Cost Estimating Methods for Evaluating the Conversion from a Functional Manufacturing Layout to Group Technology

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Abstract: In recent years the group technology approach to the organization of production has been receiving increasing attention in relation to the eventual automation of discrete parts manufacturing. In this paper we describe a procedure for estimating some of the reductions in component manufacturing cost associated with converting an existing traditional discrete parts production facility to one organized along group technology principles. An example is provided to illustrate the use of these cost estimation procedures.

■ Over the past several years the method of group technology (GT) production has been receiving increasing attention in relation to the eventual automation of discrete parts manufacturing. Surprisingly, no set of cost estimating procedures has been developed to aid potential users in measuring the economic effectiveness of GT when compared to the more traditional job shop organization of production of such manufacture. Little research exists in this area; the major proportion of what has been done comes from the USSR [6, 9]. Recently, Grayson [5] noted this absence and further observed that "Soviet methods have little to commend themselves to the practitioner of group technology [in the West]."

In this paper we describe a procedure for estimating some of the reductions in component manufacturing cost associated with converting an existing traditional job shop to a group technology production system. We begin with a discussion of the characteristics of a classic GT system, followed by a detailed description of the computational methods for estimating manufacturing cost reductions. We then present an example using data typical of a discrete parts manufacturer.

GROUP TECHNOLOGY VS FUNCTIONAL MANUFACTURING LAYOUT

Group technology is a method of applying some of the engineering techniques of mass production to production processes of the small and medium batch type. The basis of this method is the recognition that similarities occur in the design and manufacture of discrete parts and that parts can be categorized into groups based on these fundamental similarities. The machinery and labor required for a particular group of parts is organized in a cell, a grouping of machines and workers dedicated to the manufacture of only that group of parts. In this way different parts requiring similar machines and tooling may be processed using common machines and group jigs which significantly reduce setup time and cost.

Figure 1 conceptualizes the difference between job shop and group technology production. The GT organization of production converts the job shop into a more simplified series of flow shops or machining cells, each handling a group of manufactured components. The resultant simplification of the system reduces complex job shop planning and scheduling as well as lead times and work-in-process inventory. For a complete discussion of the classic GT production organization, see Gallagher and Knight [4].

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Fig. 1. Product flow under functional organization and group technology.

Prior to cost estimating it is necessary to determine the method of grouping to be used and the resulting layout. There are several group classification schemes available [2, 3, 4, 7] and management would have to select one or more to be evaluated. Once this decision is made and a candidate layout is put forth, estimating cost differences against the current functional layout can begin.

FACTORS INFLUENCING MANUFACTURING COST REDUCTION IN GROUP TECHNOLOGY

In contrasting the two production systems of Fig. 1, there are three primary areas of difference in system performance. They are (1) machine setup times, (2) production lead times, and (3) system support functions and other allocated costs.

Machine setup times are invariably lower in group technology component manufacture. These reductions occur due to the similarity of machining operations required among members of the group. Major machine changeovers are eliminated, and group jigs are developed to reduce changeover time further. In addition, for each machine, a kit of tooling is kept within the group cell, eliminating the time and effort associated with withdrawing tooling from stores. The result of these features of GT production is a dramatic reduction in setup times. It is necessary for the production engineer in conjunction with his tool designer to make preliminary estimates of the order of magnitude of these reductions for the combinations of machines and component groups of the candidate layout. DeVries, Harvey, and Tipnis [3] report actual industry experience in

machine setup time reductions as high as 69%.

Reductions in setup time are transferred into cost reductions in two ways: (1) increased labor and capital productivity, and (2) reduced inventory carrying cost due to reduced production lot sizes. The modeling and measurement of these cost reductions will be subsequently demonstrated.

Production lead time also declines after a conversion to group technology. This is not surprising when one considers the movement of components through a production facility organized in a functional layout. In a functional layout, the largest components of lead time are movements times between machines and possibly into and out of a material storage area, information delays, and queueing time. Since machining operations are located adjacent to one another in a GT cell, movement, storage, and the effects of information delays are largely eliminated.

Queueing time in a functional layout is mainly the outgrowth of the difficulties in machine scheduling associated with the complexity of the production system. Relatively high levels of machine tool and labor utilization are insured by buffers of work-in-process inventory. In recent years this problem has been addressed using computer based MRP systems, which are theoretically able to establish a perfectly coordinated time phased schedule for all machining operations [8]. However, in practice, queueing still occurs and continues to be a problem in manufacturing using a functional layout. Queueing time under GT is, relatively speaking, a smaller problem due to the greater control of scheduling provided by the simplified flow line or machining cell structure.

It is necessary for the production engineer to estimate the reduction in manufacturing lead time resulting from the conversion. Data on average lead time in the existing functional layout is usually readily available since job order cost sheets accompany jobs through production, and release and completion times are recorded. Estimating lead times in a proposed group technology cell can be done in two ways. As a rough estimate, one can assume negligible queueing time and estimate lead times using the previously estimated group setup times and the standard machining times per unit. Since total machining time for a job is a function of lot size, it will be necessary to compute the appropriate GT lot size first.

If a more detailed analysis is required, a simulation of the group layout is appropriate. Employing a simulation has some additional advantages as well. It enables the layout designer to evaluate cell balance and cell capacity. It also allows experimentation with alternative scheduling methods. In any event, simulation can be employed when some queueing is anticipated and a better estimate of production lead times is desired.

Lead time reduction is a key reason for converting from a functional to a group layout. These reductions affect manufacturing cost by reducing work-in-process inventory, finished component safety stocks, the number of hot jobs, and the difficulty of controlling the production process. Also, customer service and responsiveness to changing

requirements are greatly enhanced. DeVries, Harvey and Tipnis [3] report actual lead time reductions in industrial applications of group technology as high as 70%.

Finally, system support functions should decline after a conversion to group technology. For example, due to the elimination of much of the tracking of component lots through the manufacturing process, control functions such as expediting jobs and dispatching work between machining centers are not needed. Once a job enters a cell, it remains under the control of cell workers until it is completed. Since lead times are relatively short and predictable, expediting and checking job progress is largely eliminated. Materials handling support is also reduced due to the reduction of inter-machine transportation. Reducing indirect support functions reduces overhead cost. We will subsequently describe the method of incorporating this into the evaluation.

In summary, three factors are to be considered which give rise to manufacturing cost reductions: (1) setup times, (2) production lead times; and (3) system support functions and other allocated costs. The influence of a conversion to group technology on these factors must be estimated prior to computing manufacturing cost reductions.

PROCEDURES FOR THE ANALYSIS OF MANUFACTURING COST IN A GROUP TECHNOLOGY CONVERSION

Using the required preliminary estimates previously described, we shall address the calculation of these cost reductions in (1) inventory cycle stock, (2) inventory safety stock, (3) work-in-process inventory, and (4) allocated costs. Since allocated costs are handled separately in the estimation process, the first three categories of costs are estimated on a direct variable cost basis.

Cycle Stock Effects

Cell production is processed in batches and released to intermediate or final inventory upon batch completion. When the mean demand rate is constant and a continuous review system is followed in which the batch size is Q , the profile of expected finished component inventory is given by Fig. 2. Similar graphs can be constructed for other situations.

It is usual in practice for manufacturing management to plan to avoid stock out conditions; i.e., to maintain relatively high service levels. When this is the case, it is convenient to compute the levels of cycle stock required, followed by a separate computation for safety stocks. This is the procedure we employ here.

The cycle stock of finished component inventory is a function of setup time, machining time, and holding cost. Since group jigs reduce setup time, the influence of group

Fig. 2. Expected inventory cycle stock and safety stock of finished component inventory.

technology is to reduce cycle stocks and to increase the number of setups per year. Assume the demand distribution for the finished component is stationary with a constant mean and a continuous review system is followed. For this situation, let

Q_f and Q_g = optimal lot sizes under functional and group technology organization, respectively,

A_f and A_g = total relevant setup cost per lot under functional and group technology, respectively,

C_f and C_g = the relevant unit cost of production under functional layout and group technology,

D = the average annual demand rate for the component, and

i = the annual inventory carrying cost rate.

The average annual cost of cycle stock, under functional layout and group technology can then be written:

$$K(Q_f) = \frac{A_f D}{Q_f} + i C_f \frac{Q_f}{2} \quad (1)$$

and

$$K(Q_g) = \frac{A_g D}{Q_g} + i C_g \frac{Q_g}{2}, \text{ respectively. (1')}$$

Other cost expressions can easily be constructed for situations in which the mean demand is not stationary, lot sizes are unequal from operation to operation, and so forth. We have chosen to illustrate our procedure using a simple model so that the discussion of the concept is the center of attention and not the mathematical details.

It is important to define the cost factors relevant to (1) and (1'). The only costs that are appropriate are the costs which will change as a result of change in lot size. Therefore, the fixed setup cost per setup consists of the total setup time per lot and the costs of performing the setup. In

production, this is largely the variable compensation of skilled machinists who adjust the machining for the production of the new component lot. Any other costs associated with that transition, such as recording the event of beginning the new lot, or the effects of "learning" due to the change in operations should be included in the total relevant setup cost. In periods when the production facility is being operated at capacity, changeovers incur an opportunity cost because production time on the machine is being lost, resulting in lost or deferred revenue. The relevant unit cost of production is the total marginal cost of manufacture, which consists of the total machining time and the marginal unit cost during machining.

For illustrative purposes we assume that the marginal cost is based on direct labor hours. Then the setup cost is a function of the setup time and the labor rates. Likewise, relevant unit cost is a function of those factors plus unit material cost and unit machining time. Let

R_f and R_g = the rate per direct labor hour of production under functional and group technology organization, respectively,

S_f and S_g = the total set-up time per batch under functional and group technology organization, respectively,

M = unit material cost, and

m = unit machining time.

Then

$$A_f = S_f R_f, \quad A_g = S_g R_g, \quad (2)$$

and

$$C_f = M + \left[\frac{S_f}{Q_f} + m \right] R_f, \quad C_g = M + \left[\frac{S_g}{Q_g} + m \right] R_g \quad (3)$$

By substituting into Equation set (1) we see that

$$K(Q_f) = \frac{S_f R_f D}{Q_f} + i \left[M + \left(\frac{S_f}{Q_f} + m \right) R_f \right] \frac{Q_f}{2} \quad (4)$$

and

$$K(Q_g) = \frac{S_g R_g D}{Q_g} + i \left[M + \left(\frac{S_g}{Q_g} + m \right) R_g \right] \frac{Q_g}{2}. \quad (4')$$

Thus

$$Q_f = \sqrt{\frac{2 S_f R_f D}{i(M + m R_f)}} \quad (5)$$

$$Q_g = \sqrt{\frac{2 S_g R_g D}{i(M + m R_g)}} \quad (5')$$

If the labor skills and their compensation are comparable under functional layout and GT, then $R_f = R_g$ and the fractional reduction in finished component cycle stock is

$$f_{cc} = 1 - \frac{Q_g}{Q_f} = 1 - \frac{\sqrt{S_g}}{\sqrt{S_f}} \quad (6)$$

where

f_{cc} = the fractional reduction in units of cycle stock

Therefore, with available measures of S_f from the standard cost system and estimates of S_g , it is a relatively simple matter to compute the reduction in unit cycle stock.

In order to compute dollar inventory marginal cost savings, one must also compute the new unit cost to apply to the reduced units of cycle stock. From Equation set (3) we note the following ratio of group technology direct variable unit cost to functional direct variable unit cost.

$$\frac{C_g}{C_f} = \frac{M + \left[\frac{S_g}{Q_g} + m \right] R_g}{M + \left[\frac{S_f}{Q_f} + m \right] R_f}. \quad (7)$$

Equation (7) is the basis for making unit manufacturing cost reduction comparisons and is also the basis for valuing inventory in the calculation of inventory cost reductions.

Safety Stock Effects

The appropriate safety stock for finished components depends upon the desired level of service. There are several ways to measure service. For example, service can be measured on the chance a shortage occurs during each cycle, or the average number of units short per cycle, or on the amount of time out of stock during a cycle. For illustrative purposes, we will assume safety stock is based on a desire to avoid a stockout of the component during the replenishment lead time. For such a case, safety stock is a function of the lead time, uncertainty in the demand and production process over the lead time and the desired level of service. Due to lower setup costs and consequent lower lot sizes, group technology generally reduces the interval between producing lots of any particular component. It is through the reduction in total lead time that group technology reduces required safety stocks.

In order to compute safety stock reductions one must know the nature of the source of uncertainty. For convenience, we will assume that the only source of uncertainty is in the demand process; specifically, we assume that the demand for finished components follows a normal distribution. In order to make the comparisons between a functional layout and group technology, one has to deter-

mine where safety stocks currently exist and where they will exist after the group technology conversion. In certain situations, buffer stocks exist between machining operations in a functional layout. For purposes of illustration, we assume a comparison between a functional layout and group technology in which safety stocks are carried only for finished components. Similar analysis can be conducted for other situations. Let

L_f and L_g = the lead times, measured in years, under functional layout and group technology, respectively,

r_f and r_g = the reorder points under functional and GT,

Z_p = the standard deviation corresponding to a level of protection p during the lead time,

f_{ss} = the fractional reduction in safety stock resulting from a conversion to group technology, and

V_D = the variance of demand per year.

Then

$$r_f = L_f D + Z_p \sqrt{L_f V_D} \quad (8)$$

and

$$r_g = L_g D + Z_p \sqrt{L_g V_D} \quad (8')$$

where

$$Z_p \sqrt{L_f V_D}$$

and

$$Z_p \sqrt{L_g V_D}$$

are the safety stocks of finished components for functional and GT production organizations, respectively. Therefore,

$$f_{ss} = 1 - \frac{\sqrt{L_g}}{\sqrt{L_f}} \quad (9)$$

Work-in-Process Inventory Effects

The dollar value of work-in-process (WIP) inventory is a function of the unit raw material cost, the value added, the lot size, and the production lead time in the system. Group technology reduces work-in-process by reducing unit cost and reducing production lead times.

For a single component, we define the average relevant cost of work-in-process inventory for one cycle as

$$\bar{W}_c = \left(M + \frac{v}{2} \right) Q, \quad (10)$$

where

$\bar{W}_c$ = the average dollar value of WIP inventory for one lot when only direct variable costs are considered,

v = the direct variable component of value added per unit.

Since $v = (S/Q + m)R$,

$$\bar{W}_c = MQ + \frac{SR}{2} + \frac{mQR}{2}. \quad (11)$$

Equation (11) assumes that raw material enters the cell at the beginning of the cycle and that value added is relatively uniform throughout the cycle. Since the average number of lots in production equals DL_f/Q_f and DL_g/Q_g for functional and group layouts, respectively, the average value of work-in-process inventory, $\bar{W}_A$, is

$$\bar{W}_{A_f} = \left(\frac{M + C_f}{2} \right) L_f D \text{ and } \bar{W}_{A_g} = \left(\frac{M + C_g}{2} \right) L_g D \quad (12)$$

for functional and group layouts, respectively, where

$$C_f = M + \left[\frac{S_f}{Q_f} + m \right] R_f \text{ and } C_g = M + \left[\frac{S_g}{Q_g} + m \right] R_g \quad (13)$$

As previously discussed, if queueing is negligible a reasonable estimate of lead time in group technology production is

$$L_g = S_g + mQ_g. \quad (13)$$

For more precise estimates a simulation can be performed. When queueing is expected to be negligible, an approximation for Equation (12) under group technology is

$$\bar{W}_{A_g} = \left(\frac{M + C_g}{2} \right) (S_g + mQ_g) D. \quad (14)$$

An estimate of the cost reduction in work-in-process as compared to the current mode of plant operation can be obtained by direct comparison of Equation (14) with existing job order cost sheets. Job order cost sheets contain the actual record of jobs in production by component. Such comparisons can be made on a sampling basis.

Reduction in Allocated Costs

Some of the effects on allocated costs from a conversion to

group technology are difficult to trace. In this section we provide a general discussion of some major impact areas that can be assessed relatively easily. The starting point for these estimates is the proposed GT layout, including estimates of the new product flows within the plant. The major allocated cost items whose change can be easily assessed are: (1) fixed plant, (2) equipment, and (3) materials handling.

Savings in plant floor space has been identified as a major cost savings in a group layout [3]. This can be estimated directly from the new plant layout. Whether or not this change represents an economic gain depends on the alternative use of that space. If factory floor space is gained but there is no plan to put it to productive use, no economic benefit has been achieved. On the other hand, if the newly available space is to be productively used, the economic savings is the foregone cost of expansion which would have otherwise been required in order to obtain the space. There is a time dimension to this cost; there may be no immediate need for this space, but it may represent a savings in the future. The appropriate timing of the benefit has to be considered.

Estimates of changes in fixed capital equipment are required for both the estimate of investment cost and cash flow. These estimates can be made from the proposed plant layout, which identifies the machines required in each cell. It is likely that fixed capital requirements will increase due to duplication of individual operations among the various cells.

Materials handling requirements are related to the number and length of moves during the flow of jobs in the plant. Under the GT configuration, materials handlers are required in component manufacture only to bring new stock to the cell and remove finished components; materials handling between manufacturing operations is mostly eliminated. However, since production under group technology is performed in smaller lots, the number of moves to and from the cell may increase. From the new layout and travel charts, an estimate of the change in materials handling requirements can be made.

There are other areas of allocated costs that are favorably influenced in a group technology conversion which are less easily estimated. For example, job expediting and dispatching activities may be reduced as lead times are shortened and dispatching between machines is eliminated. The improvement will depend on how well the current production information and control system operates. The categories of allocated costs we cite above represent a conservative estimate of the possible cost reductions.

The question of whether or not a conversion is warranted will depend on a traditional discounted cash flow analysis. The major outlays are those involved with the reorganization of equipment within the plant (including foregone production, if any) and the investment in additional machines and equipment, as required to complete the cells. Such estimates can be made once the configuration of the cells within the plant have been determined.

EXAMPLE OF ESTIMATION PROCEDURE

The preceding computations are easy to apply, especially in manufacturing establishments where cost standards are maintained by manufactured component. In order to demonstrate the application of this procedure, we introduce the data of Table 1, which reflects the composition of a sample for one group. Such data should be available from the standard cost cards; actual lead times can be ascertained from past production reports or manufacturing orders.

The data of Table 1 is input to the computation of inventory levels under the functional layout as shown in Table 2. These estimates should be compared to the actual experience of the manufacturing unit by comparing the sum of population estimates for all groups to a sample of past inventory reports.

Table 3 is the comparable estimate of unit cost and inventory levels under group technology. For this calculation we have assumed an estimated setup time reduction of 60%. Once again, population effects are measured by extrapolation of the sample.

Table 4 is a comparison of the direct variable cost results. The lower direct variable unit cost and the reduction in component inventory carrying cost, when summed over all groups, is a measure of the economic benefits of the proposed facility conversion from sources other than allocated costs. Allocated cost savings must then be computed to complete the analysis of cost reductions.

SUMMARY

It is our observation that one of the existing impediments to group technology plant conversions is the difficulty of assessing the economic benefits. In this paper we have presented a simple systematic approach for estimating the economic benefits associated with a conversion from a functional layout to group technology that is applicable to a wide range of situations. When used in conjunction with estimates of initial investment cost and the standard discounted cash flow analysis, the economics of a proposed conversion can be completely assessed.

In our presentation we have focused on the cost estimating concepts as opposed to application to a diverse range of production situations. These concepts would have to be tailored to other situations, for example, for multi-stage lot sizing or where production rates are time varying.

In the past, group technology was generally considered an approach for reorganizing existing equipment within a plant. However, in recent years the group technology approach has become the foundation for new machining center concepts, such as flexible manufacturing systems. In these new systems, several sequential steps, traditionally performed on different machines in different work centers, would be carried out on a single machine or a series of machines linked together through conveyor systems and programmable automation, such as robots.

Table 1: SetUp Times, Lead Times, and Unit Cost Under Functional Layout (Proposed Group A, 10% Sample).

Part	Annual Unit Demand	Standard Production Times (years) ¹			Lot Size ₂ Q_f	Actual Lead Times (wks)	Direct Variable Unit Cost (\$) ³
		Set-Up per Batch	Machining per Unit	Material Cost per Unit (\$)			
1	130	.0044	.00084	3.00	64	6	30.26
2	200	.0050	.00026	2.50	139	6	11.38
3	700	.0042	.00056	4.00	168	10	21.55
4	2000	.0041	.00073	3.50	254	19	25.88
5	320	.0050	.00034	2.20	161	7	13.33
6	420	.0042	.00038	1.80	163	7	13.97
7	700	.0046	.00070	4.00	161	12	25.86
8	400	.0050	.00050	3.20	148	8	19.21
9	100	.0040	.00061	2.60	62	6	22.84
10	100	.0048	.00036	2.90	84	6	15.41

¹ Based on 40 hours/week and 50 week/year (120,000 min/year).

$$^2 Q_f = \sqrt{\frac{2S_f R_f D}{i(M + mR_f)}}, \text{ Assumption: } i = 30\%.$$

$$^3 C_f = M + \left[\frac{S_f}{Q_f} + m \right] R_f, \text{ Assumption: } R_f = \$30,000/\text{year } (\$15/\text{direct labor hour}).$$

Table 2: Inventories under Functional Layout (Proposed Group A, 10% Sample).

Part	Average Cycle Stock		Safety Stock		WIP ³
	Units ¹	\$	Units ²	\$	
1	32.0	968	7	212	259
2	69.5	791	8	91	167
3	84.0	1,810	20	431	1,789
4	127.0	3,287	46	1,190	11,164
5	80.5	1,073	11	147	348
6	81.5	1,139	13	182	464
7	80.5	1,139	21	543	2,508
8	74.0	2,082	13	250	717
9	31.0	1,422	6	137	153
10	42.0	708	6	92	110
		647			
		\$13,927		\$3,275	\$17,679

Estimated Population Inventories:

	10% Sample	Population
Cycle Stock	\$13,927	\$139,270
Safety Stock	3,275	32,750
Work-in-Process	17,679	176,790
		\$348,810

$$^1 \text{ Average Cycle Stock} = \frac{Q_f}{2}$$

$$^2 \text{ Safety Stock} = 1.65 \sqrt{\frac{L_f}{50} V_D}; \text{ Assumed variance/mean ratio of the demand process} = 1.0; \text{ desired service level for finished components} = 95\%.$$

$$^3 \text{ WIP} = \left(\frac{M + C_f}{2} \right) \frac{L_f}{50} D.$$

Table 3: SetUp Times, Lead Times, Unit Cost, and Inventory Levels Under Group Technology (Proposed Group A, 10% Sample).

Part	S_g	Q_g^1	L_g (wks) ²	Unit Cost ³	Average Cycle Stock		Average Safety Stock		WIP ⁴
					Units	\$	Unit	\$	
1	.00176	40	1.8	29.52	20.0	590	4	118	76
2	.00200	88	1.2	10.98	44.0	483	4	44	32
3	.00168	106	3.1	21.28	53.0	1128	11	234	549
4	.00164	161	6.0	25.71	80.5	2070	26	669	3505
5	.00200	102	1.8	12.99	51.0	662	6	78	87
6	.00168	103	2.0	13.69	51.5	705	7	96	130
7	.00184	102	3.7	25.54	51.0	1303	12	306	765
8	.00200	94	2.5	18.84	47.0	885	7	132	220
9	.00160	39	1.3	22.13	19.5	432	3	66	32
10	.00192	53	1.1	14.79	26.5	392	2	30	19
					8650		1773		5415
Estimated Population Inventories					10% Sample		Population		
Cycle Stock					\$8650		\$ 86,500		
Safety Stock					1773		17,730		
Work-in-Process					5415		54,150		
							\$158,380		
Assumptions: $S_q = .4 S_f$					$R_g = R_f$				
$^1 Q_g = \sqrt{\frac{2S_g R_g D}{i(M + mR_g)}}$					$^2 L_g = (S_g + mQ_g) / 50$				
$^3 C_g = M + \left[\frac{S_g}{Q_g} + m \right] R_g$					$^4 WIP = \left(\frac{M + C_g}{2} \right) \frac{L_g}{50} D$				

Table 4: Comparison of direct unit variable cost and inventory levels: Functional Layout vs. Group Technology.

Part	Functional C_f	G.T. C_g
1	30.26	29.52
2	11.38	10.98
3	21.55	21.28
4	25.88	25.71
5	13.33	12.99
6	13.97	13.69
7	25.86	25.54
8	19.21	18.84
9	22.84	22.13
10	15.41	14.79
Component Inventory:		
	Functional	G.T.
Cycle Stock	139,270	86,500
Safety Stock	32,750	17,730
Work-in-Process	176,790	54,380
TOTAL	348,810	158,380

Generally speaking, existing commercial flexible manufacturing systems have combined the organizational principles of group technology with mechanical designs based on programmable automation. The group technology organizing principle reduces the variability in component geometry and machining requirements that the machine cell and its

attendant robots have to accommodate. Hence, the approach we have presented in this paper can be applied as well when calculating the benefits of these new proposed system designs.

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