A DECISION SUPPORT SYSTEM FOR CAPACITY MANAGEMENT

A Senior Project

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by

Anton Slobodnik

Graded by:_____   Date of submission:_____
Checked by:_____   Approved by:_____

Executive Summary

Every manufacturer faces the challenge of managing production capacity. How effectively a company meets required capacity as compared to competitors will be a determinant of profitability and success.

This paper details the creation of a best of breed software that can act as a decision support system and help planners reschedule work, add shifts and make sure that the master production schedule is feasible before putting it into an MRP system.

As a part of my senior project I've created a Rough-Cut Capacity Tool that takes lead time into account and performs basic what if analysis on level loading a profile for a critical work center, thus facilitating the efforts of a master scheduler.

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Notations

RCCP - Rough Cut Capacity Planning

MPS - Master Production Schedule

ERP - Enterprise Resource Planning

BoB - Best of Breed

MRP - Material Requirements Planning

DSST - Decision Support System Tool

CPOF - Capacity Planing using Overall Factors

BoL - Bill of Labor

RP - Resource Profile

LCA - Learning Curve Analysis

PLAN - Swedish Production and Inventory Management Society

MRPII - Manufacturing Resource Planning

S&OP - Sales and Operations Planning

RRP - Resource Requirement Planning

APP - Aggregate Production Plan

WIP - Work in Progress

Introduction

Every manufacturer faces the challenge of managing production capacity. Due to the high costs associated with facilities, equipment, and labor, companies are confronted with the challenge of meeting demand with minimal resources. Ideally, a manufacturer's capacity would match their demand requirements exactly. How effectively a company meets required capacity as compared to competitors is a determinant of profitability and success.

Rough-cut Capacity Planning (RCCP) is a long-term validation exercise that enables the planner to compare required and available capacity. By incorporating the RCCP as a part of the Master Production Schedule (MPS) creation, the planner is empowered with the ability to asses the impact on resources required to carry out high-level business plans.

In a Manufacturing Resource Planning (MRPII) system there is a need for checks and balances to evaluate the feasibility of the MPS before proceeding with the next steps of the MRPII system. This is why RCCP is an important tool for creating a Master Production Schedule. It helps the business meet required demand while reducing excess or shortage of available resources. By optimizing capacity in order to meet demand, a company will reduce their production costs.

RCCP tools are usually available as a feature of a large Enterprise Resource Planning (ERP) or MRPII packages. Such packages are expensive and may require a company to change its infrastructure to align with the package. There is a market for Best of Breed (BoB) software that provides RCCP information to small companies that cannot afford expensive ERP packages. The main portion of this project will be to create a Decision Support System Tool (DSST) that will serve as an external software capable of integrating with Microsoft Access databases, providing necessary RCCP information.

Background

A typical MRPII system begins with a high level Aggregate Production Plan (APP). The high level plans include business, sales and operations, production and the MPS which can be described as a schedule plan. An important check and balance must performed to see if the MPS is feasible before the Material Requirement Planning (MRP) process is initiated.
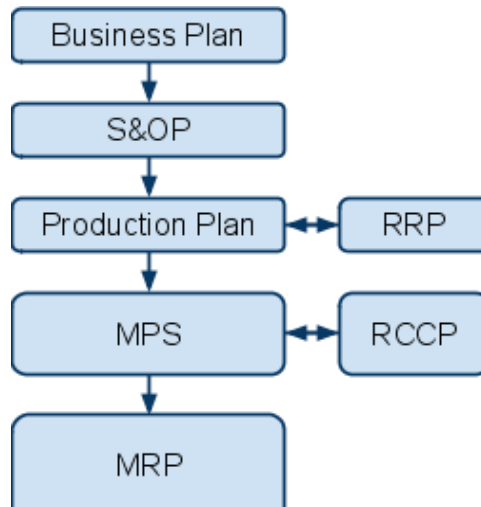
Figure 1: Typical MRPII Diagram (up to MRP)

Resource Requirements Planning (RRP) determines the amount of production resources (labor hours, machine hours, and inventories) that are needed in order to meet planned production in the APP. RCCP determines if there is available capacity to meet the production plan, it is the final check an balance before the MPS is fed in to the MRP system.

A MRP system uses a MPS of end items to determine the quantity and timing of component part production. MRP by itself is capacity insensitive; if demand shows an order for 1 million end items, the system will proceed with the manufacturing steps regardless of capacity. This is why it is so important to carry out a rough cut capacity analysis before running MRP.

A common problem of an MRP system is over production. An overstated MPS will release more orders for production than can be completed. This can increase raw material, WIP, and create queues on the shop floor. Because of the queues, lead time may also increase. Thus, overstated master production schedules may lead to missed deadlines, higher production costs, and other problems. Validating the MPS with respect to capacity is an extremely important step in creating a MPS. This validation exercise has been termed rough cut capacity planning (RCCP).

RCCP is a long-term capacity planning tool that marketing and production use to balance required and available capacity. This is important to business operations as it deals with adding or removing shifts, using overtime or subcontracted labor, and adding or removing machines. If resources cannot be increased, RCCP empowers the master scheduler with the information needed to schedule and update the MPS by changing dates and quantities.

Most of the RCCP analysis is done through approximations, where products are grouped

into families and machines or departments are grouped into work centers. Rough cut capacity plans are a statement of the capacity required to meet gross production requirements.

Literature Review

Break down of RCCP

There are generally three techniques available for RCCP computation. All are designed to convert the MPS of end items into the amount of time required on certain key resources. The three techniques are Capacity Planning using Overall Factors (CPOF), the Bill of Labor approach (BoL), and the Resource Profile (RP) approach. CPOF requires the least detailed data and computational effort, but is insensitive to shifts in product mix [1]. The BoL uses detailed time standards for each product at the key work centers. With a time standard being the time it should take an average worker working at normal pace to produce one unit of the product. The final and most detailed technique is the RP approach. Like the BoL the RP approach requires detailed time standard data. In addition, the RP approach also uses lead-time data.

The CPOF method requires three data inputs; the MPS, the standard or estimated total time required to produce one "typical" part, and the proportion of total time required by each resource to produce the part. CPOF calculations can rely heavily on intuition and may be computed on a typical calculator. The estimated cumulative lead time is multiplied by the MPS quantity to obtain the total time required in the factory to match the MPS. This time is than prorated among all the key work centers by multiplying the total time by the historical proportion of time used at a given resource.

A good definition of the BoL technique is given in [8]:

> The bill of labor is a listing by item number of the amount of labor required by a major labor category to produce that item or group of part numbers. It is not intended to be a routing, but merely a means of estimating the capacity requirements for a particular item. The bill of labor (BOL) may be compiled for every distinct item or for groups of similar items, and extended by the scheduled quantities to determine capacity requirements.

BoL is a more detailed approach of the CPOF, where the computations are done for each individual key resource. A simple matrix multiplication of the MPS and the bill of labor yields the labor requirements of the MPS.

Out of the three RCCP techniques the RP approach is the only one that considers lead-time offsets. The previous two techniques assume that all components are built in the same time period as the end item. The RP approach uses the same detailed time standards for each product and also time phases the labor requirements to create a resource profile. For a rough-cut approach it is the most detailed and calculation intensive. The RP approach is always implemented on a computer system because of the tedious calculations. Once the resource profile is created, the rough cut requirements are calculated by multiplying the resource profile by the MPS. Because of the lead time offsets of the resource profile, the multiplication is not a simple matrix multiplication of the BoL approach. Instead, the procedure has to keep track of the hours accumulated in each period.

Planning Horizon

The purpose of RCCP is to check if available production capacity is sufficient to produce the required volumes. Such a check could be based on detailed schedules that exactly specify at what date and time specific operations of specific orders are preformed in the far future. However it would not make sense to perform these detailed calculations, when the future is still unknown.[9] There is still uncertainty in customer orders, inventory levels, machine availability, operator availability, and etc. Therefore capacity checks that apply to a longer term are usually performed on a higher level.

Since the exercise is a "rough cut", the planning horizon should be broad and give the company long-term visibility. If the product manufacture lead-time is large in comparison to the planning horizon, the RP may be useful because the BoL and CPOF assumption that the components and the end item are built during the same period might not be met. In such a case the extra computational effort of the RP technique may very well be worth it. In any event, rough cut capacity plans should be used only to determine if sufficient capacity exists over broad time frames, such as months or a quarter.[1]

Learning Environment

It has been shown in past empirical research that many firms exhibit productivity improvements, or learning , as more units are produced. The productivity improvements can be associated with a learning process (human, technological, or organizational) and have been

measured by log functions known as learning curves.[3] There are various benefits to integrating Learning Curve Analysis (LCA) with capacity planning procedures.

By incorporating and periodically updating an efficiency ratio to align total standard hours of production with total actual hours, future capacity projections will be more precise and not under estimated. A possible methodology for updating productivity improvements in the production process, is to base future productivity predictions on a moving average. The moving average can be as effective as the LCA at predicting productivity improvement.[3] It is important to incorporate such logic in a system. If productivity improvements are not taken into account the accuracy of the capacity estimates will degrade over time.

Possible Market

A survey was sent to the members of the Swedish Production and Inventory Management Society (PLAN), with each member representing a different manufacturing company. The members of PLAN are distributed among the Swedish manufacturing industries. The survey responses were compiled and the statistics were presented in.[5]

The study found that as many as 46% of the companies use CPOF as their main method of RCCP. Intuition is more commonly a source of data for small companies compared with medium and large sized companies. A possible relationship may exist between the size of the company and the preferred RCCP standard. Smaller companies are more reluctant to purchase ERP systems and may just prefer to base their analysis on intuition because of their relatively small size. It was surprising to find that as many as half of the CPOF users employ weekly planning periods. A period measured in weeks is an unnecessarily short planning period for long-term RCCP techniques. Such a use of a the CPOF technique may indicate a lack of tools available to the companies, which most likely are small in size.

The study also asked the participants to rate their degree of satisfaction with the three RCCP techniques as well as the Capacity Requirement Planning (CRP) method (not a rough cut). Their satisfaction was measured on a 5-point Likert scale. The highest degree of satisfaction out of the three RCCP techniques was associated with the CPOF (3.32/5). The study also found that in general, satisfied users base the parameter determination on objective calculations rather than on subjective intuition.[5] The satisfaction with CPOF maybe related to the simplicity of the technique, but none the less people prefer the results based on calculations and historical data.

Companies that are currently relying on the CPOF technique stand to benefit from a simple, automated, rough cut analysis that provides a method to calculate desired parameters, as well as pull information from historical data.

Software Features to Include

Several articles have touched on the issue of features that should be available in a RCCP software tool. An important function for the tool would be to level load capacity and conduct "what if" analysis. In order to be able to schedule work backwards lead time of the end item as well as components must be taken into account. For example scheduling the production backwards (into a period with excess capacity) may result in an infeasible schedule because the lead time on the components are in excess of available time. An important aspect of the tool should be to create a feasible schedule more importantly that an optimized one, if there is such a thing.

Creation of a computer software purporting to give the optimized answer is unrealistic and should be out of scope for this project. Instead the software should act as an aid to the planner, providing possible alternatives with a feasible schedule in every case. The software should allow the user to override the computer-suggested feasible schedule when ever he or she wants to. The user can thus apply his or her knowledge of external factors to the schedule, making it even more realistic.[11]

Short Comings of Current RCCP Software

The short comings of current RCCP methodology and tools according to [4] are the lack of ability to allow the quick evaluation of many alternatives. Because of the volume of data and amount of number crunching required to do RCCP calculations the process takes time and makes it difficult to perform "what if" analysis of different alternatives. A possible solution could be to develop a new technique that can evaluate improvements without redoing the calculations, then when a possible solution is chosen, it should be put through the RCCP calculations to make sure it is feasible.

Design

Define Inputs and Outputs

Inputs

The first step of creating a Rough Cut Capacity Planning tool (RCCP) was to define my inputs and desired output. The input data can be broken down into three tables. The Orders, Routing file, and Machine tables. Based on the information provide in these three data sets I would create the logic and algorithm of calculating the current profile load.

The Orders table contains information about a unique order detailing what products were ordered, the quantity, due date, and whether the order should be prioritized. The priority of the order is determined by external factors and can be edited at the planner's discretion. A sample order table is given below in Table 1.

Order Number	Product	Qty	Due Date	Priority
N1	X007	1	2/18/2010	☐
N10	X007	3	1/18/2010	☐
N11	V003	2	1/8/2010	☐
N12	K001	2	1/1/2010	☑
N13	X007	3	12/23/2009	☐
N14	V003	2	12/14/2009	☐

Table 1: Sample ORDER Table

The order number column contains a number or text that uniquely identifies an order. The Product column shows what product needs to be produced in order to fulfill the order. The "qty" column specifies the quantity of the product ordered. The due date column gives the due date of the order. The Priority column establishes whether or not priority should be given to the particular order, this is incorporated into the system at the users discretion.

The Routing table breaks down a product by work centers (machines), specifies the product breakdown structure and gives the estimated run time at each work center. A sample routing file is given below in Table 2.

Product	Process #	Machine ID	Run Time (Hours)	Process Level
X007	1	M1	5	2
X007	2	M5	3	2
X007	3	M2	4	1
V003	1	M1	5	3
V003	2	M5	6	2
V003	3	M3	3	1

Table 2: Sample ROUTING Table

The product column is used to relate the information contained in the routing file to a particular product found in the Orders table. The process number column is used to uniquely identify each process in the build of the given product. The machine id (work center) column relates the particular product to the Machines table. The run time gives the standard hours required at the given work center. The process level column is used to let the system know if jobs can be run in parallel.

Product	Process #	Machine ID	Run Time (Hours)	Process Level
X007	6	Machine3	10	1
X007	5	Machine4	10	1
X007	4	Machine1	10	2
X007	3	Machine2	10	2
X007	2	Machine1	10	2
X007	1	Machine2	10	3
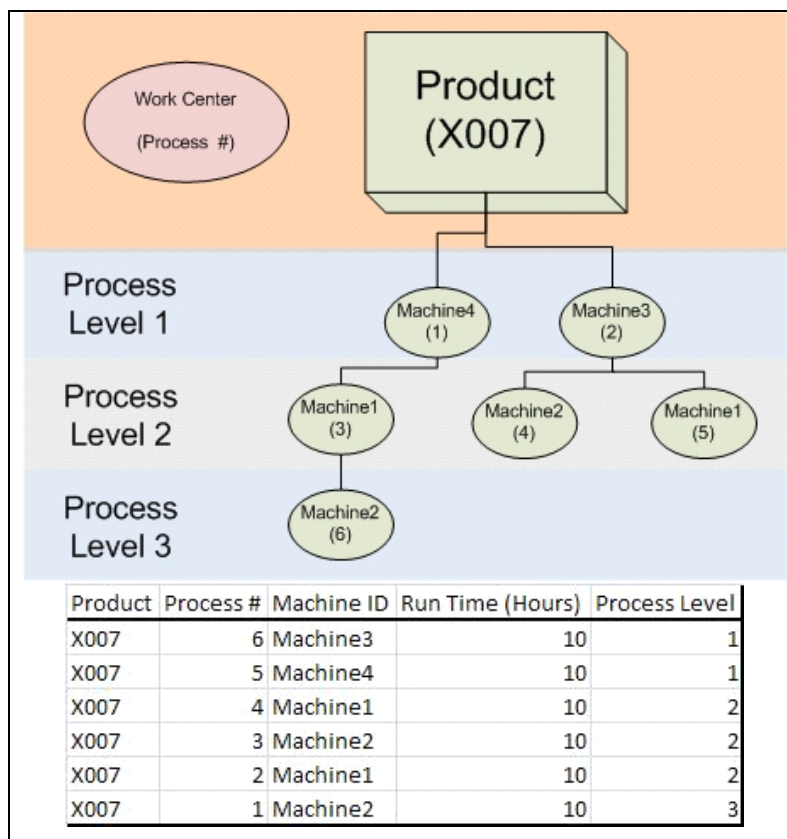
Table 3: Proper setup of a ROUTING table

For more information on how the contents of a routing file relate to the product process structure please look at the Table 3.

The Machine table contains information about the machines (work center), whether or not the work center is critical, the demonstrated capacity, max capacity, and the cost associated with exceeding the demonstrated capacity. A sample machine table is given below in Table 4.

Machine ID	Critical WC	Station	Demonstrat	Max Capacit	Cost of Exce
M1	☑	Welding	35	40	11.1
M2	☑	Milling	15	20	21
M3	☐	Lathe	20	30	7.45

Table 4: Sample MACHINE table

The machine id (work center) is used to identify the unique work center and relate it to the routing table. The 'critical wc' column determines if a work center is critical (bottleneck). The station column provides a description of the work center. The demonstrated capacity column gives the weekly demonstrated capacity in standard hours for the particular work center. The max capacity column gives the weekly maximum capacity in standard hours for the particular work center. The cost of exceeding DC column specifies the cost associated with exceeding the demonstrated capacity up to the maximum capacity of that work center.

Outputs

The desired system output is to generate a table that can be turned into a graph containing information about the total run time required by a work center for a given period, as well as the maximum and demonstrated capacities for that work center. The demonstrated capacity is the amount of standard labor hours the work center is capable of handling. The maximum capacity is maximum feasible standard hours that can be achieved on a work center, given that overtime is used to increase capacity. A visual representation of the desired output can be seen below in Figure 2.
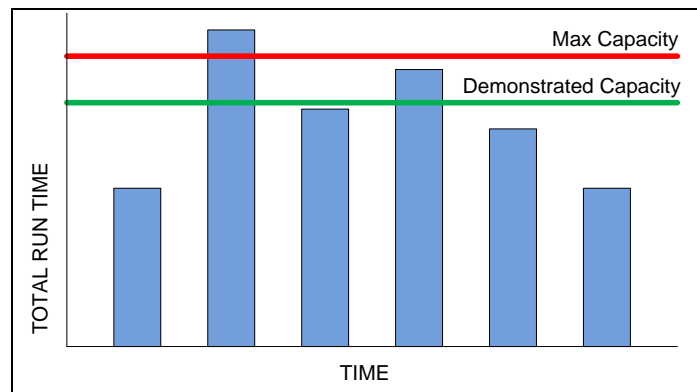
Figure 2: Desired system output

Based on this information the system will be able to perform all its desired functions.

Determine Basic Design

Program Selection

Based on the wide availability of Microsoft Access I chose to use the database software as the basis of my tool. Access offers various tools that I would need to create a successful decision support system. The relational database is useful for storing information about the orders, routing file, and machines. The software also offers the development of a unique graphical user interface. These traits coupled with the ability to use visual basic for applications with in the software makes it an ideal chose for this project.

Program Capability

To increase the usefulness and power of the RCCP tool it will contain two well developed features. First, I've chosen to model the algorithm using a resource profile approach. By taking lead time into account the information provided by the software will be more detailed and accurate, this should make the tool a useful part of the MPS process. Second, in order to help the master scheduler and facilitate the creation of a master schedule, the proposed decision support system will have an algorithm that will try to level load the profile, if in fact the total run time exceeds the demonstrated capacity. The system will attempt to schedule work early one week, and if the amount of work that could be scheduled early is inadequate the system will proceed to schedule work late one week. If the user specified that a certain job is critical, the system will not attempt to schedule that job late.

Logic used

Profile Load Logic

Desired Information

I began the creation of the software by looking at the end result that I would like to see. In order to develop a chart such as the one portrayed in Figure 2, I would need to create a query or table with five attributes. The first attribute is the period, which will be depended on what period level the user specifies (month or week) as well as how far into the future the user would

like to look (quarter or half year). The second attribute is the total run time in standard hours required by the critical work center. The third and fourth attributes are the demonstrated and maximum capacities for the critical work center, respectively. These two attributes are determined by the user specified period level. The fifth and final attribute will specify the critical work center in question. A sample of such information is given below in Table 5, please note that in this case information is given at a weekly period level.

Week	Total Run Time	Demonstrated Capacity	Max Capacit	Machine ID

Table 5: Attributes needed for a profile load

The decision support system only needs to look at the critical work centers because they will determine the throughput of the entire system. In a sense the manufacturing system will only be as strong as its weakest link (bottleneck). For simplicity in my design I chose to compute the information by month and week separately and display the information to the user upon request.

Hours by Order/Product/Process

The first step involved to achieving my desired output is to determine the amount of work that has to be done. By linking the Orders table with the Routing file (table) the system is able to output information about every process that needs to be ran in order to fill the orders. To account for the fact that different work centers may have different amounts of standard hours available weekly, I converted the required run time of a process from standard hours to number of weeks needed to complete the process. If a process requires ten standard hours to run and the demonstrated capacity of that machine is 40, then the process will take .25 weeks.

Cumulative Time by Product

Based on the information provided in the previous step, the system will proceed to sum up the required run time (now given in weeks) and compute the cumulative times for the completion of each product given the information contained in the Routing table. If two or more process can be ran at the same time the system will take the longest run time for that process level and use that number for computing the total run time for the product. Using this approach the system can account for processes that have to be run in parallel.

Process Start Dates

One of the major assumptions made by this software is that the products are going to be scheduled for production so that the product is finished on the due date. Calculating the start time

for all the process becomes very simple. By converting the cumulative week run time to days and subtracting it from the due date the system is able to compute the start dates. This is a very important assumption that the processes are all running perfectly in a truly lean system. To make the system more realistic given real world delays, the planner can increase the run times on the work centers to have the processes start earlier. By doing this the planner can guarantee that the products are still manufactured on time.

Convert Date to Week

Now that the system has a specific date associated with the start of each process the next step is to convert the date either to week or month depending on user specification. If week is selected than the system will output the Monday of that week, if month is selected than the first day of that month is displayed.

Standard Hours by Critical Work Center

At this point every process has an associated work center along with an expected date that the work is to be scheduled to start and the duration of the process given in standard hours. The next step is to link this information to the list of critical work centers which are selected by the user in the Machine Table. After this it's a simple process of summing up the total run time in standard hours for the given work center. The demonstrated and maximum capacity information is also pulled from the Machines table and all the needed information for the desired output is present in one table. A sample of the output is given below in Table 6.

Week	Total Run Time	Demonstrated Capacity	Max Capacit	Machine ID
11/23/2009	0	35	40	M1
11/30/2009	10	35	40	M1
12/7/2009	36	35	40	M1
12/14/2009	15	35	40	M1
12/21/2009	16	35	40	M1

Table 6: Sample query used to generate a profile load

Display Info

For the final step of generating a profile load the information is passed into a pivot chart and a graph is generated. A sample profile load generated by the program can be seen below in Figure 3.
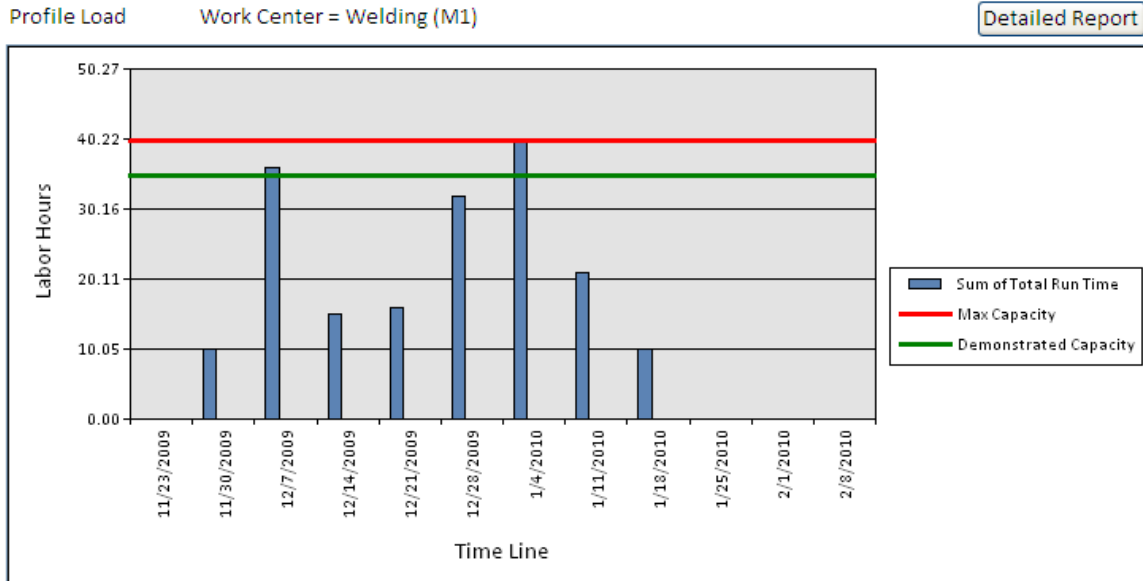
Figure 3: Profile load output

Level Load Logic

Critical and Non-Critical Jobs

Critical

If the job is flagged a critical, the system follows a basic rule of trying to move work early if possible. If a job was flagged as critical by the user the system will give priority of moving that job over a non-critical job. Critical jobs may only be rescheduled to earlier dates. If several jobs are flagged as critical the system will process the larger job first, if possible.

Non-Critical

In the non-critical case, after the critical jobs are evaluated by the system, the non-critical jobs will try to be rescheduled to an earlier date, with priority given to larger jobs. After the first iteration, the system will proceed to look at the possibility of rescheduling jobs to a later date.

Available Capacity

The first step in figuring out what jobs should be rescheduled in order to meet the demonstrated capacity is to figure out how many standard hours is the total time run time exceeding the demonstrated capacity (overtime). The system will also check the available capacity of the work center both one week earlier and one week later. Based on these values the support system will make a preliminary guess as to what the most likely solution will be, if the jobs should be scheduled early or late.

Lack of Capacity

Ideally the system would reschedule the work so as to decrease any overtime to zero, so the demonstrated capacity matches that of the required run time for the given period. A main assumption of this program is that the jobs cannot be broken down. Because of this, certain situations arise in which the amount of work that is exceeding the demonstrated capacity (the amount desired to be rescheduled) is less than the size of the smallest job (the actual amount that can be moved). In this situation the system will perform a another iteration this time looking at the size of jobs that can be moved and the amount of space available at the period we would like to move the work to. If in fact it is possible to move more work than the overtime amount, the system will move the least amount of work possible.

Rerun Profile Load Given Update

Once the system generates a list of jobs that should be rescheduled as early or late, the system will then artificially edit the due dates of the effected orders to one week early or late. The system will proceed to rerun the profile load given the changed dates. Using the exact same algorithm as mentioned in the profile load section. Once a level load analysis is run, access to the level load analysis is blocked off by the system. This is done to prevent reiteration of the level load analysis. Otherwise the system will start rescheduling work more than one week early or late, and there are no provisions to keep track of such information. In order be able to run the analysis again the user has to run the profile load which will reset all the information within the system.

Assumptions

There various assumptions that were made during the creation of this tool, some of which are mentioned through out the design section of this report.

- To simplify the model, I assumed that jobs could not get split.
- The RCCP analysis is only done on critical work centers
- Critical jobs cannot be rescheduled to a later date.
- The level load analysis can only look at rescheduling work either one week early or late.
- Critical jobs are given priority.
- Secondary priority is determined by the size of the job. Larger jobs have higher priority
- The level load analysis is performed at a weekly level, even though the results are applied to a monthly period level.

Project Development

User Interface

Upon opening the access database the user will be presented with the main dialog box from which all functions of the software maybe accessed. A screenshot of the main menu can be seen below in Figure 4.
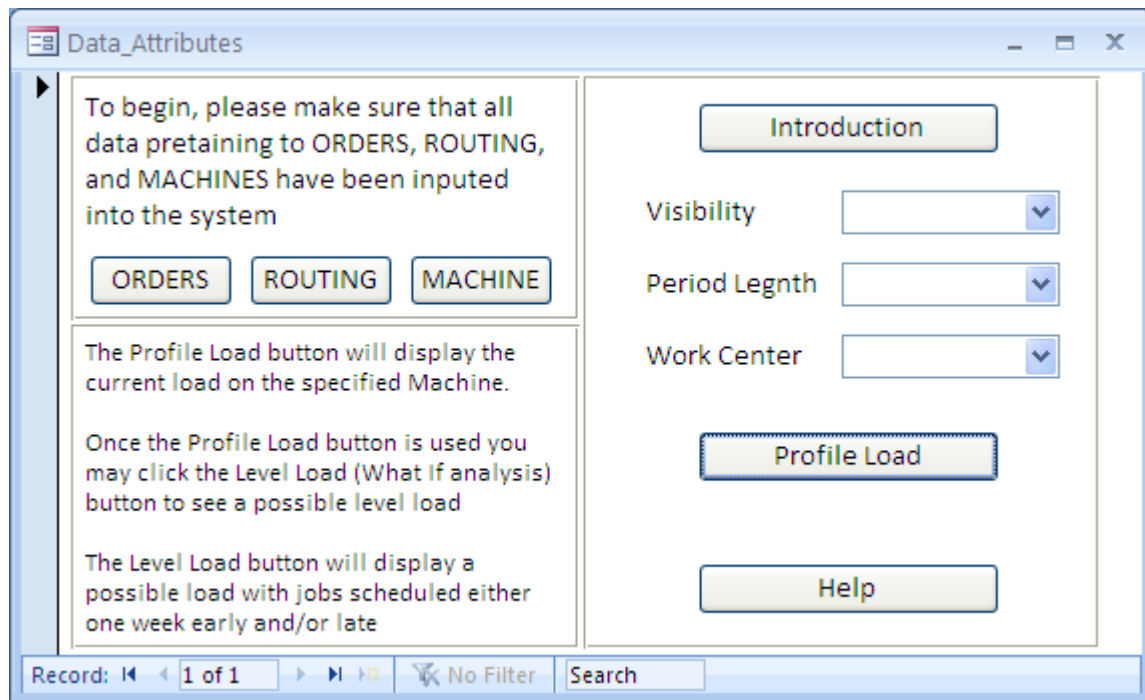
Figure 4: Main menu dialog box

From this menu the user can input the order, machine and routing information directly into the database. For examples of these tables please refer to Table 1, Table 4, and Table 2, respectively.

The main purpose of this software is to assist the master scheduler with the process of RCCP, and it enables the planner to see a graphical representation of the profile load, a detailed report and perform what if analysis of a possible level loaded profile. This is explained in the introduction form of the database.
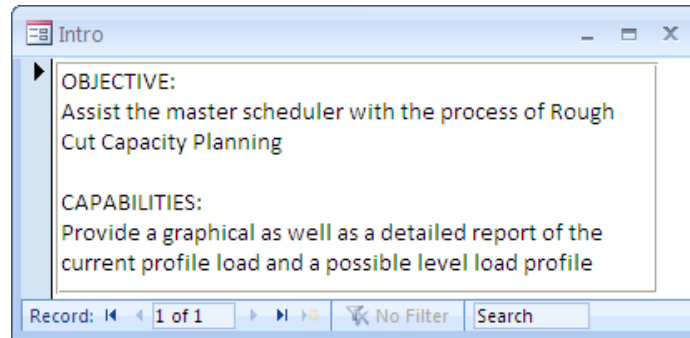
Figure 5: Introduction to the tool

If the user requires help they may look to the help section for information on how to properly input the data into the system. Please refer to Figure 6 for a screenshot of the help menu.
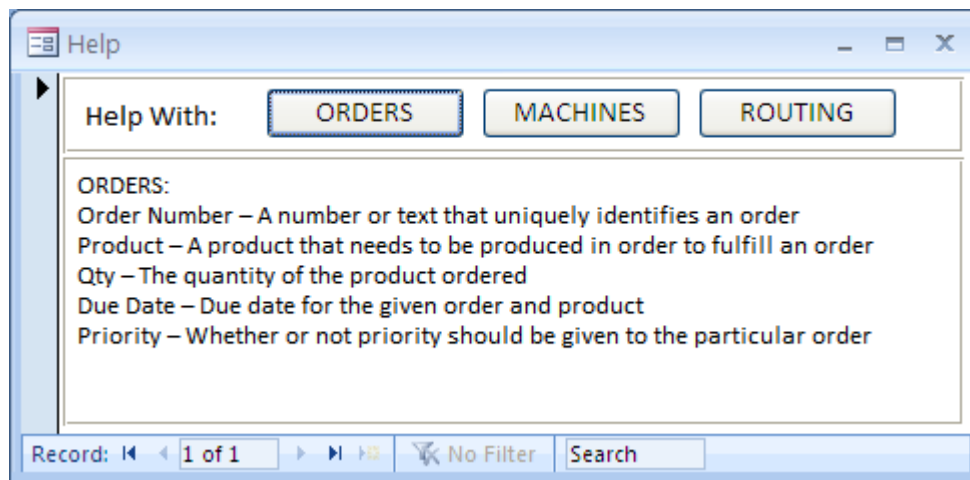
Figure 6: Help menu

Once the data has been correctly inputted into the system the user is able to select how far into the future should the load profile cover (visibility). Also, the user can select at what period levels should the data be broken up (month or week) as well as the critical work center in question. Next the user may generate a profile load to see how the work will be distributed among the work centers. For an example of a profile load please refer to Figure 3. From the profile load output the user may request to see a detailed report of the current load. The report also contains information about the costs associated with exceeding the demonstrated capacity. This calculation is based on the number of standard hours of overtime multiplied by the costs of exceeding the demonstrated capacity, which are stored in the machines table. An example of a detailed report for a profile load is given below in Figure 7.

Final Report for Work Center M1

All units given in std. hours per week

Week of	Required Run Time	Demonstrated Capacity	Max Capacity	Excess Capacity	Overtime Capacity	Overtime Cost	Infeasible
11/23/2009	0	35	40	35	0	0	0
11/30/2009	10	35	40	25	0	0	0
12/7/2009	36	35	40	0	1	11.1	0
12/14/2009	15	35	40	20	0	0	0

Figure 7: Profile load detailed report

Once the system has run a profile load, the user will be able to perform what if analysis and see a possible level loaded profile. Once again graphical representation is generated by the system, but in the case of a level load profile the system will provide information as to which orders and products need to be rescheduled in order to meet the demonstrated capacity.
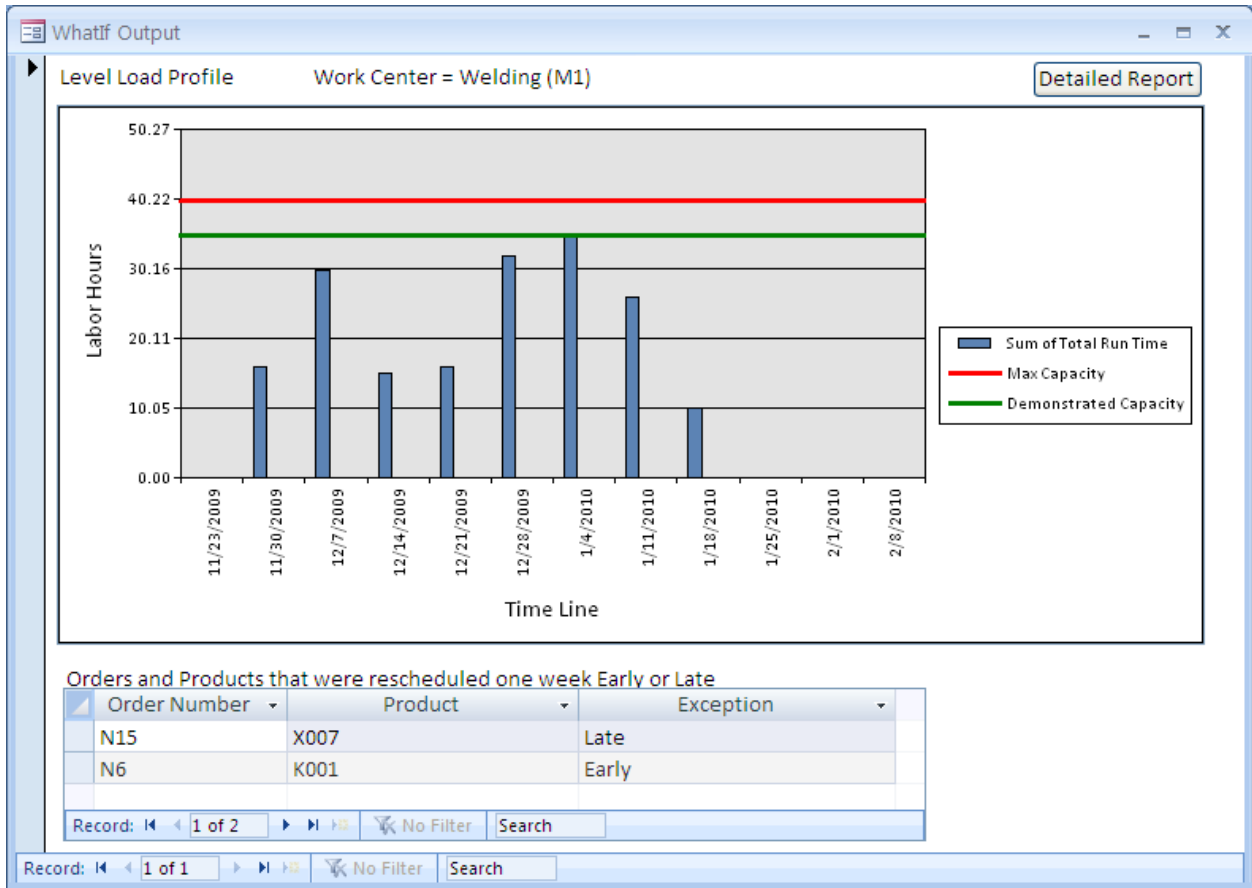
Figure 8: Level load output

If the user wants to see a detailed report of the level load profile they may call up the detailed report from the graphical output. The information contained in this detailed report is similar to that found in the detailed report for the profile load.

Using the information provided by the tool the planner is empowered to make quick decisions with respect to rescheduling work.

Methodology

To test the design and functionality of my program design I generated random data for the Orders, Machines, and Routing information. The simulated scenario consists of 21 orders for either one of three products. The first possible product of this simulation is X007 and needs to be put through three work centers in order to complete its production with two of the three processes running at the same time. The second possible product is K001and needs to be put through two work centers to complete its production. The third and final product is V003 and needs to be put through three work centers to complete its production. The possible work centers that are used in the simulation are designated as M1, M2, M3, M4, and M5. I randomly assigned due dates for the orders. The Order, Machine, and Routing tables are listed below in Tables 7, 8, and 9, respectively.

The validation of my project will be based upon a quantitative criteria of costs associated with overtime and the decrease of costs that result with rescheduling work based on the level loading analysis. I will proceed to run this simulation for three of the five work centers that I have deemed as critical.

Order Number	Product	Qty	Due Date	Priority
N1	X007	1	2/18/2010	☐
N10	X007	3	1/18/2010	☐
N11	V003	2	1/8/2010	☐
N12	K001	2	1/1/2010	☑
N13	X007	3	12/23/2009	☐
N14	V003	2	12/14/2009	☐
N15	X007	1	1/11/2010	☐
N16	V003	2	1/27/2010	☐
N17	X007	2	12/31/2009	☐
N18	K001	2	1/1/2010	☐
N19	K001	3	1/15/2010	☐
N2	V003	2	11/28/2009	☐
N2	X007	1	11/10/2009	☐
N20	V003	2	1/19/2010	☑
N21	X007	3	12/21/2009	☐
N3	K001	2	12/28/2009	☐
N4	X007	2	1/8/2010	☐
N5	V003	2	1/15/2010	☐
N6	K001	2	12/11/2009	☐
N7	X007	3	12/17/2009	☑
N8	K001	4	1/18/2010	☐

Table 7: Full simulated ORDERS table

Machine ID	Critical WC	Station	Demonstrat	Max Capacit	Cost of Exce
M1	☑	Welding	35	40	11.1
M2	☑	Milling	15	20	21
M3	☐	Lathe	20	30	7.45
M4	☐	Packaging	30	45	54.2
M5	☑	Saw	15	20	32

Table 8: Full simulated MACHINE table

Product	Process #	Machine ID	Run Time (Hours)	Process Le
K001	1	M1	3	2
K001	2	M4	4	1
V003	1	M1	5	3
V003	2	M5	6	2
V003	3	M3	3	1
X007	1	M1	5	2
X007	2	M5	3	2
X007	3	M2	4	1

Table 9: Full simulated ROUTING table

Results

Under my first simulation for work center M1, at a weekly period level, and looking one quarter into the future. The system shows that under the current load there will be overtime costs. Given the costs of exceeding the demonstrated capacity that I have inputted into the system, there will be an additional cost of $66.6 associated with overtime. Please refer to Table 10 for more information.

Final Report for Work Center M1
All units given in std. hours per week

Week of	Required Run Time	Demonstrated Capacity	Max Capacity	Excess Capacity	Overtime Capacity	Overtime Cost	Infeasible
11/23/2009	0	35	40	35	0	0	0
11/30/2009	10	35	40	25	0	0	0
12/7/2009	36	35	40	0	1	11.1	0
12/14/2009	15	35	40	20	0	0	0
12/21/2009	16	35	40	19	0	0	0
12/28/2009	32	35	40	3	0	0	0
1/4/2010	40	35	40	0	5	55.5	0
1/11/2010	21	35	40	14	0	0	0
1/18/2010	10	35	40	25	0	0	0
1/25/2010	0	35	40	35	0	0	0
2/1/2010	0	35	40	35	0	0	0
2/8/2010	0	35	40	35	0	0	0

Table 10: Profile load detailed report for work center M1

After running the level load analysis the system manages to reschedule work so there is no extra cost due to overtime. Saving the company the $66.6 that would have been lost given the basic profile load.

For the second simulation this time of work center M2, at a weekly period level, and looking one quarter into the future. The system shows that under the current load there will be overtime costs. Given the costs of exceeding the demonstrated capacity that I have inputted into the system, there will be an additional cost of $105 associated with overtime. Please refer to Table 11 for more information.

Final Report for Work Center M2

All units given in std. hours per week

Week of	Required Run Time	Demonstrated Capacity	Max Capacity	Excess Capacity	Overtime Capacity	Overtime Cost	Infeasible
11/23/2009	0	15	20	15	0	0	0
11/30/2009	0	15	20	15	0	0	0
12/7/2009	12	15	20	3	0	0	0
12/14/2009	24	15	20	0	5	105	4
12/21/2009	0	15	20	15	0	0	0
12/28/2009	8	15	20	7	0	0	0
1/4/2010	12	15	20	3	0	0	0
1/11/2010	12	15	20	3	0	0	0
1/18/2010	0	15	20	15	0	0	0
1/25/2010	0	15	20	15	0	0	0
2/1/2010	0	15	20	15	0	0	0
2/8/2010	0	15	20	15	0	0	0

Table 11: Profile load detailed report for work center M2

After running the level load analysis the system manages to reschedule work so there is no extra cost due to overtime. Saving the company the $105 that would have been lost given the basic profile load.

For the third simulation this time of work center M5, at a weekly period level, and looking one quarter into the future. The system shows that under the current load the schedule is infeasible. There are 14 standard hours that cannot be run on the M5 work center in the desired weeks. Please refer to Table 12 for more information.

Final Report for Work Center M5

All units given in std. hours per week

Week of	Required Run Time	Demonstrated Capacity	Max Capacity	Excess Capacity	Overtime Capacity	Overtime Cost	Infeasible
11/23/2009	0	15	20	15	0	0	0
11/30/2009	0	15	20	15	0	0	0
12/7/2009	30	15	20	0	5	160	10
12/14/2009	9	15	20	6	0	0	0
12/21/2009	6	15	20	9	0	0	0
12/28/2009	18	15	20	0	3	96	0
1/4/2010	24	15	20	0	5	160	4
1/11/2010	12	15	20	3	0	0	0
1/18/2010	12	15	20	3	0	0	0
1/25/2010	0	15	20	15	0	0	0
2/1/2010	0	15	20	15	0	0	0
2/8/2010	0	15	20	15	0	0	0

Table 12: Profile load detailed report for work center M5

After running the level load analysis the system manages to reschedule work and decrease the amount of infeasible hours from 14 to two. Even though, the system fails to provide a feasible solution it does give the planner a basis to continue rescheduling work to come to a feasible solution. Please refer to Table 13 for more information.

Final Report for Work Center M5

All units given in std. hours per week

Week of	Required Run Time	Demonstrated Capacity	Max Capacity	Excess Capacity	Overtime Capacity	Overtime Cost	Infeasible
11/23/2009	0	15	20	15	0	0	0
11/30/2009	9	15	20	6	0	0	0
12/7/2009	21	15	20	0	5	160	1
12/14/2009	9	15	20	6	0	0	0
12/21/2009	12	15	20	3	0	0	0
12/28/2009	12	15	20	3	0	0	0
1/4/2010	21	15	20	0	5	160	1
1/11/2010	15	15	20	0	0	0	0
1/18/2010	12	15	20	3	0	0	0
1/25/2010	0	15	20	15	0	0	0
2/1/2010	0	15	20	15	0	0	0
2/8/2010	0	15	20	15	0	0	0

Table 13: Level load profile detailed report for work center M5

Conclusion

Capacity management is an important aspect of optimizing production; by effectively managing capacity as compared to competitors a company will be able to remain profitable and successful. To facilitate the MPS process it is important to validate the feasibility of a master schedule, thus through the use of a RCCP tool the planner is able to reschedule work, add shifts and make sure that the master production schedule is feasible before putting it into an MRP system.

The RCCP tool detailed in this paper is a DSST that will serve as external software capable of providing necessary RCCP information. The system is not meant to find a final solution, but to act as a decision support system, and facilitate the efforts of the planner. In two out of the three simulated cases the system found an ideal solution but had only a partial solution for the third case. In all three cases the tool managed to lead the planner in the right direction of either decreasing the infeasible hours or overtime. The RCCP tool has several applications where it can be used as an offline tool by master schedulers in their process of creating a feasible MPS.

Future Work

Possible additions to the software include expansion of the level load analysis to include evaluation of shuffling jobs more than one week earlier or later. Under the current system situations arise where the tool fails to perform adequately by not shuffling jobs two or more weeks backwards or forwards.

The system also fails to reschedule partial work. The tool will only reschedule full jobs, an assumption that is not realistic given real world environment.

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