Research on Reliability and Cost Integrated Optimization Algorithm of Construction Project Logistics System

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Abstract

The structure of the construction project logistics system is decomposed in detail; some uncertain factors affecting system reliability are analyzed. This paper applies the probability-influence coordinate graph to screen out the logistics subsystem that has great influence on system reliability under the conditions of occurring failure, and establishes an allocation model of the reliability index in construction project logistics system based on the restriction of cost, makes use of the presented model and algorithm to calculate the cost-based reliability, contrasts it with the index reliability assigned by the scoring method to the optimal distribution value of reliability index and the optimal cost. The presented detailed methods and steps can offer the meaningful reference for reliability optimization management of the logistics system in the construction project.

Keywords: Reliability, Optimization, Algorithm, Costs, Logistics, Construction, Project management

1. Introduction

In the process of engineering construction, there are purchasing, transportation, safekeeping, inventory and other activities of a lot of special mechanical equipment, raw materials, and preliminary products. Considering some characteristics existed in construction projects, such as high investment, large scale, complex technology, long construction cycle, having an important influence on the development of national economy, and etc, studying the reliability of logistics system in construction project is very necessary. However, the high reliability of the construction project logistics system often means increasing the investment cost. The purpose of research is to make the operation of logistics system of construction to meet the requirements of the corresponding reliability index, at the same time to realize the optimal investment cost and to guarantee to transport the correct amount of materials and equipment to the right place in the right time.

2. Detailed analyzing some related references

Until now, there have been many references studying construction logistics, and many concepts about it have been set up. In reference [1], a best-in-class solution to the supplier selection problem has been presented by means of an intelligent evaluation engine to rank suppliers via a hybrid fuzzy mechanism. The proposed mechanism has been carefully implemented and verified via a real world case study in a large building and construction corporation [1]. The reference [2] considers the applicability of logistics management in construction and facilitates a better understanding of construction supply chains by studying the logistical functions of builders' merchants [2]. The reference [3] aims to identify the possible savings in time and cost due to different amounts of buffer stock on site, by introducing an activity-based simulation model, details and data of a residential project involving substantial amounts of pre-cast components are collected, the project participants are asked to unveil the constraints on site and throughout the material delivery and storage processes [3]. The reference [4] reports a research that employs logistic regression (LR) to predict the probable relationship between negotiator tactics and negotiation outcomes, to achieve this, three main stages of work were involved, and Negotiator tactics and negotiation outcomes were identified from the literature [4]. The reference [5] presents the analysis of three chosen variants of supply the construction in building materials, the costs connected with the supply the construction in building materials and the benefit as an effect of deduction in price in materials are discussed [5]. In reference [6], based on the principle of cyberspace for a workshop on meta-synthetic engineering, real-time dispatching command system for cement and fly-ash in Three Gorges Project was developed [6]. The reference [7] determines the optimal carrier selection based on a multi-commodity reliability criterion for a logistics network subject to budget, a genetic algorithm integrating minimal paths and Recursive Sum of Disjoint Products is developed to identify an optimal carrier selection strategy [7]. In reference [8], new procurement strategies have been developed by both public and private sectors to focus on the R, M and S characteristics inherent to the design of a system. One such strategy known as Performance Based Logistics (PBL) has gained popularity due to its success in improving the operational effectiveness of the system [8]. The reference [9] discussed the characteristics, heterosexual, timeliness and one-time, about a construction project, and points out the uncertainty factors which is due to its characteristics, in the logistics system of construction projects, but did not do any further analysis to put these uncertainty factors on the influence of construction project logistics system reliability [9]. The reference [10] constructs the structure frame model of the construction project logistics system, the key link include owner, design business, the contractor and supplier; discussed that the establishment of a specialized logistics management department and the study of their operation process and responsibility is necessary, it has a great help to the division of the construction project logistics system's logic structure, the division is the foundation for the research of reliability allocation problems [10]. The reference [11] proposes a dynamic stocking policy that adaptively replenishes the inventory to meet the time-varying parts demand; the study provides theoretical insights into the performance-driven service operation in the context of changing system fleet size due to new installations [11], and etc [12-14].

By detailed analyzing these references, we find that they general studies the optimization problems of the construction project logistics system from two independent sides including reliability and cost, and many meaningful outcomes has been gotten, but the special studies aiming to reliability and cost integrated optimization research of this system are scarce. However, the high reliability of the construction project logistics system often means increasing the investment cost. This paper considers these integrated factors, and studies how making the operation of logistics system of construction to meet the requirements of the corresponding reliability index, at the same time to realize the optimal investment cost.

3. Construction project logistics system

3.1 Characteristics of construction project logistics

The essence of engineering project construction is the consumption of materials. The final purpose of the construction project logistics system is transporting the right quantity equipment, raw materials to the right place at the right time to meet the requirements of the project progress and quality. The different characteristics distinguished construction project logistics system from general logistic system include: 1) disposable, just exist for a construction project; 2) uncertainty; 3) supply chain end when the project completion, 4) high risk, the occurrence of risk always lead to serious financial loss; 5) system reliability is complex, and controllability is weak .

3.2 The Structure of construction project logistics

The construction project logistics system is a complex system consisted of project owner, design unit, the general contractor, professional subcontractors, material suppliers, mechanical equipment suppliers by certain contract relations. The owner is an eventual member of the logistics chain, which plays a leading role.

Aim at a certain construction project, the structure of the construction project logistics system is shown as Fig. 1

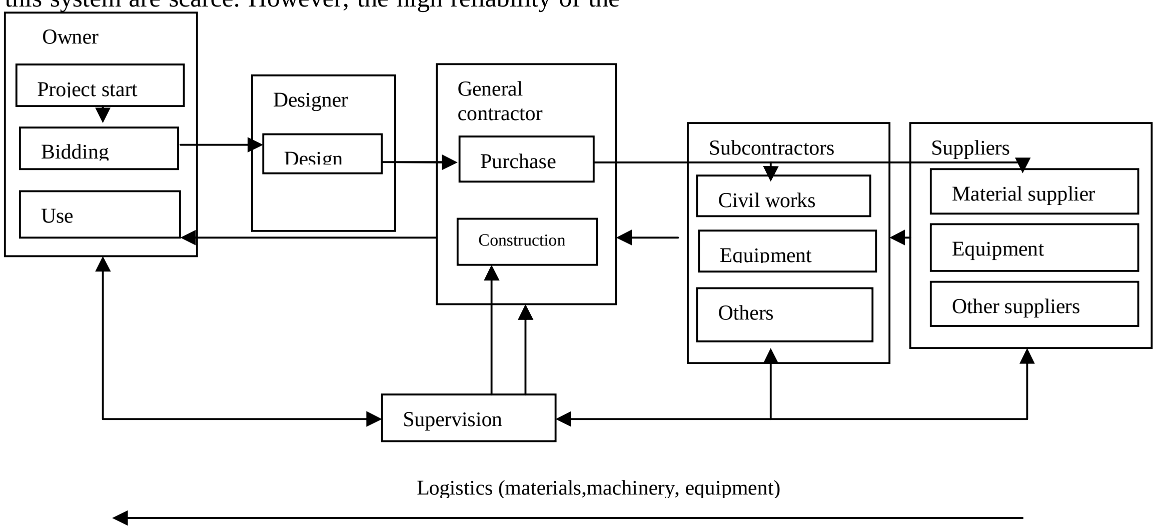

Fig. 1 the structure diagram of construction project logistics system

4. The uncertainty factors affecting the reliability

4.1 The definition of reliability of construction project logistics system

Reliability refers to the ability to complete required function within the prescribed time and regulations conditions. In the point of this paper, the reliability for construction project logistics system refers to the ability that, through the organization and coordination, construction project deals in completing the material supply, storage, fabrication processing, human resource supply, site layout, equipment layout, site logistics management and all exchanging of information related logistics and service flow in the provision of time, quantity and quality to guarantee delivering for use on schedule smoothly.

4.2 Analyzing uncertainty factors

1) Uncertainties caused by project participants
The operation of the project is influenced greatly by the owner, designer, supervisors and the general contractor. During the construction, some unforeseen and changeable cases frequently occur, every detail changes need timely logistics guarantee. Such as the change of civil sub-project schedule will cause changes of concrete products on time or quantity in demand, it will extend to the quantity and time of raw material supply, eventually can cause adjustment of the whole storage, transportation, loading and unloading handling system of construction project. Such schedule delay, material supply delay, and etc., will inevitably lead to the changes of the local material supply scheme. But the logistics system management can't obtain the material supply quantity and exact time information.
2) Uncertainties caused by logistics operation link
The equipment or materials transportation and distribution are greatly influenced by the climate conditions and geographical environment. For arriving to the construction site on time, flexible time should be fully considered in logistics solutions. The contractor usually contracts the logistics transportation business to the third party, which is logistics enterprise. Such logistics operation is not in the unified management environment, which increases uncertainties. Therefore, the selection of the logistics enterprise, transportation capacity and credibility of the enterprise should be taken into consideration.
3) The uncertain factors caused by management of the construction project logistics system
Another uncertainty affecting the reliability of logistics system is the organization management. The lack of enforceable reliability norms causes the uncertainty of managing. Project management of our country uses matrix functional organization, although there is a special material management department in construction projects, but stick division and department division are serious, the rights of materials department are weakened, it takes difficult for system organization, and logistics system management.

5. The fault condition impact assessment of construction project logistics system

According to the influence of fault state on the reliability parameters, sorts the system by the influence degree, which will intuitively show which events have a high failure rate, and which events have high impact resistance. The analysis result can be expressed in the probability-influence coordinate chart, shown as Fig. 2.

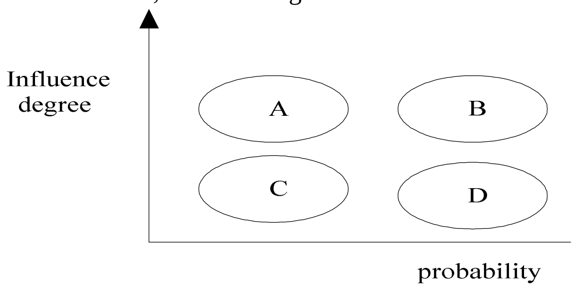

Fig. 2. Probability - impact coordinate chart

By state analyzing in Figure 2, the failure happed in B area is high probability and high influence events, once it occurs, which will take serious harm to the system reliability. So the event in the B area must be taken a key consideration in distribution of reliability index. Large operation equipments are often used in construction project. There are usually problems during the transportation and installation of these devices, because of no spare solution. If any failure occurs during the logistics process, it will be affect other activities in the logistics system. Such fault is origin fault; it is also the weak links of the system. Marking the location of origin faults in the total logistics system will help the project management staff to make out corresponding strategies.

6. The distribution of the reliability index

Before the project started, management staff of subproject logistics must clear about the reliability index that should be achieved in logistics link. The reliability index distribution can be used to look for the situation about index implementation of construction project logistics

subsystems from aspects of human, time, resources, and find a weak link.
The high reliability often means the high cost; therefore, it is needed to find out a break-even point between the reliability requirement and the optimal cost. The minimum cost and the highest reliability indexes are an ideal state in the optimization. In the actual project, we can only be close to this state area and make a relatively reasonable choice of acceptable cost and reliability index.

6.1 Establishes the cost and reliability relationship of logistics subsystem

It is difficult to establish the function of the cost and reliability in the subsystem of construction project because of two reasons, such as 1) lack of statistical data; 2) too many factors influence the cost and the reliability relationship of subsystem unit, such as the environment, technology level and resources, and etc. Strictly speaking, the relationship between cost and reliability is not one-to-one. The characteristics of function $C_i(R_i)$ have 1) low reliability accompanying low cost, high reliability accompanying high cost; 2) cost is monotone increasing function of reliability, cost to reliability derivation is monotone increasing function.
According to the above experience, the relationship between reliability and cost of subsystem is

$$R_i = 1 - e^{-\alpha_1 (C_i - \beta_i)} \quad \text{For} \quad i = 1,2,\ldots n; \quad (1)$$

6.2 Establishes the ideal cost reliability index distribution model

According to the structure of the construction project logistics system and time scale network planning arrangement, the back closely activity cannot begin until the front closely activity construction have been finished. The conclusion is drawn that this system is a complicated series-parallel mixed system. That partition logistics system conforms to the Time-Scaled Network Diagram is reasonable. Around the critical path, combines the single engineering that in parallel into a logistics unit. Finally, the system is divided into n series logistics subsystems in the critical path.
We select the minimizing cost of logistics system as the target and select the maximum reliability as a constraint, use Lagrange multiplier method for the reliability index distribution, C^* is the ideal cost, R_s^* is the reliability index. The model is as follows.

$$\begin{cases} \min \sum_{i=1}^{n} C_i \le C^* \\ \prod_{i=1}^{n} R_i \ge R^* \end{cases} \quad \text{For} \quad i = 1,2,\ldots n \quad (2)$$

Introducing Lagrange multiplier λ,

$$H = \sum_{i=1}^{n} C_i + \lambda (R_S^* - \prod_{i=1}^{n} R_i) \quad (3)$$

Make $\frac{\partial H}{\partial C_i} = 0$, then $\frac{\partial R_i}{\partial C_i} = \alpha_i (1 - R_i)$, so:

$$\begin{cases} \frac{R_1}{\alpha_1 (1 - R_1)} = \frac{R_i}{\alpha_i (1 - R_i)} \\ \prod_{i=1}^{n} R_i = R_s^* \end{cases} \quad (4)$$

Resolves the equations, then get the subsystem reliability R_i, within the limits of the ideal cost, take it into the type (1).

$C_i = \beta_i - \frac{\ln(1 - R_i)}{\alpha_i}$, The total cost of the system is: $C = \sum_{i=1}^{n} C_i$;

Where α_i, β_i for backlog experience parameters, β_i for the cost when the reliability is 0 in the logistics system, α_i decided the curve trend, α_i is smaller, the forepart of $C_i(R_i)$ curve slope is flat, the posterior segment is steeper, it shows that if R is small, improve R ,the cost is small, if want to improve it in the case of R is bigger, it needs high cost.
On the basis of above analysis, the cost is the only factor in the distribution of the reliability indexes, that is not scientific, the origin fault events in the construction project logistics system demand high reliability. It can't reduce the reliability index just because of the high cost, which will affect the success of the construction project because 1) The uncertainties that affect the reliability is more; 2) Lacking data on predictive each subsystem reliability; 3) The failure of logistics subsystems are not independent. So chooses scoring method to redistribute R_s^*, then gets R_i^P, contrasts with R_i^C, screening R_i^C, which do not satisfy R_i^P, in accordance with the scoring method

distribution, for further optimization, then uses with the scoring method for reliability index of construction project logistics system.

The factors that the traditional evaluation method considering is not comprehensive, in view of the construction project logistics subsystems, some factors such as {important degree, complexity, the technical level of members, operation time and operation environment condition, investment cost, expressed by j said, (j = 1, 2 ... 6)} should be considered.

Calculates the score coefficient: ω_i --score coefficient of i subsystems

$$\omega_i = \frac{\prod_{j=1}^{6} r_{ij}}{\sum_{i=1}^{n}\prod_{j=1}^{6} r_{ij}} \tag{5}$$

r_{ij} : Score evaluation of the j factor in i subsystems

The required reliability index of Logistics system, R_s^*

Puts R_s^* in accordance with equal principle distributes subsystem reliability index, then subsystem reliability index is $\overline{R_s^*}$, so

$$\overline{R_s^*} = 1 - \omega_i (1 - R_i^P) \tag{6}$$

The distribution value of the i logistics system reliability is

$$R_i^P = 1 - \frac{1 - \overline{R_s^*}}{\omega_i} \text{ ; (i=1, 2, ……n)} \tag{7}$$

According to this method, allocates a reliability index to each subsystem unit step by step. Refines the reliability index, makes scientific quantitative index to the basis of construction project logistics system management. Similarly, if subsystem unit is parallel structure, then

$$R_i^P = 1 - \frac{(1 - R_s)^{\frac{1}{n}}}{\omega_i}, \quad i = 1, 2 \ldots n \tag{8}$$

Contrasting the two distribution methods:

1) $R_i^C = R_i^P$, Keep R_i^C , cost and reliability index are optimal;

2) $R_i^C \geq R_i^P$, The cost is ideal, and a reliability index is high;

3) $R_i^C \leq R_i^P$, Screening this part of logistics subsystems, make further analysis.

Takes this situation, $R_i^C \leq R_i^P$ for analysis. First, find out the coordinate position of the subsystems in fault state probability/influence. Judging on whether it belongs to the area that the high failure rate and high impact, if so, improve R_i^C , make R_i^C = R_i^P ; if not, then making judgment according to the actual situation.

Finally, finds a set of new relative optimal reliability index $R_i^*, (i = 1, 2, \ldots n)$, then the system reliability $R_S > R_s^*$, the cost C also realized the optimization, take R_i^* in to the type (1), concluded C. Although the ideal cost is improved, but it makes sure the logistics system highly reliability operating, so the distribution of reliability index is more scientific, achieve the optimization target.

7. Conclusions

The risk of construction project extends to all the logistics activity, the reliability of its logistics system is related to the whole project economic value, and even decides the success of the construction project. Because the management of engineering construction logistics is all most extensive in our country, the reliability of logistics system operation is far more than the allowed range of variation, so the cost is out of control.

The paper puts forward a structural division of the construction logistics system, and finds out the weak links of the logistics system, makes a preliminary distribution of the system reliability index from cost angle, and then integrates more influential factors to distribute reliability index by scoring method. Contrasting the two indexes, combining with the failure probability/influence coordinates, screening out the subsystem which need to improve the reliability index, and ultimately distributes a new scientific reliability index set R_i^* , calculates the optimal cost C. The presented detailed methods and steps can offer the meaningful reference for reliability optimization management of the logistics system in the construction project.

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