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Performance Optimization of Reconfigurable Manufacturing System Using Dual Step Metaheuristic Approach

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Abstract

Reconfigurable manufacturing system aka RMS is a novice topology in manufacturing sector that is designed in accordance with the product requirement, however re-configurability is considered as the non-functional system requirement and it is long term behavior. Thus considering the conventional approach dynamic change is highly improbable; hence it is necessary to design the model that has the dynamic change capacity. In this research work, we have developed (DSMO) dual step metaheuristic optimized approach to solve the two distinctive problem; in first step we optimize the product changes reaction. In second step, we develop the optimized layout for machine selection by optimizing the machine floor arrangement and position of machine. Further dual step mechanism is evaluated through comparison analysis with the existing model of ANC90. Moreover, evaluation is performed by considering two cases adopted from the existing model; in case 1 cost comparison has been carried out whereas in case 2 re-configuration cost, total cost and capital cost are compared. Further comparison has been carried out considering the various scenarios in both cases and comparative analysis indicates that proposed methodologies simply outperforms the existing model.

Keywords: RMS, dual step, process planning.

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1 Introduction

In Last decade economy has been on edge and considering the volatile and personalized demand, manufacturing companies are focusing on the novel flexibility norms; in general, there should be assurance of manufacturing system to adjust the future scenario through replacing nominal component [1]. Further manufacturing system has evolved in these years with increase in global and dynamic market; several manufacturing company uses the FMS (Flexible Manufacturing System) and Dedicated Manufacturing Lines aka DML for product. Moreover, both possesses their own disadvantage such as

DML are non-flexible and non-scalable, however they are low cost and have multi tool operation. Although FMS is flexible and scalable, it is much more expensive and gives very low throughput [2][3].

Moreover, often batch production is applied in manufacturing context of low volume diversified sector that is gaining fine attention due to the customization of product; a batch is nothing but part set which are manufactured in bundle which means entire parts of that particular batch follows the similar manufacturing path, however each has its own operations. Further, in reconfigurable manufacturing system, operating modules can be adopted in case of every batch. However, it is highly recommended to not use equipment's reconfiguration. Hence these batches are designed in such a way that parts processing does not require any kind of configuration reconfiguration of equipment [4]- [6].

Hence RMS (Reconfigurable Manufacturing System) concept was introduced based on the equipment component that can be arranged, moved as well as replaced based on the primary principle of customization, maintainability, reliability, convertibility, Integrability, scalability and modularity. The main intention behind RMS is to integrate the high throughput of DML and FMS flexibility for efficiency and fast. RMS possesses various manufacturing aspects such as modular machine configuration, modular configuration, building blocks and machine controller configuration and industry software [7].

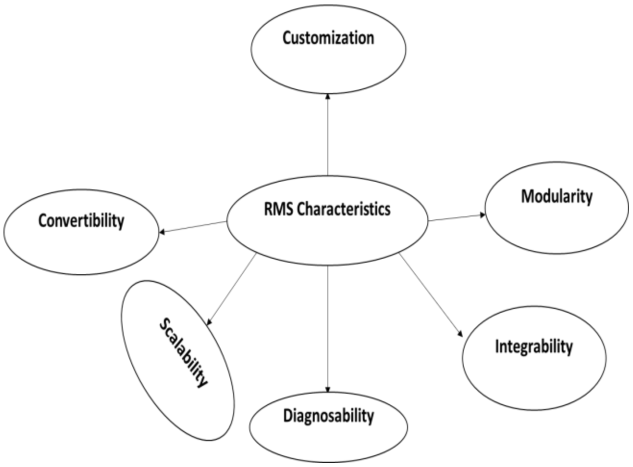

Figure 1 RMS principles

Figure 1 shows the basic principles of re-configurable manufacturing system; these principles are elaborated through below points.

- RMs comprises the scalable production in accordance with the customer requirement i.e. RMS is capable of scaling the small increments and also adoptable for the new products.
- RMS is designed for improvisation in manufacturing response.
- RMS comprises mixture of reconfigurable and flexible with their customized facility such as re-configurable machines are subject to changes in accordance with the customer demand.
- Moreover, system that has several routes for producing the particular part but it requires high investment cost in material handling model and tooling.
- RMS has the software as well as hardware capabilities for handling the unpredicted situations in terms of machine failure and market changes.

- RMS has the stand by and cost effective safety characteristics which is utilized for the unpredictable events.

Moreover, in the above discussed points first three points is the basic characteristics of RMS; other principle discussed are secondary which further helps in cost effective design. RMS typical configuration has hierarchy and it is shown in figure1.

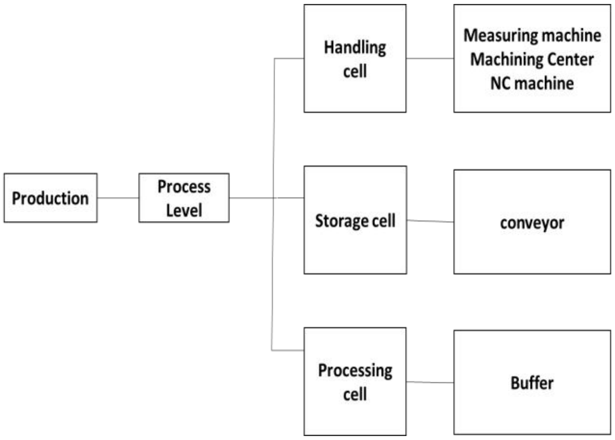

Figure 2 RMS Hierarchy

1.1 Motivation and contribution of research work

RMS possesses various distinguish feature that has the ability for configurational change to provide the capacity and functionality, moreover these configurational change occurs in various aspects such as adding or removing the spindles, adding or removing the machine.

Further the contribution of this research work is highlighted through the below points:

- The main aim of this research work is to design the responsive model based on re-configurability features by addressing the RMS designed issue.
- We propose a DSMO for solving two designed problems first problem includes the product evolution to meet the customer requirement
- Dual step mechanism is optimized approach which helps in assuring the optimal transition between the various products of given same family.
- In dual step mechanism product family evolution is combined for better responsiveness of machines.

This research work is organized in following way: first section starts with manufacturing industry and its background; further RMS and its core characteristics is discussed. Later in the same section, motivation and contribution of this particular research work is discussed. Second section reviews the existing RMS mechanism and highlights their drawbacks. Third section focus on designing and development of dual step mechanism approach with mathematical model and algorithm. Last but not least, fourth section focuses on dual step mechanism evaluation through comparing with the existing model.

2 Literature Survey

Reconfigurable manufacturing system products comprises various product families where each of them are considered to be the similar product; further in each product family various configurations are observed. Moreover,these configurationshave different changeover cost, production cost and production speeds. Furthermore, manufacturer chooses product family as given production task and RMS produces various products which belongs to the chosen family in given configuration. Hence when the product is sold, reward is achieved. Moreover, while production task is completed manufacturer should select its family as given subsequent production task. Changeover cost is occurred while change in configuration from one product another. In past several researchers have developed a RMS technique; [8] proposed very first stochastic model which provided the complete modeling RMS, here the main concern was with three distinctive factor for RMS implementation such as designing stage, policy selection stage and performance measurement.Moreover, here two different case studies get evaluated; their further work developed an algorithm to select the optimal configuration for a product family for maximizing the average profit [9]. Similarly, [10] focused on the optimal selection policy considering the performance measure which allows the manufacturer to optimize the order number in such a way that there is marginally fluctuation in market [11]. Further to get rid of the complicated stochastic model and time consuming analysis [9] focused on the design process where single feasible configuration is chosen and it is fixed as an optimum configuration in the given utilization process i.e. In here several parameters are excluded such as flexibility, scalability and alternative routes are ignored. Hence to avoid such mistakes [12] observed that in general RMS reacts to the arrival orders and each faces with huge delay. Moreover,RMS faces backorders without any additional cost and when there doesn't exist any arrived order RMS halts and wait until the RMS is terminated.

Furthermore, as it is observed that RMS reacts on the order arrivals and thus it faces the unpredictable delay i.e. There are several assumptions such as RMS has to wait for an order concerning over the cost and time. Moreover, several assumption has been discussed in paper [13]; however, considered assumptions needs to be ignore as it requires time to switch from one particular configuration to the other configuration[14].Moreover, several layout strategies were developed for the re-configuration requirement such as [15] and [16] on focusing the designing the dynamic layout; moreover, dynamic layout configuration haveadvantage of requirement of minimal effort. Other paper like [17]-[19] considered the specific topologies such as flexible manufacturing system and cellular, manufacturing system. However, managing the resource positioning were quite difficult. Other papers like [19]- [25] did extensive research on modelling, configuration, layout design and they provided great contribution towards the review of RMS.

Further all these discussed paper failed in one or the other thing such as machine layout evolution, positioning of machine and also they were not cost effective. Hence considering the extensive review, we have developed dual step mechanism to enhance the RMS performance.

3 Proposed Methodology

Problem of machine layout possesses yet another dimension considering the RMS; further apart from the general constraint it is also necessary to combine the re-configurability characteristics. In this research work, we focus on developing a decision making mechanism for ensuring the optimal transition among the product in the family.Moreover, decision making mechanism is designed in accordance with defining problem; first problem is facilitationof residualresources in order to use the same model. Second problem is considering the optimal layout for these machines; in general,second problem is defined as the machine selection for given product and how these machine has to be arranged on the floor. Moreover, these two problem comprises different sub-problem discussed later in the same section. Further considering these two problem we design an optimal decision approach.

3.1 Hypothesis:

Further in order to design the optimal mechanism of problem, we have considered eight hypotheses that are given below:

H1:	Machine set that are involved in the process are selected in first place, hence optimized process plan for the different product of same family are formed based on the different performance metrics.
H2:	In case of each product that needs to be manufactured from the product family; only one unit of product is taken to process.
H3:	In product family, each unity in product family has been assigned for the optimal process; hence selected machine set to design occurrence and RMS is known.
H4:	Machine set that are used for generating the process plan is known and further used for solving the problem discussed later.
H5:	Layout configuration consists of its location and these machines have the restricted occurrences.
H6:	Product family consists of various products.
H7:	Each product gets realized through machine set.
H8:	Each product uses the various machine duplication.

Moreover, the main intention through this research is to identify the optimal RMTs layout and reducing the penalties. Furthermore, theabove discussed problem, first problem is transition effort;

3.2 Dual step metaheuristic optimization algorithm (DSMO-algorithm)

In this sub-section we design the dual step mechanism for solving the above discussed problem. Moreover, in the below algorithm step1 to step 3 is first step and generated output is given to the input which is from step 4 to step9

***Step*1**:	*start*
***Step*2**:	*Initial layout evolution effort*
***Step*2. 1**:	*Given input as inclusion matrix and process plan*
***Step*2. 2**:	*deploy the proposed mechanism.*
***Step*3**:	*Machine layout formation*
***Step*3. 1**:	*Initial layout generation*
***Step*3. 2**:	*generate the minimum desired distance and maximum desired distance*
***Step*4**:	*create machine based matrix and generate new process plan*
***Step*5**:	*generate an optimal solution for positioning machine*
***Step*6**:	*solution evaluation by using the penalty function*

$\boldsymbol{Step7}$:	$If\ penalty\ is\ less\ than\ the\ solution\ then\ \ go\ to\ step8\ else\ goto\ step10$
$\boldsymbol{Step8}$:	$developed\ solution\ is\ equivalent\ to\ the\ current\ solution$
$\boldsymbol{Step9}$:	$search\ space\ if\ found\ go\ to\ step10\ else\ \ go\ to\ step5$
$\boldsymbol{Step10}$:	$return\ the\ current\ solution$
$\boldsymbol{Step11}$:	end

3.3 Initial step for product evaluation

In this section we consider the problem of transition effort; in here at first machine is chooses that possesses better functionalities in comparison with the initial product. Further functionality selection is not only for the initial product it can be for any additional product, hence this rises the replacement of one particular machine with the other. Further load balancing mechanism and the idea of alternative machine needs to be considered as there is a risk of machine failure. Further we consider the machine diversity which is considered for reducing the exclusive relation among the machine. Moreover, considering the above scenario, optimization of transitional effort is carried out.Average maximization of machine uses to achieve the equilibrium can be given through the below equation

$$AM_{\mathscr{q}}(\mathbb{N}_{\mathscr{k}}) = \left(\frac{Dup_{\mathscr{q}}(\mathbb{N}_{\mathscr{k}})}{\daleth_{\mathscr{q}}}\right) \times \sum_{\mathscr{v}=0}^{\daleth_{\mathscr{q}}} \left(\mathrm{A}_{\mathscr{k}}(\beth_{\mathscr{v}}^{\mathscr{q}}) \times \mathbb{N}_{\mathscr{k}}(\beth_{u}^{\mathscr{q}})\right) \quad (1)$$

$$Max\left\{\eth = (\Finv \times \varkappa)^{-1} \sum_{\varkappa=1}^{\varkappa} \sum_{\mathscr{q}=0}^{\Finv} AM_{\mathscr{q}}(\mathbb{N}_{\mathscr{k}}) \right. \quad (2)$$

In above equation $\mathbb{N}_{\mathscr{k}}(\beth_{u}^{\mathscr{q}})$is considered as unit, in case if $\mathbb{N}_{\mathscr{k}}$ achieves the $\mathscr{v}$ operation on $\mathcal{Q}_{\mathscr{q}}$ product, else it is considered as null. Similarly α is considered as unit if $\mathbb{N}_{\mathscr{k}}$ is chosen as machine to perform operation v, else $\mathcal{Q}_{\mathscr{q}}$ is 0.

Moreover, machine replacement in the production line is given as:

$$Max\left\{\mathfrak{E} = \frac{1}{\Finv} \sum_{\mathscr{q}=0}^{\Finv} \left(\frac{1}{\daleth_{\mathscr{q}} \times \mathfrak{D}_{\mathscr{q}}} \sum_{v=0}^{\daleth_{p}} \sum_{k=0}^{\mathfrak{D}_{q}} \left(\mathbb{N}_{\mathscr{k}}(\beth_{u}^{q} \times \mathfrak{Y}_{\mathscr{q}}(\mathbb{N}_{\mathscr{k}})\right)\right)\right\} \quad (3)$$

$$\mathrm{Sim}\mathbb{N}[\mathbb{N}_{\mathscr{k}}][\mathbb{N}_{\ell}] = \mathrm{B}(\mathscr{k},\ell) - \frac{\mathrm{B}(\mathscr{k},\ell) \times |\mathcal{O}\mathfrak{S}_{\mathscr{k}} - \mathcal{O}\mathfrak{S}_{\ell}|}{\mathcal{O}\mathfrak{S}_{\mathscr{k}} + \mathcal{O}\mathfrak{S}_{\ell}}$$

Where,

$$\mathrm{B}(\mathscr{k},\ell) = \begin{cases} 1, & if\ machines\ \mathbb{N}_{\mathscr{k}}\ and\ \ \mathbb{N}_{\ell}\ have \\ & 0, \quad otherw \\ & \ell, \mathscr{k} \in 1 \ldots \end{cases} \quad (4)$$

Further we tend to optimize the layout evolution as it tends to changes while selecting the machines and their rearrangement; layout evolution is optimized based on the two distinctive phenomena. First is similarities of machines, which helps in choosing the appropriate machines, later average similarity is formulated based on the configuration type and configuration number.

$$\text{average similarity}\mathcal{N}_q = \frac{1}{\mathfrak{O}_q}\sum_{k=1}^{\mathfrak{O}_q-1} \mathrm{SimM}[\mathbb{N}_k][\mathbb{N}_\ell] \qquad (5)$$

Similarly, we identify the average similarity among machines that are chosen to realize the product and it is given in the below equation.Further difference in machine type is considered which is nothing but selected machine; here number of machine added, deleted are formulated and given through the below equation.

$$deleted\_nachine = \sum_{k=0}^{\mathfrak{R}} Min\big(\mathfrak{M}_q[M_j] - \mathfrak{M}_{q'}[\mathbb{N}_k], 0\big) \qquad (6)$$

$$added\_machine = \sum_{k=0}^{\mathfrak{R}} Min\big(\mathfrak{M}_q[M_j] - \mathfrak{M}_{q'}[\mathbb{N}_k], 0\big) \qquad (7)$$

Used type quantification is formulated through equation, this represents the quantification while moving.

$$\mathfrak{U} = \sum_{k=0}^{\mathfrak{R}} Max\big(\mathfrak{M}_q[\mathbb{N}_k] - \mathfrak{M}_{q'}[\mathbb{N}_k]\big)$$

Where,

$$\mathfrak{M}_q[\mathbb{N}_k] = \begin{cases} 1, & if\ product\ Q_q is\ realized\ by \\ 0, & otherwise \end{cases} \qquad (8)$$

Moreover, using equation 6, 7 and 8, difference is computed between the selected machines.

$$\mathfrak{W}\,if_q = \frac{deleted\_nachine + added\_machine}{\mathfrak{U}} \qquad (9)$$

Further the layout evolution effort is given as and also it is minimized

$$Min\left\{\mathfrak{L} = \frac{1}{\Finv}\sum_{=1}^{\Finv}\left(\frac{\mathfrak{W}\,if_q}{\text{average similarity}\mathcal{N}_q}\right)\right\} \qquad (10)$$

3.4 Second Step for Machine layout problem

In this section we focus on machine layout problem through the matrix localization; matrix localization provides the flexibility to design a layout configuration through considering the system constraint and distance among machines; further it also includes the position. Moreover, matrixlocalization helps in developing the generic model that can include possible configuration of layout. Moreover, distance among the position mainly depends on transfer capacities. Transfer capacities are generated by decision maker and it is considered as the input for proposed model.

Further in our proposed model RMS comprises various RMTs that have the manufacturing capacity; in here each RMT possesses number of instances for workshop according to the requirement of given product.Further in proposed model we assume single unit assigned to each product for optimal processing; hence machine included are well known, also machine can be used various times in process plan and number of user might exceed from the number of occurrence availability. Further a machine might have number of occurrence and appear various times.

Moreover, considering these inputs, an initial layout is generated in accordance with machineappearance. For instance if any given machine $\mathbb{N}_{\mathscr{k}}$ is applied after other machine, then selected layout offers the connection possibility among these machines. Further considering the constraint and initial layout maximum distance and minimum distances are defined among the different machine as well as machine occurrence. This further helps in defining the significance of machine for adopting the process plan. $MI(M_j)$Indicates the machine significance that provides the dependency factor, further process plans is given as:

$$MI(\mathbb{N}_{\mathscr{k}}) = \frac{1}{NP} MI_p(M_j)/NSM_p \qquad (11)$$

Where:

$$\mathfrak{C}_{\mathscr{q}}(\mathbb{N}_{\mathscr{k}}) = \sum_{\ell=1}^{\mathfrak{Y}_{\mathscr{q}}[\mathbb{N}_{\mathscr{k}}]} \mathfrak{d}_{\mathscr{q}}(\mathbb{N}_{\mathscr{k}\ell}) \qquad (12)$$

$$\mathfrak{d}(\mathbb{N}_{\mathscr{kp}}) = \mathfrak{y}_{\mathscr{q}}(\mathbb{N}_{\mathscr{kp}}) \times \sum_{\ell=1}^{\mathfrak{D}_{\mathscr{q}}^{\mathscr{p}}} \frac{\mathfrak{g}_{\mathscr{q}}[\mathbb{N}_{\mathscr{kp}}][\mathbb{N}_{\mathscr{k}'\ell}] + \mathfrak{g}_{\mathscr{q}}[\mathbb{N}_{\mathscr{k}'\ell}][\mathbb{N}_{\mathscr{kp}}]}{\mathfrak{Y}_{\mathscr{q}}(\mathbb{N}_{\mathscr{k}})} \qquad (13)$$

$CP_P(\mathbb{N}_{\mathscr{kp}})$Represents the occurrence of machine $\mathbb{N}_{\mathscr{k}}$ in product $\mathcal{Q}_{\mathscr{q}}$, $\mathfrak{g}_{\mathscr{q}}[\mathbb{N}_{\mathscr{kp}}][\mathbb{N}_{\mathscr{k}'\ell}]$ indicates the relation among the machines and given as:

$$\mathfrak{g}_{\mathscr{q}}[\mathbb{N}_{\mathscr{kp}}][\mathbb{N}_{\mathscr{k}'\ell}] = \begin{cases} 1 & if\ machine\ \mathbb{N}_{\mathscr{k}'}\ occurs\,after \\ & 0 \end{cases} \qquad (14)$$

Further equation 11 helps in penalty determination which occurs if position of machines are satisfied or not. Further once machine metric is defined, occurrence of machine for the complete product leads to achieve the initial layout through available input. Further initial machine assignment is based on these machine sequence in given metrics and process plans.

Moreover using the initial layout distance of different machines for whole product is formulated, based on the initial layout and constraint , we define the two distinctive matrices i.e. maximum desired distance and minimum desired distance is formulated and it is given as$MinAD\left[\mathbb{N}_{\mathscr{kp}}\right]\left[M_{jo}^{'}\ \right]$ and $MaxAD\left[\mathbb{N}_{\mathscr{kp}}\right]\left[\mathbb{N}_{\mathscr{kp}}^{'}\ \right]$. Moreover, these two matrix is formulated through the below steps:

Step1: detect and select the occurrence that are retained in initial layout

Step2: compute the distance to right and distance to left and denoted as $\mathcal{E}^{\mathcal{M}}$ and D^R

Step3: expression to the left distance$\mathbb{N}_{\mathscr{k}}$ is given as:

$$\mathcal{E}_{pos}^{L\_k} = \begin{cases} |\mathcal{L} - pos|\mathcal{T}_j\mathcal{L} \geq pos \\ |\daleth - \mathcal{L}| + \mathcal{L} \quad \mathcal{T}_j\,\mathcal{L} < pos \end{cases} \qquad (15)$$

Step4: expression to the right distance of machine $\mathbb{N}_{\mathscr{k}}$ is given as:

$$\mathcal{E}_{pos}^{R\_k} = \begin{cases} |\mathcal{L} - pos|\mathcal{T}_j\mathcal{L} \geq pos \\ |\daleth - \mathcal{L}| + pos \quad \mathcal{T}_j\mathcal{L} > PI \end{cases} \qquad (16)$$

In the above equation i.e. equation 14 and 15,$pos$is index occurrence retained through initial layout.

Step5: compute $MinAD_P$ as the distance between the two machine

$$MinAD_P[\mathbb{N}_{\mathcal{kp}}][\mathbb{N}_{\mathcal{kp}'}] = Min\left(\mathcal{E}_{pos_{\mathbb{N}_{\mathcal{kp}}}}^{\mathcal{S}'_{\mathbb{N}_{\mathcal{kp}}}}, D_{pos_{\mathbb{N}_{\mathcal{kp}}}}^{\mathcal{M}'_{\mathbb{N}_{\mathcal{kp}}}}\right) \quad (17)$$

Step6: compute $MaxAD_P$ as the distance between two machine

$$MaxAD_P[\mathbb{N}_{\mathcal{kp}}][\mathbb{N}_{\mathcal{kp}'}] = Min\left(\mathcal{E}_{pos_{\mathbb{N}_{\mathcal{kp}}}}^{\mathcal{S}'_{\mathbb{N}_{\mathcal{kp}}}}, D_{pos_{\mathbb{N}_{\mathcal{kp}}}}^{\mathcal{M}'_{\mathbb{N}_{\mathcal{kp}}}}\right) \quad (18)$$

Moreover, in accordance with the importance indicator, penalty function is formulated; penalty function analyses and generates the various process plan through generating the layout of RMT. Hence our aim is to minimize the penalty function given in the below equation.

$$Min\left\{Pen' = \sum_{\mathcal{k}=1}^{\mathfrak{D}}\sum_{\ell=1}^{\mathfrak{D}} \mathcal{Y}_{\mathcal{k}\ell} \times \mathfrak{C}(\mathbb{N}_{\mathcal{k}})\right\} \quad (19)$$

Where,

$$X_{jk} = \begin{cases} 1, if\ MinAD[\mathbb{N}_{\mathcal{kp}}][\mathbb{N}_{\mathcal{k}'\ell}] \leq LoC[\mathcal{Q}(\\ \quad [\mathcal{Q}(\mathbb{N}_{\mathcal{k}'\ell}) \leq MaxAD][\mathbb{N}_{\mathcal{kp}}][\mathbb{N}_{\mathcal{k}} \\ \qquad 0, \quad otherwise \end{cases} \quad (20)$$

Moreover, since our mechanism lies in metaheuristic approach; combining the two problems helps in achieving the satisfactory outcome. In here the result from first step is given input to the second step. Further once dual step metaheuristic optimization method is designed, method is evaluated by considering two cases from existing methodology.

4 Performance Evaluation

In this section we evaluate DSMO mechanism for optimized configuration of RMS, for evaluation we have considered the standard system configuration. Here Python is used as the programing language on windows platform packed with 8 GB RAM i7 processor.

4.1 Cases Description

In this sub-section, we discuss about the cases, first case has been adopted from paper [23] whereas second case is adopted from the existing model. Moreover, these two cases belong to the RFL with two similar parts E and F derived from the ANC-90 part. Further Table 1 and table 2 provides the machine description which includes cost and capacities; table 2 provides the demand as well as job information for each and every part in both cases. Further in order to simulate the proposed mechanism we have used python as programming language in system environment of 1TB hard disk, i7 processor packed with 8 GB RAM and 2GB NVidia graphics card. Further windows 10 platform is chosen for simulation.

Table 1machine description.

$\boldsymbol{Base\ Name}$	$\boldsymbol{Base\ Description}$	$\boldsymbol{configuration}$	$\boldsymbol{Description\ of\ spindle}$

MCI	$Reconfigurable$ $- HMM(Horizontal\ Milling\ Machine)$	MCI_1 MCI_2 MCI_3 MCI_4 MCI_5	$Three\ axis\ with\ single\ spindle$ $Three\ axis\ with\ two\ spindle$ $Three\ axis\ with\ three\ spindle$ $Three\ axis\ with\ four\ spindle$ $Four\ axis\ with\ single\ spindle$
$Operation\_Setup$	MCI_1	MCI_2	MCI_3
$Operation\_Setup1$	30	15	10
$Operation\_Setup2$	20	10	6.667
$Operation\_Setup3$	30	15	10
$Operation\_Setup4$	20	10	6.667
$Operation\_Setup7$	18	9	6

Table 2 Demand information

$Demand\ information\ for\ case1\ and\ case\ 2$					
$Name$	$Cycles$	$Due\ Date(h)$	MPS	$Branch\ numbers$	$Part\ set$
$Case1$	6000	50	$< 1,2 >$	$< 6000, 12000 >$	$< E, F >$
$Case2$	7200	50	$< 2,3 >$	$< 14400, 21600 >$	$< E, F >$

4.2 Comparative analysis

4.2.1 Case1

Table 3 provides the comparison of cost for case 1 with tardiness; here the comparison is based on the existing model scenario. Moreover, in first, second and third scenario, existing model cost is 22.8, 24.2 and 25.6 respectively whereas proposed model cost is 21.74, 22.91 and 22.95. Similarly, for fourth, fifth, sixth and seventh; existing model cost is 27, 28.4, 29.8 and 31.2 respectively whereas proposed model cost is 23.17, 23.98, 24.16 and 24.55 respectively. Graphical comparison has been carried out in figure3

Table 3pareo solution obtained for case1

scenario	COST ES	COST PS	Tardiness (h)
1	22.8	21.74092	113.33
2	24.2	22.9104	85.56
3	25.6	22.95267	64.45
4	27	23.17811	52.22
5	28.4	23.98124	36.67
6	29.8	24.16441	26.94
7	31.2	24.55893	19.17

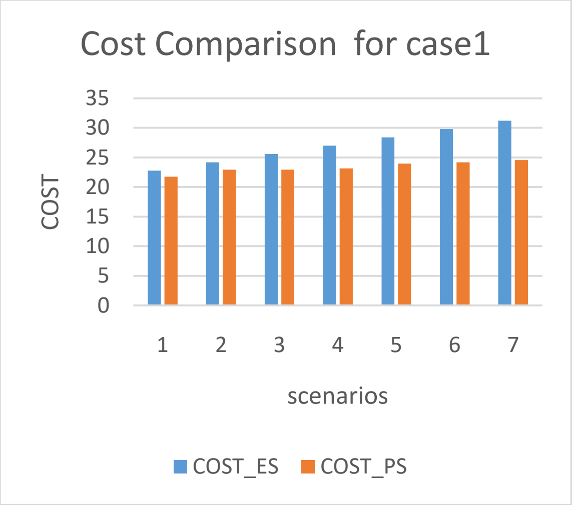

Figure 3Cost Comparison for case1

4.2.2 Case2

Further DSMO mechanism is compared based on three different parameters i.e. reconfigurable cost, total cost and capital cost. For each parameter discussed, we have considered six scenarios from the existing model.

4.2.2.1 RC (Reconfiguration Cost)

Reconfiguration cost is nothing but recycling cost of the model, the minimum cost indicates better efficiency of mode; Table 4 presents the comparison on re-configurability cost. In first scenario existing re-configurability cost is 5.48 whereas proposed model has 5.58 which is slightly higher, similarly in case of second scenario, existing model re-configurability cost is 5.62 whereas proposed model has 5.94. However, in other four scenario proposed mechanism excels with re-configurability cost of 6.07, 6.12, 6.24 and 6.17 respectively.

Table 4Pareto solution in terms of reconfigurable cost.

Existing	**proposed**
5.48	5.5874
5.62	5.94
6.3	6.0795
6.44	6.12105
9.2	6.2472
9.48	6.17091

4.2.2.2 CC(Capital Cost)

In general capital cost are one-time investment and it is fixed; the less capital cost indicates the better efficiency of model. Table 5 shows the comparison of existing and proposed model, in here for first, second and third scenario existing model requires the capital cost of 38.3, 39.7 and 41.1 whereas proposed model requires 35.33, 37.62 and 38.38. Similarly, for fourth, fifth and sixth scenario, existing model requires42.5, 44.0 and 46.8 whereas proposed model requires38.68, 39.51 and 38.95 respectively. Graphical comparison has been depicted in figure 2

Table 5 Capital Cost comparison

Existing	**Proposed**
38.3	35.3357
39.7	37.6299
41.1	38.3877
42.5	38.6828
44.0	39.5108
46.8	38.95095

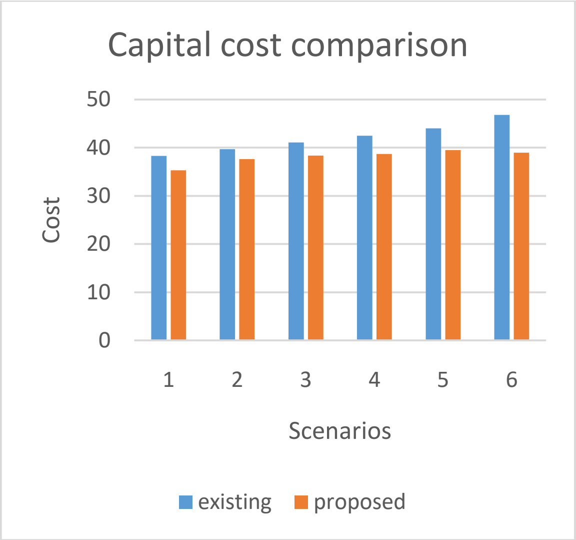

Figure 4 Capital cost cmparison for case 2

4.2.2.3 TC (Total Cost)

Further we comparethe existing model and proposed mechanism based on the total cost; total cost is computed through the below equation.

$$\begin{aligned} Total\ cost = {} & capital\ cost \\ & + 0.9973\ X\ re \\ & - configurability\ cost \end{aligned}$$

Further table 6 shows the comparison of existing model and proposed model; for first, second, third and fourth scenario existing model requires the total cost of 43.76, 45.30, 47.38 and 48.92 respectively whereas proposed mechanism requires the total cost of 40.92, 43.59, 44.46 and 44.80 respectively. Similarly, for fifth and sixth scenario, existing model requires the total cost of 53.17 and 56.25 whereas proposed model requires 45.78 and 45.12 respectively. Figure 3 shows the graphical comparison

Table 6 total cost comparison

ES	Proposed(DSMO)
43.76	40.9231
45.30	43.5996
47.38	44.4672
48.92	44.80385
53.17	45.7854
56.25	45.12705

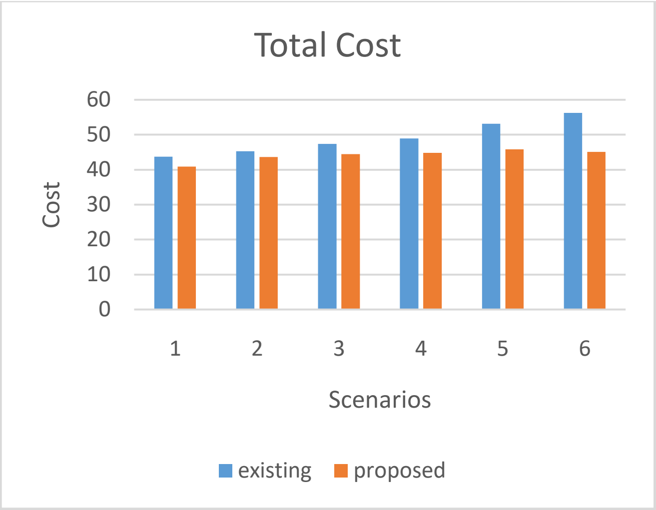

Figure 5 total cost comparison in case2

Conclusion

In this research work we proposed dual step mechanism named DSMO for enhancing the RMS performance; DSMO is designed through optimization process of two problems i.e. product evolution for meeting the customer requirement and machine layout problem. Further DSMO is metaheuristic optimization process where these two problem are solved and combine to enhance the RMS performance. Moreover,DSMOmechanism approach is evaluated on ANC 90 part.Further two distinctive cases are considered for evaluation. In case there are seven scenarios; for each scenarios cost are compared and our method outperform existing model with effective cost of 35.33, 37.62, 38.38 and 23.17, 23.98, 24.16 and 24.55 respectively. Similarly in case 2 comparative analysis is carried out with the existing methodology in terms of total cost, capital cost and re-configurability cost.Moreoverout of various scenarios we have picked six scenarios and proposed mechanism achieves optimized cost of 40.92, 43.59, 44.46,45.78 and 45.12 for all six scenarios respectively.

Although proposed mechanism leaves an outstanding impact through minimizing the cost without any performance degradation. RMS is still considered as novice area of research and several other aspects needs to researched.

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