

A Relation Model for Manufacturing Capacity and Information

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Abstract. Aiming at the difficulty of clearly defining relationship between manufacturing capacity(MC) and information due to high volume of information, this paper presents definitions of MC and production processing capacity , the sub manufacturing capability, by combining existing research. Further, MC is decomposed and represented by adopting set theory, especially production processing capacity and relative information, in details. Based on this, a relation model between MC and information is established. The model could provide support for MC calculation and assessment. Last but not least, some manufacturing sub-capacity is calculated using manufacturing information of model, which effectively supports quantitative analysis of any MC and sub-capacity.

Introduction

In the wake of the third industrial revolution in United States and “industrial 4.0” strategy in Germany, China, another manufacturing super power, is planning Chinese version of “industrial 4.0”- “Made in China 2025”. Customizing with Chinese national situation, Professor Guo Chongqing, the academician of Chinese Academy of Sciences, emphasized the importance of MC and resources.

In order to integrate MC, there are three questions to be answered: first, to determine which kind of MC is needed; second, to analyze MC in different enterprises per specific requirement; third, to figure out which enterprise(s) meets requirement based on MC evaluation. To answer the first question, we need to clarify the connotation of MC, which is the basis of MC analysis. Currently, from macro strategic economy and micro resource perspectives, scholars, both domestic and overseas, provides definition of MC. In the view of macro strategic economy, scholars, represented by R. H. Hayes, S. C. Wheelwright, Andreas, Eloisa Diaz-Garrid[1-2], point out that MC is comprised of cost, quality, flexibility, innovation, service, environment and the relationship among each element. In the view of micro, Luo yongliang[3] and other scholars perceive MC as a capacity of integrating and configuring manufacturing resources; C. Liu[4] and some scholars define MC as an effective integration of resources in the process of manufacturing work. So far, there is no general definition and standard of MC. Different research views lead to different definitions of MC. So, research purpose must be considered when defining MC.

Besides, during manufacturing, manufacturing capacity and sub-capacities are a certain level achieved after integrating several manufacturing information. In order to do MC qualitative and quantitative analysis, we need to describe the relationship among manufacturing information, MC, and manufacturing sub-capacity. For the moment, relative research is only a few in references retrieved. Though, in paper [5], process capability of processing system has been formally described, to provide more persuasive evidence to MC analysis and to analyze more accurate and faster, further information breakdown is needed.

In conclusion, the concepts of MC and production processing capacity, the sub capacity of MC, are provided based on previous research in this article. Moreover, manufacturing sub-capacity, especially production processing capacity and relative information, is decomposed in details and is formally represented by adopting set theory. The paper presents the relationship model of MC and information, providing information support for MC calculation and evaluation. Finally,

manufacturing sub-capacity is calculated by applying information in the model, which gives strong evidence and method to quantitative analyze any manufacturing sub-capacity and MC.

Manufacturing Capacity Definition

Capacity is the condition and level to achieve some goal or task. Shown in layer ①-④ of Fig.1. It determines what enterprises could do. Any enterprise, who owns certain capacity, may not compete with others. But competing with others is a way of showing capacity.

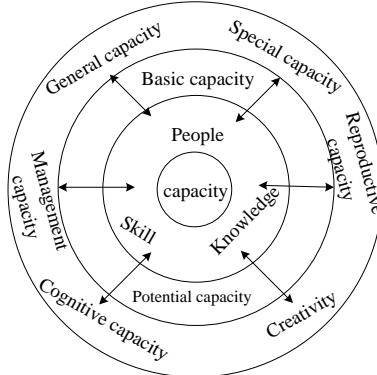


Fig.1 Connotation of capacity

According to the concept of manufacturing, combining the connotation of MC and competitiveness, MC is a comprehensive capacity system containing all capacity in product manufacturing process, as shown in Fig.1. In conclusion, the MC is defined in this paper:

Definition 1: For achieving the goal of less production time, lower production cost, less pollution to environment and higher processing quality, the skills, technology, knowledge and resources a specific enterprise has are organized and innovated effectively in a certain range, the research and development achievements satisfying consumers requirement are translated into batch production capabilities complying with the design requirement making use of a certain amount of processing equipments.

Based on definition 1, enterprise manufacturing capacity can be decomposed continuously into sub-capacity step by step, and each sub-capacity can be decomposed into manufacturing information.

Formalized Representation of Manufacturing Information

Formalized Representation of Production Processing Capacity Information. production processing capacity refers to the processing capacity aiming at producing Hi-tech products in maxi volume, under appropriate and advanced organization conditions in a certain period of time. It can be represented formally as: $PR = \{ BA, J, I \}$. Where, BA, J, I represents respectively for basic attribute information,

Formalized Representation of Processing Capacity. According to the influencing factors of processing capacity, processing capacity can be represented formally as: $J = \{ WT, E, C, P, TP, WO, LC, HR, MS, OT \}$. Where, $WT, E, C, P, TP, WO, LC, HR, MS, OT$ represents respectively workshop type, machining equipment, processing characters, performance qualities, technological processes, operation plan, workshop logistic control, human resource, materials storage; other factors.

Formalized Representation of Machining Equipment. As the basis of manufacturing, the level of product manufacturing depends on machining equipments having strong processing capacity. Machining equipment can be represented formally as $E = \{ EM, EP_{EM}, EB, ET, EP_{ET}, \dots, OT \}$. Where, EM stands for equipment type, consisting of heat treatment equipment $EM_{(1)}$, forging equipment $EM_{(2)}$, machine tool $EM_{(3)}$ etc. $EP_{EM}, EB, ET, EP_{ET}, OT$ represents respectively equipment parameters, productive capacity of equipment, tool parameters, other information.

Formalized Representation of the Device Type. Based on processing object, each type can be divided into several groups. Each group is divided into several type and is decomposed step by step. It can be represented as $EM_{[i_1, i_2, \dots, i_j, \dots, i_n]}$, $i_1, i_2, \dots, i_j, \dots, i_n$ represents layer j ($j = 1, 2, \dots, n$), n represents the number of layers, $i_j = 1, 2, \dots, m$ represents equipment m of layer j .

Taking an example of machine tool, equipment 5 of layer 1 can be represent $EM_{[3]}$, then machine tools can be divided into general-purpose machine tool $EM_{[3,1]}$, precision machine tool $EM_{[3,2]}$, high precision machine tool $EM_{[3,3]}$ and CNC machine tool $EM_{[3,4]}$, etc.. Then, CNC machine tool can be divided into metal cutting class CNC machine tool $EM_{[3,4,1]}$, metal forming CNC machine tool $EM_{[3,4,2]}$, CNC special machining tool $EM_{[3,4,3]}$, other types of CNC machining tool $EM_{[3,4,4]}$, etc..

Formalized Representation of Production Capacity Information. Production capacity for processing equipment is relevant to equipment quantity, efficient working time and production efficiency of equipment. It can be represented as: $EB = \{Q_i, L_i, H_O, \eta, \theta, S, F_O, H_e, t_d, A, n_E\}$ Where, Q_i , L_i , H_O , η , θ , S , F_O , H_e , t_d , A , n_E represents respectively output, amount of labor, working time per year, plan utilization of equipment system work time, downtime ratio of equipment planning repair, idle time of equipment planned repair, equipment system work time, the effective work plan(hour) of one equipment planning period (year), time quota of one product processed on the equipment(hour per piece), workshop production area, the number of equipment.

Formalized Representation of Technological Innovative Capacity Information. Because different people have different views to analyze and evaluate research of innovative capacity, in this paper, considering the production and processing, technological innovative capacity can be represented formally as: $I = \{n_R, n_p, n_{dp}, E_{lab}, E_{R&D}, E_{\overline{R&D}}, S_{R&D}\}$. Where, n_R , n_p , n_{dp} , E_{lab} , $E_{R&D}$, $E_{\overline{R&D}}$, $S_{R&D}$ denote respectively the number of R&D institutions cooperating with external business, the number of patent ownership, the number of project developing, the level of laboratory, input-intensity of R&D, input-intensity of technology import, retrofit funds and success rate of R&D.

Manufacturing Capability and Information Relation Model Establishment

Based on the relationship of MC, sub-capacity and information, manufacturing capability is described in multi-dimensional space. The whole entity stands for MC, irregular curved surface expresses a manufacturing sub-capability, the circle represents relevant information of manufacturing sub-capability, Φ represents a functional relationship formed when all manufacturing sub-capacity get together. Ω represents constraint conditions, namely enterprise requirement.

Let Φ define in the closed region Ω , the volume after computing multiple integral is the total MC. So, MC and information relation model is established by Eq.(1). By the above definition and formalized representation of relevant information, production processing capacity information can be decomposed hierarchically as:

$$MC = \iiint_{\Omega} \dots \int \Phi(\dots, \{BA, \{WT, \{\{EM_{[1]}, EM_{[2]}, \{EM_{[3,1]}, EM_{[3,2]}, EM_{[3,3]}, \{EM_{[3,4,1]}, EM_{[3,4,2]}, \\ EM_{[3,4,3]}, EM_{[3,4,4]}, \dots\}, \dots\}, EP_{EM}, Q_i, L_i, H_O, \eta, \theta, S, F_O, H_e, t_d, A, n_E, ET, EP_{ET}, \dots, OT\}, (1) \\ C, P, TP, WO, LC, HR, MS, OT\}, \{n_R, n_p, n_{dp}, E_{lab}, E_{R&D}, E_{\overline{R&D}}, S_{R&D}\}\}, \dots) dV$$

In Eq.(1), the number of double integral equals the number of parameters in Φ .

Due to the dimension of information is different, if MC needs to be quantitatively disposed, all information must be carried out normalization processing.

Calculation and Analysis of Sub-capacity and Information

In the model, Information of EB can be calculated. This paper, taking EB for example, computation process is shown as follows. In the paper[6], four kinds of products having similar structure and process have been produced in a workshop, output and amount of labor, see Table2. $t_d = 5, H_e = 4650, n_E = 6$.

Table1 Output and amount of labor about four kinds of products

| Parameters | Name of Product | | | |
|------------|-----------------|------|------|-----|
| | A | B | C | D |
| Q_i | 2100 | 1500 | 1000 | 800 |
| L_i | 20 | 40 | 50 | 60 |

Computing $\max[Q_i \times L_i] = 1500 \times 40 = 60000$ for A, B, C, D , So B is chosen as typical product.

Productive capacity of equipment group: $P_B = H_e \cdot n_E / t_d = 4650 \times 6 / 5 = 5580$

Conversion ratio of output: $K_A = L_A / L_B = 20 / 40 = 0.5, K_B = 1, K_C = 1.25, K_D = 1.5$

The output of each specific product though conversion: $Q_{dA} = K_A \cdot Q_A = 2100 \cdot 0.5 = 1050, Q_{dB} = 1500, Q_{dC} = 1250, Q_{dD} = 1200$

Proportion of each specific product output: $d_A = Q_{dA} / (Q_{dA} + Q_{dB} + Q_{dC} + Q_{dD}) = 1050 / 5000 = 0.21, d_B = 0.3, d_C = 0.25, d_D = 0.24$

Production capacity of each specific product: $P'_A = P_B d_A / K_A = 5580 \cdot 0.21 / 0.5 = 2344, P'_B = 1674, P'_C = 1116, P'_D = 893$

Summary

Having focused on describing the relation between MC and information, this paper mainly defines MC and production processing capacity. Moreover, MC is decomposed and formally represented by adopting set theory, especially production processing capacity and relative information, in details. Then, the relationship model is presented. Last, some manufacturing sub-capacity is calculated using manufacturing information of model, which effectively supports quantitative analysis of any MC and sub-capacity

The model and methodology illustrated in the paper may still need further improvement. No doubt that further research is needed with regards to manufacturing information acquisition.

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