A Survey of Information System Value Evaluation

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Abstract—With the development and application of information technology (IT) and modern enterprise management theory, information system (IS) plays an increasingly important role in enterprises. Information system not only provides enterprises with benefits that can be measured by financial figures, but also brings a lot of intangible values that are difficult to quantify and show in the short term. It is of great significance to do a good job in the value evaluation of information systems. This paper summarizes the existing information system valuation methods and models, sorts out the evaluation methods from different angles, and looks forward to the development direction of information system value evaluation. The research results can provide valuable reference and basis for future related work.

Keywords-Information system; Value evaluation; Evaluation method; Evaluation model

1. Introduction

As early as the 1990s, information technology has become an important strategic tool for the development and acquisition of enterprise advantages, and the dependence of enterprises on information system is also strengthened. Besides the field of financial accounting, the information demand in other fields such as marketing and sales, human resources, supply chain management, inventory and manufacturing has gradually increased. In the 21st century, information system has ushered in a new stage of cloud computing. Nowadays, people can work without leaving home, and can use any terminal equipment to access information systems. The traditional command management style of enterprises is no longer applicable, and employee autonomy is gradually prevailing. IS provides great benefits for all walks of life. At the same time, information overload and information security threats in the process of informatization seriously affect and restrict the further development of enterprises.

In other words, the return on investment in the system is much lower than expected. In the two upsurge of management informatization in the 20th century, Chinese enterprises invested about 8 billion yuan in application system, but the success rate of application was less than 10%. A large number of enterprises have developed management information system (MIS) almost without success, and the huge investment in it has not received the expected return[1]. Therefore, people pay more and more attention to the value evaluation of enterprise information system. How to conduct scientific, accurate and efficient value evaluation of information system has become an urgent problem to be solved.

This paper summarizes the two important directions of information system value evaluation: evaluation method and evaluation model. The research ideas are as follows: firstly, the domestic and foreign research on information system value evaluation is sorted out, and then the

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characteristics and shortcomings of existing research are summarized, and the possible direction for future research is proposed.

2. Evaluation method of information system value

2.1 Traditional evaluation method

2.1.1 Financial-based evaluation method

The traditional financial evaluation method focuses on cost and benefit to evaluate the value of information system. The cost accounting of income present value method can better reveal the future income and profit level of assets, and can deeply reflect the potential value of assets. This is the result of James and others' deep research on the advantages of income present value method and the accounting characteristics of income present value method [2]. Wilson et al. made a supplementary calculation to the traditional replacement cost method, and they analyzed the defects of the replacement cost method. This method has been recognized by many enterprises [3]. Some scholars improve on the basis of the cost method, and put forward the overall cost research method, which takes the construction, operation and stop of information system as a cycle, analyzes and calculates all the explicit and implicit costs in this cycle, and finally obtains its overall cost.

Robert S. Kaplan and David P. Norton put forward the balanced score card method in 1992. It is different from the traditional financial method and only focuses on the financial point of view. The balanced score card method mainly measures the value of information system from four aspects: financial perspective, user satisfaction, system process and enterprise growth speed [4]. It decomposes the strategic objectives into various specific and balanced performance appraisal index systems. In the following decades, the balanced score card method has been constantly improved and developed. Li zongqi, a domestic scholar, used the balanced score card to set up sub items and relevant standards from four dimensions of finance, business, customer and innovation to evaluate the value of information system, and finally weighted the evaluation result [5]. Wang Yi evaluated the value of the information system of nuclear power enterprises from the strategic point of view, and introduced "strategic coordination" into the balanced card. Together with finance, internal operation, learning development and customer satisfaction, the strategic performance evaluation index of information system was composed [6].

2.1.2 Economics-based evaluation method

Parker M. and Benson RJ. conducted an in-depth study on the relationship between information technology and business performance of enterprises, and proposed that financial benefits brought by information systems should not be considered only, but also business values brought by information systems, such as better customer service or improvement of competitiveness [7]. Yannis Bakos J. and Kemerer Chris F. adopted the theory based on information economics and summarized information system evaluation into six main fields: information economics, production economics, economic model of organizational performance, industrial economics, institutional economics and macroeconomics [8]. In recent years, many new theories and methods have been derived on the basis of the original economic evaluation methods.

2.1.2.1 Economic Value Added (EVA)

EVA refers to the income after deducting all capital input including equity from net operating profit. Its core idea is that there is a cost of capital input, and only when the profit exceeds the cost of capital can an enterprise create value for shareholders. This method is widely used in enterprise performance evaluation and financial management, and also applies to the value evaluation of enterprise information system. The value brought by the system is the income brought by the use of the information system minus the input cost of the information system. However, EVA is a short-term indicator. If an enterprise only focuses on the value of the information system in the short term instead of continuing to invest in research and development for the long-term development, it is likely to lead to the loss of long-term interests of the enterprise, and the accuracy of the value assessment of the information system will be lost.

2.1.2.2 Total Cost of Ownership (TCO)

TCO, which covers everything from purchase to installation, as well as internal support and implicit costs, is favored in cost analysis and comparison. Many manufacturers can increase sales by reducing maintenance and support costs and adding slogans such as "low TCO" into product marketing [9]. However, the disadvantage of TCO is that it can't assess the risk, so it can't give managers the technical and strategic decision guidance.

2.1.2.3 Total Economic Impact (TEI)

When evaluating the investment value, TEI not only considers the costs and benefits, but also evaluates the promoting effect of a certain technology in improving the utility of the overall business process, that is, considers the delayed benefits or potential values excluded by the direct cost-benefit method [10]. The four basic evaluation elements of this method are cost, benefit, risk and flexibility, which can fully reflect the overall economic impact of the decision. Quantitative risk assessment enables TEI to fully understand the enterprise's product satisfaction, employee turnover, technological environment changes, etc., when evaluating the value of the information system, so as to facilitate the adjustment of the calculated information system revenue. However, some experts believe that the risk assessment of TEI is subjective and may not be able to play a due role in the evaluation of the value of information system.

2.1.2.4 Rapid Economic Justification (REJ)

REJ combines IT investment with business focus and enriches TCO's evaluation system. The methodology consists of the following steps: Establish a methodology to identify key participants in the project, identify key success factors and key performance indicators; Identify with participants how technology affects success factors; Measure the cost-benefit balance; Delineate the probability of potential risks and their impact; Calculate ROI, NPV, IRR and other financial indicators. REJ is suitable for the evaluation of a single project. Although it is subjective to a certain extent, its advantage lies in the consideration of risk factors [11].

2.2 Comprehensive evaluation method

The comprehensive evaluation method is often used in the selection of multi-attribute evaluation objects. The evaluation of enterprise information system needs comprehensive measurement, so some scholars use the comprehensive evaluation method to implement the value evaluation of enterprise information system. The commonly used comprehensive evaluation methods include fuzzy comprehensive evaluation (FCE), analytic hierarchy process (AHP) and principal component analysis (PCA), among which FCE and AHP are often combined.

Chen Yaohui built a comprehensive evaluation model of fixed assets based on fuzzy comprehensive evaluation method, and reduced the evaluation deviation caused by subjective factors through fuzzy concept [12]. Shao Peiji et al. built three evaluation index systems of management information system with AHP, which are the evaluation system of system structure, the evaluation system of system performance and the evaluation system of system application. There are corresponding third order indicators under the second order evaluation index system. For example, the "system application evaluation system" includes management benefit and decision-making benefit. There are four third order indicators of the application degree of the performance benefit system [13]. Based on the characteristics of the information system, Guo Dongqiang built a set of index system for comprehensive evaluation of information. On this basis, he combined fuzzy mathematics and matrix to build a hierarchical analysis model to evaluate the value of the enterprise information system [14]. Luo Yan proposed to use AHP to establish a hierarchical structure model, set up four first order indicators, including the system construction index, the system performance index, the system benefit index and the value to the user, and then use the fuzzy comprehensive evaluation method to evaluate the information system[15].

3. Evaluation model of information system value

3.1 General model

3.1.1 Investment return model

Generally speaking, the value of enterprise information system in a broad sense can be measured by return on investment (ROI), namely:

$$ROI = (\Delta C + \Delta R)/TC \tag{1}$$

Where ΔC refers to the reduced cost, ΔR refers to the increased revenue, and TC refers to the total cost. The cost reduction and revenue growth can be classified as "output", while the total cost is "input". Output index Including general profit rate, capital turnover rate, customer satisfaction rate, delivery punctuality rate, product quality rate, etc.. Investment indicators generally include labor cost, process cost, system operation cost, maintenance and improvement cost, opportunity cost, etc. [16].

3.1.2 Utility difference model

In addition to ROI, the value of information system can also be expressed as the difference between the maximum target utility of enterprises after informatization and the maximum target utility before obtaining information, namely:

$$\begin{cases} V = E_i - E_0 \\ E_0 = max \sum_j \beta(a, z_j) p(z_j) \\ E_i = max \sum_j \beta(a, z_j) p(z_j | y_j) \end{cases} \tag{2}$$

Among them, a stands for action, namely the decision made by the enterprise. z_j stands for event, that is, the enterprise decides to invest in the information system. y_j is for different information systems. $\beta(a, z_j)$ is the payoff function of utility. $p(z_j)$ stands for prior probability. $p(z_j|y_j)$ stands for a posteriori probability in the presence of information systems.

Probability in the model refers to the possibility that an enterprise makes the best choice. If we want to construct the efficiency index of enterprise information system according to this model, we can introduce the cost of information system, which is marked as C, and the efficiency index of information system relative to the cost can be expressed as:

$$V = \frac{E_i - E_0}{C} \tag{3}$$

The above two models are the basic models of information system valuation, that is, the calculation methods used to determine the value. In order to make the results as accurate as possible, there are also many models about the calculation methods and function expressions of costs and benefits in the formula, which are also the focus of scholars' full study.

3.2 Cost-benefit model

The model is derived from the theory of Cost Benefit Analysis (CBA), which is an economic decision-making method to help investors find the investment scheme with the minimum cost for the maximum benefit, including the quantitative analysis of cost and benefit. In the valuation of enterprise information system, CBA can be used to evaluate the input cost and utility of information system, and their ratio can be used to measure its value, namely:

$$BCR = B/C \tag{4}$$

Where B represents cost and C represents revenue. If the time value of money is considered [17], there is:

$$BCR = \frac{\sum_{t=0}^{n} \frac{B_t}{(1+m)^t}}{\sum_{t=0}^{n} \frac{C_t}{(1+m)^t}} \tag{5}$$

Where t represents the year, B_t represents the revenue in year t, C_t represents the cost in year t, m represents the benchmark rate of return, and n represents the project life period.

Information system will have a variety of costs and benefits, so let:

$$B_t = \sum_k B_{tk} \tag{6}$$

$$C_t = \sum_k C_{tk} \tag{7}$$

Where B_{tk} represents the kth income of the information system in year t, and C_{tk} represents the kth cost of the information system in year t.

Substitute formula (6) and (7) into formula (5) to get:

$$BCR = \frac{\sum_{t=0}^{n}(\sum_k B_{tk})/(1+m)^t}{\sum_{t=0}^{n}(\sum_k C_{tk})/(1+m)^t} \qquad (8)$$

When BCR is greater than 1, it means that the benefits brought by the information system to the enterprise are greater than the costs, and the enterprise's investment in the system is feasible. The greater the BCR, the higher the investment income of this information system.

Measuring the value of enterprise information system from the perspective of income has always been a research hotspot, that is, choosing information system as an investment product. Cost-benefit model is to measure the investment income of information system from the financial point of view. It should not only consider the usefulness of information technology to enterprises, but also consider the relationship between cost and income. Although scholars have followed suit, there has been no breakthrough in the quantitative research of information system benefits, and the research results are inconsistent or even contradictory [10]. Even so, the research on quantitative analysis of economic benefits continues.

3.3 Model based on production function

Besides exploring the value of information system from the financial point of view, another point of view is the production function method, in which Cobb-Douglas production function is the most widely used one. According to the data of Computer Weekly and Computer World Magazine, Lichtenberg F. used Douglas production function to analyze the income of information system investment, found huge potential value, and estimated that the working efficiency of a skilled system worker is equivalent to the productivity of six non-IT system workers [18].

The basic form of Cobb-Douglas production function is as follows:

$$Y = A(t)L^{\alpha}K^{\beta}\mu \qquad (9)$$

Among them, Y represents the total industrial output value, $A(t)$ represents the comprehensive technical level, L is the input labor, K is the input capital (generally refers to the fixed net assets), α is the elasticity coefficient of labor output, and β is the elasticity coefficient of capital output.

This function is mainly used to measure the influence of capital input and labor input on output in the production process, and also to determine the contribution rate of scientific and technological progress, capital growth and labor growth to output growth. The production function is as follows:

$$Y = aK^{\beta_1}L^{\beta_2} \qquad (10)$$

In this case, Y represents the output growth rate, a is the rate of scientific and technological progress, K and L represent the capital growth rate and labor growth rate respectively, β_1 and β_2 are the elasticity coefficient of capital output and labor output respectively.

Douglas production function is only applicable to the benefit analysis after the operation of information system, and it is difficult for enterprises to formulate specific measurement methods and determine the production function, so it is difficult to implement it in enterprises. So in recent years, few scholars continue to dig deep into the application of production function method in the value evaluation of enterprise information system. However, in the last century, some foreign scholars have made improvement research on the value evaluation of information system based on production function method. Brynjolfsson E. and Hitt L. studied and analyzed the difference of the role of information technology in different enterprises, replaced Douglas production function model with translogarithm function, and considered the "influence of enterprises" as a factor based on the original data [19].

3.4 Value engineering model

Value Engineering (VE), also known as value analysis (VA), is to analyze the function and cost of research object, reflect the realization degree of its function, and study its value. The value here refers to the proportion between expenses and benefits, so the value engineering model can be expressed as follows:

$$V = F/C \tag{11}$$

Where V represents value index, F represents function, and C represents cost.

From formula (11), we can see that if the function F can be monetized, the value engineering model can be transformed into a cost-benefit model, which reflects the internal unity of the two evaluation methods. However, some benefits of information system can only be measured by function. On the other hand, how to quantify the different dimensions of each function is also an urgent problem to be solved [20].

When using this model to explore the value of information system, Qian Wenhai and Zhang Shaoqiang used the method of function coefficient and function score to unify the dimension [17]. The function and realization degree of enterprise information system include profit index such as strategic target matching degree and risk index such as technology uncertainty. It can be assumed that there are n indicators in total, and the scores of each index are obtained according to the deepening degree Q_i ($i = 1,2,3, \dots, n$ and $Q_i \in [0,10]$). Then, the importance coefficient of each index f_i is determined according to the enterprise culture and strategic objectives. The importance coefficient is positive, while the importance coefficient of risk indicators is negative. The coefficients of all indicators meet the requirements:

$$\sum_{i=1}^{n} f_i = 10 \tag{12}$$

Then the function coefficient can be obtained as:

$$F = \sum_{i=1}^{n} Q_i f_i \tag{13}$$

Since the importance coefficient of risk indicators is negative, if there are k ($k < n$) risk indicators, the value range of sum of the importance coefficients is generally $[-k, -1]$. Then, the value range of the function coefficient F is $[-10k, 100 + 10k]$. The larger the function coefficient, the better the performance of the information system. The value index can be obtained by substituting the function coefficient into formula (11):

$$V = \frac{\sum_{i=1}^{n} Q_i f_i}{C} \tag{14}$$

3.5 Model based on comprehensive evaluation method

With the development of information technology and the evolution of its application, the value of information system to the organization has far exceeded the traditional value of reducing cost and improving productivity. However, traditional methods such as return on investment or qualitative analysis mostly measure the value of information system from the perspective of finance. Although they can reflect the value of information system to a certain extent, they can't adapt to the actual situation of information system development. Therefore, some scholars began to use the comprehensive evaluation method to evaluate the value of information system.

Yang Qin and Yao Juan proposed to combine the value chain analysis with the balanced scorecard to establish the value evaluation index system of information system, so as to pursue the integration of enterprise strategy in the evaluation and evaluate the information system as comprehensively as possible [21]. After the value chain is used to analyze the intangible value of the information system, it is combined with the four dimensions of the balanced scorecard to match the index to measure the intangible income, and then quantify the value of the information system. Because AHP is too subjective and has certain limitations when transforming qualitative problems into quantitative problems, fuzzy analytic hierarchy process (FAHP) combines FCE with AHP and constructs evaluation matrix through expert scoring method, which strengthens the reliability of qualitative problem quantification transformation.

When using the comprehensive evaluation method to evaluate the value of enterprise information system, it is often divided into three steps: establishing the evaluation system, determining the weight of evaluation indicators and implementing the comprehensive evaluation. Scholars usually apply balanced scorecard, AHP and FCE to the model at the same time, that is, the balanced scorecard is used to construct the evaluation index system, then the AHP is used to confirm the right, and finally FCE is used to carry out the evaluation.

4. Conclusions and limitations

4.1 Conclusions

Through the discussion of this paper, we can see that the historically difficult value evaluation of information system is not impossible to achieve. This paper reviews traditional financial methods, comprehensive evaluation methods, and evaluation models, systematically showing the research status of information system valuation. We can draw the following conclusions.

First, the comprehensive evaluation method can more clearly reflect the "hidden benefits" generated by the information system, namely the improvement of management and performance, while the traditional financial method can accurately evaluate the "explicit benefits" brought by the information system, namely the reduction of costs and the increase of profits. Therefore, we should explore the combination of these two methods and construct a comprehensive evaluation system and model to increase the accuracy and efficiency of evaluation.

Second, after combing the related literature and resources of information system value evaluation, it can be found that the evaluation and prediction of information system performance, the quality evaluation of information system itself and the multi-index comprehensive evaluation of information system are the main research directions of information system evaluation or prediction. Information system is a very complex social system, and its evaluation method should consider not only the cost, economic benefits and financial factors, but also many factors such as system performance, system construction, system environment and user evaluation. Many foreign scholars have studied this. In China, the comprehensive evaluation method is used to evaluate information systems, but the deficiency of the existing research lies in the lack of empirical research linking the evaluation indicators and systems with real enterprises. The follow-up should pay attention to the concrete implementation of the indicators and evaluation systems.

4.2 Limitations

Starting from the methods and models of information system value evaluation, this paper summarizes the previous studies, which will promote the subsequent construction of a perfect evaluation system. Of course, there are some shortcomings in this paper. After summarizing different methods and models, more detailed horizontal and vertical comparisons should be made to show the relationship and differences between methods and models. There are many scenarios of information system value evaluation. This paper focuses on enterprises, and other scenarios include consumers, software, railways, etc.. In these cases, the information system valuation methods will be different. In a word, this paper simply sums up the work of information system value evaluation, and in the future, it is necessary to discuss the construction of evaluation system from different angles.

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