



**UNIVERSITI PUTRA MALAYSIA**

***SCHEDULING DYNAMIC CELLULAR MANUFACTURING SYSTEMS IN  
THE PRESENCE OF COST UNCERTAINTY USING HEURISTIC METHOD***

**AIDIN DELGOSHAEI**

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By

**AIDIN DELGOSHAEI**

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

**January 2016**



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## **DEDICATION**

I Sincerely dedicate all my efforts to my beloved parents who support me in every moments of my life.



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Abstract of thesis presented to the senate of Universiti Putra Malaysia in fulfillment of requirement of the Degree of Doctor of Philosophy

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**AIDIN DELGOSHAEI**

**January 2016**

**Chair : Mohd Khairol Anuar Mohd Ariffin, PhD**  
**Faculty : Engineering**

Nowadays in production rivalry world, designing appropriate layouts and locating machines is an important step in lean production which can increase the performance of a manufacturing system. Cellular Manufacturing Systems covers a wide range of industries. Cost uncertainty which can happen as a result of market changes and inflation rate, is a big concern in scheduling cellular systems as they may impose financial harms to a manufacturing system. Initial investigation in the literature of the CMS studies reveals that the issue uncertain cost in CMS is less developed. It is assumed that a strong production planning can smooth the consequences of uncertain costs in CMS. In this regard, 4 mathematical programming models are developed for forming cells and scheduling the materials on appropriate machines while the system costs are considered uncertain. Since the proposed models (like similar models in the literature) are likely to fall into local optimum points, a Branch and Bound based heuristic, a hybrid Simulated Annealing and Genetic algorithm, a hybrid Tabu search and Simulated Annealing, a hybrid Genetic algorithm and Simulated Annealing, a hybrid Ant Colony Optimization and Simulated Annealing and a hybrid Multi-layer Perceptron and Simulated Annealing algorithms are developed. Then, design of experiments is used to examine the sensitivity of the parameters of each solving algorithm using Taguchi method. Afterward, the proposed solving methods are verified using 17 data sets from the literature and results are analyzed. Results show that during the part-routing process in a normal manufacturing circumstance, nearer set of required machines for producing a product are employed more than other parallel machines. This phenomenon can cause increasing machine-loads in such cells and may lead to machine-load variation in set of closer machines while other machines are allocated less (or even left idle). It is observed that in 67% of studied cases, inflation rate can strengthen cell load variation. To prevent this event a new method is proposed using the statistical process control terms (SPC) which prevent allocating each machine type more than a dynamic upper limit of average of a machine type inside a cell. Results show that in 96.7% of studied cases, the proposed method can significantly prevent machine over allocating in cellular manufacturing systems. While machine broken comes into account, it is found that machine unreliability can cause increasing machine-load variation and strengthen the system imbalance as well. It is also found that using appropriate preventive maintenance program can cause up to 75% reduction in cell-load variation. Similarly using a proper plan for promoting human resources can

significantly reduce cell load variation (76% of studied cases). After designing a cellular manufacturing system and during constructing period, it is shown that using an appropriate backward method to maximize the Net Present Value of activities can be used as a tool for reducing the financial harms imposed by uncertain costs.



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

**PENJADUALAN DINAMIK CELLULAR SISTEM PEMBUATAN DENGAN  
KEHADIRAN KETIDAKTENTUAN KOS MENGGUNAKAN KAEDAH  
HEURISTIC**

Oleh

**AIDIN DELGOSHAEI**

**Januari 2016**

**Pengerusi : Mohd Khairol Anuar Mohd Ariffin, PhD**  
**Fakulti : Kejuruteraan**

Pada masa kini, dalam persaingan industri pengeluaran rekabentuk susun atur yang sesuai dan mesin pengesan adalah satu langkah penting dalam pengeluaran tanpa lemak yang boleh meningkatkan prestasi sistem pembuatan. Sistem Pembuatan Selular meliputi pelbagai industri disamping kos yang tidak menentu yang boleh berlaku akibat daripada perubahan pasaran dan kadar inflasi. Hal ini membimbangkan dalam penjadualan sistem selular kerana perkara ini boleh mengakibatkan kemudatan kewangan kepada perindustrian. Siasatan awal dalam kajian Sistem Pembuatan Selular mendedahkan bahawa kos tidak tetap dalam Sistem Pembuatan Selular adalah kurang memuaskan. Perkara ini dianggap bahawa perancangan pengeluaran yang tinggi boleh merugikan akibat kos tidak menentu Sistem Pembuatan Selular. Dalam hal ini, empat model pengaturcaraan matematik dibangunkan untuk membentuk sel-sel dan penjadualan bahan pada mesin yang sesuai sambil kos sistem adalah dianggap tidak menentu.

Model yang dicadangkan seperti model yang sama dalam kajian mempunyai kebarangkalian jatuh ke dalam titik optimum, cawangan dan terikat berasaskan heuristik, penyepuhlindapan hibrid simulasi dan algoritma genetik, carian tabu hibrid dan penyepuhlindapan simulasi, algoritma genetik hibrid dan simulasi penyepuhlindapan, pengoptimuman koloni semut hibrid dan penyepuhlindapan simulasi dan pelbagai lapisan perceptron hibrid dan algoritma penyepuhlindapan simulasi dibangunkan. Rekabentuk eksperimen digunakan untuk memeriksa sensitiviti parameter setiap algoritma dalam menyelesaikan masalah menggunakan kaedah Taguchi. Selain itu, penyelesaian menggunakan 17 set data daripada kajian dan keputusan dianalisis. Keputusan menunjukkan bahawa semasa proses pembuatan biasa, set mesin yang diperlukan untuk menghasilkan produk yang bekerja lebih daripada mesin selari lain. Fenomena ini boleh menyebabkan peningkatan beban mesin dan boleh membawa kepada perubahan beban mesin dalam set mesin berdekatan manakala mesin lain kurang diperlukan.

Menurut kajian, diperhatikan bahawa dalam 67% kadar inflasi boleh menguatkan perubahan beban sel. Untuk mengelakkan kejadian ini, satu kaedah baru dicadangkan menggunakan istilah kawalan proses statistik yang menghalang setiap jenis mesin lebih



daripada had atas yang dinamik purata jenis mesin di dalam sel. Keputusan kajian menunjukkan 96.7% daripada kaedah yang dicadangkan ketara boleh mencegah mesin melebihi had dalam sistem pembuatan selular. Bagi mesin yang rosak, didapati bahawa mesin tidak berfungsi boleh menyebabkan peningkatan perubahan beban mesin dan mengukuhkan ketidakseimbangan sistem juga. Ia juga mendapati bahawa menggunakan program penyelenggaraan yang sesuai boleh menyebabkan pengurangan sehingga 75% dalam variasi sel beban. Begitu juga menggunakan pelan yang betul untuk mempromosikan sumber manusia boleh mengurangkan variasi beban sel 76% daripada kes yang dikaji. Selepas rekabentuk sistem pembuatan selular dan tempoh pembinaan semasa, kajian menunjukkan bahawa dengan menggunakan kaedah ke belakang yang sesuai untuk memaksimumkan nilai bersih boleh digunakan sebagai alat untuk mengurangkan kemudaratan kewangan yang dikenakan oleh kos yang tidak tetap.



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I also thank all other faculty members who helped me prepare this thesis.

“I dedicate my greatest love to my parents for their love, faith and support.”

I certify that a Thesis Examination Committee has met on 19 January 2016 to conduct the final examination of Aidin Delgoshaei on his thesis entitled "Scheduling Dynamic Cellular Manufacturing Systems in the Presence of Cost Uncertainty Using Heuristic Method" in accordance with the Universities and University Colleges 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.

Members of the Thesis Examination Committee were as follows:

**Shamsuddin bin Sulaiman, PhD**

Professor  
Faculty of Engineering  
Universiti Putra Malaysia  
(Chairman)

**Norzima binti Zulkifli, PhD**

Associate Professor  
Faculty of Engineering  
Universiti Putra Malaysia  
(Internal Examiner)

**Faizal bin Mustapha, PhD**

Associate Professor Ir.  
Faculty of Engineering  
Universiti Putra Malaysia  
(Internal Examiner)

**Ahad Ali, PhD**

Professor  
Lawrence Technological University  
United States  
(External Examiner)



---

**ZULKARNAIN ZAINAL, PhD**

Professor and Deputy Dean  
School of Graduate Studies  
Universiti Putra Malaysia

Date: 16 February 2016

This thesis 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:

**Mohd Khairol Anuar Mohd Ariffin, PhD**

Associate Professor  
Faculty of Engineering  
Universiti Putra Malaysia  
(Chairman)

**Zulkifli Bin Leman, PhD**

Associate Professor  
Faculty of Engineering  
Universiti Putra Malaysia  
(Member)

**B.T. Hang Tuah Bin Baharudin, PhD**

Associate Professor  
Faculty of Engineering  
Universiti Putra Malaysia  
(Member)

---

**BUJANG KIM HUAT, PhD**

Professor and Dean  
School of Graduate Studies  
Universiti Putra Malaysia

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Signature: \_\_\_\_\_

Name of

Chairman

Supervisory

Committee : Mohd Khairol Anuar Mohd Ariffin, PhD

Signature: \_\_\_\_\_

Name of

Member

Supervisory

Committee : Zulkifli Bin Leman, PhD

Signature: \_\_\_\_\_

Name of

Member

Supervisory

Committee : B.T. Hang Tuah Bin Baharudin, PhD

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## LIST OF ABBREVIATIONS

|                 |  |
|-----------------|--|
| AB              | Allowed Backorder  |
| ACO             | Ant Colony Optimization  |
| ALINK           | Average Linkage Clustering   |
| ALPHA           | Inter-Cellular Cost  |
| ANN             | Artificial Neural Networks   |
| AOA             | Activity on Arc  |
| AON             | Activity on Node   |
| AR              | Maximum Available Resource   |
| ART             | Adaptive Resonance Theory  |
| B               | Training Budget  |
| BBC             | Black Box Clustering Algorithm   |
| BC              | Backorder Cost   |
| BDF             | Block-diagonal Form  |
| BEA             | Bond-energy Algorithm  |
| Best-observed-F | Best Observed Function   |
| BETA            | Intra-cellular Cost  |
| BFA             | Bacteria Foraging Algorithm  |
| BnB             | Branch and Bound (Algorithm)   |
| BnBLEP          | Branch and Bound with Local Escaping Possibility                                       |
| BP              | Binary Programming   |
| BS              | Batch Size   |
| CASE            | CASE Clustering Algorithms   |
| CC              | Course Cost  |
| CCDCMS          | Capacity Constrained Dynamic Cellular Manufacturing Systems                            |
| CCDCMS-HR       | Capacity Constrained Dynamic Cellular Manufacturing Systems Considering Human Resource |
| CCDCMS-UM       | Capacity Constrained Dynamic Cellular Manufacturing Systems With Unreliable Machines   |
| CDR             | Clustering and Data Organization   |
| CF              | Cash Flow  |
| CFP             | Cell Forming Problem   |
| CL              | Cell Size  |
| CLINK           | Complete Linkage Clustering  |
| CLLA            | Competitive Leaky Learning Algorithm   |
| Cmax            | Maximum Completion Time (Refers To Make Span)  |
| CMS             | Cellular Manufacturing System  |
| CS              | Constant Salary  |
| CSz             | Colony Size  |
| D               | Product Demand   |
| DCA             | Direct Clustering Algorithm  |
| D-CMS           | Dynamic Cellular Manufacturing System  |
| DEA             | Data Envelopment Analysis  |
| DOE             | Design of Experiments  |
| DPA             | Dynamic Part Assignment (Method)   |
| DR              | Depreciation Rate  |

|             |  |
|-------------|--|
| Ds.R        | Discounted Rate  |
| Du          | Duration   |
| e           | Epoch  |
| EE          | Exceptional Element  |
| EMT         | Emergency Maintenance Time                                 |
| ES          | Early Start  |
| ESC         | Emergency Services Cost                                    |
| Eq          | Equation   |
| EVR         | Evaporating Rate   |
| F           | Firing   |
| F.Fcn       | Failure Function   |
| FCM         | Fuzzy C-means Algorithm                                    |
| F-iteration | Function Value in Iteration                                |
| FLC         | Fuzzy Logic Controller                                     |
| FLC-HGA     | Fuzzy Logic Controller And Hybrid of GA                    |
| FR          | Failure Rate   |
| FSP         | Forward Serial Programming                                 |
| G           | Generation   |
| GA          | Genetic Algorithm  |
| GATSP       | Graphical Asymmetric Traveling Salesman Problem            |
| GDP         | Gross Domestic Product                                     |
| GMDAS       | Generalized Mixture Decomposition Algorithmic Scheme       |
| GP          | Genetic Programming  |
| GP-SLCA     | Genetic Programming and Single Linkage Cluster Analysis    |
| H           | Hiring   |
| HRM         | Human Resource Management                                  |
| IP          | Integer Programming  |
| IR          | Inflation Rate   |
| itr         | Iteration  |
| JSC         | Jaccard's Similarity Coefficient                           |
| K           | Machine Purchasing Cost                                    |
| KHM         | K-Mean Harmonic Clustering Algorithm                       |
| KNN         | K Nearest Neighbor   |
| LearnParam  | Learning Parameter   |
| LEP         | Local Escaping Probability                                 |
| LF          | Late Finish  |
| Long.memo   | Long Term Memory   |
| MA          | Machine Capacity   |
| MCDM        | Multi Criteria Decision Making Model                       |
| MCIM        | Machine Component Incidence Matrix                         |
| MG          | Machine Group  |
| MIP         | Mixed Integer Programming                                  |
| MJSC        | Modified Jaccard's Similarity Coefficient                  |
| MLB-SC      | Machine Level Based-Similarity Coefficient                 |
| MLP         | Multi-layer Perceptron                                     |
| MP          | Mathematical Programming                                   |
| MRCPSP      | Multi-mode Resource Constraint Project Scheduling Problems |

|            |  |
|------------|--|
| MRCPSP-DCF | Multimode Pre-emptive Resource-constrained Scheduling with Discounted Cash Flows |
| MST        | Minimum Spanning Tree Algorithm  |
| Mu         | Mutation   |
| MVFCM      | Modified Version of Fuzzy C-means Algorithm                                      |
| NLMIP      | Nonlinear Mixed Integer Programming  |
| NOM        | Initial Number of Machines   |
| NP-hard    | Non-polynomial Hard  |
| NPV        | Net Present Value  |
| OC         | Operator Capacity  |
| OP         | Operation Cost   |
| OPC        | Operation Process Chart  |
| OS         | Outsourcing Cost   |
| OSGTMA     | Operation Sequences Group Technology Machine Assignment Algorithm                |
| P          | Predecessor  |
| PCA        | Part Coding Analysis   |
| PCM        | Possibilistic C-means Algorithm  |
| PerfFcn    | Performance Function   |
| PF         | Part Family  |
| PL         | Preventive List  |
| PMC        | Preventive Maintenance Cost  |
| PMP        | P-median Problem   |
| pop.size   | Population Size  |
| PP         | Progress Payment   |
| PPGA       | Predator-prey Genetic Algorithm  |
| PSO        | Particle Swarm Optimization  |
| PSOKHM     | Particle Swarm Optimization with K-Mean Harmonic                                 |
| PST        | Preventive Service Time  |
| QAP        | Quadratic Assignment Problem   |
| QDDH       | Quadra-directional Decomposition Heuristic                                       |
| r          | Resource Usage of an Activity  |
| R          | Neighborhood Radius  |
| RC         | Resource Capacity  |
| RC-MPSP    | Resource-constrained Multiple Project Scheduling Problem                         |
| RCPSP      | Resource-constrained Project Scheduling Problem                                  |
| RCPSP-DCF  | Resource constrained Project Scheduling Problem with Discounted Cash Flows       |
| ROC        | Rank Order Clustering  |
| S          | Setup Cost   |
| SA         | Simulated Annealing  |
| SCI        | Sub-contractor Capability  |
| SDCWP      | Simultaneous Dynamic Cell Formation and Worker Assignment Problem                |
| Sem.coef   | Similarity Coefficient   |
| Seucc      | Successor  |
| Short.memo | Short Term Memory  |
| SI         | Similarity Index   |

|        |   |
|--------|---|
| SLINK  | Single Linkage Clustering Algorithm                               |
| SOM    | Self-organizing Map   |
| SR     | Skill Rate  |
| SQC    | Statistical Quality Control                                       |
| STD    | Standard Deviation  |
| TAU    | Initial Level of Pheromone  |
| TB     | Training Budget   |
| Tbs    | Tabu List Size  |
| TH     | Time Horizon  |
| TOPSIS | Technique for Order of Preference by Similarity to Ideal Solution |
| TQM    | Total Quality Management  |
| TR     | Training Cost   |
| Tr     | Threshold Value   |
| TS     | Tabu Search   |
| TSP    | Travel Sale Man Problem   |
| UB     | Upper Bound   |
| VS     | Valley-seeking Clustering Algorithm                               |
| W      | Wage  |
| WIP    | Work-in-process   |
| WLINK  | Weighted Linkage Clustering                                       |
| ZETA   | Inspiration Rate  |
| ZODIAC | Zero-one Data Ideal Seed Algorithm for Clustering                 |



## CHAPTER 1

### INTRODUCTION

#### 1.1 Manufacturing Systems and Lean Production

Nowadays in production rivalry world, it is necessary for every manufacturing systems to plan and control the manufacturing process in details from the ordering and receiving raw material until delivery and after sale services to customers. Food, oil, petrochemical, motor vehicle and tobacco are examples of manufacturing industries. Designing appropriate manufacturing systems is an important part of Lean Manufacturing. Tompkins et al. (2003) reported an estimating of over \$250 billion which is spent annually in the United States of America for facility designing, planning and re-planning.

##### 1.1.1 Facility layout

Facility layout is a very important steps in lean production. Generally, scientists classified manufacturing companies to 3 types based on their system design.

a) Flow shop: or multi-product batch plants are employed when all the products in a production line following the same sequence of operations. Ice cream, cookies, lamp and keyboard are good examples of flow shop companies as shown by figure 1.1. Normally assembly line is good for those products which have many similarities in their production process which enables them be produced in one production line. Moreover, due to small changes, the speed of production is usually high and therefore this arrangement is suitable for mass volume production.



Figure 1.1 Icecream production line needs a flow shop design (Icecream Production Line. Retrieved at 21/1/2016 from [www.allposters.com/-sp/Ice-Cream-Production-Line](http://www.allposters.com/-sp/Ice-Cream-Production-Line))

b) Job Shop: in job shop or multi-purpose batch plants, machines are located in shops based on their functions (cutting, welding, press and painting shops). Products can follow different processing sequences according to their Operational Process Chart (OPC) but not necessarily they visit all the stages. Job shop includes wide range of businesses. Most of the assembly products which contain several parts are produced in companies with job shop design like cutting glass company (whom different types of



glasses uses various machines to cut, form or bend), some vehicle parts which needs cutting, pressing, welding and painting as shown by figure 1.2.



Figure 1.2 Functional shops in glass cut company (Bordering, Sekuritting, Punching and Bending) (Arian Shisheh Company. Retrived at 25.05.2013 from [www.arianshisheh.com](http://www.arianshisheh.com).)

c) Group technology: is defined as an engineering philosophy of recognizing similar parts and grouping them in order to take the advantage of similar product designing and producing.



Figure 1.3 Various stages in a GT company (design department, technical department, part families, scheme of a cell) (Amirnia Company. Retrived at 25.05.2013 from <http://www.amirnia.com>)

Figure 1.3 shows Amirnia Company which is considered as a mass producer of various motor vehicle parts. In design department, engineers try to find similarities between

products to make product families. They also try to make best machine groups which can meet production requirements of part families based on their needs. Second image of figure 1.3 shows a training course, which is prepared by technical department, for operators. In this stage, lecturer tries to show similarities in detail for operators. Figure 1.3 shows similar parts in part families and last image shows one of the GT shops which are designed based on part family needs.

Cellular manufacturing systems (CMS) as shown by figure 1.4 is considered as effective way of using group technology by defining manufacturing system as a hybrid system of cells linking the advantages of both the jobbing (flexibility) and mass (efficient flow and high production rate) production approaches (Papaioannou and Wilson, 2010).

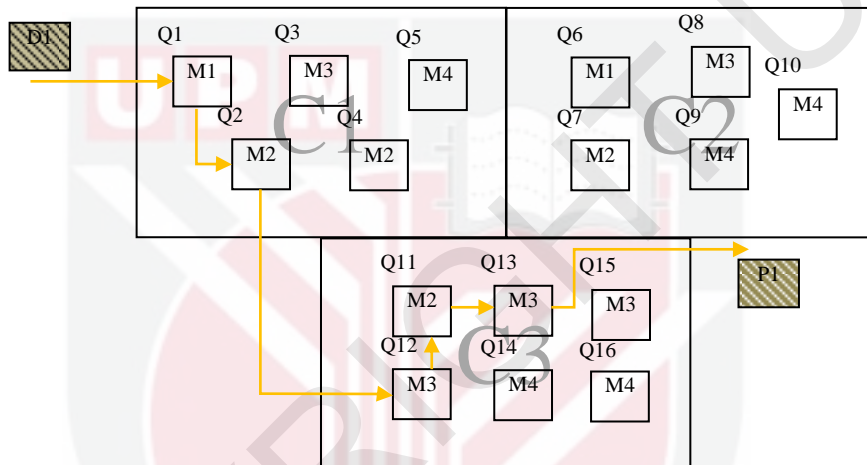


Figure 1.4 A typical layout of a CMS

### 1.1.2 Choosing Cellular Manufacturing Systems

This research focuses on scheduling cellular manufacturing systems. Reasons for such choosing are summarized below briefly:

- a- Cellular Manufacturing Systems covers a wide range of industries Hyer & Wemmerlov (2002). Most of the motor vehicle part manufacturers and electrical home appliances manufacturers use benefits of part family and machine groups in their firms. Machines can be located in cells to rapid up production speed and also reduce set up, production and transportation time and cost as shown by figure 1.3.
- b- During last 2 decades, there are many companies that re-structured their system from job shop and flow shop to cellular manufacturing systems Agarwal (2008).
- c- Cellular manufacturing has a lot of advantages than other traditional systems. CMS can reduce flow time, flow distance, floor space, inventory, handling, scheduling transactions, and scrap and rework. Moreover, cells lead to simplified, higher validity costing, since the costs of producing items are contained within the cell rather scattered in distance and the passage of reporting time (Papaioannou and Wilson, 2010).

Therefore, in this research, cellular manufacturing systems are considered as the main project environment. However, the achievements of this research are also useful for job-shop and flow-shop systems.

## 1.2 Problem statement

Financial aspect is considered as important issue in scheduling cellular manufacturing systems which has direct impact to many areas of manufacturing system studies such as production planning, facility design and utilization. [Shanker & Vrat \(1998\)](#) provided some reasons for considering cost uncertainty in modelling manufacturing systems. They considered cost uncertainties in modelling exceptional elements and bottleneck machines by considering a coefficient in range interval. However, as shown in literature review, the issue of considering uncertain costs in dynamic cellular manufacturing systems is not developed further so far.

Inflation rate is a very important aspect in financial studies which can cause expenses to be changed periodically.

In this research the main aim is to investigate the impacts of inflation rate on scheduling manufacturing systems.

### 1.2.1 Inflation rate and its importance

Inflation is defined as a sustained increase in the general level of prices for goods and services (according to investopedia website). The same resource provided many reasons why inflation rate must be considered but perhaps the most important is that “the entire economy must absorb repricing costs (“menu costs”) as price lists, labels, menus and more have to be updated”.

Results of the recent survey which has been done by trading economics institute shows that that expenses in a society are not fixed and can be varied in short periods (like months and quarters) by inflation rate ([figure 1.5](#)).

| No. | Country   | Calendar   |            |            |            |
|-----|-----------|------------|------------|------------|------------|
|     |           | 04.01.2015 | 05.01.2015 | 06.01.2015 | 07.01.2015 |
| 1   | Malaysia  | 1.9        | 2.8        | 3.1        | 3.5        |
| 2   | Japan     | 3.2        | 3.3        | 1.6        | 1.5        |
| 3   | USA       | 0.9        | 0.8        | 1          | 1.1        |
| 4   | UK        | 1          | 0.9        | 1.1        | 1          |
| 5   | Euro Area | 0.4        | 0.7        | 0.9        | 1          |
| 6   | Germany   | 0.6        | 1.09       | 1.3        | 1.5        |
| 7   | France    | 0.6        | 0.7        | 0.9        | 1.1        |

**Figure 1.5 Monthly inflation rate of some countries (tradingeconomics website. Retrieved at 25/8/2015 from [www.tradingeconomics.com](http://www.tradingeconomics.com))**

Such changes in system costs can have effects on many system costs in manufacturing systems like purchasing raw material, production costs, maintenance, emergency

services, material transferring, warehousing, human resources. Figure 1.6 shows some of costs in a manufacturing system.



Figure 1.6 Various types of system costs may suffer from financial crisis

Beyond inflation rate, there are also some other reasons for cost uncertainty:

- 1) Uncertain market changes (wikinvest website. Retrieved at 26.01.2016 from [www.wikinvest.com](http://www.wikinvest.com))
- 2) Currency drop of a country (investopedia website. Retrieved at 21/8/2015 from [www.investopedia.com](http://www.investopedia.com))
- 3) Global or regional financial crisis (globalissues website. Retrieved at 14.04.2013 from [www.globalissues.org](http://www.globalissues.org))

In this research inflation rate and market changes are considered during the research. Note that the global financial crisis and currency drop is out of the scope of this research and is better to investigate by economic researchers. Moreover, it should be mentioned that dealing with the roots of emerging cost uncertainty in enterprises is out of the scope of this research. Instead, as describe later, our aim is to find ways to reduce the financial harms of such event through happening.

Changing in the costs in short periods may cause difficulties in providing raw material, human resource availability and also can make tremendous effects on costs include transport, production, purchasing, maintenance and even utilization of companies directly or indirectly (figure 1.6).

Hence, it seems necessary to get involve with inflation rate in scheduling manufacturing systems in order to study its negative effects to production systems to set appropriate strategies to smooth the financial harms as much as possible.

### 1.2.2 Important objectives in studying cellular manufacturing systems

As mentioned in section 1.2.1 manufacturing systems have different types of costs. Although all of them are considered in the models that the models that will be developed in chapter 3, but more attention will be done on 4 objectives which are mentioned below.



- **Material Transferring**

As mentioned in section 1.1, in the year 2003, there are more than \$250 billion is spent annually in the United States for facility designing, scheduling and re-scheduling (Tompkins et al., 2003). Of this, a percentage between 20 and 50 belongs to material handling. Using the reported values for GDP that is given in TRADING ECONOMICS® website (contains both production and services expenses); an amount between \$3137 and \$7842.5 billion can be estimated for United States in year 2012 which is noticeable (according to tradingeconomic website). Moreover, it was also reported that an effective planning can reduce such costs over 10% to 30% that can be estimated an amount between \$313.7 and \$2352.75 billion can be saved by using appropriate scheduling.

- **Maintenance and emergency services costs**

Besides, Luxhøj et al. (1997) provided a benchmark over maintenance costs in Scandinavian countries (Denmark, Finland, Sweden, & Norway) and United States. They reported an average between 4.9% and 4.8% of annual turnover was dedicated to maintenance activities in Denmark and Finland respectively in 1991. They also reported that in studied cases, 39% of spent times were related to unforeseen repairs. In Norway, 60% of companies believed that maintenance activities were the major cause of production down time. It is also reported that since 1979 maintenance costs in U.S firms have been raised up 10% to 15% per year. By growing up the industries it can be expected more percentage of annually expenses for maintenance issues. As consequence, maintenance issues (both preventive and emergency) are playing key role in reducing costs of manufacturing company.

- **Human resource costs**

Human resources are another factor that play a key role in manufacturing systems. During year 2013, U.S spent \$7.0 billion for training and employment (according to usgovernmentspending website). Besides, the jobless rate was 6.7% in U.S in the same year. Since then, during last 2 decades, scientists did their best to define and solve facility problems in various circumstances, conditions and situations to find out new ways to reduce such expenses. Hence, appropriate strategies must be defined to reduce part of the financial harms by using appropriate scheduling.

- **Constructing the manufacturing system**

After designing a manufacturing system, the system must be constructed. Since the uncertain costs can also impose financial harms to manufacturing projects, scheduling manufacturing projects is considered as the last objective of this research.

This research focuses on designing and scheduling of cellular manufacturing systems in dynamic conditions where total costs of system including material transferring, maintenance and services of machines, human resources and also constructing costs are uncertain and supposed to be changed through the time by inflation.

### 1.3 Hypothesis, questions and objectives

As mentioned in the section 1.2.1 (last paragraph) the aim of this research is to evaluate the impact of cost uncertainty in CMS and the find appropriate ways to reduce its negative effects. Hence, the hypotheses of this study is considered as follow:

1) *First Hypothesis:*

- {  $H_0$ : Uncertain costs can increase system imbalance
- {  $H_1$ : Opposite of  $H_0$

2) *Second Hypothesis:*

- {  $H_0$ : Using appropriate Scheduling can reduce negative effects of cost uncertainty
- {  $H_1$ : Opposite of  $H_0$

- **Main question:**

After completing the study, it is expected to answer the main question of this study as:

“How an appropriate scheduling can reduce the financial harms of uncertain costs in dynamic cellular manufacturing systems?”

- **Sub-Questions:**

Respecting the topic of the research, the main question can be divided into different subquestions.

- 1) To what extent uncertain costs can increase system entropy?
- 2) How could managers be able to reduce the system imbalance by modifying material transferring between machines?
- 3) How the impact of machine unreliability (service failure) in condition of confronting with uncertain costs event and dynamic customer demands can be reduced?
- 4) How using appropriate human resource strategy can reduce the system costs in the presence of cost uncertainty?
- 5) How using an appropriate method can increase manufacturing systems' profit in the presence of cost uncertainty?

- **Objectives**

The main aim of this research is to reduce impact of cost uncertainty while scheduling cellular manufacturing systems.

According to the main objective of the research the following objectives can be defined as:

- 1) To analyze current scheduling methods of dynamic cellular manufacturing systems.
- 2) To develop appropriate models for designing, scheduling and constructing dynamic cellular manufacturing systems in the presence of cost uncertainty.
- 3) To propose multi-period scheduling methods for evaluating and reducing impact of cost uncertainty on material transferring, machine unreliability, human resource (hiring, firing and training) and constructing cellular manufacturing systems.
- 4) To verify and validate the results of the proposed methods in real industries.

The outcomes of this study will help companies to analyse their systems and be ready to make quick response in condition of confronting with cost uncertainty. Such strategies will also help to schedule parts in cells to minimize system imbalance and subsequently system costs in condition of dynamic part demands and uncertain costs.

#### **1.4 Significance of study**

- 1) Evaluating the impact of cost uncertainty and proposing scheduling methods for CMS by considering material handling, machine reliability and human resource costs. (Contribution of the research)
- 2) New scheduling method(s) will be developed to reduce system costs in the presence of encountering with uncertain costs and dynamic product demands. (Outcomes for applicants)
- 3) This study will also provide a framework for decision makers in CMS-based companies to set proper decisions while encountering with the mentioned condition in real industries. (Application in Industry)

#### **1.5 Achievements and novelties**

As seen in chapter 2, results of studying the literature show us there are some gaps can be filled regarding to CMS studies. Hence, in this study a frame work will be developed to evaluate impact of cost uncertainty on system performance:

- 1) Proposing appropriate multi-period scheduling method(s) for reducing impact of cost uncertainty of material transferring.
- 2) Developing appropriate multi-period scheduling for CMS by considering machine failures in dynamic condition of cost uncertainty.
- 3) Proposing appropriate multi-period scheduling for CMS by considering human resource factor in dynamic condition of cost uncertainty.
- 4) Proposing an appropriate method for increasing profits of activity planning in manufacturing projects.

#### **1.6 Scope and limitation of the research**

The scope of this study is cellular manufacturing factories in condition of confronting with cost uncertainty as shown by [figure 1.7](#). The detailed scope and limitation of the study based on the date of the study (2012-2015) are as follows:

- 1) It is considered that financial crisis is probable to occur in many industries through the world.
- 2) During financial crisis system costs may be uncertain. The product demand can be also dynamic and change from period to period.
- 3) The negative consequences of cost uncertainty can be smoothed and controlled effectively by appropriate production planning.
- 4) To verify findings, the approaches and methods in virtual systems must be examined using simulation. Then in the next step, the proposed approaches shall be validated in real companies to verify the results. Malaysia is considered as project environment.

❑ **Research Domain:**

This research evaluates the impacts of uncertain costs in cellular manufacturing systems under dynamic condition of product demands and proposes appropriate methods for reducing the harms of cost uncertainty.

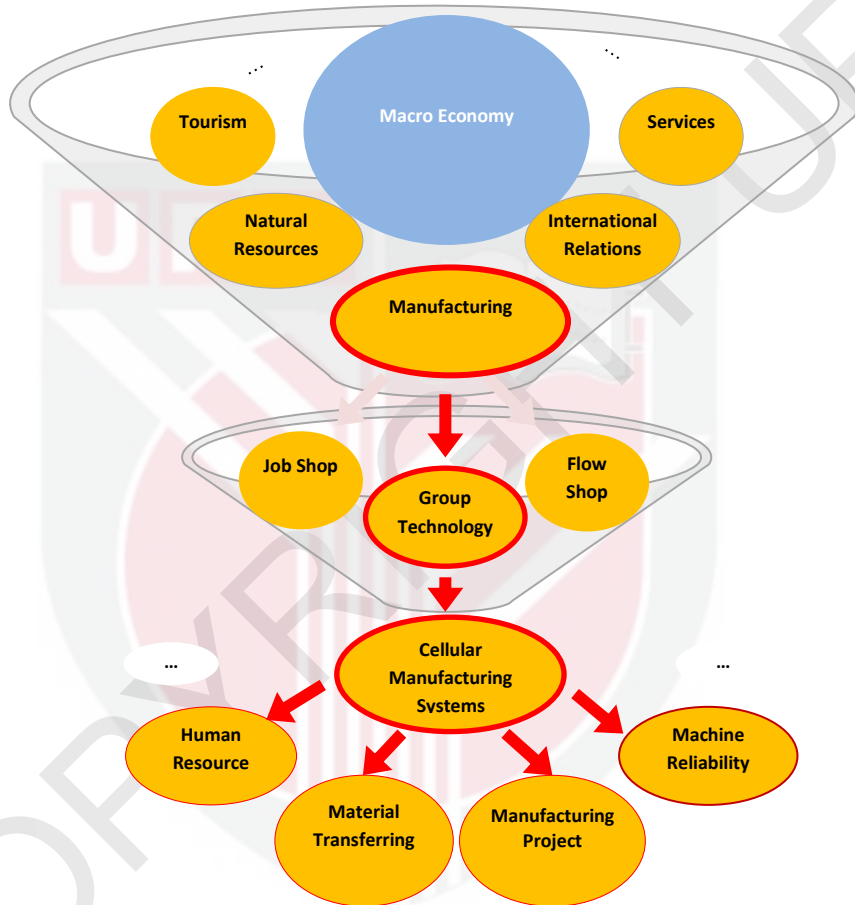


Figure 1.7 A flow diagram for narrowing down and clarifying the scope of the research



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