

# Eighth international conference on Operations and Supply Chain Management (OSCM)

9-12 September 2018

**Cranfield**  
School of  
Management

## Proceedings

Hosted by Cranfield School of Management, UK in collaboration with the Department of Industrial Engineering, Institut Teknologi Sepuluh Nopember (ITS), Indonesia, and Coventry University, UK



# Message from the conference chairs

**It is a great pleasure to welcome you to the 8<sup>th</sup> 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

## General Chair

## General Co-Chair

## General Co-Chair

## Program Chair

## Arrangement Co-Chairs

## Conference Administrator

## Lead Event Organisers

Benny Tjahjono, Coventry University, UK

Hendrik Reefke, Cranfield University, UK

Nyoman Pujawan, ITS, Indonesia

Soroosh Saghiri, Cranfield University, UK

Carl Kuhl and Tobias Widmer, Cranfield University, UK

Libbi Smith, Cranfield University, UK

Sarah Lloyd and Gemma Haynes, Cranfield University, UK

## Scientific Committee:

Benny Tjahjono, Coventry University, UK

I Nyoman Pujawan, Sepuluh Nopember Institute of Technology (ITS), Indonesia

Imam Baihaqi, Sepuluh Nopember Institute of Technology (ITS), Indonesia

Soroosh Saghiri, Cranfield University, UK

Hendrik Reefke, Cranfield University, UK

Michael Bourlakis, Cranfield University, UK

Kamrul Ahsan, RMIT University, Australia

The Jin Ai, University of Atmajaya, Jogjakarta, Indonesia

Thunyarat (Bam) Amornpetckul, NIDA Business School, Thailand

Watcharavee Chandraprakaikul, University of the Thai Chamber of Commerce, Thailand

Hing Kai Chan, The University of Nottingham Ningbo China

Paul Childerhouse, Massey University, New Zealand

Ajay Das, Baruch College, The City University of New York, USA

Rene De Koster, Erasmus University, The Netherlands

Per Engelseth, Molde University College, Norway

Javad Feizabadi, Malaysia Institute for Supply Chain Innovation, Malaysia

Dimitris Folinas, Alexandrion Technological Educational Institute of Thessaloniki, Greece

George Hadjinicola, University of Cyprus

Per Hilletoft, Jönköping University, Sweden

Petros Ieromonachou, University of Greenwich, UK

Takashi Irohara, Sophia University, Japan

Sakun Boon-Itt, Thammasat University, Thailand

Sanjay Jharkharia, Indian Institute of Management Kozhikode, India

Yasutaaka Kainuma, Tokyo Metropolitan University, Japan

Kap Hwan Kim, Pusan National University, Korea

Duangpun Kritchanchai, Mahidol University, Thailand

Reza Lashkari, University of Windsor, Canada

Ioannis Manikas, University of Greenwich, UK

Bimaraya Metri, Indian Institute of Management, Trichy, India

Rajesh Piplani, Nanyang Technological University, Singapore

Daniel Prajogo, Monash University, Australia

T. Ramayah, Universiti Sains Malaysia

Violeta Roso, Chalmers University of Technology, Sweden

Ruhul Amin Sarker, University of New South Wales, Australia

Anders Segerstedt, Lule University of Technology, Sweden

Togar Simatupang, Bandung Institute of Technology, Indonesia

Himanshu Shee, Victoria University, Australia

Harm-Jan Steenhuis, Hawaii Pacific University, USA

Suprayogi, Bandung Institute of Technology, Indonesia

Katsuhiko Takahashi, Hiroshima University, Japan

Armagan Tarim, Hacettepe University, Turkey

Blanka Tundys, University of Szczecin, Poland

Jyri Vilko, Lappeenranta University of Technology, Finland

Kun-Jeng Wang, National Taiwan University of Science and Technology, Taiwan

Hui Ming Wee, Chung Yuan Christian University, Taiwan

Gede Agus Widyadana, Petra Christian University, Indonesia

Joel Wisner, University of Nevada, Las Vegas, USA

Hartanto Wong, Aarhus University, Denmark

Sha'ri Mohd Yusof, Universiti Teknologi Malaysia

Yahaya Yusuf, University of Central Lancashire, UK

Suhaiza Zailani, University of Malaya, Malaysia

Vipul Jain, Victoria University of Wellington, New Zealand

## LIST OF PAPERS

### Sustainable Logistics and Operations 1

- Drivers and barriers of consumer purchase intention of remanufactured mobile phones: a study on Indonesian consumers 1  
*Didik Wahjudi, Shu-San Gan, Yopi Yusuf Tanoto, Jerry Winata*
- Modelling Circular Economy using Game Theory 11  
*Nariaki Nishino, Benny Tjahjono*
- A review of organisational theories to explore the phenomenon of green bullwhip effect 26  
*Nandu Devi, Qile He, Nigel Berkeley, Jill Timms*
- An exploration of the green bullwhip effect in food supply chains: an institutional theory perspective 42  
*Nandu Devi, Qile He, Nigel Berkeley, Jill Timms*

### Procurement and Supply Management

- Supplier Involvement in New Product Development: A Topology for Project Complexities 49  
*Eman Nasr, Chris Tabi Amponsah*
- Mitigating talent retention issues through impact sourcing: evidence from Malaysia and Sri Lanka 61  
*Aini Aman, Abdul Aziz Ahmad, Yusasniza M. Yunus, Zaini Embong, Ruhanita Maelah*
- A genetic algorithm approach for dynamic supplier selection 74  
*Purnawan A. Wicaksono, Sutrisno, I Nyoman Pujawan, Erwin Widodo*
- Fuzzy logic based decision-support for reshoring decisions 87  
*Anders Adlemo, Per Hilletoft, Vladimir Tarasov*

### Innovation and Technology

- Business model innovation in additive manufacturing value chains 103  
*Carsten Feldmann, Sebastian Fernströning, Colin Schulz*
- Implementing enterprise resource planning systems within a process innovation framework 127  
*Alireza Javahernia, Funlade Sunmola, Leslie Mitchell*
- Business process analysis and potential IT implementation based on Supply Chain Operations Reference (SCOR) framework 134  
*Mahendrawathi Er, Dewi Chumairoh*
- The implementation of ICT (Information and Communication Technology) in Verification Gross Mass (VGM): the case at Semarang Container Terminal (SCT) and Jakarta International Container Terminal (JICT) 145  
*Triyan Indrawan, Muhammad B. Zaman, R.O. Saut Gurning*

Reality of autonomous transportation technologies in global supply chains: the consumer driven demand chain <i>Satya Shah, Milagros A. Piragine</i>	157
--------------------------------------------------------------------------------------------------------------------------------------------------------	-----

## **Sustainable Logistics and Operations 2**

Sustainability assessment of car terminal in the vehicle supply chain management: The case of Indonesia <i>Syahnan Ardi Azharie, R.O. Saut Gurning</i>	170
-----------------------------------------------------------------------------------------------------------------------------------------------------------	-----

A circular economy system for electronic product recovery <i>Eva Ripanti, Benny Tjahjono</i>	182
-------------------------------------------------------------------------------------------------	-----

The impact of Industry 4.0 on supply chains and sustainability <i>Sukhraj Takhar, Kapila Liyanage</i>	189
----------------------------------------------------------------------------------------------------------	-----

## **Operations Planning and Management 1**

Hybrid approach for location routing problem with transportation modes <i>Junko Hosoda, Takashi Irohara</i>	227
----------------------------------------------------------------------------------------------------------------	-----

Optimisation of inventory policy in a public distribution system using simulation and genetic algorithm <i>Rohit Kapoor</i>	239
--------------------------------------------------------------------------------------------------------------------------------	-----

Evaluating Sri Lanka's perishable cold chain to increase rural supply to urban markets <i>Keshala Gunaratne, Pradeepa Jayaratne</i>	260
----------------------------------------------------------------------------------------------------------------------------------------	-----

Variability Causes in the Manufacturing and Assembly of Complex Products <i>Daniela Silva, Américo Azevedo</i>	274
-------------------------------------------------------------------------------------------------------------------	-----

## **Block-chain Applications**

The analysis of Blockchain technology implementation for developing digital port in the supply chain operations <i>Prasetyo Azman, R.O. Saut Gurning</i>	286
-------------------------------------------------------------------------------------------------------------------------------------------------------------	-----

The scope for Blockchain technology to aid rural food producers in the Thai agrifood industry <i>Fakkhong Korawit</i>	298
--------------------------------------------------------------------------------------------------------------------------	-----

Blockchain technology to improve the traceability along the pharmaceutical supply chain <i>Janya Chanchaichujit, Albert Tan, Vithya L. Samiappan</i>	311
---------------------------------------------------------------------------------------------------------------------------------------------------------	-----

## **Sector Studies 1**

Managing electricity procurement uncertainty through the market governance set-up: a TCE perspective	323
------------------------------------------------------------------------------------------------------	-----

*Jan Vasek, Soroosh Saghiri, Michael Bourlakis*

Comparison analysis of classification societies in gaining international recognition 335  
*Sukma Maharani, R.O. Saut Gurning, Badruz Zaman*

Supply and Distribution of fertilizer as a catalyst to agricultural production and challenges in Nigeria 344  
*Jacob Gwa, Rhys Williams, John Mulyata*

Effectiveness of e-procurement applications of ship maintenance management system based on ISM code in shipping management 352  
*Heru Susilo Budiman, Muhammad B. Zaman, R.O. Saut Gurning*

### **Sustainable Logistics and Operations 3**

Hyper-connected Modular Renewable Energy Production and Logistics Network 364  
*Changliang Liu, Samsad Reza, Suzanne Marcotte*

Impacts of Industry 4.0 within Sustainable Production and Logistics in Food Manufacturing SMEs 365  
*Olumide Ojo, Satya Shah, Alec Coutroubis*

Leanness, Resources conservation and Recycling for economic and social well-being in emerging economies; Impact on operational Performance 377  
*Samsad Reza, Changliang Liu, Zakaria Rahman*

Impacts of I4.0 on Sustainable Manufacturing to Achieve Competitive Advantage 379  
*Sarath Menon, Satya Shah, Alec Coutroubis*

### **Financial and Humanitarian Performance**

An exploration of measures of buyer-supplier relational capital in supply chains 388  
*Barbara Ocicka, Grażyna Wieteska*

Time-driven activity-based costing in logistics services 400  
*Dyah Santhi Dewi, Fitria Kurnia Putri, I Ketut Gunarta*

Solving a sea cargo revenue management model 414  
*Chi-Leung Chu, Vincent Li*

The analysis of service performance using hand-held instrument for operational survey of classification services: the case of Biro Klasifikasi Indonesia (BKI) 423  
*M.Y. Oktovianto, Semin, R.O. Saut Gurning*

### **Human Factors and Operations Safety**

The analysis of regulation cost of ship safety and its impact to supply chain cost: the case of future application of Non-Convention Vessel Standard (NCVS) in Indonesia 434  
*Wasito Abdul Mukit, R.O. Saut Gurning*

Human Reliability in Rail Transport to Support Supply Chain System Efficiency <i>Wiwik Budiawan, Novie Susanto, Heru Prastawa, Widhi A. Setiawan Putra</i>	445
Implementation of ergonomic programs to evaluate manual material handling in a mining industry <i>Eko Nurmianto, Udisubakti Ciptomulyono, Suparno, Sudiyono Kromodihardjo, Hari Setijono</i>	453
Ergonomic intervention in improvement program for export leather product industry <i>Eko Nurmianto, Arino Anzip</i>	461
 <b>Humanitarian Logistics and Sustainability</b>	
Cause-effect analysis for distinctive visibility in sustainable supply chains: a systematic literature review <i>Uje Daniel Apeji, Funlade T Sunmola, Petros Khoudian</i>	470
SMEs development through campus social responsibility: a conceptual framework <i>Imam Baihaqi, Satria Fadil Persada, Sutikno, Setiawan</i>	483
Identifying the influencing factors in sustainable tea supply in the Sri Lankan tea industry <i>Pradeepa Jayaratne, Lee Styger, Nelson Perera</i>	492
Humanitarian Logistics Model for Disaster Relief Operation Considering Relief Time and Satisfaction Level of Victims <i>Yasutaka Kainuma, Yacob Khojasteh</i>	512
 <b>Lean Thinking and Lean Techniques</b>	
The reciprocal effect between lean manufacturing and supply chain integration <i>M.Y. El-Mokadem, Magdy A. Khalaf</i>	521
Developing lean performance evaluation for a press form production line of an aircraft industry <i>Dewanti Anggrahini, Putu Dana Karningsih, Imandio Wicaksono</i>	532
Fuzzy logic based leanness assessment: a systematic analysis of literature <i>Rishi Choudhary, Amr Mahfouz, John Ryan, Amr Arisha</i>	541
Enablers and Main Factors for successful implementation lean principles in hospital supply chain: a Saudi case <i>Abdulaziz Almutairi, Konstantinos Salonitis, Ahmed Al-Ashaab</i>	556
 <b>Maritime Logistics</b>	
The analysis of domestic shipping connectivity and accessibility of maritime logistic operations: the case of Indonesian maritime highway <i>R.O. Saut Gurning</i>	567
The correlation analysis of seafood supply chain and the formation of national fishery fleet: The	577



case of Indonesia

*Doddy Widodo Laksono, Semin, R.O. Saut Gurning*

Managing supply chain risks of Indonesian marine and fisheries products 592

*Putu Karningsih, Dewanti Anggrahini, Olivia Panjaitan*

The analysis of determining factors required for the development of ship component industry: the 606

case of fishing vessel development in Japan, China and South Korea

*Adhi Kholiddin, Semin, R.O. Saut Gurning*

### **Supply Chain Uncertainty & Risk**

Risk analysis of containerized Stevedoring operational-based in supply chain: the case of Tanjung 615

Priok port Indonesia

*Harrys Pahala Manalu, R.O. Saut Gurning, Semin*

Supply chain disruption recovery for single-vendor-single-buyer system 627

*Vincent Li, Hui-Ju Hsu, Chi-Leung Chu*

Enhancing supply chain resilience through risk information sharing: a triadic perspective 638

*Ibrahim Labaran Ali, Abigail Hird, Robert Ian Whitfield*

Choice and diversification decisions under demand and supply uncertainty 639

*Somak Paul, Nate Craig, Elliot Bendoly*

### **Operations Planning and Management 1**

Critical operations capabilities in a high cost environment 640

*Cinzia Sansone, Per Hilletoft, David Eriksson*

Measuring and Improving Logistics Service Quality: A case study of logistics service provider. 648

*Imam Baihaqi, Syarif Hanoum, Aang Kunaifi*

Quality based maintenance – an effort for production performance improvement 657

*Nani Kurniati, Asri Amalia Muti, Lasmer Samuel Damanik*

Policy analysis of production facility investment to increase productivity of salt production system 665

using dynamics programming

*Saiful Mangnggenre, Muhammad Rusman, Syamsul Bahri, Nadzirah Ikasari Syamsul*

### **Sector Studies 2**

Comparing information sharing behaviour in high and low reliability blood supply chains: does 666

collective mindfulness matter?

*Luluk Lusiantoro, Nicky Yates, Liz Varga*

Dynamic capabilities in micro, small and medium sized start-up ventures: a case of Indonesia 677

*Florencia F. Suryanto, Liliani, Benny Tjahjono*

The assessment of operational performance and working governance of Stevedoring operations: the case of a container terminal in Tanjung Priok Indonesia <i>Ogi Haris, R.O. Saut Gurning</i>	689
The performance analysis of shipyard in managing their supply chain: The Indonesian case <i>Muhamad Sodik, R.O. Saut Gurning</i>	701
Monitoring the evolution of aerospace ecosystems by applying network science <i>Jose Jr. Luna Andrade, Alexandra Brintrup, Konstantinos Salonitis</i>	710

# A GENETIC ALGORITHM APPROACH FOR DYNAMIC SUPPLIER SELECTION

---

**Purnawan Adi Wicaksono**

Department of Industrial Engineering, Diponegoro University, Semarang, 50275 Indonesia,  
E-mail: [purnawan@live.undip.ac.id](mailto:purnawan@live.undip.ac.id)

**Sutrisno**

Department of Mathematics, Diponegoro University, Semarang, 50275 Indonesia, E-mail:  
[tresnowijoyo@gmail.com](mailto:tresnowijoyo@gmail.com)

**I Nyoman Pujawan**

Department of Industrial Engineering, Sepuluh Nopember Institute of Technology,  
Surabaya 60111 Indonesia, E-mail: [pujawan@ie.its.ac.id](mailto:pujawan@ie.its.ac.id)

**Erwin Widodo**

Department of Industrial Engineering, Sepuluh Nopember Institute of Technology,  
Surabaya 60111 Indonesia, E-mail: [erwin@ie.its.ac.id](mailto:erwin@ie.its.ac.id)

## 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	√
Aguezoul & Ladet (2007)	√	--	--	√	√	--	TSSP	--	Non linear MOP	Math lab	--
Rezaei & Davoodi (2011)	--	√	--	√	--	√	DSSP	√	MOMINLP	GA	--
Choudhary & Shankar (2011)	√	--	--	√	--	√	TSSP	--	ILP	Classical	√
Mansini <i>et al.</i> (2012)	--	√	--	√	√	--	TSSP	√	Integer Program	Heuristic	--
Choudhary & Shankar (2013)	√	--	--	√	--	√	TSSP	--	ILP	Classical	√
Choudhary & Shankar (2014)	√	--	--	√	--	√	TSSP	--	MOILP	Classical	√
Ware <i>et al.</i> (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 <i>et al.</i> (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 consideration 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, multiple 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  
 $\phi$  : Buyer's service level requirement in period t so  $(1 - \phi)$  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**

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

where

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

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

subject to:

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

$$\Leftrightarrow \left[ \begin{array}{l} \underbrace{1-l(0p+1)-d(0p+1), 0_{1,p-1}, 1-l(1p+1)-d(1p+1), 0_{1,p-1}, \dots, 1-l((s-1)p+1)-d((s-1)p+1), 0_{1,p-1}}_{s \text{ times}} \\ 0_{1,isp-sp}, 0_{1,t \times s+t \times s+s}, -1, 0_{t \times p-1}, 1, 0_{t \times p-1}; \\ \underbrace{0, 1-l(2)-d(2), 0_{1,p-2}, 0, 1-l(p+2)-d(p+2), 0_{1,p-2}, \dots, 0, 1-l(ps-p+1)-d(ps-p+1), 0_{1,p-2}}_{s \text{ times}} \\ \Leftrightarrow 0_{1,isp-sp}, 0_{1,t \times s+t \times s+s}, 0, -1, 0_{t \times p-2}, 0, 1, 0_{t \times p-2}; \\ \vdots \\ \underbrace{0, 0, \dots, 1-l(p)-d(p), 0, 0, \dots, 1-l(2p)-d(2p), \dots, 0, 0, \dots, 1-l(sp)-d(sp)}_{p \text{ times}} \\ \underbrace{\phantom{0, 0, \dots, 1-l(p)-d(p), 0, 0, \dots, 1-l(2p)-d(2p), \dots, 0, 0, \dots, 1-l(sp)-d(sp)}}_{p \text{ times}} \\ \underbrace{\phantom{0, 0, \dots, 1-l(p)-d(p), 0, 0, \dots, 1-l(2p)-d(2p), \dots, 0, 0, \dots, 1-l(sp)-d(sp)}}_{s \text{ times}} \\ 0_{1,isp-sp}, 0_{1,t \times s+t \times s+s}, \underbrace{0, 0, \dots, -1, 0_{tp-tp}}_{t \times p}, \underbrace{0, 0, \dots, 1, 0_{tp-tp}}_{t \times p} \end{array} \right] \begin{array}{l} X_{isp} \\ S_{is} \\ Z_{ts} \\ W_s \\ i_{tp}^+ \\ i_{tp}^- \end{array} \geq D_{ip}; \quad (2)$$

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

$\Leftrightarrow t > 1:$

$$\left[ \begin{array}{l} \underbrace{l(1), 1-l(2)-d(2), 0_{1,p-2}, l(p+1), (1-l(p+2)-d(p+2), 0_{1,p-2}, \dots, l((s-1)p+1), 1-l(ps-p+2)-d(ps-p+2), 0_{1,p-2}}_{s \text{ times}} \\ , 0_{1,isp-sp}, 0_{1,t \times s+t \times s+s}, 1, 0_{1,p-1}, -1, 0_{1,p-1}, 0_{t \times p-2p}, -1, 0_{1,p-1}, 1, 0_{1,p-1}, 0_{t \times p-2p}; \\ \underbrace{0, l(2), 1-l(3)-d(3), 0_{1,p-3}, l(p+2), (1-l(p+3)-d(p+3), 0_{1,p-3}, \dots, l(ps-p+2), 1-l(ps-p+3)-d(ps-p+3), 0_{1,p-3}}_{s \text{ times}} \\ , 0_{1,isp-sp}, 0_{1,t \times s+t \times s+s}, 0, 1, 0_{1,p-2}, -1, 0_{1,p-2}, 0_{t \times p-2p}, 0, -1, 0_{1,p-2}, 1, 0_{1,p-2}, 0_{t \times p-3p}; \\ \underbrace{0, 0, l(3), 1-l(4)-d(4), 0_{1,p-4}, l(p+3), (1-l(p+4)-d(p+4), 0_{1,p-4}, \dots, l(ps-p+3), 1-l(ps-p+4)-d(ps-p+4), 0_{1,p-4}}_{s \text{ times}} \\ , 0_{1,isp-sp}, 0_{1,t \times s+t \times s+s}, 0, 0, 1, 0_{1,p-3}, -1, 0_{1,p-3}, 0_{t \times p-2p}, 0, 0, -1, 0_{1,p-3}, 1, 0_{1,p-3}, 0_{t \times p-4p}; \\ \vdots \\ 0, 0, \dots, l(p-1), 1-l(p)-d(p), 0_{1,p-p}, l(2p-1), (1-l(2p)-d(2p), 0_{1,p-p}, \dots, l(ps-1), 1-l(ps)-d(ps), 0_{1,p-p} \\ \underbrace{\phantom{0, 0, \dots, l(p-1), 1-l(p)-d(p), 0_{1,p-p}, l(2p-1), (1-l(2p)-d(2p), 0_{1,p-p}, \dots, l(ps-1), 1-l(ps)-d(ps), 0_{1,p-p}}}_{s \text{ times}} \\ , 0_{1,isp-sp}, 0_{1,t \times s+t \times s+s}, 0, \dots, 0, 1, 0_{1,p-p}, -1, 0_{1,p-p}, 0_{t \times p-2p}, 0, \dots, 0, -1, 0_{1,p-p}, 1, 0_{1,p-p}, 0_{t \times p-tp} \end{array} \right] \begin{array}{l} X_{isp} \\ S_{is} \\ Z_{ts} \\ W_s \\ i_{tp}^+ \\ i_{tp}^- \end{array} \geq D_{ip}; \quad (3)$$

$$-\sum_{s=1}^S X_{isp} \leq -D_{ip} \Leftrightarrow \left[ \begin{array}{l} \underbrace{1, 0_{1,p-1}, 1, 0_{1,p-1}, \dots, 0_{1,isp-sp}, 0_{1,t \times s+t \times s+s+t \times p+t \times p}}_{s \text{ times}}; \\ \underbrace{0, 1, 0_{1,p-2}, 0, 1, 0_{1,p-2}, \dots, 0_{1,isp-sp}, 0_{1,t \times s+t \times s+s+t \times p+t \times p}}_{s \text{ times}}; \\ \vdots \\ \underbrace{0, 0, \dots, 1, 0, \dots, 1, 0_{1,isp-sp}, 0_{1,t \times s+t \times s+s+t \times p+t \times p}}_{p \text{ times}}; \\ \underbrace{\phantom{0, 0, \dots, 1, 0, \dots, 1, 0_{1,isp-sp}, 0_{1,t \times s+t \times s+s+t \times p+t \times p}}}_{s \text{ times}} \\ 0_{1,sp}, \underbrace{1, 0_{1,p-1}, 1, 0_{1,p-1}, \dots, 0_{1,isp-2sp}, 0_{1,t \times s+t \times s+s+t \times p+t \times p}}_{s \text{ times}}; \\ 0_{1,sp}, \underbrace{0, 1, 0_{1,p-2}, 0, 1, 0_{1,p-2}, \dots, 0_{1,isp-2sp}, 0_{1,t \times s+t \times s+s+t \times p+t \times p}}_{s \text{ times}}; \\ \vdots \\ 0_{1,sp}, \underbrace{0, 0, \dots, 1, 0, \dots, 1, 0_{1,isp-2sp}, 0_{1,t \times s+t \times s+s+t \times p+t \times p}}_{p \text{ times}}; \\ \underbrace{\phantom{0, 0, \dots, 1, 0, \dots, 1, 0_{1,isp-2sp}, 0_{1,t \times s+t \times s+s+t \times p+t \times p}}}_{s \text{ times}} \end{array} \right] \begin{array}{l} X_{isp} \\ S_{is} \\ Z_{ts} \\ W_s \\ i_{tp}^+ \\ i_{tp}^- \end{array} \leq -\sum_{t=1}^T D_{ip}; \quad (4)$$



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

$$\Leftrightarrow \left[ \begin{array}{c} 1_{1,p}, 0_{1,(t \times s \times p) - p}, -C, 0_{1,(t \times s) + (t \times s) + s + (t \times p) + (t \times p) - 1}; \\ 0_{1,p}, 1_{1,p}, 0_{1,(t \times s \times p) - 2p}, 0, -C, 0_{1,(t \times s) + (t \times s) + s + (t \times p) + (t \times p) - 2}; \\ 0_{1,p}, 0_{1,p}, 1_{1,p}, 0_{1,(t \times s \times p) - 3p}, 0, 0, -C, 0_{1,(t \times s) + (t \times s) + s + (t \times p) + (t \times p) - 3}; \\ \vdots \end{array} \right]_{(t \times s) \text{ times}} \left[ \begin{array}{c} X_{tsp} \\ S_{ts} \\ Z_{ts} \\ W_s \\ i_{tp}^+ \\ i_{tp}^- \end{array} \right] \leq S_{ts}; \quad (5)$$

$$X_{tsp} \leq Q_{tsp} \Leftrightarrow I_{(t \times s \times p), (t \times s \times p)}, 0_{(t \times s \times p), (t \times s + t \times s + s + t \times p + t \times p)}$$

$$\left[ \begin{array}{c} X_{tsp} \\ S_{ts} \\ Z_{ts} \\ W_s \\ i_{tp}^+ \\ i_{tp}^- \end{array} \right] \leq Q_{tsp}; \quad (6)$$

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

$$\Leftrightarrow \left[ \begin{array}{c} 1_{1,p}, 0_{1,(t \times s \times p) - p}, -M, 0_{1,(t \times s) + (t \times s) + s + (t \times p) + (t \times p) - 1}; \\ 0_{1,p}, 1_{1,p}, 0_{1,(t \times s \times p) - 2p}, 0, -M, 0_{1,(t \times s) + (t \times s) + s + (t \times p) + (t \times p) - 2}; \\ 0_{1,p}, 0_{1,p}, 1_{1,p}, 0_{1,(t \times s \times p) - 3p}, 0, 0, -M, 0_{1,(t \times s) + (t \times s) + s + (t \times p) + (t \times p) - 3}; \\ \vdots \end{array} \right]_{(t \times s) \text{ times}} \left[ \begin{array}{c} X_{tsp} \\ S_{ts} \\ Z_{ts} \\ W_s \\ i_{tp}^+ \\ i_{tp}^- \end{array} \right] \leq 0_{ts,1}; \quad (7)$$

$$i_{tp}^+ \leq Q_{tp} \Leftrightarrow 0_{(t \times p), ((t \times s \times p) + (t \times s) + (t \times s) + s)}, I_{(t \times p), (t \times p)}, 0_{(t \times p), (t \times p)}$$

$$\left[ \begin{array}{c} X_{tsp} \\ S_{ts} \\ Z_{ts} \\ W_s \\ i_{tp}^+ \\ i_{tp}^- \end{array} \right] \leq Q_{tp}; \quad (8)$$

$$\sum_{t=1}^T Z_{ts} \leq M * W_s \Leftrightarrow \sum_{t=1}^T Z_{ts} - M * W_s \leq 0 \Leftrightarrow \begin{bmatrix} 0_{1,(t \times s \times p) + (t \times s)}, \underbrace{1, 0_{1,s-1}, 1, 0_{1,s-1}, \dots, -M, 0_{1,s-1+t \times p+t \times p}}_{t \text{ times}}; \\ 0_{1,(t \times s \times p) + (t \times s)}, \underbrace{0, 1, 0_{1,s-2}, 0, 1, 0_{1,s-2}, \dots, 0, -M, 0_{1,s-2+t \times p+t \times p}}_{t \text{ times}}; \\ \vdots \\ 0_{1,(t \times s \times p) + (t \times s)}, \underbrace{0, 0, \dots, 1, 0, \dots, 1, 0, 0, \dots, -M, 0_{1,t \times p+t \times p}}_{\substack{s \text{ times} \\ t \text{ times}}} \end{bmatrix} \begin{bmatrix} X_{tsp} \\ S_{ts} \\ Z_{ts} \\ W_s \\ i_{tp}^+ \\ i_{tp}^- \end{bmatrix} \leq 0_{s,1}; \quad (9)$$

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

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

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

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

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. Constraint (5) tells that the delivery of all products from all suppliers cannot exceed the full truck load (FTL) capacity. Constraint (6) assures that the order from the buyer cannot exceed the capacity of the supplier. Constraint (7) is to guarantee that the buyer is charged an ordering cost when procured products from a supplier. Constraint (8) ensures that the inventories in period  $t$  do not exceed the buyer's storage capacity. Constraint (9) has a role to ensure that a new supplier is charged a contract cost. Constraint (10) assures that the stock out quantity cannot exceed the buyer's service level requirement. Constraint (11) and (12) are integer constraints and non-negative for decisions variables. Constraint (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  $x = [X_{isp}, S_{ts}, i_{ip}^+, i_{ip}^-, Z_{ts}, W_s]^T$  as a chromosome in the GA. A chromosome has  $(t \times s \times p + t \times s + t \times p + t \times p + t \times s + s)$  elements where the first  $(t \times s \times p + t \times s + t \times p + t \times p)$  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  $F(x) = \frac{1}{1 + f(x)}$  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 ( $O_s$ )	Contract cost ( $NC_s$ )
	1	2	3		
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

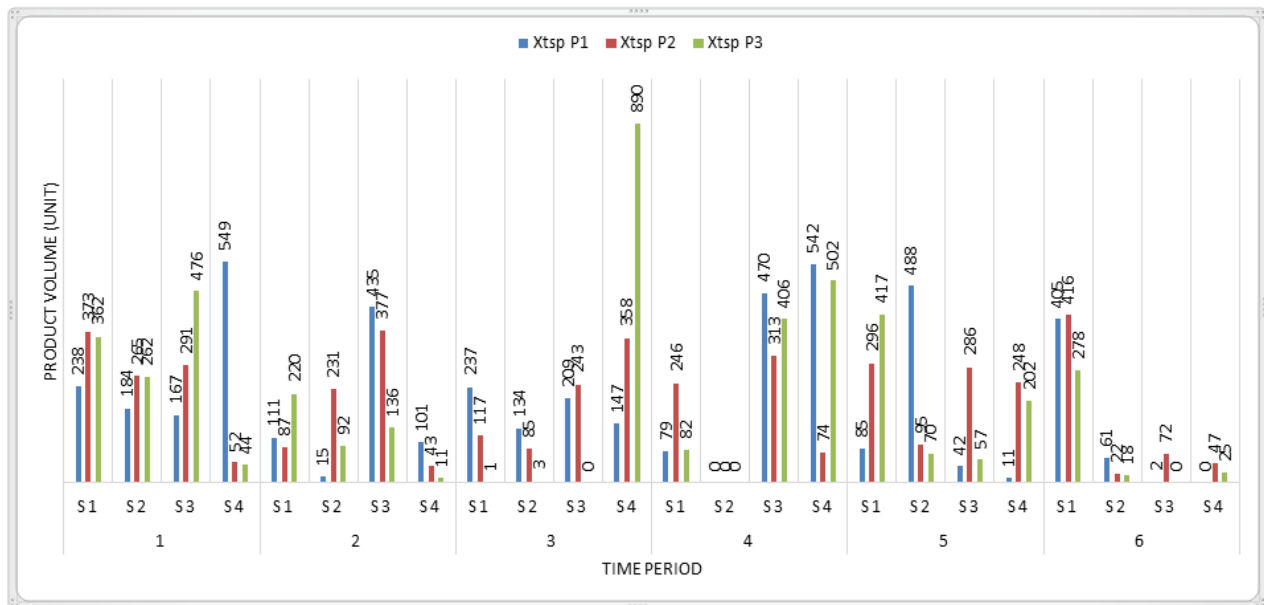
**Table 4** Transportation cost ( $TC_s$ ) using truck from supplier to manufacturer

	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
$P_n^d$	4	3	5
$P_n^l$	10	12	15
$H_n$	1	1	1
$SOC_n$	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.

## 7. REFERENCES

- Aguezzoul, A. and Ladet, P. (2007) A nonlinear multiobjective approach for the supplier selection, integrating transportation policies. *Journal of Modelling in Management*, 2(2), pp. 157–169.
- Ahmad, M. T. and Mondal, S. (2016). Dynamic supplier selection model under two-echelon supply network. *Expert Systems with Applications*, 65, pp. 255–270.
- Aissaoui, N., Haouari, M. and Hassini, E. (2007). Supplier selection and order lot sizing

- modeling : A review. *Computer & operation research*, 34, pp. 3516–3540.
- Chopra, S. and Meindl, P. (2010) *Supply chain management: Strategy, planning, and operations*. 4th editio. New Jersey: Prentice-Hall.
- Choudhary, D., & Shankar, R. (2011). Modeling and analysis of single item multi-period procurement lot-sizing problem considering rejections and late deliveries. *Computers & Industrial Engineering*, 61, 1318–1323.
- Choudhary, D., & Shankar, R. (2013). Joint decision of procurement lot-size , supplier selection , and carrier selection. *Journal of Purchasing and Supply Management*, 19, 16–26.
- Choudhary, D. and Shankar, R. (2014). A goal programming model for joint decision making of inventory lot-size , supplier selection and carrier selection. *Computers & Industrial Engineering*. 71, pp. 1–9.
- Ghaniabadi, M. and Mazinani, A. (2017). Dynamic lot sizing with multiple suppliers, backlogging and quantity discounts. *Computers and Industrial Engineering*, 110, pp. 67–74.
- Hamdan, S. and Cheaitou, A. (2017). Dynamic green supplier selection and order allocation with quantity discounts and varying supplier availability. *Computers & Industrial Engineering*, 110, pp. 573–589.
- Liao, Z. and Rittscher, J. (2007). A multi-objective supplier selection model under stochastic demand conditions. *Intern. Journal of Production Economics*, 105, pp. 150–159.
- Mansini, R., Savelsbergh, M. W. P. and Tocchella, B. (2012). The supplier selection problem with quantity discounts and truckload shipping, *Omega*. 40, pp. 445–455.
- Meena, P. L. and Sarmah, S. P. (2013). Multiple sourcing under supplier failure risk and quantity discount : A genetic algorithm approach, *Transportation Research Part E.*, 50, pp. 84–97.
- Moghaddam, K. S. (2015). Fuzzy multi-objective model for supplier selection and order allocation in reverse logistics systems under supply and demand uncertainty. *Expert Systems with Applications*, 42(15–16), pp. 6237–6254.
- Pazhani, S., Ventura, J. A. and Mendoza, A. (2016). A serial inventory system with supplier selection and order quantity allocation considering transportation costs. *Applied Mathematical Modelling*, 40(1), pp. 612–634.
- Rezaei, J. and Davoodi, M. (2011). Multi-objective models for lot-sizing with supplier selection. *Intern. Journal of Production Economics*, 130, pp. 77–86.
- Trivedi, A., Chauhan, A., Sing, S. P. and Kaur, H. (2017). A multi objective integer linear program to integrate supplier selection and order allocation with market demand in a supply chain. *International Journal of Procurement Management*, 10(3), pp. 335–359.
- Ware, N. R., Singh, S. P. and Banwet, D. K. (2014). A mixed-integer non-linear program to model dynamic supplier selection problem. *Expert Systems With Applications*, 41(2), pp. 671–678.
- Wetzstein, A., Hartmann, E., Benton jr, W. C. and Hohenstein, N.-O. (2016). A systematic Assessment of supplier selection literature – state-of-the-art and future scope. *Intern. Journal of Production Economics*.
- Wicaksono, P. A., Purwanggono, B., Pujawan, I.N., Widodo, E. (2016) Supplier Selection Model Considering Truckload Shipping, *Proceedings of 7<sup>th</sup> OSCM International Conference*, Phuket, Thailand.
- Wicaksono, P. A., Pujawan, I.N., Widodo, E. (in press). A Mixed Integer Linear Programming Model for Dynamic Supplier and Carrier Selection Problems. *International Journal of Procurement Management*..