Economic Justification of Implementation of Cellular Manufacturing

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Abstract

Cellular Manufacturing is a manufacturing philosophy that identifies and exploits the similarities of product design and manufacturing process throughout the manufacturing cycle. Application of Cellular Manufacturing results in reduced material handling, setup time, work–in process inventory, etc. Cellular Manufacturing plays a vital role in the successful operation and implementation of Computer Integrated Manufacturing and Flexible Manufacturing Systems. Implementation of Cellular Manufacturing is a herculean task. It is difficult to convince the top management for switching over from traditional to Cellular Manufacturing since most of the benefits of Cellular Manufacturing are intangible. Needless to say, economic justification of Cellular

Manufacturing is a formidable task. This paper discusses the economic justification of implementation of Cellular Manufacturing. The example is demonstrated with the hypothetical data. Various benefits realized by different companies after implementing Cellular manufacturing which are available in published literature are also presented. It is expected that the outcome of this paper will be of use to Industries, Researchers and Consultants involved in the implementation of Cellular Manufacturing.

Key words: *Cellular Manufacturing, Economic justification*

Introduction

Today manufacturers are attempting to compete more and more at the global level, and are striving hard for improving manufacturing flexibility, quality of products produced and to reduce manufacturing costs. To meet these stringent requirements, it is very important to have the ability to produce small volume batches consisting of complex parts in shorter lead times. Cellular Manufacturing is one such a strategy, which has emerged as an important technique to cope with the fast changing industrial demands and for the application of newer manufacturing systems. Cellular Manufacturing can be defined as the organization of production facilities in self-contained and self-regulated group of cells (group of machines dedicated to the manufacture of group of components) each of which undertakes complete manufacture of a family of components with similar manufacturing characteristics. (Nagendra Parashar 2008). Implementation of Cellular Manufacturing gives several benefits. Benefits of Cellular Manufacturing are shown in Figure 1.

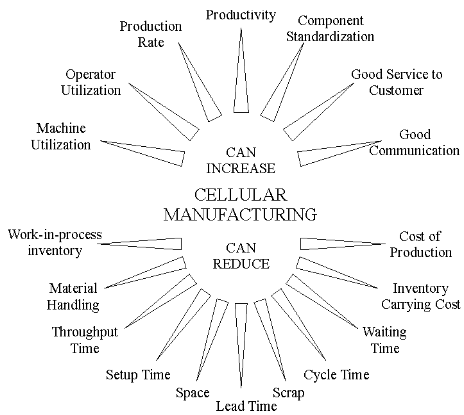

Figure 1 : Benefits of Cellular Manufacturing

Though the implementation of cellular manufacturing gives several benefits, majority of the benefits of cellular manufacturing are ethereal. Hence, for the people involved in the implementation of cellular manufacturing, economic justification is a herculean task. It should also be noted that implementation of cellular manufacturing involves just not only dislocation of machines and equipments but also demands the change in mindset which they have developed over the years.

For these reasons, much management do not come forward or take a gallant step in implementing cellular manufacturing. When a proposal for implementing cellular manufacturing is made, the first question the top management is going to ask will be: What is it going to cost? How much are we going to earn? It is palpable that no management will be willing to make investment for switching over from traditional to cellular layout (or make any changes) until and unless they are convinced about the benefits. In order to convince the top management about benefits of changes, it is essential to carry out the economic justification (Nagendra Parashar 2002). This paper deals with economic justification of implementation of cellular manufacturing. The example is demonstrated on a hypothetical data.

Economic justification of implementation of cellular manufacturing

As mentioned earlier convincing the top management to switch over from traditional to cellular manufacturing is a herculean task. People involved in the implementation of cellular manufacturing should understand that the top management will not be convinced if a mention is made that the application of cellular manufacturing will result in X% saving in material handling, Y% saving in setup time and so on. Because in most of the cases, top management is not knowledgeable about the benefits of cellular manufacturing. There are certain benefits of cellular manufacturing which can be quantified; there are other benefits which are obvious and some others intangible. For example, reduction in material handling can be traced through string diagram. It is also possible to calculate reduction in makespan, inventory levels, etc., through mathematical models. As stated earlier, a few benefits are obvious. For example, application of cellular manufacturing results in reduced setup time. When setup time is reduced, it becomes obvious that machine utilization and operator utilization are increased; waiting time and throughput time are reduced. Whereas, other benefits such as employee satisfaction, ease of supervision, better control over cells, etc., are intangible and cannot be quantified. Hence, people who are involved in the implementation of cellular manufacturing should understand which are the benefits that can be quantified, and how these benefits can be calculated. For the benefits which are obvious what logic should be used to convince the top management?

Economic justification of implementation of cellular manufacturing is illustrated with a hypothetical problem in the next section.

Economic justification - an example

In this section, the economic benefits that can be realized by the application of cellular manufacturing are demonstrated on a hypothetical problem. Different criteria considered include number of machines, investment on machines, floor space and cost, machining cost, tooling cost, minimum lot size, material cost, direct labor cost and consumable cost.

Assumptions

The following assumptions are made in the study:

i. Components are simpler in shape and have a few varieties.

ii. Company produces 500 parts and part demand/annum is 500000 units.

iii. Company operates 8 hrs a day and total working days in a year are 300. Any backlog orders will be done by working overtime.

iv. Labor cost is Rs. 24/- per hour.

v. Average machining time per piece is 20 minutes.

vi. Machine utilization is 85%.

Gallaghar, et al. (1973) argue that machine utilization in case of cellular manufacturing is less compared to traditional methods of manufacturing. This argument is not correct. Because, in cellular manufacturing since setup times are reduced, it obviously increases machine and labor utilization. However, for the purpose of this study, machine utilization is assumed to be 85% for both traditional and cellular manufacturing.

All the other assumptions stated above are made commonly for both traditional and cellular manufacturing methods.

vii. For traditional method of manufacturing, it is assumed that processing is done on 50 machines and average setup time between each part is 8 min. In cellular configurations, because of similarities of components in part family and usage of group tooling methods, a reduction in setup time of more than 50% is possible. Hence, for cellular manufacturing, setup time of 3 min is assumed.

viii. Since the parts are simple and varieties are less, it is assumed that completely independent cells are formed.

ix. A total of 10 cells and 10 part families are formed and all parts are distributed equally among each cell. That is, each part family will have 50 parts and each part family is assumed to have five sub-groups (components which are more similar within the part family) each with 10 parts. Moreover, it is assumed that parts assigned under each sub-group are completely similar and hence there is no setup time between parts within the sub-group. Setup time between sub-groups is assumed as 3 min.

x. As the components are simpler in shape and have less variety, group tooling (flexible fixtures) is being made use of while processing the components in cellular manufacturing so that all the components in a sub-group can be processed with one fixture with the help of an adaptor. Since design and manufacture of flexible fixtures are costlier than traditional ones, cost of flexible fixture is taken five times (Rs. 15,000) that of traditional fixture (Rs. 3000/-). Since each sub-group processes parts which are completely similar, each sub-group is equipped with one adaptor and the cost of each adaptor is Rs. 1000/-.

The following sections will explain the justification of implementation of cellular manufacturing considering various parameters stated earlier.

Number of machines

By intuition we can say that the investment required for machines depends upon number and type of parts to be processed. Leone (1967) made comparative requirements for capital investments in traditional and cellular manufacturing by considering relative productive factor. Productive factor is given by:

$$PF = \frac{T_{s1} + T_{c1}}{T_{s2} + T_{c2}}$$

Where Ts indicates average setup time and Tc indicates average machining time. Suffixes 1 and 2 indicate traditional and cellular manufacturing methods of manufacturing respectively.

Substituting the assumed values of setup and machining time for traditional and cellular methods we get,

$$PF = \frac{8+20}{3+20} = 1.22$$

Leone (1967) suggested that when a switchover is made from traditional layout to cellular layout, the number of machines required in cellular methods can be calculated by using:

$$\frac{MU_{tr}}{MU_{cm}} \times nm_{tr} \times \frac{1}{PF}$$

MUtr = machine utilization in traditional machining, MUcm = machine utilization in cellular manufacturing and nmtr = number of machines in traditional machining

Therefore,

Number of machines required for cellular manufacturing

$$= \frac{0.85}{0.85} \times 50 \times \frac{1}{1.22}$$

= 41 machines (approx)

Hence, the number of machines required for traditional and cellular manufacturing methods would be:

Traditional	50 machines
Cellular	41 machines

Investment on machines:

If average cost of machine is assumed to be Rs. 6 lacs investment required for machines by traditional and cellular method of manufacturing will be:

Traditional 50 machines × Rs. 6 lacs = Rs. 300/- lacs

Cellular 41 machines × Rs. 6 lacs = Rs. 246/- lacs

Floor space and cost

If average space required by each machine is assumed as 20 ft2 (including aisle space), space required by traditional and cellular method of manufacturing will be 1000 ft2 (20×50) and 820 ft2 (41×20) respectively.

If cost of land for each square foot is assumed as Rs.1000/-, the investment required for land by traditional and cellular method of manufacturing will be:

Traditional 50 machines × 20 ft2 × Rs.1000/- = Rs.10.00/- lacs

Cellular 41 machines × 20 ft2 × Rs.1000/- = Rs. 8.20/- lacs

Tooling cost calculation

In cellular manufacturing, since parts coming under one part family are similar, we can make use of group tooling approach. The cost analysis of group tooling in comparison with that of conventional tooling can be done by using the equations (Mitrafanov 1966):

For traditional method of manufacturing:

Tooling cost =

$$= \sum_{i=1}^{p} C_{j1}$$

Where

Cj1 = cost of jig or fixture of traditional tooling method in Rs., p = number of jigs or fixtures used (also, possibly number of parts to be produced),

Substituting assumed values in equation. (3) we get Tooling cost for traditional method

$$= \sum_{i=1}^{p} C_{jf} \quad = \sum_{i=1}^{500} 3000$$

= Rs. 1500000

For cellular manufacturing:

Tooling cost

(4)

Where

C j2 = cost of a group jig or fixture in Rs., Ca = cost of adaptor in Rs., q = number of adaptors used for the production of family of parts.

For cellular manufacturing, we have assumed that parts coming under a particular sub-group are completely similar and hence they can be processed using common fixture. We have also assumed that each sub-group can be processed with one adaptor. Since there are 50 part families each with 5 sub-groups, total number of sub-groups will be 250 and hence 250 adaptors are required.

From equation (4) Group tooling cost

$$= \sum_{i=1}^{q} C_a + C_{j2} \quad = \sum_{i=1}^{q} C_a + C_{j2}$$

= Rs. 265000

Hence, cost of tooling for traditional and cellular manufacturing will be:

Traditional	Rs. 1500000
Cellular	Rs. 265000

Machining cost calculation

The total machining cost for traditional and group machining methods are calculated using the equations (5) and (6) respectively.

Traditional manufacturing

Machining cost = C0

$$\left[\sum_{i=1}^{n} T_{c1} + \sum_{i=1}^{n} T_{s1} \right]$$

where,

= unit machining time per piece by traditional machining, min/piece., = setup time per lot for traditional machining, min/piece, n = number of different parts produced C0 = labor rate Rs.

Substituting in equation (5) we get,

Machining cost for traditional manufacturing = 0.4

$$\left[\sum_{i=1}^{500} 20 + \sum_{i=1}^{500} 8 \right]$$

Cellular manufacturing

$$\text{Machining cost} = C0 \left[\sum_{j=1}^{np} \sum_{i=1}^{nf} T_{c2} + \sum_{i=1}^{q} T_{sa} \right]$$

where,

= machining time per piece, Rs./piece , = setup time per adaptor, min/adaptor, np = number of parts in the part family, nf = number of part family, q = number of adaptors.

Substituting in equation (6) we get,

Machining cost for cellular manufacturing

$$= 0.4 \left[\sum_{j=1}^{50} \sum_{i=1}^{10} 20 + \sum_{i=1}^{250} 3 \right]$$

= Rs. 4300

Hence, cost of machining for traditional and cellular manufacturing will be:

Traditional	Rs. 5,600
Cellular	Rs. 4,300

Minimum lot size calculation

By intuition we can say that inventory level required depends upon part demand/period, number of parts to be produced in given time and setup time per part. We can mathematically express the relationship between these variables as:

Minimum lot size =

$$\frac{setup\ time / part \times part\ demand / period \times number\ of\ parts}{shop\ operting\ time / period}$$

Using equation 7 calculate minimum lot size for traditional and cellular manufacturing methods as:

Traditional method:

$$\text{Minimum lot size} = \frac{8 \quad 500000 \quad 500}{8 \quad 300 \quad 60} = 13889 \text{ units}$$

Cellular manufacturing method:

Hence, lot size for traditional and cellular manufacturing will be:

Traditional	13889 units
Cellular	5208 units

Material cost

Assuming Rs. 500/unit towards material cost, which includes raw material cost, interest on capital invested for material, floor space cost and material storage cost. Material cost for traditional and cellular method of manufacturing will be Rs. 6944500 (500×13889) and Rs. 2604000 (500×5208) respectively.

Direct labor cost calculation

With traditional method of manufacturing, direct labor will be approximately equal to number of machines. Whereas, in case of cellular manufacturing, due to high labor utilization, the number of operators required will be less.

We have assumed that a company operates 8 hrs a day and 300 working days in a year and any backlog orders will be done by working overtime. We also assumed a labor cost of Rs. 24/- per hour.

Working hours per year

= 8×300 = 2400 hr/ year

Direct labor cost

= 24×2400 = Rs. 57,600 per man year

Traditional method of manufacturing

For traditional method of manufacturing the direct labor per shift will be approximately equal to the number of machines.

Direct labor cost = 50 × 57600 = Rs. 28, 80,000 per annum

Cellular manufacturing

For cellular manufacturing the number of operators per machine will be less than traditional machining. In highly developed applications in which complete factories have been organized on cellular basis, one operator for every two machines is quite common (Astrop, 1969, Connolly et al. 1971, Allen 1979).

Assuming 50 operators are required for 50 machines in traditional method; on the basis of published literature (Gombinski et al. 1967, Astrop, 1969, Durie 1970) 41 machines will need 27 operators in cellular manufacturing. Direct labor cost can further be reduced with automation and flexible fixture concepts.

Direct labor cost = 27×57600 = Rs. 15, 55,200 per annum

Hence, direct labor cost for traditional and cellular manufacturing will be:

Traditional	Rs. 28, 80,000 per annum
Cellular	Rs. 15, 55,200 per annum

Cost of consumables

In cellular manufacturing the production rate is high for the same machine when compared to the output of machines by traditional method of manufacturing. Hence, it becomes obvious that cost of consumables will be more for cellular manufacturing when compared to traditional methods of manufacturing.

Assuming cost of consumables as Rs. 500/annum/machine in traditional manufacturing and Rs. 600/-/annum/machine in cellular manufacturing cost of consumables for both methods of manufacturing will be:

Traditional

Cost of consumables

= Rs.500×50 machines = Rs. 25,000/ annum

Cellular manufacturing

Cost of consumables

= Rs.600×41 machines = Rs. 24,600/annum

We can see that for the assumed problem, application of cellular manufacturing resulted in total cost saving of 25.29%.

Benefits realized by other firms

It is too immature to think that the top management will give green signal for the implementation of cellular manufacturing by looking at the benefits on a hypothetical problem. For convincing the top management successfully for the implementation of cellular manufacturing, one has to present the various benefits realized by different companies after implementing cellular manufacturing, which are available in published literature.

Several benefits realized by various companies after the implementation of cellular systems are shown in Appendix A (Nagendra Parashar 2009). Several such survey results are required to convince the management for the implementation of cellular systems. Especially survey results of the companies involved in similar type of manufacturing activities will have better impact than generalized applications. But, one should realize that the magnitudes of benefit may vary from organization to organization. It depends upon the type and nature of products, the level of application, methods of operating system used (i.e. scheduling, line-balancing, inventory control procedures, etc,).

Conclusions

To convince the top management one has to workout the details of technical and economic issues related to its implementation of cellular manufacturing. In this paper economic justification of implementation of cellular manufacturing considering various parameters is done on a hypothetical problem. The study has indicated that the implementation of cellular manufacturing resulted in cost saving of more than 25%.

People, who are involved in the implementation of cellular systems, should understand and appreciate that it will be close impossible to convince the top management by just illustrating the benefits with the hypothetical data. To persuade the management for implementation of cellular systems benefits realized by various organizations after the implementation of cellular systems also need to be presented. However, it should be carefully noted that these benefits cannot be carelessly generalized. The magnitudes in the benefits may vary from organization to organization. Any attempt to apply cellular manufacturing without working out these details could be disastrous.

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APPENDIX - A

Reduction in WIP inventory

Sl.no	Organization	Saving
1.	Ferodo limited, UK	WIP reduced by 85%
2.	Sheffield Twist Drill Company Limited, Sheffield	WIP reduced by 75%
3.	British Oxygen Company Ltd, Bletchley	WIP reduced from 15-18 weeks to 3 weeks
4.	Platt Saco Lowell Ltd, Bolton	-------
5.	Whittaker Hall Ltd, Manchester	WIP reduced by 50%
6.	Thomas Mercer Ltd	WIP reduced by 45%
7.	Machine Tool Manufacture, UK	WIP reduced by 92% in top slide cell and 72% in gear cell

Reduction in throughput time

Sl.no	Organization	Reduction
1.	Ferodo limited, UK	Through put times up to 20 times faster
2.	Platt Saco Lowell Ltd, Bolton	11 weeks to 2 weeks
3.	Machine Tool Manuacture,UK	36 weeks to 3 weeks in top slide cell and 18 weeks to 3 weeks in gear cell
4.	Ferodo limited, UK	Average finishing time reduced from 12 days to 1.6 days

Increase in labor productivity

Sl.No	Organization	% Increase
1.	Optico Mechanical Association	Increase in labor productivity from 33% to 50%
2.	Serck Audco Valves, UK	Increase in labor productivity by 50%
3.	Platt Saco Lowell Ltd, Bolton	Output per employee increased 75% (labor saving £51000 pa)

Increase in Productivity

Sl.No	Organization	Increase
1.	Optico Mechanical Association	Saving in production cost per tonne from 25% to 28%
2.	Platt Saco Lowell Ltd, Bolton	Production increase from 2500 gears per week to 8500 per week
3.	Whittaker Hall Ltd, Manchester	Unit output increased by 50%

Saving in floor space

Sl.No	Organization	% Saving
1.	Whittaker Hall Ltd, Manchester	20% floor space saving
2.	Fastener Production in an Indian Factory	21% floor space saving

Increase in sales output

Sl.No	Organization	% Increase
1.	Serck Audco Valves, UK	Sales increased by 32%
2.	Philips	Sales output increased by 12% per employee

Reduction in direct labor

Sl.No	Organization	% Reduction
1.	Whittaker Hall Ltd, Manchester	Direct labor reduced by10%

Reduction in scrap

Sl.No	Organization	% Saving
1.	Platt Saco Lowell Ltd, Bolton	Scrap reduced from 3% to 0.25%(saving £19000 pa)

Increase in average machine utilization

Sl.No	Organization	% Increase
1.	Fastener Production in an Indian Factory	Average utilization increased by 51% to 74%

Reduction in tooling time

Sl.No	Organization	% Saving
1.	Optico Mechanical Association	Reduction in tooling time of about 30% to 35%

Reduction in cost of assembling

Sl.No	Organization	% Saving
1.	Volvo Car at Kalmar plant	Cost of assembling reduced by 10%