EOQ Inventory Model with Carbon Emission Consideration: A Literature Review

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Abstract

This paper presents a literature review on economic order quantity (EOQ) models that consider carbon emissions. This research aims to analyze the studies about the determination of the optimum re-order amount by implementing EOQ, which considers the carbon emission, published in international journals. It is done by a systematic review process covering publication from 2010 until 2019. This research identifies the key elements of EOQ models under the carbon emission policy investigated in the literature. This research categorizes or groups investigated articles based on the elements. It also presents the main characteristics of the concerning articles with annual publication distribution and the most studied sector. This research is expected to facilitate researchers by identifying and offering several topics, opportunities for the sake of future studies.

The data consists of English articles published in Scopus indexed journals. The research collected, ordered, and reviewed articles from 893 publications. About 29 relevant articles were then analyzed as they met the scope of this research. The findings showed the most promoted matters in developing the EOQ model with carbon emission problems still assumed the types of deterministic demands. This article found some gaps that have not been investigated..

Keywords: Economic Order Quantity (EOQ), Inventory, Optimization, Carbon Emission, Literature Review.

I.   INTRODUCTION

In the last ten years, research on inventory and supply chain model by considering the carbon emission policy has been frequently published. It inspires some researchers to do a literature review. The researchers collected and analyzed various research information based on papers that discussed various inventory models with carbon emission problems. Su et al. (2016) conducted a literature review about a management model under carbon emission policy. They discussed the operational management under carbon emission policy, such as the newsvendor model, economic order quantity (EOQ), and lot sizing in general. Chelly et al. (2019) also conducted a review on supply chain management under carbon emission policy with some logistics decisions (operational management, technology investment, and supply chain design coordination).

Our current research is different from the previous review research. This research comprehensively discusses the single-echelon EOQ inventory model under carbon emission policy. This research aims

to find the key elements of EOQ under the carbon emission constraints studied in the literature and identify research gaps for future studies. Following this introduction, we present a short literature review in section 2 and explain the research methodology in section 3. Section 4 elaborates on the finding and discusses the result. Finally, Section 5 gives the conclusion and some research suggestions.

II. LITERATURE REVIEW

For many years, the accumulation of carbon emissions causes global warming. Many studies show that most carbon emissions come from materials or energy consumed in the production process (Tsiliyannis, 2015). Production activities that can produce carbon emissions are inventory activities, production activities, and transportation (Chelly et al., 2019). Bonney & Jaber (2011) proposed the idea to study the effect of inventory decisions on carbon emissions. A new inventory cost model is proposed that includes vehicle emissions and waste disposal costs, in addition to ordering costs, purchasing costs, storage costs, and transportation costs. The study developed an EOQ model that suggests a higher order quantity. The idea is continuously growing for about ten years. Many researchers examine the optimum decision considering many managerial situations. However, a literature review that studies comprehensively on the development of this idea is still limited. Hence, our study aims to fill this gap.

Fink (2014) argued that "literature review is a systematic, explicit, and reproducible design for identifying, evaluating, and interpreting the existing body of recorded documents". The objective of a literature review is such as to summarize the existing researches by identifying the patterns, themes, and problems. The second objective of a literature review is to foster conceptual content identification from the field and contribute to developing a theory.

III. RESEARCH METHODOLOGY

According to Mayring (2003), a literature review may contain four stages, i.e., material collection, descriptive analysis, category selection, and material evaluation. Hence, each stage of the research methodology in our literature review could be seen in Figure 1.
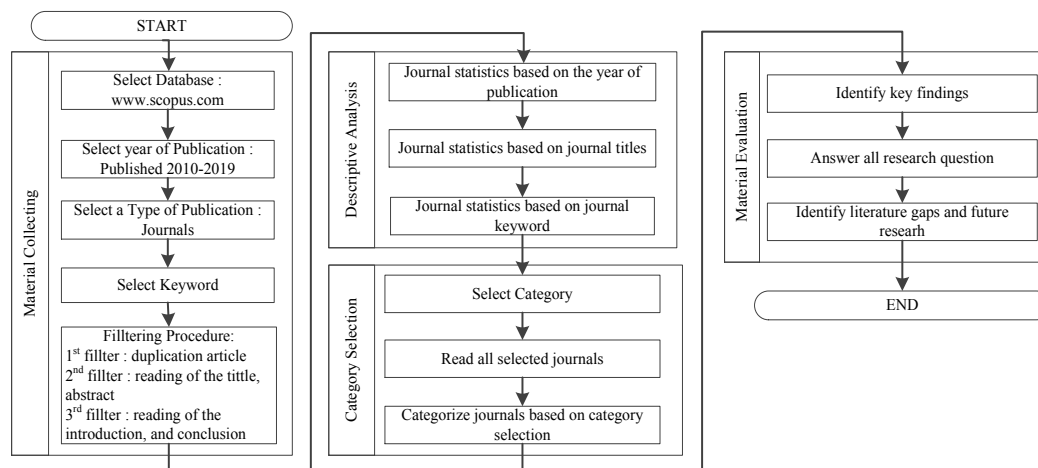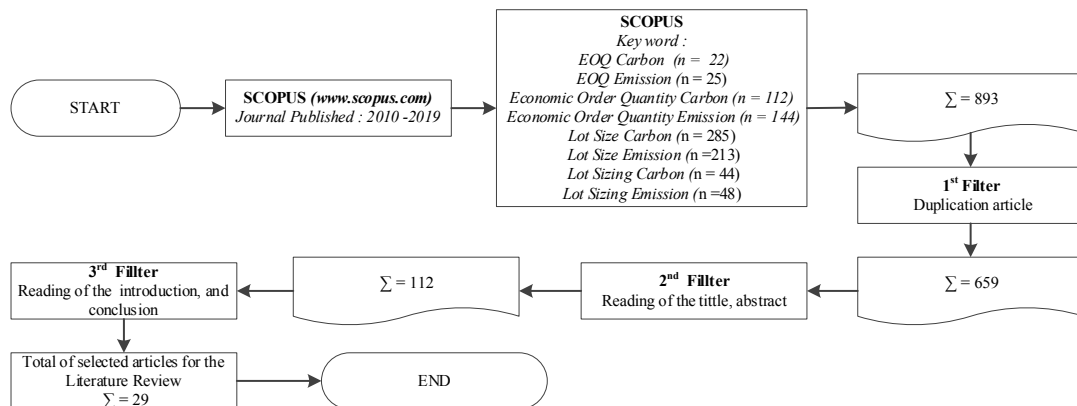

Figure 1. Research methodology

Figure 2. Screening results for material collection

IV. FINDING AND DISCUSSION

Figure 2 shows the systematic process of the material collection, which includes the database source, keywords, and three filtering processes. The study targeted any published articles in the range of 2010 until October 2019, and Scopus indexed journal in English. Finally, the relevant articles with the topic of one-echelon EOQ with the carbon emission problems consisted of 29 articles. Figure 3 presents the distribution of the article from 2010-2019 that shows the trend on this topic.
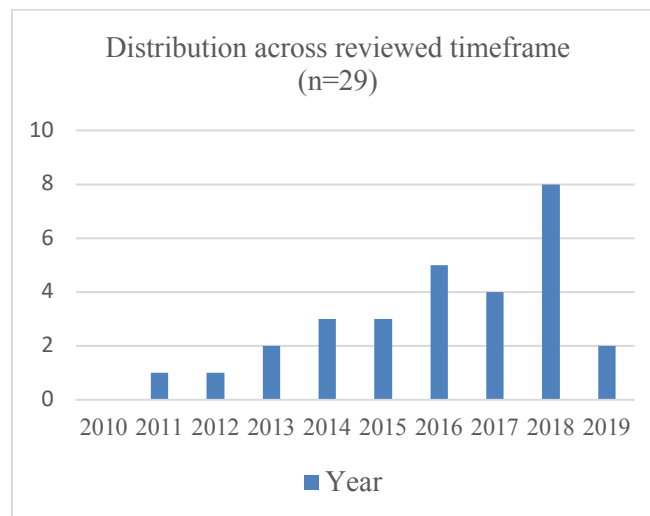

Figure 3. Distribution across a reviewed time frame

From those 29 articles, a detailed review of each article is performed. A categorical analysis is performed based on 16 key topics on the inventory model proposed by Janssen et al. (2016). Table 1 presents the result, including some examples of publications.

Table 1. Classification based on some key topics

Key topics	Number of articles	Examples
Pricing & discount	1	Taleizadeh et al., 2018
Shortage	5	Taleizadeh et al., 2018; Lee et al., 2017; Sarkar et al., 2018; Lin, 2018
Multi-item inventory models	2	Lamba and Singh, 2018; Bozorgi, 2016
Inflation and time value of money	0	-
Credit and different payment Problems	2	Cao et al., 2018; Sarkar et al., 2018
Investments, Promotion or Budget Constraint	4	Lee, 2019; Toptal et al., 2013; Lin, 2018; Zhao et al., 2017
Out-dating, waste or shrinkage	7	Zadjafar and Gholamian, 2018; Kazemi et al., 2018; Shu et al., 2017; Lin, 2018; Soleymanfar, 2015
Product characteristics or customer specifics, including behavior, reservations, returns, etc.	2	Wu et al., 2017; Bazan et al., 2016
Issue policies (FIFO, LIFO, etc.) or substitutions of perishable items	0	-
Advances in technology (RFID, TTI) corresponding to inventory models	1	Toptal et al., 2013
Distribution, routing, transportation, and location problems	4	Lee et al., 2017; Wu et al., 2017; Bozorgi et al., 2014; Zhao et al., 2017
Rework, process breakdown, machine interruption, preventive maintenance, etc	3	Liao and Deng, 2018; Shu et al., 2017; Sarkar et al., 2018
Two-and multi-warehouses	0	-
Sources of emission		
Transportation	18	Wang and Ye, 2018; Tian et al., 2013; Gurtu et al., 2015; Bouchery et al., 2012; Shu et al., 2017; Purohit et al., 2013; Bonney & Jaber, 2011
Production	8	Zadjafar and Gholamian, 2018; Tao and Xu, 2019; Shu et al., 2017; He et al., 2014; Zhao et al., 2017
Inventory	19	Wang and Ye, 2018; Tian et al., 2013; Kazemi et al., 2018; Chen at al., 2013;

		Hovelaque and Bironneau, 2015; Purohit et al., 2013; Bonney & Jaber, 2011
Carbon emissions legislation		
Carbon cap	5	Liao and Deng, 2018; Lee, 2019; Toptal et al., 2013; Chen at al., 2013
Cap & Trade	10	Lee, 2019; Toptal et al., 2013; Cao et al., 2018; Lamba and Singh, 2018
Carbon tax	12	Liao and Deng, 2018; Gurtu et al., 2015; Lee, 2019; Toptal et al., 2013
Demand Type		
Deterministic	21	Bouchery et al., 2012; Lee, 2019; Toptal et al., 2013; Taleizadeh et al., 2018; Shu et al., 2017; Hovelaque and Bironneau, 2015
Stochastic (price, stock-level, or stock-age-dependent demand, etc.)	13	Zadjafar and Gholamian, 2018; Tian et al., 2013; Zhang et al., 2019; Lee, 2019; Toptal et al., 2013; Liao and Deng, 2018

The above results show several findings:
a. EOQ models with carbon emissions consideration have been studied in 29 papers from 2011-2019. This number is increasing, especially in 2018.
b. The EOQ models consider emissions from transportation, production, and inventory holding.
c. The effect of a carbon tax, cap-and-trade, and carbon cap regulations are considered.
d. Most of the reviewed articles applied the deterministic-type demand.
e. This research founds some key topics of the general inventory model that had not been investigated regarding their effect on emission level and costs. It dealt with articles that discussed EOQ with carbon emission problems. The effect of inflation, inventory issuing policy, and multiple-warehouse has not been studied. Besides, the effects of pricing and discount, multi items, payment methods, rework and remanufacturing products, and advanced technology are received little attention.

Further study on the literature found that EOQ models considering carbon emission and environmental impact have higher total costs. It is caused by the additional carbon tax of each production, inventory, or transport activity (Chelly, 2018). Several literature has an objective function of maximizing profits and finds that the greater the carbon emissions released, the smaller the benefits. This is because the total costs increase considering carbon emissions. New models have been created to assist companies in making optimal decisions or improving aspects that can reduce emission levels. For example, companies can invest in technology by using environmentally friendly means of transportation to reduce carbon emissions, thereby reducing total costs incurred.

V. CONCLUSION AND FURTHER RESEARCH

This research discusses the single-echelon EOQ inventory model under carbon emission policy. This study identifies 29 papers from the Scopus database. The developed models considering various aspects or key topics in inventory decisions besides environmental factors. The models considered

emissions from transportation, production, and inventory holding. Most of the models assumed a deterministic customer demand and worked under a carbon tax or car-and-trade emission regulations. Several key topics received little attention. Hence, this study recommends further research on the sustainable EOQ model considering the effect of inflation, inventory issuing policy, and multiple-warehouse, the effect of pricing and discount, multi items, payment methods, rework and remanufacturing product, and advance technology. In addition, in the future, a literature review is also needed for EOQ models in multi-echelon supply chain systems.

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