CHAPTER 5

5.0 CAPACITY PLANNING

5.1 INTRODUCTION 64
5.2 MANUFACTURING PLANNING AND CONTROL 64
5.3 CAPACITY PLANNING 64
5.4 SYSTEM MODEL SIMULATION 66
5.5 CONCLUSION 75
PAPERS PUBLISHED


5.1 INTRODUCTION

Determination of production capacity of any manufacturing system is essential not only at the time of designing that system or expanding, but also for its operating periods. The system is described in terms of its inputs and outputs for internal and external environment of the company. This work involves in developing a mathematical model of the manufacturing system through INDUSTRIAL DYNAMICS[4] approach and then studying its capacity utilisation under fluctuating market conditions. A computer simulation program as described in section 5.4 has been developed for this purpose.

5.2 MANUFACTURING PLANNING AND CONTROL

Because of the problems encountered with manufacturing planning, attempts have been made in recent years to capture the logic, judgement and experience required for this important function and incorporate them in computer programs. Based on the characteristics of a given process, the program has to automatically process the operation sequence. The activities of manufacturing planning and control in general cover forecasting, planning, estimating, scheduling, requirements planning, purchase planning, load and capacity requirements, operation planning & sequencing, dispatching, expediting, quality control, shipping and inventory control.

5.3 CAPACITY PLANNING

Fig.2.1 shows the flow diagram of the manufacturing inventory system. This includes manufacturing, distribution sales and inventory.
\( UOR.K = (UOR.J + DT(RRR.JK - SSR.JK)) \) (1)

\( IAR.K = (IAR.J + DT(SSR.JK - SSR.JK)) \) (2)

\( STR.KL = ((UOR.K) / (DFR.K)) \) (3)

\( NIR.K = (IAR.K) / DT \) (4)

\( SSR.KL = (STR.K) OR (NTR.K) \) (5)

\( DFR.K = (DHR + DUR.(IDR.K)/(IAR.K)) \) (6)

\( IDR.K = (AIR) (RSR.K) \) (7)

\( RSR.K = (RSR.J + (DT l/DRRKRRR.JK - RSR.J)) \) (8)

\( PDR.KL = (RRR.JK + (((1/DIR) (IDR.I) - RSR.JK)) + \)

\( (LDR.K - LAR.K) + (UOR.K-UNR.K)) \) (9)

\( LDR.K = ((LDR.K-LAR.K) + (UOR.K-UNR.K))) \) (10)

\( LAR.K = (CPP.K + PMR.K + UOD.K + MTR.K) \) (11)

\( UNR.K = ((RSR.K) (DHR + DUR)) \) (12)

\( CPR.K = (CPR.J + ((DT)PDR.JK - PSR.JK)) \) (13)

\( PSR.KL = (PSR.JK + (DT(1/DCR)(PDR.JK-PSR.JK))) \) (14)

\( PMR.K = (PMR.J + DT(PSR.JK - RRD.JK)) \) (15)

\( RRD.KL = (RRD.JK + (DT(1/DMR0)(PSR.JK-RRD.JK)) \) (16)

\( MTR.K = (MTR.J + DT(SSD.JK - SRR.JK)) \) (17)

\( SSD.KL = STD.K OR NID.K \) (18)

\( DFD.K = (DHD + DUD (IDD.K/IAD.K)) \) (19)

\( IDD.K = (AID) (RSD.K) \) (20)

\( RSD.K = (RSD.J + DT (1/DRD0)(RRD.JK-RSD.J)) \) (21)

\( PDD.KL = (RRD.JK +((1/DID) (IDD.K - IAD.K) + \)

\( (LDD.K-LAD.K)+(UOD.K-UND.K)) \) (22)

\( LDD.K = (RSD.K) (DCD + DMD + DFF.K + DTD) \) (23)

\( LAD.K = (CPD.K + PMD.K + UOF.K + MTD.K) \) (24)

\( UND.K = (RSD.K) (DHD + DUD) \) (25)

\( CPD.K = (CPD.J + (DT)(PDD.JK-PSD.JK)) \) (26)

\( PSD.KL = (PSD.JK + (DT(1/DCD)(PDD.JK-PSD.JK)) \) (27)

\( PMD.K = (PMD.J + DT(PSD.JK - RRF.JK)) \) (28)

\( RRF.KL = (RRF.JK + DT(1/DMR)(PSD.JK-RRF.JK)) \) (29)

\( MTD.K = (MTD.J + DT(SSF.JK-SRD.JK)) \) (30)

\( SSR.KL = (SSD.K + DT(1/DMR)(SSF.JK-SRD.JK)) \) (31)

\( UOF.K = (UOF.J + DT(RRF.JK-SSF.JK)) \) (32)

\( IAF.K = (IAF.J + DT(SRF.JK-SSF.JK)) \) (33)

\( STF.K = (UOF.K/DFF.K) \) (34)
5.4 SYSTEM MODEL SIMULATION

The computer simulation program for this model has been developed in 'Turbo C' language. The Fig 5.1, shows the flow chart for this purpose. The simulation runs are made with selected inputs of solution interval, various delays, proportionality constants, inventory level at factory and initial value of requisitions received at retail. The program records the outputs like requisitions received at retail, manufacturing wanted at factory, load in terms of hours required to manufacture the products and the capacity utilisation of each work center to assess the availability for further manufacturing schedule. An Interactive software package has been developed to perform simulation of the shop floor system in batch production environment.
Fig. 5.1 FLOW CHART FOR MANUFACTURING SYSTEM SIMULATION
5.4.1 Test Runs
A very informative and one of the simplest test inputs for the study of the manufacturing system using industrial dynamics is the step function. Using this procedure the simulation program is done for a selected interval of 0.125, 0.25, 0.5, 1.0 week. Table 5.1 predicts the manufacturing rate wanted at the factory for the rate of requisitions received. The Figure 5.2 shows the graphical output of MWF for the values shown in Table.5.1. After finding the required production rate, the values are fitted to a standard distribution.

The second part of the simulation program is run using the above data-such as MWF, number of manufactured components, capacity available in terms of hours of each machine, standard process planning and machining time of each components and backlogs. The output of this simulation run shows the number of components to be machined to meet out the demand in each type of machine at every simulation interval, status of the machine, number of unmachined components at end of each interval and additional capacity required to meet the demand. The utilisation of each machine at every interval (100 Hrs), machine status and machine output are shown as barchart, Fig.5.3 and computer screen output, Fig 5.4 respectively. Figure 5.5 shows the shop floor model of the manufacturing system chosen for this analysis.

To study this shop floor model, the user can select the system throughinput option. Simulate option in the software will perform the simulation of the chosen manufacturing system. By choosing the digital output option, the user can see the status of the system at any time, breakdown details and the total system output through a separate option again. By selecting the graphics menu, the user can see the graphical representation of the cumulative waiting time, time spent in queues, waiting line lengths and capacity utilisation of each machines with respect to the number of components in the system. This option is provided to enable the user to understand the dynamic and stochastic behaviour of the system being simulated. By selecting the animation option the physical layout of the model can be seen, Fig.5.5.
IN simulation option, the simulation process is initiated by inputting into the program, the number of components to be manufactured with respect to the MWF. The unit time advance method is followed here to simulate the system. At the time of the starting of the simulation clock, the components are transferred to TC1 (Turning Center 1), TC2 (Turning Center 2) and TC3 (Turning Center 3) as given in Fig. 5.5. Then the turning centers will start processing the components and the clock will be advanced. When the next batch of components arrives, it is also transferred to these turning centers. At this time, if all the turning centers are already engaged by the previous components, it will join in the waiting line and wait till a turning center is free.

The component that is first released from these turning centers will enter the machining center and machining center will start processing the components. The next arrival will join the waiting line until this machine is free. During the run of simulation, at each unit increments of time, the status of the work centers will be seen, i.e., whether they are processing, idle or under breakdown condition.

If the turning center 1 is in breakdown condition at the arrival of the jth component to the machine, the system will check for the status of the other two turning centers. At this time, if the turning center 2 is free and its waiting line length is zero then the component now currently in the turning center 1 will be routed to the turning center 2. After the breakdown time is over the turning center 1 will start processing the (j + 1)th component.

At the breakdown of turning center 1, if the other two turning centers are busy, then the waiting time for turning center 1 for the jth component will be increased by the breakdown time. After the breakdown is set right, the turning center will start processing the jth component. The same will hold good with other turning centers when they are in breakdown condition.

If the MC (machining center) is in breakdown condition at the arrival of the kth component the idle time and waiting time for the kth component
will be increased by an amount equal to breakdown time. When the clock reaches present time plus breakdown time, the machining center will start processing with k\textsuperscript{th} component.

At the end of the simulation runs, the user is directed to main menu. The digital output options give the result of the current system being simulated. In this work a digital simulation model has been developed for a pump manufacturing industry for the sales period of one year. Due to the restrictions in the computer graphics facilities the output on capacity utilisation (Fig. 5.3), interactive computer graphics (Fig. 5.4) and shop floor model (Fig. 5.5) is restricted to four machines and one week period. The same algorithm can be made run on computing systems with higher memory capacity for more number of machines.
## TABLE 5.1 Prediction of MWF based on RRR

| WEEK | RRR | UOR | IAR | PDR | UOD | IAD | PDD | UOF | IAF | MWF |
|------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 01   | 1000 | 1400 | 8000 | 1000 | 1600 | 6000 | 1000 | 2000 | 4000 | 1000 |
| 02   | 1012 | 1400 | 8000 | 1000 | 1600 | 6000 | 1000 | 2000 | 4000 | 1000 |
| 03   | 1035 | 1427 | 7992 | 1041 | 1600 | 6000 | 1000 | 2000 | 4000 | 1000 |
| 04   | 1067 | 1462 | 7944 | 1086 | 1600 | 6000 | 1000 | 2000 | 4000 | 1000 |
| 05   | 1095 | 1514 | 7880 | 1126 | 1656 | 5976 | 1074 | 2000 | 4000 | 1000 |
| 06   | 1082 | 1515 | 7823 | 1143 | 1684 | 5946 | 1102 | 2021 | 4000 | 1000 |
| 07   | 1035 | 1505 | 7772 | 1185 | 1840 | 5713 | 1243 | 2226 | 4000 | 1000 |
| 08   | 1095 | 1514 | 7880 | 1126 | 1656 | 5976 | 1074 | 2000 | 4000 | 1000 |
| 09   | 1082 | 1515 | 7823 | 1143 | 1684 | 5946 | 1102 | 2021 | 4000 | 1000 |

Note: The above table shows the arrival of orders (units per week).
Fig. 5.2 MANUFACTURING RATE WANTED AT FACTORY

Fig. 5.3 CAPACITY UTILISATION (WEEKLY)
\[ \text{MO} = 2252 \quad \text{MO} = 584 \quad \text{MO} = 520 \]
\[ \text{AUC} = 1485 \quad \text{AUC} = 3233 \quad \text{AUC} = 3217 \]
\[ \text{MO} = 963 \quad \text{MO} = 398 \quad \text{MO} = 720 \]
\[ \text{AUC} = 2987 \quad \text{AUC} = 3339 \quad \text{AUC} = 2774 \]
\[ \text{AUC} = 3817 \]

**Fig. 5.4.** INTERACTIVE COMPUTER GRAPHICS SHOWING SHOP FLOOR STATUS

\[ \text{MO} = \text{MACHINING OVER (No. of Components)} \]
\[ \text{AUC} = \text{UNUSED CAPACITY (No. of Hours)} \]
\[ \text{CU} = \text{CAPACITY UTILISATION (No. of Hours or \%) } \]

**ALLOTTING PERIOD** = 52 WEEKS

**LOAD IN PERIOD** = 2290 (Components)

\[ \times \text{OF CAPACITY UTILISATION} = 53.94 \]

**UNMACHINED COMPONENTS** = 598 (TO BE SUBCONTRACTED)
Fig. 5.5 SHOP FLOOR MODEL
5.5 CONCLUSION

This simulation study has been carried out to assess the capacity utilisation for batch manufacturing system under fluctuating market conditions. The inputs needed for simulation runs are user defined to achieve the desired result. The outputs of simulation runs show the values of manufacturing rate required, capacity utilisation of each machine, available capacity for each week/month and the amount of work to be subcontracted to meet the delivery dates at each simulation interval in desired form of output by considering the rates of flow of materials and orders. With this type of output the user can evaluate the status of the system at each interval and can assess capacity utilisation effectively. The interactive computer graphics facilitates the user to measure the actual status of the manufacturing system. This study has helped to quantify and improve the utilisation of manufacturing systems. The generalised scheduling model of batch manufacturing systems given in this chapter are used for the analysis of specific types of systems adapting different scheduling rules. Such an analysis of dynamic scheduling of job shop is presented in Chapter 7.