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Productivity Measurement of The Manufacturing System

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Abstract

As industrialization has taken a great place in our world and also the competitiveness among industry is increasing day by day, so every industry is in a way of manufacturing products of high quality at low cost with a priority of delivering product to customers in stipulated time span. Every industry uses a system to manufacture the product. Therefore, industry needs a manufacturing system which is capable to produce the high quality product in the minimum input. This can be achieved by keeping the manufacturing system productivity high. Hence Productivity measurement is essential to measure the performance of the manufacturing system. In this present work we are developing the methodology to measure the productivity of manufacturing systems Therefore, we are proposing a mathematical model for productivity measurement of manufacturing system such as dedicated system, cellular system and flexible manufacturing system which are capable of producing mass and batch type product. Further the productivity is considered as one of the significant factor for performance measurement of manufacturing systems. The present work include the development of model for the measurement of productivity for the three manufacturing system followed by the case study for the application of the proposed model.

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*Keywords:*Manufacturing system, Productivity, case study.

1. Introduction

The advancement of economy of any country is sustained by development of its manufacturing industries. Currently the manufacturing firms are passing through a period of very strong competition. Now a day's industries are using different manufacturing system, these are such as Dedicated Manufacturing system, Cellular Manufacturing System and Flexible Manufacturing system. The output of the manufacturing system depends upon the various factors. These factors include the production rate, the quality of the product and flexibility of the system. The production rate is greatly depends upon the productivity of the system, where as the quality is related with the conformance of

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produced product with the available quality standards. The system flexibility is greatly depends upon the responsiveness of the system with respect to changeover in the product or product specification therefore these factors are considered as the performance parameters for measuring overall performance of the manufacturing system. As stated above the productivity is to be considered as one the key factor or measuring the performance of the manufacturing system.

Lieberman and Kang [1] showed that public financial data can establish productivity measure to give a suitable measure of industrial performance than profit rates only. four decades ago POSCO was established by Korean steelmaker which is considered as world’s most profitableand well-organized steel producer, and their analysis shows that POSCO has better record of good profitability and labor productivity. They applied productivity methods to assess the historical performance record of POSCO. David N. card [2]discuses the key considerations for defining on effective productivity measure. It also explore the relationship between quality and productivity. SonandPark [3] quantified and incorporated the Productivity, quality and flexibility measures. The conventional productivity measure was developed so that it could be used in integrated manufacturing production systems.. These three measures were integrated for the evaluation of a manufacturing system. They improved the conventional productivity measures for use in IMPS as a whole. Tangen [8] concluded that performance measures like, profitability,productivity,efficiency,effectiveness andperformancecan be measured by different methods and advantage and disadvantages of different performance measures are also explained. Park and Kim [9] developed costing procedures for numerous manufacturing activities under ABC systems, and these procedures are integrated into the recommended multistage investment decision model. They showed a case study which was based on AMS system and they have given a decision model which found that opportunity cost plays more significant role for cost accounting system. Ali Emrouznejad [10] gives technique such as decision-making units (DMUs) using data envelopment analysis (DEA) techniques by using optimization measures in SAS/OR software for calculation of a productivity and efficiency. E. Balla et al[11] that conformist measures of productivity development can be used as measure of commercial performance which neglects exterior or public output, are predisposed. This technique is very common and may possibly be applied to measure commercial public responsibility.

1.1. Types of manufacturing system

1.1.1. Dedicated Manufacturing System

In dedicated FMSs, exceptionally dedicated machines are devoted to a fine range of parts. Sequential and random FMSs are mentioned according to the direction of flow of parts through machines, and the manufacturing cell (MC) refers to a cluster of numerically controlled machines functioned by robot. Dedicated manufacturing systems are centered on fixed automation and yield a company’s core products or parts at large production. As DML has low flexibility but high productivity, therefore it is cost effective when it functions at full capacity that signifies that demand should be higher than supply. When the number of the variants is high then it is not suitable system.

1.1.2. Flexible manufacturing system

A flexible manufacturing system has been demarcated in several contexts through different terminologies but all come close to each other in recognizing the characteristics common to most of these systems. FMSs can be defined as follows: Flexible Manufacturing Systems are caused, computer controlled manufacturing process that can adjust automatically to random changes in product design formations, models or styles. The system will always attempt to optimize production output and work-in-process inventory.

1.1.3. Cellular manufacturing system

Cellular Manufacturing Systems (CMS) have developed the conventional idea for conveying the structural problems in manufacturing system. The connection could be based on the constraint of machines, the system arrangement, the design qualities such as shape or the size the resources are important. Range of similar measurements is working for this idea. A distinctive manufacturing system creates different set of goods. These goods in turn are joined from different parts, which are not completely created in the industry. Although a designer has two choices of designing a part through CMS. The first choice is built up the cells based on the machine information and the second choice is to consider the important part for the designing of the products to complete its task at initial phase. The main constraint of Cellular Manufacturing is to ensure that all tools required for production is operating at 100% efficiency at all times

2. Proposed model

For analysis of productivity measurement of three different types of manufacturing system following equation and methodology has been used. Six machines are taken to measure the productivity and the layout of DMS, FMS and CMS has been designed as shown in figure 1, 2, 3. For DMS, machines are connected in series so production work has to go through machine M_1 to M_6 to complete its job. In FMS, production work can be submitted to any of the machines which are connected in parallel and work independently. For CMS, production work has to go through series process in each cell but each cell can work independently or in parallel as shown in figure 3.

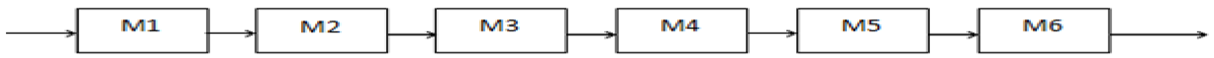

Figure 1.Layout of DMS

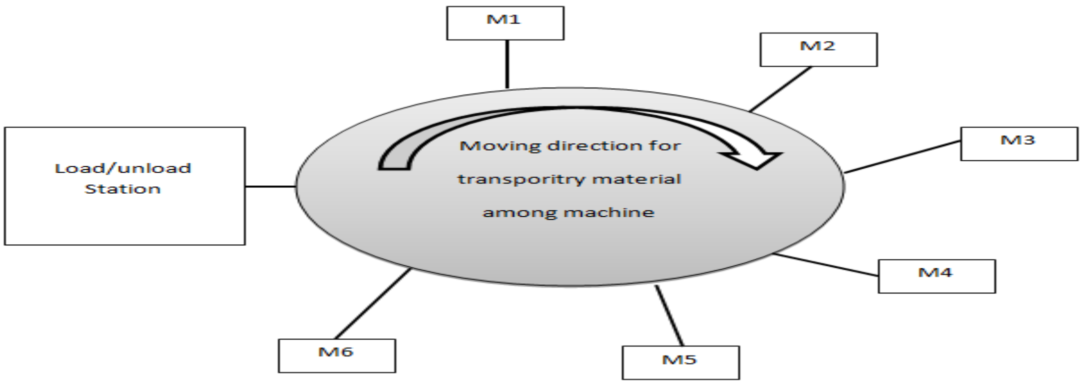

Figure 2. Layout of FMS

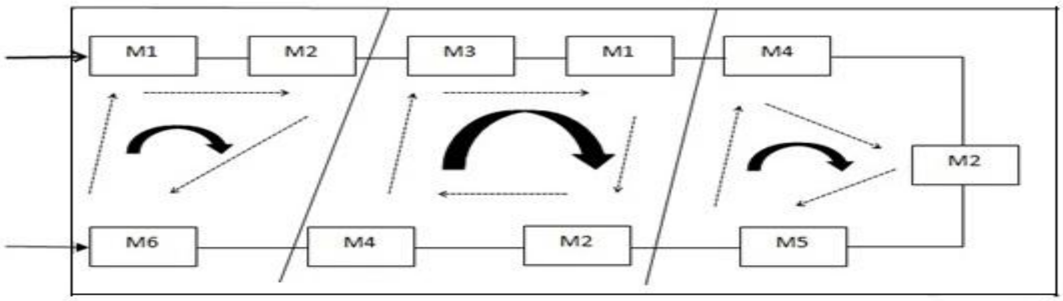

Figure 3. Layout of CMS

2.1. Productivity

To measure the firm efficiency productivity is an important factor which is calculated by converting inputs to total outputs. The output (O_T) by any manufacturing system is usually expressed in units of physical volume, such as pieces, tons, and any other measurable units. These physical units must be weighted in some manner so they can be added together. Good productivity means how much input is converted to output. For this work productivity is being calculated in terms of Labour productivity, Overhead productivity, Material productivity and Capital productivity.

2.1.1. Labour Productivity

Labour productivity calculates that how much labour performance is necessary to give maximum output. This productivity is useful in manned cellular manufacturing systems or labour-intensive industries. We have chosen to define labour productivity for a given period (P_L) as

$$P_L = \frac{O_T}{C_L} \quad (1)$$

Where C_L = labour cost

O_T = total output

$$C_L = \sum_{d=1}^{L1} c_d N n_d + \sum_{i=1}^{L2} c_i n_i \quad (1.1)$$

Where, L_1 = no. of various jobs using direct labour,
L_2= no. of various jobs using indirect labour,
c_d= Labour charges for job d per unit time,
N = A planning horizon,
c_i = Salary of job i during a planning horizon,
n_d= no. of direct labour units for job d,
n_i = no. of indirect labour units for job i.

2.1.2. Capital productivity

Capital Productivity measures the efficiency of capital that is invested on equipment and buildings that are used in producing the output. This productivity measure is especially useful in unmanned cellular manufacturing systems or capital intensive sum of the annual values measured for every belonging on the basis of its productive life, base year cost, and the firm's cost of assets. Capital productivity for a given period (P_C) as

$$P_C = \frac{O_T}{CC} \quad (2)$$

Where CC = the service of using invested capital

2.1.3. Material Productivity

Material productivity calculates the capacity of raw material use. This criteria is beneficial when material cost is a large scrap of the total cost. We have chosen to define material productivity for a given period (P_M) as

$$P_M = \frac{O_T}{C_R} \quad (3)$$

Where C_R = Raw material cost.

$$C_R = C_o + \sum_{j=1}^{J} c_d(j)\, n_d(j) + C_{id} \quad (3.1)$$

Where, C_o = material ordering cost,J= number of different parts,c_d(j)= unit cost of direct material for part j, n_d(j)= amount of direct material used for part j,c_{id} = indirect material cost expect tools.

2.1.4. Overhead Productivity

Except labour, capital and material efficiency of all resources refers to overhead productivity. This group consists of various inputs such as floor space, machines, tools, and computer software, if any. Machine cost may include charges like energy (power and fuel), preservation, renovate and property tax. Tool cost may occur from monitoring tool wear and potential breakage. Floor space cost may consist of energy, maintenance, repair, insurance and property tax. Therefore we define overhead productivity for a given period (P_O) as

$$P_O = \frac{O_T}{OH} \quad (4)$$

Where, OH = overhead cost.

3. Methods to Measure the Productivity of Manufacturing System

3.1. *DMS*

In DMS configuration all the components are hooked up in series, so in order to working of the system the entire component must be functioning. Configuration of DMS is shown above in figure1. In this work we are taking the Productivity in terms of Reliability and if the components function independently, then Reliability R(M) of the system can be obtained by

$R(M) \leq \min (M_1, M_2 \ldots M_n)$

If the component in series than reliability goes down.

3.2. *FMS*

In FMS configuration system, it fails, if all the components failsimultanously.Configuration of FMS is shown in above figure 2. All the components connected in parallel system do not depend on the another component in the same configuration and here also Productivity is taken as in terms of Reliability which is obtained by

$R(M) \geq \max(M_1, M_2 \ldots M_n)$

System composed of composition functioning independently in parallel, reliability will be higher than reliability of each component.

3.3. *CMS*

In CMS configuration, first three cells are formed as shown above in figure 3 and for each celle machine are connected in series configuration from where productivity value for each cell is calculated based on their machines configuration and minimum value of productivity is chosen from there. After calculating productivity for each cell the maximum value is chosen from these three cells because cells are working parallel and maximum value of productivity is chosen as the reliability value of the entire system.

4. Result and Discussion

For the proposed layout of these three systems, productivity measurement is calculated from the equation (1), (2), (3), (4) and result of these layouts is shown in table 1.

Table 1.Productivity Measures

Machines / Productivity	M_1	M_2	M_3	M_4	M_5	M_6
Expected Labor Productivity (P_L)	0.694	0.6613	0.6313	0.6038	0.5787	0.556
Expected Overhead Productivity (P_O)	0.72	0.74	0.792	0.72	0.638	0.616
Expected Material Productivity (P_M)	0.699	0.73	0.7354	0.729	0.769	0.7369
Expected Capital Productivity (P_C)	0.36	0.374	0.396	0.392	0.372	0.3774

From the table 1. It can be concluded that with Dedicated Manufacturing System, series system is used and from the equation no (1),(2),(3),(4) minimum value of table 1 is used for each productivity, for Flexible Manufacturing system, equation no (1),(2),(3),(4) has been applied and maximum value of table 1 is used for each productivity and Cellular Manufacturing System, first values are calculated according to DMS(series) configuration and final value is chosen by arranging the system in FMS(parallel) configuration.

Table 2.Productivity values for DMS, FMS and CMS.

Method	**Expected Labor Productivity (P_L)**	**Expected Overhead Productivity (P_O)**	**Expected Material Productivity (P_M)**	**Expected Capital Productivity (P_C)**
DMS	0.556	0.616	0.699	0.360
FMS	0.694	0.792	0.769	0.396
CMS	0.6038	0.720	0.729	0.372

Table 2 shows that in DMS configuration, we have taken minimum value of each productivity measures and FMS configuration; we have taken maximum value of each productivity and in CMS configuration, first minimum value of each cell is calculated and from these minimum values a maximum value is chosen for each productivity.

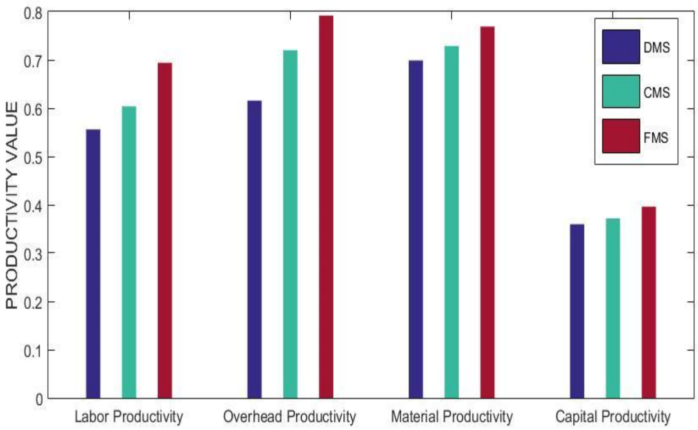

Figure 4: Productivity value comparison between DMS, CMS and FMS

In figure 4 productivity values for Expected Labor Productivity, Expected Overhead productivity, Expected Material productivity and Expected capital productivity is shown and it can be observed that productivity value of FMS is higher than DMS and CMS respectively.

5. Conclusion

In this case study we have defined a method to measure the productivity of manufacturing system and mathematical formulae are applied to find the productivity of systems. For our case study productivity is calculated in terms of Expected Labor Productivity, Expected Overhead productivity, Expected Material productivity and Expected capital productivity, and for these case study three systems are chosen namely DMS, FMS and CMS and productivity for these three systems are calculated in terms of reliability. Reliability equations has been applied on values retrieved from table 1 which are showing the expected Labor, Overhead, material and Capital productivity for each machines taken for each layouts and results are compared for each systems layout defined for this case study and it has been observed that for our case study FMS is showing better performance among DMS and CMS.

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