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DEVELOPMENT OF A FRAMEWORK FOR MIXED MODEL MANUFACTURING SYSTEM CONSIDERING PRODUCTIVITY, RELIABILITY AND RESPONSIVENESS TO MARKET CHANGE

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Abstract
Selection of manufacturing paradigm is a critical decision at the stage of designing the system, as it has strong impact on the performance of system during entire life time of the system. There are generally seven parameters which must be considered during the selection of manufacturing paradigm. Out of seven, three parameters are chosen based upon there relevance and importance i.e., productivity, reliability and responsiveness to market change. Equations for productivity, reliability and responsiveness to market change are developed for reconfigurable manufacturing system and flexible manufacturing system and modified according to scenario, as both manufacturing systems has capability to process mixed model products. Constraints are defined according to the scenario considering practical applications and realistic situations. There are certain assumptions as it is not practically possible to develop a frame work without any assumptions because system will be very much complex without assumptions. Objective function is constructed using all the gathered necessary information. Developed frame work of equations is programmed in matlab and tested for problem. There are certain situations when flexible manufacturing system is suitable and sometimes reconfigurable manufacturing system is suitable depending upon the values of all input data.

1 INTRODUCTION

Multiple objectives must be considered while designing the manufacturing system. These objectives include: minimizing equipment capital cost, maximizing productivity, responding rapidly to changing market demand, providing high-quality products and minimizing performance loss when disruptive events occur. While considering large manufacturing system, number of machine configurations are possible.

It includes: 1) Arrangement of machines in production stages.
2)the way that the machines are connected to transfer the part between them(1)

The critical decision at the stage of designing a system is the choice of the system configuration because it will impact the performance of entire system during the system lifetime – the next 30–35 years. The last decade of the twentieth century resulted as beginning of globalization of world market. It instigated following factors as a result system design considerations were changed dramatically.(2)

(1) Instability in market, as a result it will be harder to predict the throughput requirement of new manufacturing systems.
(2) Reduction in price occurred for high-power, high-precision Computer Numerical Control (CNC) machines, which made them attractive to be utilized in large machining systems
The major goal of this paper is to elaborate on selecting the system configuration, achieving the three major design objectives: Productivity, reliability and responsiveness to market change. This paper will contribute in decision making to select a specific manufacturing paradigm, the role of these parameters in selection of manufacturing paradigm, importance and description of these parameters in practical circumstances. This paper will also determine the importance of productivity, reliability and responsiveness of manufacturing system their effects on manufacturing systems and how these variables play role in selection of manufacturing paradigm. Now a day researcher's quest for selection of manufacturing paradigm, variables involved in selection of manufacturing paradigm and how to finalize the manufacturing paradigm(3)

1.1 Classification of manufacturing systems configurations

Let N be the number of machines. Following formula calculates the minimum value of N.

$$N = \frac{D \times T_{task}}{T_{sys} \times A_m}$$

Manufacturing Systems can be classified on the following basis:
1.Types of operations performed
2.Number of workstations and system layout.
3.level of automation
4.Part or product variety
5.System layout(4)

1.2 Based on Part or Product Variety

Based on the part or product manufacturing system it can be further classified in three groups. This factor characterizes a manufacturing system to the degree at which it is capable of dealing with variations in the products or parts it produces.
1.Single model
2.Batch model
3.Mixed model

In the mixed model case different parts or products are made by the manufacturing system, but the system is able to handle these differences without need for a changeover in setup and/or program. This means that the mixture of different styles can be produced continuously rather than in batches. The requirement for continuous production of different work unit styles is that the manufacturing system be designed so that whatever adjustments need to be made from one part or product style to the next. these adjustments can he made quickly enough that It is economical to produce the units in batch sizes of one. New manufacturing systems has to be designed for mixed model manufacturing system which may be linked back with 1913 moving assembly line invention.(1)

2 Literature review

In the last hundred years, world of manufacturing has changed in a dramatic way as a response to social and circumstances economic. Which is driven by different requirements in various manufacturing technologies, periods and new paradigms of manufacturing systems have been introduced to address these economic challenges, and to respond social needs. Facing the cost effectiveness requirement, Henry Ford invented the moving assembly line in 1913, which started the mass production in manufacturing systems.
There are manufacturing systems having highly customized products and low volume, are considered as intermittent production systems. They have very long time of delivery. It is not possible to produce such kind of products in mass production system(5)
In the 1970s, the manufacturing industry of Japan started formulating the principles of lean manufacturing, and since quality of product is a major focal point. In the late 1970s, computer numerical control (CNC) machines initiated the creation of flexible manufacturing systems (FMS), which allows to produce a variety of products on the same manufacturing system For manufacturing systems formation of product families has much great importance, which rely

on commonality and similarity between products(3, 6).Different flexible taxonomies are detailed as:

In 1977 the development of FMS Complexes, a test-factory consisting of modular machining units and assembly robots for the production of a whole range of parts within a given envelope started in Tsukuba, Japan. In the late 1970's Flexible Manufacturing System's development started, it provides the possibility that small batches of many different parts which uses a single manufacturing system may be produced(7-11)

Rodney P. Parker et al. stated that Flexible manufacturing systems (FMSs) are kind of technologies which combines the beneficial effects of both numerical and computers to control machine tools. But after the rapid growth in installations of FMS, it is realized by operations managers that the simply investing in flexible manufacturing systems will not answer the market's desire for more product variety, rapid delivery, more product customized designs, and higher design turnover as length of product life cycle is reduced.(12) Companies have shown the successful use of FMS, results in benefits to customers which are mentioned above. (e.g. Toyota, Motorola).(13)

When there are changes in design of product very frequently and variety is increased, it has significant impact on product and systems design, planning, and manufacturing cost(6)

Bolwijn et al. identified that the flexibility will be the focus in next competitive battle and further this battle ``will be waged over manufacturers' competence to overcome the old trade-off between flexibility and efficiency "However it is still a confusion that what will be the constitutes of flexibility(14, 15)

Gerwin et al. studied the flexibility measurement and performance as a notable hurdle for achieving a full comprehensive study of behavior of FMS(16, 17)

Dr. Koren proposed a new design for factories which he called "reconfigurable manufacturing system." having an open system architecture enabling adding machines to the existing operational systems very fast, to respond (1) rapidly, and (2) economically to unexpected market demand. Utilizing RMS allows building a "live" factory that its structure changes cost-effectively responding the markets and customers' needs, to keep supplying products at the competitive price over many years after the factory design(18)

Reconfigurability deals with design of manufacturing systems and production machines and for rapid reconfigurability and cost-effectiveness to respond quickly to market changes. The RMS is, a responsive manufacturing system whose production's capacity is adjustable to fluctuations and whose functionality is very much adaptable to new products(19)

The RMS is designed in such a way that it may cope with such situations in which both productivity and the ability of the system to react to change have importance.

RMS have the two levels in reconfigurability:

(1) In the connection and arrangements of machines at system level

(2) In some of system's machines which are reconfigurable(20)

The major characteristics of RMS may be stated **as:**

Scalability
Modularity
Customization
Convertibility
Integrability
Diagnosability(21)

Dedicated manufacturing lines (DML), or transfer lines, are based on fixed automation and produce a company's core products or parts at high-volume. Each **dedicated** line is typically designed to produce a single part (e.g., specific engine block) at high production rate(21)

The table shown above shows the relationship between DML and FMS, limitations of both systems and advantages associated with DML and FMS.

Table 01: RMS combines features of dedicated and flexible system.

	Dedicated	RMS	FMS/CNC

Machine structure	Fixed	Adjustable	Fixed
System focus	Part	Part family	Machine
Scalibility	No	Yes	Yes
Flexibility	No	Customized	General
Simultaneously Operating Tool	Yes	Yes	No
Productivity	High	High	Low
Life Time	Low For a single part when fully utlized	Medium Or production at medium to high volume new parts and variable demand during system life time	Reasonable For simultanous production of many parts (at low volume) otherwise high

3 Selection of system configuration

The characteristics of system and its performance depend upon the adopted configuration of system. So, system's configuration must be determined with great care at designing stage. The configuration of the system must be determined carefully at the stage of system design, as changing the configuration in future is almost unrealistic.

The selection of system mainly depends upon the goals of system. It can be listed as following.

These goals may be treated as variables of system configuration.

Investment cost(1, 18)

Productivity (22, 23)

Responsiveness to changes in market markets(24)

Minimum loss of performance for destructive events(25, 26)

Consistency in quality of product (27)

Operation capability(2)

Reliability of system(28, 29)

Based on literature review and current based scenario of world three parameters are selected:

Productivity (22, 23, 30)

Responsiveness to changes in market markets (24)

Reliability of system(28, 31, 32)

3.1 Development of equations for RMS and FMS relating productivity

To find productivity of FMS firstly we have to find the work load at each station. Work load can be calculated at a specific station as shown in equation below.

Equation 01: Calculation of work load for first station

$$WL_{1=}[t \times p \times f]_{1A} + [t \times p \times f]_{1B} + [t \times p \times f]_{1C} \cdots\cdots\cdots [t \times p \times f]_{1m} \quad (1)$$

Equation 02: Calculation of work load for nth station

$$WL_{n=}[t \times p \times f]_{nA} + [t \times p \times f]_{nB} + [t \times p \times f]_{nC} \cdots\cdots\cdots [t \times p \times f]_{nm} \quad (2)$$

To find work load at each station we must know time spent on work piece, product mix of a part and frequency of parts. But this work load is of a single part if multiple parts are processed through the station ,this process must be repeated for all the parts to calculate their individual workloads i.e., multiplication of time product mix and frequency and at the last all workloads calculated for different parts must be added to find work load at that particular station. After finding the work load, workload is divided by number of servers at each station which gives us value of ratio. Minimum value of ratio is selected which tells us about bottle neck station. At bottle neck station number of servers is divide by work load which gives us value of productivity.

Where
WL= workload at the station (min/pc).
t =processing time for operation in process plan at a station
f=operation frequency for operation of a part at a station
P=part mix fraction for part

Ratio is calculated which will facilitates in finding the Bottle neck station using following formula
Equation 03: Calculation of ratio using work load and number of servers

$$R = [W * L/S_i] \tag{3}$$

S= number of servers
Equation 04: Number of servers in case of FMS
In case of FMS following equations is used for servers

$$\mathrm{S_i} = [1,2,3 \dots \dots \dots \dots \dots \mathrm{n}] \tag{4}$$

Equation 05: Number of servers in case of RMS
In case of RMS following equations is used for servers

$$S_i = S_r = Constant \tag{4}$$

Maximum value is chosen from all the ratios using following equation.
Equation 06: Calculation of work load for all the stations

$$\sum_{j=1} \sum_{i=1} WL_{ji} = WL_{nm} \tag{5}$$

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Rm=max(R)
Rm is maximum value from the entire ratios. If Rm is chosen from FMS it means maximum productivity is in case of FMS and vice versa. To find the production rate we will use following formula.
Equation 07: Calculation of production rate using ratio already calculated

$$R_p = {}^{1}/{}_{R_m} \tag{6}$$

R_p = Production rate of all part styles produced by the system
Hence production rate of bottle neck station determines the productivity of manufacturing system

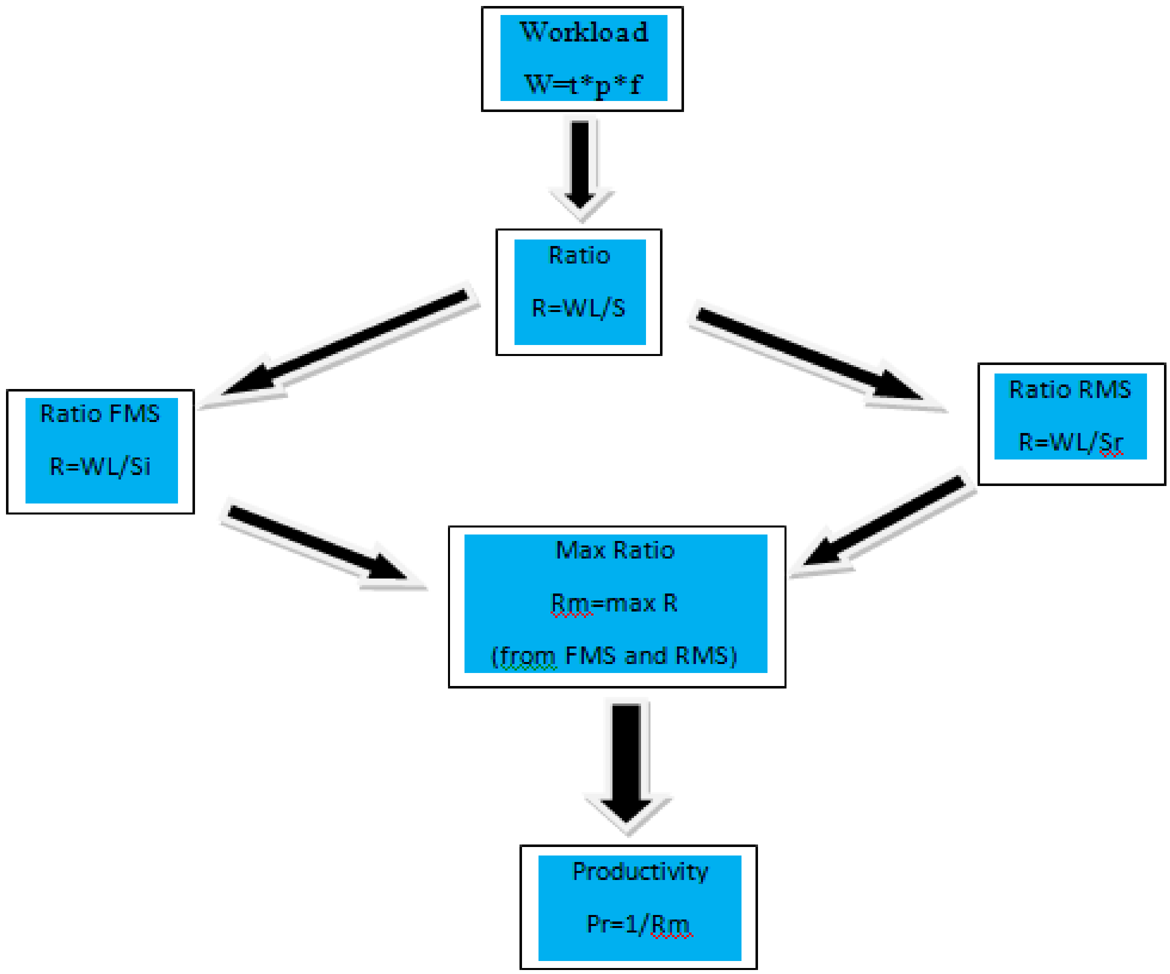

Figure 01: Flow chart for calculation of productivity

3.2 Development of equations for responsiveness of RMS and FMS (11)

Responsiveness of a manufacturing system can be found using following equation. To find the value of responsiveness we have to define the values of Ul and U2 (the relative importance assigned to setup cost and time), αH (Maximum acceptable % of value-added time that can be spent on setup),αs (Maximum acceptable % of value-added cost that can be spent on setup) ,H_{std} (Total value-added production per standard time interval) ,H_{new} (Average cost to set up the facility for production of a new product), T_{std} (Standard time interval),S_{new} (Time to set up facility for production of a new product), These values are defined in ranges, after putting these values in equations we have values of responsiveness of system.

Equation 08: Calculation of Responsiveness of a manufacturing system

$$\boldsymbol{PFLX} = U_1 * \alpha_H * H_{std}/H_{new} + U_2 * \alpha_s * T_{std}/. \quad (7)$$

where

Ul and U2 be the relative importance assigned to setup cost and time,

αH = Maximum acceptable % of value-added time that can be spent on setup,

αs = Maximum acceptable % of value-added cost that can be spent on setup.

H_{std} = Total value-added production per standard time interval (T_{std}),
H_{new} - Average cost to set up the facility for production of a new product,
T_{std} - Standard time interval,
S_{new} - Time to set up facility for production of a new product,

The values of all the stated below variables are defined after literature review and real time industry survey. Values are defined in ranges as no strict value is possible because values may vary from one case to another.

Table 02: FMS and RMS values of different variables(32)

Sr.No.	Variable	FMS value	RMS value
1.	U1	1 to 10	0.1 to 0.9
2.	U2	1 to 10	0.1 to 0.9
3.	αH	0.1 to 0.85	0.01 to 0.09
4.	As	0.1 to 0.70	0.01 to 0.09
5.	H_{std}	0.1 to 0.15	0.85 to 0.95
6.	H_{new}	0.5 to 0.85	0.01 to 0.05
7.	S_{new}	30 to 60	5 to 10

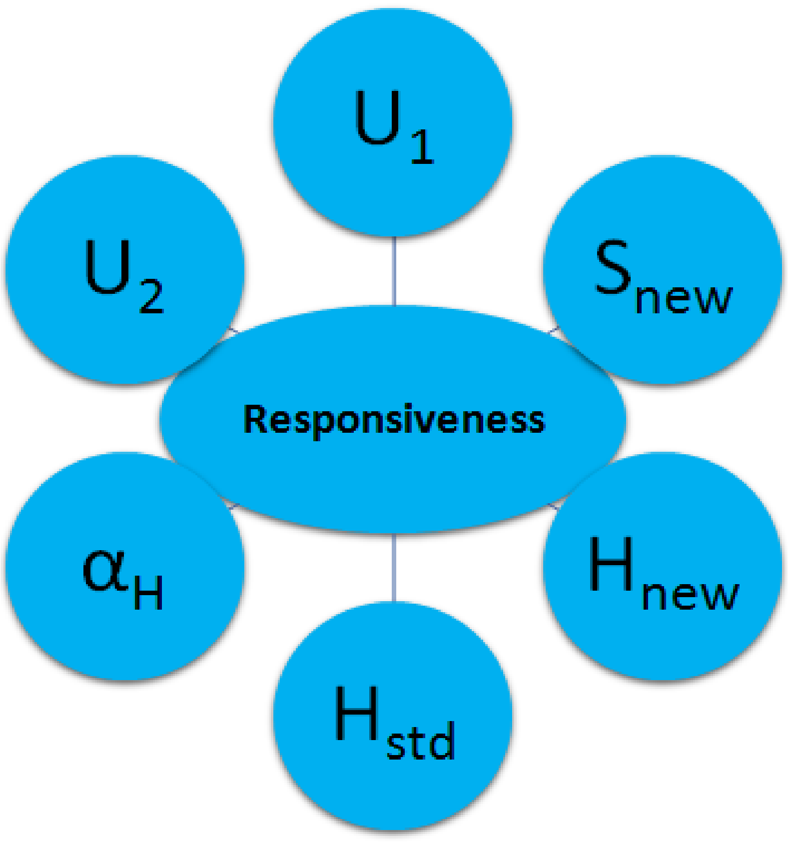

Figure 02: Flow chart diagram for responsiveness

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3.3 Development of equations for RMS and FMS relating reliability

Reliability of system is combination of mean time between failure (MTBF) and mean time to repair (MTTR).

To find reliability of system firstly we will find the meat time between failure which is found by dividing total available time by no. of failures and then mean time to repair is found by dividing times of failures by no. of failures. After finding both values a particular weightage is assigned to them and then added as a result, we have reliability value.

MTBF mean time between failures

MTTR mean time to repair.

MTBF means time after which generally a machine fails and MTTR means time needed to repair a machine. For FMS system MTBF can be calculated using following equation.

MTBF$_{FMS}$=total available time/no. of failures

For FMS system MTTR can be calculated using following equation.

MTTR$_{FMS}$=times of failures/no. of failures (31)

For FMS system Reliability equation will be stated as:

$$R_{FMS} = W_1 * MTBF_{fms} + W_2 * MTTR_{fms} \quad (8)$$

Equation 09: Reliability of FMS considering MTTR and MTBF

W1 and W2 are weight age assigned. The value of these variables may vary as following

Value of W1 varies from 0.05 to 0.09 for FMS and

W2=1-W1

In case of RMS MTTR and MTBF can be finding using following equation. For MTBF we will use following equation

MTBF$_{RMS}$= (***Average*** total available time/ ***Average*** no. of failures)

For MTTR we will use following equation

MTTR$_{RMS}$=***Average*** times of failures/***Average*** no. of failures

$$R_{RMS} = W_1 * MTBF_{rms} + W_2 * MTTR_{rms} \quad (9)$$

Equation 10: Reliability of RMS considering MTTR and MTBF

W1 and W2 are weight age assigned. The value of these variables may vary as following

Value of W1 varies from 0.03 to 0.09 for RMS and value of w2 will be

Equation 11: Values of weightage assigned

$$W_2 = 1 - W_1 \quad (10)$$

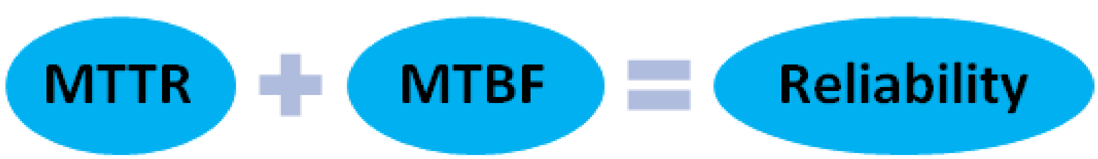

Figure 03: Flow chart diagram of reliability calculation

3.4 Defining constraints

Following are the equations of constraints.

Constraint 01: Value of time must be greater than zero

$$t > o$$

Constraint 02: Value of product mix must be less than zero

$$p < 1$$

Constraint 03: Value of frequency must be less than zero

$$f < 1$$

Constraint 04: Value of ratio must be greater than zero

$$R > 1$$

Constraint 05: Value of servers of FMS must be greater than zero

$$S_i > 0$$

Constraint 06: Value of servers of RMS must be greater than zero

$$S_r > 0$$

Constraint 07: Value of servers' Si must be less than Sr

$$S_i > S_r$$

Constraint 08: Sum of p1, p2 and p3 must be unity

$$p_1 + p_2 + p_3 \ = 1$$

Constraint 09: Sum of f1, f2 and f3 must be unity

$$f_1 + f_2 + f_3 \ = 1$$

Constraint 10: Sum of L, M and N must be unity

$$L + M + N = 1$$

Constraint 11: Sum of x1 and x2 must be unity

$$X_1 + X_2 = 1$$

Assumptions

As it is very clear that without assumptions it is almost impossible to solve the problem. Following assumptions are made during the problem evaluation.

The system is without buffer

The system layout is straight line

There are only forward moves no backward move is allowed

All parts pass through the bottle neck station

All the assumptions are based on realistic situations.

3.5 Construction of objective function

Using all the above stated data equation for objective function is stated as:

Obj =L*PRODUCTIVITY + N*RESPONSIVENESS + M*RELIABILITY (11)

Equation 12: Definition of objective function

Where L, M and N are variables, whose values are defined in a range based on different real time and hypothetical problems.

In case of RMS

Value of L varies from 0.0006 to 0.0009

Value of M varies from 0.0006 to 0.0008

In case of FMS

Value of L varies from 0.00001 to 0.00009

Value of M varies from 0.0006 to 0.0008

4 Application on the problems

First of all, equations are applied on two hypothetical problem which are assumed but very close to real time data, then two real time problems are considered and equations are applied on that.

Problem 01

A system consists of seven stations. Station 1 is a load/unload station with one server. Station 2 performs facing operations with three servers (three identical CNC Lath machines). Station 3 performs turning operations with two servers (two identical CNC Lath machines). Station 4 is horizontal milling station with2server.Station 5 is Drilling milling station with4 servers (identical CNC Drilling machines). Station 6 is vertical milling station with3 servers (identical CNC vertical milling). Station 7 is inspection station with 2 servers. The stations are connected by a part handling system that has two work carriers and whose mean transport time = 35 min. The system receives an order to produce a family of products having seven parts. A, B, C, D, E, F and G. All the machines available for production are light weight category machines. The part mix fractions and process routings for the four parts are presented in the table below. Note that the operation frequency at the inspection station is less than 1.0 to account for the fact that only a fraction of the parts is inspected. Standard time for production is eight hours per day and six days in a week. Determine the system configuration which is most suitable considering productivity, reliability and responsiveness only?

Table 03: Data of problem 01

Part	Part mix	Operation	Description	Station	Process Time	Frequency
A	0.2	1	Load/Unload	1	5	1
		2	Facing	2	10	1
		3	Turning	3	15	1
		4	H.Milling	4	18	1
		5	Drilling	5	25	1
		6	V.Milling	6	20	1
		7	Inspection	7	17	0.4
B	0.1	1	Load/Unload	1	5	1
		2	Facing	2	13	1
		3	Turning	3	17	1
		4	H.Milling	4	35	1
		5	Drilling	5	25	1
		6	V.Milling	6	20	1
		7	Inspection	7	10	0.9
C	0.2	1	Load/Unload	1	5	1
		2	Facing	2	27	1
		3	Turning	3	20	1
		4	H.Milling	4	18	1
		5	Drilling	5	10	1
		6	V.Milling	6	38	1
		7	Inspection	7	20	0.4
D	0.15	1	Load/Unload	1	5	1
		2	Facing	2	24	1
		3	Turning	3	20	1
		4	H.Milling	4	22	1
		5	Drilling	5	15	1
		6	V.Milling	6	18	1
		7	Inspection	7	25	0.2
E	0.1	1	Load/Unload	1	5	1
		2	Facing	2	22	1
		3	Turning	3	27	1
		4	H.Milling	4	35	1
		5	Drilling	5	41	1
		6	V.Milling	6	27	1
		7	Inspection	7	29	0.7
F	0.15	1	Load/Unload	1	5	1
		2	Facing	2	33	1
		3	Turning	3	25	1
		4	H.Milling	4	27	1
		5	Drilling	5	43	1
		6	V.Milling	6	24	1
		7	Inspection	7	31	0.5
G	0.1	1	Load/Unload	1	5	1

		2	Facing	2	35	1
		3	Turning	3	41	1
		4	H.Milling	4	27	1
		5	Drilling	5	22	1
		6	V.Milling	6	27	1
		7	Inspection	7	22	0.5

Above stated equations are programmed in matlab (annexure 1).

Results and discussion

Problem 02

An organization encourages its customers to place orders to produce new products of same family. One of clients places an order to produce ten parts (A, B, C, E, F, G, H, I and J) of same family. The space available in organization facility limits all stations to be arranged in a straight line. After checking all the constraints associated with the manufacturing of parts; it is decided to arrange stations in such a way that Station 1 is a load/unload station with two servers. Station 2 performs turning operations with three servers (three identical CNC Horizontal Lath machines). Station 3 performs Horizontal milling operations with two servers (two identical Horizontal CNC Milling machines). Station 4 is drilling machines station with 2 servers (identical CNC milling machines). Station 5is vertical milling station with 4 servers (identical CNC vertical milling machines). Station 6 is vertical lath station with 3 servers (identical CNC vertical Lath machines). Station 7 is Planner station with4 servers. Station 8is Hobbing machines station with3 servers (identical CNC Hobbing machines). Station 9 is inspection station with 2 servers. The stations are connected by a part handling system that has two work carriers and whose mean transport time = 55 min. All the machines available for production are light weight category machines. The part mix fractions and process routings for the all parts are presented in the table below. Note that the operation frequency at the inspection station is less than 1.0 to account for the fact that only a fraction of the parts is inspected. Standard time for production is eight hours per day and six days in a week. Determine the system configuration which is most suitable considering productivity, reliability and responsiveness only.

Table 04: Data of problem 02

Part	Part mix	Operation	Description	Station	Process Time	Frequency
A	0.1	1	Load/Unload	1	5	1
		2	H.Turning	2	10	1
		3	H. Milling	3	15	1
		4	Drilling	4	18	1
		5	V.Milling	5	25	1
		6	V.Turning	6	20	1
		7	Planning	7	17	1
		8	Gear Cutting	8	15	1
		9	Inspection	9	18	0.7
B	0.1	1	Load/Unload	1	5	1
		2	H. Turning	2	13	1
		3	H. Milling	3	17	1
		4	Drilling	4	35	1
		5	V.Milling	5	25	1
		6	V.Turning	6	20	1

		7	Planning	7	17	1
		8	Gear Cutting	8	35	1
		9	Inspection	9	25	0.4
C	0.1	1	Load/Unload	1	5	1
		2	H.Turning	2	27	1
		3	H. Milling	3	20	1
		4	Drilling	4	18	1
		5	V.Milling	5	10	1
		6	V.Turning	6	38	1
		7	Planning	7	17	1
		8	Gear Cutting	8	35	1
		9	Inspection	9	25	0.3
D	0.1	1	Load/Unload	1	5	1
		2	H. Turning	2	24	1
		3	H. Milling	3	20	1
		4	Drilling	4	22	1
		5	V.Milling	5	15	1
		6	V.Turning	6	18	1
		7	Planning	7	24	1
		8	Gear Cutting	8	20	1
		9	Inspection	9	22	0.8
E	0.1	1	Load/Unload	1	5	1
		2	H.Turning	2	22	1
		3	H. Milling	3	41	1
		4	Drilling	4	27	1
		5	V.Milling	5	29	1
		6	V.Turning	6	35	1
		7	Planning	7	41	1
		8	Gear Cutting	8	27	1
		9	Inspection	9	29	0.5
F	0.1	1	Load/Unload	1	5	1
		2	H.Turning	2	33	1
		3	H. Milling	3	25	1
		4	Drilling	4	27	1
		5	V.Milling	5	50	1
		6	V.Turning	6	34	1
		7	Planning	7	43	1
		8	Gear Cutting	8	24	1
		9	Inspection	9	31	0.5
G	0.1	1	Load/Unload	1	5	1
		2	H. Turning	2	35	1
		3	H. Milling	3	34	1
		4	Drilling	4	26	1
		5	V.Milling	5	41	1
		6	V.Turning	6	37	1
		7	Planning	7	21	1

		8	Gear Cutting	8	40	1
		9	Inspection	9	29	0.6
H	0.1	1	Load/Unload	1	5	1
		2	H. Turning	2	33	1
		3	H. Milling	3	25	1
		4	Drilling	4	27	1
		5	V.Milling	5	30	1
		6	V.Turning	6	21	1
		7	Planning	7	43	1
		8	Gear Cutting	8	24	1
		9	Inspection	9	31	0.6
I	0.1	1	Load/Unload	1	5	1
		2	H. Turning	2	35	1
		3	H. Milling	3	34	1
		4	Drilling	4	27	1
		5	V.Milling	5	41	1
		6	V.Turning	6	20	1
		7	Planning	7	22	1
		8	Gear Cutting	8	44	1
		9	Inspection	9	35	0.7
J	0.1	1	Load/Unload	1	5	1
		2	H. Turning	2	35	1
		3	H. Milling	3	22	1
		4	Drilling	4	28	1
		5	V.Milling	5	41	1
		6	V.Turning	6	20	1
		7	Planning	7	33	1
		8	Gear Cutting	8	42	1
		9	Inspection	9	22	0.7

Results and discussion

Selection of correct manufacturing paradigm is an essential and key process when new industry is to be established. In this research work a complete frame work is developed which will make easy for the industrialists to select the correct manufacturing paradigm based upon calculations by just providing basic data. Three parameters are considered during the development of frame work. Other parameters may also be included after modifying the equations.

Work load is calculated using task time, frequency and part mix. Ratio is found using work load and number of servers. Minimum is found from that ratio, which tells us weather FMS is suitable or RMS. Than production rate is determined. Next step is to find the responsiveness and reliability using given equations. Then all these parameters are plugged into objective function using matlab program which tells the manufacturing paradigm. Results are stated as following.

		Parameters			
	Manufacturing paradigm	**Productivity**	**Responsiveness**	**Reliability**	**Objective function**
Problem 01	RMS	25.7373	0.0040	51.3000	0.0579

Problem 02	FMS.	31.3725	0.0019	8.6400	0.0299

Results shows that correct manufacturing paradigm cannot be selected based on hypothesis, it must be based on correct data plugged into frame work developed for that purpose and let the frame work decide the manufacturing paradigm. It is concluded that selection of parameters plays key role in determination of manufacturing paradigm. In this research work, the selected parameters: productivity, reliability and responsiveness to market change are independent parameters and most concerned in today's world scenario. The results obtained after the consideration of these parameters are valid in real world. All the assumptions made during the formulation are correct and may be assumed in real world for simplification of problem and did not exploit the results. Small variation in number of machines and productivity calculation may change manufacturing paradigm from FMS to RMS and vice versa.

5 Future recommendations

Some of the future recommendations related to the research work are explained below.

5.1 Selection of parameters

During this research work three parameters are considered. Research may be conducted considering all the parameters.

5.2 Selection of moves

During this research work only forward moves in both FMS and RMS are considered. Research may be conducted including backward and by pass moves.

5.3 Selection of path

During this research work straight line system is considered. Research may be conducted including U-type or ladder type structure.

5.4 Optimization of parameters

During this research parameters are not optimized. All the parameters can be optimized.

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