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Improvement of Manufacturing Plant Throughput by Using Reconfigurable Manufacturing System a Step Beyond Flexible Manufacturing System

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Abstract

Africa is very rich contentment. In terms of population work force it has more than 1.3 billion people. Also, in terms of materials all kinds of materials, it is also a resource rich continent, with abundant reserves of oil, gas, minerals, and other natural resources. On the other side the industrial output of the contented is very low.

In This research an attempt to increase the use of the industrial recourses by introducing reconfigurable manufacturing concept in order to decrease the production cycle time and increase manufacturing process efficiency. This new concept emerged in recent years as a new category in classification of manufacturing systems. In this paper this concept is tested for its potential benefits to the industry by a simulation comparison versus flexible manufacturing system. The results presented an improvement in the system output and thus reduction in the cost and time.

Keywords: Plant Throughput, Reconfigurable Manufacturing System, Flexible Manufacturing System

1. Introduction

Classically the manufacturing systems were classified into dedicated and flexible manufacturing systems. Dedicated manufacturing lines (DML) are based on inexpensive fixed automation to give high volume of production. Flexible manufacturing systems (FMS), produce a variety of products, with changeable volume and mix, and consist of general-purpose computer numerically controlled (CNC) machines and other programmable automation. Combination of high equipment cost and low throughput makes the cost per part relatively high. Therefore, the FMS production capacity is usually lower than that of dedicated lines and their initial cost is higher. The reconfigurable manufacturing system is a multi-objective model containing the objectives of the total cost, the total time, the scalability, and the modularity. Modularity and scalability is used to assess the various factors impact on manufacturing and supply chain systems (Khan, A.S., 2022) (Gurjanov, A., et al., 2020). An important study carried out on a manufacturer of components for the car industry has shown that the average utilization of the transfer lines available was only 53% (M. Matta, T.T., 1999). The reason for this low average utilization is that some products being in the early stages, or at the end of their life cycle are required in low volumes. Even products in the maturity phase do not always reach the production volumes this challenge is theoretically met by flexible manufacturing systems that are scalable when designed with multi-axis CNC machines that operate in parallel (Mehrabi, M.G., A.G. Ulsoy, and Y. Koren, 2000). However, when a production cell needs to be reconfigured to meet new configuration for new products, manual reconfiguration is time-consuming process. This problem will be even worse if there are industrial robots with characteristics of complex functions and inflexible programming in the manufacturing system. The digital twin-based

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manufacturing system is a typical representative of smart manufacturing. It has a number of advantages namely the power of simulation and the ability of real implementation. (Zhang, C., et al., 2021).

2. RMS System Explanation

MCNPX code version 2.7 (Pelowitz, D.B. 2011) with ENDF-VII cross section library was used A cost-effective response to market changes requires a new manufacturing approach that not only combines the high throughput of DML with the flexibility of FMS, but also is able to react to changes quickly and efficiently. This is achieved through the design of the system and its machines for adjustable structure that enable system scalability in response to market demands and system/machine adaptability to new products. Design of a manufacturing system is based around the part family

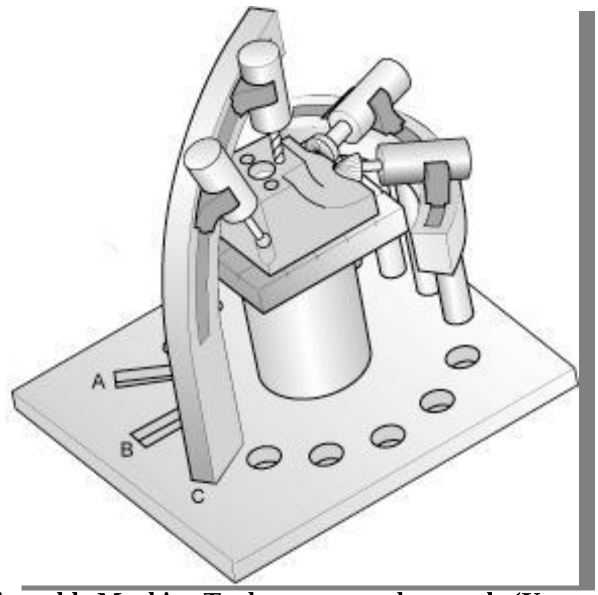

Figure 1 Reconfigurable Machine Tools- conceptual example (Yoram Koren, S.K., 1997)

A new type of modular machine with a changeable structure Reconfigurable Machine tool RMT that allows adjustment of its resources (e.g., adding a second spindle unit) was implemented. In addition to RMTs, also reconfigurable controls that can be rapidly changed and integrated in open-architecture environment are critical to the success of RMS. RMTs should have modularity, integrability. customization, convertibility
The RMS should accommodate Variation of products, as; workpiece size, Part geometry and complexity, Production volume and production rate, variations in processes, geometrical accuracy, surface quality, and material properties.

Table **1** presents the comprehensive comparison on various important aspects of RMS with the conventional manufacturing systems (Kumar, G., K. Kumar Goyal, and N.K. Batra, 2019).

Table 1 Comparison of DMS, FMS and RMS

S.N	Aspect	Traditional.Mfg. System (DMS)	Flexible.Mfg. system (FMS)	Reconfig.Mfg. (RMS)
1.	Manufacturing policy	Pushing	Pulling	Customizing
2.	Process technology	Fixed	Adaptable	Responsive
3.	System Structure	Fixed	Adjustable	Adjustable
4.	Scalability	Nil	Yes	Yes
5.	Machine structure	Fixed	Fixed	Adjustable
6.	Flexibility	Nil	General	Customized
7.	System focus	Part	Machine	Part Family

Examples of Some Implantations

In 1996 the Engineering Research Center of Reconfigurable Machining Systems (ERC/RMS) was founded at the University of Michigan by the National Science Foundation and 25 companies with the mission to develop the complete spectrum of RMS (Yoram Koren, S.K., 1997). The SRP467 make use of equal modules for different machines and the design of interfaces, which are important research issues in this project, as well as in another.

3. Case Description

This study is carried out to compare an existing flexible manufacturing system to proposed reconfigurable system of manufacturing. The part under investigation is from automotive industry. The semi product is casting. The manufacturing operations required are turning and milling

The study is involved in answering the following questions; Is RMS better than FMS, what criteria to judge that.

And the method to answer that is to monitor the improvement in lead time to production and the improvement in throughput. Another aspects of the comparison should be taken into moderation like the initial and running cost of both systems, the flexibility to accommodate various products

4. The Conceptual Model

The system input is two different types of products from the same product family but with different number of operations. The semi products arrive in patches of 100 every other day

Fms (Original) System

The original system consists of Three CNC Lathes, one CNC Machining center and Inspection station. Three turning and one milling operations are required to produce this part with inspection operation after each machining operation. The details of this operations are in Table 2

Table 2 Operation Cycle of Case study

Operation	Description
Turning	Rough facing, rough boring and forming technological datum
Turning	Other side facing, Boring and external forming
Milling	face milling of both faces, Drilling and

	tapping
Turning	Finishing of outer and inner diameters

After each machining operation an inspection operation is done with only one inspection station is available, the machining operation has to wait for the outcome of its corresponding inspection operation, in order to minimize the production of defective parts.

Simulation model

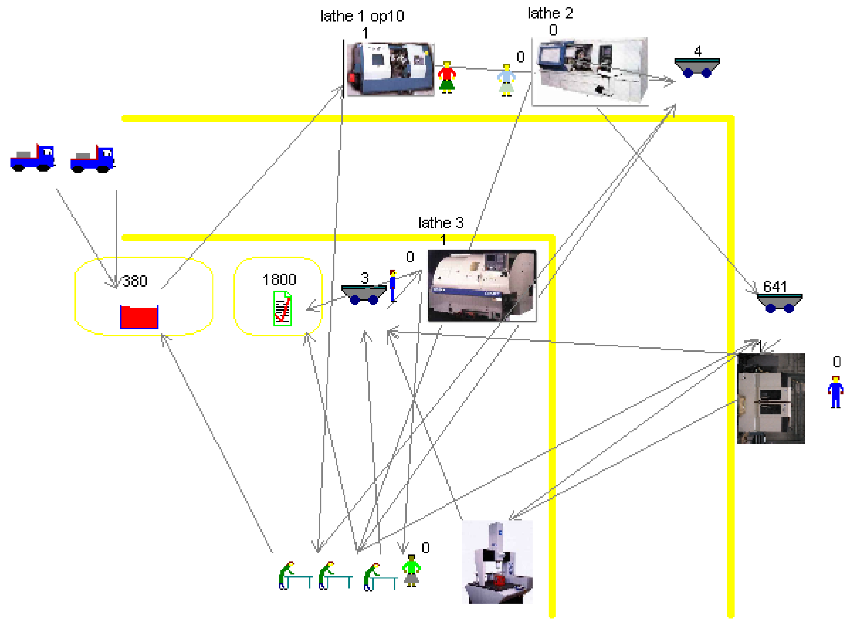

Figure 2 FMS simulation layout

Following the Physical mode, four work centers and four storage bins were created as in

Rms (Proposed) System

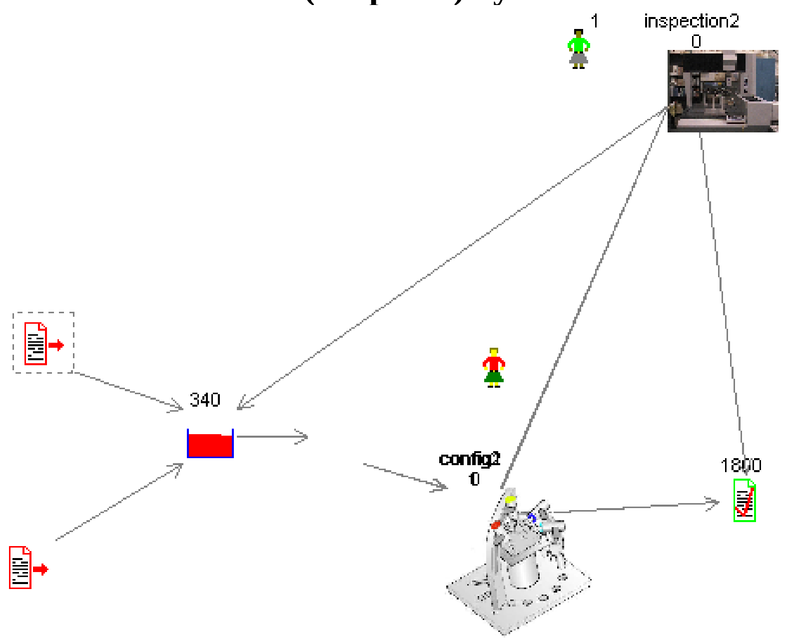

Figure 3 RMS simulation layout

The proposed Reconfigurable alternative for the above flexible manufacturing system consists of one reconfigurable machine tool capable of performing all the operations, which was originally done on four different machine tools.
The machine tool can be reconfigured to perform different versions of this product family. As in the old system only one inspection station available, but unlike the old system only one inspection operation is to be performed. There is reconfiguration time needed whenever the product changes for both the machining and inspection centers.

Simulation model

To model the above system, the machine tool was modeled by two different work center with different process times.
Each of these centers will operate as the same machine tool but with different configuration. As in the original system when inspection process is in progress the machine tool operator has to be at the inspection station.

Data acquisition

To complete the simulation model, the times and rates of each individual process had to be acquired. The data was gathered from the machine shop where the FMS system was implemented. This data was fed to each simulation object to get the simulation runs. This data is presented in **Table 3**

Table 3 Actual data of the FMS workshop

Station name	Op. time	Distribution			Routing in	Routing out
		Upper	Mean	lower		
Input1					Patch of 100	
Input 2					Patch of 100	
Lathe 1	4	2	4	6	Ava. 2 each 100	Inspect 1/10
Inspection1	3	1	2	2.5	Each 10	
Lathe 2	3	1	3	5	2 each 10	
Inspection2	5	8	10	12	Each 10	
Mill 1	5	4	5	6	Ava. 2 each 100	Inspect 1/10
Inspection 3	10	7	12	15	Each 10	
Lathe 3	3	1	3	5	Ava. 2 each 100	Inspect 1/10
Inspection 4	5	9	10	13	Each 10	

The given setup values were suggested to be modeled as triangular distribution, which acceptable approximation for the operator behaviour in the absence of data cases (Kumar, G., K. Kumar Goyal, and N.K. Batra, 2019).
The new system estimated data was also given by both the operators and by the manufacturing company.

Table 4 Data for RMS implementation

Station name	Op. time	Distribution			Routing in	Routing out
		Upper	Mean	lower		

Station name	Op. time	Distribution			Routing in	Routing out
		Upper	Mean	lower		
Setup for reconfiguration	0	9	10	12	When product change	
Configuration 1	Dist.	3.5	4	4.5	Ava. 2 each 100	Inspect 1/10
Configuration 1	Dist	5.5	6	6.5	Ava. 2 each 100	Inspect 1/10
Inspection1	10	1	1.5	2.5	Each 10	

. Output Analysis

The input to the system is patches of semi products, which arrives every other day, and the system deals with two different products. This resulted in sever fluctuation in the system time diagram.

The transient period estimation was performed to eliminate the effect of the worm up period from the results.

The simulation runes were performed in three ways:

1. The daily output analysis
2. One-, two- and three-month output
3. And for 1800 product output analysis

6. Estimation of the Transient Period

For estimating the transient period for each system, five independent simulation runs were done for period of month each the analysis of the simulation was done using the moving average method.

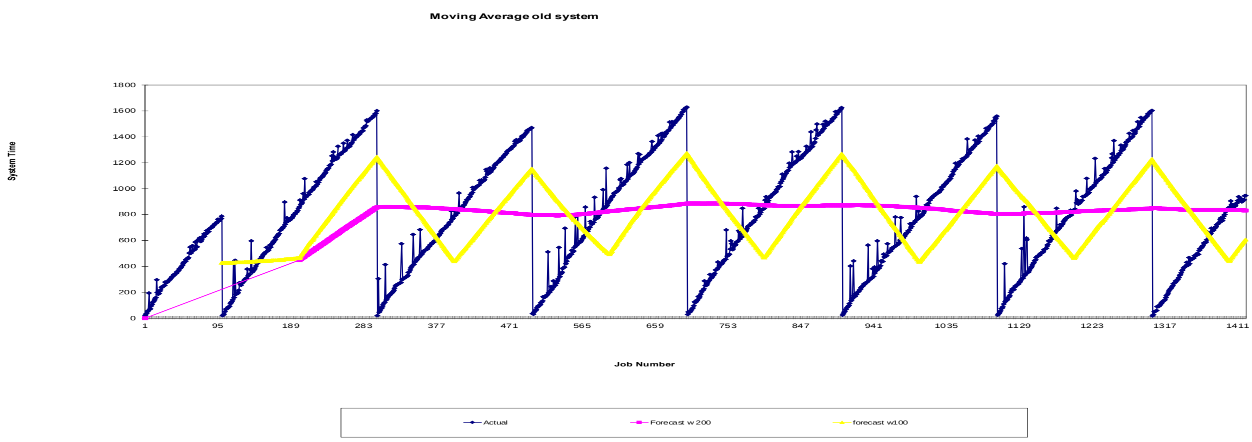

Figure 4 Transient period for FMS layout

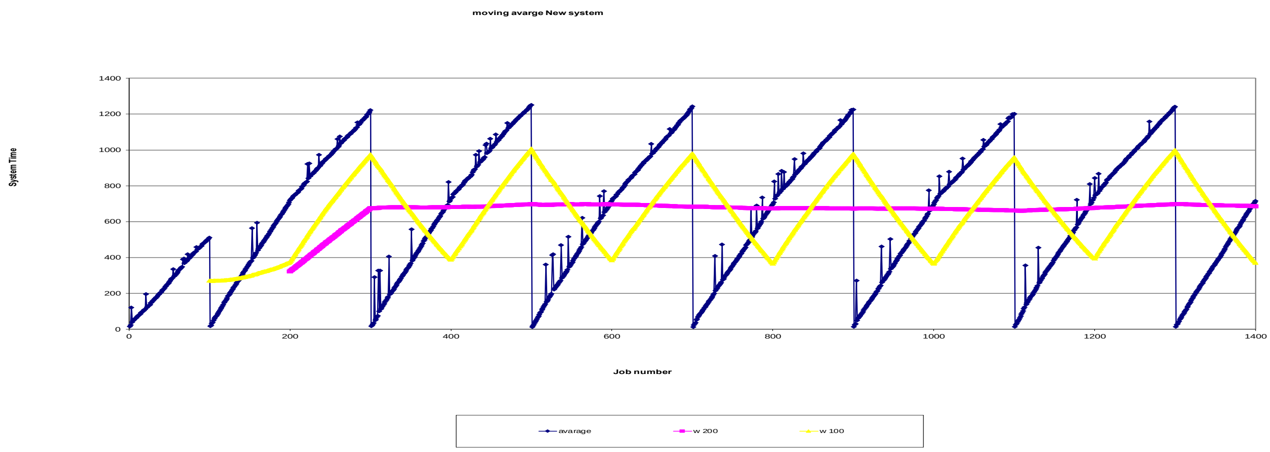

Figure 5 Transient period for RMS layout

Table 5 Comparison of transient periods

Old system		New system	
Selected value for W	End of transient state (job number)	Selected value for W	End of transient state (job number)
200	305	200	329

The pattern of the average system time for both system was severely fluctuating because of the semi product arrival pattern (every 48 hours), while the daily throughput for both system is enough to finish most of the input.

7. Analysis of Steady State System

After the estimation of the worm up period, all the following analysis was done for the steady state systems. The results of average monthly product throughput with five independent runs are listed in table Table 6.

Table 6 Productivity comparison of the two systems

Old system- Job completed		New system- Job completed	
Monthly	Daily	Monthly	Daily
1836	61.22	2189.4	72.99

The average processing time for FMS was 15.519 min. and for RMS 5.2 min. these average processing time per product is not tangible comparison figure and the daily throughput confirm that. The reason is that the old system is working simultaneously, while the new one is taking only one product at a time. The real output rate of the old system is around 7.8 min. per product.

Confidence interval comparison of the two system means

Comparing the confidence interval of the two systems to investigate the improvement the results after 100 independent as listed below(
Table 7): By plotting the two system time outputs (
Figure 6) it is seen that the average system time was reduced in the new system by 50 % and the two intervals are not intersecting, then it can be said that an improvement was done by the introduction of the new system.

Table 7 Average improvement of cycle times

Average system time- old system		
Lower 95%	Average	Upper 95%

2941.527542	3013.177002	3084.826
Average system time- new system		
Lower 95%	Average	Upper 95%
1489.473406	1521.269763	1553.066

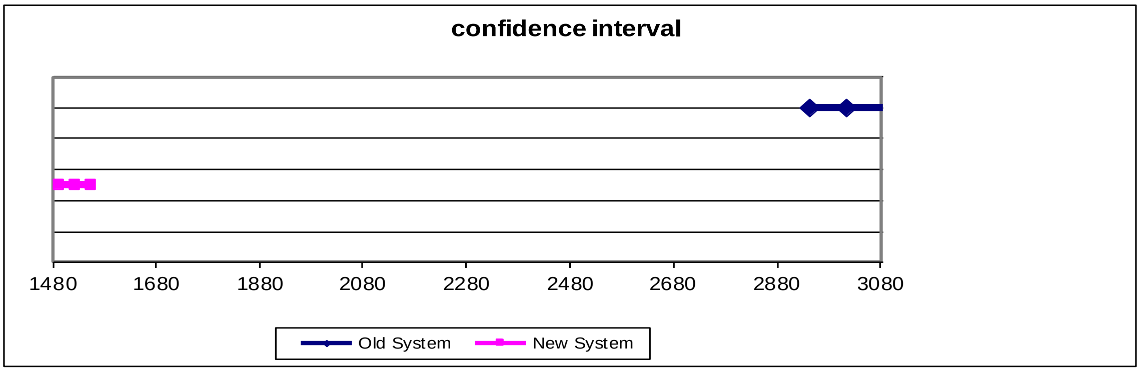

Figure 6 Confidence intervals of the two systems

t-paired confidence interval comparison:

To be sure that this improvement is genuine, further analysis using t-paired confidence interval method was carried out. The comparison was done for 1800 product as nominal output for both systems and for total of 10 independent trials the results were:

Table 8 t-paired confidence interval comparison

system	1	2	3	4	5	6	7	8	9	10
Old	3861.521	3920.325	3987.997	3480.17	4246.035	4249.32	3851.991	4002.291	4158.222	3815.768
New	1879.098	1879.497	1919.774	1940.308	1895.747	1883.004	1794.192	1844.044	1910.473	1910.401
(old-new)	1982.423	2040.828	2068.223	1539.863	2350.289	2366.317	2057.799	2158.247	2247.749	1905.367

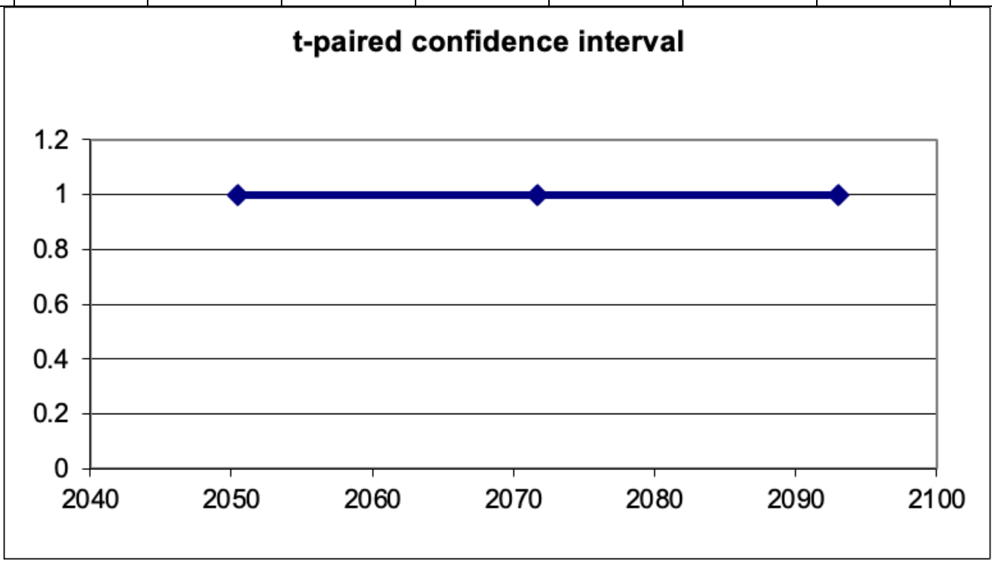

Figure 7 t-paired confidence interval

From the above analysis **Figure 7**, it can be said that it is with 95% confident that the two systems do not have the same mean, and the introduction of the new system is superior because it reduced the system time per job.

8. Conclusions and Discussions

In an effort to minimize the carbon foot print and the time for manufacturing, a new concept beyond flexible manufacturing systems was introduced. This reconfigurable approach proved to increase productivity and reduce cycle time, this study was done to compare two different types of manufacturing system and to explore the benefits and disadvantage of each.

While the old system is working, bottlenecks were observed, especially in the first queue before the first turning operation and the waiting for the milling operation. This system can be reconfigured by:

1. Altering the arrival pattern of the semi products and match it with the daily throughput of the system.
2. Adding another milling machine or using faster machine tool to perform the task.

The new system carries cost of the custom-built machine and custom-built controller, but on the other hand it will spare the payment of 3 machine operators out of five currently working in the old system.

The new system reduced the time in the system per product to the half and this is good improvement, though the output is not doubled.

The new system is space saving, since only two pieces of machinery constitute the whole system.

The reconfigurable manufacturing system is built around product family and suitable for long term commitment of the machine shop which will utilize it.

On the other hand, the flexible manufacturing system (general purpose machines) has the versatility to accommodate large variety of products, but with less productivity.

It can be said that apart from the cost and labour considerations, the reconfigurable manufacturing system improved the performance of the old system

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