Scientific
Research
Publishing

# Methods of Importance Evaluation for Information Subsystems in Manufacturing Enterprises Based on Centrality

## Zhiting Song, Yanming Sun, Jingrong Yi, Li Ni

School of Business Administration, South China University of Technology, Guangzhou, China
Email: szt05_scut@163.com, meymsun@scut.edu.cn, jryi@scut.edu.cn, riskll@qq.com

## Abstract

**Determining the importance of information subsystems is critical to the construction and maintenance of the information systems in manufacturing companies. From the perspective of the interactions among subsystems, several centrality models are developed to assess the importance of subsystems by using software called Code Blocks. A case study is done to test the methods. The results can provide an objective basis for decision making in management activities of an information system, such as information system planning and maintenance, resource allocation and utilization in manufacturing enterprises. The proposed methods will provide new approaches to the quantitative evaluation of the importance of information subsystems.**

## 1. Introduction

Manufacturing companies often cannot scientifically determine the priorities of information subsystems in management activities such as information system planning, resource allocation and utilization or information system maintenance. As a result of these limitations, phenomena such as low customer satisfaction, low productivity and systematic failures frequently appear in enterprises [1]. Therefore, the evaluation of information subsystems is essential to be considered as an important management activity for manufacturing companies.

Most studies of an information system focus on internal structures and properties of approximation spaces [2]-[11]. Missing from the traditional information system, relevant research on the importance of information subsystems is neglected from previous literature. The evaluation in other domains relies mainly on a series of

indexes to reflect the importance of objects. The index values are derived from expert evaluations or sample data. Based on expert evaluations, AHP, Delphi, fuzzy comprehensive evaluation and integrated models of them have rapidly penetrated into and are widely applied to many fields of engineering, economy and finance, transportation, ecosphere, energy and etc. [1] [12]-[21]. Given the prevalence of expert evaluations, an interesting question becomes whether or not other methods can objectively assess the importance of subjects. The regression model is one of the approaches in point, which is tested effectively to evaluate the importance of variables in theory and demonstrated its feasibility in practice [22]-[24]. Based on sample data, other evaluative methods including principal component analysis, grey relational analysis, entropy evaluation methods and factor analysis are available and widely used in the manufacturing, agricultural, communications and tourism industries [25]-[32].

However, the evaluation methods of experts are subjective while the evaluation methods based on sample data are ex-post. These methods are difficult to objectively evaluate objects in advance. Centrality based evaluation methods take the nodes in systems or networks as evaluative subjects, and evaluate importance of the nodes by the real interactions between nodes. These centrality based methods provide new approaches for importance evaluation of information subsystems.

Centrality based evaluation methods are derived from social networks [33]. Until now, these methods have already extended to fields of physics, psychology, transportation, economy and finance, and etc. [34]. Some scholars have also demonstrated practicability and effectiveness of centrality in those fields [35]-[42]. Nevertheless, centrality based methods have not been applied to the information systems of firms. The information systems of manufacturing enterprises are composed of many subsystems and the interactions between all of the adjacent subsystems. Considering information subsystems as nodes or vertexes and interactions as edges between the nodes, the structures of information systems are then transformed into network structures. From the perspective of interactions, the centrality models are applied to determine the importance of each information subsystem. We will discuss the implementation of our model that uses the example of an elevator enterprise. Results can supply theoretical direction for specific practices in management activities of an information system.

The paper is organized as follows. The structure for a manufacturing enterprise information system is presented in Section 2. Centrality models that are used to evaluate the importance of information subsystems are shown in Section 3. The implementation of centrality based models for an elevator enterprise is shown in Section 4. Finally it is conclusions, acknowledgements.

## 2. Structure for Information Systems in Manufacturing Companies

Information systems in different manufacturing companies are varied. To facilitate our research, the article puts forward a typical and functional structure for the purpose of representing diverse information systems. The division standard of the proposed structure of the information system is in accord with the functions that are covered by the commercial software in current time. Its scope limits to the information system in applied layer, excluding operating system, security management system etc. ERP (Enterprise Resource Planning) System does not contain the systems of CRM (Customer Relationship Management) System, SCM (Supply Chain Management) System, HR (Human Resource) System, etc. As is shown in **Figure 1**, the combination of a line and an arrow stands for interaction between two subsystems. Arrow is the direction that information flows. Thus, the double-headed arrow means the information transmission between the two subsystems is bidirectional while the single arrow means unidirectional.

The networks include nodes and edges, in which nodes are subjects and edges are relations between subjects. In the network structure of the information system, nodes on behalf of subsystems while edges stand for information flow relationship between subsystems. **Figure 2** shows the network structure of the information system. Nodes are adjacent if they are connected by an edge. The nodes arrows pointing to are downstream nodes, otherwise upstream nodes. There are two edges between nodes if a line has two arrows.

**Figure 2** displays that some nodes have some obvious characteristics of strongly gathering or radioing information, and being close to others. All these apparent features indicate the importance of nodes. However, these visual features still cannot multi-dimensionally reflect the importance of nodes. From interactions perspective, the paper proposes centrality based methods to evaluate the importance of subsystems multi-dimensionally.

## 3. Centrality Models for Information Subsystems

Information systems are heterogeneous systems [43] [44]. The functions of each system are diverse. Conse-
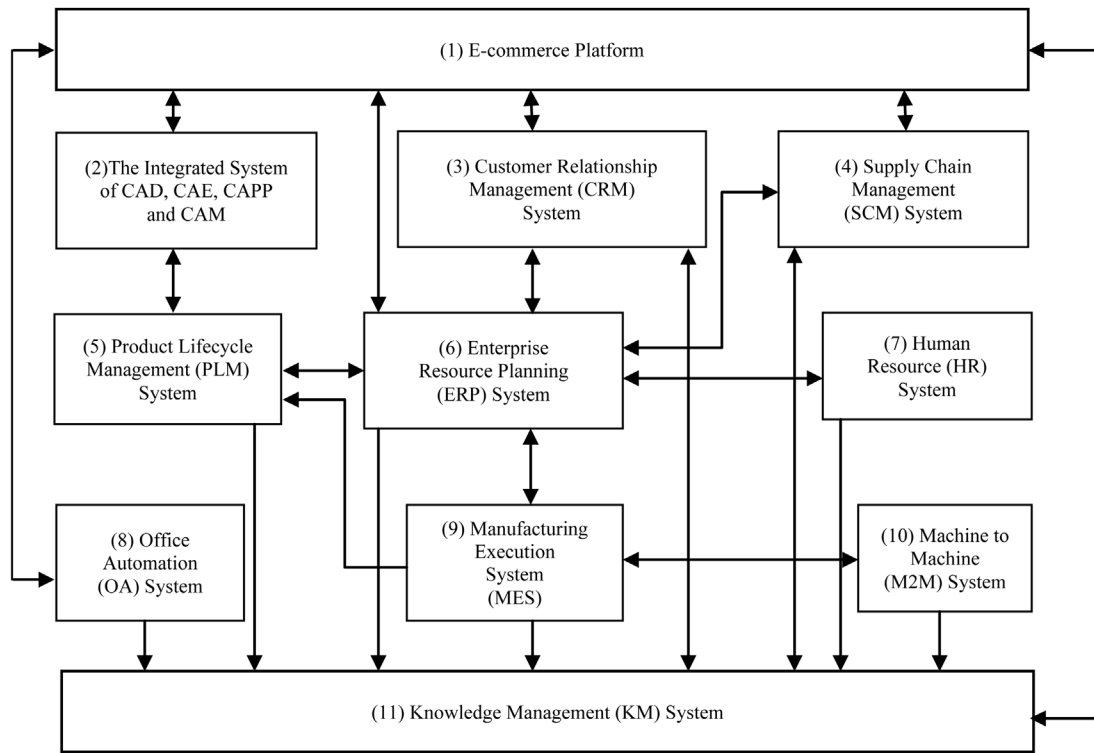
**Figure 1.** The functional structure of the information system in the manufacturing enterprise.
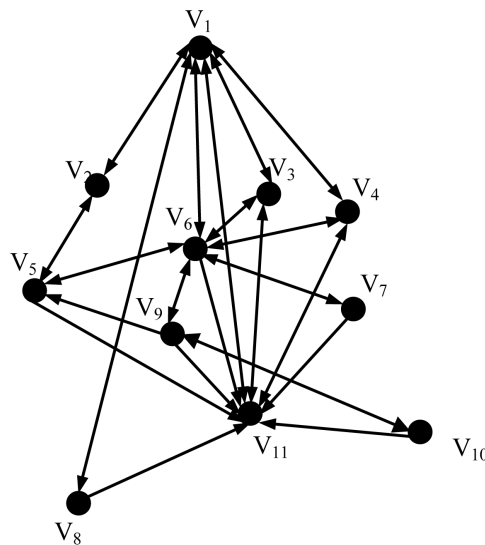


**Figure 2.** The network structure of the information system presented in **Figure 1**.

quently, their importance for enterprise is not the same. The network structures of enterprise information systems are real network, and edges between subsystems are determined when enterprises planning their information systems. Hence, nodes are connected by defined laws, and the network structures of information systems are certain. Centrality is widely employed to analyze the properties in various networks, and different measures of centrality capture aspects of what it means for a node to be important to the network. Therefore, the paper applies several centrality models evaluate the importance of subsystems. In order to objectively evaluate the importance of subsystems before put into use, centrality models are established.

## 3.1. Model Assumptions

1) The route that information follows is path;
2) When information passing $v_i$, it can stop at $v_i$ and also can flow to its downstream nodes;
3) The possibilities that information stop at $v_i$ or flow to each of its downstream nodes are the same;
4) The distance between any two adjacent nodes is 1;
5) The information capacity between any two adjacent nodes is infinite.

## 3.2. Model Establishment

The centrality models are constructed in the perspectives of the ability to gather or radio information to their neighborhood, the ability to control information, the ability to affect system function, information transmission efficiency and the amount of information. Among the diverse measures of centrality, degree centrality and semi-local centrality reflect the ability of a node to influence its surrounding nodes. Besides, betweenness centrality and flow betweenness centrality depict the ability of nodes to control information while closeness centrality shows information transmission efficiency of nodes. Finally, entropy centrality measures the amount of information of each node, and residual closeness centrality shows the influence of each node to system function.

### 3.2.1. The Ability to Influence Surrounding Nodes

1) Out-degree centrality and in-degree centrality

For directed network, degree centrality usually refers to out-degree centrality and in-degree centrality. Out-degree centrality and in-degree centrality of a vertex $v_i$ are respectively marked as $C^{d+}(v_i)$ and $C^{d-}(v_i)$. $C^{d+}(v_i)$ and $C^{d-}(v_i)$ indicate the number of downstream nodes and upstream nodes that directly influenced by vertex $v_i$. The vertex $v_i$ with bigger values of $C^{d+}(v_i)$ and $C^{d-}(v_i)$ can influence more vertexes in its neighborhood. Therefore, the vertex $v_i$ is more important. On reference [45], the expression of $C^{d+}(v_i)$ and $C^{d-}(v_i)$ are written as

$$C^{d+}\left(v_i\right) = d^+\left(v_i\right) \tag{1}$$

$$C^{d-}\left(v_i\right) = d^-\left(v_i\right) \tag{2}$$

$d^+(v_i)$ and $d^-(v_i)$ denote the out-degree and in-degree of a vertex $v_i$.

2) Semi-local centrality

To nodes with the same out-degree and in-degree, we cannot pick out which is more critical just through degree centrality method. In such a case, semi-local centrality is a valid approach. This method reflects the ability of a node to affect other nodes in its indirect neighborhood [46]. The node with bigger value of semi-local centrality is more important. The expression of semi-local centrality for each node is described by the equation

$$C^{sl} = 10^{-c(v_i)} \sum_{v_j \in V^f(v_j)} \left(d^+\left(v_j\right)+1\right) \tag{3}$$

$$c\left(v_i\right) = \frac{N\left\{e_{jk} | v_j, v_k \in V^f\left(v_i\right), j \neq k\right\}}{d^+\left(v_i\right)\left\{d^+\left(v_i\right)-1\right\}} \tag{4}$$

$c(v_i)$ is the clustering coefficient of a vertex $v_i$. Let $e_{jk}$ as the edge between vertex $v_j$ and vertex $v_k$, and information flows from vertex $v_j$ to vertex $v_k$. $V^f(v_i)$ is the set of downstream vertexes of vertex $v_i$, and $N\{e_{jk}/v_j,v_k \in V^f(v_i), j \neq k\}$ is the number of the edges that are composed by the downstream nodes of vertex $v_i$. Let $c(v_i) = 0$ if $d^+(v_i) \leq 1$.

### 3.2.2. The Ability to Control and Transfer Information

1) Betweenness centrality

A vertex $v_i$ can control information to a great extent if there are many geodesics passing through it. Under the circumstances, the vertex $v_i$ has a big value of betweenness centrality. What's more, the node with high value of betweenness is important [47]. Betweenness centrality calculates the number of geodesics passing by each node, and is denoted by $C^b(v_i)$. We need appropriately weight if there are multiple geodesics [48]. For example, from vertex $v_1$ to vertex $v_3$, there are two geodesics, they are geodesic $g_1(v_1,v_3) = \{v_1,e_{12}, v_2,e_{23}, v_3\}$ and geodesic $g_2(v_1,v_3) = \{v_1,e_{14}, v_4,e_{43}, v_3\}$. However, geodesic $g_1(v_1,v_3)$ is the only geodesic via vertex $v_2$, so $C^b(v_2) = 0.5$.

2) Flow betweenness centrality

Betweenness centrality merely considers the ability to control information of each node in geodesics. However, information is not always transferring by geodesics [49]. Flow betweenness centrality counts the number of paths via each node [50]. The high value of flow betweenness centrality of a vertex $v_i$ means that vertex $v_i$ can strongly control information. The flow betweenness centrality of a vertex $v_i$ in directed network is expressed by following equations

$$N^{v_i} = \sum_{t=1,t<j}^{n-1}\sum_{j=2}^{n}N^{v_i}\left(v_t,v_j\right) + \sum_{t=2,t>j}^{n}\sum_{j=1}^{n-1}N^{v_i}\left(v_t,v_j\right) \tag{5}$$

$$N = \sum_{i=1}^{n}\left\{\sum_{t=1,t<j}^{n-1}\sum_{j=2}^{n}N^{v_i}\left(v_t,v_j\right) + \sum_{t=2,t>j}^{n}\sum_{j=1}^{n-1}N^{v_i}\left(v_t,v_j\right)\right\} \tag{6}$$

$$C^f b\left(v_i\right) = N^{v_i}/N \tag{7}$$

$N^{v_i}$ is the number of paths that passing through vertex $v_i$, and $N$ is the total number of paths in the directed network.

3) Closeness centrality

Closeness centrality measures the efficiency of information transmission for each node. The closeness centrality of a vertex $v_i$ counts the total distance from vertex $v_i$ to the remaining vertexes in the network [45]. The vertex with short distance can transmit information efficiently. Closeness centrality in directed networks is defined as

$$C^c\left(v_i\right) = \sum_{t=1,t<j}^{n-1}\sum_{j=2}^{n}L\left(g^{v_i}\left(v_t,v_j\right)\right) + \sum_{t=2,t>j}^{n}\sum_{j=1}^{n-1}L\left(g^{v_i}\left(v_t,v_j\right)\right) \tag{8}$$

$g^{v_i}\left(v_t,v_j\right)$ is the geodesic starting at vertex $v_t$, ending at vertex $v_j$ and passing by $v_i$. $L\left(g^{v_i}\left(v_t,v_j\right)\right)$ is the length of the geodesic $g^{v_i}\left(v_t,v_j\right)$.

### 3.2.3. The Amount of Information and the Effect to System Function

1) Entropy centrality

In general, there are $N(v_i,v_j)$ paths from vertex $v_i$ to vertex $v_j$. Let $g_k(v_i,v_j)$ be such a path, and its length is $L(g_k(v_i,v_j))$. The probability that a vertex $v_t$ transfers information to its downstream vertexes is given by:

$$\mu^k\left(v_t\right) = \frac{1}{d^+\left(v_t\right)+1} \tag{9}$$

and the probability that information stops at vertex $v_t$ is

$$\pi^k\left(v_t\right) = \frac{1}{d^+\left(v_t\right)+1} \tag{10}$$

The vertexes between vertex $v_i$ and vertex $v_j$, and travelling along the path $g_k(v_i,v_j)$ are $v_i=v_0, v_1, \ldots, v$ $(L(g_k(v_i,v_j))) = v_j$. The information transfer probability from vertex $v_i$ to vertex $v_j$ in the path $g_k(v_i,v_j)$ is

$$P^k\left(v_i,v_j\right) = \pi^k\left(v_j\right)\prod_{t=0}^{L\left(g_k\left(v_i,v_j\right)\right)-1}\mu^k\left(v_t\right) \tag{11}$$

For all the paths from vertex $v_i$ and vertex $v_j$, the ending and transfer probabilities of vertex $v_j$ are the same. Therefore, the transfer probabilities from vertex $v_i$ to vertex $v_j$ are summed as

$$P\left(v_i,v_j\right) = \sum_{k=1}^{N\left(v_i,v_j\right)}\prod_{t=0}^{L\left(g_k\left(v_i,v_j\right)\right)}\mu^k\left(v_t\right) \tag{12}$$

Finally, entropy centrality of a vertex $v_i$ is

$$C^e\left(v_i\right) = \sum_{j=1}^{N}-P\left(v_i,v_j\right)\log_2 P\left(v_i,v_j\right) \tag{13}$$

Entropy centrality [48] shows the quantity of information that each node contains, and the node with more information is more vital.

2) Residual closeness centrality

Residual closeness centrality reflects the significance of each node to the function of the information system. The node will be more important if removing this node leads the system more vulnerable [51]. Specifically, after the removal, the node with smaller value of residual closeness centrality can influence the system function more greatly and thus it is more important. The residual closeness centrality of a vertex $v_i$ in the directed networks is described as

$$C^{rc}(v_i) = \sum_{t,t<j}\sum_j \frac{1}{2^{L^{(-v_i)}(g(v_t,v_j))}} + \sum_{t,t>j}\sum_j \frac{1}{2^{L^{(-v_i)}(g(v_t,v_j))}} \tag{14}$$

After removing the vertex $v_i$, $g(v_t, v_j)$ is one of the geodesics between vertex $v_t$ and vertex $v_j$, and its length is $L^{(-v_i)}(g(v_t,v_j))$. Let $L^{(-v_i)}(g(v_t,v_j)) = \infty$ if there is no path from vertex $v_i$ to vertex $v_j$.

## 4. Case Study: Application to an Elevator Manufacturing Enterprise

This section presents an application of the proposed methods in an elevator manufacturing enterprise. We use the elevator manufacturing enterprise as an example because: 1) it has a relatively long history of 30 years and it is the biggest elevator manufacturing enterprise in southern China; 2) driven by the advanced technology and dynamic requirements, the enterprise is going through a transformation; 3) the company spends a lot on constructing and perfecting its information system for its development highly relies on information system. However, with the relatively well-developed information system, some problems remain appear.

### 4.1. Problems Description

Since it set up, the enterprise has implemented a series of information subsystems, such as ERP System, Manufacturing Execution System (MES) and Knowledge Management (KM) System. In response to requirements, the enterprise devotes itself to developing new systems and improving the old systems. Now information systems have been widely applied in the company. **Figure 1** shows the function structure of the information system in the enterprise. Although the function structure was relatively perfect, some unfavorable phenomena were still very serious. For example, the consumer satisfaction was still low in accordance with the report from the marketing department; the productivity was poor and the failures of the information system had not been improved. Under this situation, the enterprise thoroughly analyzed all the problems. They found that: 1) the implementation order of subsystems cannot meet the business requirements well, for the needed subsystems had not been well implemented while the running systems were not required much; 2) the resource distribution to subsystems was unreasonable when function structure of the information system was relatively completed, for example some subsystems occupied large number of resources of which other subsystems needed extremely; 3) in addition, when maintaining the information system, IT department treated subsystems equally so that the subsystems with bugs occurred frequently received insufficient attention before bugs occurred.

### 4.2. Results Analysis

The centrality models in the paper can be used to find out the vital subsystems. Results provide decision basis for management activities of information system, such as the step-by-step implementation, resource distribution and maintenance of the subsystems. As is shown in **Figure 2**, there may be more than one geodesics or paths between nodes for the directed relationships between subsystems, and it is difficult to find out all the geodesics or paths artificially. Therefore, software called Code Blocks is used to aid the computation of centrality for each node. **Tables 1-3** show the centrality values and ranks of each node.

1) As is shown in **Tables 1-3**, the capability of ERP System (vertex $v_6$) to influence its surrounding subsystems is strong. Moreover, its transmission efficiency of information, controlling ability of information and influence on system function all rank first. Besides, ERP System contains much information. ERP System shows the optimal combination for information since it integrates the information on main resources of purchase, production, inventory, distribution, finance and human resources etc. Thus, it contains abundant information and

**Table 1.** Statistics for the ability to influence surrounding nodes.

| | Vertex | $v_1$ | $v_2$ | $v_3$ | $v_4$ | $v_5$ | $v_6$ | $v_7$ | $v_8$ | $v_9$ | $v_{10}$ | $v_{11}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $C^{d+}(v_i)$ | 6 | 2 | 3 | 3 | 3 | 7 | 2 | 2 | 4 | 2 | 3 |
| Value | $C^{d-}(v_i)$ | 6 | 2 | 3 | 3 | 3 | 6 | 1 | 1 | 2 | 1 | 9 |
| | $C^{sl}(v_i)$ | 12.16 | 11.00 | 2.81 | 2.81 | 4.28 | 14.50 | 3.79 | 1.10 | 7.22 | 2.85 | 0.01 |
| | $C^{d+}(v_i)$ | 2 | 8 - 11 | 4 - 7 | 4 - 7 | 4 - 7 | 1 | 8 - 11 | 8 - 11 | 3 | 8 - 11 | 4 - 7 |
| Rank | $C^{d-}(v_i)$ | 2 - 3 | 7 - 8 | 4 - 6 | 4 - 6 | 4 - 6 | 2 - 3 | 9 - 11 | 9 - 11 | 7 - 8 | 9 - 11 | 1 |
| | $C^{sl}(v_i)$ | 2 | 3 | 8 - 9 | 8 - 9 | 5 | 1 | 6 | 10 | 4 | 7 | 11 |

**Table 2.** Statistics for the ability to control and transfer information.

| | Vertex | $v_1$ | $v_2$ | $v_3$ | $v_4$ | $v_5$ | $v_6$ | $v_7$ | $v_8$ | $v_9$ | $v_{10}$ | $v_{11}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $C^b(v_2)$ | 27.67 | 1.92 | 1.57 | 1.57 | 4.83 | 36.75 | 0.00 | 0.00 | 12.50 | 0.00 | 12.17 |
| Value | $C^{fb}(v_i)$ | 0.18 | 0.06 | 0.09 | 0.09 | 0.10 | 0.19 | 0.02 | 0.01 | 0.08 | 0.02 | 0.17 |
| | $C^c(v_i)$ | 15 | 22 | 18 | 18 | 19 | 13 | 21 | 23 | 17 | 21 | 22 |
| | $C^b(v_2)$ | 2 | 6 | 7 - 8 | 7 - 8 | 5 | 1 | 9 - 11 | 9 - 11 | 3 | 9 - 11 | 4 |
| Rank | $C^{fb}(v_i)$ | 2 | 8 | 5 - 6 | 5 - 6 | 4 | 1 | 9 - 10 | 11 | 7 | 9 - 10 | 3 |
| | $C^c(v_i)$ | 2 | 9 - 10 | 4 - 5 | 4 - 5 | 6 | 1 | 7 - 8 | 11 | 3 | 7 - 8 | 9 - 10 |

**Table 3.** Statistics for the amount of information and the effect to system function.

| | Vertex | $v_1$ | $v_2$ | $v_3$ | $v_4$ | $v_5$ | $v_6$ | $v_7$ | $v_8$ | $v_9$ | $v_{10}$ | $v_{11}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Value | $C^e(v_i)$ | 2.03 | 1.94 | 1.95 | 1.95 | 2.08 | 2.16 | 2.02 | 1.93 | 2.37 | 2.10 | 1.86 |
| | $C^{rs}(v_i)$ | 20.31 | 25.63 | 25.19 | 25.19 | 24.06 | 16.84 | 26.56 | 27.75 | 23.25 | 27.38 | 23.50 |
| Rank | $C^e(v_i)$ | 5 | 9 | 7 - 8 | 7 - 8 | 4 | 2 | 6 | 10 | 1 | 3 | 11 |
| | $C^{rs}(v_i)$ | 2 | 8 | 6 - 7 | 6 - 7 | 5 | 1 | 9 | 11 | 3 | 10 | 4 |

can strongly control information. In order to efficiently combine resources and roundly reflect its status, EPR System should strongly gather and radio information on a large scale. Furthermore, ERP System needs quickly transmit the integrated information to make timely decisions.

2) The E-commerce platform (vertex $v_1$) has prominent influence on the information system function although it contains little information. It can efficiently transmit and strongly control, gather and radio the information. For businesses, E-commerce platforms play an important role in presenting enterprise image, advertising the product and increasing its trade opportunities. So the platform needs to interact with other subsystems as much as possible to promote the mutual understanding between consumers and enterprises themselves. Meanwhile, it should accurately transmit the external information to other internal subsystems in time to facilitate the lateral interaction and information sharing among subsystems. In fact, the E-commerce platform is a dynamic system which frequently transfers information to other systems in small batches. This transferring mode of information enables the enterprise to respond to requirements quickly and timely. E-commerce platform is the system with small amount of information, and it is the feature that makes it possible to accept the outside information. E-commerce platform is critical to system function for it is the most direct system to make profits.

3) MES (vertex $v_9$) has the relatively strong ability to gather and radio information, to influence system function and to transmit information efficiently. The most notable is that MES contains the largest amount of information. As a workshop-oriented management information system, MES covers all the information involved in production activities, includes numerous models of resource distribution, status management, operation, assignment of production cells and control of file etc. The products output by MES are the profitable carriers for an enterprise. MES is the basic and special subsystem of the manufacturing enterprise, and other subsystems exist by assisting it to complete production. Therefore, MES must possess relatively strong ability to radio and transfer information. Only in this way can it be better to interact with other systems, then to guarantee the order of productive activities. In addition, due to its own features, KM System (vertex $v_{11}$) is the most capable to collect

information from its neighborhood. As the electronic library of an enterprise, KM System holds and manages the knowledge assets from other systems.

In conclusion, ERP System in the manufacturing company has the largest values of centrality in accordance with the case, and it is the core of the information system. The new features of consumer participation and network collaboration in supply chain in manufacturing enterprises attribute to the relatively high values of centrality for E-commerce platform. Besides, MES still possesses relatively high values of centrality when service accounts for a large proportion in the manufacturing enterprise. The importance of E-commerce platform and MES is only next to ERP System.

After distinguishing the key information subsystems, the enterprise gave preference to the critical subsystems in the subsequent activities of resource allocation, system improvement and maintenance. After the improvement, the information system operates more smoothly and the relationships between subsystems become more coordinated. From visual perspective, system failures strikingly decrease, productivity improves, and so does the customer satisfaction.

## 5. Conclusions

We construct centrality models to evaluate the importance of information subsystems mainly from three aspects. The paper uses an elevator manufacturing enterprise in Guangzhou as an example. Our analysis yields a number of managerial insights pertaining to the research questions posed in the introduction. First and foremost, the priorities of subsystems in manufacturing companies are not the same. In our study of a typical manufacturing enterprise, the importance of the 11 subsystems varies. Moreover, ERP System, E-commerce platform and MES are the top 3 subsystems in manufacturing enterprises. Second, when manufacturing firms are greatly influenced by the dynamic requirements and the rapid development of the Internet, E-commerce platform is increasingly critical to them. Therefore, manufacturing enterprises should pay special attention to the E-commerce platform in the management activities of information systems. Third, service is increasingly vital to manufacturing enterprises. Consequently, the status of MES has declined but it is still an important part of the information systems. Finally, let the key information subsystems be the decision basis in the activities of planning and maintenance, resource allocation and utilization etc for the information systems can reduce systematic failures, enhance productivity and increase customer satisfaction.

The proposed centrality based evaluation methods can objectively evaluate the importance of information subsystems in advance. The application of Code Blocks makes the calculation more scientific, accurate and rigor. Methods proposed can avoid numerous data collection, eliminate the influence of subjective factors and avert irremediable consequence that feedback control usually cannot make up for. The approaches applied are applicable for complex systems of enterprise information systems, transportation systems, management systems.

## Acknowledgements

## References

[1] Yau, C. and Davis, T. (1993) Using Analytic Hierarchy Process (AHP) to Prioritize Auditing Tasks for Large-Scale Software Systems. *Journal of Systems Management*, **44**, 26-31.

[2] Yao, Y.Y. (1998) Relational Interpretations of Neighborhood Operators and Rough Set Approximation Operators. *Information Sciences*, **111**, 239-259. http://dx.doi.org/10.1016/S0020-0255(98)10006-3

[3] Skowron, A. and Polkowski, L. (1998) Rough Mereological Foundations for Design, Analysis, Synthesis and Control in Distributed Systems. *Information Sciences*, **104**, 129-156. http://dx.doi.org/10.1016/S0020-0255(97)00078-9

[4] Miao, D.Q. and Hou, L.S. (2004) A Comparison of Rough Set Methods and Representative Inductive Learning Algorithms. *Fundamenta Informaticae*, **59**, 203-219.

[5] Yaoa, Y.Y. (2006) Neighborhood Systems and Approximate Retrieval. *Information Sciences*, **176**, 3431-3452. http://dx.doi.org/10.1016/j.ins.2006.02.002

[6] Chen, D.G., Wang, C.Z. and Hu, Q.H. (2007) A New Approach to Attribute Reduction of Consistent and Inconsistent Covering Decision Systems with Covering Rough Sets. *Information Sciences*, **117**, 3500-3518. http://dx.doi.org/10.1016/j.ins.2007.02.041

[7]    Zhang, H.Y., Zhang, W.X. and Wu, W.Z. (2009) On Characterization of Generalized Interval-Valued Fuzzy Rough Sets on Two Universes of Discourse. *International Journal of Approximate Reasoning*, **51**, 56-70. http://dx.doi.org/10.1016/j.ijar.2009.07.002

[8]    Hu, Q.H., Yu, D. and Guo, M.Z. (2010) Fuzzy Preference Based Rough Sets. *Information Sciences*, **180**, 2003-2022. http://dx.doi.org/10.1016/j.ins.2010.01.015

[9]    Wei, W., Liang, J.Y. and Qian, Y.H. (2012) A Comparative Study of Rough Sets for Hybrid Data. *Information Sciences*, **190**, 1-16. http://dx.doi.org/10.1016/j.ins.2011.12.006

[10]   Zhu, W. and Wang, F.Y. (2012) The Fourth Type of Covering-Based Rough Sets. *Information Sciences*, **201**, 80-92. http://dx.doi.org/10.1016/j.ins.2012.01.026

[11]   Dai, J.H. and Tian, H.W. (2013) Entropy Measures and Granularity Measures for Set-Valued Information Systems. *Information Sciences*, **240**, 72-82.

[12]   Amer, M. and Daim, T.U. (2011) Selection of Renewable Energy Technologies for a Developing County: A Case of Pakistan. *Energy for Sustainable Development*, **15**, 420-435. http://dx.doi.org/10.1016/j.esd.2011.09.001

[13]   Keil, M., Lee, H.K. and Deng, T. (2013) Understanding the Most Critical Skills for Managing IT Projects: A Delphi Study of IT Project Managers. *Information & Management*, **50**, 398-414. http://dx.doi.org/10.1016/j.im.2013.05.005

[14]   Zhang, R., Zhang, H. and Liu, B. (2012) Selection of Reverse-Logistics Servicer for Electronic Products with Fuzzy Comprehensive Evaluation Method. *Grey Systems*: *Theory and Application*, **2**, 207-216.

[15]   Kim, M., Jang, Y. and Lee, S. (2013) Application of Delphi-AHP Methods to Select the Priorities of WEEE for Recycling in a Waste Management Decision-Making Tool. *Journal of Environmental Management*, **128**, 941-948. http://dx.doi.org/10.1016/j.jenvman.2013.06.049

[16]   Tang, Y., Sun, H.H., Yao, Q. and Wang, Y.B. (2014) The Selection of Key Technologies by the Silicon Photovoltaic Industry Based on the Delphi Method and AHP (Analytic Hierarchy Process): Case Study of China. *Energy*, **75**, 474-482.

[17]   Ma, D., Chang, C.C. and Hung, S.W. (2013) The Selection of Technology for Late-Starters: A Case Study of the Energy-Smart Photovoltaic Industry. *Economic Modelling*, **35**, 10-20. http://dx.doi.org/10.1016/j.econmod.2013.06.030

[18]   Ma, Z.L., Shao, C.F., Ma, S.Q. and Ye, Z. (2011) Constructing Road Safety Performance Indicators Using Fuzzy Delphi Method and Grey Delphi Method. *Expert Systems with Applications*, **38**, 1509-1514. http://dx.doi.org/10.1016/j.eswa.2010.07.062

[19]   Joshi, R., Banwet, D.K. and Shankar, R. (2011) A Delphi-AHP-TOPSIS Based Benchmarking Framework for Performance Improvement of a Cold Chain. *Expert Systems with Applications*, **38**, 10170-10182. http://dx.doi.org/10.1016/j.eswa.2011.02.072

[20]   Orencio, P.M. and Fujii, M. (2013) A Localized Disaster-Resilience Index to Assess Coastal Communities Based on an Analytic Hierarchy Process (AHP). *International Journal of Disaster Risk Reduction*, **3**, 62-75. http://dx.doi.org/10.1016/j.ijdrr.2012.11.006

[21]   Chen, C. and Liu, Y. (2007) A Methodology for Evaluation and Classification of Rock Mass Quality on Tunnel Engineering. *Tunnelling and Underground Space Technology*, **22**, 377-387. http://dx.doi.org/10.1016/j.tust.2006.10.003

[22]   Johnson, J.W. (2000) A Heuristic Method for Estimating the Relative Weight of Predictor Variables in Multiple Regression. *Multivariate Behavioral Research*, **35**, 1-19. http://dx.doi.org/10.1207/S15327906MBR3501_1

[23]   Johnson, J.W. and LeBreton, J.M. (2004) History and Use of Relative Importance Indices in Organizational Research. *Organizational Research Methods*, **7**, 238-257. http://dx.doi.org/10.1177/1094428104266510

[24]   Tonidandel, S. and LeBreton, J.M. (2010) Determining the Relative Importance of Predictors in Logistic Regression: An Extension of Relative Weights Analysis. *Organizational Research Methods*, **13**, 767-781. http://dx.doi.org/10.1177/1094428109341993

[25]   Petroni, A. and Braglia, M. (2000) Vendor Selection Using Principal Component Analysis. *Journal of Supply Chain Management*, **36**, 63-69. http://dx.doi.org/10.1111/j.1745-493X.2000.tb00078.x

[26]   Morchid, M., Dufour, R., Bousquet, P., Linarès, G. and Torres-Moreno, J. (2014) Feature Selection Using Principal Component Analysis for Massive Retweet Detection. *Pattern Recognition Letters*, **49**, 33-39. http://dx.doi.org/10.1016/j.patrec.2014.05.020

[27]   Li, J. and Yu, W. (2013) An Improved Grey Incidence Analysis Method Based on TOPSIS Thinking and Its Applications. *Mathematics in Practice and Theory*, **43**, 76-80.

[28]   Guo, X.G. (1998) Application of Improved Entropy Method in Evaluation of Economic Results. *Systems Engineering-Theory & Practice*, **18**, 98-102.

[29] Li, L., Liu, F. and Li, C.B. (2014) Customer Satisfaction Evaluation Method for Customized Product Development Using Entropy Weight and Analytic Hierarchy Process. *Computers & Industrial Engineering*, **77**, 80-87. http://dx.doi.org/10.1016/j.cie.2014.09.009

[30] Geng, J.H., Gao, Q.S. and Zhang, S.Y. (2007) Community Satisfaction Evaluation System's Research Based on AHP and Factor Analysis. *Journal of Systems & Management*, **16**, 673-677.

[31] Ma, Q.H., Li, Y.H., Liang, L.S., Li, Q., Wang, H., Xu, Y.F., Sun, Y.B. and Wang, G.X. (2010) Factor Analysis and Synthetical Evaluation of the Fruit Quality of Dongzao Advanced Selections. *Scientia Agricultura Sinica*, **43**, 2491-2499.

[32] Guo, L., Zhang, Y. and Li, Z.J. (2008) Evaluating the Efficiency of Listed Tourism Companies by Data Reduction Factor and DEA Model. *Chinese Journal of Management*, **5**, 258-262.

[33] Bonacich, P. (1987) Power and Centrality: A Family of Measures. *American Journal of Sociology*, **92**, 1170-1182. http://dx.doi.org/10.1086/228631

[34] Stefani, S. and Torriero, A. (2014) Networks, Topology and Dynamics. *Quality & Quantity*, **48**, 1817-1819. http://dx.doi.org/10.1007/s11135-014-0017-8

[35] Grassi, R. (2010) Vertex Centrality as a Measure of Information Flow in Italian Corporate Board Networks. *Physica A*: *Statistical Mechanics and Its Applications*, **389**, 2455-2464.

[36] Kuzubaş, T.U., Ömercikoğlu, I. and Saltoğlu, B. (2014) Network Centrality Measures and Systemic Risk: An Application to the Turkish Financial Crisis. *Physica A*: *Statistical Mechanics and Its Applications*, **405**, 203-215.

[37] Hossain, L. (2009) Effect of Organizational Position and Network Centrality on Project Coordination. *International Journal of Project Management*, **27**, 680-689. http://dx.doi.org/10.1016/j.ijproman.2008.11.004

[38] Yang, J. (2014) Study on Emotion Spaces with Centrality Measure. *New Ideas in Psychology*, **35**, 11-17. http://dx.doi.org/10.1016/j.newideapsych.2014.06.001

[39] Wang, F., Antipova, A. and Porta, S. (2011) Street Centrality and Land Use Intensity in Baton Rouge, Louisiana. *Journal of Transport Geography*, **19**, 285-293. http://dx.doi.org/10.1016/j.jtrangeo.2010.01.004

[40] Kim, H., Tang, J., Anderson, R. and Mascolo, C. (2012) Centrality Prediction in Dynamic Human Contact Networks. *Computer Networks*, **56**, 983-996. http://dx.doi.org/10.1016/j.comnet.2011.10.022

[41] Dang, Y. and Peng, L. (2012) Hierarchy of Air Freight Transportation Network Based on Centrality Measure of Complex Networks. *Journal of Transportation Systems Engineering and Information Technology*, **12**, 109-114. http://dx.doi.org/10.1016/S1570-6672(11)60207-9

[42] Gonçalves, J.A.M., Portugal, L.D.S. and Nassi, C.D. (2009) Centrality Indicators as an Instrument to Evaluate the Integration of Urban Equipment in the Area of Influence of a Rail Corridor. *Transportation Research Part A*: *Policy and Practice*, **43**, 13-25. http://dx.doi.org/10.1016/j.tra.2008.06.010

[43] Kettinger, W.J., Zhang, C. and Chang, K. (2013) A View from the Top: Integrated Information Delivery and Effective Information Use from the Senior Executive's Perspective. *Information Systems Research*, **24**, 842-860. http://dx.doi.org/10.1287/isre.1120.0473

[44] Systems, H.I., Rantzau, R., Constantinescu, C., Heinkel, U. and Meinecke, H. (2002) Champagne: Data Change Propagation for Heterogeneous Information Systems. In: *Proceedings of the International Conference on Very Large Databases* (*VLDB*), Demonstration Paper, Hong Kong, 20-23 August 2002, 1099-1102.

[45] Freeman, L.C. (1979) Centrality in Social Networks Conceptual Clarification. *Social Networks*, **1**, 215-239. http://dx.doi.org/10.1016/0378-8733(78)90021-7

[46] Chen, D.B., Gao, H., Lü, L.Y. and Zhou, T. (2013) Identifying Influential Nodes in Large-Scale Directed Networks: The Role of Clustering. *PLoS ONE*, **8**, e77455.

[47] Freeman, L.C. (1977) A Set of Measures of Centrality Based on Betweenness. *Sociometry*, **40**, 35-41. http://dx.doi.org/10.2307/3033543

[48] Tutzauer, F. (2007) Entropy as a Measure of Centrality in Networks Characterized by Path-Transfer Flow. *Social Networks*, **29**, 249-265. http://dx.doi.org/10.1016/j.socnet.2006.10.001

[49] Yan, G., Zhou, T., Hu, B., Fu, Z.Q. and Wang, B.H. (2006) Efficient Routing on Complex Networks. *Physical Review E*, **73**, Article ID: 046108. http://dx.doi.org/10.1103/PhysRevE.73.046108

[50] Freeman, L.C., Borgatti, S.P. and White, D.R. (1991) Centrality in Valued Graphs: A Measure of Betweenness Based on Network Flow. *Social Networks*, **13**, 141-154. http://dx.doi.org/10.1016/0378-8733(91)90017-N

[51] Dangalchev, C. (2006) Residual Closeness in Networks. *Physica A*: *Statistical Mechanics and Its Applications*, **365**, 556-564.