IOP Conf. Series: Materials Science and Engineering **114** (2016) 012087 doi:10.1088/1757-899X/114/1/012087

Simulation Modeling by Classification of Problems: A Case of Cellular Manufacturing

K N Afiqah[1, 2,6] and Z R Mahayuddin[1, 3]

[1]Center for Artificial Intelligence Technology (CAIT), Faculty of Information Science and Technology, Universiti Kebangsaan Malaysia (UKM), 43600 Bangi, Selangor Darul Ehsan, Malaysia

[2]Email: afiqahka@siswa.ukm.edu.my
[3]Email: zainalr@ukm.edu.my

Abstract. Cellular manufacturing provides good solution approach to manufacturing area by applying Group Technology concept. The evolution of cellular manufacturing can enhance performance of the cell and to increase the quality of the product manufactured but it triggers other problem. Generally, this paper highlights factors and problems which emerge commonly in cellular manufacturing. The aim of the research is to develop a thorough understanding of common problems in cellular manufacturing. A part from that, in order to find a solution to the problems exist using simulation technique, this classification framework is very useful to be adapted during model building. Biology evolution tool was used in the research in order to classify the problems emerge. The result reveals 22 problems and 25 factors using cladistic technique. In this research, the expected result is the cladogram established based on the problems in cellular manufacturing gathered.

1. Introduction

As manufacturing industry keep develops to cope with the challenging requirements demand, group technology is one of the options available to achieve the goal. The proposed research approach is to analyse the problems emerge in cellular manufacturing by exploiting the analogy with biological evolution tool. The papers reviewed are collected from previous conference papers and journals. There were almost 100 papers were completely reviewed and few factors had been identified to be taken in account during data collection. The first introduction section presenting problems obtained from previous research. Figure 1 shows problems classification in cellular manufacturing. These problems were classified to few categories in cellular manufacturing.

Based on 100 papers reviewed, 43 percent problems were categorized in the minor category. Minor category consists of minor problems in various aspects. Problems include in this category are: i) To optimize scheduling system; ii) To convert MTS (make to stock) to MTO (make to order) system; iii) To investigate the relation between routing flexibility and correspondent cost; iv) To reduce total intracellular part movement distance and v) To reduce total intercellular part movement distance. Second highest proportion is performance category at 26 percent. Problems in the category including: i) Efficiency of workers: ii) Efficiency of utilization machine; iii) Efficiency of cell formation; iv) Efficiency of cell layout and v) Performance in cell. However, performance in cell usually focused on labor efficiency and cost variances due to complexity of measurement system.

[6] ACKNOWLEDGEMENT
This research is supported by Ministry of Higher Education Malaysia Research Grant Scheme of **FRGS/2/2013/ICT01/UKM/02/4**

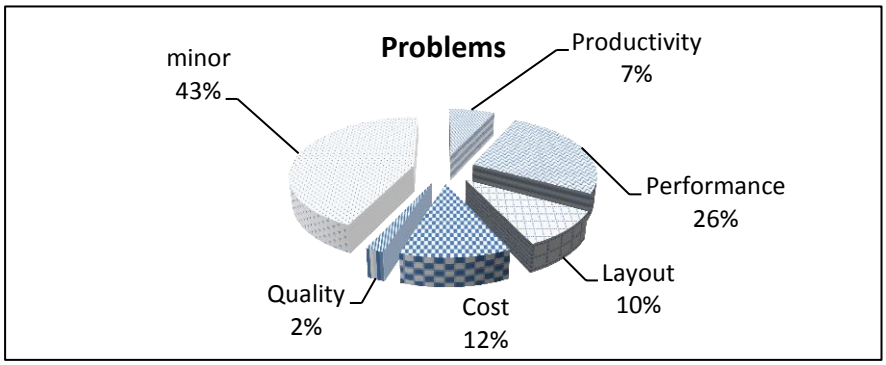

Figure 1. Problem Classification Pie Chart

Based on the reviewed research papers, 12 percent from them have pointed cost issues. Cost category includes six problems which are: i) Machine set up cost ; ii) Total material handling cost; iii) Holding inventory cost; iv) Backorder cost ;v) Reconfiguration cost and vi) Investment cost. 10 percent from the chart shows that layout category is in the third rank lowest located. Generally, layout category describes formation of cells in the shop floor with the issues taken. It focuses on physical allocation of equipment and work stations at the shop floor [1]. Productivity issues take about 7 percent in the pie chart. A part from that, most of the productivity problems involves on how to increase the productivity in the production, how to increase the durability of the product and how to balance workload among the cell. In addition, even though quality is a goal for a modern manufacturing, according to this research, it takes only 2 percent to emphasize quality issues in the shop floor of cellular manufacturing.

2. Manufacturing Evolution

This section briefly presents evolution of processes in manufacturing and cellular manufacturing. The proposed research of the problems and factors classification using the analogy of biological evolution is perfectly apply as it is driven by the same concept. Definition of evolution can be interpreted as the process of developing or gradually developing [2]. Biological evolution presents hypothesis of descent of modification by means natural selection [2]. Cellular manufacturing is undergoing fundamental changes. Therefore, the concept suits to apply to this research. New technologies in manufacturing environment are continuously developed to enhance the system and increase the performance of the manufacturing process. James Scott Baldwin et. al (2013) in their research reported that the first to evolve in manufacturing is *Discrete Manufacturing* which involve management style and power over resources [3]. The changes in management affected process layout in order to achieve optimum production. Thus, more workers are hired and were trained on their expertise to perform significant process. In addition, based on previous research, typical evolution in manufacturing began with the first stage which is labor. Later, after labor problems are solved, technical issues became the problem. Conflict over resources is one of the examples of technical issue [4]. Manufacturing system slowly began to apply few concepts such as JIT, MRP, MRP II, Lean manufacturing and flexible manufacturing to cope with the variety requirements of product demand.

2.1 Cellular Manufacturing Evolution

Changes in cellular manufacturing happen in order to cope with the certain circumstances such as exist of product variants. Problems in cellular manufacturing undergo evolution based on the factors and features possessed. To design a cellular manufacturing system, three basic criteria have been highlighted which are the size of cells, layout of the cells and variation of manufacturing process.

The evolution of cellular manufacturing also involves additional of cells. This happen when new machines are purchase according to the high and variety products [3]. Thus, in order to reduce the cost invested, some of the shop floor change concept to "one worker, multiple machine". However, this concept requires effort in order to broadening operator's tasks [1].

Apart from that, cellular manufacturing develop into more enhance automated and technology integration. As examples in aspect of product processing, material handling, inventories management and raw material management.

3. Method of Classification

According to some of the previous researches related to manufacturing, a biology tool is used to classify and analyze the changes. 'Cladistic' is one of the biology tools which is used in this research in order to help during problems classification. Cladistic is an evolutionary classification scheme that not only describes the attributes of the entities but also the ancestral characteristic [5]. Each path of the evolutionary ancestral in cladistic is developed according to the acquisition and polarity of each characteristics [5]. The branch which exists with few splitting nodes shows a very active evolutionary process that would lead to successful products [9]. The framework for constructing cladistic classification of manufacturing was proposed and adapted from biological approaches [11, 12, 13, 14]. The framework is useful to enhance the performance of manufacturing systems. McCarthy [17] was the first person to approach cladistic technique in order to classify evolution in manufacturing. In addition, McCarthy also the one who concerns regarding organizational systematics, numerical taxonomy and numerical classification. He found the way to construct the manufacturing cladogram and compare result by the difference statistical clustering taxa analysis. Therefore, cladogram is the best accepted approach in biology classification and the most accepted starting point to view the manufacturing evolution and classification [18,19,20]

The first phase of the research is collecting data to identify common problems which appear in cellular manufacturing. 100 research papers have been reviewed including conference papers and research articles to recognize these problems along the factors that caused them. All the information is required to form a matrix table before generating the cladogram. During cladogram generation, there are more than one software were used. In order to get a precise cladogram, comparisons were made between software outputs. Softwares used were Mesquite and WinClada. Even though WinClada was an outdate software, the output given quite satisfying as well as Mesquite. However to decide the most parsimonious cladogram Mesquite output is used.

3.1 Constructing cladogram

Generally, in order to generate a cladogram, the end taxa were chosen along with the characteristics. In this case, after information gathering, problems were identified and represent taxa. Factors of the problems represent characteristics of taxa. Characteristics for the cladogram are divided by two categories which are primitive and derived categories [10]. Thorough further analysis, problems will be located according to two categories. Primitive character is the root of ancestor which is *Plesiormorphy* whereas derived character is the new state, *Apamorphy*.

Based on previous research papers reviewed, 25 characters were recognized causing problems which emerge in cellular manufacturing. Design structure matrix is the tool used in order to represent the interactions between characteristics and it is usually binary based system [15, 16]. Figure 2 identifies those characters along with their state variations and code. For character states column; (0)

means that the problem did not caused by this characteristic and (1) means that the characteristic is the factor of the problem for cellular manufacturing. Figure 3 shows problems recognized in cellular manufacturing along with the data matrix.

	FACTORS	States	Performance Measure
1	ecxessive scrap	0	Absence
		1	Scrap rate
2	Rework	0	Absence
		1	Rework cost
3	Lack of coordination	0	Absence
	(labour)	1	Labor efficiency
4	Flexibility of worker	0	Absence
		1	Workload
5	Efficiency training	0	Absence
	for workers	1	Labor efficiency
6	Productivity low	0	Absence
		1	Production volume
7	Lack of product	0	Absence
	understanding	1	Production volume
8	Excessive inventories	0	Absence
		1	WIP Inventory
9	High machine	0	Absence
	breakdown	1	maintenance cost
10	Machine utilization	0	Absence
		1	Machine efficiency
11	No. of machines	0	Absence
	more than no of worker	1	Labor efficiency
12	High equipment cost	0	Absence
		1	Total cost
13	High allocation of machine cost	0	Absence
		1	Total cost
14	Setup time	0	Absence
		1	Setup cost
15	Total delay time	0	Absence
		1	Backorder cost (delay delivery parts)
16	Bottleneck/ total waiting	0	Absence
		1	Delivery time performance
17	Lead time	0	Absence
		1	Production volume/ produstion rate
18	high setup cost	0	Absence
		1	Total cost
19	high operation cost	0	Absence
		1	Total cost
20	high reconfiguration cost	0	Absence
		1	Total cost
21	High intercellular movement distance	0	Absence
		1	material handling cost
22	High intracellular movemnet distance	0	Absence
		1	material handling cost
23	Space limitation	0	Absence
		1	intra/inter cellular movement cost
24	Machine capacity	0	Absence
		1	Machine efficiency
25	Operation time	0	Absence
		1	Production volume/rate

Figure 2. Characteristics and States Coded

3.2 Parsimony analysis

After listing the data matrix, next step is generating the cladogram. The information is used in softwares in advance to generate most parsimonious cladogram. During cladogram generation, to determine most parsimonious tree is by considering length of tree, retention index (RI) and consistency index (CI) [6] [7]. Consistency index is the relative amount of the *homoplasy* whereas Retention Index calculates the *synapomorphy* expected from the data set that are retained as *synapomorhpy* on the tree [6]. *Synapomorphy* is the trait that shared by two or more taxa present by recent ancestor [7].

	PROBLEM	FACTORS / CHARACTERS																									
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1	To increase productivity	1	1	1	0	1	1	1	0	1	0	0	0	0	1	1	1	1	0	0	0	0	0	0	1	1
2	To increase quality	1	1	1	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	To increase the performance in cell	0	0	1	1	0	1	0	0	1	1	1	0	0	0	1	1	1	0	0	0	1	1	1	1	1
4	To increase the efficiency of cell layout	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	1	1	1	0	1
5	To increase the efficiency of cell formation/sequence	0	0	1	1	1	1	0	1	0	0	1	1	1	1	1	1	1	0	0	0	1	1	1	0	1
6	To increase the efficiency of utilization machine	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1
7	To increase efficiency of workers/operators	1	1	1	1	1	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	To reduce the total intercellular & intracellular part movent distance	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	1	1	0	0
9	To reduce the quantity of operators	1	1	1	1	1	1	1	0	0	0	0	1	1	0	0	1	0	1	1	1	1	1	1	0	0
10	To reduce the total material handling cost	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	1	1	0	0
11	To minimize the holding inventory cost	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1
12	To minimize the backorder	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0
13	To minimize reconfiguration cost	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
14	To reduce investment cost	1	1	1	0	1	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
15	To reduce machine setup cost	1	1	0	1	0	0	1	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0
16	To increase product lifecycle	1	0	1	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
17	To improve the performance	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1
18	To optimize scheduling system	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	1	0	0	0
19	To balance workload among the cell	0	1	1	1	1	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
20	To investigate the relation between routing flexibility and correspondent cos	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0	0	0
21	To minimize space requirement	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	1	1	0	0
22	To convert make-to-stock system to make-to-order system	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0

Figure 3. Data Matrix for Problems in Cellular Manufacturing

The next step after performing the cladogram is based on data evolutionary path for problems identified in cellular manufacturing. Based on the cladogram in figure 4, the black circle shows the homoplasious state and hollow circle shows non- homoplasious state. Homoplasy is character that shared by multiple species due to some roots other than common ancestors. In this case, factors which contribute to same problem other than common ancestors. The term 'homoplasy' can be described as when the taxa shares common characteristic and unrelated taxa evolve the same characteristic independently. According to Hennig Argumentation, all studied taxa came from the same nod [8]. Based on further analysis, the problem categorizations were based on most derived characters.

Basically, character 21 (High Intercellular movement distance) and character 22 (High intracellular movement distance) were placed on top of root and present for taxa in branch I.

Problems which located at branch I that carries character 21 (High Intercellular movement distance) and character 22 (High intracellular movement distance) are ; i) To increase performance in cell; ii) To increase efficiency of cell formation/sequence; iii) To reduce investment cost; iv) To reduce quantity of operators and v) To improve the performance of movement flow. Branch II placed character 23 (Space limitation) on top of the root. Hence, half of the taxa at branch II do not carries

character 21 (High Intercellular movement distance) and character 22 (High intracellular movement distance).

From the case study, the cladogram yields the evolution of the characters for each of the level problems. Based on figure 3, both external branches carry character 21 (High Intercellular movement distance) and character 22 (High intracellular movement distance) as ancestral roots and the problems evolve downwards regarding to characteristic possessed. Branch I possessed character 15 (Total delay time) as one of the common character which takes place after character 21 (High Intercellular movement distance) and character 22 (High intracellular movement distance). There is only one taxa in branch I do not possessed character 15 (Total delay time) which is: i) To reduce quantity of operators. Besides that, branch I carries one character that become *homoplasy*, character 12 (high equipment cost).

There are five sets of splitting at the cladogram. Branch I carries one set of splitting and branch II carries four sets of splitting. Look upon taxon: To convert MTS System to MTO System, cladogram shows character 23 (space limitation) is absence. In addition, character 23 (space limitation) begin to disappear at splitting III and downwards. Figure 5 represents evolution trends occur at the evolutionary path of the classification problems cladogram. There are few sets of splitting in the cladogram shows characters brings fundamental changes for the problems. However, a typical cladogram would show characteristic changes along downwards to primitive characteristics where the situation can be called negative polarity of characters. This research`s cladogram brings different evolutionary path which is even though taxa possessed variation of characteristic downwards, but the situation did not revert to primitive characteristics possessed.

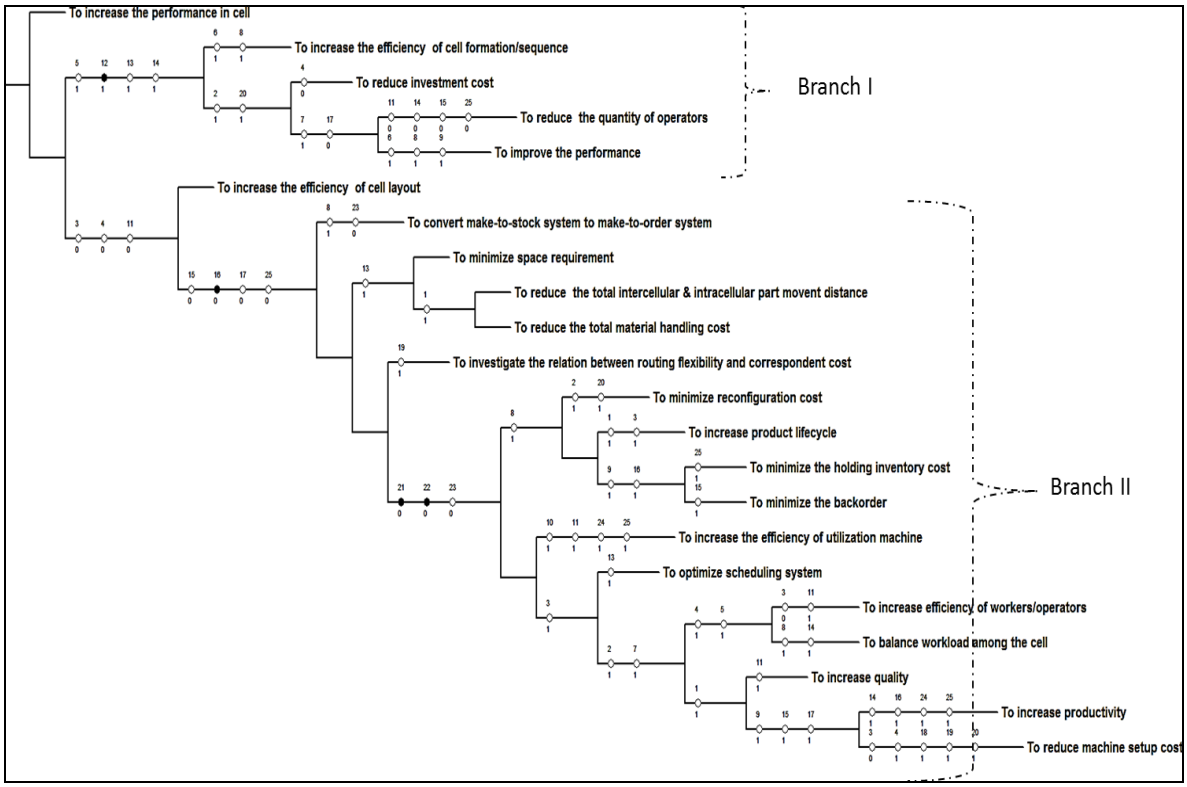

Figure 4. Problems Classification Cladogram

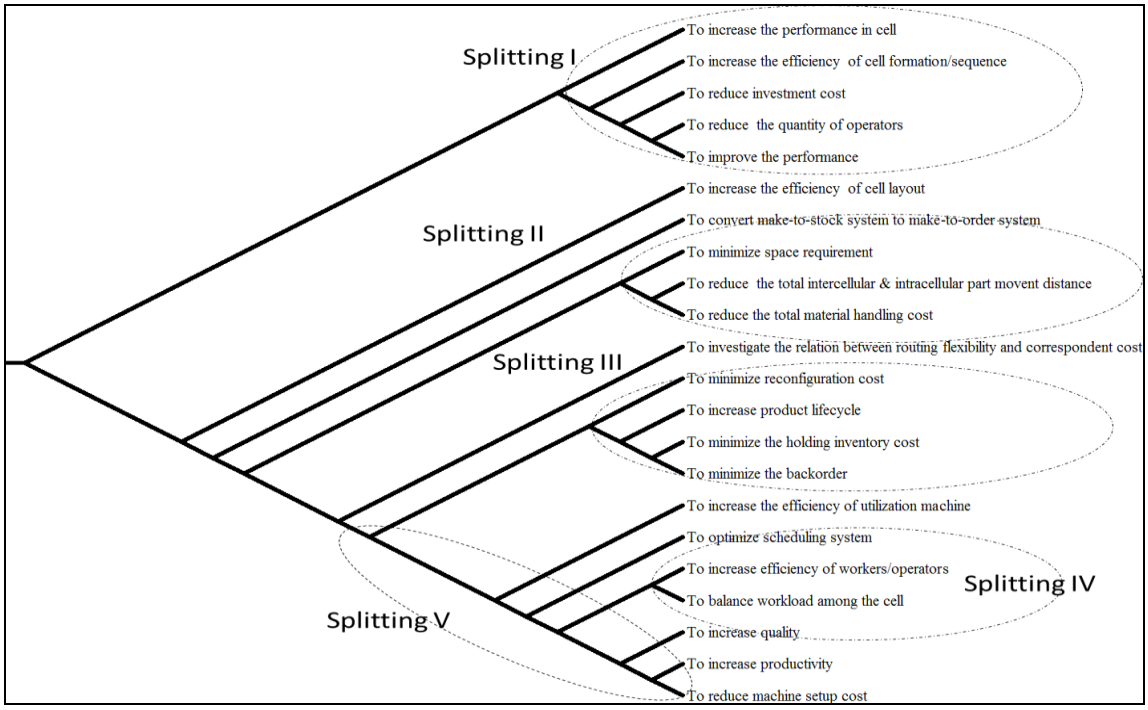

Figure 5. Evolution Trend

At first node, combination character 21 (High Intercellular movement distance) and character 22 (High intracellular movement distance) along with character 9 (High machine breakdown) affect the performance in the cell. Optimization of inter – cell movement corresponds to minimize the inter – cell movement cost and reducing investment cost [22]. Move along downwards of the cladogram, more characters are derived. It is shown that characters 12 (High equipment cost), character 13 (High allocation of machine cost) and character 14 (setup time) caused problems at four taxa downwards. A factory will reconsider to purchase an equipment or machine because of the highly cost equipment. Thus, cells will be rearranged according to existing machine and resulting low efficiency of cell formation. Furthermore, derivation of character 6 (productivity low) and 8 (excessive inventories) contributes efficiency of cell formation. This is because the efficiency in cell formation is measured by total production, time process and the smoothness of flow in the cell. Besides that, by possessing character 2 (rework) and character 20 (high reconfiguration cost), investment cost was emerged. In order to reduce investment cost one have to reduce the rework rate and find a solution approach for reconfiguration cost. Move further downwards, character 7 (lack of product understanding) caused quantity operators problem and performance problem. Due to lack of understanding the product, most of the workers do not understand the importance of the work skill and presents a bad performance.

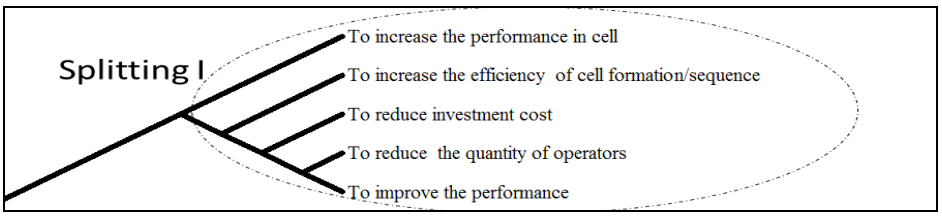

Figure 6. Splitting I

Figure 6 represents splitting I at branch I. From previous explanation, it is known that character 21 (High Intercellular movement distance) and character 22 (High intracellular movement distance) is main characters which caused problems in branch I. In addition, character 23 (space limitation) was also founded to cause all the problems at branch I.

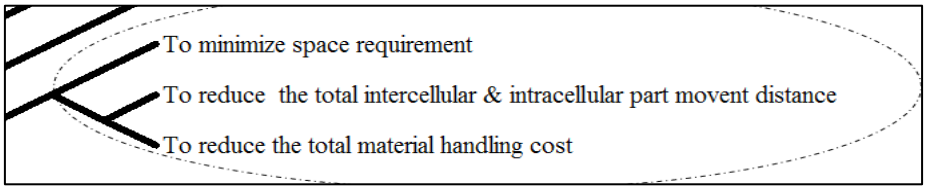

Figure 7. Splitting II

All taxa in splitting II possessed character 13 (high allocation of machine cost). In order to solve limited space requirement, factory planning is needed, however require high cost for machine allocation. Machine allocation cost becomes factor to the other problems as well such as total intracellular and total intercellular movement distance.

Based on figure 8 splitting V consists of two main sets splitting which are splitting III and splitting IV. Splitting V shows the loss of the primitive characters which are character 21 (High Intercellular movement distance) and character 22 (High intracellular movement distance). A part from that, splitting III consists of problems which are caused by character 8 (excessive inventories). However, along with other characteristics appearances, more problems are triggered. Taxon in splitting IV were triggered by characters 4 (Flexibility of worker), character 5 (Efficiency training of workers) and character 6 (Low productivity). In order to create a supportive cell infrastructure, job design and labor task become a vital element of problem. Thus, all the characteristics mentioned previous are logically may cause these problems in splitting IV.

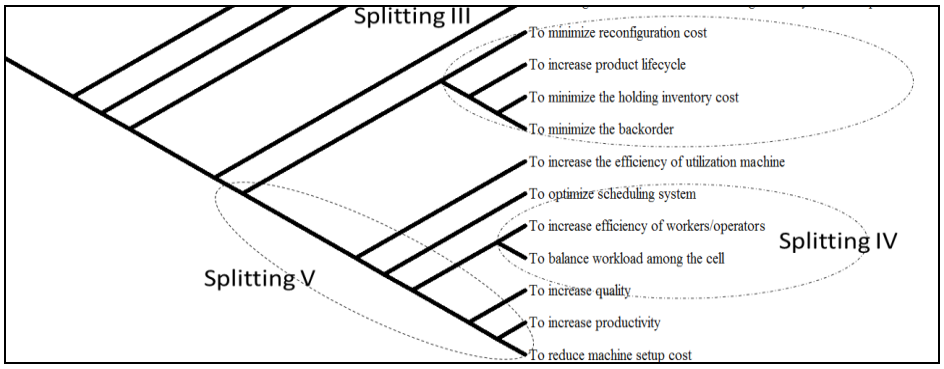

Figure 8. Splitting V

4. Conclusion

Biological analogy has been a subject of method in manufactured products before. Thus, in this research, the biological analogy tool is once again borrowed in order to identify and categorizing problems which happen in cellular manufacturing. Furthermore, this classification technique is very useful in order to build a simulation model for the problems occur in cellular manufacturing. The obtained results may bring a potential future in cellular manufacturing research. Cladistic has shown a new concept in manufacturing issues identification. By rearranging problems in a few groups brings simpler way for a solution approach. In addition, the difficulties of identifying numerous problems in cellular manufacturing enable this technique to be used wisely.

References

[1] Hyer N, 2002 *Cellular Manufacturing - A Platform for Improvement in Reorganizing The Factory* (Productivity Press) p 5-428
[2] Darwin C R 1859 *On the Origin of Species* Origin 1 ed **1**
[3] Baldwin J S, Rose-Anderssen C, Ridgway K, Boettinger F, Michen M, Agyapong-Kodua K and Krain R 2013 The Evolution of Manufacturing SPECIES. *Procedia CIRP*, ***7*** 187–192. doi:10.1016/j.procir.2013.05.032
[4] Chakravorty S S and Hales D N 2008 The evolution of manufacturing cells : An action research study **188** 153–16
[5] Tsinopoulos C and Mccarthy I P 2000 Achieving agility using cladistics : an evolutionary analysis **107** 338–346
[6] AlGeddawy T and ElMaraghy H 2013 Reactive design methodology for product family Technology **6**(1) 34–43 doi:10.1016/j.cirpj.2012.08.001
[7] ElMaraghy H, AlGeddawy H, and Azab A 2008 Modelling evolution in manufacturing: A biological analogy, *CIRP Ann. - Manuf. Technol.*, **57** no. 1, 467–472
[8] Hennig W 1966 *Phylogenetics Systematic* University of Illinos Press
[9] AlGeddawy T, Abbas M, ElMaraghy H, 2014 Design for Mobility – A Customer Value for Creation Approach *Procedia CRP* **16** 128-133
[10] ElMaraghy H, AlGeddawy T and Azab A 2008 Modelling Evolution in Manufacturing: A biological analogy *CIRP Annals – Manufacturing Technology* **57** 467-472
[11] Jeffrey C 1977 *Biological Nomenclature, Systematics Association*, Chapman and Hall **3**
[12] Forey P L Humpries C J, Kitching I J, Scotland R W, Siebert D J, Williams D M, 1992 Cladistics A practical course in Systematics
[13] Minelli A 1994 *Biological Systematics The State of The Art,* Chapman & Hall
[14] Sneath P and Sokal R, 1973 *Numerical Taxonomy, The Principles and Practises of Numerical Classification*, Freeman
[15] AlGeddawy T 2014 A DSM Cladistics model for product family architecture design, *Procedia CIRP* **21** 87-92
[16] Eppinger S D and Browning T R 2012 *Design Structure Matrix Method and Applications, Engineering Systems* MIT Press, Cambridge
[17] McCarthy IP 1995 Manufacturing classification: lessons from organizational systematics and biological taxonomy. *Integr Manufact Syst*
[18] McCarthy IP, Leseure M, Ridgway K and Fieller N. 2000 Organisational diversity, evolution and cladistic classifications. *Int J Manage Sci*.
[19] McKelvey B. 1978 Organisational systematics: taxonomic lessons from biology. Manage Sci 1978;24(13)

[20] McKelvey B. 1982 *Organisational systematics: taxonomy evolution, classification.* Berkeley: University of California Press
[21] Good IJ 1965 *Categorisation of classification. Mathematics and computer science in medicine and biology*. London: H.M.S.O.
[22] Siva P D, Naiju C D, Polu V S and Venkat Likhit B 2014 Optimization of Inter Cellular Movement of Parts in Cellular Manufacturing System Using Genetic Algorithm *Res J App Sci, Eng and Tech* **7(1**) pp165-168