A Research Proposal on Development of Dynamic Manufacturing Theorem, Optimization and Modeling Methodology in a Manufacturing System

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***Abstract*—**The research aims are to develop dynamic manufacturing theorem, perform improvement on optimization methodology using analytical technique and enhance current modeling system in spreadsheet interface through application of dynamic theorem and analytical optimization method. The research begins to search for mathematical theorem to represent dynamic manufacturing system through analysis of simulation data and is validated using real time data from system. The dynamic manufacturing theorem is employed into optimization method through analytical study using Operations Research tools as reference. The result from analytical, statistical and simulation optimization methods are correlated to determine if there is any significant different among these three techniques. Through the establishment of dynamic theorem and an improvement of analytical optimization concept, these two elements are incorporate into modeling system in spreadsheet environment for research model enhancement and compare with current modeling techniques available in manufacturing system.

***Keywords*—**Dynamic Manufacturing Theorem, Modeling System, Optimization Methods.

I. Introduction

Through the establishment of discipline Industrial Engineering and Operations Research, manufacturing system has been studied through static and dynamic environment of mathematics. As the time progresses, researchers, academicians and practitioners have involved in developing mathematics analysis in dynamic environment of manufacturing system.For example, Muhammad Saidi-Mehrabad and Seyedeh Maryam Mirnezami-Ziabari [18] developed a multi-objective mathematical model for dynamic environment in cellular manufacturing system. The authors [18] built a non-linear mathematical model that minimizes cell formation cost, cell load variation and maximizes utilization rate of human resource. Other aspects of manufacturing system such as system reconfiguration on dynamic cellular manufacturing environment have been explored by researchers, academicians or practitioners. One example is Mingyuan Chen [17] explored a mathematical model for system reconfiguration in a dynamic cellular manufacturing system. However, the study which involves product movement from first process to the last process indicates lack of literatures within the search of journals and internet database. The mathematical analysis in this subject has yet received attention due to the introduction of simulation modeling packages such as Pro-Model and Arena which creates models dynamically with data for analysis. With this study, it sets a platform for researchers and practitioners to enhance quantitative analysis in order for the development of mathematics in dynamic manufacturing system.

The methods among mathematical analysis, statistical analysis and simulation analysis are found to be crossed function during optimization activity. It is seen that researchers are using two of these methods for comparison or integrating them to support in order to find solutions to problems (Jason Cong et.al [10], Peter Buchloz et.al[21], Amit K. Gupta and Appa Iyer Sivakumar[1]). However, based on literature survey, there is lack of information to correlate three methods instead of two methods of the relationship among mathematical optimization, statistical optimization and simulation optimization in applications especially under category of manufacturing performance such as output. Therefore, the analytical optimization study focuses on connection between dynamic manufacturing theorem and mathematical optimization method which is correlated with statistical and simulation optimization methods.

Two popular tools to assist in decision making analysis are mathematical models through spreadsheet and simulation modeling. Through the establishment of Industrial Engineering discipline, it is very common to observe the practice of using spreadsheet to analyse manufacturing system. The customized spreadsheet models which are developed by users in manufacturing system are based on mathematical definitions from Industrial Engineering or Operations Research fields with the visual observation on the system. Therefore the research incorporates dynamic manufacturing theorem and analytical optimization into spreadsheet for testing the model between planning and real time data. Through this research, it will enable a breakthrough to minimize the gap between mathematical modeling and simulation modeling which enhances the important of quantitative analysis to support decision making in manufacturing system analysis.

II. Research Problem

The research questions associated with the topic are stated

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for the research study:

a) How to derive dynamic manufacturing system into mathematical theorem?

b) Is there any correlation among analytical using Operations Research tool as reference, statistical and simulation optimization methods which yield same result?

c) How does the application of dynamic manufacturing theorem is applied to analytical optimization method on manufacturing performance response variable?

d) How to link dynamic mathematical theorem and analytical optimization into the development of research model using spreadsheet interface?

e) How does the research model is tested between the theoretical planning and real time data schedule and compares with current available models in the manufacturing system.

III. Research Objectives

The research aims are to develop dynamic manufacturing theorem, study analytical optimization methodology improvement, perform correlation study on optimization methodologies among analytical, statistical and simulation techniques and enhance modeling system through the application of dynamic theorem and analytical optimization method.

IV. Research Hypothesis

The first hypothesis is written as:

H1: The product movement from first process to last process is derived into dynamic manufacturing using completion time at the end of the process as response variable.

Fig.1 illustrates the concept of the first hypothesis methodology.

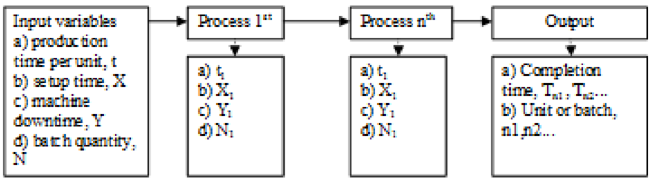

Fig. 1 The Concept Of The First Hypothesis Methodology

The second hypothesis is written as:

H2: There is no significant different on correlation study among analytical using Operations Research tools as reference, statistical and simulation optimization method on output response variable at the end of the process.

Fig.2 illustrates the concept of the second hypothesis methodology.

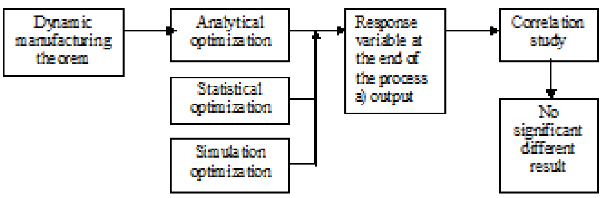

Fig. 2 The concept of the second hypothesis methodology.

V. Practical Implications

The establishment of dynamic theorem in manufacturing system develops new body of knowledge in Industrial Engineering or manufacturing subject. The discovery of improvement on optimization helps to extend the field of Operations Research. The gap between real world system and modeling technique can be narrowed through the study of this research with the application of both dynamic theorem and optimization into modeling system. In the management aspect, the adaptation of dynamic theorem and optimization into modeling system help to improve current decision making models to assess and analyze data nearer to the representation of real world system.

VI. Literature Review

Many textbook were written to expand and convey the knowledge of manufacturing to engineering discipline till today [16,20]. The isolation of production and industrial engineering department in an organization of manufacturing system has caused the modeling technique to be done by individual basis. As a result, there is a huge gap between modeling and real time system as there is communication gap between the departments and their limitation to explore the manufacturing system complexity which is associated to modeling and real time system.

With the advanced of computing and software development such as simulation software, the works which are related to manufacturing system have taken to new level of visualization which the purpose is to bridge the gap between theoretical and real time system. Today, more and more practitioners from industrial engineering and production departments including researchers are using enhanced techniques in the manufacturing sector such as simulation, operations research tools and mathematics modeling. This has provided an additional option for researchers and practitioners to further study the complexity of manufacturing system using simulation and mathematical modeling techniques with an improved methodologies. For example, researchers could use the simulation and mathematical modeling techniques to validate their theories of manufacturing system. Chincholkar et. al. [7] presented an analytical model using numerical results that showed the queuing model yielded similar to those of a simulation model. Marsudi et. al. [19] validated the developed mathematical model using spreadsheet has maximum relative error of 10% between simulation and spreadsheet which is below the limit value suggested by Koo et. al. [13].

The techniques of using simulation, operations research tools and mathematical modeling enhance the objective to employ quantitative factor in decision making model of manufacturing system. Researchers had studied various mathematical relationships on the manufacturing system. For instant, R. Venkata Rao and Manukid Parnichkurn [22] developed a methodology based on a combinatorial mathematics based decision making to evaluate of alternative flexible manufacturing system for the industrial application considered. Other researchers, M Savsar and Majid Aldaihani [15] developed a stochastic model to describe the states of a manufacturing system by a set of differential equations. They [15] studied changes of the equations into a set of difference equations at steady state using MAPLE software to analyze performance measures of flexible manufacturing modules under different operational conditions.

Mathematics plays a very important role in manufacturing since the establishment of industrial engineering discipline. Paper calculation analysis and spreadsheet models

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application are common practices which are found in manufacturing system. Jennifer Robinson et. al [11] stated most people in the semiconductor industry today do their capacity planning with spreadsheet. Spreadsheets are increasingly becoming a popular tool as they are used to model a system through the application of mathematics. For example, industrial engineering team produces capacity model while the production team builds planning model and monitoring manufacturing performances such as output or inventory using spreadsheet modeling system. Researchers have started to use combination techniques using simulation and statistical tools to study mathematics on manufacturing system. Anu Maria [3] described a model intended for a simulation study is a mathematical model developed with the help of simulation software. Basem El-Haik and Raid Al-Aomar [4] stated using simulation output data for analysis through appropriate model output analysis method including statistical analysis, experimental design and optimization. The researchers works intend to bring closer to narrow the gap between theory and practice.

Generally, there are two approaches which are used to optimize the manufacturing system. They are simulation optimization model and analytical model optimization model which uses mathematical methodology and incorporates into spreadsheet modeling. Many researchers have been involved in both approaches of optimization techniques. Yaser Ghorbanzard et. al [25] studied production planning optimization in production systems based on product using a mathematical model in a beverage manufacturing. They [25] employed capability of Lingo software in solving mathematical problems using spreadsheet interface. Jingang Liu et. al [12] formulated the production planning problem as a simulation-based multi-objective optimization problem, and adapted a genetic algorithm to search for set of release plans that are near-Pareto optimal. Some researchers compare relationship of optimization methods among analytical, statistical or simulation techniques. Jason Cong et.al [10] developed a framework for deriving a theoretical upper-hand on the sub optimality that is incurred by using deterministic optimum as an approximation for statistical optimum. It is a thorough analysis of statistical optimization compared to conventional deterministic optimization method [10]. The authors [10] indicated the optimizations yield near-identical results by error 0.003% on the average difference. Wen-Chih Huang et. al [24] compared analytical method of queuing model and simulation for container terminal planning. The authors [24] showed the outcomes with and without the classification of ships and berths are located opposite to the outcome obtained from simulation. They [24] indicated the result of the analytical method is not as accurate as that of the simulation. Erhan Kozan [8] developed model as a batch-arrival multi-server queuing system and designated as a stochastic model. In contrast to Wen-Chih Huang et. al [24], Erhan Kozan [8] compared developed model with another analytical model and a simulation approach indicating the results showed that the analytical model can take the place of the simulation model. Some researchers study material usage optimization using analytical method. In the majority of Industrial Engineering or Operations Research textbooks [16,20], they illustrate mainly on the mathematical, and spreadsheet methods of optimization such as inventory models, linear programming models and non-linear programming models. Brenda L. Dietrich and Robert J. Wittrock [6] used a set of linear mathematical relationships in matrix form to be inserted in a computer which determines the optimum number of each material in accordance with linear programming optimization algorithm. The optimization using spreadsheet model which applies mathematical analysis concept is not ruled out as this practice had been seen in some of the textbooks [16,20] and researchers topics analysis [2,25].

This research develops the analysis to narrow the gap between theoretical planning and actual data in the modeling methodology in a dynamic model using spreadsheet interface. Many researchers are found to be involved in such activity [9,23]. The literature review on this topic by some researchers indicating there had been discussion about the theory and practice of modeling in this aspect. In short, both simulation and mathematical modeling technique in developing modeling system of dynamic manufacturing system receive serious attention from researchers. Some researchers compare simulation models in software packages and spreadsheet models which exhibit mathematical modeling technique. Muhammad Marsudi et. al [19] found that both techniques were not much different from authors' integrated deterministic-static feature and stochastic feature into spreadsheet and used the Arena software for validation process of spreadsheet. Baudin, Michel et. al [5] illustrated the differences between spreadsheet and simulation models through the examples of diffusion cell staffing, material flows through a process segment, and the operations of a full fab. Leonardo Chwif et. al [14] explained the comparison between spreadsheet and simulation tools that showing the impact of using these two different approaches on the analysis of a real supply chain case study. In conclusion, the finding on dynamic manufacturing system using mathematical methodology enhances an improved modeling system in realizing the objectives of future models which are to narrow the gap between theory and practice including quantitative enhancement implementation.

VII. Research Methodology

The research begins to search for a dynamic mathematical theorem using completion time response variable which is defined as product movement from first process point to the last process point of a system. Initially, a model to represent manufacturing system is developed using simulation software. The simulation model is run virtually to collect data of completion time response variable. At the same time, data from real time manufacturing system is obtained to validate the simulation model. The data which are collected from simulation model is used to analyze using statistical software in order to arrive into inductive reasoning concept for the development of dynamic mathematical theorem. Once the dynamic mathematical theorem is established, it is used to validate the theorem with some sample data from real time manufacturing system. The established dynamic mathematical theorem is used to support a revised optimization concept from analytical method aspect using Operations Research tools as reference. A study is carried out to deduce the theory of optimization using analytical method with reference from Operations Research tools and employ dynamic mathematical theorem. This deduction reasoning of optimization will later co-relate with other optimization methods which are statistical and simulation tools on output response variable at the end of the process. In addition to this topic discussion, the research is further evaluated with current optimization method which is performed in a company of a manufacturing system. The deduction reasoning of analytical optimization methods and dynamic mathematical theorem are incorporated into modeling technique in order to improve the gap between theoretical planning and real time data of manufacturing system. The research model is compared with current modeling aspect in manufacturing system for discussion. The real time data from manufacturing system are attached to the research model for the testing of the model between theoretical planning and actual manufacturing system. Fig. 3 illustrates the overall view of research design of the study. Fig. 4 shows the process methodology of the study.

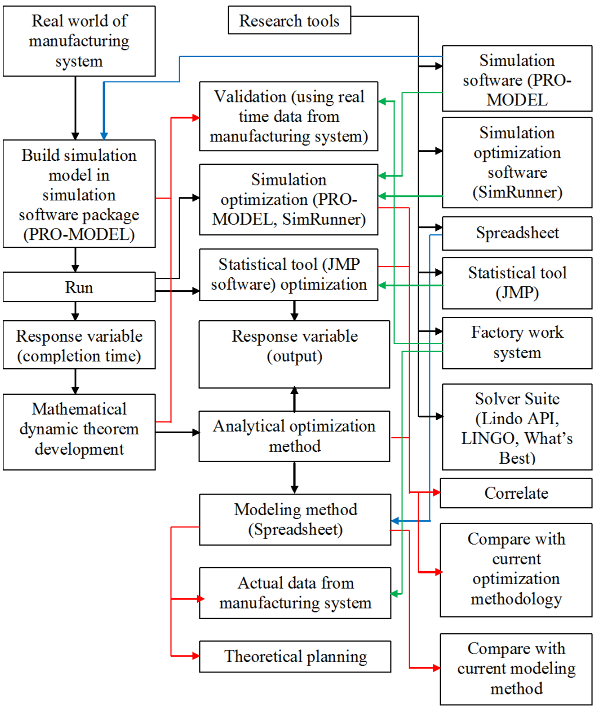

Fig. 3 The Overall View Of Research Design Of The Study

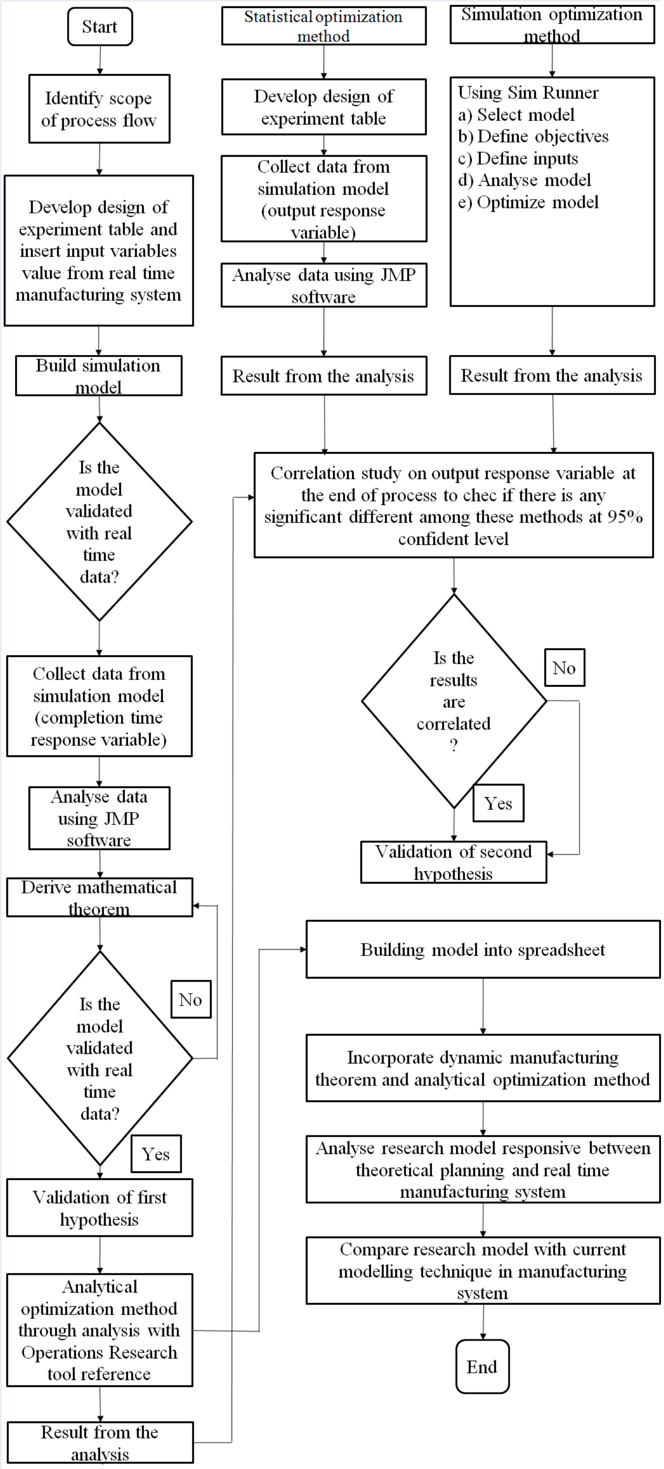

Fig. 4 The Process Methodology Of The Study

VIII. Research Instruments

Table I illustrates the research instruments which are used for this research.

TABLE .I
RESEARCH INSTRUMENTS

Research Instruments	Purpose
Factory work system software	To collect real time data from manufacturing system
Pro-Model	To develop simulation model for deriving dynamic manufacturing theorem. Once the statistical optimization method finds the optimuSm setting for input variables such as production time per unit, machine downtime, batch quantity and setup time, the setting is inserted into simulation model to further collect optimum output response as subject variable to correlate with analytical and simulation optimization methods. In addition, the simulation model is run using Pro-Model software with SimRunner package to perform simulation optimization technique for output response variable.
Sim Runner	To take simulation model from Pro-Model software and perform optimization algorithms to find optimized result on output response variable at the end of process through simulation optimization method.
JMP (Statistical software)	The real time data from manufacturing system are analyzed using JMP software in order to define input data for production time per unit, machine downtime, and setup time. The collected data of completion time response variable using full factorial design of experiment table are inserted into JMP software to derive dynamic manufacturing theorem. In addition, JMP is used to perform optimization of assembly semiconductor manufacturing system through statistical method on output response variable. The unoptimized output response variable data is collected using full factorial design of experiment table as reference through simulation model. Once the optimum setting is achieved on optimized output response variable, the input variables optimum setting are rerun on simulation model from Pro-Model in order to collect optimized output data. The statistical optimization method is correlated with analytical and simulation optimization methods on optimized output response variable.
Excel spreadsheet	To model manufacturing system in theoretical planning and require real time data from system to analyze the model response
Solver Suite (Lindo API, LINGO, What's Best)	One of the Operations Research tools which is Solver Suite software (contains Lindo API, LINGO, What's Best, source: www.lindo.com) to be used as reference to study the analytical optimization method which includes dynamic mathematical theorem.

IX. Originality / Value

The methodology to derive dynamic manufacturing theorem using simulation software, design of experiment and statistical method enables the researchers or practitioners to further explore mathematical theorem in representing the dynamic manufacturing system as an alternative to current solutions using simulation or stochastic analysis. The research correlates the study among three optimization methods which are analytical, statistical and simulation techniques. The building both dynamic theorem and analytical optimization into modeling system improve the representation of actual reality and enhance human decision making models in manufacturing field.

X. Research Potential Result

From this research study, we are expected to obtain findings on:

a) Development of dynamic manufacturing theorem from mathematics equations.

b) Optimization methodology from analytical, statistical and simulation techniques are correlated.

c) Enhancement of research model and model testing between actual data and theoretical planning.

d) Improvement of research model when compared with current available models in a manufacturing system.

XI. Research contribution to Nation

The development of dynamic manufacturing theorem and optimization methods introduce new body of concept to search for an improvement on national economy analysis through quantitative technique. The research modeling methodology enhances the national economy modeling principles to narrow gap between theoretical concept and real time system with better quantitative decision science making for both manufacturing and economy analysis.

XII. Conclusion

This research focuses on mathematical analysis in both optimization and dynamic manufacturing theorem prior to the spreadsheet modeling technique. Past literature indicates many researchers are exploring the complexity of manufacturing system with the assistance of simulation tool, mathematical analysis and the expansion knowledge of industrial engineering and operations research. As a result, many ideas and topics are developed by researchers for the future of realizing the narrow gap between theory and practice which signify the contribution to industrial engineering and operations research disciplines including manufacturing and management societies.

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References

[1] Amit K. Gupta, Appa Lyer Sivakumar. Semiconductor Manufacturing: Simulation Based Multiobjective Schedule Optimization in Semiconductor Manufacturing. WSC'02: Proceedings of the 34th Conference on Winter Simulation: Exploring New Frontiers, Winter Simulation Conference, December 2002.

[2] A.O. Odior, F.A. Oyawale. Application of Mathematical Model to Optimization of the Production Capacity of Paint Manufacturing Company.The Pacific Journal of Science and Technology, Volume 10, Number 1, May 2008. Available from: http://www/akamaiuniversity.us/PJST10_1_178.pdf [Accessed 10 October 2013].

[3] Anu Maria. Introduction to Modeling and Simulation. Proceedings of the 1997 Winter Simulation Conference, Winter Simulation Conference, 1997.

[4] Basem El-Haik, Raid Al-Aomar. Simulation-Based Lean Six Sigma and Design for Six Sigma. John Wiley & Son, Inc, New Jersey, 2006.

[5] Baudin. Michel, Mehrotra , V., Tullis, B., Yeaman, D., Hughes, R.A.

From Spreadsheet to Simulations: A Comparison of Analysis Methods for IC Manufacturing Performance. Semiconductor Manufacturing Science Symposium, IEEE / SEMI International, 1992.

[6] Brenda L. Dietrich, Robert J. Wittrock. Optimization of Manufacturing Resource Planning. International Business Machine Corporation , assignee. Patent US 5630070A. 13 May 1997.

[7] Chincholkar, M.M, Barroughs, T., Herrmann, J.W. Estimating Manufacturing Cycle Time and Throughput in Flow Shops with Process Drift and Inspection. Institutes of Systems Research and Department of Mechanical Engineering, University of Maryland, 2004.

[8] Erhan Kozan. Comparison of Analytical and Simulation Planning Models of Seaport Container Terminals. Transportation Planning and Technology, Vol.20, pp.235-248, 1997.

[9] Geoff Buxey. Production Scheduling: Practice and Theory. European Journal of Operational Research, Volume 39, Issue 1, pages 17-31, March 1989.

[10] Jason Cong, Puneet Gupta, John Lee. On the Futility of Statistical Power Optimization. ASP-DAC'09: Proceedings of the 2009 Asia and South Pacific Deisgn Automation Conference, IEEE Press, January 2009.

[11] Jennifer Robinson, John Fowler, Eileen Neacy. Capacity Loss Factors in Semiconductor Manufacturing, 2003. Avalaible from: www.fabtime.com/files/CapPlan.pdf [Accessed 28 December 2013].

[12] Jingang Liu, Chihui Li, Feng Yang, Hong Wan, Reha Uzsoy. Production Planning for Semiconductor Manufacturing via Simulation Optimization. WSC'11: Proceedings of the Winter Simulation Conference, Winter Simulation Conference, December 2011.

[13] Koo,P.H., Moodie, C.L., Talavige, J.J. A Spreadsheet Model Approach for Integrating static Capacity Planning and Stochastic Queuing Models. International Journal of Production Research, Vol.33, No. 5, pp. 1369-1385, 1995.

[14] Leonardo Chwif, Macros Ribeiro Pereira Barretto, Eduardo Saliby. Supply Chain Analysis: Spreadsheet or Simulation?. WSC'02: Proceedings of the 34th Conference on Winter Simulation: Exploring New Frontiers, Winter Simulation Conference, December 2002.

[15] M. Savsar and Majid Aldaihani. A Stochastic Model for Analysis of Manufacturing Modules. Applied Mathematics & Information Science Journal, Natural Science Publishing Cor.,September 2012. Available from: www.naturalpublishing.com/files/published/7760ttgc3f379n.pdf [Accessed on 5 December 2013].

[16] Martand Telsang. Industrial Engineering and Production Management. S. Chand & Company LTD, New Delhi, 2010.

[17] Mingyuan Chen. A Mathematical Programming Model for System Reconfiguration in a Dynamic Cellular Manufacturing Environment. Annal of Operations Research, Volume 77, Issue 0, pp:109-128, 1998.

[18] Mohammad Saidi-Mehrabad and Seyedeh Maryam Mirezami-Ziabani. Developing a Multi-Objective Mathematical Model for Dynamic Cellular Manufacturing Systems. Journal of Optimization in Industrial Engineering, 2011. Available from: http://www/qjie.ir/?_actioan=showPDF&article-61&_ab=cbdece63Oa0cce29d06436 [Accessed 5 June 2013].

[19] Muhammad Marsudi, Dzuraidah Abdul Wahab, Che Hassan Che Haron. Application of Spreadsheet and Queuing Network Model to Capacity Optimization in Product Development. World Academy of Science, Engineering and Technology, 2009. Available from: www.waset.org/journals/waset/v58/v58-183.pdf [Accessed 18 December 2013].

[20] P.C. Sharma. A Textbook of Production Engineering. S. Chand & Company LTD, New Delhi. 2006.

[21] Peter Bucholz, Alex Thummler. Enhancing Evolutionary Algorithms with Statistical Selection Procedures for Simulation Optimization. WSC'05: Proceeding of the 37th Conference on Winter Simulation, Winter Simulation Conference, December 2005.

[22] R. Venkata Rao & Manukid Parnichkurn. Flexible Manufacturing System Selection using a Combinatorial Mathematics Based Decision Making Method. International Journal of Production Research, Volume 47, Issue 24, October 2009.

[23] Stephen G. Powell. Kenneth R. Baker, Barry Lawson. A Critical Review of the Literature on Spreadsheet Errors. Decision Support System, Volume 46, Issue 1, pages 128-138, December 2008.

[24] Wen-Chich Huang, Tu-Cheng Kuo, Sheng-Chieh Wu. A Comparison of Analytical Methods and Simulation for Container Terminal Planning. Journal of the Chinese Institute of Industrial Engineers, Vol.24, No.3, pp.200-209, 2007.

[25] Yaser Ghorbanzad, Abbas Toloie Eshlaghy, Mohammadali Afshar Kazemi. Optimization of Production Planning Using Mathematical Model (Case Study: Behnoush Iran Company). Interdisciplinary Journal of Contemporary Research in Business, Vol. 4, No. 5, September 2012. Available from http://journal-archieves23.webs.com/845-856.pdf [Accessed 8 October 2013]

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