logistics

MDPI

Review

A Literature Review on the Sustainable EPQ Model, Focusing on Carbon Emissions and Product Recycling

Rubayet Karim [1,*] and Koichi Nakade [2]

[1] Department of Industrial and Production Engineering, Jashore University of Science and Technology, Jashore 7408, Bangladesh
[2] Department of Architecture, Civil Engineering and Industrial Management Engineering, Nagoya Institute of Technology, Nagoya 466-8555, Aichi, Japan; nakade@nitech.ac.jp
* Correspondence: rubayet26@gmail.com

Abstract: *Background*: Many businesses want to include sustainability in their manufacturing operations. A conventional economic production quantity (EPQ) model is employed to calculate the ideal number of products to manufacture at one time. The goal of this study was to look at the current research on sustainable economic production quantity and supply chain models and suggest prospective future research directions based on existing knowledge gaps. *Methods*: In this perspective, we used systematic procedures to conduct a survey that included studies from two scenarios: (1a) a sustainable EPQ model that accounts for carbon emissions from inventory storage and manufacture, (1b) a sustainable EPQ model that includes product recycling, and (2) a reverse logistics model that accounts for emissions and product recycling. *Results*: According to the inquiry, there are reverse logistics models in the literature that consider carbon emissions and product recycling together, but they are not jointly considered for modeling a sustainable EPQ model considering the situation where the manufacturing system is imperfect, although both are vital for ensuring environmental sustainability. *Conclusions*: In the future, the EPQ model can be developed with these two aspects in mind to understand the effects of product recycling on carbon emissions while controlling production and inventories for an imperfect manufacturing system.

Keywords: recycling; EPQ model; carbon emission; environmental sustainability; imperfect manufacturing system

check for updates

Citation: Karim, R.; Nakade, K. A Literature Review on the Sustainable EPQ Model, Focusing on Carbon Emissions and Product Recycling. *Logistics* **2022**, *6*, 55. https://doi.org/10.3390/logistics6030055

Academic Editor: Robert Handfield

Received: 28 June 2022
Accepted: 25 July 2022
Published: 1 August 2022

1. Introduction

Economic production quantity (EPQ) is the most generally applied inventory model for estimating the size of production batches [1]. The ideal level of production, also known as the economic manufacturing quantity (EMQ), is the amount of output generated while reducing total inventory costs [2]. The EPQ model's broad development encompasses the state of multi-item goods, the presence of back-order strategies, potentially deteriorating goods, the presence of imperfect goods, and rework operations [3]. The EPQ model represents several real-world production scenarios. This model has been the subject of extensive research throughout the years.

Many studies were conducted in the past on an imperfect manufacturing system. For example, Taleizadeh et al. [4] proposed an EPQ inventory model that considers reworking the imperfect quality products. This model calculates the manufacturing lot size and the price of sale at the same time to optimize the function of profit. Öztürk [5] developed an EPQ model that takes into account imperfect goods and partial back-ordered demand. This model assumes that rework will be outsourced to a repair center rather than occurring during the manufacturing cycle. All reworked goods are returned to the firm and received by the inventory at the end of the reworking process. Öztürk [6] investigated an economic production quantity model that explores the impacts of a flawed manufacturing process with stochastic breakdowns and inspection policies on a manufacturing inventory system with repair to provide a more pragmatic view. This model determines the optimal production run time and assumes that the scrutiny process continues after the manufacturing cycle is completed. Marchi et al. [7] studied an EPQ model for a producer whose production speeds up as a result of production learning. Faster production, according to the authors, puts stress on machinery, causing it to fail. Production and rework operations consume energy. As a result, increasing the rate of production increases expenses and energy consumption. Their work took these factors into account, and the authors believed that implementing energy efficiency measures (EEMs) results in a variety of benefits ranging from energy savings to improved process quality (e.g., decreased probability of machine failure).

Today, one of the most discussed topics in the world is climate change. Emissions of greenhouse gases, particularly carbon emissions, are thought to be the most significant contributor to today's climate change. Thus, governments, non-governmental groups, and the industrial world continue to push initiatives toward sustainable development. As a result, governments devise and implement various carbon emission policies to limit or reduce carbon emissions resulting from industrial activities. Various supply chain processes have a detrimental environmental impact. As a result, it is critical that we carefully manage operations of the supply chain, such as inventory control and production. Any supply chain management must ensure the reduction of carbon emissions while also improving product quality [8]. Product quality must be improved daily, and carbon emissions must be kept to a minimum [8]. As a result, researchers are currently concentrating on sustainable EPQ and sustainable supply chain models. Essentially, environmental sustainability is more prevalent here. For example, Kugele et al. [9] investigated a smart, dependable manufacturing system by incorporating carbon emissions and a reliability factor. A geometric programming approach was utilized to address the problem. Fuzziness, according to the authors, might be included in the future to bring the study closer to reality. Yadav et al. [10] investigated a variable pollution cost sustainable manufacturing model under the effect of three pollution control strategies. The authors considered a flexible manufacturing process with a partial backlog and rework under uncertain market situations. They offered theoretical derivations as well as a solution approach for determining the best manufacturing rate, length, and total cost for each cycle.

Disposal of used products can also be harmful to the environment. Here comes the concept of recycling used products, which is both environmentally friendly and profitable for the industries. Manufacturers can minimize carbon emissions while maintaining the same production level via recycling. Recycling, as an environmentally responsible method of production, can both cut carbon emissions and save production costs. When compared to the production of new items, recycling can save 60% of the energy, 70% of the raw materials, 80% of the air pollution emissions, and 50% of the expenditure [11]. Many well-known consumer electronics businesses, including Xerox, Canon, Apple, and Hewlett-Packard, have greatly decreased their negative environmental impacts while also achieving significant cost savings by creating and selling refurbished devices [11]. Recycling is a burgeoning sector in which used goods can be rehabilitated or deconstructed into useful modules, parts, or resources or disposed of. This resource reuse is a constructive reaction to increase environmental and regulatory demands and it has the potential to generate economic benefits.

Many inventory system activities, including purchasing, warehousing, and transportation of products, result in carbon emissions. Additionally, inventory management is a major concern for the industries from a manufacturer's perspective. If the industries can design their jobs considering carbon emission costs and recycling of used products in an EPQ (economic production quantity) setting, that can be a perfect combination. Researchers are coming up with different theories and developing new models to beat the problems by combining more factors to create more realistic approaches. This study looked into articles that explain sustainable EPQ models that account for carbon emissions, as well as papers that use product recycling to build a sustainable EPQ model and, finally, some reverse logistics models. The following are our main contributions to this review work.

1. We examined several recent studies on reverse logistics models and EPQ models focused on carbon emissions, product recycling, and imperfect production systems.
2. We investigated the existing research trend of the sustainable EPQ model and identified prospective research gaps.
3. Based on the potential research gap, we attempted to provide a research path for what we might accomplish in the future for the development of a realistic and sustainable EPQ model.

The remainder of this paper is arranged as follows. Section 2 demonstrates how we surveyed and organized the literature. Section 3 deals with descriptive analysis. Section 4 discusses content analysis. This content analysis discusses all articles that have incorporated carbon emissions in the development of EPQ models. We examined all the studies that address product recycling in the context of EPQ model development. This section also goes through different reverse logistics models that include emissions. Sections 5 and 6 explore the potential research gap and the analytical explanations, respectively. Finally, Section 7 delves into the potential future research directions as well as the limitation of this study.

2. Methodology for Reviewing the Literature

We collected publications related to our research from online research databases using our study keywords. Following the collection of articles, they were screened based on our research keywords and the significance of the research. The irrelevant articles were removed, leaving just the articles relevant to our research scope for further evaluation. Our primary research keywords included carbon emissions, product recycling, imperfect manufacturing systems, and the EPQ model. We performed literature searches using these terms in renowned research databases such as Science Direct (Elsevier B.V., Netherlands), Taylor & Francis (Informa, United Kingdom), SpringerLink (Springer publishing company, United States), Emerald Insight (Emerald Publishing Limited, England), and Google Scholar (Google, United States). A total of 315 articles were identified based on the search terms. Irrelevant publications were removed after analyzing their titles and abstracts. Furthermore, the same articles located in different databases were removed to avoid repetition. Finally, from the selected articles, 32 key articles were considered for descriptive analysis. Our review technique is illustrated in Figure 1 below.

Following a thorough review of the literature, the articles were divided into different sections based on the study keywords, and the main content of each article was discussed and compared in the content analysis section.

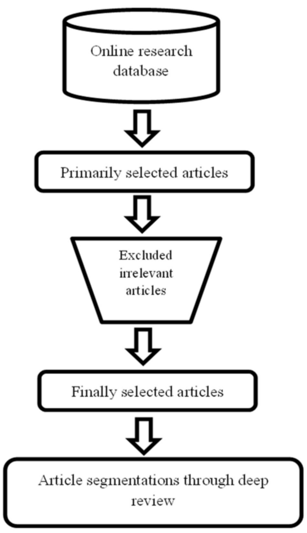

Figure 1. The literature review technique.

3. Descriptive Analysis

This section includes a distinct descriptive arrangement as well as a summary of the results. As illustrated in Figure 2, the development of an EPQ model that considers environmental emissions and recycling has grown in importance in recent years. The maximum number of publications was reached in 2021, with four total publications. There was an average of 0.95 publication per year about the sustainable EPQ model between 2003 and 2022. The total number of publications on the reverse logistics model was 0.65 per year on average between 2003 and 2022. Therefore, the researcher recently prioritized the mathematical modeling of a sustainable EPQ model that focuses on emissions and recycling. Furthermore, the recent increase in the number of publications on sustainable EPQ model development shows that the importance of the research is growing over time.

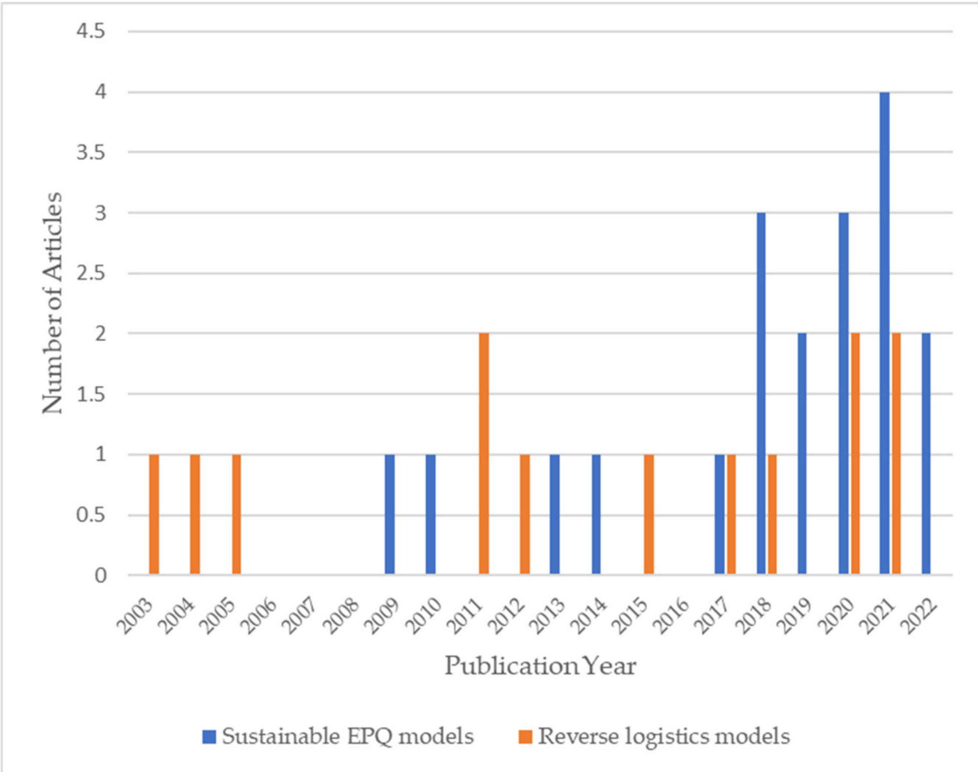

Figure 2. Number of articles per year.

Figure 3 depicts both the number of publications and the publisher. According to the research findings, many publishers have only published a few publications. The Journal of Cleaner Production and Computer & Industrial Engineering published the most papers, each with five, while other journals, such as the International Journal of Production Economics and the International Journal of System Science: Operations & Logistics, published three and two papers, respectively. A total of 15 of the 21 publishers, according to the data, have published papers on sustainable EPQ models. This suggests that sustainable EPQ modeling research is becoming more important.

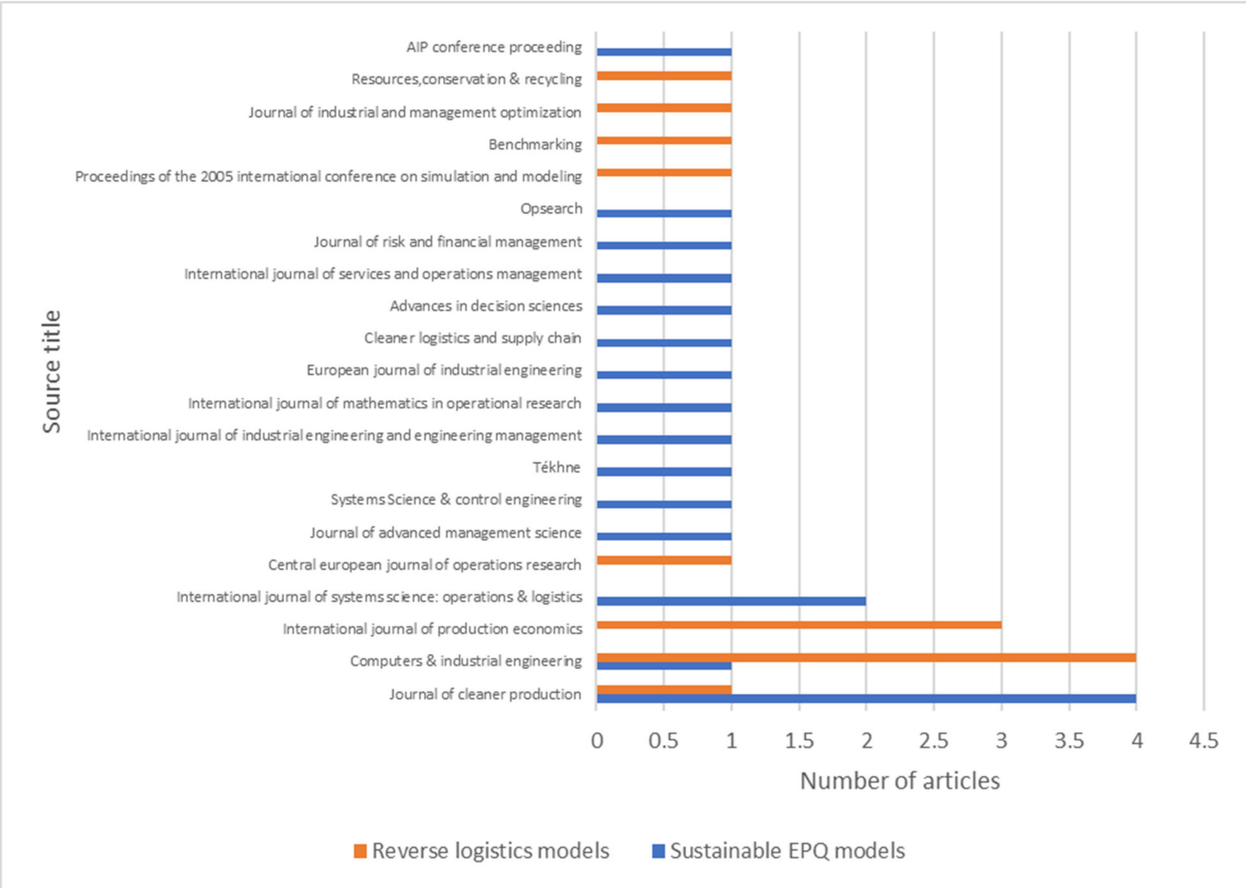

Figure 3. Number of articles per source.

4. Content Analysis

4.1. EPQ Model with Carbon Emission

There is growing agreement that carbon emissions from business activities are one of the primary causes of global climate change; many governments and regions put various rules on the operations of businesses to reduce carbon emissions [12]. As a result, carbon emissions have become a significant factor in the modeling of supply chains and production-inventory systems. Gharaei et al. [13] provided an EPQ model under green policies that take greenhouse gas emission costs into account. Fadlil et al. [3] presented an EPQ model that considers the remanufacturing of returned, unused, defective products by customers and carbon emission costs at the same time. Daryanto and Wee [14] suggested two sustainable EPQ models in which the emission of carbon is considered in the total cost function. They expanded the model to account for full back orders. The goal of these models is to develop a more environmentally friendly manufacturing system with reduced carbon emissions and to minimize the total cost. Mukhopadhyay and Goswami [15] provided an economic manufacturing quantity model that includes three types of defective goods as stochastic fractions of the manufacturing lot size under two pollution cost situations: variable and fixed. Three types of faulty products are regarded to represent the manufacturing-inventory environment: non-reworkable faulty items, reworkable faulty items, and good quality items. They arrived at the best tactics for two pollution-prevention manufacturing models. Manna et al. [16] analyzed a producer–retailer–consumer supply chain model by considering stochastic carbon emissions and two levels of trade credit. They presented a joined manufacturing-inventory model with a repair policy, taking the faulty production process into account. According to the authors, one conceivable future extension of their suggested approach is the combined optimization of carbon emission and expected total profit (i.e., maximize overall profit while minimizing carbon emissions).

Taleizadeh et al. [17] proposed four sustainable EPQ models that take into account various inventory shortage scenarios in a manufacturing system. The basic SEPQ model, the shortage SEPQ, the SEPQ with complete back-ordering, and the SEPQ with limited back-ordering are their derivative models. In their models, the direct accounting tactic is used and, therefore, emissions' expenses such as cost of emission for obsolete inventory, cost of emission for inventory storage, and emission expense from production are considered. The authors felt their models could be valuable for firms looking for ecologically aware manufacturing systems because of their relevant and simple computing methods.

Daryanto and Wee [18] developed an economic manufacturing quantity model that accounts for emissions of carbon. They also looked into the influence of the carbon pricing rule on potential emissions' reductions from the degrading item model. The output of the model verifies the role of carbon pricing laws in reducing carbon emissions. The authors believed that their model can be expanded by including technological investments to limit the possibility of generating imperfect or deteriorating goods. Sinha and Modak [19] created an EPQ model of a corporation that takes into account carbon caps and trade policy. They later broadened their concept by integrating a tree plantation scheme. A comparative analysis revealed that the latter case (tree planting) is more effective at reducing CO_2 emissions. According to the results of their model, increasing the number of tree plantations increases the manufacturer's total annual profit. Later, the authors speculated on the potential future extension of their model by incorporating technological advancement and related aspects to reduce emissions. Moon et al. [20] developed a manufacturing system based on a basic economic-manufacturing paradigm with a storage limitation and demand-dependent unit manufacturing cost under carbon emissions. In their developed model, a geometric programming approach is used to obtain a quasi-closed form of the optimal solution.

Manufacturers are seeking ways to boost the effectiveness of their manufacturing and inventory systems to fulfill growing environmental concerns in inventory systems [21]. One of the most important long-term duties is to make investments in CO_2 reduction technologies [21]. Researchers emphasize the need for green technology investment decisions to reduce carbon emissions while modeling a supply chain inventory model. For example, Datta [22] examined a manufacturing-inventory model in the context of a carbon price regime. The author considered the rate of production as a decision variable that can be adjusted to any amount within the machine restrictions. The author also assumed that a percentage of the things produced were faulty and that this percentage varied with the manufacturing rate. He included carbon emissions in his model and assumed that these emissions can be decreased to some level through utilizing money in green technology; the author also considered the quantity of capital investment as a decision variable. Mishra et al. [23] presented a sustainable economic order quantity model that employs two kinds of price-dependent needs for manageable carbon emissions and decay rates. Manageable carbon emissions and decay rates are accomplished in their model by green and preservation technology investment in both back-ordering and no back-ordering scenarios. Lu et al. [24] addressed investment in technology for the decrease in carbon emission under carbon offset and carbon cap-and-trade rules to examine the possible competitive and cooperative challenges of a sustainable model of a product-inventory system. They used game theory's Stackelberg technique to determine the ideal equilibrium result between the client and the seller under various carbon emission decreases. Marchi et al. [25] investigated a seller–purchaser green supply chain model that accounts for capital funds to speed up production and decrease carbon emissions. According to the authors, investing in the learning process to decrease unit manufacturing time increases emissions of carbon, necessitating an investment in green technology to lower emissions. Sarkar and Bhuniya [26] created a supply chain model that takes into account a waste reduction campaign and investment in green technology. According to the authors, by employing an environmentally friendly strategy, remanufacturing with investment in green technology plays an important role in sustainable supply chain management. Taking into account the social, environmental, and economic evolution of society, their model focuses primarily on the flexibility of the manufacturing rate under the multi-seller-based supply chain to meet customer demand. Bachar et al. [27] studied an inventory model for an imperfect production system. The prime goal of their model is to maximize profit by taking into account the optimum lot size amount, optimum selling price, and optimum green technology investment. The classical technique of optimization is used to optimize the solution. For the future, the authors proposed expanding their model by incorporating a fuzzy random environment. Many supply chain manufacturing inventory models have been developed with the effectiveness of investment in green technology to reduce carbon emissions. However, there is a scarcity of studies highlighting a sustainable EPQ model with a green technology investment decision.

Mishra et al. [28] examined a sustainable economic manufacturing quantity (SEMQ) carbon cap-and-tax model for a manageable rate of CO_2 emissions by exploiting money in green technology (GT) initiatives under various with and without scarcity scenarios. Considering sustainability, they investigated three scenarios: (1) an economic manufacturing-quantity carbon cap-and-tax model with no deficiencies; (2) an economic manufacturing-quantity carbon cap-and-tax model with limited back-ordering; and (3) an economic manufacturing-quantity carbon tax-and-cap model with complete back-ordering with and without investment in green technologies. They developed a technique for obtaining the best strategies for investment in green technology and cycle time. Based on the model examined by Rout et al. [29], Sepehri et al. [30] developed an EPQ model focusing on sustainability for a system with a single producer and buyer to fill the gap. According to their approach, the producer makes products at a consistent rate to suit the needs of the merchant. In actuality, generating defective (low-quality) objects as a result of operator or machine fault is unavoidable. As a result, just a portion of the faulty products remain, and those items have been reworked. The authors believed that money invested in quality enhancement technologies can reduce the initial rate of faulty items. They accounted for carbon emissions from manufacturing, maintenance, scrapping, inventory holding, and spending money on green technologies to reduce emissions. They also showed the effect of carbon emission reduction investment and preservation technologies.

By focusing on sustainability, Sepehri and Gholamian [21] created an EPQ model in which goods deteriorate at a steady rate. They calculated the overall emissions due to inventory holding and setup activities by taking into account investment in technology for carbon emission reduction. Their model discusses the formation of conservation technology in the perishing process. Finally, they built the total profit function for three separate examples to highlight the impact of investment in conservation technology and emission decrease technology on the profit gained. Recently, Priyan et al. [31] offered an EPQ model for controlled emission of carbon in the context of cleaner production in flawed manufacturing processes where a portion of the goods are imperfect. The model takes into account emissions from transport, manufacturing, and inventory storage, which are supposed to be reduced through green investment. Their model's findings mostly showed that increasing the carbon fee cuts emissions. Furthermore, with the support of green technologies, the company has more alternatives for reducing emissions created by industrial activities. Though green technology requires a higher initial expenditure, the maker will benefit from decreased emissions.

These studies combine the concepts of EPQ and carbon emission costs. However, the consideration of remanufacturing/recycling/reworking of used products returned by customers, which was our concern, has the potential to advance this research.

4.2. Circularity in EPQ Model

4.2.1. EPQ Model with Product Recycling

Used product recycling is crucial in lowering carbon emissions; therefore, researchers are attempting to understand its impact on production and inventory decisions by adding the issue of recycling used products in the development of economic production quantity models. Dem and Prasher [32] studied a reverse logistic inventory model under an EPQ setting with faulty production, stock-based demand, flexible production, and lost sales. The goal was to come up with a collaborative policy for optimal production, recycling, gathering of recyclable things and collection and discarding of faulty items that will minimize the total cost. The model is solved using Mathematica 7.0. According to the authors, their research can be expanded to incorporate more practical assumptions into the suggested model, such as multiple manufacturing, machine malfunction, probabilistic natures of demand, gathering of used goods during the reverse production period, and so on.

Konstantaras et al. [33] studied an inventory system that considers manufacturing as well as remanufacturing of used products and the EPQ concept. The main objective of this model is to attain the optimal inventory level to optimize the total cost. Hwang et al. [34] developed an EPQ model that considers manufacturing as well as remanufacturing of used products collected from the users. This model assumes that used products are collected based on a minimum quality level. The manufacturing and remanufacturing cycle length, the minimum allowable quality level, and the unit price of old products are determined to minimize the production and inventory costs. This model develops a heuristic algorithm based on PSO and uses the grid-search method to solve it. A sustainable recycling technique is created in a manufacturing-inventory model for a faulty manufacturing system with a fixed percentage of recyclable faulty goods in the study of AlArjani et al. [35]. Their proposed method is based on the recycling of damaged goods obtained from conventional manufacturing after the appropriate screening, with 100% retrieval of materials used in manufacture. This model is a simplified version of versions that incorporate recycled materials. In the event of a stochastic event, the authors believe that used materials can be employed as an alternate basis for raw resources. According to the authors, another intriguing expansion of their work would be to add CO_2 emissions [36,37]. The above-discussed models take into account both the EPQ setting and the recycling of used products at the same time. The addition of the concept of carbon emission can add a different dimension to the research. However, Kundu and Chakrabarti [38] considered both carbon emissions and recycling when creating a sustainable EPQ model. They assumed a flawless production system, but in reality, the production system is flawed in many situations. The authors provided a manufacturing, recycling, and waste removal model for a corporation that sells a new and recycled product in two distinct markets under different carbon control systems. The discarded item is gathered, recycled, and sold on the second-hand market at a lesser price than a newly made item. The new item is sold on the open market. They studied the impact of several carbon emission strategies on the production, gathering of used goods, and recycling decision making. The findings from their model showed that recycling is a suitable policy to reduce emissions in comparison to production.

4.2.2. Reverse Logistics Model

The primary purpose of reverse logistics is to recover value from used goods, which begins with the assortment of discarded goods from end users, followed by categorization, dismantlement, and eventually reworking to replace its economic value [38]. Manufacturing, procurement, management of materials, inventory control and warehousing, delivery, freight, and logistics of transportation are all part of reverse logistics [39]. Inventory management has received a lot of attention in reverse logistics in recent years [39]. Jaber and Saadany [39] investigated the manufacturing, remanufacturing, and waste discarding model in a manufacturing context using two stocks. The serviceable stock consists of both remanufactured and new items. Used items from the market are gathered and held in the repairable stock. They extended Dobos and Richter's [40,41] work by exploring the impacts of learning on the reconstruction and manufacturing processes. According to the authors, well-known learning models can be used by management to exploit capacity, control inventories, and synchronize manufacturing and delivery across the supply chain. The model's numerical results show that there is a learning rate beyond which spending on learning can result in savings. Hwang et al. [42] proposed a recycling system model based on reverse logistics. A recycling system's deterministic inventory model is built and tested, in which returned products serve as raw materials. The proposed model, according to the authors, can be expanded by taking into account both the remanufacturing and recycling processes. A manufacturing-recycling and pollution decline inventory model was developed by Karmakar et al. [43]. Hawkers collect used or scrap materials for remanufacturing purposes in exchange for a small fee. The authors demonstrated how recycling decreases environmental contamination and improves the livelihood status of persons involved in collecting used products and scrap for recycling in the manufacturing process by examining a genuine case study of a sponge-iron (SI) plant. Khara et al. [44] considered a closed-loop supply chain inventory manufacturing model that includes a fresh material seller, a producer, a distributor, and an accumulator who accumulates secondhand items from customers at a rate of return based on the accepted quality standard of the secondhand item. They developed a mathematical model and resolved it through global and sequential optimizations to obtain the optimal quantity of supplies from accumulator to producer, seller to producer, and producer to distributor. The model also gives the optimal acceptance level of quality of the used item and refill cycle time from producer to distributor, thus maximizing the average profit. According to their findings, in a closed-loop supply chain inventory manufacturing model, the global technique outperforms the sequential technique in terms of total profit on average.

Wang et al. [45] developed an assembling–reassembling model that considers different carbon emission amounts for manufacturing and remanufacturing used products. The cap-and-trade system as well as subsidies or penalty costs are used in this model. Diverse quality standards of returned used products are also taken into account by this model. They solved and studied this model using the particle swarm optimization (PSO) algorithm and the genetic algorithm (GA). Bazan et al. [46] proposed a model that accounts for the typical costs of an assembling–reassembling inventory system for reverse logistics, as well as carbon emissions from production and reassembling and the expense of energy consumption for production, transport, and reassembling. They eventually discovered that optimizing for financial expenditures and all environmental expenditures will only result in less reassembling to keep the environment safe, as opposed to concentrating on the disposal of solid waste, which is the attention of prior 'traditional' models of reverse logistics considering reassembling. Arora et al. [47] investigated a fuzzy model of economic manufacturing for both reproduction and recycling with stochastic price parameters under the cap-and-trade system to reduce carbon emissions from various modes of transportation. Their proposed approach included an explicit criterion to regulate the manufacturer's carbon emissions and minimize the optimum cost. According to the model results, the gathering of utilized products that can be reassembled should be increased. Yan et al. [48] investigated price and recycling decisions in a cap-and-trade closed-loop supply chain comprised of a seller, a producer, and a third party. In a reverse supply chain, the producer creates new items using both new materials and discarded products returned by consumers. The producer requests that discarded products be recycled directly from the consumer by a third party. The producer is subject to the cap-and-trade rule and controls the item's wholesale price as well as the rate of carbon emission reduction. To suit client demand, the seller chooses its resale price. The collecting rate of recycled and remanufactured used items is decided by a third-party recycling center. Krikke [49] assessed the carbon footprint of a copier's reverse supply chain to decrease CO_2 emissions from facility installation, product movement processing, and shipping. Sarkar et al. [50] created a multi-tiered reverse supply chain to investigate the effects of transport and environmental emission costs. Chaabane et al. [51] investigated the planning and design of an environmentally conscious supply chain that considers emissions from the manufacturing process, recycling, demolition at the recycling center, and transport. They also imposed two restrictions on the total quantity of carbon credits that can be bought and traded in a specific period. The models presented above consider recycling used products as well as carbon emissions or only recycling. However, the concept of EPQ was not considered in those investigations. Table 1 below provides a brief description of the findings. This table shows the contrast between our recommended research direction and previous research. Table 2 contains information on the stochastic parameters of the articles in Table 1 that investigated the stochastic model.

Table 1. Major findings from the literature survey.

References	Research Considerations						
	EPQ	Modeling Approach		Carbon Emission	Recycling /Remanufacturing	Imperfect Manufacturing System	Green Technology Investment
		Deterministic	Stochastic				
Taleizadeh et al. [4]	√		√			√	
Öztürk [5]	√		√			√	
Öztürk [6]	√		√			√	
Dem and Prasher [32]	√	√			√	√	
Gharaei et al. [13]	√		√	√		√	
Sinha and Modak [19]	√	√		√			
Fadlil et al. [3]	√	√		√		√	
Daryanto and Wee [14]	√	√		√			
Daryanto and Wee [18]	√	√		√		√	
Konstantaras et al. [33]		√			√		
Sepehri et al. [30]	√	√		√		√	√
Mishra et al. [28]	√	√		√			√
Priyan et al. [31]	√	√		√		√	√
Sarkar et al. [8]		√		√		√	
Hwang et al. [34]	√		√		√		
Wang et al. [45]			√	√	√		
Bazan et al. [46]		√		√	√		
Karmakar et al. [43]	√	√			√		
Khara et al. [44]		√			√	√	
Kundu and Chakrabarti [38]	√	√		√	√		
Kugele et al. [9]		√		√			√
Sarkar et al. [52]			√			√	
Bachar et al. [27]		√				√	√
Future research consideration	√		√	√	√	√	√

Table 2. Information on stochastic model-related articles.

References	Research Considerations		
	Modeling Approach	Stochastic Parameter	Probability Distribution
	Stochastic		
Taleizadeh et al. [4]	EPQ	The portion of faulty goods	Uniform distibution
Öztürk [5]	EPQ	The fraction of nonconforming items	Uniform distibution
Öztürk [6]	EPQ	The proportion of faulty goods, the proportion of scrap goods, the time to breakdown	Uniform distibution
Gharaei et al. [13]	EPQ	Resources	Normal distribution
Hwang et al. [34]	EPQ	The quality of returned goods	Uniform distibution
Wang et al. [45]	Multi-period hybrid manufacturing/ remanufacturing model	1. Core quality level 2. Remanufacturing cost	1. Four distributions (uniform, erlang truncated, triangular, gamma) 2. Normal distribution
Sarkar et al. [52]	Multi-phase manufacturing model	The portion of defective goods	Uniform distibution

5. Potential Research Gap

We can infer from the discussion and evaluation of Section 4 that although several reverse supply chain model studies have been performed, taking both product recycling and carbon emissions into account, most EPQ models, however, just looked at carbon emissions or product recycling. Some studies concentrated on EPQ and carbon emissions, whereas others focused on EPQ and recycling. To evaluate the environmental impact of production, recycling, and inventory control in imperfect manufacturing systems, we must look at both carbon emissions and product recycling while examining an EPQ model.

Although information and strategies on how to integrate operations while addressing environmental concerns are widely available, pollutant emission issues remain unaddressed [53]. This is due to the high costs and expenses associated with applying sustainable practices, which are a significant impediment to achieving a cleaner industrial system [54]. Reusing resources, on the other hand, is a constructive response to increasing environmental and regulatory demands and can result in economic gains [55]. European Union regulatory policies for vehicles with motors (ER Directive 2002/525/EC) and electronic garbage (EU Directives 2002/96/EC and 2003/108/EC), Japanese recycling regulations for home instruments and computers [56], and e-waste legislation in 23 states of the USA impose manufacturer accountabilities for end-of-life goods (ETC, 2010) [55].

Just as product recycling is vital for guaranteeing environmental sustainability, lowering carbon emissions is equally important. By using circular manufacturing or recycling used products, we may drastically reduce carbon emissions. This is because, to make a completely new product, it must go through many manufacturing operations, each of which generates a significant amount of carbon emissions. However, when a used product is recycled into a new product, it naturally has to go through fewer activities than typical manufacturing operations, resulting in lower carbon emissions. Furthermore, recycling used products rather than disposing them as scrap allows for the avoidance of carbon emissions produced by dumping. Interestingly, when a product is made in a completely new way, more carbon is emitted than recycling the product. However, when selling this new product, manufacturers often set a profit margin for a new product that is higher than the profit margin of a recycled product. As a result, the manufacturer's income from a new product is higher than that of a recycled product.

Although product recycling has been incorporated into EPQ modeling, it is not stated how product recycling affects carbon emissions. In particular, for an imperfect manufacturing system, disruption in either production or recycling not only affects normal production or recycling but may also have an influence on carbon emission generation; however, the impact of disruption on carbon emission is still ignored. As a result, it is time to develop an EPQ model for an imperfect manufacturing system that includes product recycling and carbon emissions. Furthermore, we can combine green technology investments to lower carbon emissions.

Table 1 shows the contrast between our recommended research direction and previous research. This table shows that almost all of the researchers have discussed the deterministic model, but we still have to deal with a lot of uncertainty when manufacturing and recycling the product in real life. For example, during manufacturing or recycling, both defective and quality items may be generated. The production of these damaged items affects not only production and recycling but also carbon emissions. This is because, if damaged products are not repaired and discarded, they pollute the environment by emitting carbon dioxide [52]. However, carbon is also emitted during the repair process because defective goods must be repaired to minimize production losses. If the production of this defective product is stochastic, then the more of this defective product that is produced, the greater the carbon emissions are. Green technology investment in production and recycling can play a significant role in lowering carbon emissions in this case. As a result, we must concentrate on stochastic model creation in light of the stochastic imperfect manufacturing system.

Given the unpredictability in production or recycling induced by a failure in product quality, a stochastic EPQ model combining product recycling and carbon emissions needs to be developed to represent a more realistic production-inventory system. According to literature searches, most of the research on sustainable EPQ model development has focused on deterministic models; however, if we want to make more realistic and approximate production and inventory decisions, we must focus on stochastic sustainable EPQ model development because there are many uncertainties in a real-life manufacturing environment, as well as many random production events. We must make a fruitful decision by taking these factors into account. We must prioritize the building of stochastic models to acquire an approximate decision.

6. Analytical Explanations

Both production and recycling emit CO_2 and other greenhouse gases, but recycling emits less CO_2 than regular production. However, if a defective product is produced during normal production or recycling, it is necessary to rework the defective pieces, which also generates CO_2. It is critical to assess separately the carbon emissions level created by manufacturing, recycling, repairing defective products produced from manufacturing, and repairing defective products produced from recycling. On the other hand, more production and recycling create more inventories, and a higher inventory level also emits more CO_2 (Figure 4). The individual quantification of emissions can aid in making a trade-off between production and recycling to reduce carbon emissions while maximizing profitability. In addition to production and recycling decisions, we can examine green technology investment decisions to reduce carbon emissions significantly while maintaining a reasonable level of production or recycling to maximize revenue. Figure 4 depicts the total intended research integration with a focus on environmental sustainability.

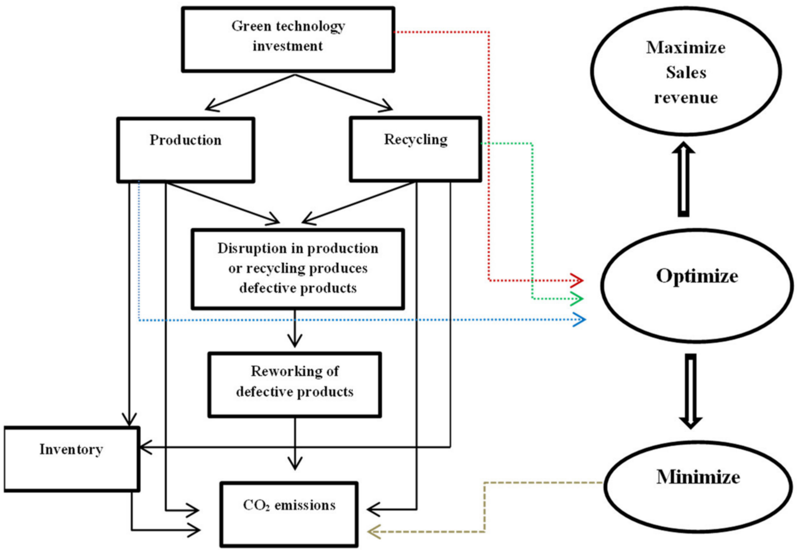

Figure 4. Integration of recycling, carbon emission, and imperfect system for the EPQ model development.

If the manufacturing system is imperfect and the number of defective products produced by this system is random, then the emission quantity created by repairing these defective items will also be random. More precisely, if the production rate of defective items is random and high, and if production and recycling continue for a long period, the number of defective products will increase and there will be an increase in carbon emissions to repair these vast numbers. However, if production and recycling continue for a short time, the number of defective items will fall drastically and a small amount of carbon will be emitted as a result of reworking these products. On the other hand, if the production rate of these damaged items is low and production and recycling continue for an extended period, fewer defective products will be produced, resulting in lower carbon emissions to repair these products. If production and recycling continue for a short period, the number of defective items will be substantially fewer, resulting in significantly lower carbon emissions to repair these faulty products.

The six-pyramid model provided in Figure 5 shows that if production is high and recycling is low in a production-recycling period, the stochastic carbon emission level will be high. As a result, environmental sustainability in terms of carbon dioxide pollution will worsen, pollution costs will rise as a result of increased carbon dioxide pollution, and profit will plummet. Green technology investment costs will need to rise to ensure a more sustainable environment or reduce carbon dioxide pollution, hence increasing profits.

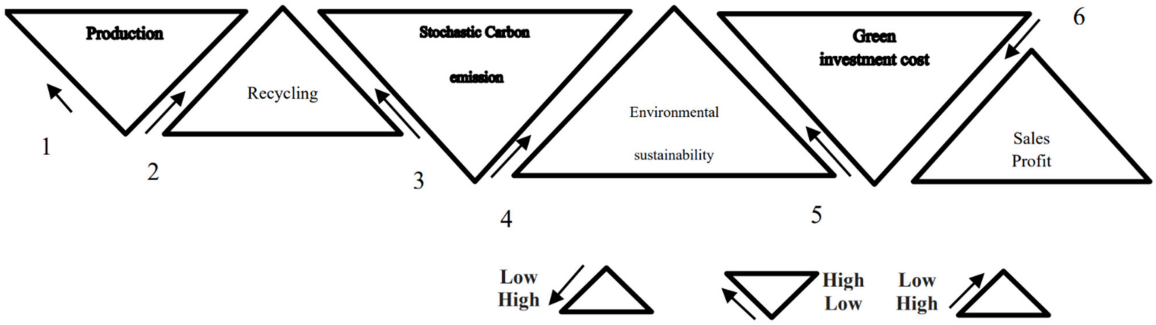

Figure 5. The six-pyramid model.

Figure 5 depicts the sequence of events using numbers ranging from 1 to 6. In Figure 6, we can better understand how green investment costs, carbon emissions, and profits are related. The X-axis depicts how production and recycling quantity levels are changing (from low to high and vice versa), as well as how the carbon emission level is changing (from low to high and vice versa) as a result of changing production and recycling quantity levels. The Y-axis, on the other hand, shows how the cost of green investment changes (from low to high and vice versa) and how the level of carbon emissions changes (from high to low and vice versa) as a result of this change. Finally, the Z-axis depicts how overall profitability changes (from low to high and vice versa) with the changes in the decision variables such as green investment costs, production, and recycling amounts. Manufacturing and recycling have an impact on the level of stochastic carbon emissions. Green technology investment also controls this emission level. Figure 6 concludes that as the cost of green investments rises, the level of carbon emissions from production and recycling decreases and, thus, the cost of carbon emissions decreases further. On the other side, while green investment costs continue to fall, carbon emissions costs will grow. More carbon will be emitted if more products are produced and recycled, resulting in a higher cost of carbon emissions while also causing significant environmental damage. Green investment, production, and recycling should be regulated in such a way that emission costs are minimized, resulting in a low total cost and, as a result, a high profit.

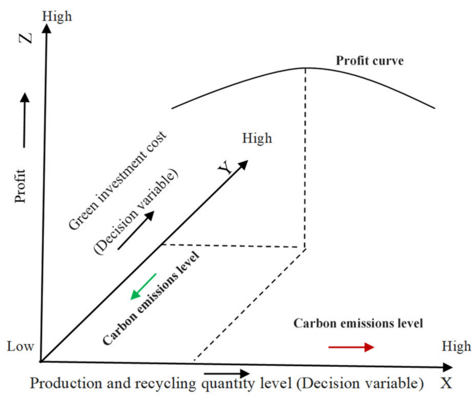

Figure 6. Trade-off between green investment cost, production, and recycling quantity.

7. Conclusions

Carbon emissions and circular manufacturing are two key concerns in the realm of environmental sustainability. In the context of EPQ modeling, researchers are thus considering these two issues. Production and inventory management are critical issues. We must ensure that there is no negative impact on the environment throughout production and inventory control. If we add environmental sustainability considerations into EPQ modeling, we can quickly comprehend how production and inventories might affect the environment in a continuous manufacturing scenario.

We attempted to highlight the main themes of the relevant research publications that were related to our proposed research topic. Adequate research articles on the subject on which we attempted to write this review paper were limited. We began by delving deeply into the EPQ models established for carbon emissions. Simultaneously, we reviewed the supply chain and the EPQ model, which were established to demonstrate how green technology investment plays a primary role in lowering carbon emissions. Second, we emphasized the fundamental aspects of the suggested EPQ models, with a focus on product recycling. Third, we thoroughly addressed all of the research that has been conducted on the reverse logistics model in terms of carbon emissions and recycling. Finally, after reviewing the published articles linked to our research, we attempted to emphasize the main research gaps we discovered and provide an analytical rationale for these research gaps.

We attempted to clarify the issues we felt needed to be investigated to advance this present research. To obtain a more realistic view of EPQ models, we intended to incorporate the ideas of EPQ, carbon emissions, and recycling into one frame. In an imperfect manufacturing system, developing an EPQ model that takes into account both product recycling and carbon emissions can reveal how production and recycling decisions affect carbon emissions. The present research can be expanded by answering the two research questions listed below.

1. Under different carbon emission policies, what are the best strategies concerning production and recycling for a stochastic imperfect production-recycling system that minimizes carbon emissions while maximizing profit or minimizing cost?
2. Under different carbon emission policies, what are the best decisions concerning production, recycling, and green technology investment for a stochastic imperfect production-recycling system that minimizes carbon emissions while maximizing profit or minimizing cost?

We limited the results of our study to carbon emissions, recycling, and imperfect production processes; however, since many products are perishable, the perishability of the material can be studied. Therefore, our proposed research direction for developing a sustainable EPQ model can be further extended in the future by integrating product perishability. Apart from carbon emission costs, prices associated with energy consumption from production must be explicitly incorporated in the development of an energy-efficient and sustainable EPQ model in the future. The proposed research consideration can also be extended further from a sustainable EPQ model to a sustainable joint economic lot size model in the future. This review work has some limitations. As such, our assessment of the literature needs to be more methodical. For example, in the future, we may use the snowball technique to review systematic literature.

Author Contributions: Conceptualization, R.K.; methodology, R.K.; formal analysis, R.K.; writing—original draft preparation, R.K.; writing—review and editing, R.K. and K.N.; supervision, K.N. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Ballou, R. *Business Logistics Management*, 3rd ed.; Prentice Hall: Englewood Cliffs, NJ, USA, 1992.
2. Darmawan, G.A.; Cipta, W.; Yulianthini, N.N. Application of Economic order quantity (EOQ) in the Management of Flour Raw Material Inventory in Pia Ariawan Business in Banyuning Village in 2013. *J. Manaj. Indones.* **2015**, *3*. Available online: https://ejournal.undiksha.ac.id/index.php/JMI/article/view/4585 (accessed on 2 June 2022).
3. Fadlil, I.N.; Novitasari, R.; Jauhari, W.A. Sustainable economic production quantity model with rework and product return policy. *AIP Conf. Proc.* **2020**, *2217*, 030078. [CrossRef]
4. Taleizadeh, A.A.; Kalantari, S.S.; Cárdenas-Barrón, L.E. Pricing and lot sizing for an EPQ inventory model with rework and multiple shipments. *Top* **2016**, *24*, 143–155. [CrossRef]
5. Öztürk, H.J. A deterministic economic production quantity model with partial backordering and outsourcing repair of non-conforming products. *Int. J. Syst. Sci. Oper. Logist.* **2021**, 1–29. [CrossRef]
6. Öztürk, H. Optimal production run time for an imperfect production inventory system with rework, random breakdowns and inspection costs. *Oper. Res. Int. J.* **2021**, *21*, 167–204. [CrossRef]
7. Marchi, B.; Zanoni, S.; Jaber, M. Economic production quantity model with learning in production, quality, reliability and energy efficiency. *Comput. Ind. Eng.* **2019**, *129*, 502–511. [CrossRef]
8. Sarkar, B.; Sarkar, M.; Ganguly, B.; Cárdenas-Barrón, L.E. Combined effects of carbon emission and production quality improvement for fixed lifetime products in a sustainable supply chain management. *Int. J. Prod. Econ.* **2021**, *231*, 107867. [CrossRef]
9. Kugele, A.S.H.; Ahmed, W.; Sarkar, B. Geometric programming solution of second degree difficulty for carbon ejection controlled reliable smart production system. *RAIRO-Oper. Res.* **2022**, *56*, 1013–1029. [CrossRef]
10. Yadav, D.; Singh, R.; Kumar, A.; Sarkar, B. Reduction of Pollution through Sustainable and Flexible Production by Controlling By-Products. *J. Environ. Inform.* 2022, *in press*. [CrossRef]
11. Guo, T.; Li, C.; Chen, Y. Remanufacturing Strategy under Cap-and-Trade Regulation in the Presence of Assimilation Effect. *Sustainability* **2022**, *14*, 2878. [CrossRef]
12. He, P.; Zhang, W.; Xu, X.; Bian, Y. Production lot-sizing and carbon emissions under cap-and-trade and carbon tax regulations. *J. Clean. Prod.* **2015**, *103*, 241–248. [CrossRef]
13. Gharaei, A.; Shekarabi, S.A.H.; Karimi, M.; Pourjavad, E.; Amjadian, A. An integrated stochastic EPQ model under quality and green policies: Generalised cross decomposition under the separability approach. *Int. J. Syst. Sci. Oper. Logist.* **2021**, *8*, 119–131. [CrossRef]
14. Daryanto, Y.; Wee, H.M. Sustainable Economic Production Quantity Models: An Approach toward a Cleaner Production. *J. Adv. Manag. Sci.* **2018**, *6*, 206–212. [CrossRef]
15. Mukhopadhyay, A.; Goswami, A. Economic production quantity models for imperfect items with pollution costs. *Syst. Sci. Control Eng.* **2014**, *2*, 368–378. [CrossRef]
16. Manna, A.; Das, B.; Dey, J.; Mondal, S. Two layers green supply chain imperfect production inventory model under bi-level credit period. *Tékhne* **2017**, *15*, 124–142. [CrossRef]
17. Taleizadeh, A.A.; Soleymanfar, V.R.; Govindan, K. Sustainable economic production quantity models for inventory systems with shortage. *J. Clean. Prod.* **2018**, *174*, 1011–1020. [CrossRef]
18. Daryanto, Y.; Wee, H. Low Carbon Economic Production Quantity Model for Imperfect Quality Deteriorating Items. *Int. J. Ind. Eng. Eng. Manag.* **2019**, *1*, 1–8. [CrossRef]
19. Sinha, S.; Modak, N.M. An EPQ model in the perspective of carbon emission reduction. *Int. J. Math. Oper.* **2019**, *14*, 338–358. [CrossRef]
20. Moon, I.; Yun, W.Y.; Sarkar, B. Effects of variable setup cost, reliability, and production costs under controlled carbon emissions in a reliable production system. *Eur. J. Ind. Eng.* **2022**, *16*, 371–397. [CrossRef]
21. Sepehri, A.; Gholamian, M.R. Joint pricing and lot-sizing for a production model under controllable deterioration and carbon emissions. *Int. J. Syst. Sci. Oper. Logist.* **2021**, 1–15. [CrossRef]
22. Datta, T.K. Effect of Green Technology Investment on a Production-Inventory System with Carbon Tax. *Adv. Oper. Res.* **2017**, *2017*, 4834839. [CrossRef]
23. Mishra, U.; Wu, J.-Z.; Sarkar, B. Optimum sustainable inventory management with backorder and deterioration under controllable carbon emissions. *J. Clean. Prod.* **2020**, *279*, 123699. [CrossRef]
24. Lu, C.-J.; Yang, C.-T.; Yen, H.-F. Stackelberg game approach for sustainable production-inventory model with collaborative investment in technology for reducing carbon emissions. *J. Clean. Prod.* **2020**, *270*, 121963. [CrossRef]
25. Marchi, B.; Zanoni, S.; Zavanella, L.; Jaber, M. Green supply chain with learning in production and environmental investments. *IFAC-PapersOnLine* **2018**, *51*, 1738–1743. [CrossRef]
26. Sarkar, B.; Bhuniya, S. A sustainable flexible manufacturing–remanufacturing model with improved service and green investment under variable demand. *Expert Syst. Appl.* **2022**, *202*, 117154. [CrossRef]
27. Bachar, R.K.; Bhuniya, S.; Ghosh, S.K.; Sarkar, B. Sustainable green production model considering variable demand, partial outsourcing, and rework. *AIMS Environ. Sci.* **2022**, *9*, 325–353. [CrossRef]

28. Mishra, U.; Wu, J.-Z.; Sarkar, B. A sustainable production-inventory model for a controllable carbon emissions rate under shortages. *J. Clean. Prod.* **2020**, *256*, 120268. [CrossRef]
29. Rout, C.; Paul, A.; Kumar, R.S.; Chakraborty, D.; Goswami, A. Cooperative sustainable supply chain for deteriorating item and imperfect production under different carbon emission regulations. *J. Clean. Prod.* **2020**, *272*, 122170. [CrossRef]
30. Sepehri, A.; Mishra, U.; Sarkar, B. A sustainable production-inventory model with imperfect quality under preservation technology and quality improvement investment. *J. Clean. Prod.* **2021**, *310*, 127332. [CrossRef]
31. Priyan, S.; Mala, P.; Palanivel, M. A cleaner EPQ inventory model involving synchronous and asynchronous rework process with green technology investment. *Clean. Logist. Supply Chain.* **2022**, *4*, 100056. [CrossRef]
32. Dem, H.; Prasher, L. Imperfect Production System under Reverse Logistics in Stock-Out Situation: EPQ Model. *Adv. Decis. Sci.* **2013**, *2013*, 915675. [CrossRef]
33. Konstantaras, I.; Skouri, K.; Jaber, M.Y. Lot sizing for a recoverable product with inspection and sorting. *Comput. Ind. Eng.* **2010**, *58*, 452–462. [CrossRef]
34. Hwang, H.; Ko, Y.D.; Yune, S.H.; Ko, C.S. A closed-loop recycling system with a minimum allowed quality level on returned products. *Int. J. Serv. Oper. Manag.* **2009**, *5*, 758. [CrossRef]
35. AlArjani, A.; Miah, M.; Uddin, S.; Mashud, A.; Wee, H.-M.; Sana, S.; Srivastava, H. A Sustainable Economic Recycle Quantity Model for Imperfect Production System with Shortages. *J. Risk Financ. Manag.* **2021**, *14*, 173. [CrossRef]
36. Mashud, A.H.M.; Roy, D.; Daryanto, Y.; Chakraborty, R.K.; Tseng, M.L. A controllable carbon emission and deterioration inventory model with advance payments scheme. *J. Clean. Prod.* **2021**, *296*, 126608. [CrossRef]
37. Mishra, U.; Mashud, A.; Tseng, M.-L.; Wu, J.-Z. Optimizing a Sustainable Supply Chain Inventory Model for Controllable Deterioration and Emission Rates in a Greenhouse Farm. *Mathematics* **2021**, *9*, 495. [CrossRef]
38. Kundu, S.; Chakrabarti, T. Impact of carbon emission policies on manufacturing, remanufacturing and collection of used item decisions with price dependent return rate. *Opsearch* **2018**, *55*, 532–555. [CrossRef]
39. Jaber, M.Y.; El Saadany, A.M. An economic production and remanufacturing model with learning effects. *Int. J. Prod. Econ.* **2011**, *131*, 115–127. [CrossRef]
40. Dobos, I.; Richter, K. A production/recycling model with stationary demand and return rates. *Cent. Eur. J. Oper. Res.* **2003**, *11*, 35–46. [CrossRef]
41. Dobos, I.; Richter, K. An extended production/recycling model with stationary demand and return rates. *Int. J. Prod. Econ.* **2004**, *90*, 311–323. [CrossRef]
42. Hwang, H.; Oh, Y.; Gen, M. An inventory policy for recycling system. In Proceedings of the 2005 International Conference on Simulation and Modeling, Bangkok, Thailand, 17–19 January 2005; pp. 17–19.
43. Karmakar, S.; De, S.K.; Goswami, A. A pollution sensitive remanufacturing model with waste items: Triangular dense fuzzy lock set approach. *J. Clean. Prod.* **2018**, *187*, 789–803. [CrossRef]
44. Khara, B.; Dey, J.K.; Mondal, S.K. Sustainable recycling in an imperfect production system with acceptance quality level dependent development cost and demand. *Comput. Ind. Eng.* **2020**, *142*, 106300. [CrossRef]
45. Wang, X.; Han, S. Optimal operation and subsidies/penalties strategies of a multi-period hybrid system with uncertain return under cap-and-trade policy. *Comput. Ind. Eng.* **2020**, *150*, 106892. [CrossRef]
46. Bazan, E.; Jaber, M.Y.; El Saadany, A.M. Carbon emissions and energy effects on manufacturing–remanufacturing inventory models. *Comput. Ind. Eng.* **2015**, *88*, 307–316. [CrossRef]
47. Arora, R.; Singh, A.P.; Sharma, R.; Chauhan, A. A remanufacturing inventory model to control the carbon emission using cap-and-trade regulation with the hexagonal fuzzy number. *Benchmarking Int. J.* **2021**, 1–29. [CrossRef]
48. Yan, G.; Song, Q.; Ni, Y.; Yang, X. Pricing, carbon emission reduction and recycling decisions in a closed-loop supply chain under uncertain environment. *J. Ind. Manag. Optim.* **2021**, 1–22. [CrossRef]
49. Krikke, H. Impact of closed-loop network configurations on carbon footprints: A case study in copiers. *Resour. Conserv. Recycl.* **2011**, *55*, 1196–1205. [CrossRef]
50. Sarkar, B.; Ullah, M.; Kim, N. Environmental and economic assessment of closed-loop supply chain with remanufacturing and returnable transport items. *Comput. Ind. Eng.* **2017**, *111*, 148–163. [CrossRef]
51. Chaabane, A.; Ramudhin, A.; Paquet, M. Design of sustainable supply chains under the emission trading scheme. *Int. J. Prod. Econ.* **2012**, *135*, 37–49. [CrossRef]
52. Sarkar, B.; Joo, J.; Kim, Y.; Park, H.; Sarkar, M. Controlling defective items in a complex multi-phase manufacturing system. *RAIRO-Oper. Res.* **2022**, *56*, 871–889. [CrossRef]
53. Li, Y.-H.C.; Sy, L.L.; Lomibao, K.C.; German, J.D.; Wee, H.M. A Survey on Multi-Product Sustainable Economic Production Quantity Model Considering Wastewater Emission Costs. *IOP Conf. Ser. Mater. Sci. Eng.* **2020**, *730*, 012068.
54. Shi, H.; Peng, S.; Liu, Y.; Zhong, P. Barriers to the implementation of cleaner production in Chinese SMEs: Government, industry and expert stakeholders' perspectives. *J. Clean. Prod.* **2008**, *16*, 842–852. [CrossRef]
55. Gagnon, R.; Morgan, S. A Literature Review of Remanufacturing Production Planning and Control. In Proceedings of the Annual Meeting of the Decision Sciences Institute, Seattle, WA, USA, 21–24 November 2015.
56. Atasu, A.; Wassenhove, L.N. An Operations Perspective on Product Take-Back Legislation for E-Waste: Theory, Practice, and Research Needs. *Prod. Oper. Manag.* **2011**, *21*, 407–422. [CrossRef]