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Imperfect Production Inventory Models: A Bibliometric Analysis

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ABSTRACT

Economic order quantity models have been fascinated to be researched since a long time ago. This article presents a bibliometric analysis for imperfection production inventory models. Analysis involved 40 peer-reviewed research articles published during 2000-2020 at Google Scholar and Sciencedirect. The articles are filtered based on trends, year of publication, countries, institution, and publisher name. Result of this study shows that a journal entitled International Journal of Production Economics has the most published article in the area. Content analysis has classified purpose of research, type of echelon, type of demand, lead-time, backorder, type of production process, quality improvement, setup cost and ordering cost reduction, logistic cost, and pick-up service. This study also recommends research gap for future studies in the field of inventory for supply chain management.

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1. Introduction

Inventory is one of the key activities for almost all industry, especially manufacturing industry. Inventory can be found as raw material, work in process, and finish goods that ready to be delivered to the end customers or to the next stage of the supply chain. Main purpose of holding inventory is to guarantee that order fulfillment can be carried out on time with minimum total cost. In the production process level, inventory of raw material or work in process can be used to ensure that materials supply is smooth during production process and to anticipate if any disruption during the production process.

To win a business competition with competitive and affordable product pricing strategies. Therefore, the focus of this study is to manage inventory and minimize total costs or maximize total profits. This study determines the lowest inventory total cost or maximum total profit. So this uses the Economic Order Quantity (EOQ) model or Economic Production Quantity (EPQ) model with mathematical methods. For solving the supply as mentioned chain system problems earlier, this study considered two essential questions in the models:

1. How much quantity should be ordered?
2. When should an order be placed?

At any stages of a production process, imperfect process somehow cannot be avoided that result defected products with certain probability. A high probability of defected products will affect on profit loss of the company due to increasing rework cost and other cost related to the profit loss. This article discusses studies on the inventory model with imperfect production process that has been received major attention from researchers since 2000. Some changes on the parameters and characteristics were also analyzed in order to find the research gap within that area. (Salameh & Jaber, 2000) proposed the first.

2. Research Methods

A systematic review of the articles is conducted to identify and analyze research in a more structured and systematic manner. In this study, there are three steps in conducting a systematic literature review, namely defining the conceptual framework and determining the research question, screening process, and analysis and report. Those steps are depicted in Figure 1.

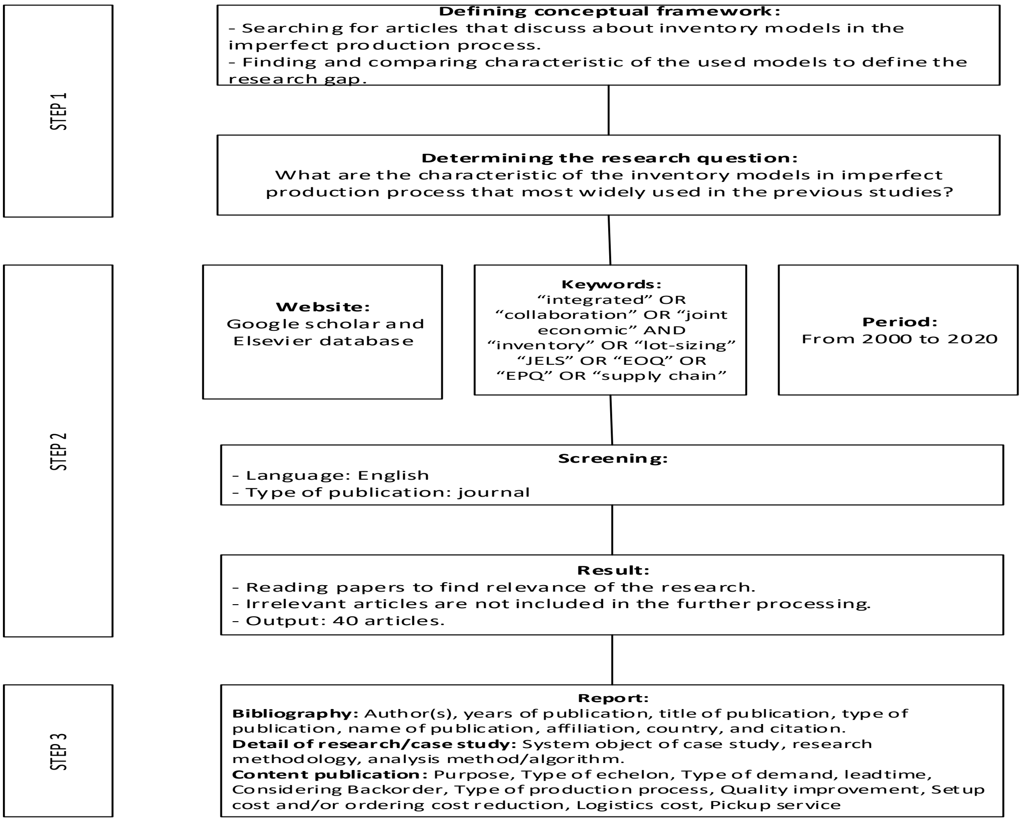


Figure 1. Research methodology

2.1 Step 1: Determining topic and keywords

Research topic that used in this study is inventory model within supply chain system. The used key words are "integrated" OR "collaboration" OR "joint economic" AND "inventory" OR "lot-sizing" "JELS" OR "EOQ" OR "EPQ" OR "supply chain".

2.2 Step 2: Searching and selecting data

The used research database are Google scholar (https://scholar.google.com) and sciencedirect (www.sciencedirect.com). After data has been collected, we selected 40 articles using defined criteria which is the year of publication, which is from year 2000 to year 2020.

2.3 Step 3: Analyzing in characteristic and content of research

A systematic review of the literature is conducted to identify and analyze research in a more structured and systematic manner. As shown in Figure 1, this study had three steps in conducting a systematic literature review: defining the conceptual framework and determining the research question, screening process, and analysis and report. In this step, the study conducted a literature analysis and report using a review protocol that consist of year of publication, type of echelon, type of demand, lead-time, backorder, type of production process, quality improvement factor, setup cost and/or ordering cost reduction, logistics cost and pickup service (Table 1). In the year of publication, the analysis is based on number of publications during each year. Type of echelon referred to previous models: single-echelon model i.e., EOQ/EPQ and multi-echelon model such as JELS. Demand type area addressed deterministic and probabilistic conditions. Backorder factor considers how to pay the backorder cost, which is by discounting the price (backorder price discount). Lead-time will be categorized in three categories which are lead-time equals to 0, static lead-time, and controllable lead time. Type of production classified the researches into two classifications namely perfect and imperfect production system with out-of-control probability. Quality improvement is classified the researches which have rework cost and without rework cost, and quality improvement investment by optimizing out-of-control probability in the imperfect production system. Investments in reducing the setup cost and ordering cost are considered to reduce setup and ordering costs that minimize the purchasing cost. Moreover, this study also classifies the researches based on logistics costs and pick up service.

Table 1.
Review protocol

Bibliography		
Author(s)	Who is/are the author(s) of the publication?	Sarkar & Giri
Year	In which year is the work published?	2020
Title	What is the title of the publication?	Stochastic supply chain model with imperfect production and the controllable defective rate
Type of publication	What kind of publication?	Journal
Name of publication	What is the name of the journal/proceeding?	Int. J. of Systems Science: Operations & Logistics
Institution	What is the name of the author's institution?	Jadavpur University
Country	What is the name of the author's country?	India
Citation	How many citations have been cited from previous studies?	62
Detail of research/case study		
System object of case study	What is the system of the case study?	Supply chain system
Research methodology	What is the research methodology used by the author(s)?	Mathematical modeling
Analysis method/algorithm	What is the analysis used by the author(s)?	Differential method
Content of research		
Purpose	What is the purpose of carrying out the study?	Minimize cost
Type of echelon	How many echelons are in this study?	Two-echelon
Type of demand	What are the types of demand patterns in this study?	Probabilistic
Lead-time	Did the research consider lead-time?	Controllable lead-time
Considering backorder	Did this research consider the shortage condition? What type is used?	Backorder price discount
Type of production process	What types of production systems are in this study?	Imperfect production process
Quality improvement	Did this research consider any quality improvement in the production process?	Yes

Content of research		
Setup cost and/or ordering cost reduction	Did this research consider any investment in lowering setup and/or messaging costs?	Ordering cost reduction
Logistics cost	Did this research involve logistics?	Not considered
Pick-up service	Did the logistics consider a pick-up service policy?	Not considered

3. Result and Discussion

3.1 Bibliography Analysis

a. Article Growth and Publication Type

The 40 articles obtained from the review protocol mentioned above resulted in a research trend line having a linear progression from year 2000 until year 2020, as shown in Figure 2. Year published 2008 and 2015 have the top number of publications during the period with 5 articles in a year.

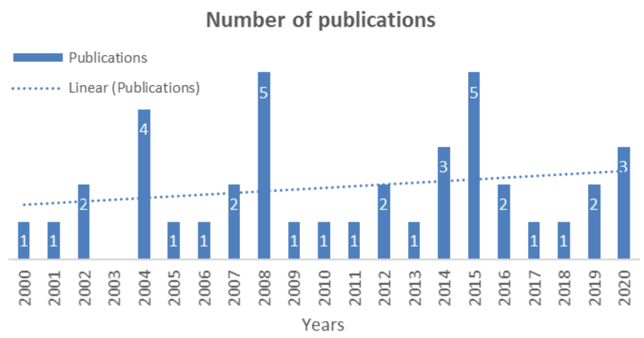


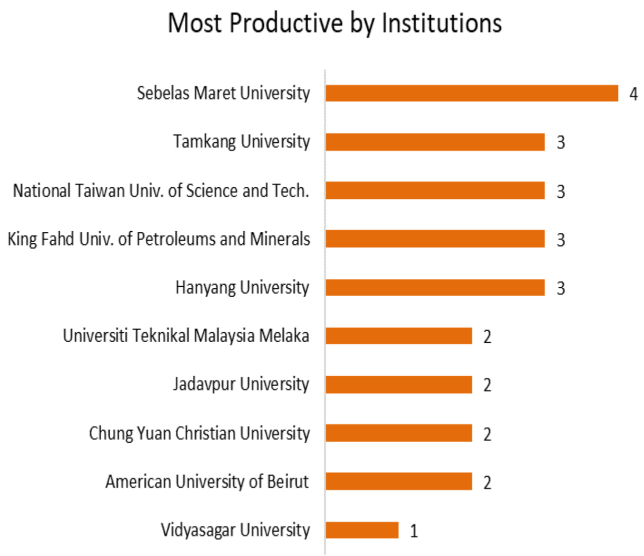
Figure 2. Year of publication

b. Top Publication, Affiliation, and Country

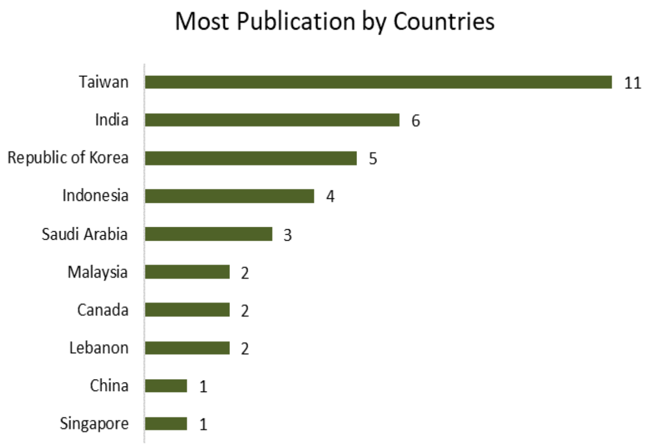
This section describes the ranking results for 40 articles based on the publication/journal name, institution, and country. Figure 3(a) shows the top ten leading of journals. The International Journal of Production Economics gave the largest contribution with 12 articles. Five journals have contributed two articles: Journal of Manufacturing Systems, International Journal of Production Research, International Journal of Operational Research, European Journal of Operational Research (EJOR), and Computers & Operations Research (COR). Figure 3(b) shows the ranking based on the authors institution. The Sebelas Maret University gave the most significant contribution of 4 articles. Then, Tamkang University, National Taiwan University of Science and Technology (NTUST), King Fahd University of Petroleums and Minerals, Hanyang University contributed 3 articles. The rest contributed 1 article to each institution. Figure 3(c) shows the ranking based on the authors country that authors from Taiwan have the largest contribution with 11 articles. Then, authors from India had 6 articles, authors from Republic of Korea with 5 articles, authors from Indonesia with 4 articles, authors from Saudia Arabia with 3 articles. While authors from Malaysia, Canada, and Lebanon had 2 articles, respectively. The authors from other countries have contributed 1 article.


Top 10 Leading Journals
Int. J. of Production Economics 12
J. of Manufacturing Systems 2
Int. J. of Production Research 2
Int. J. of Operational Research 2
European J. of Operational Research 2
Computers & Operations Research 2
Int. J. of Systs. Science: Ops. & Logistics 1
Revista de la Real Academia de Ciencias... 1
RAIRO-Operations Research 1
Omega 1

(a)


Most Productive by Institutions
Sebelas Maret University 4
Tamkang University 3
National Taiwan Univ. of Science and Tech. 3
King Fahd Univ. of Petroleums and Minerals 3
Hanyang University 3
Universiti Teknikal Malaysia Melaka 2
Jadavpur University 2
Chung Yuan Christian University 2
American University of Beirut 2
Vidyasagar University 1

(b)



(c)

Figure 3 (a) Top 10 leading journals; (b) The most productive by the institution; (c) The most publication by countries

c. Top Citations of Article

This section describes the ranking results based on citations from Google Scholar database. Table 2 shows the top 10 citations, with the highest ranking of 1166 citations and total citation per year is 55.52. It is achieved by authors (Salameh & Jaber, 2000) with article entitled Economic production quantity model for items with imperfect quality published in the International Journal of Production Economics journal. The second rank of citation is 393 citations or 28.07 citations/year achieved by authors (Wee et al., 2007) with article entitled Optimal inventory model for items with imperfect quality and shortage backordering published by Omega journal. Furthermore, the third rank is 339 citations with 26.08 citations/year, achieved by authors (Maddah & Jaber, 2008) with article entitled Economic order quantity for items with imperfect quality: revisited that published in the International Journal of Production Economics journal.

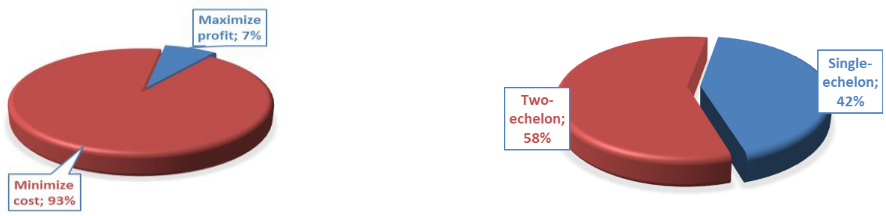
Table 2.
Citations of article

Author (s)	Article Name	Name of publication	Total Citation (TC)	TC / Year
Salameh & Jaber (2000)	Economic production quantity model for items with imperfect quality	Int. J. of Production Economics	1166	55.52
Wee et al. (2007)	Optimal inventory model for items with imperfect quality and shortage backordering	Omega	393	28.07
Maddah & Jaber (2008)	Economic order quantity for items with imperfect quality: Revisited	Int. J. of Production Economics	339	26.08
Pan & Yang, (2002)	A study of an integrated inventory with a controllable lead time	Int. J. of Production Research	326	17.16
Ben-Daya & Hariga (2004)	Integrated single vendor single buyer model with stochastic demand and variable lead time	Int. J. of Production Economics	315	18.53
Ouyang et al. (2004)	Integrated vendor–buyer cooperative models with stochastic demand in controllable lead time	Int. J. of Production Economics	277	16.29
Ertogral et al.	Production and shipment lot sizing in	European J. of	200	14.29

Author (s)	Article Name	Name of publication	Total Citation (TC)	TC / Year
(2007)	a vendor–buyer supply chain with transportation cost	Operational Research		
Ouyang et al. (2007)	An integrated vendor–buyer inventory model with quality improvement and lead time reduction	Int. J. of Production Economics	191	13.64
Yang & Pan (2004)	Just-in-time purchasing: an integrated inventory model involving deterministic variable lead time and quality improvement investment	Int. J. of Production Research	178	10.47
Glock (2012)	Lead time reduction strategies in a single-vendor–single-buyer integrated inventory model with lot size-dependent lead times and stochastic demand	Int. J. of Production Economics	175	19.44

3.2 Content Analysis

This content analysis conducts a literature review for the model classified into two types: minimize total cost and maximize total profit. From the analysis, we obtained the model's purpose that maximized total profit is 7% or three articles (Salameh & Jaber, 2000), (Wee et al., 2007), (Abad & Aggarwal, 2005) and minimized the total cost for the remaining article, 93% or 37 articles (Figure 4a).



(a) (b)

Figure 4 (a) Purpose of model; (b) Type of echelon in the supply chain

The inventory model is classified into two types in the literature review result: Economic Order Quantity / Economic Production Quantity (EOQ/EPQ) and Joint Economic Lot Size (JELS). The EOQ/EPQ model is a model that optimizes order quantity for a single-echelon (supplier or buyer only), both optimizing total cost or total profit (Abad and Aggarwal, 2005; Darwish, 2008; Gurtu et al., 2015; Huang, 2010; Kurdhi and Doewes, 2019; Lo et al., 2008; Maddah and Jaber, 2008; Mendoza and Ventura, 2008; Ouyang et al., 2002; Pan and Hsiao, 2001; Pan et al., 2004; Salameh and Jaber, 2000; Sarkar et al., 2015a; Sarkar et al., 2015c; Sarkar and Moon, 2014; Wee et al., 2007; Yoo et al., 2012). The number of articles identified amounted to 17 articles or 42%. The JELS is a model that optimizing and collaborating the order lot size and production lot size for a supply chain system consisting of two or more echelons. In this study, JELS creates an optimal total cost or profit from the supply chain system (two-echelon or multiple echelons). The model provides a win-win solution for all parties in the supply chain system (Ben-Daya and Hariga, 2004; Nie et al., 2006; Ouyang et al., 2004; Pan and Yang, 2002; Yang and Pan, 2004; Ertogral et al., 2007; Glock, 2012; Hoque, 2013; Jauhari et al., 2011; Jauhari et al., 2016; Jauhari et al., 2009; Jindal and Solanki, 2016; Leuveano et al., 2014a; 2014b; Ouyang et al., 2007; Sarkar et al., 2015b; Tiwari et al., 2018; Vijayashree and Uthayakumar, 2015; Wangsa and Wee, 2017; Guchhait et al., 2020; Mukherjee et al., 2019; Sarkar and Giri, 2020; Tiwari et al., 2020). The number of articles with the JELS model is around 58% or 23, as shown in Figure 4b.

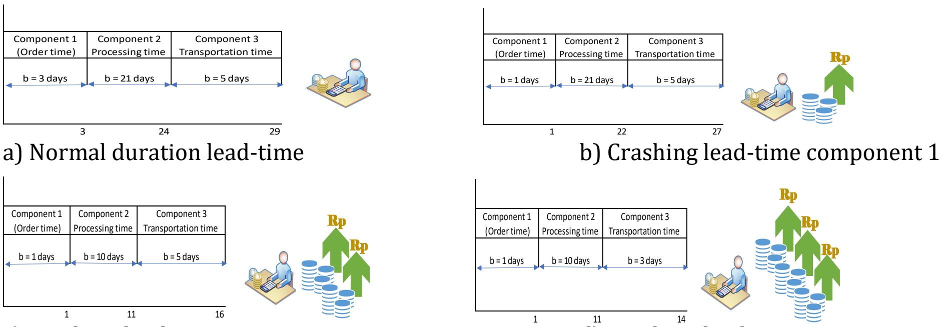
(a) (b)

Figure 5 (a) Type of Demand; (b) backorder case

Based on demand from each articles, this study obtained two types of demand i.e., the deterministic and probabilistic conditions. Deterministic demand is a known and certain demand. On the other hand, probabilistic demand is an uncertain demand and possible change during each period of demand. Figure 5a showed that probabilistic demand (63% or 25 articles) such as: Pan & Yang (2002), Ben-Daya & Hariga (2004), Pan & Hsiao (2001), Pan et al. (2004), Darwish (2008), Glock (2012), Guchhait et al. (2020), Huang (2010), Jauhari et al. (2011; 2016; 2009), Jindal and Solanki (2016), Kurdhi and Doewes (2019), Lo et al. (2008), Mukherjee et al. (2019), Ouyang et al. (2004; 2007), Sarkar et al. (2015a; 2015c), Sarkar and Giri (2020); Sarkar and Moon (2014); Tiwari et al. (2020, 2018); Vijayashree and Uthayakumar (2015); Wangsa and Wee (2017) had more researches compared to deterministic demand (37% or 15 articles) includes Abad and Aggarwal (2005), Ertogral et al. (2007), Maddah and Jaber (2008), Nie et al. (2006), Wee et al. (2007), Yang and Pan (2004), Gurtu et al. (2015), Hoque (2013), Kurdhi and Doewes (2019), Leuveano et al. (2014a; 2014b), Maddah and Jaber (2008), Mendoza and Ventura (2008), Sarkar et al. (2015b), Wee et al. (2007), and Yoo et al. (2012). Subsequently, the probabilistic demand often patterned the backorder case. Therefore, the probabilistic demand could determine the optimal safety stock due to stock out of inventory. Backorder in the buyer occured if the amount of inventories or stocks were not sufficient to meet fluctuating demand of the end-customer. So, the safety stocks were needed in the buyer. From 40 articles, only few article considered backorder price discount (10% or 25 articles), such as Huang (2010), Jindal and Solanki (2016), Kurdhi and Doewes (2019), Lo et al. (2008), Mukherjee et al. (2019), Pan and Hsiao (2001), Pan et al. (2004), Sarkar et al. (2015c), Sarkar and Giri (2020), and Tiwari et al. (2020). Meanwhile 16 articles ((Ben-Daya and Hariga, 2004; Darwish, 2008; Glock, 2012; Jauhari et al., 2011; 2016; Ouyang et al., 2002; 2007; Pan and Yang, 2002; Sarkar et al. 2015a; Sarkar and Moon, 2014; Tiwari et al., 2018; Vijayashree and Uthayakumar, 2015; Wangsa and Wee 2017) or 40% considered backorder as a point in the research. The rest of 14 articles (Abad and Aggarwal, 2005; Darwish, 2008; Ertogral et al., 2007; Nie et al., 2006; Salameh and Jaber, 2000; Wee et al., 2007; Yang and Pan, 2004; Guchhait et al., 2020; Gurtu et al., 2015; Hoque, 2013; Leuveano et al., 2014a; 2014b; Maddah and Jaber, 2008; Mendoza and Ventura, 2008; Sarkar et al., 2015a; 2015b; Wee et al., 2007; Yoo et al., 2012) or 35% did not consider backorder on the research (Figure 5b).

Further analysis on the lead-time is classified into three categories. Firstly, without lead-time involved 14 articles or 35% (Abad & Aggarwal, 2005; Darwish, 2008; Ertogral et al., 2007; Nie et al., 2006; Salameh & Jaber, 2000; Wee et al., 2007; Yang & Pan, 2004; Guchhait et al., 2020; Yoo et al., 2012; Gurtu et al., 2015, Sarkar et al., 2015a; Mendoza & Ventura, 2008; Hoque, 2013, Leuveano et al., 2014a; 2014b, Sarkar et al., 2015b). Secondly, deterministic or static lead-time had five articles or 15% (Sarkar et al., 2015a; Darwish, 2008; Jauhari et al., 2016; 2009; 2011). Thirdly, controllable lead-time included

53% or 21 articles (Ben-Daya & Hariga, 2004; Pan & Yang, 2002; Pan et al., 2004; Lo et al., 2008, Jindal & Solanki, 2016; Wangsa & Wee, 2017; Mukherjee et al., 2019; Vijayashree & Uthayakumar, 2015; Sarkar & Giri, 2020; Tiwari et al., 2020; Ouyang et al., 2004; Glock, 2012; Ouyang et al., 2007; Yang & Pan, 2004; Huang, 2010; Sarkar & Moon, 2014; Sarkar et al., 2015c, Pan & Hsiao, 2001). The deterministic lead-time is indicated positive since the supply of the products from buyers to customers is fixed. Controllable lead-time showed a lead-time model that could be separated into several lead-time components, such as: the order time, setup time, processing time, transportation time). At the same time, the controlled one required additional cost (crashing cost) therfore the order from the vendor to buyer can be fulfilled. As an illustration, controllable lead-time concept can be seen in Figures 6a-6d. In Figure 6a, it can be explained that in normal duration it takes a lead-time of 29 days. While in Figure 6b there is a crashing lead-time for lead-time component 1 from 3 days to 1 day at a cost of $/days with a total lead-time of 27 days. In Figure 6c there is a crashing lead-time in components 1 and 2 with a total lead-time of 16 days. Crashing lead-time on components 1, 2 and 3 can also be done so that the total lead-time is 14 days with a higher total acceleration cost (Figure 6d).



a) Normal duration lead-time b) Crashing lead-time component 1

c) Crashing lead-time component 2 d) Crashing lead-time component 3

Figure 6. Crashing lead-time illustrations

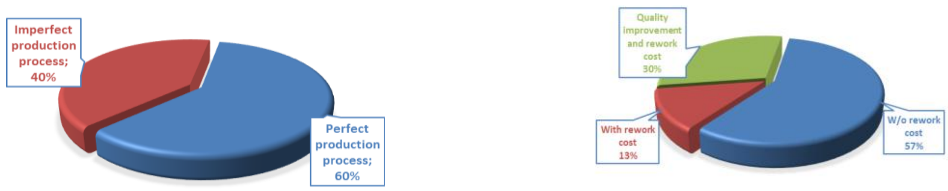
The review protocol is classified into two types in the production process: perfect production process and imperfect production process. A perfect production process is a system that does not consider the conditions of damage or disruption to the production system. In constrast, the imperfect production process involves a disruption in the production process resulting in defective or rejected products (such as: machine breakdown, human error, and poor-quality materials). In the review of perfect production process, we find 24 articles or 60% (Ben-Daya & Hariga, 2004; Pan & Yang, 2002; Darwish, 2008; Jauhari et al., 2016; Lo et al., 2008; Mendoza & Ventura, 2008; Nie et al., 2006; Pan et al., 2004; Jauhari et al., 2009; 2011; Tiwari et al., 2018; Wangsa & Wee, 2017; Ouyang et al., 2004, Hoque, 2013; Leuveano et al., 2014a; 2014b; Sarkar et al., 2015b; Ertogral et al., 2007; Abad & Aggarwal, 2005; Glock, 2012; Huang, 2010; Gurtu et al., 2015; Kurdhi & Doewes, 2019; Pan & Hsiao, 2001) more often than imperfect production process in 16 articles or 40% (Salameh & Jaber, 2000; Wee et al., 2007; Guchhait et al., 2020; Mukherjee et al., 2019; Sarkar & Giri, 2020; Tiwari et al., 2020; Vijayashree & Uthayakumar, 2015; Maddah & Jaber, 2008; Ouyang et al., 2007; Yang & Pan, 2004; Sarkar & Moon, 2014; Yoo et al., 2012; Sarkar et al., 2015a; 2015c, Jindal & Solanki, 2016) as shown in Figure 7a. This study also found five articles or 13% articles (Maddah & Jaber, 2008; Salameh & Jaber, 2000; Wee et al., 2007; Tiwari et al., 2020) that had imperfect production process considering the rework cost. The other 21 articles or 30% (Ouyang et al., 2007; Yang & Pan, 2004; Sarkar & Giri, 2020; Sarkar & Moon, 2014; Yoo et al., 2012; Sarkar et al., 2015a 2015c; Jindal & Solanki, 2016; Guchhait et al., 2020; Mukherjee et al., 2019; Vijayashree & Uthayakumar, 2015) are considered as the out-of-control probabilistic along with the investment of quality improvement. Quality improvement is defined as a company's efforts to improve the quality of the production process by increasing the costs incurred. The cost issued is in the form of capital in the quality improvement. Investment of quality improvement is carried out to improve the system from an imperfect production process with high defects to common defects. In quality improvement model is used a logarithmic functions approach. The formulation of quality improvement is given by:

$$tn \, . \ln\left(\frac{\theta_0}{\theta}\right) \tag{1}$$

Subject to: $0 \leq \theta \leq \theta_0$

t = capital (interest) in quality improvement
n = quality improvement
θ_0 = initial probability out-of-control
θ = probability out-of-control optimal

The remaining 23 articles or 57% related to quality improvement are Ben-Daya & Hariga (2004), Pan & Yang (2002), Darwish (2008), Jauhari et al. (2016), Lo et al. (2008), Mendoza & Ventura (2008), Nie et al. (2006), Pan et al. (2004), . Jauhari et al. (2009), Jauhari et al. (2011), Tiwari et al. (2018), Wangsa & Wee (2017), Ouyang et al. (2004), Hoque (2013) Leuveano et al. (2014a; 2014b), Sarkar et al. (2015b), Ertogral et al. (2007), Abad & Aggarwal (2005), Glock (2012), Huang (2010), Gurtu et al. (2015), Kurdhi & Doewes (2019), and Pan & Hsiao (2001) do not consider a rework cost as most of them using perfect production process. The percentage yield using quality improvement is shown in Figure 7b. The effect of quality improvement investment on lot size and total cost as depicted in Figure 8. In the figure, it can be explained that the impact of the model without considering quality improvement will result in a higher lot size and total cost than the logarithmic function model that considers quality improvement.



(a). Type of Production System (b). Quality Improvement

Figure 7. Production system type and quality improvement

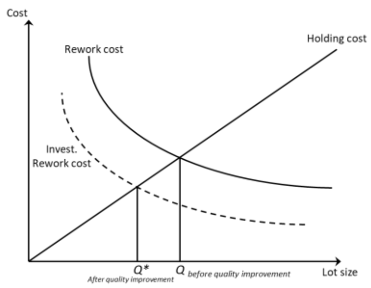


Figure 8. Effect of logarithmic functions on quality improvement

The costs incurred in each process of sourcing and preparing items to produce are called the procurement cost. The procurement costs are divided into two parts: order costs and set up costs. Ordering costs are expenses to buy goods from the vendor, such as sourcing, determining the vendor, and checking inventory before placing an order. Setup costs are incurred for each time starting the preparation of production of goods, including the cost of setting the machine and product design. To reduce total inventory costs, the vendors can reduce the setup costs, and the buyers can reduce the ordering costs. These costs are from activities that do not add value. The setup and order activities can be performed shortly to reduce total inventory. The research that considered by reducing of the ordering/setup cost investment consists of 11 articles or 28% (Glock, 2012; Huang, 2010; Sarkar & Moon, 2014; Sarkar et al., 2015a; Kurdhi & Doewes, 2019; Tiwari et al., 2018; Sarkar et al., 2015b; Guchhait et al., 2020; Sarkar & Giri, 2020; Tiwari et al., 2020) while 29 articles or 72% (Salameh & Jaber, 2000; Wee et al., 2007; Yoo et al., 2012; Gurtu et al., 2015; Sarkar et al., 2015c; Pan & Hsiao, 2001; Darwish, 2008; Jauhari et al., 2016; Jindal & Solanki, 2016; Lo et al., 2008; Mendoza & Ventura, 2008; Nie et al., 2006; Pan et al., 2004; Wangsa & Wee, 2017; Maddah & Jaber, 2008; Hoque, 2013; Jauhari et al., 2009; 2011; Leuveano et al., 2014a; 2014b; Mukherjee et al., 2019; Vijayashree & Uthayakumar, 2015; Ben-Daya & Hariga, 2004; Ertogral et al., 2007; Ouyang et al., 2004, 2007; Pan & Yang, 2002; Yang & Pan, 2004; Abad & Aggarwal, 2005) without the investment cost to reduce ordering or setup. The model by considering delivery services of logistics providers has grown rapidly and widely in recent years. Third-party logistic (3PL) is outsourced logistics company to deliver products from vendors to buyers. The review of research find the 15 articles or 38% on the inventory (Ben-Daya & Hariga, 2004; Ertogral et al., 2007; Abad & Aggarwal, 2005; Glock, 2012; Darwish, 2008; Jauhari et al., 2016; Mendoza & Ventura, 2008; Nie et al., 2006; Jauhari et al., 2009,Gurtu et al., 2015; Wangsa & Wee, 2017; Leuveano et al., 2014a; 2014b; Mukherjee et al., 2019) that considered logistics cost. Otherwise, the other 25 articles or 62% (Maddah & Jaber, 2008; Pan & Yang, 2002; Salameh & Jaber, 2000; Wee et al., 2007; Kurdhi & Doewes, 2019; Pan & Hsiao, 2001; Sarkar et al., 2015a; 2015c; Pan et al., 2004; Lo et al., 2008; Jindal & Solanki, 2016; Tiwari et al., 2018; Jauhari et al., 2011; Sarkar et al., 2015b; Vijayashree & Uthayakumar, 2015; Guchhait et al., 2020; Sarkar & Giri, 2020; Tiwari et al., 2020; Ouyang et al., 2004; Ouyang et al., 2007; Yang & Pan, 2004; Huang, 2010; Sarkar & Moon, 2014; Yoo et al., 2012) do not consider logistics cost. Subsequently, only 1 article (Wangsa & Wee, 2017) considered pick-up services while others did not. Wangsa & Wee (2017) formulated a logistics cost model by considering the additional costs proposed by logistics providers due to the pick-up and delivery service policy. The buyer will bear these costs. Furthermore, the model also considered the fuel price, fuel consumption, vehicle load capacity, distance between vendors, logistics providers, and buyers.

3.3 Research and Gap Analysis

After analyzing 40 studies, the research opportunities can be identified on the inventory models under the imperfect production process for further researches. The research gap is from recommendations of the research and the shortcomings of each protocol. This research gap is expected to provide another research gap and state-of-the-art (SOTA) so that future research can accommodate the gap to produce new inventory models. Table 3 shows the research gap and research opportunities for inventory models considering imperfect production processes. The extension models can be developed at least five inventory models to maximize total profit or minimize total cost, as shown in Table 4. From these results, this study recommends further research on improving the system on the characteristic of the study.

Table 3.
Research Gap

Researchers	Purpose/ Goal*	Type pf echelon	Demand Type	A	B	C	D	E	F	G
Salameh & Jaber (2000)	MP	Single	Deterministic	-	-	●	-	-	-	-
Pan & Hsiao (2001)	MC	Single	Probabilistic	●	●	-	-	-	-	-
Pan & Yang (2002)	MC	Two	Probabilistic	●	-	-	-	-	-	-
Ouyang et al. (2002)	MC	Single	Probabilistic	●	-	●	●	●	-	-
Ben-Daya & Hariga (2004)	MC	Two	Probabilistic	●	-	-	-	-	●	-

Researchers	Purpose/ Goal*	Type pf echelon	Demand Type	A	B	C	D	E	F	G
Pan et al. (2004)	MC	Single	Probabilistic	●	●	-	-	-	-	-
Yang & Pan (2004)	MC	Two	Deterministic	●	-	●	●	-	-	-
Ouyang et al. (2004)	MC	Two	Probabilistic	●	-	-	-	-	-	-
Abad & Aggarwal (2005)	MP	Single	Deterministic	-	-	-	-	-	●	-
Nie et al. (2006)	MC	Two	Deterministic	-	-	-	-	-	●	-
Ertogral et al. (2007)	MC	Two	Deterministic	-	-	-	-	-	●	-
Ouyang et al. (2007)	MC	Two	Probabilistic	●	-	●	●	-	-	-
Wee et al. (2007)	MP	Single	Deterministic	-	-	●	-	-	-	-
Darwish (2008)	MC	Single	Probabilistic	-	-	-	-	-	●	-
Lo et al. (2008)	MC	Single	Probabilistic	●	●	-	-	-	-	-
Maddah & Jaber (2008)	MC	Single	Deterministic	-	-	●	-	-	-	-
Mendoza & Ventura (2008)	MC	Single	Deterministic	-	-	-	-	-	●	-
Jauhari et al. (2009)	MC	Two	Probabilistic	-	-	-	-	-	●	-
Huang (2010)	MC	Single	Probabilistic	●	●	-	-	●	-	-
Jauhari et al. (2011)	MC	Two	Probabilistic	-	-	-	-	-	-	-
Glock (2012)	MC	Two	Probabilistic	●	-	-	-	●	●	-
Yoo et al. (2012)	MC	Single	Deterministic	-	-	●	●	-	-	-
Hoque (2013)	MC	Two	Deterministic	-	-	-	-	-	●	-
Leuveano et al., (2014a)	MC	Two	Deterministic	-	-	-	-	-	●	-
Leuveano et al. (2014b)	MC	Two	Deterministic	-	-	-	-	-	●	-
Sarkar & Moon (2014)	MC	Single	Probabilistic	●	-	●	●	●	-	-
Gurtu et al. (2015)	MC	Single	Deterministic	-	-	-	-	-	●	-
Sarkar et al. (2015a)	MC	Single	Probabilistic	-	-	●	●	●	-	-
Sarkar et al. (2015c)	MC	Two	Deterministic	-	-	-	-	●	-	-
Sarkar et al. (2015b)	MC	Single	Probabilistic	●	●	●	●	-	-	-
Vijayashree & Uthayakumar (2015)	MC	Two	Probabilistic	●	-	●	●	-	-	-
Jauhari et al. (2016)	MC	Two	Probabilistic	-	-	-	-	-	●	-
Jindal & Solanki (2016)	MC	Two	Probabilistic	●	●	●	●	-	-	-
Wangsa & Wee (2017)	MC	Two	Probabilistic	●	-	-	-	-	●	●
Tiwari et al. (2018)	MC	Two	Probabilistic	●	-	-	-	●	-	-
Mukherjee et al. (2019)	MC	Two	Probabilistic	-	●	●	●	-	●	-
Kurdhi & Doewes (2019)	MC	Single	Probabilistic	●	●	-	-	●	-	-
Guchhait et al. (2020)	MC	Two	Deterministic	-	-	●	●	●	-	-
Tiwari et al. (2020)	MC	Two	Probabilistic	●	●	●	-	●	-	-
Sarkar & Giri (2020)	MC	Two	Probabilistic	●	●	●	●	●	-	-

*MC= Minimize total cost, MP= Maximize total profit; A = Crashing lead time; B = Backorder Price Discount; C = Imperfect production; D = Quality Improvement; eE = Setup/ordering cost reduction; F = Logistics cost; G = Pick-up service

Table 4.
Future research

Scenario/ model	Purpose/ Goal*	Type pf echelon	Demand Type	A	B	C	D	E	F	G
1	MP/MC	Two	Probabilistic	●	-	●	-	-	●	●
2	MP/MC	Two	Probabilistic	●	-	●	●	-	●	●
3	MP/MC	Two	Probabilistic	●	●	●	●	-	●	●
4	MP/MC	Two	Probabilistic	●	-	●	●	●	●	●
5	MP/MC	Two	Probabilistic	●	●	●	●	●	●	●

*MC= Minimize total cost, MP= Maximize total profit; A = Crashing lead time; B = Backorder Price Discount; C = Imperfect production; D = Quality Improvement; eE = Setup/ordering cost reduction; F = Logistics cost; G = Pick-up service

4. Conclusions

This paper presents a bibliometric analysis of publication from 2000-2020. The analysis indicated that the leading journal is the International Journal of Production Economics (IJPE). According to the review protocol, identification and analysis were carried out on 40 literatures through a selection process. The analysis is based on a predetermined review protocol into three parts: bibliography, details of the research/ case study, and content analysis. Each section had its protocol, such as a bibliography containing the author's name, publication year and title, publication type, and publication name. The research case study section contained the year of publication, countries, institution, and name of a publication. The content analysis section included the purpose of research, type of echelon, type of demand, type of lead-time, type of backorder, type of production process, quality improvement, setup cost and/or ordering cost reduction, logistic cost, and pick-up service. Finally, this research suggests that the model can be carried out in future research, as shown in Table 4.

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