UNIVERSITI PUTRA MALAYSIA

# *INTER-CELL AND INTRA-CELL FACILITY LAYOUT MODELS UNDER DIFFERENT DEMAND ENVIRONMENTS IN CELLULAR MANUFACTURING SYSTEMS*

SHAHRAM ARIAFAR

**INTER-CELL AND INTRA-CELL FACILITY LAYOUT MODELS UNDER DIFFERENT DEMAND ENVIRONMENTS IN CELLULAR MANUFACTURING SYSTEMS**

**By**

**SHAHRAM ARIAFAR**

**Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfillment of the Requirements for the Degree of Doctor of Philosophy**

**April 2012**

# DEDICATION

Dedicated to my family for their love, encouragement and support

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the degree of Doctor of Philosophy

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**Chairman: Professor Datin Napsiah Ismail, PhD**

**Faculty : Engineering**

Facility layout aims to arrange the facilities, including aisles, machines, instruments and tools in the shop floor to provide an efficient layout. Efficiency of layout has tremendous effects on the performance of the system. Cellular Manufacturing System (CMS), as a promising manufacturing system has emerged to manufacture mid-variety, mid-volume products. In a CMS parts based on their similarities are classified into some groups named part families, and different machines are dedicated to produce these parts. The aim of implementation of a CMS is to take advantages of the similarities in the design and manufacturing of products.

In the design of cellular manufacturing systems, two important decisions should be made; Cell Formation (CF), and Facility Layout (FL). Cell formation aims to group part families and dedicate each part family to one or more machine cells. The literature in the CF is extensive and abundant but layout models have not absorbed the attention of researchers as much as cell formation. Hence, in the first part of the study, a facility layout model in a CMS is developed that considers unknown locations for machine cells. The model minimizes both inter-cell and intra-cell material handling cost. To solve the model, an algorithm based on Simulated Annealing (SA) is developed in C/C++ namely SA1. Comparison of the results with an adapted algorithm from the literature, in terms of the quality of solutions (material handling cost) shows that the proposed algorithm produces better solutions with a maximum of 0.08% error compared to 0.12% error in the benchmarked algorithm. Moreover, the computation time (CPU Time) of the developed SA algorithm is significantly less than the benchmarked algorithm. In the worst case, the proposed algorithm finds good solutions about 50 times faster than the benchmarked.

Cellular manufacturing system is an important technique in the planning and control of manufacturing systems. There are a lot of success stories about its implementation but rapid changes in manufacturing systems may cause a CMS not to perform well in every case. Therefore, it is quite important to investigate the effects of uncertainty of demand of products on the layout of facilities in a cellular manufacturing system. For this purpose, two mathematical models for layout in a CMS are proposed, which considers the stochastic nature of demand. One of the models considers a Normal distribution function for demand, and another one, a Uniform distribution function. In order to validate the models several cases are generated and demonstrated by two methods, Lingo 12.0 optimization software and an enumeration algorithm which is developed in C/C++. The results show that uncertainty in the demand of products can lead to changes in the arrangement of facilities.

In a volatile manufacturing system, implementation of a CMS might not be applicable. In such a situation, the use of a Hybrid Cellular Manufacturing (HCM) seems to be more reasonable. Hence, in another part of this study, a model for layout of facilities in a HCM is developed that considers demand of products varies in the planning horizon. To solve the mathematical model, the SA1 is improved, and called SA2. Comparison of the results shows that the SA2 produces better solution quality in terms of the material handling cost with a maximum of 0.06% error compared to 0.08% error in the SA1. In addition, the computation time (CPU Time) of the SA2 is nearly half of the SA1.

Abstrak of tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

**MODEL SUSUN ATUR KEMUDAHAN INTRO SEL DAN ANTARA SEL UNTUK PERSEKITARAN PERMINTAAN YANG BERBEZA DALAM SISTEM PEMBUATAN SELULAR**

**Oleh**

**SHAHRAM ARIAFAR**

**April 2012**

**Pengerusi: Profesor Datin Napsiah Ismail, PhD**

**Fakulti : Kejuruteraan**

Susun atur kemudahan bertujuan untuk menguruskan kemudahan, termasuk lorong, mesin, instrumen dan alatan di lantai kilang untuk menyediakan susun atur yang cekap. Kecekapan susun atur mempunyai kesan besar terhadap prestasi sistem. Sistem Pembuatan Selular (CMS), sebagai sistem pembuatan yang baru telah muncul untuk mengeluarkan produk pertengahan pelbagai pertengahan isipadu. Dalam CMS bahagian kerja adalah berdasarkan persamaan dan diklasifikasikan kepada beberapa kumpulan yang dinamakan kekeluargaan bahagian, dan mesin yang berlainan berdedikasi untuk menghasilkan bahagian ini. Tujuan pelaksanaan CMS adalah untuk mengambil kelebihan kepada persamaan dari segi reka bentuk dan pembuatan produk.

Dalam reka bentuk sistem pembuatan selular, dua keputusan penting perlu dibuat; Pembentukan Sel (CF), dan Kemudahan Susun Atur (FL). Pembentukan sel

bertujuan untuk mengumpulkan kekeluargaan bahagian dan mendedikasikan setiap keluarga bahagian kepada satu atau lebih sel mesin. Kajian ilmiah dalam CF adalah luas dan banyak tetapi model susun atur yang tidak menarik perhatian penyelidik sebanyak pembentukan sel. Maka, bahagian pertama dari kajian ini, model susun atur kemudahan CMS dibangunkan yang menganggap lokasi sel-sel mesin tidak diketahui. Model ini mengurangkan kos pengendalian bahan untuk kedua-dua antara sel dan intra sel. Untuk model, algoritma berdasarkan penyepuhlindapan tersimulasi (SA) dibangunkan dalam perisian C/C++ dinamakan SA1. Perbandingan keputusan-keputusan dalam soal kualiti penyelesaian (kos pengendalian bahan) menunjukkan yang algoritma dicadangkan menghasilkan penyelesaian yang lebih baik dengan ralat maksimum 0.08% berbanding dengan 0.12% dalam algoritma tanda aras. Tambahan pula, masa pengiraan (CPU Time) algoritma SA yang dicadangkan adalah kurang sekali daripada algoritma tanda aras. Dalam kes paling teruk, algoritma dicadangkan mendapati penyelesaian yang baik kira 50 kali terdahulu daripada tanda aras.

Sistem pembuatan selular adalah satu teknik yang penting dalam perancangan dan kawalan sistem pembuatan. Terdapat banyak kisah kejayaan tentang pelaksanaan nya tetapi perubahan yang pesat sistem pembuatan boleh menyebabkan CMS tidak menunjukkan prestasi yang baik dalam semua kes. Oleh itu, ia cukup penting untuk menyiasat kesan permintaan produk yang tidak menentu bagi susun atur kemudahan dalam sistem pembuatan selular. Untuk tujuan ini, dua model matematik dicadangkan dalam CMS, yang menganggap sifat stokastik permintaan. Satu daripada model menganggap fungsi taburan Normal untuk permintaan, dan satu lagi menganggap fungsi taburan sekata. Dalam usaha untuk mengesahkan model beberapa kes dihasilkan dan ditunjukkan oleh dua kaedah, iaitu perisian pengoptimuman Lingo 12.0 dan algoritma penghitungan yang dibangunkan dalam perisian C/C++. Keputusan menunjukkan bahawa sebarang ketidaktentuan dalam permintaan produk boleh membawa kepada perubahan dalam susunan kemudahan.

Dalam sistem pembuatan yang tidak menentu, pelaksanaan CMS tidak mungkin boleh diterima pakai. Dalam keadaan sedemikian, penggunaan Pembuatan selular Hibrid seolah-olah menjadi lebih munasabah. Oleh itu, dalam bahagian lain kajian ini, model bagi susun atur kemudahan HCM dibangunkan yang mempertimbangkan permintaan pengeluaran berbeza di ufuk perancangan. Untuk menyelesaikan model matematik, teknik SA1 ditambah baik, dan dinamakan teknik SA2. Perbandingan keputusan menunjukkan yang algoritma SA2 menghasilkan kualiti penyelesaian lebih baik dalam soal pengendalian bahan kos dengan maksimum 0.06% ralat berbanding dengan 0.08% ralat daripada SA1. Sebagai tambahan, masa pengiraan (CPU Time) algoritma SA2 ialah hampir separuh daripada SA1.

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At last but not least, I would like to express my sincere thanks to my parents and family; without their support, I would have never accomplished anything.

I certify that a Thesis Examination Committee has met on 5 April 2012 to conduct the final examination of Shahram Ariafar on his PhD thesis entitled "Inter-cell and Intra-cell Facility Layout Models Under Different Demand Environments in Cellular Manufacturing Systems" in accordance with the Universities and University College Act 1971 and The Constitution of the Universiti Putra Malaysia [P.U. (A) 106] 15 March 1998. The Committee recommends that the student be awarded the Doctor of Philosophy.

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Date: 21 May 2012

This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfillment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

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# DECLARATION

I declare that this thesis is my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously, and is not concurrently, submitted for any other degree at Universiti Putra Malaysia or at any other institution.

**SHAHRAM ARIAFAR**

Date: 5 April 2012

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