Research on Capability Evaluation Methods for Discrete Aircraft Manufacturing Enterprise

Haijun Yin [1, a*], Yuning Wang [2,b], Hui Cai [3,c] , Qingyang Jiao [4,d] , Jiahui li [5,e]

[a*] yin_hj2010@163.com,[b] wang_ yn2010@163.com,[c]cai_hui2010@163.com,[d]jiao_qy2010@163.com, [e] li_ jh2010@163.com

[1,2,3,4]Shenyang Aircraft Industry (Group) Co., Ltd., Shenyang, China
[5]AECC Harbin Dongan Engine Co., Ltd., Harbin, China

Abstract: Aiming at the current situation that discrete aircraft manufacturing enterprises lack quantifiable production capacity data to support the capacity balance of production line, this paper establishes a production line capacity accounting model suitable for discrete aircraft manufacturing enterprises, forms a set of classification factors for production capacity influencing factors, and customizes the linear calculation relationship of production capacity formed by each index factor. It can be used to calculate available capacity and load demand capacity of production line, and provides a set of practical methods for the accurate calculation of production capacity and the balance of production line capacity, and obtains a good application effect based on the application verification of a certain type of aircraft.

Key words: production capacity, model, assessment, capacity balancing

1.INTRODUCTION

Capacity assessment is an effective approach for an enterprise to systematically identify and assess its production management, equipment use and management level. The use of capacity assessment and analysis approach provides a reasonable foundation for making capacity decision, promotes the enterprise to reasonably deploy various resources, strengthen production planning and control, and enhance the enterprise' reaction capability and marketing completeness. The reasonable allocation of manufactured product quantity and production resources not only makes full use of the limited production resources of an enterprise, but also maximizes its productivity efficiency.

Aircraft manufacturing enterprises feature[1] a great number of detail parts and components involved, large-scale production, long manufacturing cycle, many departments engaged, complex input-output relationship and lots of unknown factors, etc. Currently, there exist many quantitative qualitative and quantitative-qualitative combined approaches[2] for the research on aircraft manufacturing enterprises' capacity assessment. However, the applicability of such approaches is not good, nor the established models established on the basis of such methods not applicable to be introduced to enterprises as the limitation is to assume that manufacturing processes must be in the stable and repeatable environment. Therefore, the models have poor applicability in the dynamic environment continuously changing[3-4]. This articles brings forwards a set of capacity models with capacity contingency as the assessment indicators based

ICEMME 2023, November 17-19, Beijing, People's Republic of China

DOI 10.4108/eai.17-11-2023.2342662

on the current situation of aircraft manufacturing enterprises, which can account the operation of production processes in a dynamic way, and provides an effective solution to the capacity assessment shortcoming of discrete manufacturing enterprises.

2.PURPOSE AND SIGNIFICANCE

Discrete process lines features complexity, multiple level, openness and dynamics. Therefore, it is very hard to assess the capacity of discrete production lines[5]. This article aims to obtain an approach suitable for the overall analysis and assessment on various elements affecting the production lines of discrete aircraft manufacturing enterprises, set up the capacity model of process line resources, simulate and optimize the production processes, perform accurate assessment and calculation on aircraft manufacturing enterprises' capacity driven by complex production tasks on the shop floor, provide a strong support [6] to the evaluation and calculation of production resources, analyze and diagnose the bottle-necks in production management so as to improve, optimize and increase enterprises' capacity and comprehensive productivity efficiency.

3. TECHNICAL SOLUTION

OEE theory and man-hour methods[7] are taken as the basis for the available capacity models[8]. Based on the available capacity models, the existing available capacity can be calculated for different process lines of each manufacturing unit; existing available capacity of each process line can be calculated out on the basis of production delivery schedule and man-hour quota within the assessment period to obtain the loading of different process lines of each year within the assessment period; calculate whether the available capacity can satisfy the demanded capacity within the assigned task period by means of uploading task demands, and to generate the capacity contingency coefficient; linear planning methods can be adopted to match up with and plan the available capacity within the task period so as to satisfy the capacity required by different process lines and various models of aircraft.The capacity relationship is shown in Figure 1.

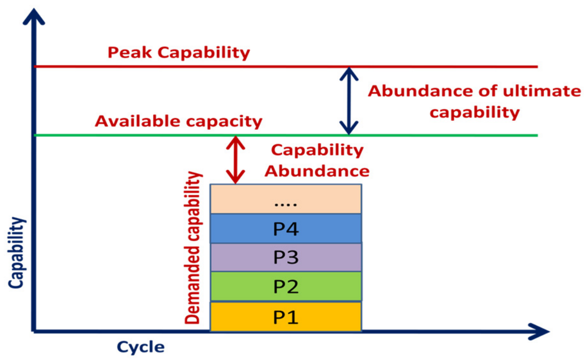

Figure1 Chart of Capacity Relationship

3.1 Basis of Capacity Model

Two model formulas are to be established:

1) Available capability – demanded capability = affluent capability

In case the affluent capability is over 0, it means the available capability of the process lines can satisfy demanded production tasks; in case of below 0, the available capability cannot satisfy the demanded production tasks, and corresponding actions shall be taken.

2)(Available capability – demanded capability) / available capability = capability

contingency coefficient

The capability contingency co-efficient indicates the degree of the capability affluence of process lines. Corresponding actions can be taken according to the coefficient of capability contingency.

3.2 Assumptions of Capability Calculation

To make the capability calculation methods more adaptable, the following assumptions shall be made during the calculation:

1) Production capacity during certain period of time, under certain technical condition and with certain process methods;

2) Production capacity under balanced production operation condition of an enterprise;

3) Only to define the capacity of productive resources at all levels, excluding auxiliary resources, such as energy equipment, power equipment, etc.;

4) To assess the capacity of various resources, process lines, and specialized shops from the bottom to the up to define the production capacity of this organization

3.3 Process of Capability Calculation

3.3.1 Establishment of available capability model

To calculate the rated capabilities and working efficiency of various personnel and equipment within system-specified working hours, respectively determine the 3 technical indicators of time efficiency, performance loss and quality effectiveness, with 3 modulating factors of standard time, appropriate time and increased time established for each indicator and corresponding to the value-added capability, standard capability and appropriate capability of resources. For each technical indicator, sub-factors affecting value-adding result of capabilities are determined according to the degree of effect upon process lines. Within the specified period of time, with the time affecting the sub-factors deducted one by one, the available capacity of a single resource, which represents the expected output capability of resource or organization at each level, can be calculated out. Therefore, the available capacity model for resources can be established on the basis of the above hierarchy and data, the available capacity model of resources can be established.The available capability model are

shown in Table 1.

Table 1 Example of Available Capacity Model Data

Major Indicator	Modulation Factors	Description of Work Section	Section 1	Section 2	Section 3	Section 4	Section 5
Time Efficiency	Actual Working Time	Work hours per day	480	480	480	480	480
		Work days per month	21	21	21	21	21
		Work hours per shift	480	450	480	450	450
		Shift No.	1	2	1	2	2
		Quantity of operators per shift	5	5	5	5	5
		No. of equipment operators	1	1	1	1	1
	Standard Allowance Time	Work break	15	15	14	12	15
		Toilet hour	10	10	8	9	10
		Equipment cleaning	8	10	8	11	9
		Cloth change	5	5	7	5	6
		Sub-total	38	40	37	37	40
	Appropriate Allowance Time	Meeting per day	10	10	9	10	11
		Learning and training	10	10	9	9	10
		Inspection preparation	5	7	6	6	6
		Shop floor cleaning	5	5	4	5	6
		Sub-total:	30	32	28	30	33
	Increased Allowance Time	Tolling waiting	13	13	12	11	13
		Meeting waiting	5	5	4	4	5
		Equipment failure	10	10	9	9	10
		Personal affairs	10	12	11	11	12
		lateness	5	5	4	5	6
		Sub-total:	43	45	40	40	46

For the production organizations at different levels, the available capacity can be calculated from the top to the bottom. Within the organization hierarchy of the available capacity model:

1) To calculate the production capacity of individual – work section– equipment – equipment team;

2) To calculate the production capacity of process line or production unit according to personnel and equipment allocation;

3) To calculate the production capacity of work shop according to quantity of process lines or the organization relationship of production unit;

4) To calculate the production capacity of the entire enterprise according to the supply-demand relationship of work shop within the enterprise.

3.3.2 Types of available capacity and calculation formula

The available capacity shall be calculated as per equipment or personnel individually in the unit of standard hour. The available capacity is classified as value-added available capacity, standard available capacity, and appropriate available capacity based on the output labor efficiency.

1) Value-added available capability: the capability to directly manufacture, inspect, measure or test products, i.e. the actual on-line operation hours of equipment or personnel.

2) Standard available capacity: with the probability time of various events occurring under the condition of relaxed standard taken into the consideration, strictly comply with the leaning process of production, and include the waiting time of equipment or personnel resulting from necessary production preparation or physiological demands on the basis of value-added capability.

3) Appropriate available capability: on the basis of standard capability, with the probability time of various events occurring under the condition of relaxed standard taken into the consideration, include the waiting time of equipment or personnel resulting from multiple event or accident event occurring at the process lines.

The available capability can be classified into available capability under statistics, available system capability, available capability at peak according to the corresponding work systems:

1) Available capabilities under statistics: the capability resulting from the actually calculated production data within the year;

2) Available systematic capability: the capability with the work system of 8 hours per day, 21 days per month and 12 months per year;

3) Available capability at peak: the capability which can be output with the work system of 3 shifts per day, 8 hours per shift, 30 days per months and 12 months per year for personnel and equipment.

The relationship of between the various available capabilities is shown in Figure 2.

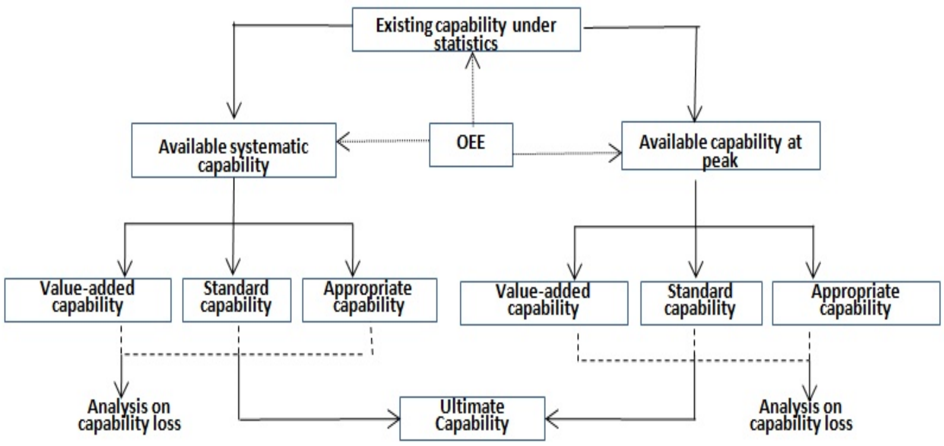

Figure2 Relationship of Available Capability

Formula of available capability calculation is as below:

Value-added available capability = (work hour per day × work day per month × work shift per day × value-added comprehensive application efficiency) × operators' proficiency

Standard available capability = (work hour per day × work day per month × work shift per day × value-added comprehensive application efficiency) × operators' proficiency

Appropriate available capability = (work hour per day × work day per month × work shift per day × value-added comprehensive application efficiency) × operators' proficiency

The standard capability data are shown in Table 2.

Table 2 Model of Standard Capability Calculation for xxx process line of xxx Work Shop

Annual Capability	Process Line					
	Cleaning	Gum-Printing	Curing	Stretching	Routering	Honeycomb Milling
Available capability under statistics (Standard)	1786.4	1815.8	1795.2	1923.0	1112.0	1755.6
Available systematic capability (Standard)	1747.2	1775.3	1755.6	1877.6	1808.9	1696.8
Available capability at peak (standard)	7488	7608.2	7524	8046.9	7752.24	7272

3.3.3 Performance indicator of available capability

Performance indicators include major performance indicator and performance sub-indicator

1) Major indictor: the comprehensive application efficiency of resources, which is the comprehensive measurement of efficient production time, manufacturing speed and manufacturing quality of products, and is a comprehensive indictor to relatively assess equipment's industrial application level in an all-round way.

Major indicators include value-added comprehensive application efficiency, standard comprehensive application efficiency and appropriate comprehensive efficiency. It has 3 hierarchies, which correspond to value-added available capability, standard available capability, and appropriate available capability respectively. The major indicator is the product of 3 sub-indictors (resource availability, performance efficiency and quality acceptance rate). The formula is as below:

Value-added comprehensive application efficiency = value-added resource availability × value-added performance efficiency × value-added quality acceptance rate

Standard comprehensive application efficiency = standard resource availability × standard performance efficiency × standard quality acceptance rate

Appropriate comprehensive application efficiency = appropriate resource availability ×appropriate performance efficiency ×appropriate quality acceptance rate

Table 3 lists the calculated performance indicators.

Table 3 Model of Various Comprehensive Efficiencies Calculation

for xxx Equipment in xxx Work Shop

Work Section	Equipment Description	Equipment No.	Value-added comprehensive	Standard comprehensive	Appropriate comprehensive
Mould Pressing Section	Hydraulic Machine	42040024	51.9%	82.9%	92.6%
	Hydraulic Machine	42040061	51.9%	82.9%	92.6%
	Hydraulic Machine	41010084	51.9%	82.9%	92.6%
	Hydraulic Machine	42040058	49.5%	81.7%	92.6%
	Hydraulic Machine	42040064	42.9%	79.5%	92.6%
	Hydraulic Machine	42040037	39.3%	79.0%	92.6%
	Rubber Forming Machine	42500014	52.9%	84.5%	94.3%
	Rubber Forming Machine	42500015	52.9%	84.5%	94.3%
	Rubber Forming Machine	42500016	52.9%	84.5%	94.3%
	Rubber Forming Machine	42500017	52.9%	84.5%	94.3%
	Rubber Forming Machine	42500018	52.9%	84.5%	94.3%
	Rubber Forming Machine	42500019	52.9%	84.5%	94.3%
	Oven	13150210	74.3%	86.7%	93.8%
	Oven	13150215	75.2%	87.6%	94.3%
	Oven	13150216	75.2%	87.6%	94.3%
	Oven	13150231	75.5%	87.9%	94.5%
	Oven	13150257	75.5%	87.9%	94.5%
	Oven	13150261	75.5%	87.9%	94.5%
	Plunger Injector	96290003	60.7%	83.6%	93.3%
	Vertical Injector	96290010	60.7%	83.6%	93.3%

2) Sub-indicators: Analyze and investigate the main factors that affect production capacity from three aspects: time effectiveness, performance and quality of resources. Sort out the events that affect resource capacity according to the normal and typical production activities in the current

production process, and obtain the occurrence time of each event with scientific statistical methods.

3.3.4 Modulating Factor

1) Modulating factor refers to the grading of events that affect resource capacity based on the correlation degree between production activities and product manufacturing. It can be divided into three levels: standard allowance, effective allowance and extended allowance.

2) Standard allowance: non value-added time that has direct effects on production and manufacturing process which is fixed and occurs routinely;

3) Moderate allowance: non value-added time that has indirect effects on the production and manufacturing process which is relatively fixed and occurs multiple times;

4) Extend allowance: non value-added time that has secondary indirect effects on the production and manufacturing process which is not fixed and occurs occasionally.

3.3.5 Data Collection Based on Available Capacity Models

The current available capacity refers to the average production capacity exhibited by resources under normal circumstances. Based on the available capacity model, production units are organized to calculate the average probability time caused by corresponding indicator items (or events) in the past three years. The result data of each sub-item are determined with statistical methods, so as to objectively calculate the average effective working time of each machine/equipment, each labor's "resource", each unit day and each shift.

Calculate the corresponding performance indicators according to the data statistics results, calculate the current available capacity of the production unit based on the performance indicators, and conduct statistical analysis. Calculation data of indicators are shown in Table 4.

Table 4 Collected Index Factor Data of Available Capabilities

Main Index	Modulating Factor	Work Team	Shift 1	Shift 2	Shift 3	Shift 4	Shift 5
		Equipment Model	CFTZF10Q	CFTZF11Q	CFTZF12Q	CFTZF13Q	CFTZF14Q
Time Effectiveness	Actual working time	Daily Specified Time (min)	480	480	480	480	480
		Working days/month	25	25	25	25	25
		Working Hours/shift	600	600	600	600	600
		Number of Shifts/day	1	1	1	1	1
		Number of Operators/shift	10	10	10	10	10
		Number of Operators for each equipment	1	1	1	1	1
	Standard preparation time	Toilet hours	12	12	12	12	12
		Working area cleaning	5	5	5	5	5
		Change the working suit	5	5	5	5	5
	Moderate allowance	Meeting	5	5	5	5	5
		Learning	10	10	10	10	10
		Equipment cleaning	5	5	5	5	5
	Extended allowance	Tooling Preparation	0	0	0	0	10
		Plan Adjustment	10	10	10	10	10

		Private Affairs	5	5	5	5	5
Performance loss	Standard preparation time	Equipment check	2	2	2	2	3
		Data preparation	3	3	3	3	3
		Program call	0	0	0	0	0
		Tooling preparation	0	0	0	0	2
	Moderate preparation time	Equipment maintenance	2	2	2	2	2
		Equipment cleaning	2	2	2	2	2
		Equipment calibration	5	5	5	5	5
		Problem disposition	0	0	0	0	5
Quality Effectiveness	Standard Allowance	Dimensional inspection	3	3	3	3	3
	Moderate allowance	Repair time	5	5	5	5	5
	Extended allowance	Scrap and new fabrication	5	5	5	5	5
		Non-conformity disposition	2	2	1	3	2
Comprehensive utilization rate		Value-added comprehensive utilization rate	81.0%	81.0%	81.0%	81.0%	78.3%
		Standard comprehensive utilization rate	86.0%	86.0%	86.0%	86.0%	84.5%
		Moderate comprehensive utilization rate	93.3%	93.3%	93.3%	93.3%	91.8%

3.3.6 Establishment of Demanded Capacity Models

Based on enterprise PBOM, classify and summarize the work task list of each model of aircraft undertaken by the unit. Based on the MBOM of each model, effectively sort and connect operations of part fabrication. Based on the actual operation time (processing cycle) recorded in MES system, statistically calculate the processing cycle of each operation of a single piece for each model of aircraft in each unit, with allowance properly taken into the consideration, so as to get the overall processing time of each model in the unit responsible for a single shipset of parts, and then obtain the demanded capacity.

Demanded capacity is calculated and statistically analyzed based on the demanded capacity model. The demanded capacity model covers all data items of the indicator factor mentioned above, and the data is automatically generated by the information system. Table 5 is demanded capacity model data list.

Table 5 Demanded Capacity Model Data List

Drawing No.	Manufactured by	Qty per shipset	Part Description	Operation No.	Operation Description	Processing method	Planned quota (min)	Practical quota (min)
020.000.01	Blanking	2	Panel	10	Blanking	NC milling	50	45
	Shop 1	2	Panel	10	Scribing	Bench work	30	25
	Shop 1	2	Panel	20	NC milling	Machining	100	95
	Shop 1	2	Panel	30	NC milling	Machining	120	115
	Shop 1	2	Panel	40	NC milling	Machining	30	25
	Shop 1	2	Panel	50	De-burring	Bench	15	10

						work		
	Shop 2	2	Panel	10	Roll bending	Machining	30	25
	Shop 2	2	Panel	20	Sizing	Bench work	20	18
	Shop 3	2	Panel	5	Painting	Bench work	30	25
	Shop 3	2	Panel	10	Anodizing	Machining	50	40
	Shop 3	2	Panel	20	Cleaning	Bench work	20	16
	Shop 4	2	Panel	10	X-ray	Machining	30	25
	Shop 4	2	Panel	20	X-ray	Machining	30	25
	Shop 2	2	Panel	20	Trimming	Bench work	25	19
	Shop 2	2	Panel	20	Marking	Bench work	20	15
020.000.02	Shop 2	2	Stringer	5	Blanking	Machining	15	10
	Shop 2	2	Stringer	10	Sheet metal processing	Machining	55	40
	Shop 2	2	Stringer	20	Trimming	Bench work	15	10
	Shop 2	2	Stringer	30	Degreasing	Bench work	10	8
	Shop 2	2	Stringer	40	Polishing	Bench work	15	10
	Shop 2	2	Stringer	50	Aging	Bench work	45	40
	Shop 2	2	Stringer	60	NC milling	Bench work	55	45
	Shop 2	2	Stringer	70	Quenching	Bench work	60	55
	Shop 2	2	Stringer	80	Packaging	Bench work	15	10

Collect demand data for each unit and each model of aircraft based on the demanded capacity model.

3.3.7 Calculation of Capacity Contingency

Capacity contingency coefficient is the percentage of difference (between available capacity and demanded capacity) and available capacity. It is an important indicator for evaluating production capacity. With the capacity contingency coefficient, the risk level of production plan tasks can be quantitatively analyzed. The calculation formula is as below:

Capacity contingency (%) = (available capacity-demanded capacity)/available capacity

Note: where, the available capacity can be calculated separately based on institutional available capacity and peak available capacity, or calculated separately based on value-added capacity, standard capacity, and moderate capacity of the available capacity.

Considering the uncertainty in actual production, the risk point of production capacity is generally determined based on 20% of capacity contingency:

1) In case of capacity contingency＞ 0, it indicates that the production line has surplus production capacity and production tasks can be completed;

2) In case of 0 < capacity contingency ≤ 20%, it indicates that there is a production capacity risk in the production line and appropriate measures need to be taken to enhance the capacity.

3) In case of capacity contingency < 0, it indicates that the production line has insufficient capacity and effective measures must be taken to enhance its capacity.

3.3.8 Balancing of Production Line Capacity

By means of linear programming technique, denote the independent variable of the task shipset of the aircraft model with a, b, c, d… (variable coefficient is man-hour per machine), and plan the task load that can be undertaken in the fourth year or subsequent years based on the tasks required by each aircraft model and on each production line in the first three years. Make planning goals by total capacity max (Z) =85% of peak capacity (constant value), and the linear programming formula is:

$$\max(Z)=6.5a+5.948b+5.909c+0.728d+1.17e+5.896f+5.889g+5.889h+2.08i+6.058j+5.564k+6.201m+5.915n+2.47t$$

Refer to Table 6 for an example of planning the next year's task load based on the tasks from the first three years.

Table 6 Example of Task Load Planning

Model	Independent variable	Man-hour per machine	Tasks in 2017	Tasks in 2018	Tasks in 2019	Planned goals for 2020
P1	a	6.5	14	0	0	0
P2	b	5.948	0	0	0	0
P3	c	5.909	24	24	20	4
P4	d	0.26	10	10	10	8
P5	e	1	10	10	10	10
P6	f	5.896	4	4	0	0
P7	g	5.889	4	4	10	8
P8	h	5.889	0	0	6	18
P9	i	2.08	1	3	3	6
P10	j	6.058	16	24	20	10
P11	k	5.564	0	4	8	10
P12	m	6.201	0	0	0	0
P13	n	5.915	2	0	0	4
P14	t	2.47	0	0	0	0

4.CONCLUSION

By classifying the capacity types of discrete aircraft manufacturing enterprises, an available capacity model and a load demand model are established. Based on the relationship between available capacity and load demand capacity, a capacity contingency coefficient is established to quantitatively evaluate and analyze production capacity and capacity surplus of various internal resources and levels of organizations within the enterprise. The method proposed in this article has been applied in production capacity evaluation process of production lines. Through production practice verification, it is basically in line with the actual situation of the production line of the aircraft manufacturing enterprise, and the evaluation conclusion drawn is reliable. It solves the problem of lacking accurate capability data in the process of balancing production line capacity, issuing production plans, and implementing technical innovation plans, and has strong application and promotion value for aircraft manufacturing enterprises.

REFERENCES

[1] Huang Yaochong, Capacity Evaluation Method for Commercial Aircraft Manufacturing Programs [J], Science and Technology Perspective, 2020.

[2] Xu Xuejun, Li Wen, Ye Guangyu, Discussion on Performance Indicators of Enterprise Production System Management, Technical Economy and Management Research, 2000.

[3] Jay Gorajia.Identifying bottlenecks in the manufacturing process [J].Optimum Manufacturing Flow,2010(11).

[4] B K Choi, J C Seo. Capacity-filtenring algorighms for finite-capacity planning of a flexible Flow line[J].Internationa Journal of Production Research, 2009(6).

[5] Fang Yexiang, Research on Production Capacity and Capacity Planning of Machinery Manufacturing Enterprises, Prediction, 2003.

[6] Wei Hongmei, Application of Industrial Engineering in Improving Production Efficiency [D], Tianjin University, 2007.

[7] Jia Chenhui, Zhang Hao, Lu Jianfeng, Manufacturing Informatization Integration Platform Based on Digital Chemical Plants, Management Technology, 2006.

[8] Dong Nan, Research on Production Capacity Evaluation Method Based on Manufacturing Enterprises [D], Xi’an University of Electronic Science and Technology, 2009.