and system dynamics  
32 modelling can be used in problematic systems, the system dynamic modelling is a more  
33 comprehensive model (Nair and Rodrigues, 2013). Therefore, it needs more data for the study.  
34 In this study, only 4 years which is inadequate for data are available, system dynamics  
35 modelling to be built and understand the relations within the study. System dynamics modelling  
36 is a comprehensive scenario-based model and it is a computer-based system which uses  
37 simulation (Nair and Rodrigues, 2013); however, in this study it is only aimed to forecast losses  
38 in red meat sector in Turkey, without forecasts different parameters and therefore scenario-  
39 based models are not applicable. Although not used in the study, the model can be applied for  
40 different scenarios, and when different parameters will be forecasted. Moreover, in this way,  
41 there is no consideration of meat consumption in relation with any other parameters.

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55 To achieve this aim, considering the condition of Turkey’s red meat sector and from circularity  
56 point of view, in this study, Grey Prediction is firstly used to predict the number of slaughtered  
57 cattle, and secondly, to predict the amount of bone and blood waste caused by improper cutting.  
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By using Grey Prediction, the structural problems of the red meat sector in Turkey is emphasized with numerical data to show the current status of the red meat sector in Turkey. To understand and find solutions for the problematic environment, it is necessary to know future values about the sector.

In the following part Grey Prediction is explained in detail.

### 5. Grey Prediction & GM (1,1) Rolling Model

The grey system theory is proposed by Ju-Long Deng in 1982. Grey numbers are represented as known or unknown information in grey system theory. A system that can be fully known is described as white, unknown, as black, and partially known, as grey (Papageorgioua and Salmeron, 2012; Bayramoğlu and Hamzacebi, 2016). The grey system is practical when there are uncertain systems (Liu et al., 2012).

GM (1,1) is used for time series problems, and it is defined as a first-order univariate estimation model (Cui et al., 2013). GM (1,1) model is preferred for time series forecasting since it is practical for problematic system within a limited data (Cui et al., 2013). GM (1,1) model is “Grey Model First Order One Variable” in the literature Mostafaei and Kordnoori (2012). The GM (1, 1) model needs only four recent sample data to make forecast (Hu, 2017; Liu and Forrest, 2007; Hui et al., 2013; Li et al., 2011). The grey model can be presented by GM (n,h) model. In this model, “n” represents the degree of grey differential equation and “h” symbolizes the number of the variables. GM (1,1) model is sub pattern of grey models. The Rolling GM (1,1) model is preferred to GM (1,1) model. GM (1,1) model is less recommended and more inaccurate because it does not consider fluctuations in data. The Rolling GM (1,1) model takes consideration of changes in data (Hsu, 2011), and is therefore used in this study.

Rolling GM (1,1) model has the following steps;

**1<sup>st</sup> Step:** Original data set ( $x_0$ ) is expressed as:

$$x_0 = (x_1^0, x_2^0, \dots, x_n^1) \quad [1]$$

In the notation;  $x_0$  = non-negative sequence and n = sample size of the data set.

$$x_k \geq 0 \quad k = 1, 2, \dots, n$$

**2<sup>nd</sup> Step:**  $x_1$  is calculated by applying AGO for  $x_0$  series. The Equation 2 is used to calculate  $x_1$ .

$$x_k^1 = \sum_{i=1}^k x_0^i \quad [2]$$

$x_1$  series is expressed after calculating the AGO for  $x_0$ .

$$x_k^1 = x_1^1, x_2^1, \dots, x_n^1 \quad [3]$$

**3<sup>rd</sup> Step:** In this step,  $z_k^1$  of  $x_k^1$  means that generated mean sequence is calculated by using Equation 4 and it is expressed as in [5].

$$z_k^1 = 0.5x_k^1 + 0.5x_{(k-1)}^1$$

[4]

$$k = 1, 2, \dots, n$$

$$z_k^1 = z_1^1, z_2^1, \dots, z_n^1 \quad [5]$$

**4<sup>th</sup> Step:** Before moving other steps, a and b parameters is found for analytical solution of corresponding grey equation. Firstly, a and b are calculated with 2 different ways Least Square Method or Parameter Method (Wen, 2004; Chen and Chang, 2000). In this study, Least Square Parameter Method will be applied. Therefore, equations for Least Square parameter method are expressed as below:

All data are substituted as Equation 7 with using Equation 6.

$$b = x_{(k)}^0 + az_k^1 \quad [6]$$

$$x_{(2)}^0 = az_2^1 + b$$

$$x_{(3)}^0 = az_3^1 + b \dots\dots\dots$$

$$x_{(n)}^0 = az_n^1 + b \quad [7]$$

After defining equations, x and z series are represented with B and Y matrices as Equation 8.

$$Y = \begin{bmatrix} x_2^0 \\ x_3^0 \\ \vdots \\ x_n^0 \end{bmatrix} \quad B = \begin{bmatrix} -z_2^1 & 1 \\ -z_3^1 & 1 \\ \vdots & \vdots \\ -z_n^1 & 1 \end{bmatrix} \quad [8]$$

For finding a and b parameters is applying Equation 9.

$$\alpha = [a, b]^T = (B^T B)^{-1} (B^T \cdot Y) \quad [9]$$

**5<sup>th</sup> Step:** After obtaining a and b parameters, Equation 10, grey differential equation, is applied to calculate predicted data.

$$x_{(k+1)}^1 = \left[ x_1^0 - \frac{b}{a} \right] e^{-ak} + \frac{b}{a} \quad [10]$$

**6<sup>th</sup> Step:** At the last step, the control of the method is making with using Equation 11.

$$x_{(k+1)}^0 = x_{(k+1)}^1 - x_k^1 \quad [11]$$

$$k = 1, 2, \dots, n$$

### 7<sup>th</sup> Step: Error Analysis in GM (1,1) Model

In GM (1,1) model, error analysis is needed to determine the average error rate for the prediction. Therefore, while applying error analysis, it is possible to identify the error rate can be seen between actual data and predicted data to continue further studies (Yılmaz and Yılmaz, 2013; Wen, 2004). To calculate average error rate of the model, Equation 12 is used.

$$e(k+1) = \left| \frac{x_{(k+1)}^0 - \hat{x}_{(k+1)}^0}{x_{(k+1)}^0} \right| \times 100\% \quad [12]$$

## 6. Implementation

As explained in the “Meat Sector in Turkey” section, implementation of the study is focused on the number of slaughtered cattle of Turkey. Since carcass meat imports began in Turkey in August, 2014, the number of slaughtered cattle by farmers is expected to change over the years.

Therefore, in this study, GM (1,1) model provided data on the number of slaughtered cattle for Turkey over three years in yearly periods. To facilitate the GM (1,1) model, the number of slaughtered cattle in Turkey in 2018, 2019 and 2020 were predicted to see how carcass meat imports affect these numbers.

In this study, the number of slaughtered cattle is predicted for each of the 3 years after carcass meat imports began, i.e., the number of slaughtered cattle is predicted by using data between 2018-2020.

**Table 1 Actual data of the amount of slaughtered cattle in Turkey**

$X_{(0)}$  original non-negative data series represent as;

$$X_{(0)} = (3,765,077, 3,900,307, 3,602,115)$$

After determining  $x_0, x_1$  was found.  $x_1$  means that new series of the actual data set with finding the AGO, the cumulative sum of the series  $(0)$ .

$$X^{(1)} = (3,765,077, 7,665,384, 7,502,422)$$

After calculating AGO, the following step was calculation of the generated mean sequence  $z_k^1$  of  $x_k^1$ .

$$z_k^1 = (5,715,231, 7,583,903)$$

The following step was to determine a and b values. To find a and b values, after finding Y and B matrices by using Equation 7, the least square method is calculated.

$$Y = \begin{bmatrix} 3900307 \\ 3602115 \end{bmatrix} \quad B = \begin{bmatrix} -5715231 & 1 \\ -7583903 & 1 \end{bmatrix}$$

To find a and b values,  $(B^T \cdot B)$ ,  $(B^T \cdot B)^{-1}$  and  $[(B^T \cdot B)^{-1}] B^T \cdot Y$  is calculated respectively.

$$(B^T \cdot B) = \begin{bmatrix} 9,019E + 13 & -1,3299E + 07 \\ -1,3299E + 07 & 2 \end{bmatrix}$$

$$(B^T \cdot B)^{-1} = \begin{bmatrix} 5,72748E - 13 & 3,80853E - 06 \\ 3,80853E - 06 & 25,82504972 \end{bmatrix}$$

$$[(B^T \cdot B)^{-1}] B^T \cdot Y = \begin{bmatrix} 0,1596 \\ 4812310,582 \end{bmatrix}$$

After calculations, results are shown as below:

$$a = 0,1596$$

$$b = 4812310,582$$

$$e = 2,7183$$

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2  
3 Thereafter, all parameters were obtained, predicted values were found by using Equation 10.

4  
5 The prediction results are presented in Table 2.

#### 6 7 **Table 2 Prediction Results**

8 According to prediction analysis, the number of slaughtered cattle was expected to be 2.829.060  
9 in 2018, 2.411.792 in 2019 and 2.056.069 in 2020, i.e. it was expected to decrease over the  
10  
11 years.

12  
13  
14 After predicted data was found, error analysis was performed for the accuracy of the method.

15  
16 In table 3, error analysis is shown.

#### 17 18 **Table 3 Error Analysis**

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20  
21 Average Relative Error =  $\Delta = \frac{1}{3} \sum_{k=2}^4 \Delta k = 2,69\%$

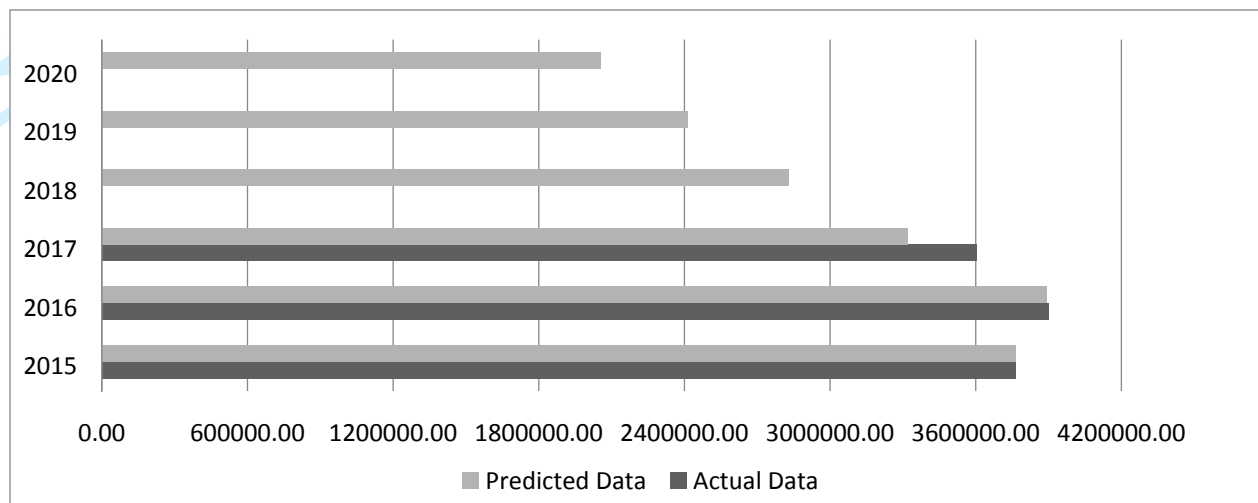
22  
23  
24 The error analysis was found by traditional error formula in Equation 12. According to  
25  
26 calculation, the average relative error was found as 2.69%, i.e. the predicted data is reliable.

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29 Table 4 shows the summarized results between actual and predicted data for 2015-2020.

#### 30 31 **Table 4 Summary of the Results**

32 According to predicted values between 2018 and 2020, it can be seen that the number of  
33  
34 slaughtered cattle would decrease after the carcass import started in 2014. Figure 6 shows the  
35  
36 comparison of actual and predicted values for the number of slaughtered cattle in Turkey  
37  
38 between 2015 and 2020. Therefore, farmers seem to have accepted the import of carcass meat  
39  
40 as a replacement for slaughtered animals.

#### 41 42 **Figure 6. Comparison of actual values and predicted values of slaughtered cattle in** 43 44 **Turkey between 2015-2020**



After calculation of the number of slaughtered cattle for 2018, 2019 and 2020, the amount of bone waste and blood waste are calculated. In this study, the main aim is to identify the amount of blood and bone waste relative to the number slaughtered cattle. Bone and blood waste were calculated as shown in Equation 13. In this calculation, average weight for cattle was considered as 250 kg in Turkey data, and the waste rates were gathered from Meat and Milk Board (2017).

*Waste Calculation = Forecasted number of slaughtered cattle \* average weight \* waste rate*  
[13]

Table 5 shows bone and blood waste calculation.

#### **Table 5 Bone and Blood Waste Calculation**

According to bone and blood waste calculation, despite a small reduction between years, the amount of waste is still high. Bone waste was expected to be 5,658,1200 kg in 2018, 48,235,840 kg in 2019 and 41,121,380 kg in 2020. Blood waste was expected to be 24,754,275 kg in 2018, 21,103,180 kg in 2019 and 17,990,604 kg in 2020.

### **7. Proposed Central and Circular Slaughterhouse Based on TBL**

Turkey has a problematic environment in the meat sector, as mentioned, and the sector is based on local farmers and producers, which makes it more vulnerable to the consequences of its chaotic nature. There are several reasons for the problematic structure in meat sector in Turkey: livestock quantity, the lack of sufficiency qualified labor force, lack of training, the quantity and quality of meat processing and storage facilities, the absence integrated slaughter facilities, the informality of milk and meat production, lack of attention to hygiene, inefficiency of the system, and underuse of technology. Thus, overall, there is a lack of competitiveness in meat and meat production.

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3 This problematic environment leads to increased meat prices and dependence on imports.  
4  
5 Factors affecting red meat prices in Turkey are: feed and labor costs, fluctuations in the currency  
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7 rate that affect cost of raw materials, decreasing livestock population, meat import regulations,  
8  
9 government interventions, livestock government support for, unstable of milk prices, consumer  
10  
11 demand, consumer preferences and purchasing power. Among these, the most influential are  
12  
13 import regulations and government interventions.  
14

15  
16 The aim of imports of carcass meat after August 2014 was to reduce meat prices in Turkey.  
17  
18 This import regulation increased the amount of meat, and briefly decreased market prices but it  
19  
20 did not provide long-term benefits. With the start of carcass meat imports, the sector became  
21  
22 dependent on import, therefore, local producers and farmers lost their source of income.  
23

24  
25 Most meat cutting and processing plants in Turkey are hybrid plants for cattle and small  
26  
27 ruminants. There are around 650 private sector and state-owned facilities (USDA, 2017). This  
28  
29 number can be regarded as large, however, considering the large geographical farmers area and  
30  
31 the current locational distribution of the slaughterhouses, many farmers have difficulties to  
32  
33 finding slaughterhouses nearby. In addition, there are informal slaughterhouses, where animals  
34  
35 often die due to diseases, or diseased animals are slaughtered, causing a huge risk for society.  
36  
37 On other hand, in private or state-owned slaughterhouses, economic and environmental losses  
38  
39 caused by improper cutting and regarding potential by-products as waste. Indeed, these wastes  
40  
41 can be transformed to value added products and may even be used as raw materials in other  
42  
43 sectors. Therefore, as mentioned in the case of slaughtering, the problematic condition in the  
44  
45 meat sector affects the country socially, environmentally and economically.  
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48 In Turkey's meat sector, large amounts of slaughterhouse byproducts, such as skin, bones,  
49  
50 internal organs, fatty tissues, horns, hoofs and bumps are discarded. However, most byproducts  
51  
52 of slaughter can be converted into useful products that are input for other sectors. An important  
53  
54 category of these byproducts are bone meal and blood meal. The recovery and recycling of  
55  
56 these has important economic, environmental and social benefits.  
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59 As mentioned, the related literature highlights that food supply chains, especially within  
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emerging countries need sustainable and permanent solutions. Using resources efficiently and  
decreasing the impact of food supply chains impact on the environment (Zaragoza et al., 2016)  
are crucial to meeting consumer demands, since non-sustainable food supply chains will not be



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2  
3 able to do this (FAO,2017). Moreover, all food supply chain operations should be sustainable  
4 to avoid negative environmental, economic and social effects (Akkerman et al., 2010; Beske et  
5 al., 2014; Pullman et al., 2009; Sgarbossa and Russo, 2017). Furthermore, the relationship  
6 between food supply chain and sustainable concerns should be considered (Beske et al., 2014;  
7 González-García et al., 2013; Sgarbossa and Russo, 2017) because a sustainable food supply  
8 chain contributes not only to the environment, but also to the improvement of food markets and  
9 of food security (FAO, 2017; Xiao-hui, 2012). Moreover, from climate change perspective, the  
10 agriculture and livestock sectors are two of the most influential sectors for greenhouse gas  
11 emissions. Even the smallest change in precipitation influences productivity, and causes more  
12 greenhouse gas emissions (Ali, 2017; FAO,2017). Losses constitute a great importance for  
13 achieving sustainable food supply chains. For sustainable solutions, it is necessary to have  
14 accurate and reliable predictions (FAO,2017; Xiao-hui, 2012). Therefore, it is essential to be  
15 able to forecast losses in the food sector. In this study, grey prediction model was used to  
16 understand changes of the number of slaughtered cattle, and the amount of bone and blood  
17 waste and to propose sustainable solutions.

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30 Although the expected number of slaughtered cattle is decreasing, between 2018-2020 no  
31 dramatic change in expected in the current structural problems in red meat sector, i.e. high  
32 prices, informal slaughtering, and the losses in byproducts, e.g. bone and blood are remained.  
33 Therefore, problematic situation and structural problems of the sector shows that the sector  
34 needs permanent and sustainable solutions to avoid losses of bone and blood wastes.  
35 Furthermore, sustainability should embrace environmental, social and economic concerns. By  
36 using Grey prediction, the expected numbers of slaughtered cattle, bone and blood wastes were  
37 examined to present the basis for permanent solutions for the sector in Turkey.

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45 The sustainable solutions are essential to avoid losses in the red meat sector as shown in the  
46 Grey prediction calculations.

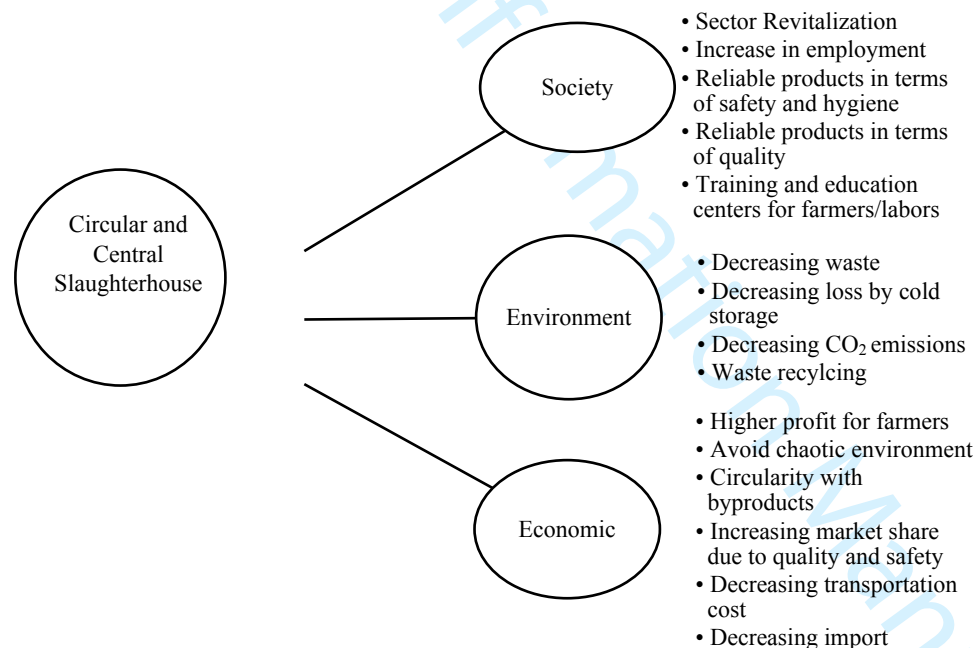
47  
48  
49 Therefore, in this study, a new circular and central slaughterhouse model is proposed based on  
50 “triple bottom line” approach. **It is essential to be in a central location where farmers/local  
51 producers can provide easy transportation. Moreover, the proposed place does not involve only  
52 slaughtering process, it also involves circularity of wastes.** Therefore, the new proposed model  
53 includes slaughterhouses, cold storage depots, waste recycling units, and other facilities which  
54 include training, hygiene and veterinary units. It is useful model for meat supply chain involving  
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all parts of slaughtering. Especially, the circularity makes the slaughterhouse more practical and efficient.

According to the proposed model, the production process of the meat product begins with the arrival of live animals from the producer, and the meat is transformed into carcass meat by processing. Then the carcass meat is stored in cold storage depots. The wastes such as blood and bone, are separated and transferred to the waste recycling unit. In this study, a model has been proposed to reduce the waste by converting it into other useful products. Being more practical, it is essential to involve sustainable and circular concerns for meat supply chain.

Moreover, the new circular and central slaughterhouse model provide not only environmental advantages but also social and economic advantages. In the Figure 7, proposed circular and central slaughterhouse model based on TBL is expressed and after the figure, detailed explanations are mentioned.

**Figure 7 TBL Based Circular and Central Slaughterhouse**



After the meat industry relied on import, local farmers and local producers began to lose their competitiveness. It is essential for emerging economies, like Turkey, to protect local farmers and producers for sustainable growth. For revival, the meat sector requires a comprehensive model that includes local farmers and local producers. Therefore, from the point of view of a

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3 sustainable society, the proposed circular and central slaughterhouses should support local  
4 producers and local farmers in the sector.  
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8 It is necessary to focus on farmers' and labors' education to decrease losses and increase quality  
9 in the sector. The training operations for labor includes animal slaughter, storage, transport  
10 operations etc. whereas the training for farmers includes feeding, hygiene, and vaccination. In  
11 addition, the proposed model provides job opportunities for local society, and increases  
12 employment rate in the sector. Furthermore, the presence of training units in the circular and  
13 central slaughterhouse increases the knowledge of labor on slaughtering process and contribute  
14 to increasing the product quality and minimizing the losses in slaughter operations. In addition,  
15 with the provided cold storage depots, the product is slaughtered, stored and distributed in  
16 hygienic and safe conditions, which are indispensable for public health.  
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24 Therefore, in order to revive the sector and to protect local farmers and producers against chaos,  
25 the proposed model offers increasing employment, and higher meat quality, safety and hygiene.  
26 All these benefits can be considered under social dimensions of the circular and central  
27 slaughterhouse model.  
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32 The location selection of the central slaughterhouse is critical to minimize the distance from  
33 farmers to slaughterhouse and from slaughterhouse to meat processing facilities. Thus, the term  
34 "central" is included in the name of the proposed model. The number of trips and travelled  
35 distance decreases, the proposed center helps to decrease CO<sub>2</sub> emissions, discussed as the  
36 environmental dimension in the model. Moreover, the model helps to decrease waste by  
37 providing safe and hygienic conditions, which is term prevent losses that may end up as waste.  
38 The existence of cold storage depots also contributes to this aim. The cold storage depots  
39 provide the safe meat conditions, and help to decrease waste caused by spoilages. All these  
40 benefits can be seen under environmental dimensions of circular and central slaughterhouse  
41 model.  
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50 As mentioned earlier in this section, problematic situation in the meat sector not only causes  
51 social and environmental problems, but also many economic problems. With the circular and  
52 central slaughterhouse model, it is aimed to minimize the effects of problematic environment  
53 in the meat sector by increasing the value of the local production. The initial economic aims are  
54 minimizing losses, converting waste into byproducts with circularity, minimizing transportation  
55 costs, increasing local producers' market share with improved quality, safety and hygiene of  
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3 the products and eventually, to provide higher profits for the local farmer and to decrease  
4 imports of carcass meat. Therefore, with the proposed model, it is aimed to recover the loss of  
5 added value within local production.  
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9 The potential by-products produced in the meat sector are currently disposed of waste. As  
10 mentioned, by-products especially, bone and blood are important ingredients of animal feed  
11 and fertilizer. The quality of feed used in animal husbandry directly affects the product quality.  
12 Bone and blood flour are an organic fertilizer which is a good source of phosphorus. Therefore,  
13 blood and bones can be used as an additional source of income. With the circular and central  
14 slaughterhouse model, blood and bone wastes can be converted into meal for fertilizer.  
15 Eventually, in terms of circularity, the conversion of by-products such as blood and bone will  
16 be the input of another sector.  
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24 In addition, as mentioned before, the location selection of the central slaughterhouse is critical  
25 and should be based on the minimizing transportation cost. This will contribute to the  
26 reachability and the attractiveness of the circular and central slaughterhouses.  
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30 To sum up, the slaughterhouse waste management system in Turkey is ineffective and most  
31 potential byproducts generated in slaughterhouses are perceived as waste. Therefore, circular  
32 and central slaughterhouse model contributes not only to environment benefits, but also to  
33 social and economic benefits in this study. Since, the proposed circular and central  
34 slaughterhouse aims to reduce the amount of slaughter waste, and recover waste to byproduct,  
35 it is a long-term solution to meat sector in Turkey.  
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## 41 **8. Managerial Implications**

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44 As mentioned before, Turkey has major problems in the meat sector. These problems have  
45 damaging effects on environment, economy and society. Therefore, the sector needs structural  
46 changes based on sustainability. From the managerial point of view, the proposed circular and  
47 central slaughterhouse model enables the meat sector to minimize these problems.  
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51 With the proposed circular and central slaughterhouses, by-products which are disposed of  
52 waste are considered as reusable in food supply chain. Especially, bone and blood waste are the  
53 most important raw materials for animal feed and fertilizer. In the proposed model, bone and  
54 blood waste are changed into bone meal and blood meal for animal feeding. Therefore, the  
55 circularity process provides new input of another sector.  
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The proposed model does not only aim to reuse wastes as raw materials, but also aims to bring new opportunities from the business perspective, based on finance, marketing, production, and human resources. While the proposed model aims an increase in market share from the marketing point of view, the model also facilitates an increase in local production volume, quality, reliability and safety of products, from the production perspective. Furthermore, the proposed model enables new career opportunities, training and education opportunities for farmers and labors, from the human resources point of view. In addition, from the finance perspective, with the proposed model, it is aimed to minimize transportation costs, CO2 emissions, wastes and import rate.

As mentioned in one of the most recent food waste studies, Ellen McArthur Foundation's "Cities and Circular Economy for Food" report (2019), there are three approach to creating a circular economy for food: growing food locally and regeneratively; decreasing food waste with redistribution of excess foods or conversion of by-products to organic fertilizers, biomaterials, drugs and bioenergy; and concentrating on healthy food marketing with changing food preferences and habits to become healthy. The proposed circular and central slaughterhouse model in this study includes the first two suggestions of the report to build circular economy for meat sector.

On the other hand, circular and central slaughterhouses based on sustainability require an investment for both the construction process, and for necessary equipment and installation. In addition, there can be a trade-off between environmental impact caused by by-product losses in slaughtering process, the cost of infrastructure of the circular and central slaughterhouse, and economic loss. In Turkey, only 30 percent of the bone and blood wastes are collected and converted to almost 150 thousand tons of animal feed annually. The economic return of this transformation of the byproducts is estimated to bring 200 million TL, according to statement of "Association of Renderings and Oil Industry", published in Lubricant World Journal in 2016. The proposed sustainable based circular and central slaughterhouse model aims to by transform waste into byproducts at the slaughtering process. Even if the proposed model achieves only 50 percent of aforementioned waste and enable them to be used as raw material other sectors, the expected income is more than 500 million TL.

## Conclusion

Red meat sector and meat waste in the supply chain are critical environmental, economic and social problems for Turkey. In this study, meat waste and waste of by-products are discussed

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3 for Turkey red meat sector. Turkey is an agricultural country and red meat is a critical economic  
4 sector. Red meat sector is crucial due to the its rate in human diet, and widespread consumption  
5 habits in Turkey. The domestic production was unable to satisfy this high demand and the  
6 government decided on a solution based on classical linear economy perspective as to increase  
7 supply via import regulation. The two important import regulations were established in 2010  
8 and 2014. In 2010, livestock import was allowed in order to meet red meat demand; however,  
9 the regulation was failed to satisfy demand, and a new regulation, carcass meat import, was  
10 introduced in 2014. However, in recent years, the number of slaughtered cattle and meat  
11 production decreased. After a temporary decrease, consumer prices increased significantly as  
12 mentioned above. Thus, the import regulations were ineffective in bringing a permanent  
13 solution to the sector, neglecting both the structural problems of the sector and sustainability as  
14 an objective. The structural problems can be listed as: untrained employees, animal deaths  
15 caused by disease and improper cutting, informal slaughterhouses, and underuse of technology  
16 causing wastes. In addition to wastes caused by improper cutting, by products i.e. skin, blood,  
17 bone, feet, fatty issues are considered as waste in Turkey. Most byproducts, such as blood and  
18 bone can be used as raw material in other sectors, feed for animals or fertilizer, but the  
19 importance given to these is limited in Turkey. Therefore, the structural problems of red meat  
20 sector pose a problematic environment, causing local farmers and producers to lose their source  
21 of income. This study proposes the circular rather than linear economy, and long-term  
22 sustainability-based solutions instead of temporary import solutions. More specifically the  
23 initial step is from circularity point of view; the bone and blood, which are currently wastes,  
24 can be a transformed to byproducts bringing additional income for local farmer and producers.  
25 The second step will be proposing a facility in which the aforementioned circular concepts may  
26 became to reality, and in which sustainability of the sector can be improved. The suggested  
27 circular and sustainable slaughtering center will not if itself solve all the structural problems  
28 nor change the problematic environment of the sector, but may significantly contribute to  
29 overcome these problems at the slaughtering stage.

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31 To achieve this, Grey Method is used to predict the number of slaughtered cattle and the amount  
32 of blood and bone waste caused by slaughtering process in this study.

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34 According to the analysis, the number of slaughtered cattle was 3,765,077, 3,900,307,  
35 3,602,115 between 2017-2019 respectively. According to calculations, the number is expected  
36 to be 2,056,069 in 2020. Moreover, with the fluctuations in the amount of slaughtered cattle,  
37 the losses in byproducts is affected, and especially in 2020 and, bone and blood waste are

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3 expected to be 41,103,180 kg and 17,990,604 kg respectively. The results showed that the  
4 sustainable solutions are essential for red meat sector to avoid structural problems, i.e. informal  
5 slaughterhouses, uneducated employee, and unhygienic conditions.  
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9 Managerial implications are given based on the proposed circular and central slaughterhouse  
10 model with its “triple bottom line” benefits. The expected economic and social benefits can be  
11 summarized as safety and hygiene for slaughtering, enhanced storing and transportation  
12 process, increased knowledge of technology, better educated farmers and laborers, increased  
13 product quality, better protection for local farmers and producers against problematic  
14 environment, increase circularity via by-products, the realization of additional income  
15 resources for farmers, decreasing transportation costs, lower import rates and the end of  
16 dependency on imports.  
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24 In addition to social and economic benefits, the proposed model has potential environmental  
25 benefits, such as decreasing wastes caused by improper cutting and unnecessary disposed of  
26 by-products, decreasing losses in the storage process, lower CO<sub>2</sub> emissions, and lower fuel  
27 consumption due to decreased travel distance, and increasing recycling. Thus, circular and  
28 central collection centers are crucial for red meat sector not only in Turkey, but in all emerging  
29 countries with increasing population, facing the need to satisfy the increasing food demand  
30 without sacrificing economic, social and environmental aspects.  
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37 For future research, red meat sector losses should be analyzed in the other stages of the red meat  
38 supply chain to final sustainable and circular solutions. Moreover, managerial implications can  
39 be developed for other types of animals in the slaughter process, in order to prevent losses and  
40 to develop the red meat sector in Turkey. In addition, network optimization models or facility  
41 location methods can be employed to determine the appropriate location of the proposed  
42 circular and central slaughterhouses.  
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3 **TABLES**  
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5 **Table 1 Actual data of the amount of slaughtered cattle in Turkey**  
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Year	2015	2016	2017
Number of slaughtered animals	3765077	3900307	3602115

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19 **Table 2 Prediction Results**

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Years	2018	2019	2020
Predicted Data	2829060	2411792	2056069

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27 **Table 3 Error Analysis**  
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2015	2016	2017
0 (Accepted)	0,2%	7,9%

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37 **Table 4 Summary of the Results**

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Years	Actual Data	Predicted Data
2015	3765077	3765077
2016	3900307	3892660
2017	3602115	3318519
2018	-	2829060
2019	-	2411792
2020	-	2056069

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52 **Table 5 Bone and Blood Waste Calculation**  
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Years	Number of Slaughtered Cattle	Average Weight (kg)	Bone Waste (%8)	Blood Waste (%3,5)
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2018	2829060	250	56581200	24754275
2019	2411792	250	48235840	21103180
2020	2056069	250	41121380	17990604

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