Systematic Literature Review and Improved Model for Mitigating Bullwhip Effect in Low Shelf Life Food Supply Chain

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***Abstract*—Bullwhip effect in the supply chain distribution network is a phenomenon that is highly avoided because it can lead to high operational costs. It drew the attention of researchers to examine ways to minimize the bullwhip effect. Bullwhip effect occurs because of incorrect company planning in pursuit of customer demand. Bullwhip effect occurs due to increased amplitude of demand variance towards upper supply chain level. If the product handled is a perishable product it will make the bullwhip effect more sensitive. The purpose of this systematic literature review is to map out some of the variables used in constructing mathematical models to minimize the bullwhip effect on food supply chains that have perishable product characteristics. The result of this systematic literature review is that the authors propose an appropriate optimization model that will be applied in the food supply chain sales on the train in Indonesian railways in the next research.**

Keywords-bullwhip effect; perishable product;; Systematic Literature Review (SLR)

I. INTRODUCTION

Supply chain plays an important role in product distribution process. Proper distribution planning is needed to meet customer needs with low logistics costs. Errors in the design of the distribution process will cause the phenomenon of bullwhip effect in a distribution chain. Bullwhip effect occurs because of the basic concept of inventory at each level distribution. Bullwhip effect will cause the high cost of logistics that must be issued by a company in doing product distribution. In general, the cause of the bullwhip effect is divided into five classifications as shown in Figure 1 [1].

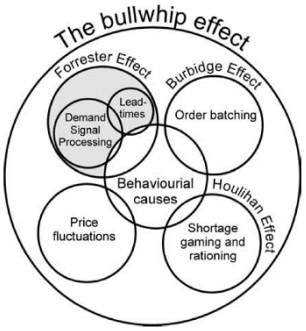

Figure 1. Cause of bullwhip effect [1]

The cost of the bullwhip effect will increase in the supply chain if the product handled is a product that has a low shelf life. This is because if there is a slight amplification of demand to the upper supply chain level, not just the cost of the store is enlarged, but the cost of product damage also enlarged due to rotten products. One type of this product is food. Food supply chain requires special attention in planning the distribution process. Food supply chain has unique characteristics because it is a perishable product, a varied demand, the influence of discount factors and demands to meet customer demand.

We are interested to review the optimization in the field of food supply chain. The distribution network to be studied is the distribution of food supply chain on sales on the train in railway in Indonesia. In addition to the unique characteristics of the food supply chain, some of the reasons for our study of these areas are:

1. The number of customers who use the rail services is increasing every year.
2. The sale of food on trains has an uncertain lead time characteristic in refilling the food. Refueling should only be done on a particular station. In the event of a train delay to a particular station, the lead time for refilling the food will be long.
3. Erratic demand of food supply chain, because it depends on the time of departure of trains and customer habits.

This literature review aims to collect and review references on mathematical modeling optimization in the supply chain to minimize the bullwhip effect. We will use this literature review as a first step to conduct research in minimizing the bullwhip effect with the characteristics of products that have low shelf life, that is, food supply chain.

II. RESEARCH METHOD

A. Systematic Literature Review (SLR) Overview

A Systematic Literature Review (SLR) is a literature review method that aims to address a problem by identifying, evaluating, integrating all relevant findings, and interpreting research on research topics to answer research questions based on the stages used in SLR [2], [3], [4]. The process of addressing the problem aims to identify the relationships and gaps in the existing literature. The process of addressing the problem aims to identify relationships and gaps in the

existing literature. The identification process is used to describe directions for future research, because this identification process consists of the process of formulating a general statement or an overarching conceptualization, commenting on, evaluating, extending, or developing theory from existing literature [3]. There are 5 steps used to describe the procedure explicit on the SLR method (See Table I.) [5].

TABLE I. STEP OF SLR METHOD

Step 1	Research questions
Step 2	Locating sources and relevant articles
Step 3	Selection and appraisal criteria
Step 4	Analysis and synthesis
Step 5	Dissemination of review findings

B. Step 1: Research Questions

A good systematic review that is the answer of a designing research question. The research question is the questions that contain the logical context used as the basis for the formulation of the discussion on the research. The structured question part for designing the research are Population, Intervention, Outcomes, Study Design (See Table II.) [6]. In Table III. shows the research questions that were made based on the structured question. There are two research questions concerning the trend of research and the variables used in most studies.

TABLE II. STRUCTURED QUESTION

Population	Bullwhip effect in supply chain
Intervention	The cause of bullwhip, bullwhip variables, model.
Outcomes	The development of mathematical models to mitigating of bullwhip effect.
Study Design	Perishable Product, Studied in industrial distribution network (≥ 2 echelon number), Future research, study case at sales on the railway in Indonesia.

TABLE III. THE RESEARCH QUESTION

ID	Research Question	Purpose
RQ1	How is the trend about mitigating of bullwhip effect research?	Identification the trend of mitigating bullwhip effect research
RQ2	What variables can affect the bullwhip effect?	Identification of variables can affect the bullwhip effect.

C. Step 2: Locating Sources and Relevant Articles

A location source is a location used to find relevant references in designing SLR. Search relevant references using the online database by entering keyword "Bullwhip Effect". The results of the article search on each online database (See TABLE IV.). After the search results, the next step is to select articles based on required criteria.

D. Step 3: Selection and Appraisal Criteria

Selection and appraisal criteria are used to select relevant articles. the first step taken in Selection and Appraisal Criteria is to determine inclusion and exclusion criteria. Inclusion criteria are criteria or standards set on a subject of research to be studied. While the exclusion criteria are criteria or standards that are not possible to be included on a particular subject in the study will be studied (See Table V.). Figure 2 describes the flowchart selection process which is identification, screening, eligibility, included. Based on the flowchart selecting the proses, then obtained articles or journals that are used as a reference (See Table VI.).

TABLE IV. NUMBER OF ARTICLES IN ONLINE DATABASE

Taylor & Francis (http://www.tandfonline.com)	755 articles
Science Direct (http://www.sciencedirect.com/)	1322 articles
IEEE Explore (http://ieeexplore.ieee.org/)	235 articles
Informs (https://pubsonline.informs.org/)	183 articles
Springer (https://link.springer.com/)	1437 articles

TABLE V. INCLUSION AND EXCLUSION

Inclusion Criteria	Exclusion Criteria
Published time 2007-2018	Published time under 2007
Articles focused on mathematical models of bullwhip effect (mitigating /reduce/ minimize bullwhip effect).	Articles focused on summarizes the existing research work, roadmap or survey.
Two or more of echelon numbers (≥ 2 echelons)	Less than two echelon numbers (< 2 echelons)
Perishable Product & Non-perishable product	-

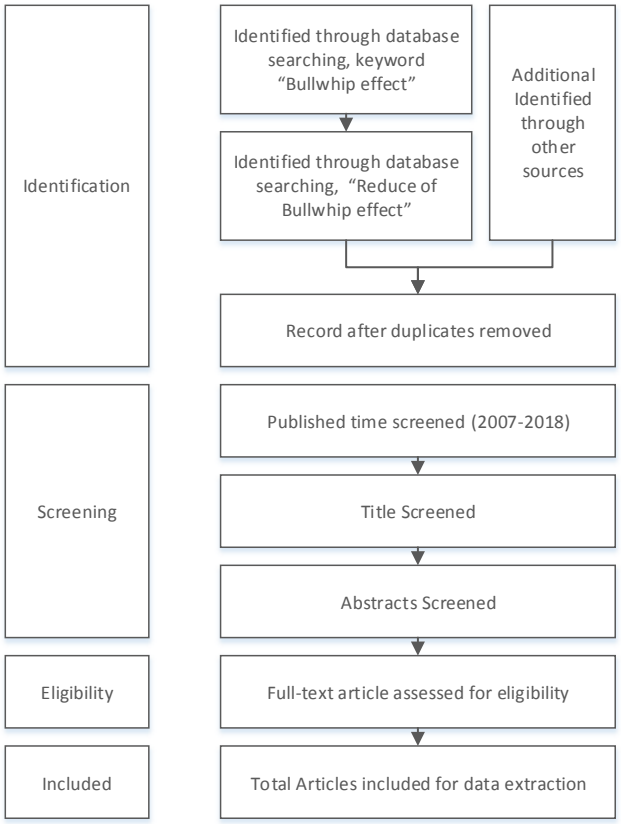

Figure 2. Flowchart selection process

TABLE VI. THE RESEARCH QUESTION LIST OF PRIMARY STUDIES

	a	b	c	d	e	f
Bullwhip effect	755	1322	235	183	1437	
Reduce Bullwhip Effect	681	1168	94	166	1144	
2007 until 2018	538	992	78	101	885	
Related journal	4	16	9	4	4	1

Information:
(a) Taylor & Francis, (b) Science Direct, (c) IEEE Explore, (d) Informs, (e) Springer, (f)And other Journals.

E. *Step 4: Analysis and Synthesis*

Analysis and synthesis is used to analyze the data and synthesize it into meaningful themes. It involves isolating relevant data, tabulation, search patterns, and incorporating common ideas [2].

F. *Step 5: Dissemination of Review Findings*

The dissemination of review findings is the final step in the SLR. This step aims to plan, direct, and manage any information received from the SLR performed.

III. RESEARCH METHOD RESULT AND DISCUSION

A. *The Trend of Mitigating Bullwhip Effect Research*

The number of studies discussing the bullwhip effect in the online data base consists of 3932 articles (See Figure 3). in the online database shows the number of articles discussing the bullwhip effect from 2007 to 2018. the number of articles shows research on bullwhip effect from year to year has increased. in 2018 there are 66 articles that discuss about reduce bullwhip effect, thus allowing author to do research on the topic of bullwhip effect (See Figure 4).

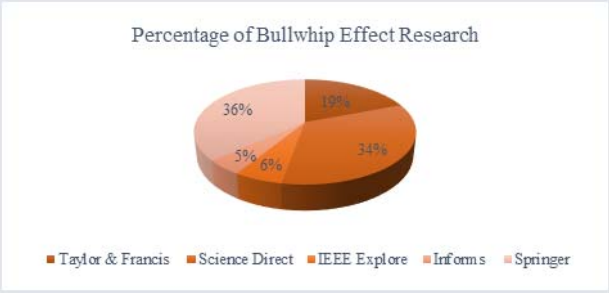

Figure 3. Percentage of bullwhip effect research

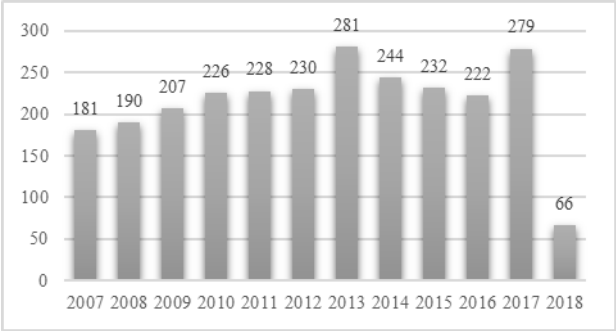

Figure 4. Number of bullwhip effect articles published from 2007- 2018

The authors analyzed 38 relevant journals discussing the bullwhip effect, of the 38 journals indicating 88.58% (31 journals) were non-perishable products, while 18.42% (7 journals) were perishable products [7]. This suggests that to develop modeling for perishable products can be done.

B. *Identify Variables of Bullwhip Effect*

In previous research the researcher has done an analysis of the variable causes bullwhip effect [7]. Variables that cause the occurrence of bullwhip effect of 17 variables (See Figure 5). These variables will increase the value of the bullwhip effect and lower the service level on a company. The authors take a study case on the sale of food on the train. The company's problem of selling perishable products, where the product has a short expiry date, often called shelf life. Shelf life is divided into two, namely long shelf life and low shelf life [8]. The existence of shelf life can also affect the demand and lead time. The shorter the life of a product, will affect the supply for the future. If the company is wrong in forecasting the demand then the level of service will decrease. This causes an erotic demand.

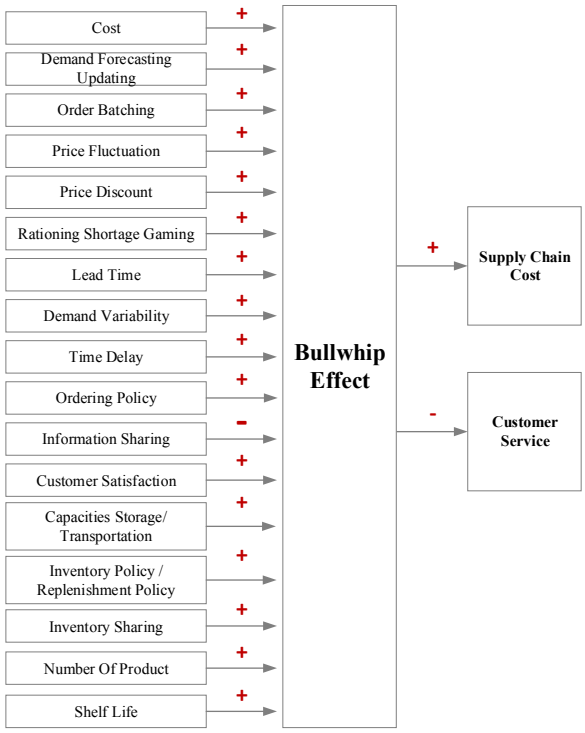

Figure 5. The variable can effect of bullwhip effect [7]

IV. MATHEMATICAL MODEL

In a previous study [7], explaining the systematic literature review that discusses the variables that affect the occurrence of bullwhip effect on the perishable product. In the study, the researchers will measure performance on product distribution activities using Supply Chain Operations Reference (SCOR) model. Performance measurement using bullwhip effect parameter exist in distribution activity. The parameter that has the lowest value

will be used as a variable used to consider calculations minimizing the bullwhip effect. In this study, researchers used some references similar to previous research. However, for future research on this systematic literature review, researchers directly consider the variables that influence the occurrence of bullwhip effect on the sales activity of food on the train.

In this section we will reviewing mathematical modeling which used to minimizing bullwhip effect in food supply chain which have specific characteristics, such as, low shelf life (perishable product), erratic demand and uncertainty lead time. Basically, we used previous model proposed by [9]. Some additional variables that are considered for further research are as follows:

1. Low Shelf Live (perishable product).
   This variable serves to define the number of damaged or rotten products caused by unsold products in a certain time unit.
2. Erratic Demand
   The food demand on the train is indeterminate, because it is influenced by departure hours and customer behavior. To refine the pre-existing model, we use Autogressive Moving Average (ARMA) which has been developed by [10].

The model we propose will be verified and validated in our future research.

A. Objective Function

The purpose function of the bullwhip effect is the combined purpose function in accordance with the model developed by [9]. The combined basic functions include basic inventory functions and basic transport functions. In this section, we add new variable which used to implemented in the food supply chain sales on the train in Indonesia, that is, minimize the number of rotten products caused by the bullwhip effect. To perform the model linearization process, a new limiting function is added. The integration of the objective function can be seen in Equation 1. The objective function consists of two terms, the first term consists of ordering costs, holding costs and lost sale costs. while the second term consists of holding in transit costs and the transportation costs. H / T multiplying factor represents the number of times that the cycle of operation mode repeats throughout the time horizon.

$$Minimasi\ total\ cost = \left(\sum_{i\in P}\sum_{j\in I}\sum_{t\in T}\left(OC_{ij}\times BV1_{ijt} + HOC_{ij}\times FI_{ijt} + LSC_{ijt}\times LS_{ijt}\right) + \sum_{i\in P}\sum_{j\in I}\sum_{k\in I}\sum_{t\in T}\left(\left(HTC_{ijk}\times LTT_{jk} + TRC_{ijk}\right)\times SQ_{ikjkt}\right) \right) \times H/T \quad (1)$$

B. Constraint

Inventory Constraint

Inventory plays an important role in multi echelon distribution. Each supply chain level has a supply in varying amounts according to the policy enacted. One of the company's steps to maintain lever inventory is to do lateral transshipment or often called inventory sharing. Inventory sharing allows the exchange of inventory among distributors in one level or the same echelon [11]. We use two type inventory constrains in [11]:

- Inventory in main production (B1), see Equation 2. The amount of inventory in echelon 1 (the production of fresh food) is considered in the research that will be done in the next research. Notation B1 is used to calculate the bullwhip value between echelon 1 with echelon 2 (regional warehouse in each distribution area). The lead time between echelon 1 to echelon 2 is the length of time the train travels from the production site to the regional warehouse. The product perishable rate on echelon 1 to echelon 2 is still very low, as new products are produced on the same day as the distribution time.
- Inventory in the train (B2), see Equation 3. The fundamental difference between the determination of the bullwhip effect on echelon 1 to echelon 2 and on echelon 2 to echelon 3 (shown in equation 2 and equation 3) is the value of lead time and the more varied types of demand. The lead time value is not fixed, as it is influenced by rail scheduling. While demand, coming from railway consumers, is erratic. Demand is also influenced by the time trend type, for example, during prime-time hours (breakfast, lunch and dinner, demand will be high). However, in non-prime time hours, demand will weaken and improper distribution planning will lead to bullwhip caused by the quality of the product will worsen and stale.

$$B_1 = \frac{\mathrm{var}(q_{t,1})}{\mathrm{var}(D_1)} = \frac{1}{(1-\lambda)^2}\left[1+\left(\frac{2L_1}{p}+\frac{2L_1^2}{p^2}\right)(1-\rho^p)\right]+\frac{z_1^2}{(1-\lambda)^2}\mathrm{var}(\hat{\sigma}_{t,1}^{I_{t1}}-\hat{\sigma}_{t-1,1}^{I_{t1}}). \quad (2)$$

$$B_2 = \frac{\mathrm{var}(q_{t,2})}{\mathrm{var}(D_2)} = \left[1+\left(\frac{2L_2}{p}+\frac{2L_2^2}{p^2}\right)(1-\rho^p)\right]+z_2^2\mathrm{var}(\hat{\sigma}_{t,2}^{L_2}-\hat{\sigma}_{t-1,2}^{L_2}) - \frac{\lambda^2}{(1-\lambda)^2}\left[1+\left(\frac{2L_1}{p}+\frac{2L_1^2}{p^2}\right)(1-\rho^p)\right]\frac{\mathrm{var}(D_1)}{\mathrm{var}(D_2)} - \frac{z_1^2\lambda^2}{(1-\lambda)^2}\frac{\mathrm{var}(\hat{\sigma}_{t,2}^{L_2}-\hat{\sigma}_{t-1,2}^{L_2})}{\mathrm{var}(D_2)}. \quad (3)$$

Storage Capacities and Safety Stock

Supply chain structure in sales on train in Indonesian railway has three echelon distribution system, i.e.:

- First echelon is the main warehouse at the food production.
- The second echelon is sub-warehouse in each station. Only certain stations contain sub-warehouses where a train replenishes food.
- The third echelon is the storage in each of train. The type of storage is a freezer (to handle frozen food) and some of compartments (to handle fresh food).

V. CONCLUSION

The purpose of this systematic literature review is to map out some of the variables used in constructing mathematical models to minimize the bullwhip effect on food supply chains that have perishable product characteristics. The variable considered in reducing the bullwhip effect is shelf life. In addition to the unique characteristics of the food supply chain, some of the reasons for this study are:

1. The number of customers who use the rail services is increasing every year.
2. The sale of food on trains has an uncertain lead time characteristic in refilling the food. Refueling should only be done on a particular station. In the event of a train delay to a particular station, the lead time for refilling the food will be long.
3. Erratic demand of food supply chain, because it depends on the time of departure of trains and customer habits.

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