Cooperative capability evaluation model of construction organization to implement cleaner production

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Abstract

Cleaner production (CP) has been considered to be an important means for effective pollution control and lead to a win-win situation of improving economic and environmental benefits. Cooperation is essential for project-orient construction organization to implement cleaner production. In the paper, the factors of cooperative capacity for construction organization will be analyzed and the evaluation model will be developed. There includes six capabilities: Consistency of project plan, Project information share, Stakeholders collaboration, Environment strategy alliances, Coordination with outside institutes and Market adaption. According the problem exist complex interaction between indicators, the Analysis Network Process (ANP) model is used to deal with the internal and external dependence relationship between various indicators, and SuperDecisions software is applied to the complicated calculate process of the data. The paper provides an new effective tool to evaluate and improve the cooperative capacities of construction organization for Cleaner Production.

Keywords: cleaner production, cooperative capability, construction organization, ANP

1 Introduction

1.1 CLEANER PRODUCTION IN CONSTRUCTION INDUSTRY

Cleaner production is a new, creative thinking, considering to be one of the main activities of the enterprises committed to effective environmental management. Difference with other Environmental protection scheme, Cleaner Production would lead to a win-win situation of improving economic and environmental benefits. In order to sustainable development strategy in construction industry, Cleaner production (CP) is currently becoming one of the key projects performances. Wang et al present that cleaner production in China is still in the initial stage, mainly relying on government mandatory actions. One of the key reasons is lacking collaboration of organization in the process (He, 2006). The importance of organization collaboration has been demonstrated to be key factors for Cleaner Production by researchers. Fresner et al. [1] developed the key factors system to Cleaner Production success by using the TRIZ method (Theory of inventive problem solving). Büyükbay et al. [2] introduced two indicators of the internal rate of return (IRR) values and payback period to analyze the key abilities of implementing CP in printed circuit board plant. Hui et al. [3] investigated the successful elements of cleaner production in saponin industry by using material flow analysis (MFA). Zeng et al. [4] analyzed the relationship between cleaner production and business performance using Structure Equation Model (SEM). Xiong [5] presents the application of gray correlation analysis in selection of cleaner production schemes. Xu and Chen [6] discussed the selection of cleaner production based on the CP capacities of construction industry. Extensive researches on CP capability have carried out by Quantitative evaluation, but there is few to consider collaboration from organization perspective. Due to complexity, collaboration is obviously crucial in project supply chains for cleaner production.

1.2 LITERATURE REVIEW

The cooperative capability for construction organization is a key factor and was studied wildly by construction researchers. Comparing with manufacturing industry [7,8], application of the collaboration in construction industry is more effective. Collaboration is an essential key of the success of projects in project organization [9] and Cooperative working is an important factor for avoiding conflict in delivery process of construction industry [10]. Peña-Mora [11] quantified the negotiation effectiveness of different delivery systems to select the optimal one. Berends [12] analyzed collaboration effectiveness on the basis of contract type. Naoum [13] proposes a cooperative method of project contrast is very important for meeting client criteria and achieving project objectives. Turner [14] presented that a cooperative project organization would contribute to alliances between partners and would have a positive benefit for project operation. Cooperative capacity of construction organization is beneficial to enhance the project performance. It is proved in relationship of contractor and subcontractor by Borg [15]. Mokhlesian [16] responded

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that contractors need to collaborate with their suppliers in partnering setting to implement the green project. More and more synergy researches in construction industry started to use qualitative tool to analyze the cooperative capability. Parrod et al [17] applied a simulation tool to cooperative relationship between contractor and subcontractor. Palaneeswaran et al. [18] assessed the impacts of construction supply chains 'performance on project success by structural equation model. Cheng [19] evaluated the strength of an organizational structure by the analytical hierarchy (ANP) to quantify communication efficiency among organizational team members. From these researches above, it is found that cooperative capability of construction organization is very important to achieve project performance, such as cleaner production. And the quantitative tool to evaluate the capability has been generally applied

2 The index system of cooperative capability of construction organization

Collaboration has been considered as an important strategy for successful CP (Zwetsloot and Geyer [20], Chiu et al [21], Kjaerheim [22]) especially for supply chain organization. Collaboration is an effective means to take advantage of all the capabilities, resources, risk-sharing, having the strategic importance for construction enterprises to finish CP, because of the insufficiency of economy, technology, awareness and so on. Basing on the characteristics of construction industry, the paper introduce consistency of project plan, project information share, stakeholders collaboration, environment strategy alliances, coordination with outside institutes and market adaption as the contents of collation capacity.

Firstly, consistency of project plan is the essential element of organizational collaboration for CP implementation, including environmental management plan, long-term sound-control plan, production ppca plan development, win-win relationship of business and environment. Secondly cleaner production generally aims at the optima zation of material and energy flows by process modifycation, so project information share is to ensure the participant for all actors in the whole of cleaner production process. The three key issues of data availability among departments, environment information system building, and environment information tracking are involved. Thirdly, the capability of stakeholders' collaboration aims at enabling both actors to understand the impact of their behavior on cleaner production performance. It suggests collective decision-making system of environment, common requirements and specifications of production, networks of actors and common performance evaluation system of CP to be the contents for this ability. Fourthly, partnering has grown out of the development of strategic alliances in order to achieve the project objects. Environment strategy alliances must be considered in cooperative capability. Strategic cooperative partnership of CP, collective ability training and transfer, and stable strategic alliances are included. Fifthly, cleaner production needs some innovation in management and technique, such as technological change and improvement on operation practice. It is unrealistic without the support of outside institutes, so cooperative capability contains the outside collaboration not only inside one. There are four indicators to include in the capability of coordination with outside institutes: participation in environment policy, enjoyment of national economic/technical support, cooperation with financial institutes, and consistency of industry environment standards. Finally, market adaption is also indispensable for construction organization. It contains quickly resolution of CP problems, Social acceptance of project and knowledge dependence of research institutions. Establishing the index system of cooperative capacity is shown in Table 1.

TABLE 1 The index system of Cooperative Capacity for cleaner production

Goal	Cluster	Criteria
Cooperative Capability	Consistency of project plan	C11 Environmental management plan
		C12 Long-term sound-control plan
		C13 Production PPCA plan development
		C14 Win-win relationship of business and environment
	Project information share	C21 Data availability among departments
		C22 Environment information system building
		C23 Environment information tracking
	Stakeholders collaboration	C31 collective decision-making system of environment
		C32 Common requirements and specifications of production
		C33 Networks of actors
		C34 Common performance evaluation system of CP
	Environment strategy alliances	C41 Strategic cooperative partnership of CP
		C42 Collective ability training and transfer
		C43 stable strategic alliances
	Coordination with outside institutes	C51 Participation in environment policy
		C52 Enjoyment of national economic/technical support
		C53 Cooperation with financial institutes
		C54 Consistency of industry environment standards
	Market adaption	C61 Quickly resolution of CP problems
		C62 Social acceptance of project
		C63 Knowledge dependence of research institutions

The interdependence between all the elements in cooperative capability according to the interviews findings is shown in Figure 1. One-way straight arrows indicate internal or external dependence of the two elements unidirectional, two-way arrows indicated the internal or external interdependence between two elements.

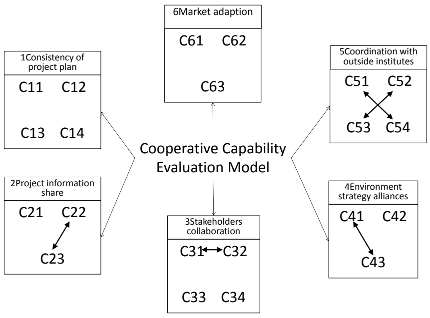

FIGURE1 The indicators structure of cooperative capability

3 Evaluation model

3.1 ANP APPROACH AND SD SOFTWARE

The analytic hierarchy process (AHP) and the analytic network process (ANP) are both the quantitative evaluation tools. However, AHP approach usually ignores the relationship and interaction among criteria and their subcriteria, while the ANP is able to consider their dependences. ANP can provide a more precision result through solving the problem with dependence and feedback among alternatives or criteria [23]. In a word, the ANP can deal with the problems that allow interactions and feedback within clusters and between clusters [24]. The paper will use the ANP to development the evaluation model of cooperative capability for construction organization, with feedback and self-loops among the clusters of indicators.

With the complexity of calculation in ANP method, Computer-aided technique has been urgently needed to improve the quality and accuracy of evaluation model. SuperDecision (SD) is a software based on the Analytic Hierarchy process and the Analytic Network Process. In the SuperDecision software priorities are derived through a series of pairwise comparisons on the factors of the problem that can including both tangible and intangible. The quality analysis is very important for evaluation model, ANP is a reliable and objective approach for making decision and SuperDecision can solve the complexity of computation work.

3.2 STRUCTURE OF EVALUATION MODEL

The evaluation model including six clusters: consistency of project plan, project information share, stakeholder's collaboration, environment strategy alliances, coordination with outside institutes and market adaption. In order to outline the structure of ANP model, we should determine the dependencies in the network as described in Figure 1. There contain feedback and self-loops among the clusters and elements in the model. Straight arrows indicate internal or external dependence of two elements; Loops indicate inner dependence among the elements in the cluster. There are 4 general steps in ANP model, including model construction; paired comparisons between each two clusters or nodes; supermatrix calculation based on results from paired comparisons; and result analysis (Saaty, 1996/2005). In the paper, we will use the SuperDecisions (SD) software to finish these four steps. The evaluation model has been given in Figure 2 using SD software. The goal of the model is to gain the priority of key indicator.

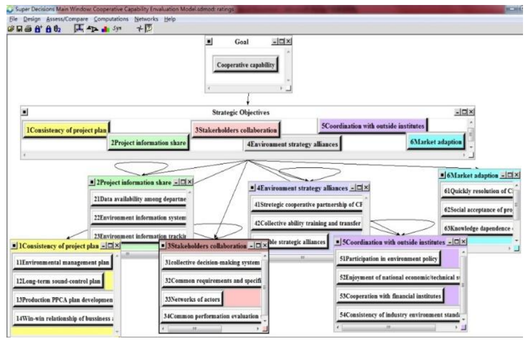

FIGURE 2 The evaluation model using ANP

3.3 COMPARISON AND CALCULATION OF INDICATORS DATA

There are qualitative and quantitative indicators, with two types of efficiency and cost. The former can be better of the bigger and the latter can be better for the smaller. According the survey data, find the dimensionless number of the indicator by the value of data means setting regionwide indicators, providing an upper limit and under limit in order to convenience the normalized the indicator data. The approach to dimensionless the data is shown in Tab. 2.

TABLE 2 Dimensionless process of indicator

efficiency indicator	cost indicator
$r_j=\begin{cases}1, y_j>y_j^{\max}\\ \dfrac{y_j-y_j^{\min}}{y_j^{\max}-y_j^{\min}}, y_j^{\max}\ge y_j\ge y_j^{\min}\\ 0, y_j<y_j^{\min}\end{cases}$	$r_j=\begin{cases}0, y_j>y_j^{\max}\\ \dfrac{y_j^{\max}-y_j}{y_j^{\max}-y_j^{\min}}, y_j^{\max}\ge y_j\ge y\\ 1, y_j<y_j^{\min}\end{cases}$

y_j means the actual value of the j-th indicators, and $y_j^{\max}$, $y_j^{\min}$ are the upper limit and lower limit predetermined of j-th respectively. Numerical judgments are made in a matrix using a nine-point scale that represents how many times one element is more important than another. It is very important that all the comparison questions are asked from the perspective of what is more important or preferred with respect to cooperative capability in the comparisons. It needs to find an effective way to increase the correctness in the model.

3.4 RESULTS

The weight of cooperative capability indicators are shown in Table 3. According to the evaluation results, the project information share the highest weight (0.2842), thus this capability is most important, followed by consistency of project plan (0.2039).Capability related with the project is more crucial for cleaner production implement, because that process control is the most effective measure for CP in China. On the contrary, Coordination with outside institutes get the smallest weight, with the reason of lacking the technique innovation for CP.

To further explore ways to improve cooperative recovery capability, the subordinate indicators were sorted by the local weight. The capability of Long-term sound-control plan has the highest weight (0.34830) in consistency of project plan. For project information share, the important capability is data availability system building (0.48232). Common performance evaluation system is most critical in Stakeholders collaboration, which account for the highest weight (0.33026).Strategic cooperative partnership ranks first in environment strategy alliances with weight of 0.4320. Participation in environment policy is the most key capability for coordination with outside institutes, which has the highest weight (0.41380). Finally, in Market adaption Knowledge dependence of research institution is most important, relying on the result of weigh (0.39387). For total priorities, strategic cooperative partnership and the common performance evaluation system are ranked first and second, respectively as 0.065275 and 0.062915.

4 Conclusion

This paper suggests an evaluation model for cooperative capability of construction organization for CP, which considers interdependencies among indicators and clusters constituting a complex network. In order to avoid the mistakes of assuming all clusters are independent, ANP approach and SD software to be used to deal with the problem in this paper. Through evaluation model development and calculation of data, there are several found from the results: first, construction organization should enhance the capability related with the project such as consistency of project plan and project information share. Second, because the CP techniques are not wildly developed, Coordination with outside institutes is considered to be the least effective capability. But with more introduction of innovation CP technique from developed countries, the capability will plan an important role in CP. Third, Construction organization should pay most attention in these capabilities of Common performance evaluation system and strategic cooperative partnership is at present, that can advance CP performance. The evaluation model of cooperative capability developed in the paper can be used to measure the CP effectiveness of various organizations.

Further research is need to do, because there are a number of shortages, such as: The qualitative indicators mostly depend on the subjective thought; The quantitative indicators lack a most effective approaches to integrate judgments; Finally, it is difficult to correctly sort these indicator without real cases. In addition to these, more research and problems needed us to do further work.

TABLE 3 The evaluation results of cooperative recovery capability

Goal	Cluster	weight	Criteria	Local weight	weight
Cooperative Capability	Consistency of project plan	**0.2039**	**C11** Environmental management plan	**0.19323**	**0.039400**
			C12 Long-term sound-control plan	**0.34830**	**0.071018**
			C13 Production PPCA plan development	**0.24291**	**0.049529**
			C14 Win-win relationship of business and environment	**0.21556**	**0.043953**
	Project information share	**0.2842**	**C21** Data availability among departments	**0.48232**	**0.137075**
			C22 Environment information system building	**0.15492**	**0.044028**
			C23 Environment information tracking	**0.36276**	**0.103096**
	Stakeholders collaboration	**0.1905**	**C31** collective decision-making system of environment	**0.22968**	**0.043754**
			C32 Common requirements and specifications of production	**0.22213**	**0.042316**
			C33 Networks of actors	**0.21793**	**0.041516**
			C34 Common performance evaluation system of CP	**0.33026**	**0.062915**
	Environment strategy alliances	**0.1511**	**C41** Strategic cooperative partnership of CP	**0.4320**	**0.065275**
			C42 Collective ability training and transfer	**0.26108**	**0.039449**
			C43 stable strategic alliances	**0.30692**	**0.046376**
	Coordination with outside institutes	**0.0765**	**C51** Participation in environment policy	**0.41380**	**0.031656**
			C52 Enjoyment of national economic/technical support	**0.13206**	**0.010103**
			C53 Cooperation with financial institutes	**0.28023**	**0.021438**
			C54 Consistency of industry environment standards	**0.17391**	**0.013304**
	Market adaption	**0.0938**	**C61** Quickly resolution of CP problems	**0.33991**	**0.031884**
			C62 Social acceptance of project	**0.26622**	**0.024971**
			C63 Knowledge dependence of research institutions	**0.39387**	**0.036945**

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