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Dependency of Capability-Based Virtual Cellular Manufacturing Systems performance on basic layouts

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***Abstract*— The performance of a Virtual Cellular Manufacturing System (VCMS), capability-based or machine-based, is affected by different layout strategies. This research presents how choosing a suitable layout can improve the performance of Capability Based VCMSs (CBVCMSs), especially to minimize the traveling distances between machines required by each family group.**

To present the efficacy of basic layouts on performances of VCMSs, a multi-objective mathematical model with a Goal Programming (GP) approach is developed to generate CBVCMSs and implemented over functional and distributed layouts of the same machines. After that, the objective function of the mathematical model is measured to compare the performance of the generated system over the both layouts. Moreover, because of the material handling costs importance, traveled distances by components are evaluated to find the best option as a basic layout for VCMSs. The result illustrates the priority of distributed layouts for generating CBVCMSs because of its flexibility, minimizing the objective function for the mathematical model, and smaller minimum traveled distances by the components.

***Index Terms*— Capability-Based Virtual Cellular Manufacturing Systems (CBVCMSs), basic layout**

I. INTRODUCTION

In classical Cellular Manufacturing Systems (CMSs), machines belonging to each cell are near to each other to minimize the material handling costs and setup times. In such systems, by reconfiguring machine cells the physical location of machines must be changed on the shop floor. Therefore, rearrangement costs may be occurred to systems and long times must be taken. In addition, doing reconfiguration very frequently may become impractical or even infeasible (Slomp, et al., 2005). Although a cellular layout simplifies workflow and reduces material handling efforts, in dynamic environments with fluctuating demands and unpredictable parts-mix compositions, implementation of CMSs is difficult because a configuration developed for one product-mix may be inefficient in another environment and frequent cell redesigns would be required or significant inter cell flows must be allowed (Irani, et al., 1993; Khilwani, et al., 2009). To minimize inter cell flows, resource duplication leads to higher investment costs and unbalances in utilization among resources duplicated (Fung, et al., 2008; Lahmar and Benjaafar, 2005). To reduce the negative implications of CMSs while keeping the positive effects, companies have been encouraged to use Virtual Cellular Manufacturing Systems (VCMSs). These systems keep the dynamic nature of systems without any need to physical rearrangement of machines against new arrived orders. In fact, a VCMS, which is predefined by a production control mechanism, is a logical grouping of resources including machines, workers, and material-handling facilities temporarily for realizing the benefits of classical CMSs to produce jobs divided into part families. This system was appeared for simultaneously using setup efficiency of classical CMSs and the routing efficiency of job shops and does not have any limitation regarding the number and size of families, which are being to process. In classical CMS, the physical location and capacity of a cell is fixed whereas a virtual cell allows flexible reconfigurations of shop floors in response to changing requirements. Unlike classical CMSs, which each machine is belonging to one family, machines can be shared among cells if needed and the common machines are accessible to each of these cells (Khilwani, et al., 2009).

The cell formation, which is the initial step and the most important problem in the design of classical CMSs and VCMSs, consists of making parts family and machines grouping and forming manufacturing cells to process each part family within a virtual or physical cell with minimum distances traveled by parts or maximization of grouping efficacy. This enables any part to be processed within a cell, which has minimum interaction with other cells. The virtual cell formation provides a manufacturing environment, which is flexible, adaptive, and reconfigurable without considerable effort, with the support of a computerized system (Babu, et al., 2000).

Before formation of manufacturing cells, the system must be defined and the parts requirements must be identified. In the literature, two categories exist to define characteristics of manufacturing systems, design layouts, and present process plans and worker skills: machine-based and capability-based. In the first category, which is more common, machines are considered as entities and in the second category, machining capabilities include entities. The machine-based approach, which is a classical way to define manufacturing systems and their capacities, does not provide sufficient details in describing the shared and unique boundaries between machines. Therefore, in the virtual cells formed by the corresponding methods, there are a number of machines in which not all functions need to be shared, and in the other side, some functions can be shared with more virtual cells (Fung, et al., 2008). In fact, the reasons behind using capabilities of machines instead of machines are increasing machines utilization because they can perform many different operations, increasing the flexibility, and decreasing the sensitivity to inaccuracies in the demand distribution. In this research, the machines capabilities and parts demands are presented by a Resource Element (RE) approach.

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II. LITERATURE REVIEW

At start, National Bureau of Standards (NBS) proposed the concept of VCMSs in the 1980s in USA. Whereas the research on VCMSs is still in a preliminary stage, it has gained momentum during the last decade and a wide and diverse variety of solution techniques have been applied mostly for solving part-machine cell formation problems and making schedule for VCMSs including (Babu, et al., 2000; Drolet, 1989; Fung, et al., 2008; Khilwani, et al., 2009; Ko and Egbelu, 2003; Mak, et al., 2005; Mak, et al., 2007; Rezazadeh, et al., 2009; Saad, et al., 2002; Slomp, et al., 2005; Xambre and Vilarinho, 2007).

Virtual cells are generally generated over a functional layout (Drolet, 1989; Kannan, 1997; Kannan and Ghosh, 1996; Ko and Egbelu, 2003; Slomp, et al., 2005). Kannan et al. (Kannan, 1998; 1996) studied the performance of virtual cells formed over a functional layout and concluded that these cells could enhance productions performance in volatile manufacturing environments. Fung et al. (2008) focused on developing a model for virtual cell formation using the RE approach over functional layouts. In the most of generated VCMSs, the traveling distances of parts in virtual cells have been known as the main disadvantages of them in comparison to the classical one. Therefore, decreasing the traveling distance by use of a suitable layout to generate VCMSs over that is extremely important in the theory and the practice. It has been discussed in the literature that distributed layouts are very good candidates for the implementation of VCMSs (Baykasoglu, 2003; Benjaafar, et al., 2002; Lahmar and Benjaafar, 2005). Drolet (1989) illustrated how a distributed layout configuration could be used to form virtual cells that are temporarily dedicated to a job order. Although a distributed layout does not presuppose a cellular structure, it can be served as the basis for one. The advantages of distributed layouts in VCMSs have been encouraged some researchers such as Baykasoglu (2003) and Xambre and Vilarinho (2007) to apply it in the manufacturing systems and others used the properties of this type of layout in their works without calling that as distributed layout including Mak, et al. (2005; 2007). They changed the original layout to the revised layout in such a way the workstations were widely spread over the production floor as suggested to reduce the material traveling distances in each VCM system. Montreuil et al. (1991) and Benajaafar (1995) proposed the implementation of a scattered layout prior to form virtual cells. In this paper also, the efficacy of distributed layouts to form VCM systems is examined.

Since VCMSs release companies from the relayout and rearrangement costs, to analyze the effect of the primary arrangement of machines before the formation of virtual cells, this paper focuses on how basic layouts can improve the performance of CBVCMSs. Then it provides a comparison between two more usable layouts, functional and distributed, to present although VCMSs can be generated over every arrangement and the developed method in this paper does not have any limitation in this matter, but a VCMS or CBVCMSs performance is dependent on the basic layout. Therefore, first CBVCMS will be generated over a functional layout and second it will be formed over another layout, which has been achieved by distributing the machines of the first layout optimally.

In this paper, machines arrangement and their capabilities based on REs are considered as the inputs to develop a new model to form virtual cells in a manufacturing system. Since to generate virtual cells multi objectives must be considered, the Goal Programming (GP) approach has been used to model the problem in the form of a mathematical model.

Mathematical model to form CBVCMSs

In this research, the CBVCMS formation is done by solving a multi-objective mathematical model, which is an Integer Non-Linear Programming (INLP). To present the proposed model, its components including indices, parameters, decision variables, and deviation variables are introduced. Then the closed form of the model with some explanations is brought out.

Indices and parameters:

i: Index for REs, $i \in I, I = \{1,2,\dots,|I|$

j: Index for virtual cells $(V), j \in J, J = \{1,2,\dots,|J|\}$

p, p': Indices for parts (C) , $p \in P, P = \{1,2,\dots,|P|\}$

m:Index for machines$(M), m \in M, M = \{1,2,\dots,|M|\}$

n: Index for grids or locations (G),$n \in N, N = \{1,2,\dots,|N|\}$

q: Index for goals (GO), $q \in Q = \{1,2,\dots,|Q|\}$

d_p: the demand for component p

$ds_{pp'}$: dissimilarity between part p and p′

e_m: Capacity of the m − th machine

ϖ_q: Weight of deviation from q − th goal

m_{min}: Minimum number of machines in a cell

m_{max}: Maximum number of machines in a cell

tp: Total time available for doing processes of all components

φ: A big number

t_{pi}: Time needed for the p − th component on the i − th resource element by machine

$\alpha_{mi} = 1$, if the i − th RE is available on the m − th machine; 0, otherwise

$\beta_{pi} = 1$, if the component p needs the i − th RE; 0, otherwise

Decision and deviation variables:

$X_{pj} = 1$, if p − th part is assigned to virtual cell j; 0, otherwise

Y_{mj}: 1, if m − th machine assigned to virtual cell j; 0, otherwise

$U_j = 1$; if virtual cell j is generated; 0, otherwise

$\delta_{ds}^-, \delta_{ds}^+$: Under and over achivement of the dissimilarity goal;

$\delta m_j^-, \delta m_j^+$: Deviations from the total machine capacity in the j − th cell;

$\delta m_{ij}^-, \delta m_{ij}^+$: Deviation from the total machine capacity of the i − th RE in the

δ_m^-, δ_m^+: Deviation from number of cells which the m − th machine is assigned ;

$\delta_{lo}^-, \delta_{lo}^+$: Under and over achievements of cell loads at machines unbalance

The closed form of the mathematical model (objective function and related constraints) is presented here.

$$minimize\ \ \varpi_1\left(\delta_{ds}^{-}+\delta_{ds}^{+}\right)+\varpi_2\sum\nolimits_{j=1}^{|J|}\delta\mathrm{m}_j^{-}+\varpi_3\left(\sum\nolimits_{j=1}^{j}\sum\nolimits_{i=1}^{|I|}\delta\mathrm{m}_{ij}^{-}\right)+\varpi_4\sum\nolimits_{m=1}^{|M|}\left(\delta_m^{+}+\delta_m^{-}\right)+\varpi_5\left(\delta_{lo}^{-}+\delta_{lo}^{+}\right) \tag{1}$$

Subject to:

$$\sum\nolimits_{j=1}^{|J|}\sum\nolimits_{p=1}^{|P|}\sum\nolimits_{\substack{p'=1\\ p'\neq p}}^{|P|} ds_{pp'}\times X_{pj}\times X_{p'j}+\delta_{ds}^{-}-\delta_{ds}^{+}=0 \tag{2}$$

$$\sum_{m=1}^{|M|}Y_{mj}\times e_m-\sum_{p=1}^{|P|}\sum_{i=1}^{|I|}X_{pj}\times\beta_{pi}\times t_{pi}\times d_p+\delta\mathrm{m}_j^{-}-\delta\mathrm{m}_j^{+}\geq 0\quad\forall\, j \tag{3}$$

$$\sum\nolimits_{m=1}^{|M|}Y_{mj}\times e_m\times\alpha_{mi}-\sum\nolimits_{p=1}^{|P|}X_{pj}\times\beta_{pi}\times t_{pi}\times d_p+\delta\mathrm{m}_{ij}^{-}-\delta\mathrm{m}_{ij}^{+}\geq 0\quad\forall\, i,j \tag{4}$$

$$\sum_{j=1}^{|J|}Y_{mj}+\delta_m^{+}-\delta_m^{-}=1\quad\forall\, m \tag{5}$$

$$\frac{\sum_{j=1}^{|J|}\left(vcl_j-\frac{\sum_{j=1}^{|J|}vcl_j}{\sum_{j=1}^{|J|}u_j}\right)^2}{\sum_{j=1}^{|J|}u_j}+\delta_{lo}^{-}-\delta_{lo}^{+}=0; \tag{6}$$

$$vcl_j=\frac{\sum_{j=1}^{|J|}\sum_{p=1}^{|P|}\sum_{i=1}^{|I|}X_{pj}\times\beta_{pi}\times t_{pi}\times d_p}{\sum_{m=1}^{|M|}y'_{mj}\times e_m} \tag{7}$$

$$X_{pj},Y'_{mj},Z_l\in\{0,1\} \tag{8}$$

$$\delta_{ds}^{-},\delta_{ds}^{+},\delta\mathrm{m}_j^{-},\delta\mathrm{m}_j^{+},\delta\mathrm{m}_{ij}^{-},\delta\mathrm{m}_{ij}^{+},\delta_m^{-},\delta_m^{+},\delta_{lo}^{-},\delta_{lo}^{+}\geq 0 \tag{9}$$

$$Y_{mj}\geq U_j\quad\forall\, m,j \tag{10}$$

$$X_{pj} \leq U_j \quad \forall\, p,j \tag{11}$$

$$X_{p,j} \times \beta_{pi} \leq \sum_{m=1}^{|M|} Y_{mj} \times \alpha_{mi} \quad \forall\, p,j,i \tag{12}$$

$$\sum_{j=1}^{|J|} X_{pj} = 1 \quad \forall\, p \tag{13}$$

$$\sum_{j=1}^{|J|} U_j \leq \frac{|M|}{m_{min}} \tag{14}$$

$$\sum_{j=1}^{|J|} U_j \geq \frac{|M|}{m_{max}} \tag{15}$$

$$\sum_{m=1}^{|M|} Y_{mj} - (U_j \times m_{max}) \leq 0 \quad \forall\, j \tag{16}$$

$$(U_j \times m_{min}) - \sum_{m=1}^{|M|} Y_{mj} \leq 0 \quad \forall\, j \tag{17}$$

Equation 1 presents the objective function of the model which is multi-objective and has been presented by the GP approach; the considered objectives are minimizing dissimilarity among parts assigned to a virtual cell, minimizing machines capacity shortage in a cell, minimizing machine-RE capacity shortage in a cell, minimizing machines sharing, and minimizing load unbalances at machines in virtual cells. Equations 2-6 are belonging to goals and respectively constrain the dissimilarity goal (Equation 2), the machine-capacity goal (Equation 3), the machine RE-capacity goal (Equation 4), the machine-sharing goal (Equation 5), and the load balancing on cells based on machines (Equation 6). Equation 7 calculates loads assigned to each cell in respect of the total capacity of that cell. Equations 8 and 9 present that the main decision variables can accept only binary values. Equations 10, 11, and 12 show dependency limitations in such a way that each machine can be assigned to each virtual cell if it is formed (Equation 10), each part can be assigned to a cell only if it is formed (Equation 11), and a part can be assigned to a virtual cell if the RE corresponding to that operation is available in that cell (Equation 12). Equations 13-17 present the limitations regarding the number of parts in each cell, number of generated virtual cells, number of assigned machines in each cell.

III. NUMERICAL EXAMPLE

This example, which has been taken from Baykasoglu & Gindy (2000), presents a shop containing 7 types of machines, with one or multiple copies. They used this example to form classical CMS based on machines capabilities. Table 1 presents the number of copies and capacity of each machine.

Table 1. Machines properties

Machine types	1	2			3		4		5		6	7
copies	1	2a	2b	2c	3a	3b	4a	4b	5a	5b	6	7
Capacity	68000	66000	66000	66000	64000	64000	64000	64000	64000	64000	65000	64000

The required data are the machine-RE matrix and the first physical arrangement of machines, which both have been presented in Figure 1. Since the first arrangement is a functional layout, heavy solid lines draw the borders of the same departments, and the number of machines presents the machines located in each functional area.

M 2a RE (1,2,3,7,8,9,10,11)	M 2b RE (1,2,3,7,8,9,10,11)	M 1 RE (1)
M 2c RE (1,2,3,7,8,9,10,11)	M 3a RE (1,2,4,7)	M 3b RE (1,2,4,7)
M 4a RE (1,2,4,7,10)	M 4b RE (1,2,4,7,10)	M 5a RE (5,6)
M 6 RE (6)	M 7 RE (5)	M 5b RE (5,6)

Figure 1. The basic arrangement in the form of a functional layout

Since obtaining the optimal distributed layout is not the subject of this paper, just the optimum distributed layout for the machines presented in Table 1 is depicted in Figure 2.

M 4a RE (1,2,4,7,10)	M 3a RE (1,2,4,7)	M2a RE (1,2,3,7,8, 9,10,11)
M 2b RE (1,2,3,7,8,9,10,11)	M 6 RE (6)	M 7 RE (5)
M 1 RE (1)	M 2c RE (1,2,3,7,8,9,10,11)	M 3b RE (1,2,4,7)
M 4b RE (1,2,4,7,10)	M 5a RE (5,6)	M 5b RE (5,6)

Figure 2. The basic arrangement in the form of the optimum distributed layout

According to Baykasoglu & Gindy (2000), in this case 20 parts proceed by 11 REs. The part-RE relations in the form of a 0-1 matrix is imported to the Lingo software. Table 2 provides the parts properties including demand per each component. The developed mathematical model to form VCMSs has been coded by LINGO as a powerful software for optimization problems. Parts are grouped and families formed considering their similarities and constraints of the model simultaneously with grouping machines and assigning them to cells. After entering the functional layout (Figure 1) as the first location of machines to the Lingo software, the result of grouping components and assigning them to formed virtual cells by the developed mathematical model is presented in Table 3. For example, it would appear from this table that in the case of functional layout as the basic, in the optimum condition, parts number 7, 8, 12, 13, 18, and 20 form a family, which assigned to the cell number 1. The same process done for the case of distributed layout (Figure 2) as the basic layout, which the result is presented in Table 4.

Table 2. Components propertied

Parts	RE1	RE2	RE3	RE4	RE5	RE6	RE7	RE8	RE9	RE10	RE11	Demand	Parts	RE1	RE2	RE3	RE4	RE5	RE6	RE7	RE8	RE9	RE10	RE11	Demand
1	1	1	0	1	0	0	0	0	0	0	0	3000	11	0	0	0	0	1	1	0	0	1	0	0	4500
2	1	1	1	0	0	0	0	0	0	0	0	1000	12	0	0	0	0	0	0	0	1	1	1	0	1000
3	0	0	0	0	1	1	1	0	0	0	0	2500	13	0	0	0	0	1	0	0	1	0	1	0	3000
4	0	0	0	0	1	0	0	1	0	0	0	1520	14	0	0	0	0	1	0	1	1	0	0	0	2500
5	0	0	0	1	1	0	1	0	0	0	0	1480	15	1	1	0	0	0	0	0	0	0	0	0	2500
6	0	0	0	0	0	1	1	1	0	0	0	3500	16	0	0	1	1	0	0	0	0	0	0	0	1900
7	0	0	0	0	0	0	0	1	1	1	0	1000	17	0	0	0	0	0	1	1	1	0	0	0	2400
8	0	0	0	0	0	0	0	0	1	1	1	2000	18	0	0	0	0	0	0	0	1	1	1	1	1200
9	1	1	0	0	1	0	0	0	0	0	0	3000	19	0	1	0	0	1	0	0	0	0	0	0	1300
10	0	0	1	1	0	0	0	0	0	0	0	2000	20	0	0	0	0	0	0	1	1	1	0	0	3000

Table 3. Parts grouping and assigning to cells over the functional layout

Cell 1	P7	P8	P12	P13	P18	P20		
Cell 2	P3	P4	P5	P6	P14	P17		
Cell 3	P1	P2	P9	P10	P11	P15	P16	P19

Table 4. Parts grouping and assigning to cells over the distributed layout

Cell 1	P7	P8	P11	P12	P13	P18	P20
Cell 2	P1	P2	P9	P10	P15	P16	P19
Cell 3	P3	P4	P5	P6	P14	P17	

The result of forming cells based on machines over the both mentioned layouts have been presented in Tables 5 and 6, which show each machine has been assigned to which cell.

Table 5. Machines grouping and assigning to cells over the functional layout

Cell 1	2c	3a	4a	7
Cell 2	2a	4b	5a	6
Cell 3	1	2b	3b	5b

Table 6. Machines grouping and assigning to cells over the distributed layout

Cell 1	1	2a	3a	5b
Cell 2	2c	3b	4a	5a
Cell 3	2b	4b	6	7

The outputs of the developed mathematical model, presents that in the first case by considering the functional layout as the basic, the optimum objective function is equal to 160.6344 achieved after 11557 iterations. In the second case by considering the distributed layout as the basic, this value is 155.9084, which was found after 8879 iterations. Whatever the objective function in latter case is smaller than the first one, to have a better judge in this matter, the traveled distances are also measured as the second performance criterion. Since the developed mathematical model is based on design issues not operational, it determines each part is assigned to which cell. By considering the machines assigned to each cell, the route, which each part travels, can be forecasted. In some parts, which more than one route is possible, traveled distances are shown as the minimum and maximum distances. The maximum and minimum distance, which each part must travel, for all parts of this example were calculated by programming in Matlab software that their specifications including demands, sequencing, and boundary of traveled distance have been illustrated in Table 7 for the functional layout and Table 8 for the distributed layout. By comparing the minimum and maximum distances that components traveled in the VCMS generated over the functional layout (92640, 165180) and the distributed layout (58520, 17680), it seems by using an optimum scheduling distributed layouts because of achieving smaller minimum traveled distance have priority to be basic layouts of VCMSs.

Table 6. Traveled distances by parts in the VCM system generated over the functional layout

Part	Sequence	Seq. Min. Dis.	Min. Dis.	Seq. Max. Dis.	Max. Dis.	Demand
1	1,2,4	3b,3b,3b	0	3b,2b,3b	12000	3000
2	1,2,3	2b,2b,2b	0	2b,3b,2b	4000	1000
3	3,6,7	2a,6,4b	12500	2a,5a,2a	20000	2500
4	5,8	5a,2a	6080	5a,2a	6080	1520
5	4,5,7	4b,5a,4b	2960	4b,5a,2a	7400	1480
6	6,7,8	6,2a,2a	10500	6,4b,2a	17500	3500
7	8,9,10	2c,2c,2c	0	2c,2c,4a	1000	1000
8	9,10,11	2c,2c,2c	0	2c,4b,2c	4000	2000
9	1,2,5	3b,3b,5b	6000	3b,2b,5b	18000	3000
10	3,4	2b,3b	4000	2b,3b	4000	2000
11	5,6,9	5b,5b,2b	18000	5b,5b,2b	18000	4500
12	8,9,10	2c,2c,2c	0	2c,2c,4a	1000	1000
13	5,8,10	7,2c,2c	9000	7,2c,4a	12000	3000
14	5,7,8	5a,4b,2a	10000	5a,4b,2a	10000	2500
15	1,2	2b,2b	0	3b,2b	5000	2500
16	3,4	2b,3b	3800	2b,3b	3800	1900
17	6,7,8	6,2a,2a	7200	6,4b,2a	12000	2400
18	8,9,10	2c,2c,2c	0	2c,2c,4a	1200	1200
19	2,5	3b,5b	2600	2b,5b	5200	1300
20	7,8,9	2c,2c,2c	0	3a,2c,2c	3000	3000
-	**Total**	***********	**92640**	***********	165180	************

Table 7. Traveled distances by parts in the VCM system generated over the distributed layout

Part	Sequence	Seq. Min. Dis.	Min. Dis.*D	Seq. Max. Dis.	Max. Dis.* D	Demand (D)
1	1,2,4	3b,3b,3b	0	3b,4a,3b	24000	3000
2	1,2,3	2c,2c,2c	0	3b,4a,2c	7000	1000
3	3,6,7	2b,6,2b	5000	2b,6,4b	10000	2500
4	5,8	7, 2b	3040	7, 2b	3040	1520
5	4,5,7	4b,7,2b	8880	4b,7,4b	11840	1480
6	6,7,8	6,2b,2b	3500	6, 4b, 2b	17500	3500
7	8,9,10	2a,2a,2a	0	2b,2a,2a	0	1000
8	9,10,11	2a,2a,2a	0	2b,2a,2a	0	2000
9	1,2,5	2c,2c,5a	3000	3b,4a,5a	24000	3000
10	3,4	2c,3b	2000	2c, 4a	6000	2000
11	5,6,9	5b, 5b, 2a	13500	5b, 5b, 2a	13500	4500
12	8,9,10	2a,2a,2a	0	2a,2a,2a	0	1000
13	5,8,10	5b,2a,2a	9000	5b,2a,2a	9000	3000
14	5,7,8	7,2b,2b	5000	7,4b,2b	15000	2500
15	1,2	4a, 4a	0	4a, 3b	10000	2500
16	3,4	2c,3b	1900	2c,4a	5700	1900
17	6,7,8	6, 2b, 2b	2400	6, 4b, 2b	12000	2400
18	8,9,10	2a,2a,2a	0	2a,2a, 2a	0	1200
19	2,5	2c, 5a	1300	4a, 5a	5200	1300
20	7,8,9	2a,2a,2a	0	3a,2a,2a	3000	3000
-	**Total**	***********	**58520**	***********	**17680**	************

IV. CONCLUSION

This study attempts to develop a new method to form VCMSs and measuring their performance over different types of basic layouts. To design virtual cells, machines independent capabilities known as REs were considered to define processing requirements of the parts and processing capabilities of machines. Therefore, the overlapping capabilities among machines and optional machines to process components were considered automatically to improve the results. Generating VCMSs was done by developing a mathematical model with the goal-programming approach for the part-machine virtual cell formation problem, which grouped parts and machines and designed virtual cells simultaneously. Minimizing dissimilarities among parts assigned to a virtual cell, minimizing the machine capacity and the machine-RE capacity shortage in a cell, minimizing the machine sharing and load unbalances at machines in virtual cells were defined as objective functions to be optimized by considering their priorities through defining a weight for each goal. Consequently, two types of constraints limited the solution space of the model: constraints belonging to goals and constraints presenting the manufacturing limitations.

To check the validity of the developed methodology, it was tested over a numerical example taken from the literature including two types of layouts, functional and distributed. The VCMS is generated over initial arrangement of the example and evaluated based on two criteria: the defined objective function in the mathematical model and total traveled distances of components during their processes. The results illustrated that the VCMS generated over the distributed layout has better performances i.e. smaller amounts for the objective function and the traveled distances, in comparing with the VCMS generated over the functional layout. Therefore, implementing VCMSs over distributed layouts can be considered as a successful solution for companies working in a highly volatile manufacturing environment but it will not force managers to change the current layouts of their companies if it is not economical. In other words, companies can use advantages of VCMSs over any basic layout.

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