Optimizing the Capacity Addition in a Component Manufacturing Industry – an Empirical Investigation

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Abstract

Capacity planning is one of the major decisions in operations management and is considered critical to the success of business operations. By proper capacity planning it is possible to decide the strategies related to capacity expansion and creating capacity cushion to absorb fluctuations. Auto component manufacturing undergoes frequent demand changes and hence should be ready to meet either deficit or surplus situations. In this paper an auto component manufacturing industry is considered and aiming the demand forecast, the capacity needs to be increased. The different scenarios under three different patterns of below normal, normal, and above normal demand are considered and the capacity expansion is planned. The paper illustrates the different theoretical backgrounds, and the subsequent changes in the content. Using the "What if" feature of Excel, different scenarios are assessed and useful inferences are drawn. The paper provides a wonderful way of deciding upon the capacity with wide options.

Keywords: *Capacity, Excel, Expansion, Manufacturing, Planning, Trend, What if.*

Introduction

Capacity planning is the process of determining the production capacity needed by an organization to meet the changing demands for its products. ("Capacity planning - Wikipedia, the free encyclopedia," n.d.)

The basic questions in capacity planning are:

- What kind of capacity is needed?
- How much is needed?
- When is it needed?

While the first questions addresses the type of capacity as defined in terms of resources required, the second and third questions look for the quantity and the timing of the capacity to suit the forecasts and the demand.

Capacity addition could be in many different forms and may include several types of resources. Typically capacity addition occurs through creating additional manufacturing facilities by adding machines, equipment, people, and space, depending upon the situation. Short term capacity additions may involve enhancing the capacity by utilizing capacity available with other firms, or leasing out or temporarily expanding the existing capacity. A long term capacity addition may occur through addition of infrastructure and other resources on a permanent basis. Several policies and practices exist and the ultimate decision is purely based on the situational requirements.

A company can create surplus capacity in anticipation of the rising demand, or wait for the demand to build and then add the required capacity. Both these capacity-lead and capacity-lag strategies require careful assessment of existing capacity to link to the demand and growth pattern. In addition the decisions related capacity lead to one of the situations of excess or shortage of capacity which in the short and the long term will cause a lot of damage to the company. Hence it is essential that a careful capacity planning strategy needs to be developed to maximize the returns.

Literature Review on Capacity Planning and Expansion

Production capacity is one of the most important strategic variables for all the manufacturing industries and typically the companies decide upon the overall level of capacity, the flexibility, and the location of that capacity. Hence capacity planning involves the three important criteria of size, timing, and the location of the production system to be ready to meet the expected demand.

Capacity planning is considered to be a complex problem that involves aggregate planning and requires a smooth production plan. Because of the demand uncertainty and also the supply chain related issues it is necessary that a firm plans the capacity expansion or contraction suitable to avoid losses.

Essential steps in capacity planning involve the following:

- Estimating the capacities of the present facilities
- Forecasting the future capacity requirement
- Identifying and analyzing sources of capacity to meet future capacity needs
- Selecting among alternative sources of capacity

In addition, the operation managers observe that all the capacity that is existing at a given point of time may not be fully available because of the following reasons considered under internal and external classes:

1. Internal to the organization

a) Breakdowns

b) Shutdown due to Maintenance

c) Non-availability of resources like materials, supplies, energy, and key personnel due to absenteeism, sickness, leave,

d) Lack of coordination

2. External to the organization

a) Disruptions in transportation and logistics systems

b) Politically imposed shutdowns

c) Downtrend in the overall economy

d) Scarcity of commodities and materials

e) Instability in the political and the eco system

In operations management textbooks (Bozarth & Handfield, 2015)) typically the capacity planning topic is addressed under two strategic plans, namely capacity lead strategy and capacity lag strategy. Capacity lead strategy suggests creating additional capacity anticipating increase in the demand in the near future. Capacity lag strategy suggests maintaining the capacity below the demand level in a conservative approach and not willing to take risk.

Another important consideration in capacity planning is to decide the "capacity cushion" which refers to the extra capacity created for the following reasons:

- To ensure extra capacity in case demand increases
- To absorb peak demand
- To lower production costs
- To provide volume and product flexibility
- To improve quality by decreasing tight schedules

It is to be noted here that capacity cushion ultimately results in unused capacity and will cost the company. Hence a balanced view of the capacity cushion and capacity addition has be taken while planning the capacity.

Further, capacity can be extended either in one single large expansion or in smaller chunks over a period of time. For deciding upon capacity expansion, the typical techniques followed are as follows:

- Breakeven Analysis
- Decision Tree Analysis

- Queuing Models
- Simulation
- Linear Programming

Operations research applications have long been explored to develop capacity planning models considering the production system design and capital investment along with scheduling and coordination decisions, and many models also include the uncertainty in demand, (Luss, 1982). Considering the four auto lines of General Motors, a model incorporating scenario planning, integer programming, and risk analysis has been developed by researchers that also has application in other industries, (Eppen, Martin, & Schrage, 1989). Capacity planning is strongly associated and controlled by demand uncertainty. This point is well examined and the robustness of the model is reconsidered to apply the model even if there is uncertainty, (Paraskevopoulos, Karakitsos, & Rustem, 1991). Scenarios are used by Escudero, Kamesam, King, & Wets (1993) to characterize the uncertainty in demand and they have developed solutions for each scenario to result in an implementable policy.

In a remanufacturing environmrnt capacity planning techniques are considered as different from the conventional new product manufacturing industries and hence new techniques are developed and implemented along with some standard capacity planning techniques (Guide, Srivastava, & Spencer, 1997). A method of rough-cut capacity planning based on the bill-of-resources approach, that can be used to plan for capacity required for firms in a remanufacturing including overhaul repair operations environment has been developed highlighting another aspect of remanufacturing industry, (Daniel, Guide, & Spencer, 1997). When there are several suppliers, it is necessary to develop a supply mechanism based on suppliers' capacity, (Cachon & Lariviere, 1999).

Large manufacturing companies like semiconductor manufacturing involve estimating the required number of special purpose machine tools and because of the intense capital investment pose a lot of difficulty and hence justify the need of special algorithms, (Swaminathan, 2000) and heuristics for capacity planning. In an interesting paper the manufacturing strategy and sales and operations planning have been linked together, to treat different issues, and a framework for long-term capacity management has been developed, (Olhager, Rudberg, & Wikner, 2001). Simulation models too have been explored for capacity planning, (Groothuis, Godefridus, van Merode, & Hasman, 2001).

The uncertainty associated with the supply and capacity in multistage situation has been studied for deciding upon the in house manufacturing and outsourcing, (Kouvelis & Milner, 2002). Scenario planning using stochastic programming model is explored by (Chen, Li, & Tirupati, 2002) for determining technology choices and capacity plans. Considering the uncertainty in demand and the risk involved in capital investment for capacity expansion, capacity planning is also considered as the process of risk assessment, examining the options, and developing solutions based on lead or lag strategies, (Van Mieghem, 2003). As explained by Zhang, Roundy, Akanyildirim, & Huh, (2004), capacity expansion decisions are done to strike an optimal balance between investment costs and lost sales costs. Special cases of multiple products' manufacturing systems have also been examined, (Zhang et al., 2004)

Capacity planning in remanufacturing facilities for reverse supply chains, considering both economic and environmental issues, is analyzed through a simulation model based on the principles of the system dynamics methodology, (Vlachos, Georgiadis, & Iakovou, 2007). This simulation model helps to evaluate alternative long-term capacity planning policies, called the "what-if" analysis, using total supply chain profit as measure of policy effectiveness. However, the balancing of demand and supply with respect to capacity planning in service industries, for example in a hospital, is much more challenging as it involves critical care patients, emergency cases, and internal resources matching of personnel, (Girard & Ely, 2008). On the other hand capacity planning in the case of make to order situations pose a different scenario because the capacity should be adequate enough to meet the required demand and sufficient provision should exist to explore both short term and long term capacity requirements, (Chen, Mestry, Damodaran, & Wang, 2009).

In order to minimize the inefficiencies associated with equipment capacity planning, (Peng, Erhun, Hertzler, & Kempf, 2012) a dynamic programming model is proposed called as dual-mode equipment procurement (DMEP) framework. This model is developed for applying in a semiconductor manufacturing industry, both to hedge against the supply uncertainty and the risk involved. Capacity planning are becoming special problems and industry specific and hence need special approaches depending on other strategic variables like capital, space, demand, and technology constraints, (Nahmias & Olsen, 2015).

As the literature review indicates, capacity planning continues to be a favorite topic for decision modelers and different methods have continuously been applied to develop robust models that are capable of solving the capacity related issues. But it is necessary to examine the sector and also the overall economy along with the technology trends while deciding upon the capacity. Just like the manufacturing industries have their worries in deciding the capacity, the service industries too face challenges in capacity building and expansion. For example, in the health care industry, several authors have examined the capacity planning issues related to hospitals and other related units, (Harper & Shahani, 2002), (Nguyen et al., 2007), and (Rechel, Wright, Barlow, & McKee, 2010). Here it is the critical health care that comes under scanner and excess capacity is normally taken as the rule.

Problem Identification

The problem identified here involves an industry producing auto components and supplying to a major automobile manufacturing company. Because of the reliability in manufacturing and delivery as well as maintaining quality, the parent company has entered into a long term agreement with the component manufacturing company to supply for the next ten years. Considering the growth pattern of the parent company the supplier company is expecting the demand to grow by a similar magnitude.

Research Methodology

Capacity expansion decision is driven by the forecasted demand and hence a good forecast is necessary to ensure that the enhancement in capacity doesn't lead to loss of capital and the associated variable costs including the additional human resource investments. In this paper the demand is forecast by trend projection method as this method is capable of generating the forecast for any number of future periods. In the other methods like moving averages or exponential smoothing, the forecast will be generated only for the immediate next period and hence a long term projection will not be possible. However after the forecast is obtained the usual forecast error analysis is carried out to ascertain the dependability of the model used in this case.

The forecast is considered under three different scenarios namely demand under pessimistic, normal, and optimistic conditions. This provides an opportunity to visualize the three different demand levels and accordingly decide upon the total investment to be made in capacity expansion. The rationale behind this approach is the model being developed here is deterministic and hence not based on probability of occurrence of different scenarios. This enables the decision maker to compare the three scenarios and then take a decision based on managerial judgment and fresh insight into the product demand.

The optimization process involves two phases: in the first phase the optimal decision is arrived at by exploring different situations using Microsoft Excel data analysis tools, in particular, goal seek and data table. This allows the decision maker to examine the situation from different perspectives and studying the effect on the model by the key variables. In the second phase a typical linear programming problem approach is developed and the decision variables are simultaneously varied to obtain the optimal results. The final analysis compares the scenarios and debates the merits and limitations in each case. This enables the decision maker to get a better picture of the entire process of decision making and allows proper control on the model.

Problem Formulation

The problem considered for analysis is first defined and discussed as basic or elementary model with only few restrictions on the decision making. Then stage by stage the complexity of the problem is increased to visualize the challenges and also build different scenarios to enable improved decision making abilities.

The company in this case manufactures auto components and two types of components are involved. The company has forecast the demand for the coming year and wants to know the adequacy of the capacity. If needed, the company would add machines to take care of the expected demand. The technical data pertaining to the production of the components is given in Table 1, as given in the operations management textbooks, (Stevenson, 2015; Ritzman and Krajewski, 2015).

Table 1 : Demand and Processing Data for the Components

Item	Component A	Component B
Demand forecast, Units/year	30000	12000
Lot size, units	20	60
Standard processing time, hour/unit	0.3	1
Standard set up time, hours/lot	3	4

The working pattern in the company is given in Table 2. The table also shows the number of machines currently available in the company and ready to take care of the production. The procedure to calculate the capacity is illustrated in the next paragraph but first it is necessary to check whether the company follows any "capacity cushion".

Table 2 : Working Pattern and Existing Capacity

Number of machines at present	4
Number of shifts per day	2
Operating hours per shift	8
Working days per year	200

Why Capacity Cushion is Required?

Capacity cushion is defined as the extra capacity available in the company that is left after utilizing the machines and equipment to produce the demanded quantity. It refers to the unused capacity and thus is maintained in anticipation of several requirements. The reasons for maintaining capacity cushion are as follows, as given by several authors, (Stevenson, 2015; Ritzman and Krajewski, 2015):

- Breakdowns
- Shutdown due to Maintenance
- Non-availability of resources like materials, supplies, energy, and key personnel due to absenteeism, sickness, leave, and labor problems
- Lack of coordination
- Government policies and regulations
- Accidents
- Natural disasters and calamities

All these unexpected situations forces the operations managers to maintain some extra capacity which is called the capacity cushion. A specific or commonly agreed upon capacity cushion is not commonly found and the companies maintain the capacity cushion according to historical patterns of demand fluctuation and also to beat the competition. It is to be noted that capacity cushion represents unused capacity and thus is a non-productive resource. Secondly the unused capacity is an idle resource and attracts investment which would ultimately go as a waste. Hence it is necessary that a judicious value of the capacity cushion is maintained and the associated cost is kept at a minimum. Further, the optimum value of capacity cushion can be regarded as a balance between the opportunity cost and the actual loss. This is similar to maintaining safety stock in a typical inventory control problem or maintaining the MRO (maintenance, repair, and operating) supplies to ensure uninterrupted or smooth production in a manufacturing company. In all these cases the obvious tendency would be to maintain a low capacity cushion to minimize the investment.

Deciding the Capacity Planning in Terms of Capacity Cushion – The Basic Model

The existing capacity is weighed against the anticipated demand and thus the "capacity gap" is first established. The capacity is calculated as follows:

Available time per machine is determined as,

$$Available\ time\ per\ machine = \begin{bmatrix} Number\ of \\ shifts \end{bmatrix} X \begin{bmatrix} \text{Number of} \\ \text{operating} \\ \text{hours per shift} \end{bmatrix} X \begin{bmatrix} Number\ of \\ working \\ days\ in\ a\ year \end{bmatrix}$$

In the present case problem,

Available time per machine using the data given

= 2 X 8 X 200 = 3200 hours per year

As there are 4 machines at present, the total capacity is = 3200 X 4 = 12800 hours per year

The assumptions are as follows:

- Machines are available over entire hours of operations without any disruption
- There is no breakdown of machines
- The machines are continuously run over the entire shift time of 8 hours
- The environment of manufacturing is such that there are no unexpected events to disrupt the number of machines working in the company. Hence the full capacity of both the machines is assumed available all around the year.

However it is to be understood the number of hours calculated as "available time" is known as the effective capacity but in reality the actual capacity can be lower than this owing to several operational issues. This means the existing available capacity needs to be discounted considering both planned maintenance and also the unexpected disruptions. Hence in a way a capacity cushion that is applied to the effective capacity ensures that the entire time is not available and a fraction of the available time is to be set aside as capacity cushion. This is an indirect advantage of using capacity cushion.

In the present example if a capacity cushion of 10% is insisted, then the actual capacity is calculated as:

$$Actual\ capacity =$$

$$\begin{bmatrix} Effective \\ capacity \end{bmatrix} X\ [1 - capacity\ cushion\ in\ decimal]$$

Therefore actual capacity is = 12800 X (1 - 0.25) = 9600 hours.

The capacity cushion, which is the planned unused capacity greatly helps to avoid running short of time should there be any disruptions in the schedule in the future, or take care of the increase in demand, without losing the opportunity.

The next step is to calculate the total time required to process the expected demand as shown in the Table 3.

The total time required is calculated as follows:

$$\begin{matrix} The\ total \\ time\ required \end{matrix} = \begin{matrix} Number\ of\ units\ or \\ forecast\ demand \end{matrix}\ X\ \begin{matrix} Processsing \\ time \end{matrix} + \left[\begin{matrix} Set\ up\ time \\ per\ lot \end{matrix}\ X\ \begin{matrix} Number \\ of\ lots \end{matrix} \right]$$

The set up time is based on the lot size and the number of lots is based on the number to be processed divided by lot size. Table 3 shows all the calculations done using Excel 2013

Table flows to next page ....

Table 3 : Capacity Planning Calculations

Item	Component A	Component B
Demand forecast, units/year	30000	12000
Lot size, units	20	60
Standard processing time, hour/unit	0.3	1
Standard set up time, hours/lot	3	4
Total time required for processing	13500	12800
Number of machines at present	4	
Number of shifts per day	2	
Operating hours per shift	8	
Working days per year	200	
Total time requirement, hours	26300	
Time available per machine, hours	3200	
Capacity cushion required	0.25	
Actual machine capacity, hours	2400	
No. of machines required	10.95833333	
No. of machines required rounded up	11	
Existing machines	4	
Additional machines required	7	

Based on the capacity cushion of 25%, which means only 75% of the time available with the machines will be utilized for processing, and hence the number of machines required is:

Number of machines required = Total time required / Actual capacity of each machine

The number of machines is quite often a fraction and hence would be rounded up to make it a whole number. In the present case we find the number of machines required as 11 after rounding up, and hence subtracting the existing number of machines. Hence the number required is 7 machines.

Exploring the Options

The decision maker is now naturally interested to know the different number of machines required under different combinations of "Capacity Cushion" and "number of working days". The reason for concentrating on these parameters only are, the set up time and the processing time are completely dependent on technological issues and hence cannot be easily changed or revised. Thus the easier options would be to examine the options as shown in Table 4.

Table 4 : Options Available Under Different Combinations

Options to explore	Number of machines	Number of working days	Capacity cushion
1	Held constant	Varied	Varied
2	Varied	Held constant	Varied
3	Varied	Varied	Held constant

The Relative Merits and Demerits of the Three Options are as Follows:

The number of machines if held constant at the present capacity, do not demand additional space and capital investment. Hence economical. Any addition demands space, capital, human resource, maintenance, and sufficient load to make it economically viable. But rising cost of the machines would be a factor if the decision to buy new machines is postponed.

The number of working days requires consensus with the workers to increase or decrease and additional variable costs will come into picture. If the regular workers do not wish to for extra days, temporary workers may have to be hired. Capacity cushion is the easiest parameter to vary as it is purely an administrative or production policy. The exact decision is not possible inn a deterministic way because of the forecast demand which is always uncertain. Hence a probabilistic model can be built shown later in the paper which again is not agreed upon by everyone easily as the situations are unpredictable.

All the possible options can be explored using the “what if’ feature of Excel and data table as shown in Table 5 is developed. In this table the table shows the number of machines that need to be added for different values of capacity cushion. For example, if the number of working days is 210 and the capacity cushion desired is 10%, then the number of machines to be added is 5. It may be noted that sometimes the same number of machines is applicable for different values of capacity cushion. This is because while the number of machines jumps by one unit meaning one machine, the capacity cushion can vary over a range as the number of machines is rounded up always. The graphs displayed in Figure 1 illustrate how the number of machines continue to drop with the increase in the number of working days. Thus the general conclusion would be to choose the number of machines keeping in mind the required capacity cushion and the possible change in the number of working days.

Table 5 : Number of machines required under different conditions of capacity cushion and number of working days.

		Capacity Cushion in Percent									
		5	**10**	**15**	**20**	**25**	**30**	**35**	**40**	**45**	**50**
Number of Working Days Per Year	**200**	5	6	6	7	7	8	9	10	11	13
	210	5	5	6	6	7	8	9	10	11	12
	220	4	5	5	6	6	7	8	9	10	11
	230	4	4	5	5	6	7	7	8	9	11
	240	4	4	5	5	6	6	7	8	9	10
	250	3	4	4	5	5	6	7	7	8	10
	260	3	4	4	4	5	6	6	7	8	9
	270	3	3	4	4	5	5	6	7	8	9
	280	3	3	3	4	4	5	6	6	7	8
	290	2	3	3	4	4	5	5	6	7	8
	300	2	3	3	3	4	4	5	6	6	7

Moving towards Optimization

The operations manager has now a wide choice to decide upon the number of machines to be added for different values of capacity cushion and number of working days. The graphs shown in Figure 1 enable to choose the desired values making a proper selection across all the three parameters. It is quite obvious that higher capacity cushions lead to higher unused capacities thus increasing the cost of the idle source. On the other hand lower capacity cushions carry the risk of losing out when demand surges and unexpected demand patterns occur. Similarly the increase in the number of working days and deciding to add more machines lead to capital expense as well as increase in the variable expenses. Hence with only these kinds of scenario building it may not be not be possible to move towards optimization. Hence we need to formulate for example a liner programming model and optimize the objective of minimizing the number of machines or using cost values minimize the total cost.

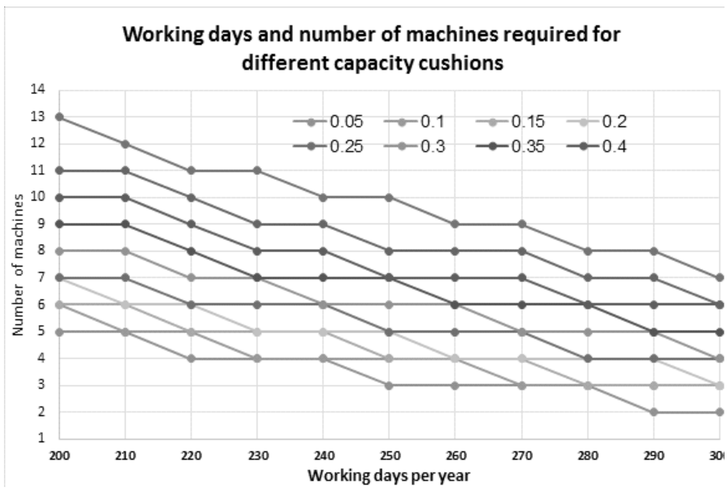

Figure 1 : Choices Available for Working Days and Number of Machines to be added for Different Values of Capacity Cushion

Another way of improving the deterministic model is to build three scenarios considering the demand under pessimistic, normal, and optimistic situations thereby giving the decision maker a choice to dice the number of machines according to the demand patter. We reconstruct the problem again but this time three demand patterns are considered. The problem is displayed in the Table 6.

Table 6 : Capacity Planning Data under Three Scenarios of Demand

	Pessimistic demand		Normal demand		Optimistic demand	
Item	**Component A**	**Component B**	**Component A**	**Component B**	**Component A**	**Component B**
Demand forecast, units/year	22500	9000	30000	12000	37500	15000
Lot size, units	20	60	20	60	20	60
Standard processing time, hour/unit	0.3	1	0.3	1	0.3	1
Standard set up time, hours/lot	3	4	3	4	3	4
Total time required for processing	10125	9600	13500	12800	16875	16000

When the demand values are considered under different situations, the same calculations can be carried out to find the number of machines to be added for a given capacity cushion. In Table 6 the demand values are obtained as follows: Normal demand as in the previous case, pessimistic demand 75% of the normal demand, and optimistic demand is 1.25 times the normal demand. Using these demand values for a capacity cushion of 25% as before the capacity addition in terms of the number of machine is obtained and the results are shown in Table 7.

Table 7 : Number of Machines to be added Under Different Demand Situations when Capacity Cushion Is 25%

	Pessimistic demand	Normal demand	Optimistic demand
Number of machines at present	4	4	4
Number of shifts per day	2	2	2
Operating hours per shift	8	8	8
Working days per year	200	200	200
Total time requirement, hours	19725	26300	32875
Time available per machine, hours	3200	3200	3200
Capacity cushion required	0.25	0.25	0.25
Actual machine capacity, hours	2400	2400	2400
No. of machines required	8.21875	10.95833333	13.69791667
No. of machines required rounded up	9	11	14
Existing machines	4	4	4
Additional machines required	5	7	10

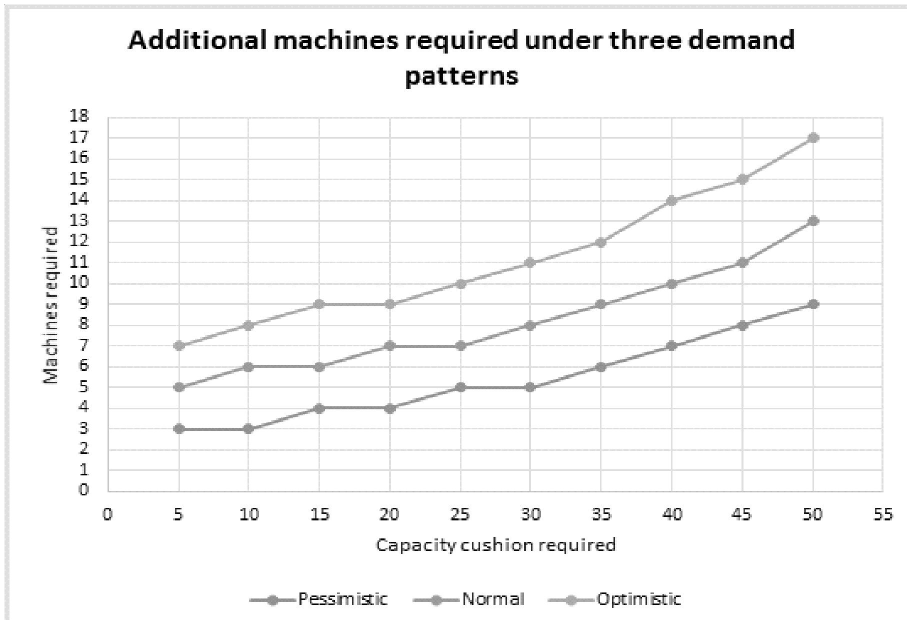

Figure 2 : Additional Machines Required Under Three Demand Patterns for Different Capacity Cushions

From the Figure 2 it is observed that the trend between the capacity cushion required and the number of machines to be added is having a linear trend across all the three demand patters. Hence it is possible to obtain the trend equations using the liner trend projection method and Excel. Continuing from Figure 2, when trend lines are added to the data pattern, a very good linear trend is visible. Referring to Figure 3 and observing the trend equations across all the three demand situations we can infer that the number of machines to be added range from 3 to 7 when pessimistic demand exists, 5 to 13 when the demand is normal, and from 7 to 17 when the demand is optimistic, depending on the level of capacity cushion. Hence the decision maker can now use the trend equation to quickly arrive at the number of machines to be added for a given capacity cushion when different demand situations exist. The Table 8 shows the equations and the key aspects of the three equations. The high value of R^2 indicates that the trend equations are quite adequate to determine the number of machines to be added under different demand situations. Table 8 also displays the number of machines required, for example, when a capacity cushion of 12% is required.

The next step is to examine the forecast errors and carrying out the residual analysis. This is done by calculating the different forecast error measures and ascertaining the suitability of the model. The residual analysis clearly indicates that the model doesn't exhibit autocorrelation or bias and hence can be relied upon. For example, Figure 4 displays the residuals for a particular case of pessimistic demand with a capacity cushion of 12% is required. The random spread of the residuals indicate that the model is not biased.

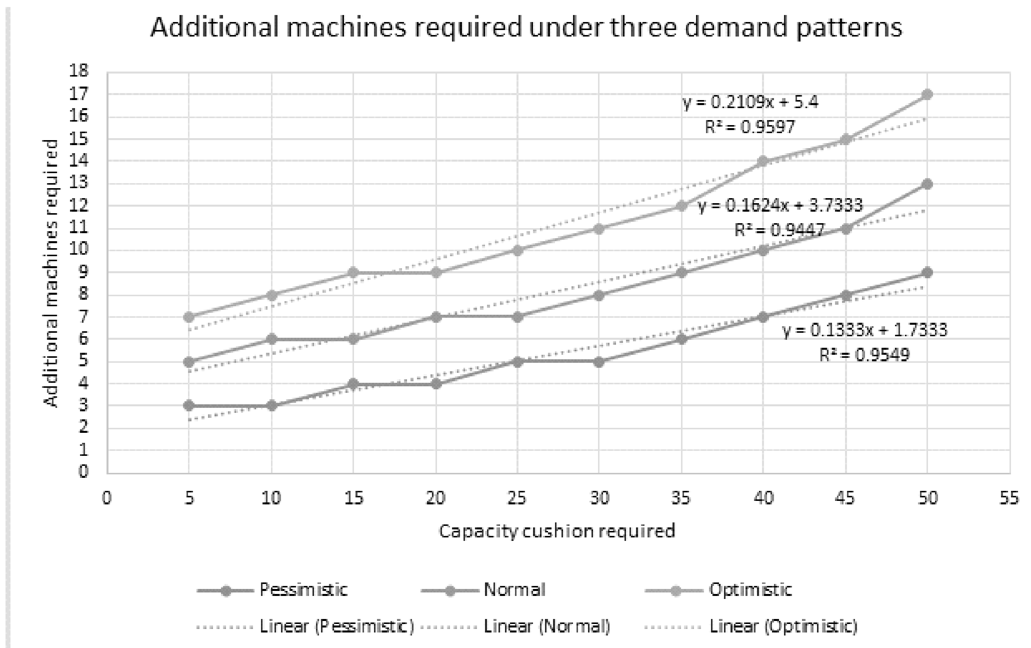

Figure 3 : Trend Equations to Determine the Number of Machines

Table 8 : Trend Equations to Determine the Number of Machines Required.

Demand situation	X = Capacity cushion	y = number of machines to be added, a + bX	Number rounded up	a	b	R^2
Pessimistic	12	3.3329	4	1.7333	0.1333	0.9549
Normal	12	5.6821	6	3.7333	0.1624	0.9447
Optimistic	12	7.9308	8	5.4000	0.2109	0.9597

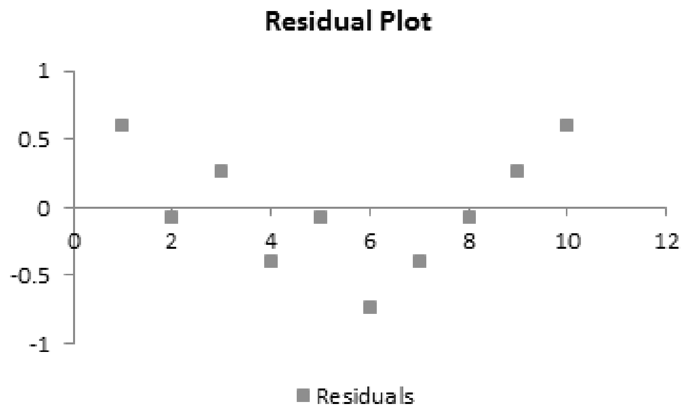

Figure 4 : Residual Analysis of the Trend Equations to Determine the Number of Machines

Conclusion

Capacity planning particularly the capacity expansion is a challenging issue and falls under the class of decision making under uncertainty. Because of the probabilistic values associated therein it is difficult to interpret and to implement in practice. In this paper the model is developed under a known forecast demand ignoring the uncertainty but considering the possibility of such demand varying under three different situations of pessimistic, normal, and optimistic demand. Considering a typical component manufacturing case, the paper illustrates how capacity expansion can be considered under different cases of capacity cushion and how the simple trend model of forecast can be used. The model is found to be quite reliable and easy to apply. The limitations of this approach are assuming the situation as deterministic and not considering any other variable that may affect the availability of the machines. However, it is possible to consider such variables influencing the capacity but each model would tend to become quite cumbersome to understand and apply. Keeping the interests of the practitioners in mind, the model's simplicity is maintained. But necessary support in terms of the statistical reliability has been established to make the model acceptable to the community.

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