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ITS Institut Teknologi Sepuluh Nopember

Coventry University

Message from the conference chairs

It is a great pleasure to welcome you to the 8th International Conference on Operations and Supply Chain Management (OSCM 2018). Held for the first time in 2005 by the Department of Industrial Engineering at Institut Teknologi Sepuluh Nopember, Indonesia, OSCM conference has grown to be one of the important international conferences in supply chain and operations management, especially in Asia, Pacific and the Far East.

OSCM 2018 is the first OSCM conference to be held outside Asia and is hosted by the Cranfield University's Centre for Logistics and Supply Chain Management. The theme of the conference is "Trends and developments in supply chain management and their implications for industry and academia". OSCM 2018 continues the OSCM long-standing tradition of wide international participation and presentation of high-quality papers in major areas of operations' management and logistics and supply chain management, including operations/supply chain strategy, purchasing/supply management, inventory planning and control, demand management, warehousing and material handling, transportation/distribution management, production planning and scheduling; as well as emerging areas of product-service systems, sustainable production and consumption, logistics, closed-loop supply chain, digital supply chain and Industry 4.0, etc.

Selected, suitable papers will be published in our official journal, *Operations and Supply Chain Management* and an edited book indexed by Scopus, as well as in several journal special issues, for instance, *World Review of Intermodal Transportation* (Scopus) and *International Journal of Intelligent Enterprise*, covering contemporary issues of supply chain relocation, intermodal transportation and sustainable supply chain management and circular economy.

We are honoured to have two excellent keynote speakers: Cranfield's Emeritus Professor Martin Christopher and Dr Phil Bamforth from Rolls-Royce, who will share their decades of experience and discuss future trends in supply chain management and their impacts on high-value manufacturing. We encourage you to take full advantage from the academic and industrial network offered by the conference, as well as the factory tour and a visit to the nearby city of Oxford.

The successful organisation of OSCM 2018 required dedication and time of the reviewers, volunteers, local organisers and admin support at Cranfield and Coventry. Our special thanks also go to the ITS team. Without their support, we would not have been able to organise this conference.

Finally, we hope that you will find the conference valuable, enjoyable and thought provoking. See you again at the next OSCM conferences.

About the OSCM conference

The OSCM Conference was first held in Bali in December 2005, hosted by the Department of Industrial Engineering, Institut Teknologi Sepuluh Nopember (ITS), Indonesia. Subsequent OSCM conferences were successfully held in various locations: Bangkok (2007), Malaysia (2009), Maldives (2011), New Delhi (2013), Bali (2014), Phuket (2016), and now in Cranfield (2018).

Since 2008, we have published the *Operations and Supply Chain Management: An International Journal*, as the main outlet of the extended papers presented at OSCM conferences. The journal publishes high quality refereed articles in the field of operations and supply chain management. The journal is indexed in Scopus and Web of Science (Emerging Science Citation Index, by Clarivate Analytics).

We invite original contributions that present modelling, empirical, review, and conceptual works.

Keynote speakers

Dr Martin Christopher

Emeritus Professor of Marketing and Logistics
Cranfield School of Management

Topic: Building the supply chain of the future

New competitive realities are reshaping supply chains in terms of complexity. This keynote speech reflects on the need for structural flexibility and presents future supply chain configurations.

Dr Phil Bamforth

Global Chief of Manufacturing Engineering Product Introduction
Rolls-Royce

Topic: Digital thread in high-value manufacturing – cutting through the hype

The digital thread and tools such as model-based definition are widely discussed in literature with significant benefits stated. However, the reality can be far from the hype. This keynote speech will discuss the benefits and challenges of deploying model-based definitions across a global enterprise and how Rolls-Royce is taking a collaborative approach with its supplier base to develop the strategy, roadmap and solutions to digitising the engineering value stream.

The committee

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General Co-Chair	**Hendrik Reefke**, Cranfield University, UK
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Yahaya Yusuf, University of Central Lancashire, UK
Suhaiza Zailani, University of Malaya, Malaysia
Vipul Jain, Victoria University of Wellington, New Zealand

LIST OF PAPERS

A GENETIC ALGORITHM APPROACH FOR DYNAMIC SUPPLIER SELECTION

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ABSTRACT

Supplier selection has a great impact on supply chain management. This decision considers many factors such as price, order quantity, quality, and delivery performance. We address a dynamic supplier selection problem (DSSP) which a buyer should procure multiple product from multiple supplier in multiple periods. Furthermore, transportation cost has significant impact in the procurement decision. However, only a few researchers consider transportation cost in their model. This paper proposes a dynamic supplier selection problem considering truckload shipping. A mixed integer non-linear programming (MINLP) model is developed to solve dynamic supplier selection problem. The purpose of model is to assign the best supplier that will be allocated products and to determine the right time to order that can minimize total procurement cost. In addition, constraints such as suppliers' capacity, truck capacity, inventory balance, service level, and buyer storage are taken into consideration in the model. Due to the complexity of the problem, the formulated problem is NP-hard in nature so a genetic algorithm (GA) is presented to solve dynamic supplier selection problem. Finally numerical example has been solved by the proposed GA and the classical method using Lingo 16. The results illustrate an understandable slight errors in total cost when GA is compared to commonly used classical method.

Keywords: dynamic supplier selection problem, mixed integer non-linear programming, genetic algorithm, truckload shipping, procurement

1. INTRODUCTION

Supply chain management relate to suppliers, manufacturers, distribution centers, and retailers to guarantee the efficient flow of raw materials, work-in-process inventory, finished products, sales information, and funds among different parties to maximize total supply chain performance (Chopra and Meindl, 2010). Most manufacturers have outsourced raw materials, unfinished/semi-finished parts, final products and services to support their production. One of the important decisions to optimize the performance of supply chain is supplier selection and order allocation to the selected suppliers (Moghaddam, 2015).

Dynamic supplier selection problem (DSSP) occurs when an organization may have to choose different suppliers from period to period. This may be due to the capacity restrictions where one supplier would not be able to satisfy the overall demand or there are variations in the supplier performance, so the best supplier in a certain period may not be the best in other periods (Wicaksono, in press). DSSP is also more appropriate when the buyer is in need of multiple products and each product may be best sourced from a certain supplier (Ware, Singh and Banwet, 2014).

In supplier selection problem, both purchasing cost and transportation cost are the key elements that build total procurement costs (Mansini, Savelsbergh and Tocchella, 2012). Considering transportation costs in dynamic supplier selection problem becomes essential to improve the efficiency of the supply chain, because splitting orders across multiple suppliers will lead to smaller transportation quantities which will likely imply larger transportation cost (Aguezzoul and Ladet, 2007). There are three common modes of freight transportation namely TL, LTL, and small packages. The transportation cost for TL is independent of the size of the shipment for a given truck (Pazhani, Ventura and Mendoza, 2016).

In this paper, we have study a mixed integer liner programming (MILP) model for dynamic supplier selection problem to determine the optimal order allocation for multiple products among multiple suppliers in multiple periods considering full truckload shipping (FTL). Wicaksono et al. (2016) have proposed DSSP model and then we developed the solution procedure to solve the problem. We have shown that the formulated dynamic supplier selection problem is NP-hard in nature, and genetic algorithm (GA) is used to solve it. The reason of using GA is that it has been proven to excel in solving combinatorial optimization problems in comparison to exact method (Meena and Sarmah, 2013).

The rest of the paper is structured as follows. Section 2 reviews the literature of dynamic supplier selection problem (DSSP) and identifies the knowledge gaps. Section 3 discusses the model of dynamic supplier selection problem (DSSP). Section 4 presents genetic algorithm procedure. Section 5 applies the model by numerical example. Section 6 contains conclusion.

2. LITERATURE REVIEW

The supplier selection problem has been widely studied by many researchers. Various supplier selection models and solutions have been published over time. The operations research community is becoming more active in supplier selection. Research on combinatorial auctions where a buyer can choose a collection of items under different preferences and supplier conditions is a promising and challenging research area (Aissaoui, Haouari and Hassini, 2007). Research on mathematical approaches clearly dominates the body of supplier selection (Wetzstein *et al.*, 2016).

Although transportation costs form a substantial part of the total procurement cost, many researchers often ignored them in supplier selection problem. Aguezzoul and Ladet (2007) proposed a model that simultaneously determines the optimal number of suppliers to employ and the order quantities to allocate to them, taking into account the transportation. Integer programming based heuristics that are capable of producing high quality solutions quickly have been developed to solve the Supplier Selection Problem with Quantity Discounts and Truckload Shipping (Mansini, Savelsbergh and Tocchella, 2012).

Some of the approaches summarized in these reviews are based on mathematical models that integrate the selection of suppliers and lot size for the selected suppliers using Integer linear programming (ILP), mixed integer non-linear programming (MINLP) and multi-objective programming. Hamdan and Cheaitou (2017) proposed a multi-period green supplier selection and order allocation problem with all unit quantity discounts, in which the availability of suppliers differs from one period to another. Mixed integer linear programming (MILP) model proposed to solve the dynamic lot sizing problem with supplier selection, backlogging and quantity discounts (Ghaniabadi and Mazinani, 2017). A multi objective integer linear program was proposed to integrate supplier selection and order allocation with market demand in a supply chain (Trivedi *et al.*, 2017).

Dynamic Supplier Selection Problem (DSSP) is the supplier selection for multiple periods, multiple products, and multiple suppliers. The difference between DSSP and Traditional Supplier Selection Problem (TSSP) is that TSSP has a condition where all the suppliers can fully meet the organization's requests in terms of quantity, quality, delivery and so on (Ware, Singh and Banwet, 2014). In TSSP, Choudhary and Shankar (2014) proposed a multi objective integer linear programming model for joint decision making of inventory lot sizing, supplier selection and carrier selection problem. . While in DSSP, a mathematical model based on MINLP was proposed to solve the DSSP under a two-echelon supply network (TESN) (Ahmad and Mondal, 2016).

We have shown here that supplier selection problem is NP-hard in nature, and some researchers using heuristic method to solve the problem. A multi objective supplier selection model under stochastic demand conditions is developed using GA to obtain the result (Liao and Rittscher, 2007). Rezaei and Davoodi (2011) proposed two multi-objective mixed integer non-linear models for multi-period lot-sizing problems involving multiple products and multiple suppliers. They used GA to solve the problem.

Table 1 Contribution of the proposed study based on different approaches

Paper	Product item		Supplier		Time period		Type of supplier selection	Freight	Methodology	Solution tool	Late delivery
	Single	Multi	Single	Multi	Single	Multi					
Liao & Rittscher (2007)	√	--	--	√	--	√	TSSP	--	MOP	GA	√
Aguezzoul & Ladet (2007)	√	--	--	√	√	--	TSSP	--	Non linear MOP	Math lab	--
Rezaei & Davoodi (2011)	--	√	--	√	--	√	DSSP	√	MOMINLP	GA	--
Choudhary & Shankar (2011)	√	--	--	√	--	√	TSSP	--	ILP	Classical	√
Mansini et al. (2012)	--	√	--	√	√	--	TSSP	√	Integer Program	Heuristic	--
Choudhary & Shankar (2013)	√	--	--	√	--	√	TSSP	--	ILP	Classical	√
Choudhary & Shankar (2014)	√	--	--	√	--	√	TSSP	--	MOILP	Classical	√
Ware et al. (2014)	--	√	--	√	--	√	DSSP	--	MINLP	Classical	√
Ahmad & Mondal, 2016	--	√	--	√	--	√	DSSP	--	MINLP	Classical	√
Ghaniabadi and Mazinani (2017)	√	--	--	√	--	√	TSSP	--	MILP	Classical	--
Hamdan and Cheaitou (2017)	√	--	--	√	--	√	TSSP	--	MOMILP	Branch and cut	--
Trivedi *et al*. (2017)	--	√	--	√	√	--	TSSP	--	MOMILP	Classical	--
This paper	--	√	--	√	--	√	DSSP	√	MILP	GA	√

Table 1 shows the position of proposed study among related publications. It summarizes the literature of the supplier selection problem which considers transportation cost in the model with regard to number of product items (single/multiple), number of supplier (single/multiple), number of time periods (single/multiple), type of supplier selection (TSSP/DSSP), freight transportation, methodology, solution tool and and late delivery condideration for supply chain disruption. From table 1 we may infer that among publications which consider freight transportation, none used MILP approach to model dynamic supplier selection problem for multiple products, multipe suppliers and multiple periods and solved the model using genetic algorithm (GA) considering supply chain disruption.

3. MODEL

The problem considered here is described as follows: a buyer procures multiple products from multiple suppliers over multiple periods considering full truck load (FTL) shipment. There is a single buyer that will procure multiple products from multiple suppliers for multiple periods, which is known in the literature as the DSSP. The mathematical model of the DSSP can be transformed equivalently into the general linear optimization form as follows:

3.1 Model assumption

There are some assumptions for DSSP model:

- The products are packed in boxes so that their dimensions are homogeneous.
- Suppliers have limited production capacity.
- The buyer's storage capacity is limited.
- Shortages are permitted and charged for through a shortage cost, and completely backlogged.
- Inventory holding cost is charged at the end of a period.
- An ordering cost is charged for each order placed with the supplier.
- A contract cost is charged to establish a new relationship with a supplier.

3.2 Model parameters and decision variables

Indices

T	Set of time periods; 1,2,...,t
S	Set of suppliers; 1,2,...,s
P	Set of products; 1,2,...,p

Parameters

UP_{sp}	:	Unit price of product p supplied by supplier s
TC_s	:	FTL cost from supplier s to the buyer
NC_s	:	Contract cost of new supplier s
SOC_P	:	Shortage cost per unit of product p
C	:	FTL capacity
D_{tp}	:	Demand of product p for time period t
SC_{sp}	:	Supplier capacity of product p for time period t
l_{sp}	:	Percentage of product delivered late by supplier s
d_{sp}	:	Percentage of rejected product delivered by supplier s
P_p^l	:	Penalty cost for late delivery

P_p^d : Penalty cost for defected product

O_s : Cost of ordering for a purchase quantity to supplier s

H_p : Holding cost of product p for one product

Q_{tp} : Buyer's storage capacity for product p in period t

ϕ : Buyer's service level requirement in period t so (1-ϕ) is the proportion of buyer's demand that are not met by supplier in period t

M : Big number

Decision variables

X_{tsp} : Number of product p supplied by supplier s for time period t

S_{ts} : Frequency of truck delivered product from supplier s in period t

Z_{ts} : Binary variable (1 if an order is placed to supplier s in period t and hence order cost is charged, 0 otherwise)

W_s : Binary variable for choosing new supplier (1 if a new contract is established with supplier s, 0 otherwise)

i_{tp}^{+} : Inventory of product p in period t

i_{tp}^{-} : Shortage of product p in period t

3.3 Mathematical Formulation

$$\min Z = \left[UP_{sp} + P_p^d * d_{sp} + P_p^l * l_{sp}, \quad TC_s, \quad O_s, \quad NC_s, \quad h_p, \quad SOC_p \right] \begin{bmatrix} X_{tsp} \\ S_{ts} \\ Z_{ts} \\ W_s \\ i_{tp}^{+} \\ i_{tp}^{-} \end{bmatrix} = c'x \tag{1}$$

where

$$x = \left[X_{tsp}, S_{ts}, Z_{ts}, W_s, i_{tp}^{+}, i_{tp}^{-} \right]' ,$$

$$c = \left[UP_{sp} + P_p^d * d_{sp} + P_p^l * l_{sp}, \quad TC_s, \quad O_s, \quad NC_s, \quad h_p, \quad SOC_p \right]',$$

subject to:

$$t = 1: \sum_{s=1}^{S} \left(1 - l_{tsp} - d_{tsp}\right) X_{tsp} - i_{tp}^{+} + i_{tp}^{-} \geq D_{tp}, \forall p;$$

$$\Leftrightarrow \begin{bmatrix} \underbrace{1-l(0p+1)-d(0p+1),0_{1,p-1},1-l(1p+1)-d(1p+1),0_{1,p-1},\ldots,1-l((s-1)p+1)-d((s-1)p+1),0_{1,p-1}}_{s\text{ times}}, \\ 0_{1,tsp-sp},0_{1,t\times s+t\times s+s},-1,0_{t\times p-1},1,0_{t\times p-1}; \\ \underbrace{0,1-l(2)-d(2),0_{1,p-2},0,1-l(p+2)-d(p+2),0_{1,p-2},\ldots,0,1-l(ps-p+1)-d(ps-p+1),0_{1,p-2}}_{s\text{ times}}, \\ 0_{1,tsp-sp},0_{1,t\times s+t\times s+s},0,-1,0_{t\times p-2},0,1,0_{t\times p-2}; \\ \vdots \\ \underbrace{\underbrace{0,0,\ldots,1-l(p)-d(p)}_{p\text{ times}},\underbrace{0,0,\ldots,1-l(2p)-d(2p)}_{p\text{ times}},\ldots,0,0,\ldots,1-l(sp)-d(sp)}_{s\text{ times}}, \\ 0_{1,tsp-sp},,0_{1,t\times s+t\times s+s},\underbrace{0,0,\ldots,-1,0_{tp-tp}}_{t\times p},,\underbrace{0,0,\ldots,1,0_{tp-tp}}_{t\times p} \end{bmatrix} \begin{bmatrix} X_{tsp} \\ S_{ts} \\ Z_{ts} \\ W_s \\ i_{tp}^{+} \\ i_{tp}^{-} \end{bmatrix} \geq D_{tp}; \quad (2)$$

$$t>1:\ \sum_{s=1}^{S} l_{(t-1)sp} X_{(t-1)sp} + \sum_{s=1}^{S}\left(1-l_{tsp}-d_{tsp}\right) X_{tsp} + i_{(t-1)p}^{+} - i_{tp}^{+} - i_{(t-1)p}^{-} + i_{tp}^{-} \geq D_{tp};$$

$$\Leftrightarrow t>1:$$

$$\begin{bmatrix} \underbrace{l(1),1-l(2)-d(2),0_{1,p-2},l(p+1),(1-l(p+2)-d(p+2),0_{1,p-2},\ldots,l((s-1)p+1),1-l(ps-p+2)-d(ps-p+2),0_{1,p-2}}_{s\text{ times}} \\ ,0_{1,tsp-sp},0_{1,t\times s+t\times s+s},1,0_{1,p-1},-1,0_{1,p-1},0_{t\times p-2p},-1,0_{1,p-1},1,0_{1,p-1},0_{t\times p-2p}; \\ \underbrace{0,l(2),1-l(3)-d(3),0_{1,p-3},l(p+2),(1-l(p+3)-d(p+3),0_{1,p-3},\ldots,l(ps-p+2),1-l(ps-p+3)-d(ps-p+3),0_{1,p-3}}_{s\text{ times}} \\ ,0_{1,tsp-sp},0_{1,t\times s+t\times s+s},0,1,0_{1,p-2},-1,0_{1,p-2},0_{t\times p-2p},0,-1,0_{1,p-2},1,0_{1,p-2},0_{t\times p-3p}; \\ \underbrace{0,0,l(3),1-l(4)-d(4),0_{1,p-4},l(p+3),(1-l(p+4)-d(p+4),0_{1,p-4},\ldots,l(ps-p+3),1-l(ps-p+4)-d(ps-p+4),0_{1,p-4}}_{s\text{ times}} \\ ,0_{1,tsp-sp},0_{1,t\times s+t\times s+s},0,0,1,0_{1,p-3},-1,0_{1,p-3},0_{t\times p-2p},0,0,-1,0_{1,p-3},1,0_{1,p-3},0_{t\times p-4p}; \\ \vdots \\ \underbrace{0,0,\ldots,l(p-1),1-l(p)-d(p),0_{1,p-p},l(2p-1),(1-l(2p)-d(2p),0_{1,p-p},\ldots,l(ps-1),1-l(ps)-d(ps),0_{1,p-p}}_{s\text{ times}} \\ ,0_{1,tsp-sp},0_{1,t\times s+t\times s+s},0,\ldots,0,1,0_{1,p-p},-1,0_{1,p-p},0_{t\times p-2p},0,\ldots,0,-1,0_{1,p-p},1,0_{1,p-p},0_{t\times p-tp} \end{bmatrix} \begin{bmatrix} X_{tsp} \\ S_{ts} \\ Z_{ts} \\ W_s \\ i_{tp}^{+} \\ i_{tp}^{-} \end{bmatrix} \geq D_{tp}; \quad (3)$$

$$-\sum_{s=1}^{S} X_{tsp} \leq -D_{tp} \Leftrightarrow \left(\begin{matrix} \begin{bmatrix} \underbrace{1,0_{1,p-1},1,0_{1,p-1},\ldots}_{s\text{ times}},0_{1,tsp-sp},0_{1,t\times s+t\times s+s+t\times p+t\times p}; \\ \underbrace{0,1,0_{1,p-2},0,1,0_{1,p-2},\ldots}_{s\text{ times}},0_{1,tsp-sp},0_{1,t\times s+t\times s+s+t\times p+t\times p}; \\ \vdots \\ \underbrace{\underbrace{0,0,\ldots,1}_{p\text{ times}},0,\ldots,1}_{s\text{ times}},0_{1,tsp-sp},0_{1,t\times s+t\times s+s+t\times p+t\times p}; \end{bmatrix}; \\ \begin{bmatrix} 0_{1,sp},\underbrace{1,0_{1,p-1},1,0_{1,p-1},\ldots}_{s\text{ times}},0_{1,tsp-2sp},0_{1,t\times s+t\times s+s+t\times p+t\times p}; \\ 0_{1,sp},\underbrace{0,1,0_{1,p-2},0,1,0_{1,p-2},\ldots}_{s\text{ times}},0_{1,tsp-2sp},0_{1,t\times s+t\times s+s+t\times p+t\times p}; \\ \vdots \\ 0_{1,sp},\underbrace{\underbrace{0,0,\ldots,1}_{p\text{ times}},0,\ldots,1}_{s\text{ times}},0_{1,tsp-2sp},0_{1,t\times s+t\times s+s+t\times p+t\times p}; \end{bmatrix}; \\ \vdots \end{matrix} \right)_{t\text{ times}} \begin{bmatrix} X_{tsp} \\ S_{ts} \\ Z_{ts} \\ W_s \\ i_{tp}^{+} \\ i_{tp}^{-} \end{bmatrix} \leq -\sum_{t=1}^{T} D_{tp}; \quad (4)$$

$$\left[\frac{\sum_{p=1}^{P} X_{tsp}}{C}\right]\begin{bmatrix} X_{tsp} \\ S_{ts} \\ Z_{ts} \\ W_s \\ i_{tp}^{+} \\ i_{tp}^{-} \end{bmatrix} \le S_{ts}$$

$$\Leftrightarrow \begin{bmatrix} 1_{1,p}, 0_{1,(t\times s\times p)-p}, -C, 0_{1,(t\times s)+(t\times s)+s+(t\times p)+(t\times p)-1}; \\ 0_{1,p}, 1_{1,p}, 0_{1,(t\times s\times p)-2p}, 0, -C, 0_{1,(t\times s)+(t\times s)+s+(t\times p)+(t\times p)-2}; \\ 0_{1,p}, 0_{1,p}, 1_{1,p}, 0_{1,(t\times s\times p)-3p}, 0, 0, -C, 0_{1,(t\times s)+(t\times s)+s+(t\times p)+(t\times p)-3}; \\ \vdots \end{bmatrix}_{(t\times s)\text{ times}} \begin{bmatrix} X_{tsp} \\ S_{ts} \\ Z_{ts} \\ W_s \\ i_{tp}^{+} \\ i_{tp}^{-} \end{bmatrix} \le S_{ts}; \tag{5}$$

$$X_{tsp} \le Q_{tsp} \Leftrightarrow I_{(t\times s\times p),(t\times s\times p)}, 0_{(t\times s\times p),(t\times s+t\times s+s+t\times p+t\times p)} \begin{bmatrix} X_{tsp} \\ S_{ts} \\ Z_{ts} \\ W_s \\ i_{tp}^{+} \\ i_{tp}^{-} \end{bmatrix} \le Q_{tsp}; \tag{6}$$

$$\sum_{p=1}^{P} X_{tsp} \le M * Z_{ts} \Leftrightarrow \sum_{p=1}^{P} X_{tsp} - M * Z_{ts} \le 0$$

$$\Leftrightarrow \begin{bmatrix} 1_{1,p}, 0_{1,(t\times s\times p)-p}, -M, 0_{1,(t\times s)+(t\times s)+s+(t\times p)+(t\times p)-1}; \\ 0_{1,p}, 1_{1,p}, 0_{1,(t\times s\times p)-2p}, 0, -M, 0_{1,(t\times s)+(t\times s)+s+(t\times p)+(t\times p)-2}; \\ 0_{1,p}, 0_{1,p}, 1_{1,p}, 0_{1,(t\times s\times p)-3p}, 0, 0, -M, 0_{1,(t\times s)+(t\times s)+s+(t\times p)+(t\times p)-3}; \\ \vdots \end{bmatrix}_{(t\times s)\text{ times}} \begin{bmatrix} X_{tsp} \\ S_{ts} \\ Z_{ts} \\ W_s \\ i_{tp}^{+} \\ i_{tp}^{-} \end{bmatrix} \le 0_{ts,1}; \tag{7}$$

$$i_{tp}^{+} \le Q_{tp} \Leftrightarrow 0_{(t\times p),((t\times s\times p)+(t\times s)+(t\times s)+s)}, I_{(t\times p),(t\times p)}, 0_{(t\times p),(t\times p)} \begin{bmatrix} X_{tsp} \\ S_{ts} \\ Z_{ts} \\ W_s \\ i_{tp}^{+} \\ i_{tp}^{-} \end{bmatrix} \le Q_{tp}; \tag{8}$$

$$\sum_{t=1}^{T} Z_{ts} \le M * W_s \Leftrightarrow \sum_{t=1}^{T} Z_{ts} - M * W_s \le 0 \Leftrightarrow$$

$$\begin{bmatrix} 0_{1,(t\times s\times p)+(t\times s)}, \underbrace{1,0_{1,s-1},1,0_{1,s-1},\ldots}_{t\text{ times}}, -M, 0_{1,s-1+t\times p+t\times p}; \\ 0_{1,(t\times s\times p)+(t\times s)}, \underbrace{0,1,0_{1,s-2},0,1,0_{1,s-2},\ldots}_{t\text{ times}}, 0, -M, 0_{1,s-2+t\times p+t\times p}; \\ \vdots \\ 0_{1,(t\times s\times p)+(t\times s)}, \underbrace{\underbrace{0,0,\ldots}_{s\text{ times}},1,0,\ldots,1,}_{t\text{ times}}\underbrace{0,0,\ldots}_{s\text{ times}}, -M, 0_{1,t\times p+t\times p}; \end{bmatrix} \begin{bmatrix} X_{tsp} \\ S_{ts} \\ Z_{ts} \\ W_s \\ i_{tp}^{+} \\ i_{tp}^{-} \end{bmatrix} \le 0_{s,1}; \quad (9)$$

$$i_{tp}^{-} \le (1-\phi)\sum_{t}^{T} D_{tp} \Leftrightarrow 0_{(t\times p),((t\times s\times p)+(t\times s)+(t\times s)+s+(t\times p))}, I_{(t\times p),(t\times p)} \begin{bmatrix} X_{tsp} \\ S_{ts} \\ Z_{ts} \\ W_s \\ i_{tp}^{+} \\ i_{tp}^{-} \end{bmatrix} \le (1-\phi_t) D_{tp}; \quad (10)$$

$$\begin{bmatrix} X_{tsp} \\ \sum_{p=1}^{P} X_{tsp} \\ i_{tp}^{+} \end{bmatrix} \le \begin{bmatrix} SC_{tsp} \\ M * Z_{ts} \\ MS_{tp} \end{bmatrix} \Leftrightarrow \begin{bmatrix} I_{(t\times s\times p),(t\times s\times p)}, 0_{(t\times s\times p),(t\times s+t\times s+s+t\times p+t\times p)} \end{bmatrix} \begin{bmatrix} X_{tsp} \\ S_{ts} \\ Z_{ts} \\ W_s \\ i_{tp}^{+} \\ i_{tp}^{-} \end{bmatrix} \le \begin{bmatrix} 0_{ts,1} \end{bmatrix} ,\forall p \in P; \quad (11)$$

$$\begin{bmatrix} \left[1, 0'_{t\times s+t\times s+s+t\times p+t\times p}\right]_{t\times s\times p} \\ \left[0'_{t\times s\times p+t\times s+t\times s+s}, 1, 0'_{t\times p}\right]_{t\times p} \\ \left[0'_{t\times s\times p+t\times s+t\times s+s+t\times p}, 1\right]_{t\times p} \end{bmatrix} \begin{bmatrix} X_{tsp} \\ S_{ts} \\ Z_{ts} \\ W_s \\ i_{tp}^{+} \\ i_{tp}^{-} \end{bmatrix} \ge 0_{t\times s\times p+t\times p+t\times p}; \quad (12)$$

$$Z_{ts}\ ,\ W_s \in \{0,1\}. \quad (13)$$

The objective function represents the goal of minimizing procurement cost that consists of eight parts namely sum of purchasing cost, penalty of defect product, penalty of late delivery, transportation cost, ordering cost, contract cost for new supplier, holding cost, shortage cost respectively. The buyer wants to optimize the total procurement cost, subject to following constrains. Constrain (2) and (3) state that the demand for a certain product in period t should be met from the available inventory and all incoming shipment arrived in that period. In case some portion of the demand cannot be satisfied, backlogging is permitted. Constrain (4) states that demand over the planning horizon has to be fully satisfied. Constrain (5) tells that the delivery of all products from all suppliers cannot exceed the full truck load (FTL) capacity. Constrain (6) assures that the order from the buyer cannot exceed the capacity of the supplier. Constrain (7) is to guarantee that the buyer is charged an ordering cost when procured products from a supplier. Constrain (8) ensures that the inventories in period t do not exceed the buyer's storage capacity. Constrain (9) has a role to ensure that a new supplier is charged a contract cost. Constrain (10) assures that the stock out quantity cannot exceed the buyer's service level requirement. Constrain (11) and (12) are integer constraints and non-negative for decisions variables. Constrain (13) specifies the integrality of the binary variables.

4. GENETIC ALGORITHM

Genetic Algorithm (GA) was used to solve many optimization problems in many areas and various type of problem. When we face a complex optimization problem (due to the problem is large of scale for example) and the analytical/classical method is inappropriate or hard to solve then GA is a good choice. It can be used to solve linear to a nonlinear optimization problem, small to large scale problem and convex to non-convex problem. GA finds the optimal solution by initially generating a set/population of feasible point (gen/chromosome) of decision variable then implements the evolution principal to it using mutation and crossover. In any iteration, a new population is created evolution till one of stopping criteria is reached. We have applied the GA into DSSP problem solving by implementing the following scheme.

4.1 Chromosome

We have taken the vector of the decision variables $x = \left[X_{tsp}, S_{ts}, i^{+}_{tp}, i^{-}_{tp}, Z_{ts}, W_{s} \right]'$ as a chromosome in the GA. A chromosome has $\left(t \times s \times p + t \times s + t \times p + t \times p + t \times s + s \right)$ elements where the first $\left(t \times s \times p + t \times s + t \times p + t \times p \right)$ elements are integer and the rest elements are binary.

4.2 Population

A population in GA is representing a set of chromosome and the size of a population is representing the number of the chromosome in the population. The larger a population's size, the larger the computers resource is needed to run the algorithm.

4.3 Fitness function.

Fitness function is used to evaluate a chromosome. Since the problem that will be solved is a minimization problem, we set the fitness function as $F(x) = \dfrac{1}{1 + f(x)}$ where $f(x)$ is our objective function.

GA will be applied to solve the DSSP problem by the following procedures:

A. Initialization. The initial population can be generated randomly where the size of a population is decided by the decision maker. Since the DSSP problem has constraints, we generate randomly an initial population which the constraints are hold (feasible initial population). In this paper, the population size is set at 100.

B. Fitness evaluation and scaling

   The initial population is evaluated by using fitness function. The chromosomes with the highest fitness are chosen for the next iteration. We used rank scale.

C. Selection
   Parents are selected from a population to produce a successive generations. There are several strategies to select parents which are roulette wheel selection, stochastic uniform selection (SUS), tournament, uniform, and remainder selection. We used stochastic uniform selection (SUS).
D. Crossover
   Crossover is a genetic operator to carry out a reproduction from the selected parents. Several common crossover strategies that can be applied are arithmetic, heuristic, intermediate, scattered, single-point and two-point strategy. We used 10 for elite count and 0.8 for crossover fraction.
E. Mutation
   Mutation is a genetic operator to carry out a reproduction from a selected parent. Several common mutation strategies are adaptive feasible, Gaussian and uniform strategy. We used constraint dependent for mutation strategy.
F. Termination
   Common terminating conditions are a solution is found that satisfies minimum criteria, fixed number of generations reached, allocated budget (computation time/money) reached, the highest ranking solution's fitness is reaching or has reached a plateau such that successive iterations no longer produce better results, manual inspection or combinations of the above. We used 10,000 for maximum iteration.

5. NUMERICAL EXAMPLE

In this section, we conduct a numerical example for the proposed mathematical model using the above described GA and LINGO 17. The purpose of this experiment is to reveal the solvability and the effectiveness of the proposed model. We then compare the result fro LINGO 17 and GA. The lingo 17 is run in a desktop computer with Intel core i3 CPU (2.7 GHz) and 4 GB RAM.GA is coding with MATLAB R2017b 64 bit in windows 10 in the same desktop.

We consider a scenario with three products, four suppliers over a planning horizon of six periods. The demand value is 800 units. Table 2 provides the unit price of three products from each supplier, ordering cost and contract cost of four suppliers. Table 3 shows percentage of product late, percentage of rejected product and supplier capacity from four suppliers. Table 4 presents transportation cost using truck from supplier s to the buyer. Each truck has capacity 100 to deliver product from the supplier to the buyer. Table 5 present penalty cost for defect product (P_p^d), penalty cost for late delivery (P_p^l), holding cost of product p (H_p), shortage cost product p (SOC_p) and buyer storage capacity for product p in time period t Q_{tp} for three product. The buyer's service level is set at 90%.

Table 2 Unit price of three product(UP_{sp}) , ordering cost (O_s), contract cost (**NC_s**) of four suppliers

Supplier	Unit Price Product (UP_{sp})			Ordering cost	Contract cost
	1	2	3	(O_s)	(NC_s)
1	35	25	30	350	650
2	37	24	32	300	625
3	33	24	28	375	650
4	35	26	31	325	600

Table 3 Percentage of product late and rejected product, and supplier capacity for four suppliers

Supplier	Percentage of product late			Percentage of rejected			Suppliers capacity		
	1	2	3	1	2	3	1	2	3
1	0.02	0.00	0.03	0.06	0.09	0.07	600	1000	1200
2	0.01	0.01	0.00	0.06	0.05	0.05	1000	700	600
3	0.03	0.01	0.02	0.02	0.01	0.02	500	500	500
4	0.00	0.01	0.00	0.01	0.02	0.09	800	800	1000

Table 4 Transportation cost (TC_s) using truck from supplier to manufacturer

	Supplier 1	Supplier 2	Supplier 3	Supplier 4
Manufacturer	600	750	650	650

Table 5 The values of P_n^d, P_n^l, H_n, SOC_n and Q_{tp} for three products

	Product		
	1	2	3
P_p^d	4	3	5
P_p^l	10	12	15
H_p	1	1	1
SOC_p	1	1	1
MS_{tp}	2000	2500	3000

GA was run to solve the DSSP. We done GA experiments 267 times on two desktop computers with Intel Core i3 2.7 GHz processor specifications (for both computers) and 4 GB of memory for the first computer and 2 GB memory for the second computer, and both computers using MATLAB R2017b 64 bit on Windows operating system 10. In Figure 1 is presented the result of DSSP by using GA.

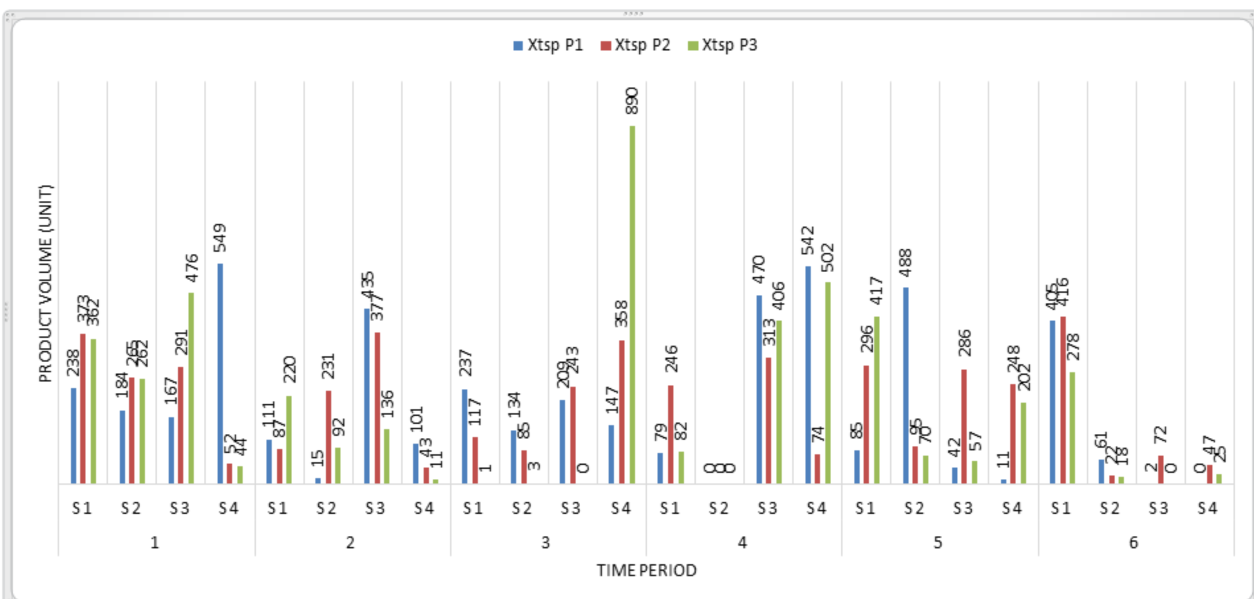

Figure 1 DSSP result by using GA

Figure 1 shows the optimal decision on the number of items purchased from GA. The amount of goods purchased for each product type for each time period is presented in figure 1. In the period 1, GA gave the decision to buy from supplier 1 238 units of product 1, 373 units of product 2 and 362 units of product 3, for supplier 2, GA gave the decision to purchase 184 units of product 1, 265 units of product 2 and 262 units of product 3, while for supplier 3, GA gave the decision to buy 167 units of product 1, 291 units of product 2 and 476 units of product 3, and for supplier 4 GA gave the decision to buy 549 units of product 1, 52 units of product 2 and 44 units of product 3.

We used the relative error formula $e_r = \frac{x_{GA} - x_{LINGO}}{x_{LINGO}} \times 100\%$ to compare the optimal decision of LINGO and GA results. Then, the relative error of the objective function value between LINGO and GA is found. The GA comparison results for the DSSP are presented in Table 6. Based on Table 6, GA with the procedures specified above can be used as an alternative to solve DSSP because GA can produce near value for objective function from the classical method using LINGO.

Table 6 Comparison between LINGO and GA

Value	Objective function	
	Value	Relative error
Min (GA)	519825.25	0,04%
Max (GA)	559302.05	7,64%
Average (GA)	531675.02	2,32%
LINGO	519611	

6. CONCLUSION

We have modeled dynamics supplier selection problem with multiple suppliers, multiple products and multiple periods. Some assumptions have added in the model like all products have same dimension, suppliers have limited capacity etc. We then formulate the problem as mixed integer linear programming in which a procurement decision maker can determine the right suppliers and split orders into lot sizes to the selected suppliers over multiple periods. We considered full truck load shipping to delivered product from suppliers to buyer.

Finally, a numerical example of dynamic supplier selection model is run by LINGO 17 and Genetic Algorithm. By solving DSSP using LINGO 17 as classical methods we have a global optimal solution. We have compared the solution using LINGO 17 and GA. GA in which procedure has determined has only 2,32% relative error in average. Therefore, decision maker can apply GA to solve DSSP to obtain almost near optimal solution. When we extend the size of the problem with five suppliers, three product and ten periods, GA can solve the extend problem. Result indicate that product must to order from which suppliers, in how many quantity and in which periods can be obtained by GA.

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