



WPI

Capacity Planning Tool for Suppliers of Caterpillar

A Major Qualifying Project Report
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Degree of Bachelor of Science By:

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In collaboration with
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Abstract

Currently Caterpillar (CAT) has many manufacturing suppliers. The suppliers who provide light fabrication need more convenient software for capacity planning, as light fabrication has many more processes and is more difficult to plan effectively than heavy fabrication. To develop this tool, one needs to figure out the logic and principles of the capacity planning process, specify CAT's requirements and polish the look and feel of the interfaces to make it easy for suppliers to operate this capacity planning tool. We also took the perspective of the suppliers to design the interface. According to the feedback of our co-advisor and the manager in charge of our project at CAT, our tool achieves the desired functions very well, and it is useful for suppliers.

Acknowledgements

First of all, we have to say thank you to Professor Rong. He is not only an advisor, a teacher, but also a friend. Thanks for his generous accommodation in Shanghai. Thanks for his patient guidance supporting our work through the project. Thanks for his critical comments and recommendations during our presentations. Thanks for his advice in dealing with other people and the attitude toward the world.

We would also have to give our thanks to Professor He, a very kind and learned advisor. He not only provided us a comfortable work place, but also tried his best to solve all the problems we came across during the project. Thanks for his arrangement of our visit in Wuhan Heavy Machine Group.

Of course, the project could not have been completed without the help of Caterpillar employees. They are Daniel Miao, Scott Panse, Misty Yang, Paul Watts. Special thanks to, Daniel Miao who gave us outright advice and necessary information about the project and his dedication to the project moved us to work hard to finish the project. Thanks to the warm welcome and reception of Scott Panse, Misty Yang's help, and Paul Watts for the reimbursement of our trips.

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1. Background

1.1. Caterpillar Inc.

Caterpillar Inc. was founded in 1925 and its headquarters are located in Illinois in the United States. It is the largest manufacturer of construction and mining equipment, diesel and natural gas engines and industrial gas turbines in the world. In the last eighty years, Caterpillar has built a global infrastructure and cooperated with agents all over the world. Caterpillar is managed following the six-sigma method.

As the industry leader, Caterpillar will face more and more tough problems as time goes by, and management should be well prepared to address the problems that emerge. Agents of Caterpillar are present in over 200 countries in the world where they supply equipment, service, and financial business for their customers. In addition, 1500 branches all over the world provide rental service.

Caterpillar regards honesty as a guiding principle for their company. As the industry leader, they know that they shoulder the compelling obligation to rebuild the positive image of American company.

1.2. Current situations and problems

Currently, there are two kinds of fabrication suppliers for Caterpillar: light fabrication and heavy fabrication. The light fabrication planning has more processes and is more complex than the planning of heavy fabrication. What's more, the capacity planning of light fabrication needs a high asset base. Because of its low efficiency, light fabrication can be considered a waste of resource. Accordingly, our major work focuses on the capacity of light fabrication. Before our project, there was no effective capacity planning tools for most of the suppliers

that could enable them to calculate capacity and working hours. In the absence of capacity planning tools, suppliers risk being either under or over capacity. Our goal is to develop software that will help suppliers conduct some capacity planning and decide whether they can meet the demand of Caterpillar and other customers.

1.3. Current method of capacity planning

Prior to our project, Excel software was used as the main method of capacity planning. Even though it could fulfill the task to some extent, its result was not thoroughly satisfying.

First of all, this method did not provide a friendly interface for the users. The users had to input the fabrication data without any guide.

Second, the fabrication information was not encapsulated. It was possible for the Excel file to get into other people's hand by accident or intentionally. In order to keep this capacity planning information private, some mechanism should be in place to restrict access to the information to authorized parties, by, for instance, requiring users to confirm their identity by using their name and password.

Third, the data maintenance of this method was not convenient. For example, if the user wanted to delete a record of a fabrication, he/she needed to delete every piece of the fabrication. Conversely, should the supply and demand information remain the same, the user had to input the same data many times. The new tool we created can have the data well encapsulated in the database, which will reduce a lot of tedious work for the user.

1.4. About capacity planning

Capacity planning is the process of determining the production capacity needed by an organization to meet changing demands for its products. In the context of capacity planning, "design capacity" is the maximum amount of work that an organization is capable of completing in a given period, "effective capacity" is the maximum amount of work that an organization is capable of completing in a given period due to constraints such as quality problems, delays, material handling, etc.

A discrepancy between the capacity of an organization and the demands of its customers results in inefficiency, either in under-utilized resources or unfulfilled customer orders. The goal of capacity planning is to minimize this discrepancy. Demand for an organization's capacity varies based on changes in production output, such as increasing or decreasing the production quantity of an existing product, or manufacturing new products. Better utilization of existing capacity can be accomplished through improvements in overall equipment effectiveness. Capacity can be increased by introducing new techniques, equipment and materials, increasing the number of workers or machines, increasing the number of shifts, or acquiring additional production facilities.

2. Methodology

During the seven-week project, our team developed a general methodology for our approach to developing the capacity planning tool for Caterpillar's suppliers. We have the original tool Caterpillar has been using for capacity planning, but there are several remarkable defects with this tool. Our efforts centered on addressing the major issues of this capacity planning tool, the Excel form, by:

1. Figuring out Caterpillar's expectations;
2. Refining our logic work through several ways;
3. Specifying our project objectives into concrete tasks:

These objectives entail the following:

1. The capacity planning tool must be more efficient than Excel both in how time-consuming and labor-intensive it is;
2. It should contain the major input information necessary to plan the suppliers' capacity;
3. The inner calculating formulation should be reliable and in accord with the capacity planning process;
4. All the input information should be clear and easy to comprehend, instead of being ambiguous.
5. It should consider the events that cost most of the processing time.
6. It should be explicit for suppliers to use, and the interface should be user friendly;
7. It is expected to generate a histogram to compare the total demand for working hours from all the customers and the total available machine working time of suppliers;

8. Customers are capable to view several years' demand and supply of working hours to manage their supply chain;

To develop this capacity planning tool, that is the software to replace the Excel form used for capacity planning, we should considering the current method. The team refined the logic work based on several proposals through contact with both staff at Caterpillar and our project advisor to develop a reasonable scheme which ensures the reliability and efficiency of the tool.

The software we designed is a capacity planning tool that can show a clear graph of the capacity of suppliers and the demand of both CAT and other customers, while suggesting adjustments to fully utilize the supplier's assets and ensure work does not exceed their maximum capability. During the seven weeks of the Major Qualifying Project, we designed a tool that can achieve the expected functions and submitted it to our CAT co-advisor, Mr. Suzhou, for his approval.

This tool is a platform for all the suppliers to use. This standardization allows CAT to compare suppliers, thus better managing its supply chain. The capacity planning tool will also present components that need special manufacturing processes.

Though we figured out the rough capacity planning process, some concerns remained.

The main issue is that we calculate the difference between the total capacity of suppliers and the capacity used by their other customers to get the available time available for CAT. However, this means CAT's needs will not be met first, and be instead the last. The parameters to compare are the available working time for CAT and the needed time for CAT's order. In the refined logic work, we obtain the total demand of processing time by adding the other customers' needs to the needs of CAT, and compare the total demand with the maximum capacity of each supplier. This way, suppliers can get a clear picture whether they can meet all the customers' need under the current work pattern.

The following flow path (figure 2) represents the refined logic work.

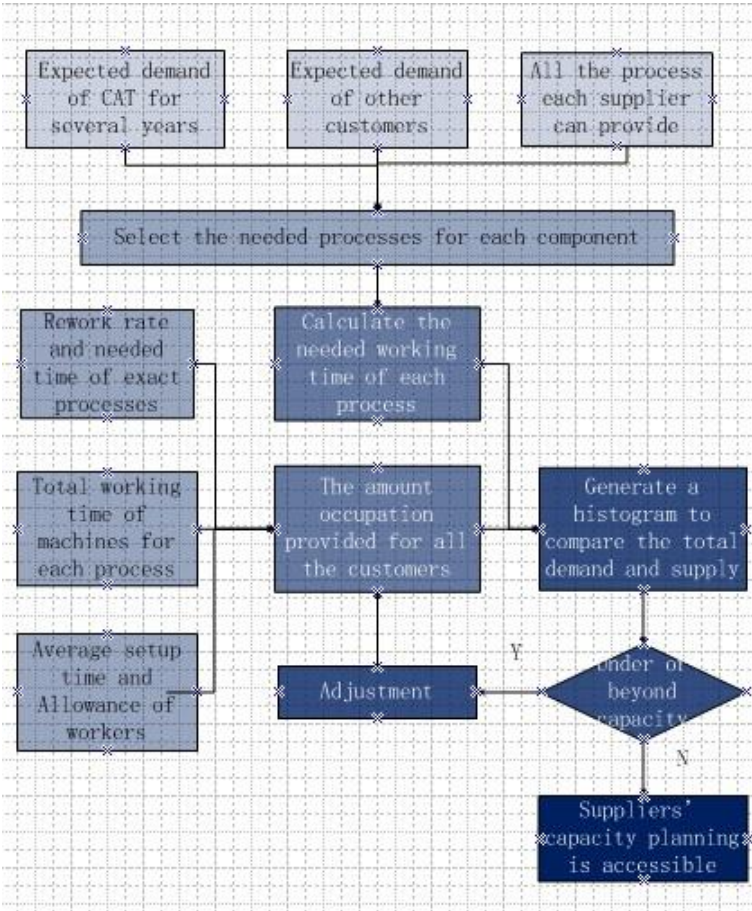


Figure 2-1 Refined Logic Work

Once the project logic work was refined, the team presented its work to both our advisor and Caterpillar staff. Meanwhile, our team developed the prototype of the planning tool with Visual Basic language. With a much clearer logic work of the project, the prototype was developed. Then the interfaces of the tool were presented to sponsors to make sure that the icons we used were indispensable and meaningful. Our sponsors also tested whether the capacity planning application worked to appraise the success of our project.

3. Procedure

In order to achieve the objectives of the project and develop a capacity planning tool that is useful for suppliers to improve capacity planning, our project has gone through a series of procedures, which were somewhat tough. Here, we summarize them into the following five procedures and also detail them.

1. Feedback about our preparing logic work,
2. Initial design of the logic flow path and the interfaces,
3. Refined logic work and the renewed flow path,
4. Useful suggestions given by Professor Rong and our sponsor,
5. Prototype of the software.

Following are the detailed procedures of our project, in the form of a Gantt chart.

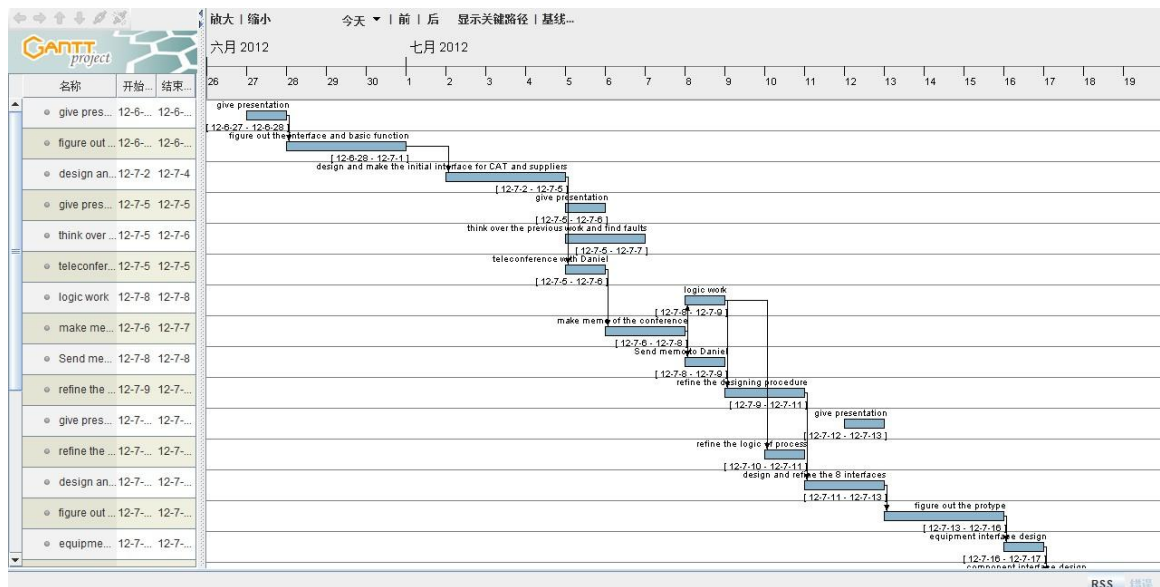


Figure 3-0-1 Gantt Chart 1

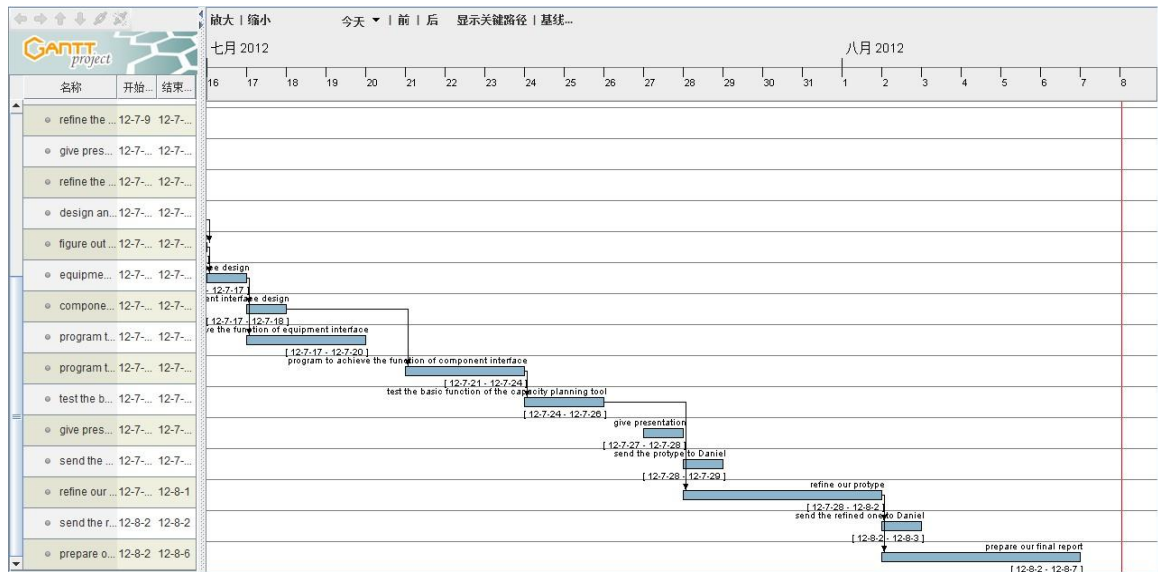


Figure 3-0-2 Gantt Chart 2

3.1. PQP review

3.1.1. General understanding of the project

According to the project charter, the first thing we did was to search for information about capacity. Because only one member of our team majored in Industrial Engineering, which is related to this project, most of us found it hard to understand the abstract concepts. So, this was initially a tough proceeding.

We made good use of the Internet and the library, through which we searched a lot of books and articles. This enabled us to gain a better understanding of concepts such as capacity, capacity planning, rework and so on.

At the same time, we tried to investigate the tasks given by the company. The final goal is to develop a tool to help suppliers make better capacity planning. But before we achieved this goal, we needed to make a detailed logic path.

3.1.2. Definition of the problem and objectives

One of the most important things in the first several weeks was to define the problem and objectives of the project. Using the project charter, related material and information from our sponsor, we made a detailed definition of both of them.

A. Problem

Caterpillar has two kinds of fabrication suppliers: heavy fabrication and light fabrication. Heavy fabrication is considered to be less complex than light and is easier to plan for capacity. Conversely, light fabrication has many more processes and is difficult to plan effectively. In addition to this, light fabrication has a higher capital asset base and it is important that these assets are used to their maximum potential.

The problem is that there are no suitable tools for suppliers to calculate capacity. That is, suppliers could not exactly know whether they would be able to meet Caterpillar's demand. Also, the necessary hours could not be estimated effectively.

B. Objectives

The final goal of our project was to develop a capacity planning tool to help suppliers see if they have ability to produce enough parts to meet Caterpillar's standard or ongoing demand. This is necessary to guarantee that suppliers can provide enough parts to Caterpillar to keep the production line running. At the same time, it enables suppliers' assets to be fully utilized and avoid exceeded their maximum production capability.

In order to achieve the final goal, we had to achieve the following several sub-objectives:

- a. Design a detailed logic flow path of capacity planning, including:
 - input information and data
 - output information and data
 - how the working hours are counted up

- how the capacity is calculated (formula)
 - how the result is displayed (data report and histogram)
- b. The software should include enough information and factors that may affect the result of capacity planning.
 - c. The working hours should be counted up effectively and the capacity should be calculated correctly. That means the inner formulas must be reliable.
 - d. The software should contain explicit information for suppliers to input, and output the information and data suppliers really want.
 - e. User friendly interfaces should be displayed and easy to understand.

3.1.3. Feedback by our sponsor

We sorted up our initial material and our understanding of the project and sent them to our sponsor. We were very glad to receive his reply, which was quite useful to our project.

Our sponsor showed his recognition of our work and gave us further information, especially about the processes of capacity planning. He presented it into three steps, which are explained in the part “Methodology”.

In addition to this, our sponsor sent us an Excel form, detailed below. The first table shows the parts information, including part number, part name, picture, working hours and demand quantity. The second table includes the process information. For each process, current machine time means working hours available, and requirement means working hours needed by Caterpillar Suzhou Co., Ltd and the other customers. Action means the measures needed to be taken to improve capacity planning.







序号	P/N	description	Picture	Module	工时 (mins/pec)							2012平均月需求	2013平均月需求	
					拉伸	激光	平塔冲	折弯	焊接	机器人	磷化			电泳
1	3291690	Rare fender		966/972H		18	26	10	100	5	5	12	102	81.6
2	3291691	Rare fender												
3	2324638	Rare fender												
4	2324639	Rare fender												
5	3238367	Battery Box												
6	3327262	Battery Box												

Figure 3-1-1 Current capacity planning tool (Excel)-1

Equipment with shift	Current machine time h/month	2012 other customer requirement h/month	2012 CSCL requirement h/month	Total machine burden (h/month)	2012 shortage of capacity h/month	Action
拉伸/1						
平面激光/2						
塔冲/2						
折弯/2						
焊接/19						
磷化/1						
电泳/1						
喷漆/3						

Figure 3-1-2 Current capacity planning tool (Excel)-2

It was a simple capacity planning tool used by most suppliers to analyze capacity. It could realize the basic functions, but was not convenient and user-friendly. These weaknesses suggested that we should use Visual Basic to develop this tool.

3.1.4. The executive plans

To finish a project, the most important thing is to make a clear and effective plan, including the personnel assignment.

Considering the tasks and our members' majors, we divided our members into two groups. Two members in our team were in charge of the logic work including the design of the flow path and the analysis of the data flow. Other two members were in charge of the realization of the software, which had much connection with programming.

Following are the executive plans we made about our project:

Weeks 1-2:

- a. Survey the company, collect the required information, and define the tasks more clearly.
- b. Figure out the structure of the interface and its basic function.

Weeks 3-4:

- a. Deal with the parts information and Caterpillar's demand.
- b. Develop the interface of Equipment Information.

Weeks 5-6:

- a. Build the interface of Demand Information.
- b. Debug the software, and get feedback from both Caterpillar and suppliers to improve it.

Week 7:

Sort out the material and prepare for the final report and presentation.

3.2. Feedback about our preparing work

3.2.1. The visit to the company

On June 26th, we paid the first visit to Caterpillar Suzhou Co., Ltd. One aim of the visit was to have a better knowledge of this company. So, we watched a video first and then visited the workshop. After this, our team was impressed by this company.

Caterpillar is a company which produces earthmoving machinery and construction machinery. Most of the work is about fabrication, while the parts are mainly produced by suppliers. So it is no surprise Caterpillar has a lot of suppliers. That is why suppliers need a tool

to help them with capacity planning. This tool is necessary, which means that our project work is valuable and meaningful.

Unfortunately, we did not have a chance to visit any suppliers, because our project aims to address the needs of Caterpillar's suppliers. If we had paid a visit to the suppliers, I think we would have a better understanding of the processes and capacity planning.

3.2.2. Discussion with engineers of the company

We gave a presentation to the engineers of the company about our project progress. Although our sponsor was not there that day, other engineers and Professor Rong gave us many valuable suggestions. These suggestions are detailed below.

- a. Narrow down to one or two supplier, and only focus on the light parts. So that the tool can be a general and unified platform. Because we focus on the common characters of suppliers. The one or two supplier is a typical representative, which contains the common characters. So that we call it a general and unified.
- b. Know about the data transformation, for example, how to get the net working hours by using other data.
- c. Understand how the data are updated.
- d. Take reworked job into account as it is an important factor that affects the capacity planning.
- e. Take safety stock into account.

One of the biggest differences between our project and the other two projects is that the summer project contains three projects. Two of them are for Caterpillar, the rest one is for a company in Wuhan. Project 1 is to design an educational robot for a Wuhan company. Project 2 is our capacity planning tool project, and project 3 is to design push block for Caterpillar as well. So everything should serve for the requirements of the company and

suppliers. Additionally, we should take the demand of the company as our project’s starting point.

3.3. Initial design

3.3.1. Initial design of the flow path of capacity planning

According to the feedback by our sponsor and suggestions by Professor Rong, we made an initial flow path of the capacity planning process, as follows.

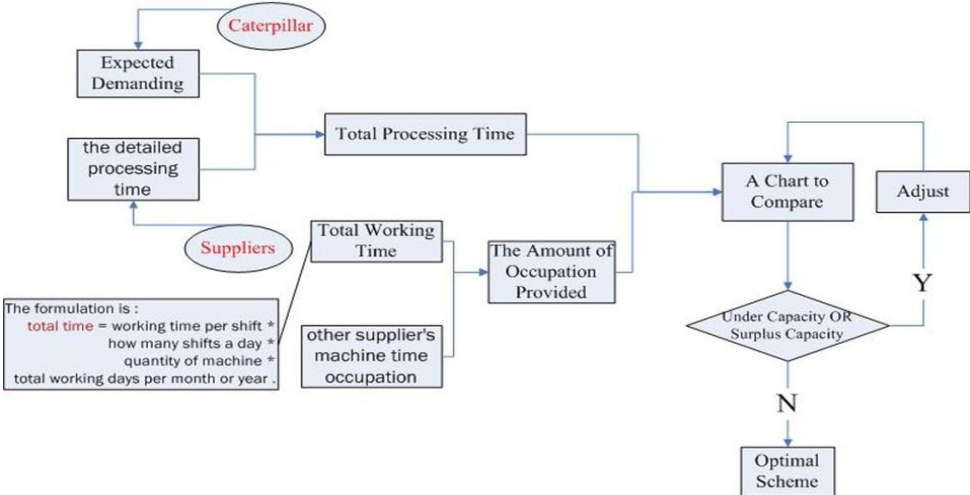


Figure 3-3-1 Initial flow path of the Capacity Planning

This flow path shows the general logic of the capacity planning process, which is the core of the “three steps”.

Step 1:

To input the total working time that equipment can provide.

The formula is:

Total available working time of each process = working time per shift * how many shifts a day * quantity of machine * total working days per month or year.

This the basic formula used to calculate the capacity of suppliers based on process.

Step 2:

To provide CAT's expected demanding to suppliers,;

To know the detailed processing time for each product, (additionally, suppliers should figure out the needed processes of each kind of part, thus helping to calculate the total needed normal processing time of each process.);

To consider the rework rate, rework time and other occupation of time of each process because rework consumes the major part of the production time besides the normal processing time; and

To generate each process's total processing time. This will include both the needs of CAT and other customers, and will be presented in the ratio form.

Step 3:

To input other machine time occupation, as the machine may not only make parts for Caterpillar but also serve other customers. Furthermore, the input information of other customers is much the same with that of CAT. Therefore, we design the CAT section and a section for other customers in the component interface. When calculating the needed process time, we consider the need from both two sides, and comparing it with the total capacity of suppliers for each process.

But, it is just an initial flow path. This is not the final flow path because many factors are not included, such as the rework rate, the average time and so on. These factors are quite important to the result of capacity planning. Moreover, the flow path is a little too general without detailed input and output information.

3.3.2. Initial design of the flow path of the software

In addition, we made an initial structure of the software. Although it was somewhat rough and unreasonable, it was our initial design of the tool. It is presented below.

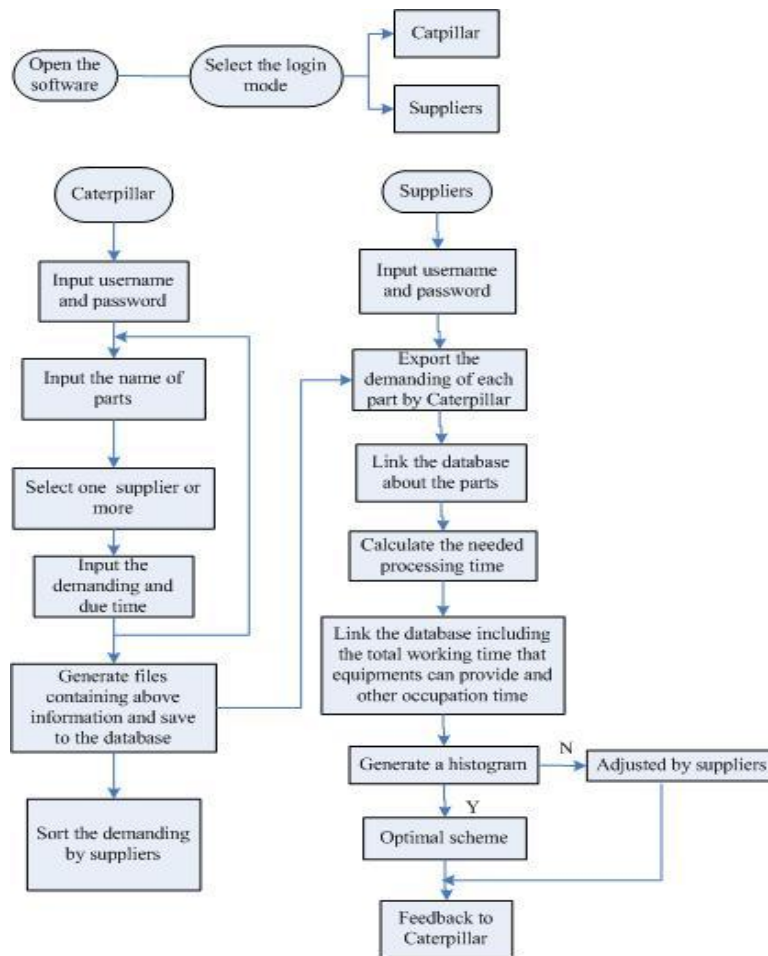


Figure 3-3-2 Initial flow path of the software

In this structure, the login model is imported. We referred some similar systems, like the human resource management system and warehouse management system. They all contain the login system, which ensures the safety and confidentiality of the systems. The users are divided into two kinds, Caterpillar and suppliers (this was subsequently modified because the supplier is the only user of the tool). This is our initial design of the tool. In the beginning, we divided the login section into two parts, one for Cat and the other for suppliers, as the initial flow path shows. So we put it we import the model. If it is ambiguous, we can put it in this way: in this structure, we get a picture of the login model.

Still, this flow path does not display the detailed information. How the data is transformed is also not mentioned. But the general logic is correct. Based on the data input by

suppliers and the inner formulas, the software can calculate the capacity and work out a histogram to see if suppliers can meet the demanding of Caterpillar.

3.3.3. Initial design of the interfaces

According to the initial flow paths of capacity planning and the software, we started the design of the interfaces, as follows.

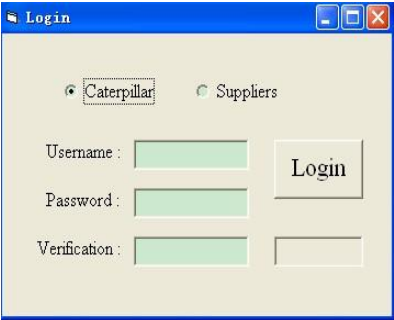


Figure 3-3-3 Initial login interface

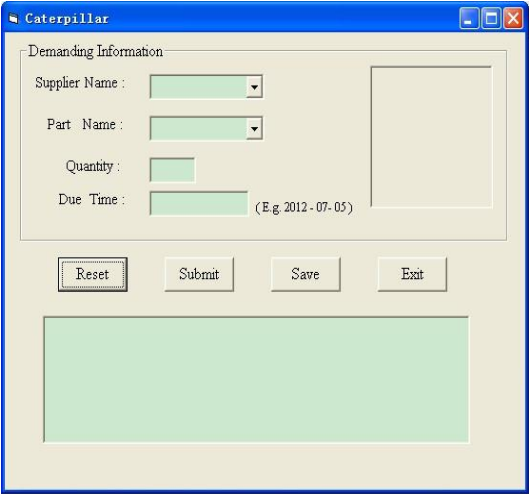


Figure 3-3-4 Initial Caterpillar interface

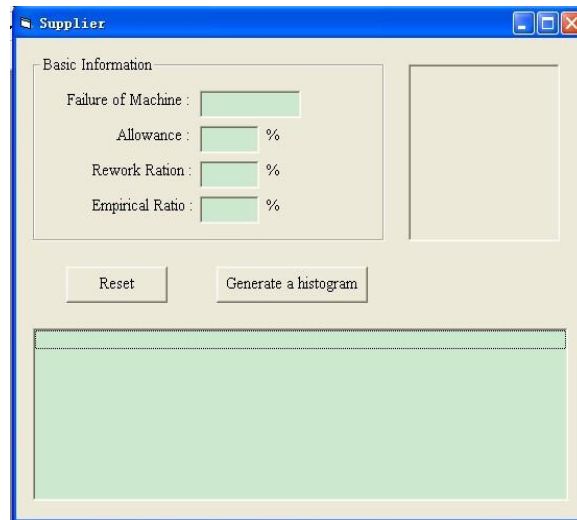


Figure 3-3-5 Initial suppliers' interface

These interfaces are just pure interfaces without codes. We can call it a skeleton of the tool.

3.4. Refined logic work and renewed flow path

For the first several weeks, because our sponsor had been away on business, it was difficult to make significant progress. At that point, we were quite eager to get information from the company, as our project was based solely on Caterpillar's requirements and we had to know exactly what they wanted.

It was the teleconference call with our sponsor that made our project road a bit smoother. Following this discussion, we had a clearer understanding of Caterpillar's expectations for the capacity planning tool.

3.4.1. The significant teleconference with our sponsor

During the one-hour teleconference with our sponsor, we talked mainly about the functions of the software. Daniel Miao, our sponsor, gave us a very detailed description of the

tool, from the input to output. Also, he introduced the normal process of capacity planning, which was the core of the project.

He recognized our previous work, but suggested that we should start the programming as soon as possible, because the software was their final requirement.

3.4.2. The summary of the content of the teleconference

The software should provide a general and unified platform. The users are the suppliers. The general function of the tool is to analyze the supply-demand information and to generate a report and a histogram to compare the working hours.

There should be two languages for users to choose, Chinese and English. Furthermore, to make this tool user-friendly, a help file should be contained in the software.

The software is divided into two sections---- equipment and component.

a. Equipment section

In this section, suppliers need to input information related to their processes and equipments. The information includes process, equipment, the number of equipments, the number of workers, working shift, working hours per shift, average setup time and other time occupation.

Based on these data, the software should calculate the net working hours the supplier can provide for each process. The formula is displayed as follows.

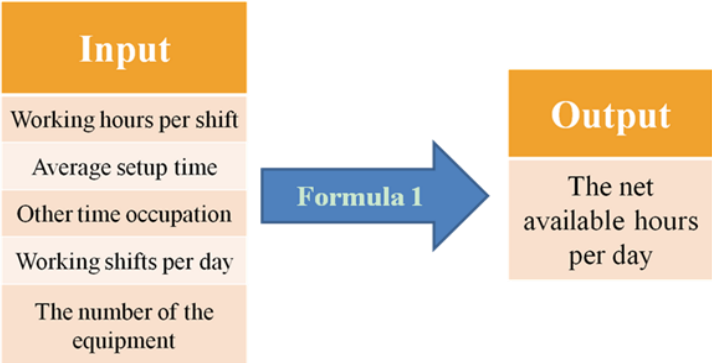


Figure 3-4-1 Input and output of formula 1

The net working hours per day = (working hours per shift – average setup time – other time occupation) * working shifts per day * the number of the equipment

All the information mentioned above will be saved into the database. A data report is generated at the same time.

b. Component section

In this section, suppliers need to input the demand information from Caterpillar and other customers. The information includes part number, part name, quantity, year and rework rate. As CAT will provide several years demand to suppliers, the tool should make analysis of each year. Therefore, users should also input the exact year when inputting the demand separately. Besides, suppliers need to input the needed process and corresponding working hours of each part.

Based on the data, the software should calculate the needed working hours of each process. The formula is displayed as follows.

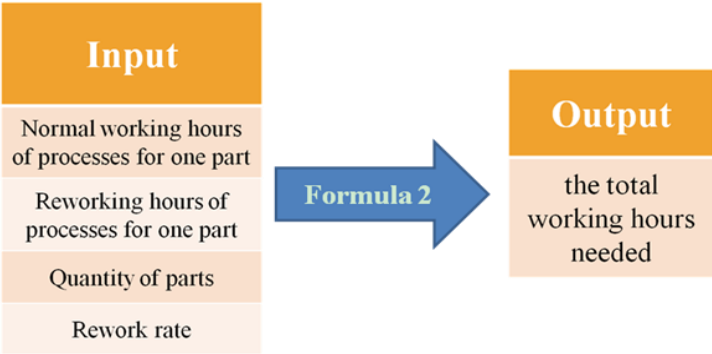


Figure 3-4-2 Input and output of formula 2

The needed working hours of each process = $\sum ((\text{quantity} * \text{normal working hours of this process for one part}) + (\text{quantity} * \text{reworked working hours of this process for one part} * \text{rework rate}))$

All the information mentioned above will be saved into the database, and a data report is also generated.

Finally, the software needs to generate a histogram to compare the net working hours provided and the needed working hours by Caterpillar. Through this histogram, suppliers can know clearly whether they can meet the demand from Caterpillar, which is the true aim of capacity planning.

3.4.3. Renewed flow paths

Following the guidance from our sponsor, we redesigned the flow paths of both capacity planning and the software. The renewed paths are more detailed and reasonable, as more input information is included and more factors are taken into consideration.

The two flow paths are displayed below.

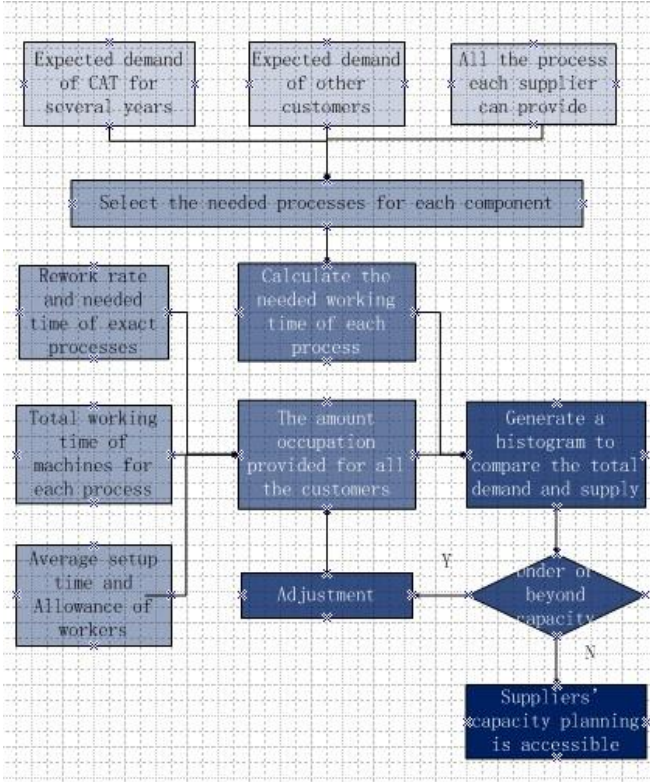


Figure 3-4-3 Renewed flow path of the Capacity Planning

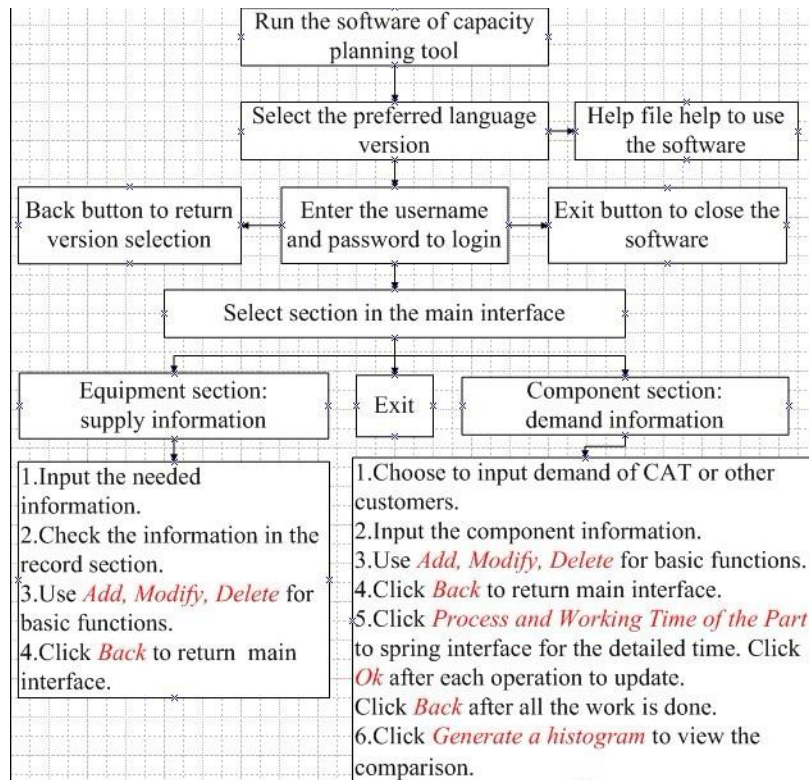


Figure 3-4-4 Renewed flow path of the software

3.5. Useful suggestions about our renewed design

3.5.1. Suggestions by Professor Rong

We gave a presentation about our renewed design to Professor Rong. To be honest, before the presentation, we felt confident because we had had a clear outline of the tool and knew exactly what goal we should achieve. However, Professor Rong raised many issues about our project. At that time, we all felt depressed. But later, as we thought about the issues mentioned by Professor Rong, we concluded that they were reasonable.

Following are the issues and suggestions given by Professor Rong.

- a. Define the objectives in detail, including what goal we should achieve. Problems and objectives should be presented every time.
- b. Redesign a more detailed flow path of the software.

- c. More logic work should be done to achieve the goal of the project, which is more important than the design of interfaces.
- d. We should know exactly what kind of information and data the users want to get and how to make decisions through our tool.
- e. Contact Daniel as soon as possible to obtain more information from the company.
- f. Develop a cost analysis (the time and money needed to develop and implement the software), develop a benefit analysis (i.e., convert the benefit to dollars to show the value of our work).
- g. Find tools to help develop the software, and also find some similar products.

3.5.2. Suggestions by our sponsor

After the presentation to Professor Rong, we found it quite necessary to make a trip to the company and have a face-to-face meeting with our sponsor. There, we met our sponsor for the first time. He was quite easy-going and energetic. We presented our renewed design to him and another engineer.

We appreciated our sponsor's recognition of our project work. He said that it was inline with his expectation for the capacity planning tool. During the meeting we ran by him the problems we ran into and obtained further guidance. In regards to our renewed design, Daniel gave some suggestions. Most of them were about the details of the software; for example, he suggested when the buttons should be enabled, how the histogram should be drawn, how reworked condition should be calculated; he also pointed out that the labels should be more explicit.

Because the tool we designed would be used by suppliers, we should take the perspective of suppliers. So our sponsor described a sale transaction taking place between

Caterpillar and their supplier, This hypothetical scenario helped us realize what we still needed to do.

3.6. Prototype the software

We completed the design of the software. Although it is just a prototype, it can realize the functions we have expected and generate the information suppliers need.

We introduce the prototype of the software below and show the various screens.

a. Welcome Interface



Figure 3-6-1 Welcome Interface

In this interface, suppliers can select the language they want to use, Chinese or English. Later I will use the English version as an example.

Also, the “Help” button is linked to a document, which shows how to set up and use this software. This reference helps suppliers manage the tool well.

b. Login Interface



Figure 4-6-2 Login Interface

For the safety mechanism, we designed this login interface. Only when suppliers input the correct user name and password can they enter the system.

c. Function Selection Interface

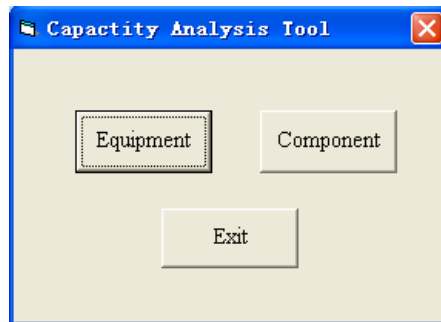


Figure 3-6-3 Function Selection Interface

This section provides the entrance to the main two functions, equipment and component. The first one is the process and equipment information, and the other one counts up the demand information of Caterpillar and other customers.

d. Equipment Section

Process : Equipment :

the Number of the Equipment : the Number of the Workers Shifts per Day :

Working Hours per Shift : Average Setup Time : / h Other Time Occupation : / h

Information of Processes and Equipments				
Process	Equipment	the Number of the Equipment	the Number of the Workers	Shifts per Day
▶ Blanking	Equipment A	6	8	2
Bending	Equipment B	4	15	2
Forming	Equipment C	5	8	1
Grinding	Equipment D	3	6	3
*				

Figure 3-6-4 Equipment Section

This section collects the information regarding the processes and equipments of suppliers, including process, equipment, the number of the equipments, the number of the workers, shifts per day, working hours per shifts, average setup time and other time occupation.

On the top of the interface is the input area and in the middle is the display area of the information. At the bottom, the first three buttons- add, modify and delete- provide the basic operations.

All the information above will be saved into the database Equipment.mdb behind the software. If suppliers want to make backups, they can press the button “generate the data report”. Then a report can be displayed as follows with the print function.

DataReport of Equipment

Print Time : 2012-8-8 12:01:37

Process	Equipment	the Number the	the Number of the Workers	of Shifts per Day	Working Hours per Shift	Average Setup Time/h	Other Time Occupation/h	Net Working Hours per
Blankin g	Equipment A	6	8	2	8	2	1	60
Bending	Equipment B	4	15	2	8	1	.5	52
Forming	Equipment C	5	8	1	8	1.5	.5	30
Grinding	Equipment D	3	6	3	8	1	.5	58.5

Figure 3-6-5 Data Report of Equipment

e. Demand Selection Section

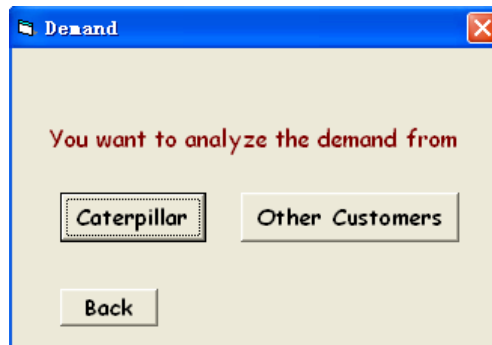


Figure 3-6-6 Demand Selection Section

In this section, suppliers need to select the demand source, Caterpillar or other customers. Later I will use Caterpillar as an example.

f. Demand_Caterpillar Section

Part Number : Part Name : Quantity :

Year : Rework Rate : %

Process and Working Hours of the Part

Information of Parts						
	PartNumber	PartName	Quantity	Year	ReworkRate (%)	Blanking
▶	01	Part A	8500	2012	10	10
	02	Part B	9000	2012	8	15
	03	Part C	16000	2013	6	10
	04	Part D	8800	2012	9	15
*						

Add Modify Delete Back Generate the Datareport

Result of Capacity Analysis

Please select the year you want to analyze : Generate a Histogram

Figure 3-6-7 Demand_Caterpillar Section

This section collects the information related to Caterpillar’s demand, including part number, part name, quantity, year and rework rate. Also, suppliers need to input the processes needed for each part and corresponding working hours of each process. The interface is displayed as follows.

Process Needed :

Normal Working Hours Needed for Every Part : min

Rework Working Hours Needed for Every Part : min

OK Back

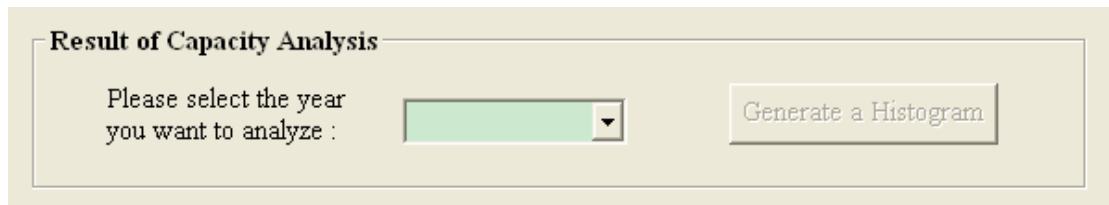
Figure 3-6-8 Process and Working Hours Interface

For each process, there are two kinds of working hours, normal working hours and rework working hours. After inputting the information, users should press “back” to return to the demand_Caterpillar interface.

Like the equipment interface, in the middle is the display of the information and also some operation buttons.

All the information above will be saved into the database Component_CAT.mdb behind the software. If suppliers want to make backups, they can press the button “generate the data report”. Then a report can be displayed.

g. Result of Capacity Analysis



Result of Capacity Analysis

Please select the year you want to analyze :

Figure 3-6-9 Result of Capacity Analysis

At the bottom of the demand_Caterpillar interface, there is an area to generate the final result of Capacity Analysis.

Suppliers can select the year they want to analyze, and then press the button “generate a histogram”. The result is showed as follows.

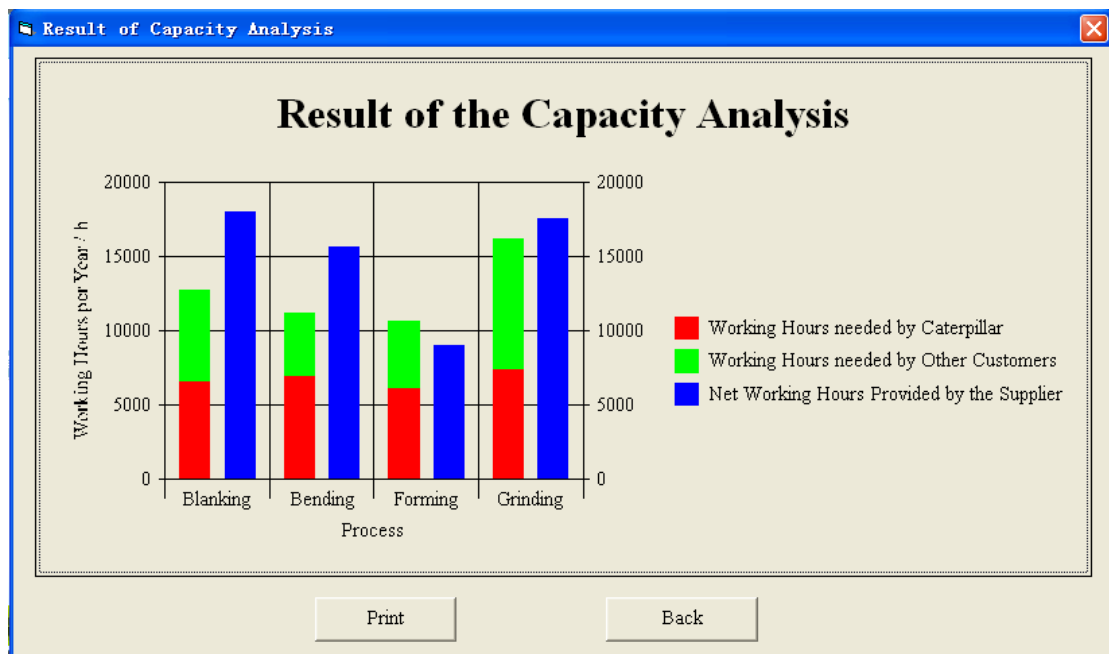


Figure 3-6-10 The Comparison histogram

The histogram shows clearly the comparison between the net working hours provided by suppliers and the working hours needed by Caterpillar and other customers. The X axis is the process and the Y axis is the working hours.

From the histogram, we can see that in the processes of blanking, bending, and grinding, there is surplus capacity, while in the process of forming, the supplier is overload.

So, after this, suppliers can know clearly if it is suitable to start the production or they have to make some adjustment. The final goal of the capacity planning is achieved.

4. Cost Analysis

4.1. Software development price

Software development price associates with workload, business cost, tax, corporate profits and others. For the convenience of calculation, a calculation formula is given as following:

Software development price= Workload of developing the software* development costs per people a month

4.1.1. Workload of developing the software

Workload of developing the software has a relationship with the estimated experience value, risk coefficient and multiplexing coefficient.

Workload of developing the software = estimating workload experience value x*risk coefficient * multiplexing coefficient

a. Estimating workload experience value

The cost of developing software can be calculated according to the length of code.

There are many methods to estimate the cost, and most of them are based the code length.

The estimation method should follow the national standard software life cycle processes set by the process of software development activities to calculate the workload.

The workload is calculated according to the work of a technical staff that is in charge of the development of the software in a month. We can put the work package into per person per month.

It is important to note that the software development process includes not only the software development, but also various types of software testing activities.

In the formula estimating workload experience value = 4 * 1.5 = 6, 4 represents the total development staff and 1.5 the mean about seven months. This is project should be finish within seven months.

b. Risk coefficient

Estimating workload experience value is associated with risks. These risks are especially high when the software enterprise is not familiar with the engineering project business areas, and the user cannot understand enough to express their true needs, resulting in software enterprises needing to improve the demand for access continuously and modify the design work. Therefore, the risk coefficient should fall within these values:

$$1 \leq \text{risk coefficient} \leq 1.5$$

Based on our understanding of software enterprise, more than half of the value of estimating work experience is unacceptable. So we define "1.5" as the ultimate value.

Since this depends on the enterprise abilities and the degree of risk users can accept, we estimate this project risk coefficient at 1.1.

c. Multiplexing coefficient

Estimating the workload experience of software enterprises when estimating the empirical workload of software, companies always deal with the common project. But if the software enterprises have adopted a "component based development method", and reuse component library (the core asset library), or some software products, it reduces the software development workload. Therefore:

$$0.25 \leq \text{multiplexing coefficient} \leq 1$$

According to the domestic and foreign enterprises in the implementation of component based software development method (the software product line), experience data can improve the work efficiency to 25% (maximum value).

We estimate this project's multiplexing coefficient at 1 because this is the first time we developed this software.

4.1.2. Development costs per people a month

Software business cost, revenue, profit, cost and quality cost management the total fee to develop the software contains software business cost, revenue, profit, cost and quality cost management. It can be apportioned to each technical staff.

Development costs per people a month = (people salary + office expenses) * management coefficient * quality factor coefficient

a. Capitation fee

Capitation fee represents staff salaries, bonuses and the provisions of a national capitation fee. Capitation fee represents staff salaries, bonuses and the provisions of government per capita. The capitation fee counts for about 70%-80% of the gross business cost in developing software.

$$P = B \times 1.476$$

B is the average wage, namely the enterprise pays, bonuses, and incentives divided by the number of employees. B is the average wage, namely the enterprise pays, bonuses, and incentives divided by the number of employees, meanwhile divided by 12 to be allocated into each month. The public accumulation funds is 7%, medical insurance is 12%, pension 22%, unemployment compensation 2%, and total amount of wages on industrial injury margin 0.5%, planning the margin 0.5%, disability fund 1.6% fund, union 2%,. Added together, they account for 47.6 % (1+47.6%).

So Capitation Fee: $900 \times 1.476 = 1328$

b. Office expenses

Office expenses include corporate office rental fees and property management fees, communications, office consumables, utilities fees, equipment depreciation, travel expenses, as well as the staff training cost.

counts for 20%-30% of the business cost in developing software.

$$Q = B / 2.5$$

Here office expenses accounts 25% of the business cost.

$$\text{So Office expenses} = 900 / 2.5 = 360$$

c. Management coefficient

Usually managers in an organization will be in a certain proportion. According to some organization, the management cost is defined as the cost of every ten technical software designers and two corresponding managers:

$$1 \leq \text{Management coefficient} \leq 1.2$$

So we think this project's management coefficient is 1.1

d. Quality factor coefficient

To improve the quality of the software firms will need to incur a quality cost. This quality cost is not the same for all software enterprises.

The ISO9000 quality system certification and CMM or CMMI authentication suggest quality cost value of 1.05, 1.1, 1.15, and 1.2.

So we estimate this project's quality factor coefficient at 1.05

Accordingly, we integrated the above points:

**Software development price = Workload of developing the software *
development costs per people a month = 6.6*1950 =12870 RMB**

Workload of developing the software = estimating workload experience value * risk coefficient * multiplexing coefficient = (6*1.1*1) = 6.6

Estimating workload experience value = $4 * 1.5 = 6$

risk coefficient = 1.1 (1 ≤ risk coefficient ≤ 1.5)

multiplexing coefficient = 1 (0.25 ≤ multiplexing coefficient ≤ 1)

Development costs per people a month = (people salary+ office expenses) *

Management coefficient * quality factor coefficient

$$= (900 * 1.476 + 900 / 2.5) * 1.1 * 1.05$$

$$= (1328 + 360) * 1.1 * 1.05$$

$$= 1950 \text{ RMB}$$

Capitation fee = $900 * 1.476$

Office expenses = $900 / 2.5 = 360$

Management coefficient=1.1 (1 ≤ Management coefficient ≤ 1.2)

Quality factor coefficient=1.05 (1.05、1.1、1.15、1.2)

4.2. Software's (system) maintenance fees

During the following 1year of delivering the completed software to users to run, the software designer is responsible for the maintenance for free.

.

In response to the demand of users, we assume that it is necessary for permanent technical personnel to solve the daily operation problems; there will be some cost to consider.

a. U (System construction investment)

Users need to use the enterprise software maintenance system. System construction investment mean the cost to invest on the software which users need technical personnel's to maintain. If the user only need to maintain the software, U is the application software development costs; if the user needs a software enterprise to maintain the whole system, including computer hardware, software, network and application software, U is the information engineering project total investment.

b. N (professionals)

we suppose that there will be N permanent technical personnel to solve the daily operation problems in users' company, then

$$\text{Software's (system) maintenance fee / year} = U \times 15\%$$

So this project software's (system) maintenance fee per year is

$$= U \times 15\%$$

$$= 12870 \times 0.15$$

$$= 1930 \text{ RMB}$$

5. Value of our work

The most important value of our project is the usability, and completeness of the software.

5.1. Usability

The usability of our capacity planning tool means that it can be used in the real industrial environment, not something only in the lab. The software can provide an histogram of the comparison between the work time needed and provided. It can reduce the over load and over capacity, hence guarantee that Caterpillar's demand will be met and fully utilize the asset of supplier. Thus, it can help the supplier adjust their resource distribution and help Caterpillar make the right decision about which supplier to choose.

5.2. Scientificalness

The capacity planning tool we have developed is scientific and complete. It makes a refined and reasonable flow path of capacity. Our tool can do the capacity just as the professional engineer does, but with much time and costs saving. The tool needs explicit input, and the working time is calculated from a reliable formula. What's more, it takes elements which may otherwise be overlooked by existing capacity tools into consideration, for example, the rework time and preparing time. Then it generates an output. So our tool is scientific and complete.

In conclusion, the tool we have developed can satisfy Caterpillar's need in a real industrial situation. This situation is the benefits outweigh the costs.

6. Conclusion

6.1. Social conclusion

During the project, we have learned a lot not only about technology, but also about working in a real corporate context. Frankly speaking, this is the first time that we dealt with a real industrial project.

During the project, we had to learn how to understand the project using its abstract requirements, how to get the necessary information from the engineer at Caterpillar, how to keep the project going in a proper way, how to work with each other, how to conduct the project, etc.

Throughout the project, we encountered many challenges. The major challenge would be that we had to obtain information from several resources, such as from Caterpillar staff, from our advisor and search for information from the Internet. Through trial and error, we figured out the blueprint of our project, and we refined it three times. While our goal was to present functional complete software, we had to leave out some functions because of the limited time. These functions are presented in the Recommendation section.

The first time we tried to contact Caterpillar staff, we experienced some information delay. Our co-advisor Daniel was busy, and had to travel on official business. When he was away, he could not receive our e-mail, and it useless to call his office phone number. Then we agreed to share our schedule. Daniel told us when he was available, and we sent him an e-mail in advance, thus not slowing down our progress of the project. What's more, the questions we asked were carefully planned to ensure that we could obtain the information we needed.

This experience was practical. One of our team members put it as follows:

“Aside from the technical dimension of the project, we also want to particularly mention the lesson learned about the reimbursement of our trip to Caterpillar most. As I have never had a chance to get reimbursed in a company, I did not know I should paste the receipts onto paper, so I just mailed the receipts as they were to Misty Yang, then she mailed the receipts back to me, and required me to rearrange them. After our second trip to Caterpillar, I added the receipts of second trip with the first trip without talking to the company, so she did not receive them. Misty Yang asked me to get the permission of Paul, and I intended to ask for Paul’s phone number of Paul but did not prepare properly. I was quite embarrassed at that moment. In a well-organized company, people should do things according to the rules and do nothing without preparation.”

6.2. Technical conclusion

In the technical aspect, we learned Visual Basic. It is a powerful programming language. We also learned Microsoft Office Access, with which we built the database on which the software is based, Microsoft office Visio, the Gantt chart, with which we learned how to make the schedule and make sure that our project could be conduct as planned.

7. Recommendation

7.1. Limitations

As the situation in which the capacity planning tool is used can change, our tool faces the problem of how to accommodate changeable situations. It is actually a general one, which depends on the users, that is the suppliers, to initiate.

The other limitation is that when there are new products to manufacture, suppliers will need to adjust the procedure right away. The software itself is not capable to keep the information accurate automatically.

7.2. Recommendations

In order to overcome the limitations, the team worked out solutions. However, as time was limited, we were not able to achieve these functions. Therefore, we make the following recommendations.

The first one is to make the software more flexible.

The second is to consider the individualization of suppliers.

Finally, suppliers should update the database regularly.

7.3. Additional recommendations——Takt time

We have learned about Takt Time the second time we visited Caterpillar Suzhou. During the limited time provided for us to conduct the project, we were not able to include the thinking pattern of Takt Time into our design of the software. However, we still kept an eye

on it, and agree that it would be better and more straightforward if the Takt Time calculation method were to be included.

Takt Time is the desired time between units of production output, synchronized to customer demand. It is most common in production lines that move a product along a line of stations that each perform a set of predefined tasks. In the supplier's company, the components are moved in the product line with needed processes.

It can be determined with the formula:

$$T = \frac{T_a}{T_d}$$

Where

T = Takt time,

Ta = Net available working time,

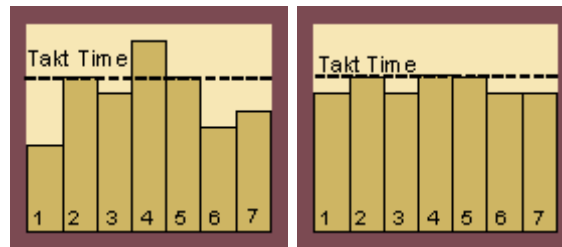
Td = Time demanded from customers;

We should consider cycle time of each process. Cycle time represent the actual working ability of suppliers. That is to say, if the takt time is longer than the cycle time of each process, suppliers can meet the demand of customers.

The simplicity of the concept of takt time belies its extraordinary effects. Among these, production stability is an important one. By limiting overproduction, it stabilizes the system and prevents buildups of inventory and subsequent stops and starts.

When comparing with the cycle time, suppliers can predict their working capacity and arrange their production.

In the first illustration below, the cell cannot make the necessary quantity because operation 4 exceeds the Takt time. In the second chart, the work has been balanced at Takt time or slightly below.



The product moves along a line, so bottlenecks are easily identified when the product does not move on in time. Workers and machines perform sets of similar tasks, so they do not have to adapt to new processes every day, thereby increasing their productivity.

Takt time is a powerful and valuable concept. It is truly another effective way to do capacity planning, in addition to identification of the production line problems.

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