Feasibility Study of Cellular Manufacturing System in a Wooden Furniture Industry: A Case Study

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Abstract

The cellular manufacturing system is a popular and effective method of redesigning a less profitable production layout into a more cost-effective production layout by rearranging the machines of having similar operations and develop a machine cell. In this research, the main goal was to find out the effectiveness of cellular manufacturing systems in the wooden furniture industry, whether it is valid or not to use at such type of industry. First, an existing layout of a wooden furniture industry has been redesigned using the Cellular Manufacturing System (CMS) and clustered into several machine cells as part family. Rank Order Clustering (ROC) has been used to develop the existing layout and establish the part family with machines of having similar operations. The Hollier method has been used to find the layout of the improved design that follows the characteristics of CMS. The feasibility test was done with the use of ARENA simulation software. The simulation showed the result as the amount of production at a unit of time. Finally, a new model was found, which is developed by ARENA Simulation software comparing with the previous one.

Keywords

Group Technology, Rank Order Clustering, Hollier Method, Feasibility Study, Cellular Manufacturing System

1. Introduction

Cellular Manufacturing is the organized approach of the manufacturing process in which the production equipment is organized. Machines are organized into machine cells; each cell specializes in the manufacturing production of a part family. It is the subpart or the application of group technology. It is a manufacturing process, which is the subpart of JIT manufacturing and also lean manufacturing with group technology. The objective of cellular manufacturing is to move as quickly as possible, make varieties of similar products, producing waste in a little amount. This process includes multiple "cells" in an assembly line, and every cell has a machine or different numbers of machines that can do specific work. The exact part goes from a cell to the next cell, each station finishing part of the cellular manufacturing process. The total amount of flexibility is the primary outcome and the foremost advantage of the cellular manufacturing system. So, in this manufacturing process, the quick changeover is possible as the process is very much flexible in nature. The machines are automatic in this process so that a little change can be made quickly when needed.

Cellular Manufacturing is a beneficial approach for an industry as it can reduce the processing time, setup time, walking time of the workers. It is the managerial and also a practical approach for an industry or a factory, in which it can have a positive influence over the whole system. It can also reduce the total cost of the process of product making by reducing the cost of the entire procedure. In such an industry, where there are several types of operation, or several types of machinery are there, this manufacturing process is much better applicable to the economic perspective. By applying cellular manufacturing in an industry, the people involvement time is reduced. Also, the total productivity of an industry is increased day by day, including the overall net productivity per day and month. It can

reduce the use of floor space in a factory. The main product is made by having simple sequences of similar kinds of operations and also segmenting the product and their parts into related categories efficiently. It can also reduce the unexpected delay time and even the time to need to take them into the next station. Group Technology (GT) is a technique of manufacturing in which the grouping of machines is done based on function (like producing parts or the products with similar characteristics) and then organized into cells to achieve a high level of repeatability. GT is applied under some following terms, such as,

- There are many plants which are using batch production, traditional process of production and a process type layout. Also, the types of plants that result in much working of material handling, even the amount of in-process inventory is extremely high, for the plants having a long manufacturing lead time.
- Part families can be made by grouping the parts. In this family, each of the machines is designed to create a given part family, so that it is possible to group the elements which are taken into the same position into part families.

The main objectives of this research are to practically implement the Cellular Manufacturing system in the wooden furniture industry to get an increasing number of productivity and to give an advantage in productivity and time of any wooden furniture industry.

2. Literature Review

Many studies are being carried out to improve the manufacturing system in the industrial sector. The cellular manufacturing system is the most extensive method that can be used in the industrial area that has been found in the recent study. But these approaches mainly focused on a different machine and operations-based industries like furniture or other sectors. Almost all the reviews are focused on the relationship between the operations and the machines that are used to gain the result. The following works were done in this track shown in Table 1.

Table 1: Related Works

Serial No.	Details
1.	The application of group technology concepts to the design and operation of manufacturing cells has had a significant impact on improving the performance of multiproduct, moderate volume manufacturing systems (Askin 2013).
2.	They conduct their research on cellular manufacturing system to apply to the industry of making hard disk drives. The main task is to betterment the production rate but decreases the distance of layout by the calculation (Varanujit and Peerapattana 2013).
3.	They discuss the process of general cell design, and a framework for mitigating the problem at constructing the cell formation problem is suggested. These approaches are based on the principle of part families. Also, the principle of group technology is used for these approaches (Wemmerlov and Hyer 1998)
4.	This research was based on several numbers of survey research on GT and cellular manufacturing system based on clustering methodology which operate rows and columns of the part family of the machine having processing indicator matrix for formatting a diagonal block structure (Heragu 1994)
5.	They worked on a clustering algorithm, which is two phases. This algorithm is used to create a cell of the machine. The least resemble group representatives are used in this process at its early phase. A clustering method named fuzzy C-means is being maintained in its last phase for developing the formation of a cell of a machine and also the part families (Yan et al. 2014)

6.	The increase in productivity and quality, also the lead time development, is the primary concern of them in this research. The assignment of the concepts of CMS can deliver the manufacturing stages of original equipment and also increasing the amount of productivity, reduction of lead time to operations (McLaughlin and Durazo-Cardenas 2013).
7.	They conduct their research on an algorithm which is mainly genetic and met heuristic based cell formation procedure. Also, the part families into cells are a matter of concern. In this case, the inter-cellular movements can be reduced (Onwubolu and Mutingi 2001).
8.	They were concerned about the sustainability in the manufacturing sector and realized an increasing interest in problems of design in "Sustainable Manufacturing Systems" (Aljuneidi and Bulgak 2017).
9.	They focused on the domain of manufacturing, which is sustainable in nature, efforts of ongoing research, including the reduction in consumption of energy, processes of manufacturing. But they gave a little effort into the efforts related to production and energy-efficient (Iqbal and Al-Ghamdi 2018).
10.	They focus on stochastic CMS design. They proposed a numerical programming approach to planning a cell, which is a layered fabricating framework in exceptionally vacillated interest conditions. Create a mathematical model for making committed, shared, and leftover portion cells with the goal to limit the number of cells (Erenay et al. 2015).
11.	They developed an extensive model and BFO algorithm for a CMS, which is dynamic. The calculation proposed by them mulls over various important cell configuration issues such as machine task, inter or intra cell material dealing with, an essential type of job, redistributing working and the outstanding task at hand by matching dependency on operational time and arrangement of activities of the parts (Nouri and SaiHong 2013).
12.	This paper discusses and reviews a fundamental issue in cellular manufacturing—cell formation. This problem is of strategic and operational importance in that it affects the underlying structure and the overall layout of a cellular manufacturing system. We first provide a comprehensive mathematical formulation of the cell, propose a methodology-based classification of prior research (Selim et al. 1998)
13.	This paper defines the problem of incremental cell formation, and different types of issues are identified and focused. One of the significant kinds of these divisions is selected to solve the problem. The branch and bound technique, mainly the other two methods. For the comparison of those two methods, data sets are generated based on the quality of solution and also demand on computational time (Srinivasan and Mahesh 2010).
14.	In this article, The GT principles are said to be applied in all aspects of an industry, such as in design by having standardization and reduction in cost and proper utilization in time and planning of work; as the basis for computer-aided process planning (CAPP) systems. Using the principle of CMS, the production can be increased in amount (Knight 1998).
15.	They include the outcomes and results of survey research of 32 U.S. firms involved with cellular manufacturing. Different areas are covered including the causes for establishing cells, the achievement of benefits, divisions and sizes of cells, breadth of cellularization in the plants, techniques used to cells design, planning change and control systems change, issues related to labor and valuable experiences achieved by the industries (Wemmerlov and Hyer 2007).
16.	They discussed Cell-based manufacturing, which has a long history and has been variously explained within various engineering traditions and in multiple countries. The outcome is a degree of hesitation over the nature of "cells", which can make uncertainties16 that are accomplished by various types of vested interests in industries introducing manufacturing based on cells (Frenders 1925).

17.	In this paper, details about cellular manufacturing are described depending on various factors in various types of industries (Mitrofanov 1966).
18.	In this paper, the authors provide a concise review of the literature on cell formation aspects of the design of cellular manufacturing systems. The usefulness and limitations of existing approaches are identified. Future research directions are explored considering manufacturing requirements (Singh 1993).
19.	Part family formation using fuzzy cluster analysis in Group Technology (GT) and feature recognition for tool access direction using relationship matrix in Computer-Aided Process Planning (CAPP) has been presented in this paper (Dhanalakshmi and Arunachalam 2008).
20.	In this paper, the authors formulate a model to solve the facility layout problem in Cellular Manufacturing Systems (CMS). This model assumes that the demand rate varies over the product life cycle. The objective is to minimize the total material handling cost and solves both inter- and intra-cell facility layout problems simultaneously (Wang et al. 2001).
21.	Group Technology, Concurrent Engineering, and Design for Manufacture and Assembly and the ideas behind cellular manufacturing are vigorously discussed. New Developments that are aimed at reducing developmental and manufacturing lead times, also discussed (Suresh and Kay 2012).
22.	This paper focuses on the entire life-cycle literature of Cellular Manufacturing as a module of OR/MS. It addresses the research strategy employed by, and the theory-vs-applied orientation exhibited by, the authors (Reisman et al. 1997)
23.	They discussed the Cellular Manufacturing System and its application (Irani et al. 1999)
24.	Several simulation studies have been conducted previously by several researchers to compare the performance of cellular and functional layouts. The purpose of this paper is to highlight the lack of objectivity of a number of these studies, in order to explain the origin of their conflicting conclusions (Chtourouet et al. 2008).
25.	The application of group technology concepts to the design and operation of manufacturing cells has had a significant impact on improving the performance of multiproduct, moderate volume manufacturing systems. Initially, the research on manufacturing cells focused (Askin 2013).

3. Methodology

The methodology of this research can be divided into some portions which are illustrated in Figure 1.

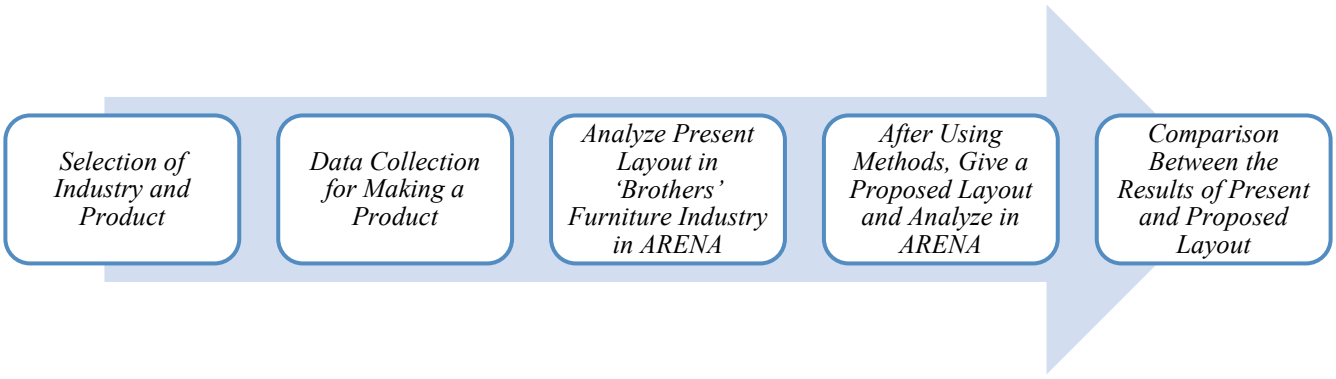

Figure 1: Overview of the Methodology

3.1 Data collection from the Brothers Furniture Industry

Mainly, for making a LOTUS chair in Brothers Furniture Industry, several machines and also the operations are needed to complete the production of it. A detailed overview of activity and required time (in second) is given in Table 2.

Table 2: Data collection from Brothers Furniture Industry (in Second)

				Raw Data			
	Marking & Sanding	Band Saw/ Panel	Jointer	Thicknesser	Mortise Tenon	Round Copy Shaper	SUM
	15	101	14	39	36	26	231
	14	104	15	40	40	28	241
	17	103	14	42	38	27	241
	18	105	15	41	37	26	242
	16	102	16	40	36	26	236
	16	103	14	39	38	25	235
	14	103	14	41	40	27	239
	15	104	15	39	35	28	236
	16	103	16	40	36	25	236
	17	102	14	41	37	26	237
Mean	15.8	103	14.7	40.2	37.3	26.4	237.4
Standard Deviation	1.3166	1.1547	0.8233	1.0328	1.7029	1.075	3.3731

3.2. ARENA Simulation Software Mechanism

ARENA simulation software was also used to prepare and analyze the layout. It is presented in Figure 2.

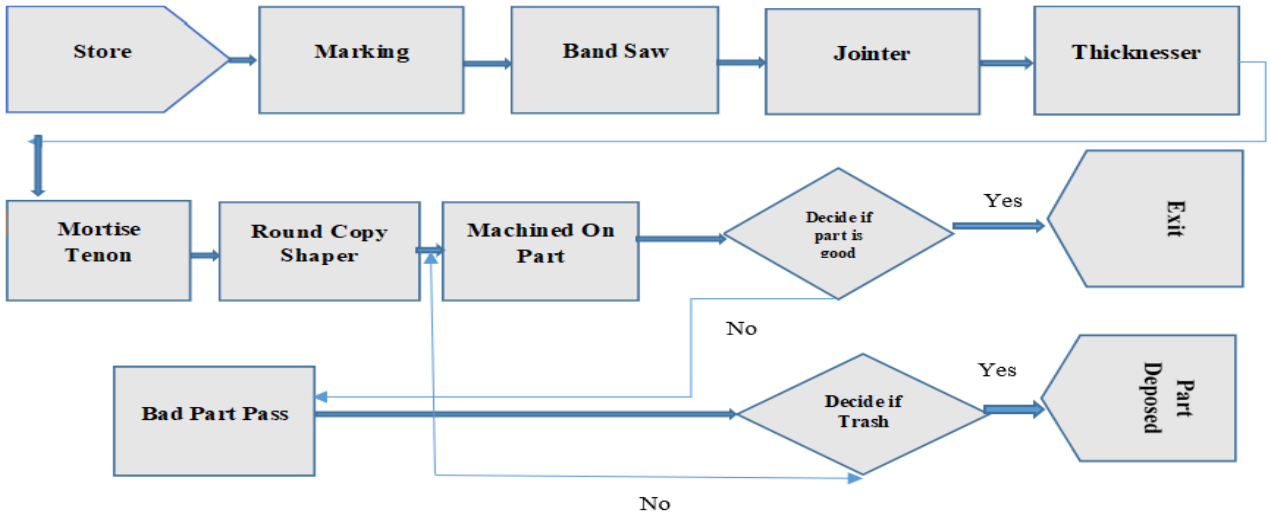

Figure 2: Present layout analysis by using ARENA Simulation

3.3. Rank Order Clustering

Rank Order Clustering is a highly used algorithm that can be found in the cell manufacturing system. Kings introduced this algorithm in the form of machine-group parts. It follows the computation of binary weights from a machine part matrix. The steps of Rank order clustering are represented in Table 3, Table 4, Table 5, and Table 6. After that, the final result can be found in Table 7.

Table 3: Step 1 of the Clustering the existing layout

	Arm Rest	Leg	Spindle	Back Rest	Seat	Apron		
							SUM	Rank
Mortise Tenon	1	1	1	1			60	1
Sanding & Mark	1	1			1		50	4
Band Saw	1	1	1			1	57	2
Jointer	1	1	1				56	3
Round Copy Shaper	1			1			36	5
Router	1				1		34	6
Thicknesser				1	1	1	7	7
Panel Saw				1	1		6	8

Table 4: Step 2 of the Clustering the existing layout

	Arm Rest	Leg	Spindle	Back Rest	Seat	Apron
Mortise Tenon	1	1	1	1		
Band Saw	1	1	1			1
Jointer	1	1	1			
Sanding & Mark	1	1			1	
Round Copy Shaper	1			1		
Router	1				1	
Thicknesser				1	1	1
Panel Saw				1	1	
SUM	252	240	224	139	23	66
Rank	1	2	3	4	6	5

Table 5: Step 3 of the Clustering the existing layout

	Arm Rest	Leg	Spindle	Back Rest	Apron	Seat		
							SUM	Rank
Mortise Tenon	1	1	1	1			60	1
Band Saw	1	1	1		1		58	2
Jointer	1	1	1				56	3
Sanding & Mark	1	1				1	49	4
Round Copy Shaper	1			1			36	5
Router	1					1	33	6
Thicknesser				1	1	1	7	7
Panel Saw				1		1	5	8

Table 6: Step 4 of the Clustering the Existing Layout

	Arm Rest	Leg	Spindle	Back Rest	Apron	Seat
Mortise Tenon	1	1	1	1		
Band Saw	1	1	1		1	
Jointer	1	1	1			

Sanding & Mark	1	1				1
Round Copy Shaper	1			1		
Router	1					1
Thicknesser				1	1	1
Panel Saw				1		1
SUM	252	240	224	139	66	23
Rank	1	2	3	4	5	6

Table 7: Step 5 of the Clustering the Existing Layout

	Arm Rest	Leg	Spindle	Back Rest	Apron	Seat
Mortise Tenon	**1**	**1**	**1**			
Band Saw	**1**	**1**	**1**			
Jointer	**1**	**1**	**1**			
Sanding & Mark	**1**	**1**				
Round Copy Shaper	**1**					
Router	**1**					
Mortise Tenon				**1**		
Band Saw					**1**	
Sanding & Mark						**1**
Round Copy Shaper				**1**		
Router						**1**
Thicknesser				**1**	**1**	**1**
Panel Saw				**1**		**1**

3.4. Hollier Method

The Hollier method involves the process of ordering of machines for minimizing backtrack flows. In this research, Hollier Method 1 is used to make that sequencing. For Cell 1 (Obtained from Rank Order Clustering), this is applied, and related information is provided in Table 8 and Table 9.

Table 8: Hollier Method for Cell 1

	Band Saw	Jointer	Mortise Tenon	Round Copy Shaper	Sanding & Mark	Router	**SUM**
Band Saw	0	30	0	0	30	0	60
Jointer	0	0	20	30	0	0	50
Mortise Tenon	0	0	0	20	0	0	20
Round Copy Shaper	0	0	0	0	0	25	25
Sanding & Mark	0	20	0	10	0	0	30
Router	0	0	0	0	0	0	0
SUM	0	50	20	60	30	25	185

Table 9: Hollier Method for Cell 1 Final Step

	Jointer	Mortise Tenon	Round Copy Shaper	Sanding & Mark	SUM
Jointer	0	20	30	0	50
Mortise Tenon	0	0	20	0	20
Round Copy Shaper	0	0	0	0	0

Sanding & Mark	20	0	10	0	30
SUM	20	20	60	0	100

For Cell 2 (Obtained from Rank Order Clustering), this is applied, and related information is provided in Table 10, Table 11, and Table 12.

Table 10: Hollier Method for Cell 2

	Band Saw	Thicknesser	Round Copy Shaper	Mortise Tenon	Sanding & Mark	Panel Saw	Router	SUM
Band Saw	0	60	0	0	0	0	0	60
Thicknesser	0	0	0	0	30	30	0	60
Round Copy Shaper	0	0	0	0	0	20	0	20
Mortise Tenon	0	0	20	0	0	0	10	30
Sanding & Mark	0	0	0	0	0	0	30	30
Panel Saw	0	0	0	30	0	0	20	50
Router	0	0	0	0	0	0	0	0
SUM	0	60	20	30	30	50	60	250

Table 11: Hollier Method for Cell 2 Second Step

	Thicknesser	Round Copy Shaper	Mortise Tenon	Sanding & Mark	Panel Saw	SUM
Thicknesser	0	0	0	30	30	60
Round Copy Shaper	0	0	0	0	20	20
Mortise Tenon	0	20	0	0	0	20
Sanding & Mark	0	0	0	0	0	0
Panel Saw	0	0	30	0	0	30
SUM	0	20	30	30	50	130

Table 12: Hollier Method for Cell 2 Final Step

	Round Copy Shaper	MortiseTenon	Panel Saw	SUM
Round Copy Shaper	0	0	20	20
Mortise Tenon	20	0	0	20
Panel Saw	0	30	0	30
SUM	20	30	20	70

4. Result and Discussion

Results and discussion can be presented in some steps.

4.1 Result Analysis After Rank Order Clustering

After the rank order clustering, the whole process is under the Cellular Manufacturing System. By doing the clustering, two cells are identified by CMS (Illustrated in Table 13). Hollier method can be applied to get the appropriate sequences of the machines according to their operations by Cellular Manufacturing system.

CELL NO 1

Machine ID (Tenon Mortgage, Band Saw, Jointer, Sanding, RCS, Router)

Part No (Arm Rest, Leg, Spindle)

CELL N0 2

Machine ID (Tenon Mortgage, Band Saw, Sanding, RCS, Router, Thicknesser, Panel Saw)

Part No (Back Rest, Apron, Seat)

Table 13: Final Cell after Rank Order Clustering

	Arm Rest	Leg	Spindle	Back Rest	Apron	Seat
Mortise Tenon	**1**	**1**	**1**			
Band Saw	**1**	**1**	**1**			
Jointer	**1**	**1**	**1**			
Sanding & Mark	**1**	**1**				
Round Copy Shaper	**1**					
Router	**1**					
Mortise Tenon				**1**		
Band Saw					**1**	
Sanding & Mark						**1**
Round Copy Shaper				**1**		
Router						**1**
Thicknesser				**1**	**1**	**1**
Panel Saw				**1**		**1**

4.2 Result Analysis After Hollier Method

After using Hollier Method, two processes sequences were found for CELL 1 (in Figure 3) and also for CELL 2 (in Figure 4).

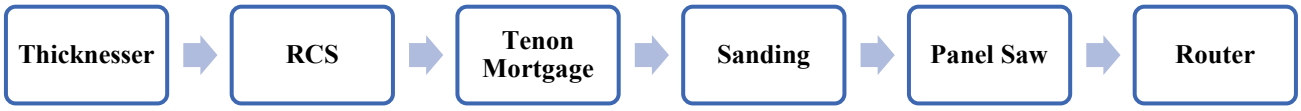

Figure 3: Resulting Machine Sequence for CELL 1

Figure 4: Resulting Machine Sequence for CELL 2

4.3. In ARENA Simulation Software (Proposed Layout)

A Final Layout is proposed after a different analysis, which is given in Figure 5.

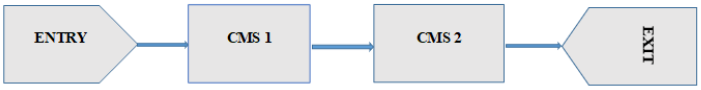

Figure 5: Final Proposed Layout

4.4. Production and Time-Based Comparison

A comparison was done based on two factors like production amount and time. A production-based comparison is given in Figure 6, and a time-based comparison is illustrated in Figure 7.

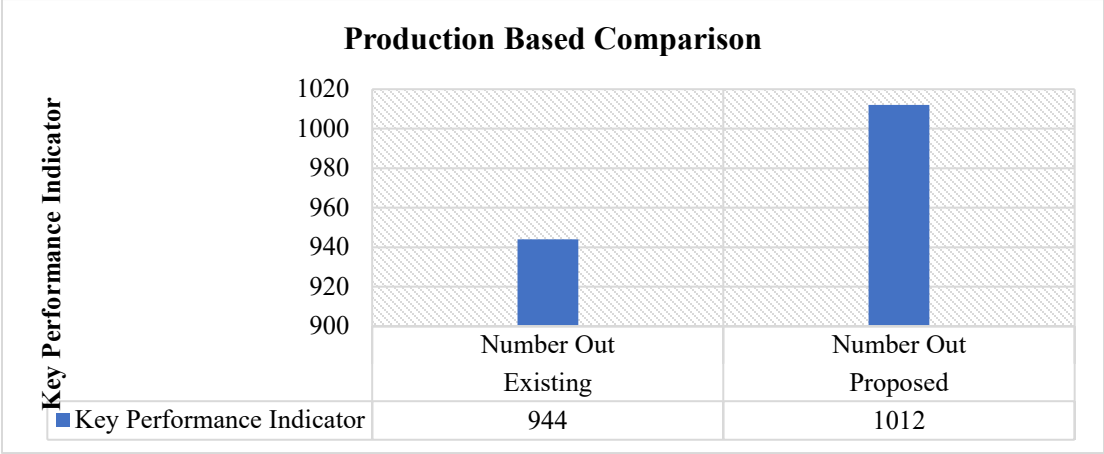

Figure 6: Production Based Comparison in Bar chart

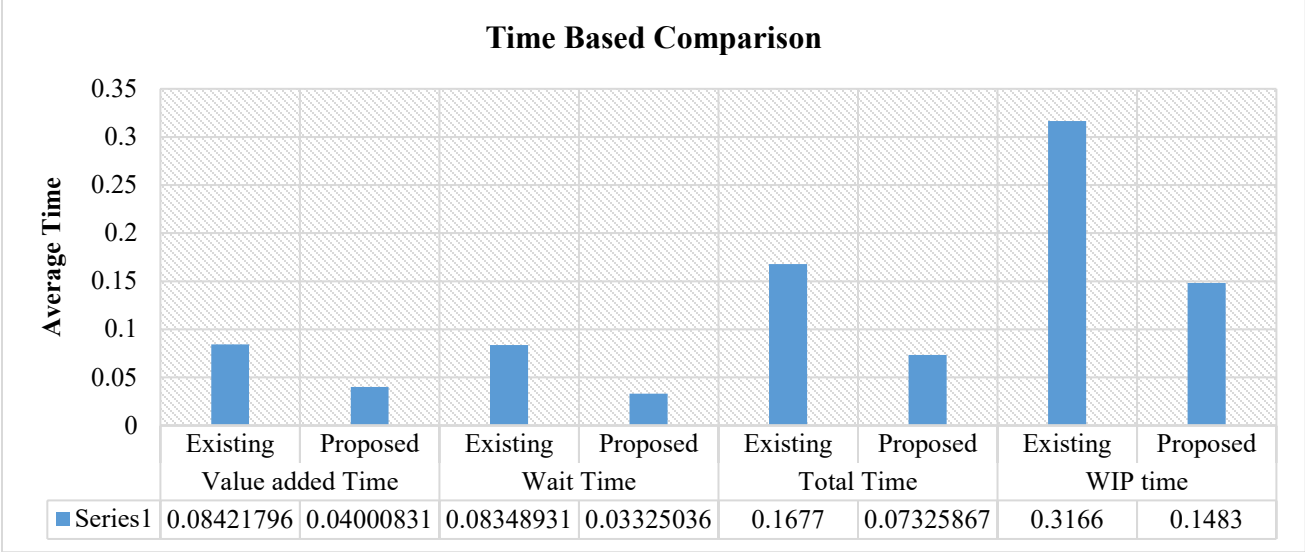

Figure 7: Time based Comparison in Bar chart

This paper targets minimizing the production time, interdepartmental travel, throughput time, lot sizes, unit cost, and simplifies scheduling at the production system in the wooden furniture industry by using Group Technology (GT) and Cellular Manufacturing System (CMS) at existing production layout. This paper has proposed a future state model for

the design of the production area by using GT and CMS. CMS has clustered the existing layout and modified into some part families consists of similar machine groups, having similar operations and consequently to form manufacturing cells using a correlation analysis approach. In this regard, the CMS first used Rank Oder Clustering (ROC) method to set the part families and then used the Hollier method to determine the most logical sequence of machines. ROC is an algorithm found in the cell manufacturing system which arranges the machines in the form of machine-group parts. It orders the parts of the machine in cells automatically with the help of binary weight, which would structure and compute the matrix. It implies a computer algorithm that would solve the problems of clustering. Both existing layout and future state layout have been simulated in ARENA software, and the distinctive calculation has been determined. The simulation software asks for the input, where we have used the collected data we gathered from the wooden furniture industry. At the traditional layout, there was a drawback between the first floor and the second floor. One of the main challenges was to mitigate or annihilate the drawback. Using cellular manufacturing did this task. The simulated calculation and the result have shown the usage of CMS will be profitable.

5. Conclusion

Even though this study was conducted to cover some necessary aspects of Cellular Manufacturing in the industrial sector, this research has its fair share of limitations. The main ones that cannot be overlooked are: The initial investments are extremely high for the proposed layout of Cellular Manufacturing System Layout. The focus of the study was to create a layout that can increase the productivity of the industry but to do this, and the present layout needs to be changed. In some respects, the established industries will not change the current layout due to the cost of it. There is still a lot of room for improvement. The CMS approach can still be improved a lot more. For the future study, a few things can be recommended: The total study can be enhanced by giving a Coded Algorithm in the future. This study focused mainly on the wooden furniture industry. But other furniture can be considered in the future which may require a different approach. It can be more and more beneficial for the upcoming new industries to achieve a better environment of work and an increase in productivity.

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