Article

A Novel Risk Metric for Staff Turnover in a Software Project Based on Information Entropy

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Abstract: Staff turnover in a software project is a significant risk that can result in project failure. Despite the urgency of this issue, however, relevant studies are limited and are mostly qualitative; quantitative studies are extremely rare. This paper proposes a novel risk metric for staff turnover in a software project based on the information entropy theory. To address the gaps of existing studies, five aspects are considered, namely, staff turnover probability, turnover type, staff level, software project complexity, and staff order degree. This paper develops a method of calculating staff turnover risk probability in a software project based on the field, equity, and goal congruence theories. The proposed method prevents the probability of subjective estimation. It is more objective and comprehensive and superior than existing research. This paper not only presents a detailed operable model, but also theoretically demonstrates the scientificity and rationality of the research. The case study performed in this study indicates that the approach is reasonable, effective, and feasible.

Keywords: staff turnover; risk metric; software project; information entropy

1. Introduction

Software is an intangible product of human logic and intelligence. The software is not consumed physically, but requires the use of time, energy, and intelligence. A software project is highly dependent on staff and personnel, the management of which is a core issue in software project management. Research have shown that software projects generally experience considerably high staff turnover, with an average turnover rate between 25% and 35% per year [1], which indicates that an

entire staff can be replaced in three to four years, thereby increasing software project risk. *American Fortune Magazine* reports that staff turnover has become a culture in the IT industry, which has an average employment time of only 13 months. Boehm [2], who is a pioneer of software project risk management, found that staff turnover risk is one of the top ten risks encountered by a software project. Infosys, which is the second largest software company in India and one of the world's top 500 corporations, ranked staff turnover risk second only to requirement risk based on their software projects. DeMarco *et al.* [3] identified staff turnover risk as one of the top five key risks of a software project that could cause a project to fail.

Staff turnover is not always a negative issue. However, a high turnover rate disrupts the normal operation of a project and results in loss, project failure, or even the collapse of a company. Thus, staff turnover risk needs to be evaluated to ensure efficient software project management.

Project managers must develop a strategy to reduce staff turnover rate and mitigate its risks and negative consequences. Such a strategy begins with risk identification and measurement. This step aims to effectively measure staff turnover risk and provide objective evidence for project managers to support personnel management decision-making and ensure efficient software project management. A risk metric is the foundation of risk ranking, analysis, tracking, and response, and can facilitate a quantitative analysis of turnover risk in a project.

Based on the information entropy, field, equity, and goal congruence theories, this paper proposes a novel risk metric for staff turnover in a software project. The proposed risk metric addresses the gaps of existing studies and prevents subjective probability estimation, which is a disadvantage of traditional risk metric approaches.

2. Related Research

Various studies have focused on risk. References [4–10] studied software project risk, but did not consider staff turnover. ACM SIGCPR (The Special Interest Group on Computer Personnel Research of the Association for Computing Machinery) meets periodically to discuss IT personnel problems and staff turnover issues. SEI (The Software Engineering Institute at Carnegie Mellon University) published a People Capability Maturity Model for Software in 1995. However, few studies show risk; no quantitative risk study focuses on staff turnover risk in a software project [11].

Studies on staff turnover risk conducted by Emberland [12] and Allen [13] *et al.* are not quantitative and do not focus on software project management. Staff turnover risk has been studied extensively by many scholars in the fields of economics, science and technology management; enterprise management; and business administration [13,14]. However, staff turnover risk in the software industry has not been studied, and a quantitative approach has not yet to be developed [11]. Wang [15] discussed the risk management of staff turnover in a software project, but did not perform a quantitative risk analysis.

Studies on software project risk management have made considerable progress in issues such as requirements, changes, budget, technology, support tools, maintenance, software process capability, schedule, resources, and marketing risks. However, their findings are considerably inadequate when it comes to staff turnover risk in a software project. So far, the author has found only one relevant study [11], which proposes a quantitative assessment model for turnover risk in a software project. However, three

key risk coefficients in the model are subjectively determined by evaluation experts [16], which present the author's findings from six years ago, a quantitative risk metric for staff turnover in a software project. However, the probability of staff turnover is subjectively determined by evaluation experts.

This paper primarily uses the information entropy theory, which is widely applied in many fields. Özmen [17] presents an entropy-based algorithm for software instrumentation to measure the amount of information content of instrumentation data to be collected. Nicolaou and Georgiou [18] investigated the use of permutation entropy for automated epileptic seizure detection. So far, studies on staff turnover risk have not used the information entropy method.

3. A Novel Risk Metric Based on Information Entropy Theory

3.1. Risk Definition

Risk is defined as a combination of the probability of an event and its consequence in ISO Guide 73 (2002 edition), and as effect of uncertainty on objectives in ISO Guide 73 (2009 edition). Staff turnover risk in a software projects has two important characteristics. First, the risk is uncertain because turnover may or may not occur. Second, staff turnover can negatively affect a software project, specifically the schedule and the software quality, which results in economic loss. Therefore, generally, the risk can be defined as a triple $R = (X, P, C)$ [16,19], where, X denotes risk factor, P denotes risk probability, and C denotes risk loss. The uncertainty and the loss degrees associated with each risk factor should be quantified to measure the risk. Accordingly, risk can be defined as the product of the risk probability and loss degree [16,19], that is, $R = P \times C$.

There is nothing wrong with the risk definition $R = (X, P, C)$, $R = P \times C$ in the above paragraph. However, usually, risk probability and risk loss are immediately generated by experts' estimations in traditional research of risk metric, which lead to crude metric and inexact metric as well as excessive subjectivity factor. Accordingly, P and C need to be further refined and studied. This paper aims to develop a risk metric model for staff turnover in a software project. The factors of risk level influence should therefore be analyzed.

3.2. Five Aspects of Risk Level Influence

This paper considers that the risk level of staff turnover in a software project has five aspects, namely, staff turnover probability, turnover type, staff level, software project complexity, and staff order degree. The first item refers to the uncertainty of turnover, namely, P in Section 3.1, while the remaining four items denote the degree of loss caused by the risk; they fall within the ambit of C in Section 3.1. The analysis is demonstrated as follows:

- Staff turnover probability

Generally, a higher risk probability and stronger influence of the project correspond to a greater risk. Therefore, a reasonable metric model should include staff turnover probability. In current studies, the probability is always estimated subjectively by experts. An objective and quantitative method in calculating the probability will be proposed in the next section of this paper.

- Turnover type

Staff turnover is frequent and uncertain in a software project, and has the following two types (Table 1):

Table 1. Two types of staff turnover.

No.	Name	Explanation
1	Staff resignation	An employee leaves the company for a new one either because of dissatisfaction or better prospects, hereinafter referred to as "resignation."
2	Replacing staff	The employee is replaced within the company. For example, one employee is originally assigned to a key position, but is then transferred to a general position because of his lack of ability, hereinafter referred to as "replacement."

The first case poses the highest risk because rehiring or training a new employee increases costs and disrupts the project schedule. Moreover, losing key staff can threaten a project as he may disclose business secrets. In the second case, even though the replacement occurred within the company, the replaced employee needs time to become familiar with new tasks, which can compromise the schedule and software quality. Therefore, both resignation and replacement pose risks to software project, and risk level varies among different turnover types. In this paper, T expresses turnover type, $T = T(T_1, T_2)$, where, T_1 denotes resignation and T_2 represents replacement.

- Staff level

The effects of turnover on a project vary depending on different staff levels, which indicates different risk levels. A larger risk loss and stronger influence on the project corresponds to greater risk. Risk of key staff turnover is evidently higher than that of other staff. A key staff is the most important employee because he possesses strong technical knowledge and skill, extensive experience, and excellent management skills, and is crucial to a company's production operations. The resignation of a key staff significantly influences the project, and finding a replacement is challenging. In this paper, the staff of a software project is divided into four levels in order of importance, namely, key, important, ordinary, and subordinate staff. Staff level is recorded as $L = L(L_1, L_2, L_3, L_4)$.

- Software project complexity

A more complex software project relies heavily on key staff, which is why such a project is affected negatively and may even be discontinued if the key staff resigns. Less complex projects rely less on key staff. Accordingly, the complexity of a software project should be considered when measuring risk.

- Staff order degree

In systems science theory, order exists when a partial order relation exists among subsystems; otherwise, disorder or chaos exists. Order degree is the opposite of balance degree. The former is the distribution of the contribution of the part to the whole, that is, the contribution comes mainly from one part of the system or an average contribution comes from all parts. A more uniform contribution of each subsystem corresponds to a more disorganized system and *vice versa*. Dissipative structure theory is one of the important theories in systems science, while fluctuation is an important concept in dissipative structure theory. If each staff contributes uniformly to the software project, that is, the order degree of the system is low, then the fluctuation caused by staff turnover is small, and the fluctuation will be dissipated easily by the system. Thus, the software project faces low risks despite staff turnover. On the contrary, if some employees contribute significantly to the project, then the system depends on only a few staff members, which indicates that a high order degree of the system. Thus, the resignation or replacement of these employees will cause a large fluctuation in the system. The system

would encounter difficulties in dissipating this fluctuation, hence the high risk. Consequently, the risk level and staff order degree are directly related.

3.3. Novel Risk Metric Model Based on Information Entropy

Based on the above analysis, this section proposes a novel information-entropy-based risk metric, which includes five aspects, namely, staff turnover probability, turnover type, staff level, software project complexity, and staff order degree, to measure the risk of staff turnover in a software project.

Staff turnover risk in a software project can be defined as $Risk = (M, P, C)$, where M represents staff, P is the risk probability, C is the risk loss. As mentioned in Section 4.1, staff turnover has two types, T_1 and T_2, represent resignation and replacement, and risk level varies among different turnover types. Likewise, turnover of different people have different risk impacted on the project, the staff of a software project is divided into four levels, L_1, L_2, L_3 and L_4 in Section 4.1, represent key, important, ordinary, and subordinate staff, separately. In order to accurately measure the risk, every case must be subdivided, $C = C(C_1, C_2)$, and

$$C_1 = (T_1, L) = \begin{cases} T_1 \bullet L_1 \\ T_1 \bullet L_2 \\ T_1 \bullet L_3 \\ T_1 \bullet L_4 \end{cases} \quad C_2 = (T_2, L) = \begin{cases} T_2 \bullet L_1 \\ T_2 \bullet L_2 \\ T_2 \bullet L_3 \\ T_2 \bullet L_4 \end{cases}.$$

In which, $T_1 \bullet L_2$ represents L_2 level staff has a T_1 event, namely, an important staff has a resignation event, the other items are similar.

Suppose n staff exist in a software project $M_1, M_2, ..., M_n$, and $C_{11}, C_{12}, ..., C_{1n}$ is the resignation risk loss, where $C_{1i} = (T_1, L)_i$, $i = 1, ..., n$, $P_{11}, P_{12}, ..., P_{1n}$ is the probability, and $C_{21}, C_{22}, ..., C_{2n}$ is the replacement risk loss, where $C_{2i} = (T_2, L)_i$, $i = 1, ..., n$, and $P_{21}, P_{22}, ..., P_{2n}$ is the probability. The loss degree of each staff is $A_1, A_2, ..., A_n$, where

$$A_i = C_{1i} \times P_{1i} + C_{2i} \times P_{2i}, \quad i = 1, ..., n \tag{1}$$

Make a normalization processing for A_i, then

$$\rho_i = \frac{A_i}{\sum\limits_{j=1}^{n} A_j} = \frac{C_{1i} \times P_{1i} + C_{2i} \times P_{2i}}{\sum\limits_{j=1}^{n} (C_{1i} \times P_{1i} + C_{2i} \times P_{2i})} \tag{2}$$

where $i = 1, ..., n$, $0 \leq \rho_i \leq 1$, $\sum\limits_{i=1}^{n} \rho_i = 1$.

According to information entropy theory,

$$H = -\sum\limits_{i=1}^{n} \rho_i \ln \rho_i \tag{3}$$

A more symmetrical ρ_i corresponds to a larger entropy value H. When absolute uniformity $\rho_i = \rho_2 = ... = \rho_n = \dfrac{1}{n}$, the entropy value is the largest, $H_{\max} = H(\dfrac{1}{n}, \dfrac{1}{n}, ..., \dfrac{1}{n}) = \ln n$.

In Formula (3), maybe H is larger than one, therefore, make a normalization processing for convenient measurement. Then

$$H^* = \frac{H}{H_{max}} \tag{4}$$

where $0 \le H^* \le 1$.

The more symmetrical ρ_i is, the larger entropy value H is, the smaller the risk is, and then,

$$Risk = CF \times (1 - H^*) = CF \times \left(1 - \frac{H}{H_{max}} \right) = CF \times \left(1 + \frac{\sum_{i=1}^{n} \rho_i \ln \rho_i}{\ln n} \right) \tag{5}$$

where $0 \le Risk \le 1$, CF is complexity degree factor of a software project, $0 \le CF \le 1$. This paper does not focus on calculation of CF, which is explained in [20,21]. [20] considers software project complexity includes project environment complexity and software product complexity, it presents a software project complexity evaluation method based on evidence reasoning. The authors of [21] mention technical complexity factor and environment complexity factor and also lists 14 technical complexity factors as well as proposes a technical complexity calculation formula.

According to Section 4.1 and the above analysis, the following preparatory model is obtained based on the information entropy theory for measuring staff turnover risk in a software project.

$$Risk = CF \times \left(1 + \frac{\sum_{i=1}^{n} \frac{C_{1i} \times P_{1i} + C_{2i} \times P_{2i}}{\sum_{j=1}^{n}(C_{1i} \times P_{1i} + C_{2i} \times P_{2i})} \ln \frac{C_{1i} \times P_{1i} + C_{2i} \times P_{2i}}{\sum_{j=1}^{n}(C_{1i} \times P_{1i} + C_{2i} \times P_{2i})}}{\ln n} \right) \tag{6}$$

The probability is the required data in this model. Reference [16] adopts the expert estimation method, which is expanded in this paper to include a more objective probability calculation. The reason for staff turnover needs to be analyzed; in this paper, this reason pertains to why employees resign. The most well-known staff turnover theories are shown in Table 2.

These theories explain the inevitability and necessity of staff turnover from the aspect of personal growth and stimulation of creativity. Other scholars present other explanations for staff turnover. The authors of [12] suggest that staff turnover depends on job satisfaction. According to [25], the prospect of a bleak future, disorganized internal management, poor working conditions, unreasonable pay, and high job pressure, among others, cause core technicians to resign. The authors of [26] state that a collective turnover reason involves the salary system, professional career planning and training, interpersonal relationships, values conception and mode of thinking, and business competition, *etc.* The authors of [27] state that staff turnover reasons include the personal characteristics of the staff, the management system, and job market competition. The authors of [13] and [28] categorize the reasons for staff turnover as follows: (1) internal factors such as unfair salary, poor career prospects, and inability to fulfill promises which indicate a lack of acknowledgment of efforts and contributions;

(2) external factors such as staff supply and demand; and (3) individual factors such as lifestyle, regional preferences, and interests.

Table 2. Three famous staff turnover theories.

Name	Introduction
Field Theory	The field theory was introduced by Kurt Lewin [22], an American psychologist. Lewin stated that personal performance and ability, and personal qualities and environment have a function relation that is similar to the field in physics. This statement indicates that personal ability is not only related to quality, but is also closely linked to work environment. If a person's job does not match his specialization or he is working in a detrimental environment characterized by poor interpersonal relationships, absence of peace of mind, unfair pay, arbitrary leadership style, and disrespect for people with knowledge and talents, he would be unable to maximize his intelligence, and achieving success would be difficult. If an employee is dissatisfied with the work environment, he is powerless to change the situation. Therefore, the employee has no other recourse than to leave for a better environment.
Equity Theory	The equity or social comparison theory was introduced by John Stacey Adams [23], an American management psychologist and behavioral scientist, in 1965. This theory studies the relation between human motivation and perception, and focuses on rationality and equity of salary and its influence on employees' willingness to work. He pointed out that staff incentive originates from a subjective comparison between the investment and gains of a person and his colleagues. Basically, a person focuses on the absolute value of his reward and the relative value compared with that of others after he achieved results and was paid. Therefore, he will make comparisons to determine whether he received a reasonable reward, and his findings will directly affect his enthusiasm for his job.
Goal Congruence Theory	• In his book entitled *Interpersonal Relation Equation*, Japanese scholar Yoshiro Nakamatsu [24] suggested that a person may not fully achieve his individual potential unless his goals are entirely consistent with the organizational goal. In addition, the organization may not perform at its best, but individual behavior can still be recognized and affirmed. When the individual goal conflicts with the organizational goal, the individual's potential will be restrained and he will not develop or be recognized by the group. Thus, the whole function level will inevitably decline. • Nakamatsu identified three approaches that can be utilized when individual goal does not conform with the organizational goal. The first is to revise individual goals to be more in line with the organizational goal. However, closing the gap between the individual and the group goals within a short time is difficult. The second approach is through staff turnover, that is, the staff leaves his old job for a new company that has a goal that is more consistent with his own. The last approach is to do nothing, which will negatively affect the organizational goal. The second and third actions all lead to human resource risk.

In this section, staff turnover mainly refers to resignation, which occurs because of job dissatisfaction. Turnover probability is inversely proportional to satisfaction, as shown in Figure 1. Higher dissatisfaction results in higher turnover probability, and *vice versa*.

Based on the existing studies (especially field theory, equity theory and goal congruence theory) as well as fully integrating the characteristic of a software project, this section presents a job satisfaction questionnaire, shown in Table 3.
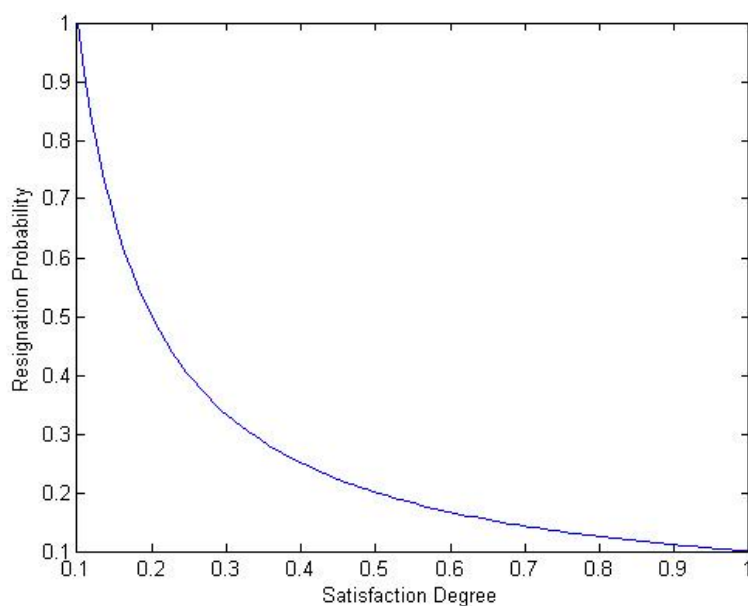
Figure 1. Resignation probability and satisfaction degree.

Table 3. Job satisfaction questionnaire.

No.	Potential Risk Items of Staff Resignation	Satisfaction Degree		
		0	1	2
1	Are you satisfied with your income?	○Dissatisfied	○Moderately	○Satisfied
2	What is your pay relative to that of others in the same industry?	○Lower	○Equal	○Higher
3	Is the salary system in your company reasonable?	○Unreasonable	○Moderate	○Reasonable
4	Are you satisfied with the incentive mechanism?	○Dissatisfied	○Moderately	○Satisfied
5	Are chances for promotion fair?	○Unfair	○Moderate	○Fair
6	Are you satisfied with your work environment?	○Dissatisfied	○Moderately	○Satisfied
7	Are you satisfied with the management system in your company?	○Dissatisfied	○Moderately	○Satisfied
8	Can you reach your full potential?	○No	○Moderately	○Yes
9	Can you be accepted and trusted by the leaders and colleagues?	○No	○Moderately	○Yes
10	Can you gain respect in your work?	○No	○Moderately	○Yes
11	Are you satisfied with your leaders?	○Dissatisfied	○Moderately	○Satisfied
12	How are the interpersonal relations and communication in your company?	○Poor	○Moderate	Good
13	How is your relationship with your colleagues?	○Frequent conflicts	○Moderate	Good
14	How significant is job pressure in your company?	○High	○Moderate	Low
15	Is your mind at ease while you are working?	○No	○Moderately	Yes
16	Are you enthusiastic about your work?	○No	○Sometimes	Yes
17	Would you like to spend more time on your work?	○No	○It depends	Yes
18	Would you like your child to have the same job with you?	○No	○Perhaps	○Yes
19	Is your goal consistent with the goal of the company?	○No	○Some what	○Yes
20	Does your specialty or knowledge match your position?	○No	○Adequate match	○Yes

Table 3. *Cont.*

No.	Potential Risk Items of Staff Resignation	Satisfaction Degree		
		0	1	2
21	Is your job you idea job?	○No	○Close	○Yes
22	Can you fulfill your career plans in your current job?	○No	○Maybe	○Yes
23	How are the chances for educational training and career development in your work?	○Poor	○Moderate	○Good
24	Is the city in which you work your ideal place?	○No	○Tolerable	○Yes
25	Do you and your spouse live in seperate places?	○Yes	○Yes, but it has no effect	○No
26	How is the competition strength of your company?	○Feeble	○Moderate	○Strong
27	How is your strength in the same industry?	○Strong	○Moderate	○Feeble
28	How is the supply and demand for professionals in your position?	○Demand exceeds supply	○Moderate	Supply exceeds demand
29	How are the long-range goals and prospects in your company?	○Poor	○Tolerable	○Good
30	How are the benefits in your company?	○Poor	○Tolerable	○Good

According to Table 3, job satisfaction is measured as follows:

$$|S_i| = \frac{\sum_{j=1}^{m} f_{ij}}{2m} \tag{7}$$

where $f_{ij} \in \{0,1,2\}$, $i = 1,...,n$, $j = 1,...,m$. Obviously, $0 \leq |S_i| \leq 1$. n is the number of project staff, and m is the number of resignation risk items.
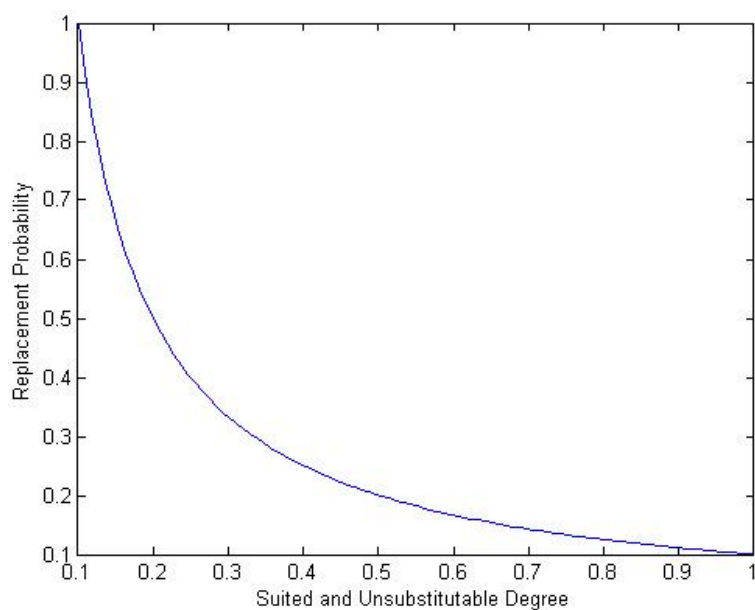

Figure 2. Replacement probability and suited and unsubstitutable degree.

Given that resignation probability is inversely related to job satisfaction, the probability is calculated as follows:

$$P_{1i} = 1 - |S_i| = 1 - \frac{\sum_{j=1}^{m} f_{ij}}{2m} \tag{8}$$

where $f_{ij} \in \{0,1,2\}$, $i = 1,...,n$, $j = 1,...,m$, and $0 \leq P_{1i} \leq 1$. n is the number of project staff, and m is the number of resignation risk items.

According to the analysis in Section 3.2, replacing staff presents risks, except in cases in which the staff resigned. The replacement probability is negatively correlated with the suited and the unsubstitutable degrees for the job, as shown in Figure 2.

A questionnaire on potential replacement risk is shown in Table 4.

Table 4. Replacement risk questionnaire.

No.	Potential Risk Items of Replacing Staff	Risk Level		
		0	1	2
1	Do you have previous experience related to your present job?	○Yes/extensive experience	○Moderately	○No
2	Are your leaders satisfied with your work?	○Yes	○Moderately	○No
3	Are your subordinates satisfied with you?	○Yes	○Moderately	○No
4	How about your work performance?	○Good	○Moderate	○Poor
5	Are there other people who can be as competent as you are in your position?	○No	○Few	○Many
6	Can a new employee quickly achieve competence at your job?	○No	○Maybe	○Yes
7	Is finding a replacement who can become competent within a short period of time difficult?	○Yes	○Moderately	○No

Risk items are summarized in Table 4. The formula that can be used to calculate the probability of replacing staff is given as

$$P_{2i} = \frac{\sum_{j=1}^{k} g_{ij}}{2k} \tag{9}$$

where $g_{ij} \in \{0,1,2\}$, $i = 1,...,n$, $j = 1,...,k$, and $0 \leq P_{2i} \leq 1$. n is the number of project staff, and k is the number of replacing risk items.

Equations (8) and (9) are substituted into Equation (6), and a new staff turnover risk metric model (10) is shown as follows:

$$Risk = CF \times \left(1 + \frac{\displaystyle\sum_{i=1}^{n} \frac{C_{1i} \times \left(1 - \frac{\sum_{j=1}^{m} f_{ij}}{2m}\right) + C_{2i} \times \frac{\sum_{j=1}^{k} g_{ij}}{2k}}{\sum_{j=1}^{n}\left(C_{1i} \times \left(1 - \frac{\sum_{j=1}^{m} f_{ij}}{2m}\right) + C_{2i} \times \frac{\sum_{j=1}^{k} g_{ij}}{2k}\right)} \ln \frac{C_{1i} \times \left(1 - \frac{\sum_{j=1}^{m} f_{ij}}{2m}\right) + C_{2i} \times \frac{\sum_{j=1}^{k} g_{ij}}{2k}}{\sum_{j=1}^{n}\left(C_{1i} \times \left(1 - \frac{\sum_{j=1}^{m} f_{ij}}{2m}\right) + C_{2i} \times \frac{\sum_{j=1}^{k} g_{ij}}{2k}\right)}}{\ln n} \right) \qquad (10)$$

where C_{1i}, C_{2i} can be obtained from statistical or historical data in the enterprise; f_{ij}, g_{ij} are the values from Tables 3 and 4; m and k represent entries in Tables 3 and 4, respectively; n is the number of staff; and CF is the complexity degree factor of a software project, which can be obtained from [20,21], $CF \in [0,1]$, $Risk \in [0,1]$.

4. Case Study

In this section, numerous case analyses are used to illustrate the rationality and feasibility of the model (10).

4.1. Case 1

Kunming Shunning Technology Company, herein after referred to as KSTC, mainly engages in software development. KSTC contracts for a software development project X. The project team has 20 members, namely, $M = \{M_1, M_2, ..., M_{20}\}$, and the number of L_1, L_2, L_3, L_4 is 2, 5, 8 and 5, respectively. Risk probability is a major problem for risk measurement. The model (10) developed in this paper effectively solves the problem. To accurately measure the risk, the personnel manager asked the staff to fill in the questionnaires according to Tables 3 and 4. Staff turnover risk probability is quantitatively calculated in Tables 3 and 4. The data as follows:

$$f_{ij} = \begin{pmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \\ A_{31} & A_{32} \end{pmatrix} \qquad\qquad g_{ij} = \begin{pmatrix} B_{11} & B_{12} \end{pmatrix}$$

$$A_{11} = \begin{pmatrix} 0 & 0 & 1 & 0 & 2 & 1 & 1 & 2 & 0 & 2 \\ 2 & 1 & 1 & 1 & 1 & 1 & 1 & 0 & 2 & 0 \\ 0 & 2 & 0 & 1 & 2 & 1 & 2 & 2 & 2 & 2 \\ 2 & 0 & 0 & 1 & 1 & 1 & 1 & 2 & 0 & 0 \\ 2 & 1 & 2 & 0 & 0 & 0 & 2 & 0 & 1 & 1 \\ 2 & 1 & 0 & 0 & 1 & 0 & 0 & 2 & 2 & 1 \\ 1 & 2 & 2 & 0 & 2 & 0 & 2 & 0 & 1 & 1 \\ 0 & 2 & 2 & 1 & 2 & 1 & 2 & 0 & 0 & 1 \\ 2 & 2 & 1 & 0 & 0 & 0 & 0 & 0 & 2 & 1 \\ 1 & 2 & 1 & 1 & 2 & 0 & 0 & 0 & 1 & 1 \end{pmatrix}$$

$$A_{12} = \begin{pmatrix} 2 & 0 & 2 & 1 & 0 & 0 & 2 & 2 & 2 & 0 \\ 0 & 0 & 1 & 2 & 0 & 2 & 0 & 1 & 0 & 1 \\ 0 & 2 & 0 & 1 & 1 & 1 & 2 & 1 & 1 & 0 \\ 2 & 2 & 0 & 2 & 0 & 1 & 1 & 1 & 2 & 2 \\ 0 & 2 & 2 & 0 & 2 & 1 & 0 & 1 & 1 & 1 \\ 0 & 2 & 2 & 1 & 2 & 2 & 0 & 0 & 1 & 1 \\ 0 & 1 & 0 & 0 & 1 & 0 & 1 & 0 & 2 & 0 \\ 2 & 0 & 0 & 0 & 1 & 2 & 1 & 1 & 2 & 0 \\ 2 & 0 & 0 & 0 & 2 & 1 & 1 & 2 & 0 & 2 \\ 2 & 1 & 1 & 1 & 1 & 1 & 2 & 1 & 1 & 2 \end{pmatrix}$$

$$A_{21} = \begin{pmatrix} 1 & 2 & 1 & 1 & 2 & 1 & 2 & 0 & 2 & 0 \\ 2 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 1 & 1 \\ 2 & 1 & 1 & 0 & 2 & 2 & 1 & 2 & 1 & 1 \\ 0 & 1 & 2 & 2 & 1 & 2 & 1 & 2 & 2 & 0 \\ 0 & 2 & 2 & 1 & 0 & 1 & 1 & 1 & 1 & 1 \\ 2 & 2 & 0 & 0 & 0 & 2 & 2 & 1 & 1 & 1 \\ 1 & 0 & 1 & 1 & 1 & 2 & 1 & 2 & 0 & 1 \\ 0 & 0 & 0 & 2 & 0 & 1 & 1 & 0 & 2 & 2 \\ 1 & 0 & 2 & 2 & 2 & 2 & 1 & 0 & 1 & 2 \\ 1 & 0 & 0 & 1 & 1 & 1 & 2 & 1 & 2 & 2 \end{pmatrix}$$

$$A_{22} = \begin{pmatrix} 2 & 1 & 0 & 1 & 0 & 0 & 1 & 1 & 2 & 0 \\ 2 & 1 & 1 & 0 & 2 & 2 & 2 & 0 & 1 & 1 \\ 2 & 2 & 1 & 2 & 1 & 0 & 1 & 0 & 2 & 1 \\ 0 & 1 & 2 & 0 & 0 & 0 & 0 & 1 & 2 & 1 \\ 1 & 2 & 2 & 1 & 0 & 0 & 1 & 0 & 1 & 2 \\ 1 & 2 & 0 & 2 & 2 & 1 & 1 & 2 & 2 & 0 \\ 0 & 0 & 1 & 0 & 1 & 0 & 2 & 1 & 0 & 0 \\ 2 & 1 & 2 & 2 & 1 & 0 & 0 & 2 & 2 & 2 \\ 0 & 2 & 2 & 0 & 2 & 1 & 1 & 0 & 1 & 2 \\ 0 & 2 & 1 & 0 & 2 & 1 & 2 & 0 & 0 & 1 \end{pmatrix}$$

$$A_{31} = \begin{pmatrix} 1 & 1 & 2 & 2 & 1 & 2 & 1 & 0 & 0 & 2 \\ 0 & 1 & 0 & 2 & 1 & 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 1 & 2 & 2 & 2 & 0 & 1 & 1 & 0 \\ 1 & 1 & 0 & 0 & 2 & 1 & 2 & 2 & 0 & 2 \\ 1 & 0 & 0 & 1 & 2 & 1 & 0 & 2 & 2 & 0 \\ 1 & 2 & 1 & 0 & 2 & 1 & 2 & 2 & 0 & 2 \\ 2 & 1 & 1 & 1 & 1 & 2 & 1 & 0 & 0 & 1 \\ 2 & 2 & 1 & 1 & 1 & 1 & 0 & 0 & 2 & 2 \\ 0 & 2 & 2 & 0 & 2 & 2 & 2 & 0 & 1 & 2 \\ 0 & 2 & 2 & 1 & 2 & 1 & 1 & 1 & 1 & 0 \end{pmatrix}$$

$$A_{32} = \begin{pmatrix} 1 & 0 & 0 & 2 & 2 & 0 & 2 & 0 & 2 & 0 \\ 1 & 0 & 1 & 2 & 1 & 0 & 0 & 2 & 2 & 0 \\ 2 & 2 & 2 & 0 & 2 & 2 & 0 & 2 & 2 & 0 \\ 2 & 2 & 1 & 1 & 2 & 1 & 1 & 1 & 2 & 2 \\ 1 & 1 & 1 & 0 & 1 & 0 & 0 & 0 & 1 & 0 \\ 1 & 2 & 0 & 1 & 0 & 0 & 0 & 1 & 2 & 0 \\ 2 & 2 & 0 & 1 & 1 & 2 & 1 & 0 & 0 & 1 \\ 2 & 1 & 2 & 0 & 1 & 0 & 1 & 0 & 1 & 1 \\ 0 & 0 & 0 & 1 & 1 & 2 & 2 & 2 & 1 & 1 \\ 1 & 2 & 1 & 1 & 0 & 1 & 2 & 0 & 0 & 2 \end{pmatrix}$$

$$B_{11} = \begin{pmatrix} 2 & 0 & 2 & 2 & 0 & 1 & 0 & 1 & 1 & 0 \\ 1 & 2 & 0 & 2 & 2 & 2 & 0 & 0 & 1 & 1 \\ 1 & 0 & 0 & 0 & 0 & 2 & 0 & 2 & 1 & 0 \\ 0 & 1 & 1 & 2 & 0 & 1 & 2 & 1 & 2 & 2 \\ 2 & 0 & 2 & 2 & 2 & 1 & 1 & 1 & 2 & 0 \\ 0 & 1 & 2 & 0 & 1 & 0 & 0 & 2 & 1 & 1 \\ 2 & 1 & 1 & 2 & 1 & 2 & 2 & 2 & 2 & 1 \end{pmatrix}$$

$$B_{11} = \begin{pmatrix} 0 & 0 & 1 & 1 & 2 & 0 & 0 & 1 & 0 & 1 \\ 2 & 1 & 0 & 2 & 2 & 1 & 2 & 0 & 1 & 1 \\ 0 & 2 & 1 & 1 & 1 & 1 & 1 & 1 & 2 & 2 \\ 0 & 2 & 2 & 1 & 0 & 1 & 1 & 0 & 1 & 2 \\ 1 & 1 & 1 & 2 & 1 & 1 & 2 & 1 & 1 & 2 \\ 1 & 2 & 1 & 1 & 1 & 0 & 2 & 0 & 2 & 0 \\ 1 & 0 & 1 & 0 & 2 & 0 & 1 & 2 & 0 & 1 \end{pmatrix}$$

The turnover of L_1, L_2, L_3, L_4 is divided into two types, namely, T_1 resignation and T_2 replacement. The resignation risk loss can be calculated both through the culture fee of the staff given by the company and the direct project loss caused by the resignation. The replacement risk loss can be determined based on the costs of selecting and training another employee as well as through the direct loss caused by the replacement. Based on historical and statistical data, risk loss is shown in Table 5.

Table 5. Risk loss for staff turnover.

●	L_1	L_2	L_3	L_4
T_1	30,000	10,000	2,000	400
T_2	10,000	4,000	400	50

According to formula (10), $Risk_1 = 0.262281316$, (for convenient calculation, take $CF = 1$, same as below).

4.2. Comparative Analysis within Seven Different Cases

Risk variation was observed through a comparative analysis of seven different cases.

Figure 3 and Table 6 indicate that risk increases as the probability increases, and *vice versa*. Figure 4 and Table 6 indicate that risk decreases as the risk loss decreases, and *vice versa*. Figure 5 and Table 6 indicate that if one project depends primarily on a few people, turnover will pose a major risk to the project once resignation or replacement occurs. Staff order degree will decrease by adding a number of key staff, thereby decreasing the risk. On the contrary, if only one key staff exists, the order degree and the risk will be significantly high.
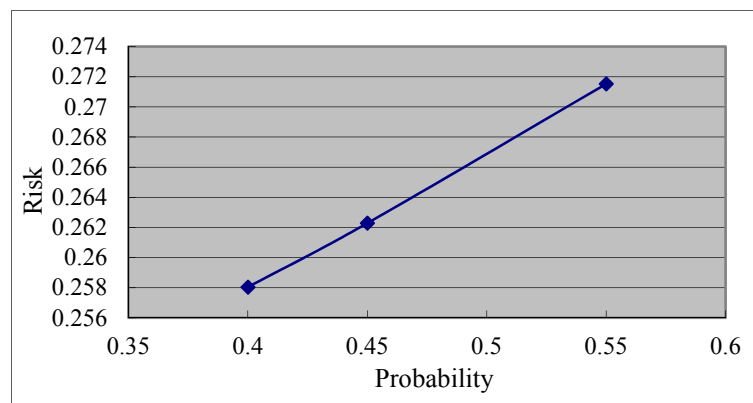

Figure 3. Probability and risk.

Table 6. Comparison of seven cases.

No.	Difference with Case 1	Risk	Risk Increase or Decrease	Graphical Representation
1	-	0.262281316	-	-
2	The probability of one key staff increases from 0.45 to 0.55, namely, $P_{12} = 0.45 \rightarrow P_{12} = 0.55$	0.271523165	0.009241849	Figure 3
3	The probability of one key staff decreases from 0.45 to 0.4	0.25804056	−0.004240756	
4	Key staff risk loss decreases from 30000 to 25000, that is, $C_{11} = C_{12} = 30000 \rightarrow C_{11} = C_{12} = 25000$	0.253114395	−0.009166921	Figure 4
5	Key staff risk loss increases from 30000 to 35000	0.271800721	0.009519405	
6	The addition one key staff, suppose $P_{121} = 0.5, P_{221} = 0.3$	0.251543609	−0.010737707	Figure 5
7	Reduce one key staff	0.288468583	0.026187267	

This observation is consistent with the findings of qualitative risk analysis. Thus, the model (10) can be used to effectively measure staff turnover risk in a software project.
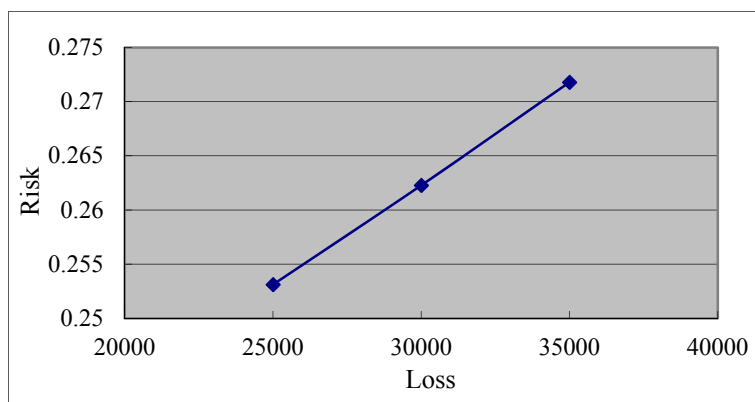
Figure 4. Loss and risk.
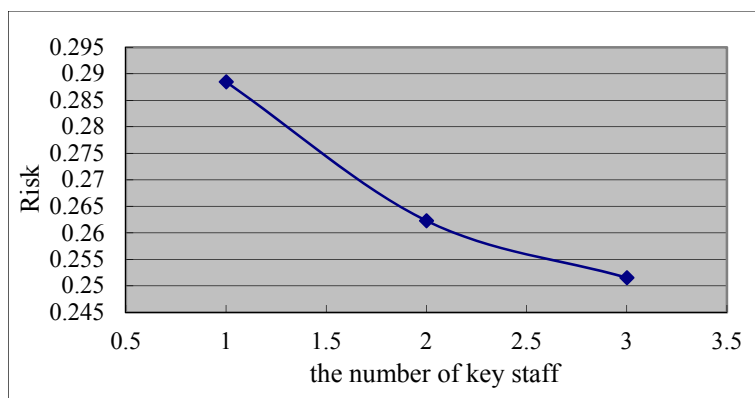
Figure 5. The number of key staff and risk.

5. Discussion

5.1. Analysis of Scientificity and Rationality on the Proposed Model

The proposed model, shown in formula (10), its scientificity and rationality mainly manifest in the following aspects:

- The model mainly uses information entropy to measure the risk. Uncertainty is the essential characteristic of risk. The risk that must happen does not exist, and it is not the risk that the event which cannot happen certainly. Information entropy is a state function that represents the system state. In information theory, information entropy can be used to effectively measure the uncertainty of random events along with the uncertainty of the system. Therefore, the use of information entropy for risk measurement is scientific and rational.
- Risk level depends on many aspects, including staff turnover probability, turnover type, staff level, software project complexity, and staff order degree. Therefore, these five aspects are considered in the model. It is more comprehensive and refined than existing risk metric research which directly estimate risk probability and risk loss. For details, please see Section 3.2, the repetitious details need not be given here.
- In the model, the reason for staff turnover is considered fully when to calculating risk probability. It is analyzed deeply based on field theory, equity theory and goal congruence theory as well as fully integrating the characteristic of a software project. By this mean the possibility information of turnover will be obtained accurately. Accordingly, the probability is more reliable as well as more objective and precise than the method that expert directly estimate risk probability.
- The model contains order degree. Information entropy can be used not only to effectively measure uncertainty, but also to measure system order degree. The entropy value reflects the chaos degree of a system. A more uniform subsystem contribution corresponds to a more unordered system and larger information entropy, and *vice versa*, which shows that risk level is related to staff order degree. Thus, the measurement of risk by using information entropy is scientific and reasonable.
- The conclusion of case study in Section 4 is consistent with the findings of qualitative risk analysis. This just shows the proposed model is correct and reasonable.

5.2. Advantages over Other Studies

The significance of the results of a study depends on its advantage over other studies or its ability to address the deficiency of existing studies. Therefore, the findings of this paper are compared with those of other research.

This paper's advantages are illustrated mainly in two aspects as follows.

- More Objective

Risk probability is a major difficulty in risk metric field and determined directly by expert's estimation in current literature, such as [16], *etc.* In the proposed model in this paper, risk probability is

calculated via formulas (8) and (9), which avoids subjective estimation risk probability of traditional research. Accordingly, the model is superior to the existing study obviously.

Quantitative risk research on staff turnover rarely focuses on software projects. Given that [11] is the only relevant paper, its findings are compared with those of this paper. The details are shown in Table 7.

Table 7. Advantages over Reference [11].

No.	Item	This Paper	Reference [11]
1	Main Result	A novel quantitative risk metric for staff turnover in a software project	A quantitative assessment model of turnover risk in a software project
2	Model	Shown in the Equation (10)	Shown in the following Equation $$R_h = \sum_{j=1}^{n} \left\{ \left[\frac{k}{t} \right]_j + mp_j \left[\alpha_j \left[\frac{i}{k} \right]_j + \beta_j \left[\frac{d}{k} \right]_j + \phi_j \left[\frac{c}{k} \right] \right] \right\}$$
3	Model Parameters	A total of 8 parameters, namely, n, m, k, f_{ij}, g_{ij}, C_{1i}, C_{2i}, and CF	A total of 12 parameters, namely n, j, t, k, i, d, c, α_j, β_j, ϕ_j, m, and p
4	Objective Parameters	n, m, k, f_{ij}, g_{ij}, CF	n, j, t, k, i, d, c
5	Parameters obtained from historical and statistical data	C_{1i}, C_{2i}	m, p
6	Parameters determined by experts	none	α_j, β_j, ϕ_j

Eight parameters exist in the proposed model, and twelve parameters exist in the model of [11]; six and seven are objective parameters, and two parameters are historical and statistical data, respectively. No parameters are determined through expert evaluation in the former. However, three parameters, namely, α_j, β_j, ϕ_j, are determined by expert evaluation in the latter. Therefore, our proposed model is more objective and superior than the model of [11], which ensures that subjective evaluation parameters are avoided.

- More Comprehensive

As mentioned earlier in this paper, generally, risk can be defined as the product of P and C. Usually, they are determined directly by expert's estimation, e.g., [16], which lead to coarse and imprecise metric. Differently, in this paper, risk level is not decided directly by expert's estimation and the factors that influence risk level are deeply analyzed. The proposed model contains fully various factors that affect risk level, including staff turnover probability, turnover type, staff level, software project complexity, and staff order degree. It is a pioneering work and more comprehensive, reasonable and refined than existing risk metric research.

6. Results and Conclusions

To address the gaps of existing studies, this paper proposes a novel risk metric for staff turnover in a software project based on information entropy theory. Generally, risk can be defined as the product of *P* and *C*, they are determined directly by expert's estimations in traditional research of risk metric, which lead to crude metric and inexact metric as well as excessive subjectivity factor. Accordingly, *P* and *C* need to be further refined and studied. Therefore, this paper considers that the risk level of staff turnover in a software project has five aspects, namely, staff turnover probability, turnover type, staff level, software project complexity, and staff order degree. It is more comprehensive and refined than existing risk metric research.

This paper develops a method of calculating the probability of staff turnover risk in a software project based on the field, equity, and goal congruence theories; this method avoids subjective estimation probability. It is more objective and comprehensive and superior to existing research, obviously.

This paper not only presents a detailed operable model, but also theoretically demonstrates the scientificity and rationality of the research. The case study performed in this study indicates that the approach is reasonable, effective, and feasible. The research results can be applied or serve as reference in managing the risk of staff turnover in a software project.

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Conflicts of Interest

The author declares no conflict of interest.

References

1. Blackburn, J.; Scudder, G.S.; van Wassenhove, L.N. Improving Speed and Productivity of Software Development: A Global Survey of Software Developers. *IEEE Trans. Softw. Eng.* **1996**, *22*, 875–885.
2. Boehm, B.W. Software risk management: Principles and practices. *IEEE Softw.* **1991**, *81*, 32–41.
3. De Marco, T.; Lister, T. *Waltzing with Bear: Managing Risk on Software Projects*; Dorset House Publishing: New York, NY, USA, 2003.
4. Raspotnig, C.; Opdahl, A. Comparing risk identification techniques for safety and security requirements. *J. Syst. Softw.* **2013**, *86*, 1124–1151.
5. Jørgensen, M. Identification of more risks can lead to increased over-optimism of and over-confidence in software development effort estimates. *Inf. Softw. Technol.* **2010**, *52*, 506–516.

6. Huang, J.S.; Han, W.M. Exploring the relationship between software project duration and risk exposure: A cluster analysis. *Inf. Manag.* **2008**, *45*, 175–182.

7. Kulk, G.P.; Peters, R.J.; Verhoef, C. Quantifying IT estimation risks. *Sci. Comput. Program.* **2009**, *74*, 900–933.

8. Bannerman, P.L. Risk and Risk Management in Software Projects: A Reassessment. *J. Syst. Softw.* **2008**, *81*, 2118–2133.

9. Yang, L.; Jones, B.F.; Yang, S.H. Genetic algorithm based software integration with minimum software risk. *Inf. Softw. Technol.* **2006**, *48*, 133–141.

10. Song, H.; We, D.; Li, M.; Cai, C.; Li, J. An Entropy Based Approach for Software Risk Assessment: A Perspective of Trustworthiness Enhancement. In Proceedings of the 2nd International Conference on Software Engineering and Data Mining (SEDM), Chengdu, China, 23–25 June 2010; pp. 575–578.

11. Chen, R.; Xie, G.G.; Zhang, D.F.; Wang, R.D. Quantitative Assessment and Analysis of Turnover Risk on Software Project. *Appl. Res. Comput.* **2006**, *2*, 38–41.

12. Emberland, J.S.; Rundmo, T. Implications of job insecurity perceptions and job insecurity responses for psychological well-being, turnover intentions and reported risk behavior. *Saf. Sci.* **2010**, *48*, 452–459.

13. Zhang, Y.L.; Yang, N.D. Analysis and Control for staff turnover risk. *Sci. Sci. Mang. Sci. Technol.* **2000**, *21*, 42–44. (in Chinese)

14. Hou, X.; Zhu, H. Precaution and resolution of risk in collectivity staff turnover. *Special Area Economy*. **2004**, *12*, 149–150. (in Chinese)

15. Wang, M.X. Risk management of staff turnover on software project. *Commer. Res.* **2004**, 52–53. (in Chinese)

16. Jiang, R.; Liao, H.Z.; Yu, J.K.; Feng, T.; Zhao, C.G.; Li, J.L. A model based on information entropy to measure developer turnover risk on software project. In Proceedings of the 2009 2nd IEEE International Conference on Computer Science and Information Technology, Beijing, China, 8–11 August 2009; pp. 419–422.

17. Özmen, A. An entropy-based algorithm for data elimination in time-driven software instrumentation. *J. Syst. Softw.* **2009**, *82*, 907–913.

18. Nicolaou, N.; Georgiou, J. Detection of epileptic electroencephalogram based on Permutation Entropy and Support Vector Machines. *Expert Syst. Appl.* **2012**, *39*, 202–209.

19. Qin, Z.; Xu, W.H.; Han, Y.; Tang, J. *Software Project Management*, 2nd ed.; Tsinghua University Press: Beijing, China, 2009. (in Chinese)

20. Jiang, G.P.; Chen, Y.W. Software Project Complexity Evaluation Based on Evidence Reasoning. *Comput. Eng. Appl.* **2005**, *2*, 4–7. (in Chinese)

21. Han, W.J.; Jiang, L.X. *A Cases Course for Software Project Management*, 2nd ed.; China Machine Press: Beijing, China, 2010. (in Chinese)

22. Tedford, K.; Baker, D. Kurt Lewin. In *Work Teams: Past, Present and Future*; Springer: Berlin/Heidelberg, Germany, 2000; Volume 6, pp. 107–114.

23. Denhardt, R.B. *Managing Human Behavior in Public and Non-Profit Organizations*, 3rd ed.; Sage Publications: Thousand Oaks, CA, USA, 2013.

24. Zhao, F.; Lu, J.; Xing, X. Review of Turnover for Creative Talent: Base on the Perspective of Organizational View. *Sci. Manag. Res.* **2012**, *30*, 87–91 (In Chinese).

25. Guan, Y.M. Risk and Prevention of Key Technician Turnover in a Small Enterprise of Hign Technology. *Market Modernization*. **2006**, 316–317. (in Chinese)

26. Hou, X.; Zhu, H. Risk Prevention and Dissolution for Collective Turnover. *Spec. Zones Econ.* **2004**, 149–150. (in Chinese)

27. Zhang, Q. Risks and Guard of Knowledge Staff'Outflow in Enterprises. *Technol. Innov. Manag.* **2009**, *30*, 506–509. (in Chinese)

28. Yao, K.; Cao, J.L. A Prelim inary Probe into the Management of Knowledge Staff Dra in Risk. *High-Technol. Ind.* **2007**, *28*, 106–109. (in Chinese)