# Faculty of Manufacturing Engineering

**HUMAN SYSTEM MODELLING FOR LABOUR UTILISATION AND MAN-MACHINE CONFIGURATION AT CELLULAR MANUFACTURING**

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**Doctor of Philosophy**

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# HUMAN SYSTEM MODELLING FOR LABOUR UTILISATION AND MAN-MACHINE CONFIGURATION AT CELLULAR MANUFACTURING

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# DECLARATION

I declare that this thesis entitled "Human System Modelling for Labour Utilisation and Man-Machine Configuration at Cellular Manufacturing" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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## APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Doctor of Philosophy.

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## DEDICATION

To my beloved parents, husband and children.

# ABSTRACT

Manufacturing complexity has become more challenging with increased in demand fluctuation, product customisation and shorter lead time expectation. It is becoming more crucial to measure manufacturing complexity to better recognise and control the various manufacturing components to achieve optimum manufacturing performance. Cellular manufacturing or group technology is a method used to manage manufacturing complexity based on clustering of different types of equipment to process parts. The organisational structure of cellular manufacturing will always need to be flexible for reconfiguration to address rapid changes in customer requirement especially in managing its dual constraints; human and machine. Very often, the human component is overlooked or overestimated due to poor understanding of the effects of human constraints and lack of study is linked to the difficulty to model human's behaviour. The purpose of this study is to develop a human system model to fill the gap in the study of human constraints on cellular manufacturing's performance. As such, a new human system framework focusing on the aspects of human dynamics and attributes was designed to be integrated with the predetermined time standards system in an expert system, eMOST. The new human system model was evaluated for applicability at the actual manufacturing environment through five case studies where accurate labour utilisation and man-machine configuration information were conceived. Thus, the newly defined approach was able to efficiently improve data capture, analysis and model human constraints. The human information from the model was integrated with other manufacturing resources using WITNESS simulation modelling tool focusing on the bottleneck area to further evaluate the dynamic impact of these components on the manufacturing performance. Simulation modelling experiments use has also proven advantageous to change manufacturing configurations and run alternative scenarios to improve the efficiency of the system in terms of the throughput, cycle time, operator utilisation and man-machine configuration. The findings of this study enabled the management to make good decisions to efficiently manage the human resource and better predictions to reconfigure and competently manage resources allocation.

### *ABSTRAK*

*Industri pembuatan menjadi lebih mencabar dengan peningkatan dalam ketidaktentuaan permintaan pelanggan, kepelbagaian produk dan jangkaan masa pengeluaran yang lebih pendek. Kepentingan untuk mengukur kerumitan pembuatan bertambah penting bagi lebih mengenali dan mengawal pelbagai komponen pembuatan untuk mencapai prestasi pembuatan optimum. Pembuatan selular atau teknologi kumpulan adalah satu kaedah yang digunakan untuk menguruskan kerumitan pembuatan berdasarkan pengelompokan jenis peralatan untuk memproses produk. Struktur organisasi pembuatan selular perlu sentiasa menjadi lebih fleksibel untuk dikonfigurasi semula bagi menangani perubahan pesat dalam keperluan pelanggan terutama dalam menguruskan kekangan dual; manusia dan mesin. Komponen manusia sering diabaikan atau dipandang remeh kerana kurang pemahaman mengenai kesan kekangan manusia dan kekurangan kajian dikaitkan dengan kesukaran untuk model tingkah laku manusia. Tujuan kajian ini adalah untuk membangunkan satu model sistem manusia untuk mengisi jurang dalam kajian kekangan manusia kepada prestasi pembuatan selular. Oleh itu, satu rangka kerja sistem manusia baru memberi tumpuan kepada aspek dinamik dan sifat-sifat manusia telah direka untuk disepadukan dengan sistem standard masa yang telah ditetapkan menggunakan sistem pakar, eMOST. Model sistem manusia baru ini telah dinilai kesesuaiannya di persekitaran pembuatan yang sebenar melalui lima kajian kes bagi menghasilkan maklumat mengenai penggunaan buruh dan konfigurasi manusia-mesin yang tepat. Oleh itu, pendekatan yang baru ditakrifkan ini dapat membantu dalam pengumpulan data, analisis dan kekangan manusia dengan cekap. Maklumat daripada model bersepadu ini berserta dengan data sumber pembuatan lain dapat digabungkan di dalam pemodelan simulasi WITNESS untuk menilai lebih lanjut kesan dinamik komponen manusia, mesin dan bahan ini terhadap prestasi pembuatan. Penggunaan kaedah model eksperimen simulasi juga sangat efektif bagi menukar konfigurasi pembuatan dan menjalankan senario alternatif untuk meningkatkan kecekapan sistem terutama dari aspek jumlah pengeluaran, masa, penggunaan manusia serta konfigurasi manusia dan mesin. Hasil kajian ini membolehkan pihak pengurusan membuat perancangan yang lebih berkesan dalam pengurusan sumber manusia dan membuat jangkaan lebih tepat dalam merangka konfigurasi sumber-sumber pembuatan dengan lebih kompeten.*

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## LIST OF ABBREVIATIONS

| | | |
|---|---|---|
| CCL | - | competency class level |
| CIMOSA | - | open system architecture for computer integrated manufacturing |
| CM | - | cellular manufacturing |
| DES | - | discrete event simulation |
| DHM | - | digital human model |
| EM | - | enterprise modelling |
| ES | - | expert system |
| ESPE-IP | - | bottleneck-centered simulation of personnel structure (German abbreviation) |
| JIT | - | just in time |
| GT | - | group technology |
| HSM | - | human system model |
| HTML | - | hypertext markup language |
| IE | - | industrial engineer |
| ILO | - | international labour organisation |
| MNC | - | multi-national company |
| MOST | - | Maynard operational sequence technique |
| MSI | - | manufacturing system institute |
| MTA | - | method and time analysis |

| | | |
|---|---|---|
| M2M | - | man-to-machine model |
| MTS | - | method and time analysis |
| OEE | - | overall equipment efficiency |
| PDF | - | personal, fatigue and delay |
| PTS | - | predetermined time standard |
| SAT | - | semiconductor assembly and test |
| SDLC | - | system development life cycle |
| SM | - | simulation modelling |
| SOP | - | standard operating procedure |
| TMU | - | time management unit |
| TOC | - | theory of constraints |
| TPS | - | Toyota production system |
| TQM | - | total quality management |
| UPH | - | units per-hour |
| WIP | - | work in progress |

# LIST OF PUBLICATIONS

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1. Abdullah, R., Abd. Hashim, H., Abd. Rahman, M. N., and Salleh, M.R., 2016. Development of Enterprise Human System Modelling Framework in Support of Cellular Manufacturing Lean Operation. *Jurnal Teknologi.* In Press.
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1. Abdullah, R., Abd. Hashim, H., Abd. Rahman, M. N., and Salleh, M.R., 2016. Development of Enterprise Human System Modelling Framework in Support of Cellular Manufacturing Lean Operation. *International Conference on Design and Concurrent Engineering (IDECON 2016).* Langkawi, Malaysia, 19-20 September 2016. UTeM Publisher. In Press.
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# CHAPTER 1

# INTRODUCTION

Chapter 1 explains the background information and the thesis organisation which aims to disclose the originality of this study. Descriptive information is given in the study: background, problem statement, objectives, significance, scope, limitations and thesis structure.

## 1.1 Background

Manufacturing companies strive to meet customer requirement in order to stay competitive in the global market. Listening to the 'voice-of-the-customers' has been the key focus in which companies sought to capture inputs from the customers or better known as gathering customer requirements. In a study of 270 businesses, Ulwick (2002) summarised the customer requirements into solution, specification, need, and benefits. The author further explained that this means providing a solution to the customers with the products they need based on the design specifications that consider aspects such as size, weight, colour, and shape to achieve their specific needs (durable, dependable, and strong) and benefits (long lasting and low cost).

The motivation to conduct this research originates from the author's twelve years working experience leading one of the multinational Company's (MNC) Industrial Engineering Department. Among the major project conducted was the manufacturing manpower productivity improvement due to the increase in manufacturing system complexity and continuous effort to pursue a reduction in cost and cycle time without affecting product quality and production agility. Various aspects contributed to the increase in manufacturing complexity such as high demand fluctuation, high product customization, globalised market demand, stiff cost competitiveness and shorter lead time expectation (Efthymiou et al., 2012). Therefore, the importance to measure the manufacturing complexity is crucial to better comprehend and control the various resources to achieve more efficient production systems (Efthymiou et al., 2014; Hon, 2005).

Over the years, the complex manufacturing issues were tackled through the introduction of various philosophies and methodologies. The Cellular Manufacturing (CM) is an example of a method being used to manage manufacturing complexity. The CM or also known as Group Technology (GT) was introduced based on the concept of clustering different types of equipment to process parts which have similar requirements (Canel et al., 2005; Huber and Hyer, 1985). This is contrary to the traditional type of job shop or batch manufacturing where identical equipment are grouped together resulting in high set-up frequency, reducing capacity and increasing queuing delays (Kannan and Ghosh, 1996).

There has been an increase in CM complexity due to the ever-changing environment and systems variations (Zhang, 2011). Moreover, the organisational structure which mainly comprises of human resources, equipment, material, and procedures will always need to be flexible for reconfiguration in the attempt to address the rapid changes in customer requirement. This is imperative to facilitate the need to meet customer delivery commitment timely and efficiently within all the related engineering and infrastructural support activities (Pandya et al., 1997).

The performance of the CM is determined by the two main components; human and machine or also known as the dual resource constraints (Cesaní and Steudel, 2005). Norman et al. (2002) included process and material in addition to human and equipment to be the major considerations in optimising manufacturing performance. Human competencies are valued as intangible assets of all businesses and are required for nearly all operational activities that affect the manufacturing performance (Morey et al., 2001). Human is also the most flexible component compared to other manufacturing resources (Ajaefobi et al., 2010). Unfortunately, most literature focused is on the equipment and technological aspects thus, undervaluing the importance of human on the production system performance (Digiesi et al., 2009). Since the human element is the most difficult component to be measured (Allender, 2000), there arises the need to model human performance and its effect on the system design, performance, and cost. This author emphasised on the modelling human in the early stage of the design in order to evaluate the effectiveness of the system in terms of the performance and cost.

The success of a manufacturing system modelled at the early stage of the design can tremendously improve with the consideration of human aspects which were typically oversimplified previously. Baines and Kay (2002) stated that the capability of the manufacturing system models is greatly appreciated with the inclusion of human factors much earlier in the system. Thus, this research is set to answer the issue of designing a human system model that can be used in the cellular manufacturing environment to study human performance and to integrate human aspects together with equipment and material to in managing the CM complexity.

## 1.2 Problem statement

Many studies have been conducted in the area of modelling and simulation focusing on the equipment and process in tackling the issues of the cellular manufacturing complexity. However, one of the greatest challenges in manufacturing is the human factor since the roles human plays are often complex and interdependent. Human resource