



**Proceedings of Abstracts and Papers of
The 16th Asia Pacific Industrial Engineering
And Management Systems Conference (APIEMS 2015)**

December 8th – 11th, 2015
Ho Chi Minh City, Vietnam

Edited by

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**PROCEEDINGS OF ABSTRACTS AND PAPERS OF THE 16th
ASIA PACIFIC INDUSTRIAL ENGINEERING & AUTHORS
MANAGEMENT SYSTEMS CONFERENCE (APIEMS 2015)**

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THE 16TH ASIA PACIFIC
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AND MANAGEMENT SYSTEMS
CONFERENCE (APIEMS 2015)**

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MESSAGE FROM THE GENERAL CHAIR



International University (IU), one of six member universities of Vietnam National University-HCMC was established on December 2003. The University is the first public international university in Vietnam that entirely uses English in all activities. IU-HCMC is considered a leading university in Vietnam National University system that excels in operations, teaching, and research aspects. This year, our university took great honor to hold the 16th Asia Pacific Industrial Engineering and Management Systems in Ho Chi Minh City, the largest city of Vietnam.

As an organizer of the APIEMS 2015, we are impressed with the number and quality of papers that we have received for the conference. On behalf of the APIEMS 2015 organizing committee, I would like to thank Prof. Hoang Pham and Prof. Chen-Fu Chien for their excellent keynote speeches, I would also like to express my gratitude to more than 300 participants and distinguished speakers for their enthusiastic supports. As the conference was first time held in Vietnam, we are very grateful for the help of the Honorary Chairs, Program Committee Co-Chairs, Reviewers, who have given us valuable counseling and assist in reviewing a huge number of abstracts and manuscripts. My sincere thanks to all faculties, staff and student volunteers of Industrial and Systems Engineering Department, staff of the Office of Research and Development Office, External and Public Relations, Facility Development in International University for their hard work to hold this event successfully. Thanks also to all of our sponsors who have generously support us for the Conference.

Finally, I would like to say a very warm welcome to all distinguished guests, speakers and participants of the APIEMS 2015. I wish you enjoy the conference, have many good presentations, fruitful discussions and meet new friends.



Dr. Ho Thanh Phong

Rector of International University

Head of Department of Industrial & Systems Engineering

APIEMS 2015 General Chair

MESSAGE FROM THE APIEMS PRESIDENT



On behalf of the Asia Pacific Industrial Engineering and Management Society, I would like to welcome the participants to this year APIEMS Conference. Started in 1998, APIEMS has grown to become the premier conference for industrial engineering and management systems in the Asia Pacific region with participants from all over the world.

I congratulate and thank to Dr. Ho Thanh Phong, Rector of International University, the Conference Chair and his colleagues who have made this conference a successful one. This is the first time the APIEMS held in Vietnam and hope we can come back again! We also welcome IEM professions join APIEMS activities and share their research results and applications.

Wish you had an enjoyable stay and have fruitful discussions at the conference!

A handwritten signature in black ink that reads "Bernard C. Jiang". The signature is stylized with a long horizontal line under the last name.

Bernard C. Jiang, Ph.D, P.E.

Professor of Industrial Management Department and
Vice President of Taiwan National University of
Science and Technology (Taiwan Tech), TAIWAN
APIEMS President (2015-2016)

KEYNOTE SPEECHES

Keynote Speech I

Research Challenges and Opportunities in Reliability Computing



Hoang Pham

Distinguished Professor

Department of Industrial and Systems Engineering

Rutgers University, State University of New Jersey, NJ - USA

Abstract

Reliability computing, which consists of modeling and prediction, has become of great interest in recent years due to spacious arrays of complex systems and applications in our everyday safety, serviceability, security and economic welfare. Modeling is hard but predicting is much harder due to the uncertainties of the system's operating environments and human will when it come to the know-how to use the analysis of complex data and modeling results in order to make effective decisions.

This talk discusses some research challenges and opportunities in reliability computing that focus on the modeling of complex systems, both hardware and software, subject to the uncertainties of operating environments. Reliability computing results and model selections based on various criteria are also discussed.

Brief Bio

Dr. Hoang Pham is a Distinguished Professor and former Chairman (2007-2013) of the Department of Industrial and Systems Engineering at Rutgers University. Before joining Rutgers, he was a Senior Engineering Specialist with the Boeing Company and the Idaho National Engineering Laboratory. He has served as Editor-in-Chief, Editor, Associate Editor, Guest Editor, and board member of many journals. He is the Editor of Springer Book Series in Reliability Engineering, the Editor of World Scientific Book Series on Industrial and Systems Engineering, and has served as Conference Chair and Program Chair of over 30 international conferences.

He is the author or coauthor of 6 books and has published over 135 journal articles, and edited 10 books including Springer Handbook in Engineering Statistics and Handbook in Reliability Engineering. He has delivered over 35 invited keynote and plenary speeches at many international conferences. His numerous awards include the 2009 IEEE Reliability Society Engineer of the Year Award. He is a Fellow of the Institute of Electrical and Electronics Engineers (IEEE) and the Institute of Industrial Engineers (IIE).

Keynote Speech II

Big Data Analytics to Empower Manufacturing Intelligence and Smart Production for Industry 3.5



Chen-Fu Chien

Tsinghua Chair Professor

NTHU-TSMC Center for Manufacturing Excellence

Department of Industrial Engineering & Engineering Management

National Tsing Hua University, Taiwan

Abstract

The leading nations including Germany and USA have reemphasized the importance of manufacturing in the corresponding national competitive strategies such as Industry 4.0 and AMP. The paradigm of production and manufacturing system is shifting, in which the increasing adoption of the multimode sensors, intelligent equipment and robotics, Internet of Things (IOT), and big data analytics have empowered an unprecedented level of manufacturing intelligence. Indeed, various companies are battling for dominant positions in this newly created arena via providing novel value-proposition solutions and/or employing new technologies to enhance smart production. On the basis of our empirical studies with various industries, this talk aims to address emergent issues and propose a strategy called Industry 3.5 as a hybrid strategy between the best practice of existing manufacturing for Industry 3.0 and to-be Industry 4.0 with a number of illustrations of disruptive innovations via data mining and big data analytics. This talk will use some case studies to foster more discussions for future industrial engineering by addressing the revolutionary industry as a whole.

Brief Bio

Chen-Fu Chien is a Tsinghua Chair Professor in National Tsing Hua University, Taiwan. He is PI for the Semiconductor Technologies Empowerment Partners (STEP) Consortium by Ministry of Science & Technology, Taiwan and the Director of the NTHU-TSMC Center for Manufacturing Excellence. From 2005 to 2008, he had been on-leave as the Deputy Director of Industrial Engineering Division in Taiwan Semiconductor Manufacturing Company (TSMC). Dr. Chien has received a number of invention patents, published two books, more than 120 journal papers, and a number of case studies in Harvard Business School. He received National Quality Award, the Distinguished Research Awards from MOST, Distinguished University–Industry Collaborative Research Award from MOEA, University Industrial Contribution Awards from Ministry of Education, and the 2011 Best Paper Award of IEEE TASE etc.

SPECIAL TALK

Why is Uncertainty Theory Useful in Industrial Engineering?



Baoding Liu

Professor

Department of Mathematical Sciences

Tsinghua University, China

Abstract

When no samples are available to estimate a probability distribution, we have to invite some domain experts to evaluate the belief degree that each event will occur. Perhaps some people think that the belief degree is subjective probability or fuzzy concept. However, it is usually inappropriate because both probability theory and fuzzy set theory may lead to counterintuitive results in this case. In order to rationally deal with belief degrees, an uncertainty theory was founded in 2007 and subsequently studied by many researchers. Nowadays, uncertainty theory has become a branch of mathematics for modelling belief degrees.

This talk will introduce some fundamental concepts of uncertainty theory and discuss why uncertainty theory is useful in industrial engineering and management Science. This presentation is based on the speaker's book *Uncertainty Theory* published by Springer-Verlag, Berlin

Brief Bio

Baoding Liu received his B.S. degree in 1986 from Nankai University, and his M.S. degree in 1989 and Ph.D. degree in 1993 from Chinese Academy of Sciences. He joined Tsinghua University as Associate Professor in 1996, and was appointed Professor of Mathematics in 1998. Dr. Liu's research led to the development of *uncertainty theory* that is a branch of mathematics for modeling belief degrees.

TUTORIAL TALK

Recent Advances in Hybrid Metaheuristics for Manufacturing Scheduling



Mitsuo Gen

Professor

Fuzzy Logic Systems Institute

Research Institute for Science and Technology

Tokyo University of Science, Japan

Abstract

Many combinatorial optimization problems (COP) in the real world manufacturing systems impose on more complex issues, such as complex structure, nonlinear constraints, and multiple objectives to be handled simultaneously and make the problem intractable to the traditional approaches because of NP-hard COP. In order to develop an efficient solution algorithm for finding a best solution with the reasonable computational time for NP-hard combinatorial problems, we have to consider the following very important issues: *Quality of solution*, *Computational time*, and *Effectiveness of the nondominated solutions for multiobjective optimization problem (MOP)*.

Evolutionary algorithm (EA) is a subset of metaheuristics, a generic population-based metaheuristic such as genetic algorithm (GA), particle swarm optimization (PSO), and estimation of distribution algorithm (EDA). EA is based on principles from evolution theory, and it is very powerful and broadly applicable stochastic search and combinatorial optimization technique which is effective for solving various NP hard COP models.

This tutorial talk will be firstly introduced a brief survey of several metaheuristics based on EA such as GA, hybrid GA (HGA), multiobjective GA (MoGA), PSO and EDA for applying to various combinatorial optimization problems in real world manufacturing systems. Secondly real applications based on hybrid metaheuristics will be introduced the recent manufacturing scheduling topics such as semiconductor devices final testing scheduling, hard-disc drive devices (HDD) manufacturing scheduling, thin-film transistor-liquid crystal display (TFT-LCD) module assembly scheduling.

Brief Bio

Dr. Mitsuo Gen is a senior research scientist at Fuzzy Logic Systems Institute (FLSI) and visiting professor at Research Institute for Science and Technology, Tokyo University of Science (TUS), Japan. PhD in Engineering: Kogakuin University in 1975 and PhD in Informatics: Kyoto University in 2006. Faculty: Ashikaga Institute of Technology for 1974-2003 and Waseda University for 2003-2010. Visiting Faculty: University of California at Berkeley, 1999-2000; Texas A&M University, 2000; Hanyang University, 2010-2012; and National Tsing Hua University, 2012-2014. Fuzzy Logic Systems Institute, 2009-currently and Tokyo University of Science, 2014-currently.

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- Karim Labadi (EPMI, France)

CONFERENCE SCHEDULE

December 8 th		December 9 th		December 10 th		December 11 th	
09:00 - 17:00	Registration	07:00 - 09:00	APIEMS Fellow Meeting	8:00 - 9:30	IFPR-APR meeting	08:20 - 10:00	Technical Sessions
		09:00 - 09:30	Opening Speech				
		09:30 - 10:30	Keynote Speech 1	09:30 - 10:30	Keynote Speech 2		
		10:30 - 11:00	Coffee Break	10:30 - 11:00	Coffee Break	10:00 - 10:20	Coffee Break
		11:00 - 12:00	Technical Sessions	11:00 - 12:00	Technical Sessions	10:20 - 12:00	Technical Sessions
			Special Talk				
		12:00 - 13:00	Lunch	12:00 - 13:00	Lunch	12:00 - 13:00	Lunch
	Excursion	13:00 - 14:40	Technical Sessions	13:00 - 14:40	Technical Sessions	13:30 – 17 :30	IU + Saigon HTP Tours (Optional)
			Tutorial Talk				
		14:40 - 15:00	Coffee Break	14:40 - 15:00	Coffee Break		
		15:00 - 17:00	Technical Sessions	15:00 - 17:00	Technical Sessions		
			APIEMS Board Meeting				
18:00 - 20:30	Welcome Reception			19:00 - 21:30	Gala Dinner		

TECHNICAL SESSION SCHEDULE

Dec 9 th	Day 1								
11:00 - 11:20	WM1-1	WM2-1	WM3-1	WM4-1	WM5-1	WM6-1	WM7-1	WM8-1	WM9-1
11:20 - 11:40	WM1-2	WM2-2	WM3-2	WM4-2	WM5-2	WM6-2	WM7-2	WM8-2	WM9-2
11:40 - 12:00	WM1-3	WM2-3	WM3-3	WM4-3	WM5-3	WM6-3	WM7-3	WM8-3	WM9-3
12:00 - 13:00	Lunch								
13:00 - 13:20	WA1-1	WA2-1	WA3-1	WA4-1	WA5-1	WA6-1	WA7-1	WA8-1	WA9-1
13:20 - 13:40	WA1-2	WA2-2	WA3-2	WA4-2	WA5-2	WA6-2	WA7-2	WA8-2	WA9-2
13:40 - 14:00	WA1-3	WA2-3	WA3-3	WA4-3	WA5-3	WA6-3	WA7-3	WA8-3	WA9-3
14:00 - 14:20	WA1-4	WA2-4	WA3-4	WA4-4	WA5-4	WA6-4	WA7-4	WA8-4	WA9-4
14:20 - 14:40	WA1-5	WA2-5	WA3-5	WA4-5	WA5-5	WA6-5	WA7-5	WA8-5	WA9-5
14:40-15:00	Coffee Break								
15:00 - 15:20	WA1-6	WA2-6	WA3-6	WA4-6	WA5-6	WA6-6	WA7-6	WA8-6	WA9-6
15:20 - 15:40	WA1-7	WA2-7	WA3-7	WA4-7	WA5-7	WA6-7	WA7-7	WA8-7	WA9-7
15:40 - 16:00	WA1-8	WA2-8	WA3-8	WA4-8	WA5-8	WA6-8	WA7-8	WA8-8	WA9-8
16:00 - 16:20	WA1-9	WA2-9	WA3-9	WA4-9	WA5-9	WA6-9	WA7-9	WA8-9	WA9-9
16:20 - 16:40	WA1-10	WA2-10	WA3-10	WA4-10	WA5-10	WA6-10	WA7-10	WA8-10	WA9-10
16:40 - 17:00	WA1-11	WA2-11	WA3-11	WA4-11		WA6-11	WA7-11	WA8-11	WA9-11
17:00 - 17:20	WA1-12			WA4-12					WA9-12

- ✓ **W:** Wednesday **T:** Thursday **F:** Friday
- ✓ **M:** Morning **A:** Afternoon
- ✓ **1st number** : Session number
- ✓ **2nd number** : Presentation order
- ✓ **Example** : WM1-2 (**Second presentation of Session 1** on Wednesday morning)

Dec 10th	Day 2								
11:00 - 11:20	TM1-1	TM2-1	TM3-1	TM4-1	TM5-1	TM6-1	TM7-1	TM8-1	TM9-1
11:20 - 11:40	TM1-2	TM2-2	TM3-2	TM4-2	TM5-2	TM6-2	TM7-2	TM8-2	TM9-2
11:40 - 12:00	TM1-3	TM2-3		TM4-3	TM5-3	TM6-3	TM7-3	TM8-3	TM9-3
12:00 - 13:00	Lunch								
13:00 - 13:20	TA1-1	TA2-1	TA3-1	TA4-1	TA5-1	TA6-1	TA7-1	TA8-1	TA9-1
13:20 - 13:40	TA1-2	TA2-2	TA3-2	TA4-2	TA5-2	TA6-2	TA7-2	TA8-2	TA9-2
13:40 - 14:00	TA1-3	TA2-3	TA3-3	TA4-3	TA5-3	TA6-3	TA7-3	TA8-3	TA9-3
14:00 - 14:20	TA1-4	TA2-4	TA3-4	TA4-4	TA5-4	TA6-4	TA7-4	TA8-4	TA9-4
14:20 - 14:40	TA1-5	TA2-5	TA3-5	TA4-5	TA5-5	TA6-5	TA7-5	TA8-5	TA9-5
14:40-15:00	Coffee Break								
15:00 - 15:20	TA1-6	TA2-6	TA3-6	TA4-6	TA5-6	TA6-6	TA7-6	TA8-6	TA9-6
15:20 - 15:40	TA1-7	TA2-7	TA3-7	TA4-7	TA5-7	TA6-7	TA7-7	TA8-7	TA9-7
15:40 - 16:00	TA1-8	TA2-8	TA3-8	TA4-8	TA5-8	TA6-8	TA7-8	TA8-8	TA9-8
16:00 - 16:20	TA1-9	TA2-9	TA3-9	TA4-9	TA5-9	TA6-9	TA7-9	TA8-9	TA9-9
16:20 - 16:40	TA1-10		TA3-10	TA4-10	TA5-10		TA7-10	TA8-10	TA9-10

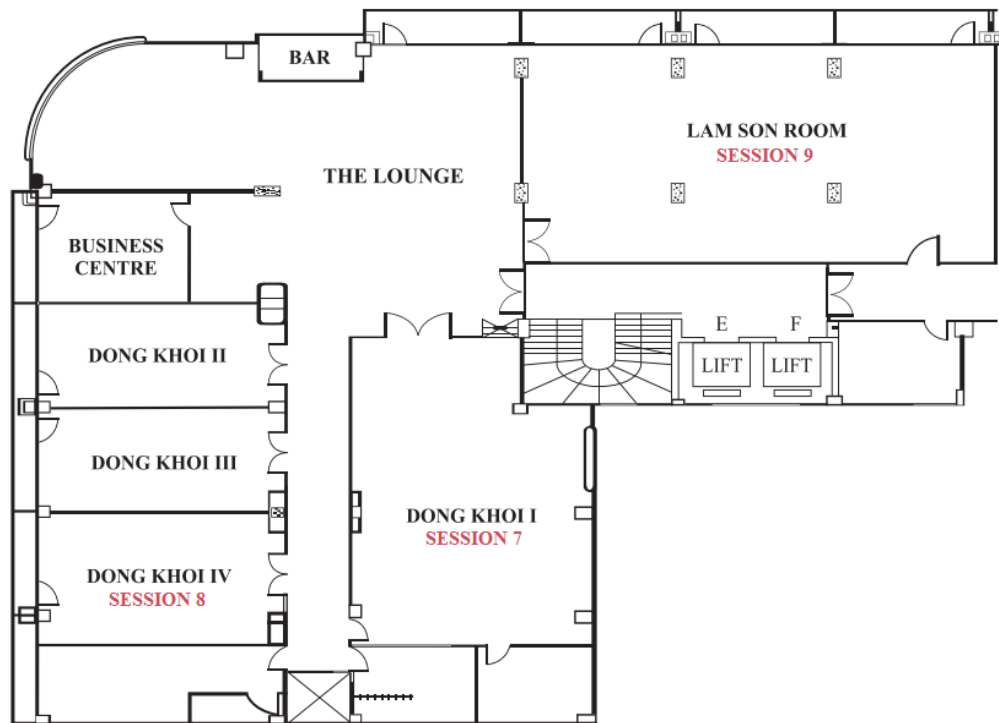
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- ✓ **1st number** : Session number
- ✓ **2nd number** : Presentation order
- ✓ **Example** : WM1-2 (**Second presentation of Session 1** on Wednesday morning)

Dec 11th	Day 3								
08:20 - 08:40	FM1-1	FM2-1	FM3-1	FM4-1	FM5-1	FM6-1	FM7-1	FM8-1	FM9-1
08:40 - 09:00	FM1-2	FM2-2	FM3-2	FM4-2	FM5-2	FM6-2	FM7-2	FM8-2	FM9-2
09:00 - 09:20	FM1-3	FM2-3	FM3-3	FM4-3	FM5-3	FM6-3	FM7-3	FM8-3	FM9-3
09:20 - 09:40	FM1-4	FM2-4	FM3-4	FM4-4	FM5-4	FM6-4	FM7-4	FM8-4	FM9-4
09:40 - 10:00	FM1-5	FM2-5	FM3-5	FM4-5	FM5-5	FM6-5	FM7-5	FM8-5	FM9-5
10:00 - 10:20	Coffee Break								
10:20 - 10:40	FM1-6	FM2-6	FM3-6	FM4-6	FM5-6	FM6-6	FM7-6	FM8-6	FM9-6
10:40 - 11:00	FM1-7	FM2-7	FM3-7	FM4-7	FM5-7	FM6-7	FM7-7	FM8-7	FM9-7
11:00 - 11:20	FM1-8	FM2-8	FM3-8	FM4-8	FM5-8	FM6-8	FM7-8	FM8-8	FM9-8
11:20 - 11:40	FM1-9	FM2-9	FM3-9	FM4-9	FM5-9	FM6-9	FM7-9	FM8-9	FM9-9
11:40 - 12:00	FM1-10	FM2-10	FM3-10	FM4-10	FM5-10	FM6-10	FM7-10		FM9-10
12:00-13:00	Lunch								

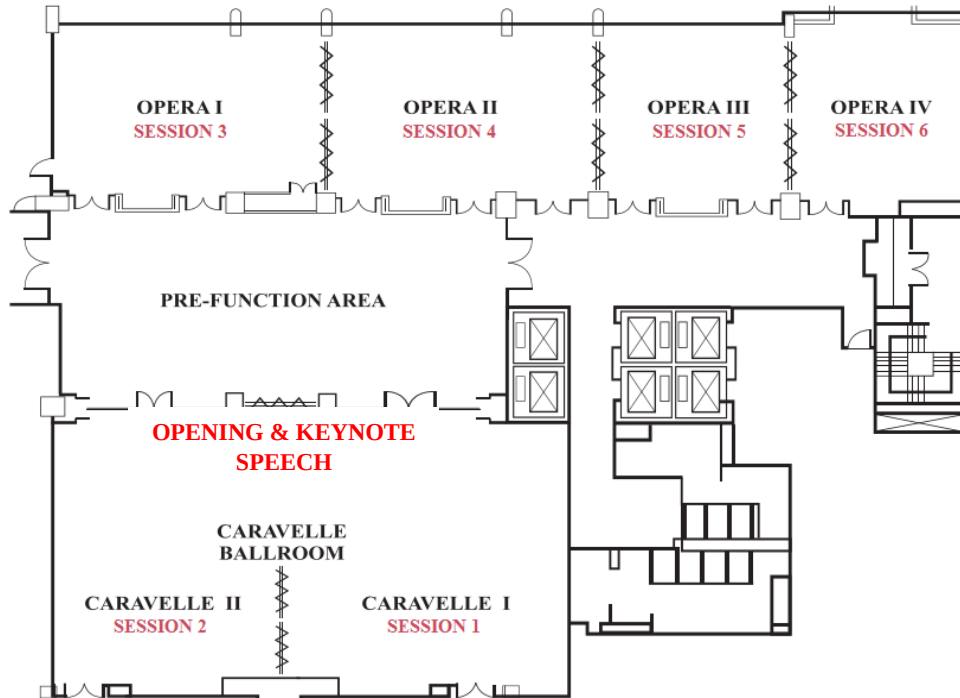
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- ✓ **M:** Morning **A:** Afternoon
- ✓ **1st number** : Session number
- ✓ **2nd number** : Presentation order
- ✓ **Example** : WM1-2 (**Second presentation of Session 1** on Wednesday morning)

CONFERENCE VENUE LAYOUT

CARRAVELLE HOTEL



2nd
Floor



3rd
Floor

Note: - SESSION 5 at day 1 will be changed to **Room 907 - 9th Floor**
- Special Talk, Tutorial Talk, and meetings are at OPERA III

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[TOPIC: DATA MINING](#)

[TOPIC: DECISION MODELING](#)

[TOPIC: E-BUSINESS](#)

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[TOPIC: FINANCIAL - E-BUSINESS](#)

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[TOPIC: QUALITY MANAGEMENT](#)

[TOPIC: RELIABILITY - PROBABILITY MODEL](#)

[TOPIC: SCHEDULING AND SEQUENCING](#)

[TOPIC: SERVICE MANAGEMENT](#)

[TOPIC: SIMULATION](#)

[TOPIC: SUPPLY CHAIN MANAGEMENT](#)

[TOPIC: SYSTEM MANAGEMENT](#)

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TOPIC: COMPUTER AND AI

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December 9th

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An Appropriate Lot Sizing Technique for Decreasing Demand

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Abstract. This paper is concern with the inventory planning of products and theirs corresponding components in theirs end-of-life phase. Following the common planning technique, the Material Requirements Planning (MRP), especially in the lot sizing steps, there are several lot sizing technique that are available to be applied. This paper is trying to find an appropriate lot sizing technique to be applied for the product that has decreasing demand pattern and its component. An empirical study is conducted to be applied for five products using five lot sizing techniques, which are Silver Meal 1, Silver Meal 2, Least Unit Cost, Part Period Balancing, and Incremental technique. The computational study concludes that Incremental lot sizing technique is suitable for this situation.

Keywords: lot sizing, MRP, decreasing demand.

1. INTRODUCTION

In a common supply chain operations, Materials Department of manufacturing company has responsibility to provide materials or components for production. Demand for materials from Production Control Department are always fluctuated by weekly, daily, or even hourly. Production Control Department as an internal customer always checks the requirements of the components and asks the Materials Department to provide the requirements.

There is a situation happened in dependent demand problem when the demand of parent follows certain pattern, such as lumpy demand. Pujawan and Kingsman (2003) explained this is a situation where a demand for an item or component does not occur every period, but rather, there is a large proportion of periods having zero demand. In other case, there is also a situation when the demand of parent follows decreasing demand pattern. Demand for parent is decreasing by time and at certain time; there will be no more demand anymore. In that situation, parent is entering “end-of-life” phase. If that situation happens, there will be a high cost occurs from holding and ordering cost. The component that is purchased no longer used to build the item (parent).

Some researchers in the past have been discussed the inventory problem with decreasing demand problem. Benkherouf (1995) did a research for non-linear decreasing demand which was exponentially distributed using numerical example and his theory. His research used finite planning horizon with zero initial and final inventory. He decided the replenishment quantity to solve the problem.

Benkherouf (1998) did another research with the same characteristic with the previous research, but he added Newton method to his research. The decision variable for his research was the lot size. Chu and Chen (2002) solved an exponential decreasing demand problem using his theory and Newton method. His research used finite planning horizon with zero initial and final inventory. He decided the replenishment quantity. It is noted that, all model solved in Benkherouf (1995), Benkherouf (1998), and Chu and Chen (2002) are deterministic.

Hill et. al. (1999) solved a poisson decreasing demand problem using numerical example and dynamic programming. His research used finite planning horizon with zero initial and final inventory which inventory stock as the decision variable. Different with previous authors, he solved a stochastic model. Ouyang et. al. (2005) solved an exponential decreasing demand problem and constructed EOQ model. They solved the problem by using numerical example and EOQ calculation, then decided the replenishment quantity. Pujawan and Kingsman (2003) solved a lumpy demand problem using lot sizing techniques and decided which lot sizing technique was appropriate to lumpy demand problem.

Goyal and Giri (2003) solved a linear decreasing demand problem by using 5 different methods: Silver; CLUC; CTPP; YZR; and Numerical method. The characteristic of the problem were finite planning horizon with zero initial and final inventory. They decided the number of replenishment quantity. Sicilia et. al. (2011) did a research of exponentially decreasing demand by using numerical example. Theirs research categorized as

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deterministic model. Wee (1995) did a research in exponential – deterministic decreasing demand problem by using numerical example, Newton, and Hollier-Mark. The characteristic of the problem was finite planning horizon with zero initial and final inventories. He decided the lot size in his research. Zhao *et al.* (2001) did a research in linear decreasing demand and construct an Eclectic model. He conducted Silver, CLUC, CTPP, YZR, and Ritchie's Cubic methods. Theirs research used finite planning horizon with zero initial and final inventory. They decided the replenishment quantity as the decision variable of the problem. It was similar from the previous research, but Yang *et al.* (2002) did a research with Parametric Model to determine the replenishment quantity.

After reviewing some papers on decreasing demand problem above, this paper is trying to fill the gap on finding the best lot sizing techniques for decreasing demand problem. An empirical testing methods are conducted by using an example data from 5 items of component and 5 different lot sizing techniques: Silver Meal 1 (SM1), Silver Meal 2 (SM2), Least Unit Cost (LUC), Part Period Balancing (PPB), and Incremental (ICR).

2. EMPIRICAL TESTING METHODOLOGY

The lot sizing problem is exist in a manufacturing company, in which some final products of the company are facing decreasing demand pattern. Each final product consists of a main component that is independent from other product In the testing, there are two alternative solution models conducted to solve the decreasing demand problem. Solution Model 1 is conducted to the problem using 5 different lot sizing techniques only for the components; parents are solved using Lot for Lot (LFL) technique. While, Solution Model 2 is conducted to the problem using 5 different lot sizing technique not only for components, but also for the parents. Both parent and component are solved using similar technique, i.e. if a parent is being solved using LUC, its component also being solved using LUC.

After the calculation of order quantity for each solution model is obtained, the results are compared using Total Cost (TC) calculation see equation (1). The lowest Total cost obtained represents the suitable lot sizing technique for solving decreasing demand problem with dependent demand characteristic. The expression of Total Cost (TC) can be seen in equation 1.

$$\text{Total Cost (TC)} = \sum_i^I (A + (h$$
 (1)

i item index, $i = 1, 2, 3, 4$, and 5

j time index $j = 1, 2, 3, \dots, n$

h holding cost per item i

A ordering cost, it has the same value for each item

S_{ij} inventory on hand per item i per time j

TC Total Cost

Before lot sizing procedures are applied, the demand trend and distribution are checked to ensure the problem follows the decreasing demand problem. Microsoft Excel worksheet is created for assisting the calculation of the order size and the total cost occurred.

There are 5 lot sizing techniques categorized in heuristic calculation and being used in this paper. Lot sizing technique is used to calculate the number of order quantity for each item. The calculation formulas for those techniques are explained as below.

2.1. Silver Meal 1 (SM1)

The objective of the Silver Meal 1 rule is to minimize the sum of ordering and holding cost per period. Based on that objective, the decision for the number of order quantity is taken from the order quantity that provides a minimum periodic cost. The calculation is presented in the equation below.

$$SM1 \rightarrow \min \left[\left(\frac{A + \sum_i^I (h \cdot S_{ij})}{\sum_i^I n_j} \right) \right] \quad (2)$$

2.2. Silver Meal 2 (SM2)

The objective of the Silver Meal 2 rule is the same with Silver Meal 1, to minimize the sum of ordering and holding cost per period. But, in this method zero demands are excluded from calculating the periodic cost. The decision for the number of order quantity is taken from the order quantity that provides a minimum periodic cost.

2.3. Least Unit Cost (LUC)

The objective of the Least Unit Cost rule is to minimize cost per unit incurred in one order that covers some periods. The decision for the number of order quantity is taken from the order quantity that provides a minimum periodic cost. The calculation is presented in the equation below.

$$LUC \rightarrow \min \left[\left(\frac{A + \sum_i^I (h \cdot S_{ij})}{\sum_i^I n_i} \right) \right] \quad (3)$$

2.4. Part Period Balancing (PPB)

The principle of the Part Period Balancing rule is to minimize the difference between ordering and inventory holding cost. Based on that objective, the decision for the number of order quantity is taken from the order quantity that provides a minimum periodic cost. The

Table 1. Total Cost Comparison for Solution Model 1

	SM1	SM2	LUC	PPB	ICR
Component A	\$ 576.24	\$ 560.53	\$ 559.91	\$ 644.00	\$ 506.70
Component B	\$ 819.07	\$ 836.54	\$ 946.17	\$ 924.33	\$ 831.82
Component C	\$ 320.95	\$ 326.90	\$ 379.74	\$ 266.94	\$ 269.94
Component D	\$ 690.89	\$ 659.18	\$ 567.44	\$ 653.65	\$ 637.19
Component E	\$ 301.12	\$ 309.87	\$ 321.33	\$ 354.28	\$ 315.96
Total	\$ 2,708.26	\$ 2,693.02	\$ 2,774.59	\$ 2,843.19	\$ 2,561.61

*) In thousands dollar

Table 2. Total Cost Comparison for Solution Model 2

	SM1	SM2	LUC	PPB	ICR
Component A	\$ 632.08	\$ 1,029.94	\$ 956.87	\$ 546.28	\$ 467.27
Component B	\$ 1,615.57	\$ 1,995.07	\$ 858.84	\$ 652.69	\$ 691.08
Component C	\$ 233.83	\$ 344.53	\$ 360.78	\$ 349.44	\$ 190.86
Component D	\$ 291.73	\$ 284.85	\$ 483.57	\$ 442.43	\$ 463.23
Component E	\$ 334.75	\$ 318.01	\$ 290.98	\$ 255.56	\$ 147.70
TOTAL	\$ 3,107.96	\$ 3,972.40	\$ 2,951.05	\$ 2,246.40	\$ 1,960.13

*) In thousands dollar

calculation is presented in the equation below.

$$PPB \rightarrow \min |A - \sum_i^j (h \cdot S_{ij})| \quad (4)$$

2.5. Incremental (ICR)

The principle of the Incremental rule is to make an order should cover the n th demand if the incremental inventory holding cost incurred by doing so is less than or equal to the ordering cost.

$$ICR \rightarrow \sum_i^j (h \cdot S_{ij}) \leq A \quad (5)$$

3. EMPIRICAL TESTING RESULTS

The problem example that is used in this paper is exponentially distributed and follow decreasing demand trend. This characteristic is provided from model development calculation.

MRP Sheets has been constructed to determine the number of order quantity for 5 Components with 5 different lot sizing techniques: Silver Meal 1(SM1); Silver Meal 2(SM2); Least Unit Cost (LUC); Part Period Balancing

(PPB); and Incremental (ICR) method. Total cost for 130 weeks demands is calculated using Microsoft® Excel 2007. The comparison of total cost for solution model 1 is presented in Table 1.

From Table 1, the minimum total cost for Component A is from Incremental method with \$ 506.70 thousands. For Component B, the minimum total cost is from Silver Meal 1 method with \$ 819.07 thousands. The minimum total cost for Component C is optimized by using Part Period Balancing method with \$ 266.94 thousands. Least Unit Cost method gives the minimum total cost for Component D with \$ 567.44 thousands. While, for Component E the minimum total cost is achieved from Silver Meal 1 with \$ 301.12 thousands. The optimum solution for alternative solution 1 is achieved from total sum of 5 Components using Incremental method with \$ 2,561.61 million. While, the combination from minimum total cost of 5 lot sizing techniques gives \$ 2,461.27 million. It is \$ 100.64 thousands less than using incremental method.

MRP Sheets has been constructed to determine the number of order quantity for 5 Components with 5 different lot sizing techniques: Silver Meal 1(SM1); Silver Meal

2(SM2); Least Unit Cost (LUC); Part Period Balancing (PPB); and Incremental (ICR) method. Total cost for 130 weeks demands is calculated using Microsoft® Excel 2007. The comparison of total cost for solution model 2 is presented in Table 2.

From Table 7.2, the minimum total cost for Component A is from Incremental method with \$ 467.27 thousands. For Component B, the minimum total cost is from Part Period Balancing method with \$ 652.69 thousands. The minimum total cost for Component C is optimized by using Incremental method with \$ 190.86 thousands. Silver Meal 2 method gives the minimum total cost for Component D with \$ 284.85 thousands. While, for Component E the minimum total cost is achieved from Incremental method with \$ 147.70 thousands. The optimum solution for solution model 2 is achieved from total sum of 5 Components using Incremental method with \$ 1,960.13 million. While, the combination from minimum total cost of 5 lot sizing techniques gives \$ 1,743.36 million. It is \$ 216.76 thousands less than using incremental method. The results from two solution model using Incremental (ICR) method give the minimum total cost with \$ 2,561.61 and \$ 1,960.13 million. But, the result from solution model 2 is lower than solution model 1 with \$ 601.48 thousands difference. It represents that the solution model 2 is the optimum solution to solve decreasing demand problem.

4. CONCLUSION

After conducting two solution models for inventory policy with decreasing demand problem by using some lot sizing techniques in Microsoft Excel, both solution models give the same result that Incremental method provides the lowest Total Cost (TC). Decreasing demand problem with dependent demand characteristic and exponentially distributed can be solved using Incremental technique.

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