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A KNOWLEDGE INTEGRATION FRAMEWORK OF EPC PROJECT BASED ON KBS AND STAKEHOLDER NETWORKS

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Abstract. *EPC projects are promising all over the world, though the management of EPC projects at present did not seem scientific and systematized particularly in the developing countries. As EPC projects are diversified in knowledge which covers different professional fields, lifecycle periods and stakeholders, the knowledge integration not only helps solve the problems of management inside the current projects, also supports the accumulation of knowledge of the forthcoming projects. However, the recent study of knowledge integration has not gone deep into the characteristics of EPC projects so the existing methods are not applicable for EPC projects. The main purpose of this paper is to propose a solution framework for the problems in the knowledge integration of EPC projects. We first put forward a new method to identify the knowledge contained in the project work packages based on the work breakdown structure. When the knowledge is decomposed into concepts, concept attributes and relationships between concepts, it is easier and clearer to integrate. Then we establish an integration model for knowledge networks in which the knowledge from different business fields and lifecycle periods can be integrated respectively. The ultimate carriers of knowledge integration are the project participants. As a result, we finally emphasize the links between stakeholders with the knowledge network and the application for knowledge integration in EPC projects which is discussed. In view of the unique challenges in management of EPC projects, the solution method has an important role in knowledge integration for EPC project firms.*
Keywords: Knowledge integration, KBS, WBS, EPC project, Stakeholder network

1. **Introduction.** Engineer-Procure-Construct (EPC) projects are so common in the engineering and construction industry presently. An EPC project can be a complex one, broader in scope and professional field, made up of a large number of interconnected subsystems and components, requiring considerable human efforts and financial commitment [1]. The practice of EPC projects is becoming the major management practice of large scale projects around the world. Especially for the emerging country such as China, EPC has already been an important channel to enter the market of Africa, Southeast Asia, and the Middle East, to "go out" and achieve an internationalization strategy.

However, not like developed countries that have experienced a long time from traditional project style in the EPC project mode, there is no established system in EPC project management or normative business process and service standards at present in the developing countries, which makes the implication of EPC project mainly based on experience [2]. To conquer the randomness and uncertainty in EPC project management, the importance of project knowledge accumulation has been taken seriously in EPC project management.

EPC projects tend to be both labor-intensive and knowledge-intensive. The input and output as well as management of EPC projects involve a wide range of knowledge and

intellectual creative activity. Thus, the process of EPC project management is meanwhile a process of knowledge management. Effective interface management cannot be carried out due to the complex relationships between subsystems, resulting in limited project knowledge communication between business models, information asymmetry in the project and weakness in information link between business modules which may generate risks [3]. On account of the knowledge of EPC project distributing among different project phase, stakeholders, and management function discretely, it is hard to complete the knowledge configuration by means of knowledge self-organization [4].

At present, the solutions to the problem of project knowledge management are evolutions based on Project Management Body of Knowledge (PMBOK) [5]. Instead of studying internal knowledge relations between the businesses in EPC project at the knowledge level, these solutions mainly provide a framework and methods for business integration in EPC project at the business level which makes them essentially business integration management based on experience.

Thus, developing a solution path from the perspective of knowledge management corresponding to business is the focus of this article. In this path, that calling the required knowledge resources targeted to work package during the project implementation, and finishing stage task and knowledge integration on subproject, and the overall project bottom up through work package is supposed to solve the problem of organization failure in knowledge management of EPC projects, to sustain business integration management efficiently, and to help make standards for the business and construct project knowledge system.

This paper is organized as follows. Section 2 presents three focused problems of this paper after analysis of the difficulties and characteristics in knowledge integration of EPC projects. Section 3 provides the knowledge integration mode design for EPC projects, which has three critical steps, solving the problems step by step. Discussions of how the mod works and the implication for practical applications are illustrated in Section 4. Finally, conclusions are discussed in Section 5.

2. **Problem Statement.** In the knowledge economy times, firms began to realize that their long-term strategies ought to be established upon the effective knowledge management, as knowledge has become the strategically most important resource of the firm [6,7]. Knowledge resides in specialized form among different functional units and individual members. Knowledge integration promoted the transition from knowledge sharing to knowledge creation, realizing the whole process of knowledge management [8,9]. The importance and relevance of knowledge integration to a firm's competitiveness is well-established [10,11], and lots of studies are carried out to find the effective ways of integrating dispersed specialist knowledge within or across organizations [12-14].

However, the focus is mostly staying over the organizational level, and the questions of how knowledge integration can be applied in projects remain largely unanswered [10]. Wang (2003) discussed about acquisition, utilization, transfer and innovation of knowledge in the phases of project management [15], leading the research in knowledge management of project in China. Tirana and Mclean (2003) proposed that the essence of knowledge integration in the project was that a project team integrated their component knowledge through the practice into the high level of architectural knowledge in the implementation of the project [16]. Mitchell (2006) suggested the ability to integrate fragmented pockets of specialized knowledge which had important implications for large-scale information technology projects [17]. Newell, Tansley and Huang (2006) argued that a project team was essentially tasked with integrating distributed knowledge, and effectively integrate knowledge would be acquired through members' bridging activity [18].

Overall, there is a lack of in-depth study of the integrated approach for project knowledge, especially when the EPC projects are so different that the existing knowledge integration approaches do not work. In terms of knowledge management, EPC projects are special in following aspects.

Firstly, EPC project is complex. With the development of specialization and outsourcing, EPC projects show a trend in massive scale, broad business areas and various changing situations. A project is a large-scale system, constituted by lots of professional activities with different characteristics.

Secondly, the organization redesigned on EPC project is temporary. The knowledge produced by project organizations within the project life cycle will lose when a project closes and organization dissolves. This knowledge does not get well integrated and saved which makes organization have to get deeper into the solution anew when the projects run into similar problems [19]. It is a huge waste of manpower, material and financial resources.

Thirdly, participants who are called stakeholders take part in EPC project activities in different stages, associating with each other based on their respective interests. They have no chance of mutual learning in the form of long-term stable partners. It also makes different opinions and behaviors of these participants, and brings out communication difficulties and misunderstanding in a time of decision making, which causes the low efficiency of project management [20].

Taking into account the above characteristics of EPC projects, the current study does not provide the satisfactory solutions for the special difficulties in knowledge integration of EPC projects, and therefore cannot solve the inefficiency problem of project management fundamentally. Based on the above considerations, this paper attempts to solve the problems that include:

(1) The difficulties in knowledge integration between different project modules owing to the highly specialized knowledge of different business area in EPC project management.

(2) To find an approach to manage boundary issues over the different stages of EPC project management and achieve the knowledge integration in the project life cycle.

(3) To solve the problems of communication and cooperation among various stakeholders, through the way of tacit knowledge integration in project management.

3. **Knowledge Integration Mode Design.**

The nature of business integration of the EPC is project knowledge integration and the research on project knowledge integration is based on the identification and organization of project knowledge. Organizational knowledge is hierarchical and knowledge structure of the organization is a hierarchy of knowledge elements which are individuals' expertise or skills distributed in the various departments within the organization, and realizing the knowledge creation, transfer and integration through the hierarchy [21]. Project Management Body of Knowledge (PMBOK®) provides a framework and methodology for business integration from the business layer of EPC based on the Work Breakdown Structure (WBS), but the essence lies in the business integration management of experience. Consequently, the intrinsic knowledge relationship between the businesses of EPC project cannot be studied from the inner knowledge layer. In this regard, this paper proposes the hierarchical division for project knowledge according to the knowledge breakdown structure (KBS), which can lead to the method and path of knowledge integration among various business models.

3.1. **From WBS to KBS.**

WBS of the project, decomposing the complex projects into a series of specific work packages, is a structured system, reflecting all the businesses in

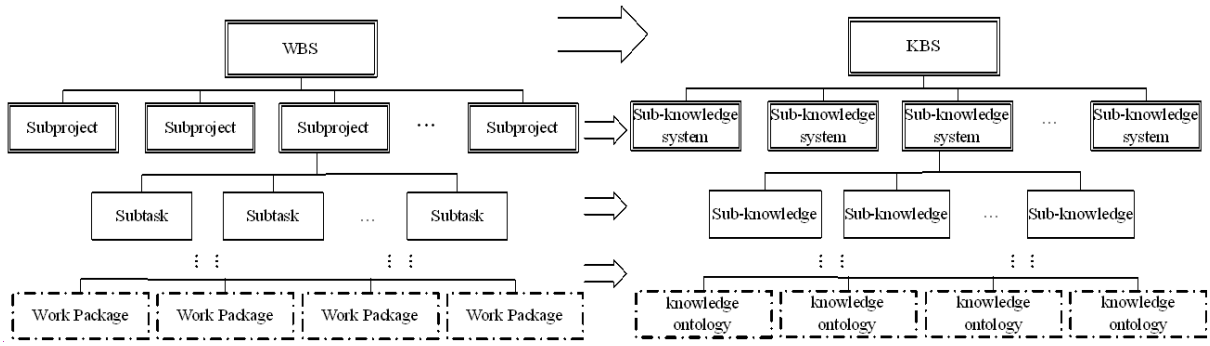

FIGURE 1. The establishment of the project knowledge breakdown structure

the project and the basis for the management and operation of the project business. Correspondingly, the project knowledge breakdown structure (Knowledge Breakdown Structure, KBS) is to deconstruct project knowledge in accordance with the WBS hierarchy, systematically identify and organize project knowledge, and thus promote the integration of business through knowledge integration. Without systematical and complete KBS, a mapping with WBS will not be established, causing the lack of knowledge premise for business integration. As a result, business integration can only rely on the experience. To this end, the division of knowledge of EPC should build a multi-level KBS on the basis of WBS, as shown in Figure 1, to achieve an effective combination of knowledge layout and business layout in EPC, contributing to the implementations of EPC knowledge integration.

Several methods can be adopted to conduct the KBS of EPC referring to WBS breakdown logic, as well as the project life cycle, project management field and other dimensions in the actual project demand. The key to establishing the KBS is how to identify the elements of project knowledge and relationships between the elements. The lowest level of the WBS covers all the work packages in the project, which are the main objects of knowledge identified in the KBS. In this paper, the smallest unit of project knowledge is called a knowledge packet, corresponding to the work packages. The work package of EPC is a set that describes the project activity cell and its associated attributes. Therefore, work package, the most direct expression and sources of project knowledge, containing all the activity cell's knowledge involved in the operation of the project, is the basis to construct a knowledge package (as shown in Figure 2). Then, the collection of all the knowledge packages constitutes the project knowledge of EPC. For comprehensive knowledge management theory and project management practical applications, the paper argues that knowledge package based on work package contains three elements, i.e., concepts, concept attribute and relationship between concepts.

Due to the multi-angle of the work package in EPC, the concept and its concept attribute of knowledge packages corresponding to work package are multidimensional constituted. Consider the project goals and process management content, knowledge package corresponding to work package may include multiple conceptual dimensions: person in charge, time, resource, cost, risk, quality, etc. Among them, there is a time dimension with the attributes such as duration and working hours, resource dimension with the attributes of quantity, specifications, and the cost dimension with the attributes of value, unit and other property (Figure 3). In EPC project, the relationship between concepts of knowledge package can be divided into two kinds: the one between concepts in the work package and the one between concepts among work packages. The former is a function or an axiom describing the relationship between concepts inside one work package, while

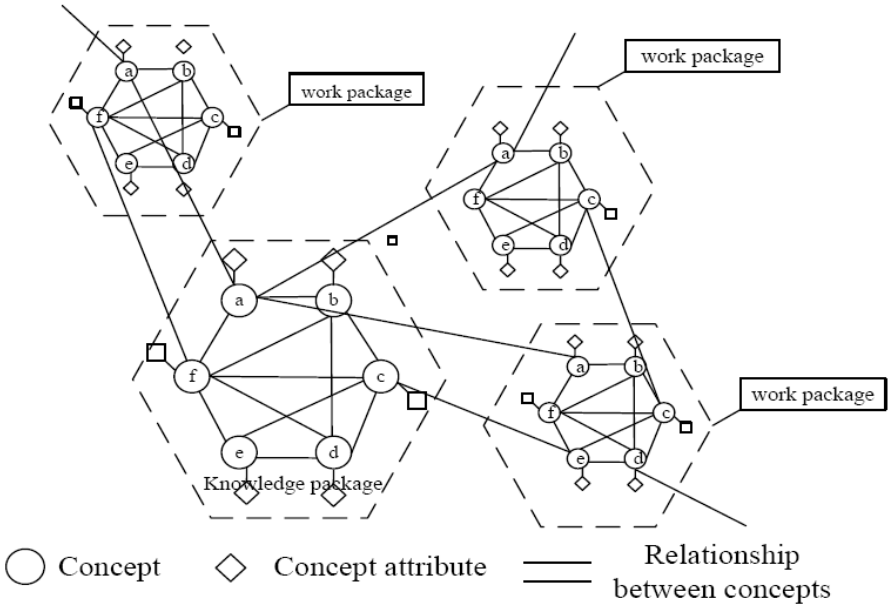

FIGURE 2. Knowledge package based on work package

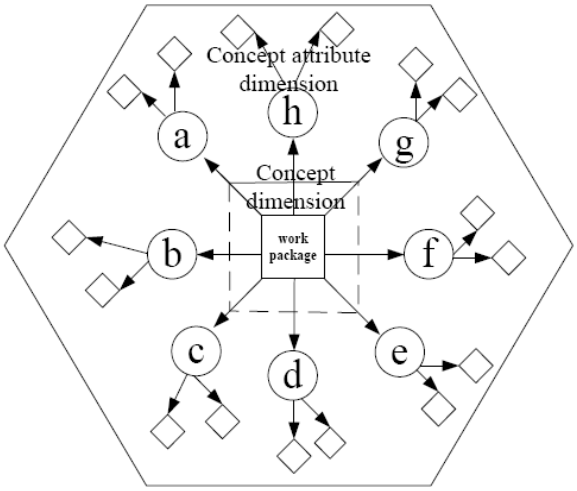

FIGURE 3. The concepts and attributes of knowledge package

the latter reflects a specific logical relationship, such as causality, primary and secondary relationship, mandatory dependencies, and priorities logical relationship according to the different concept attributes.

3.2. **Integrating into knowledge network crossing fields and periods.** In PMBOK®, project business is divided into nine project management knowledge fields, including Project Integration Management, Project Scope Management, Project Time Management, Project Cost Management, Project Quality Management, Project Human Resource Management, Project Communication Management and Project Risk Management. In order to effectively realize the integration and management of knowledge in EPC projects, the knowledge package should be integrated in every project management field, and then the whole project knowledge integration can be conducted according to the life cycle of EPC, forming the whole project knowledge network (PKN).

The concepts, attributes and their relationships of the knowledge packages in various dimensions are integrated into every field in accordance with the different stages of the project life cycle, and then knowledge integration model in every field is established, promoting the knowledge integration management in all the fields. The knowledge integration in the field level is based on the identification of the critical logic between knowledge packets, reflecting the optimization of the logical relationships between concepts, playing a

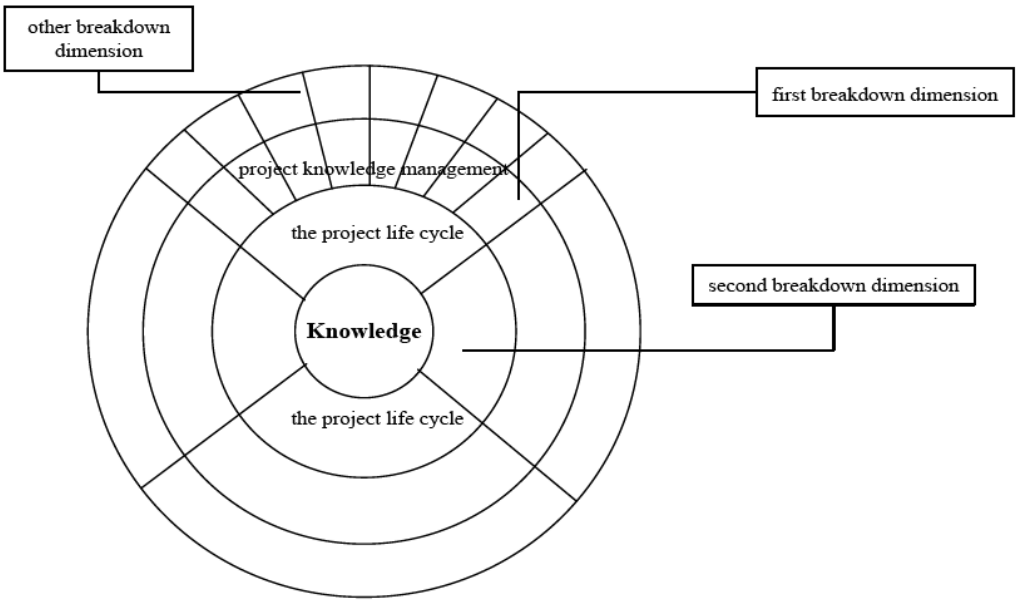

FIGURE 4. The deconstruction process of project knowledge

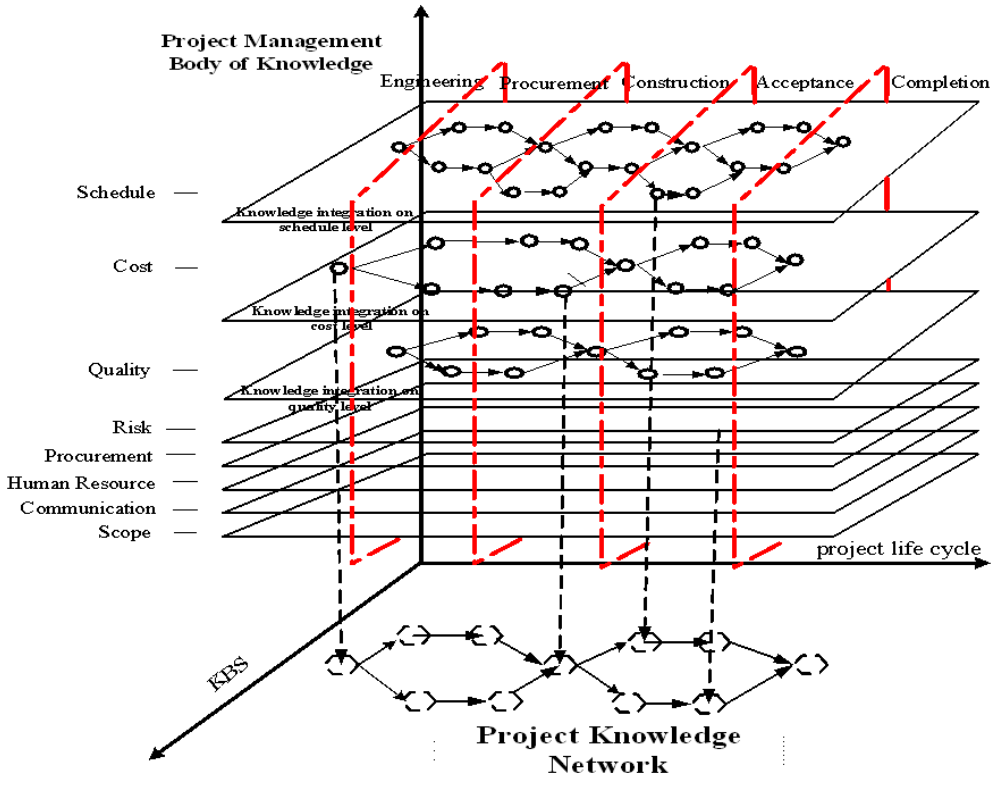

FIGURE 5. Project knowledge network in the entire life cycle

guiding role in business integration. On the basis of the field-level knowledge integration, the knowledge network in each field is established based on KBS.

However, because of life cycle, the attribute of EPC, in the process from field-level to the project-level knowledge integration, knowledge in the different stages of the project life cycle is integrated in the meantime. In the project business level, the knowledge integration is shown as project integration management conducted in every field of project management. The entire deconstruction process of knowledge is shown in Figure 4.

Overall knowledge integration model and project-level knowledge network of EPC project are constructed on the basis of the integration of the knowledge integration models in various fields and various life cycle stages (Figure 5). The cross-sections in Figure 5 are different interfaces produced in different stages.

3.3. **Making links of stakeholders with knowledge network.** Project knowledge network with knowledge package as the smallest structural unit is carrying all the knowledge of EPC, including explicit knowledge which is tangible and easily externalization-described and implicit knowledge which is professional skills, management experience, insight, intuition, value and so on created and accumulated in a long time. The normative integration management of explicit knowledge is conducted according to computer technology and touchstone; however, for the implicit knowledge, the diffusion and sharing process is difficult to regulate through PKN because of the knowledge characteristics of individuality and tacitness. Since the implicit knowledge has work-related individuals or groups as the carrier, the implicit knowledge integration at the business level can be realized with the help of stakeholder knowledge network (SKN). It is an important complement for PKN and has answered the research question, expressing knowledge semantically.

SKN is dominant in the entire process of project knowledge integration, not only realizing the application of explicit knowledge in business process, but also being the major carrier platform for explicit knowledge. The communication and application of implicit knowledge, indeed, is the process of knowledge sharing and innovation. In the process, with the help of SKN to identify knowledge, acquire node and integrate both, the business processing has been finished while new knowledge has been created. And then the organizational knowledge system supported by implicit knowledge externalization is developed to facilitate an organizational restructuring, system improvement and coordinated management process in the EPCM enterprises.

Based on WBS, during the identification of PKN, the SKN can be further built, making the stakeholder as the main body of knowledge for knowledge storage and processing. Consequently, there is a corresponding relationship between PKN and SKN of EPC, which can be mapped by Responsibility Assignment Matrix. As shown in Figure 6, the stakeholders have a variety of project knowledge and may be involved in completing tasks of different work packages; and a certain task can also be assigned to a particular person or persons with corresponding knowledge. The distribution of knowledge in SKN determines the sites knowledge sharing, application and innovation occur. It is an important evidence for the implementation of the staffing allocation and adjustment for project manager, which can effectively guarantee the implementation of the project activities and the high efficiency of resource use.

With regard to SKN, there is a certain correlation among network nodes. This correlation which indicates the communication path of implicit knowledge in the EPC business level breaks the functional boundary between the stakeholders and makes the formal and informal knowledge targeted. It not only generates the knowledge-sharing needs, but also provides a clear goal for the individual learning and knowledge innovation, contributing

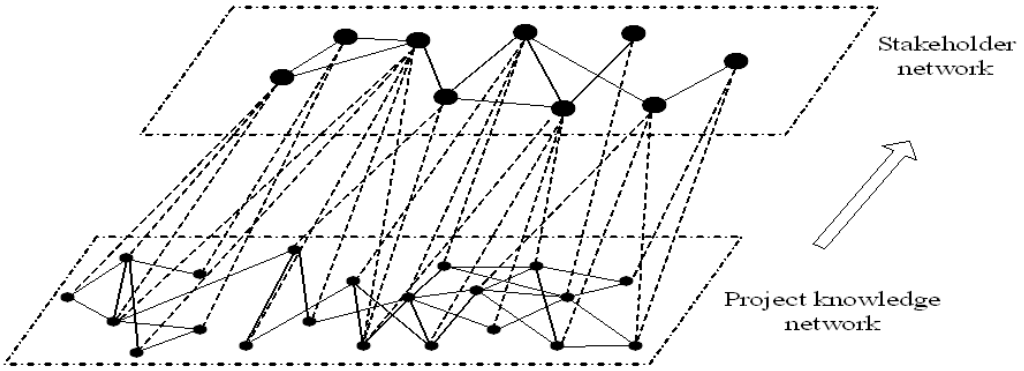

FIGURE 6. The correspondence between project knowledge network and stakeholder network

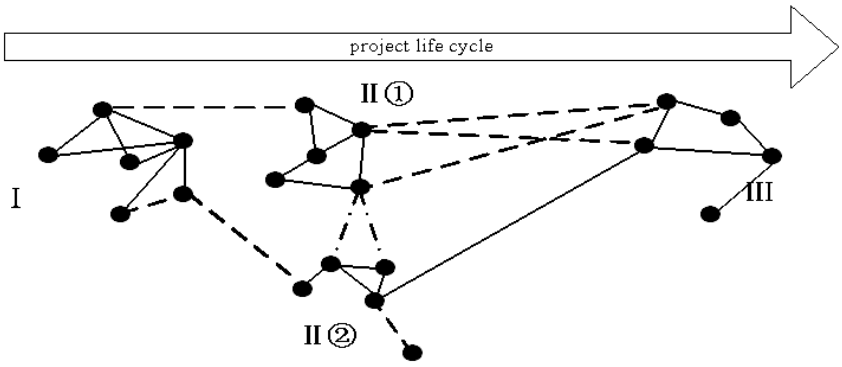

FIGURE 7. The evolution cycle of stakeholder knowledge network

to the establishment of harmonious relations in the various stages of the project in the complex organizational system of EPC. As shown in Figure 7, SKN will take on the distribution characteristics of node clustering.

In the figure, I, II, III refer to the periodical network of stakeholders in the different stages of project life cycle; II①, II② indicate periodical sub-networks of the stakeholders in different fields but the same stage. Strong links (solid line) are established among individuals in the same stage or field. Because of its high similarity of individuals (knowledge, emotion, language, etc.), the internal knowledge exchange and innovation activities will be significant. However, the knowledge integration will form islands of knowledge, which cannot meet the multi-disciplinary and coordinated-control requirements for project integration management. Therefore, attention should also be paid to the weak links (dashed line) between various stages or fields. Compared with strong links, the efficiency of weak link knowledge exchange and integration is relatively lower. However, it enlarges the storage of knowledge network to a great extent, extends the range of knowledge transfer and sharing and, what is more, plays an important role in the integration management of multi-field and multi-interface complex projects.

At the same time, the knowledge input and output of EPC in various stages are all the processes of knowledge management conducted by members of the project organization, including the identification, organization, sharing and application of knowledge. And the final output of the knowledge forms knowledge innovation. In this process, the project managers guarantee the achievement of project objectives through effective knowledge management of the project.

4. **Discussion and Application of the Knowledge Integration Mode.** EPC project is not only a labor-intensive industry, but also a knowledge-intensive industry [18]. Accordingly, the process of EPC project management is also the process of knowledge management. Due to the complicated relationships between modules in EPC project, knowledge of EPC project takes on the discrete distribution for different stages of the project, stakeholders, fields of expertise, and management functions. In other words, EPC project is interdisciplinary and multi-functional complex behavior. In this process, people ceaselessly acquire, create and apply knowledge to achieve the continuous circulation of knowledge. The knowledge in large-scale complex project is integrated by the utilization and integration of the knowledge resources with work package as an object in the project business level, then facilitating the project to be effectively implemented. Therefore, the critical measure is to utilize required knowledge resources with the work package as an object in the project implementation and then the knowledge integration in stages, subproject and the whole project are achieved by the work packages from the bottom to the top, achieving the spiral escalation of identification, organization, sharing, application and innovation. A knowledge integration mode is designed for an EPC project which includes identification of project knowledge with KBS, sharing and integrating knowledge through project knowledge network and stakeholder knowledge network, and finally achieving the unity and evolution of the above-mentioned two knowledge processes in the project knowledge integration. The framework of knowledge integration model for EPC project is shown in Figure 8.

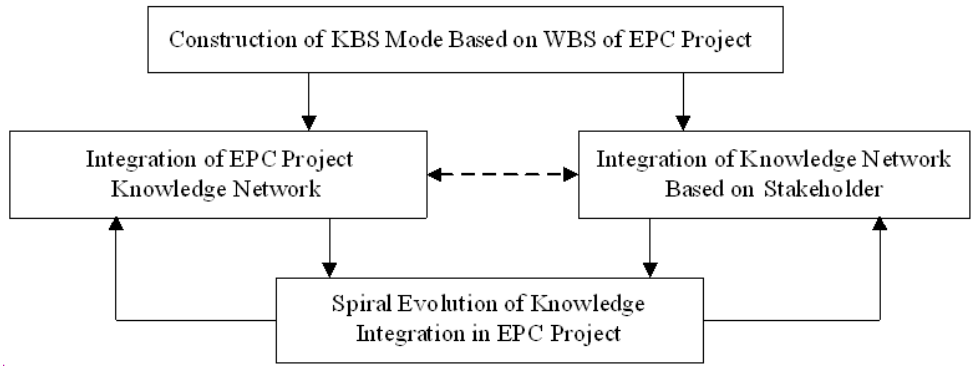

FIGURE 8. Framework of knowledge integration for EPC project

This knowledge integration model shows a process of ceaseless transfer and innovation between implicit knowledge and explicit knowledge as well as personal knowledge and organizational knowledge. This process is understood as the spiral in the knowledge processing, i.e., the explicit knowledge and implicit knowledge take spiral dynamic transformation in the different stages, to continue moving forward in the cycle [22]. In the dynamic evolutionary process, knowledge integration promotes the transition from knowledge sharing to knowledge innovation [23], and the knowledge innovation causes changes in the structure of knowledge. Along with the life cycle of the project within the system, new knowledge is emerging in each stage, which can interact and transform with the stock of knowledge. With the classification and fusion of the instinct concepts of knowledge, sequential knowledge integration system is formed.

There is correlation and co-evolution existing between Ontology networks based on SKN and WBS. On the one hand, the body identification and relationship optimization of the knowledge in EPC of the ontology network establish the scope and logical relationship of the project knowledge management and provide guidelines for the exchange of

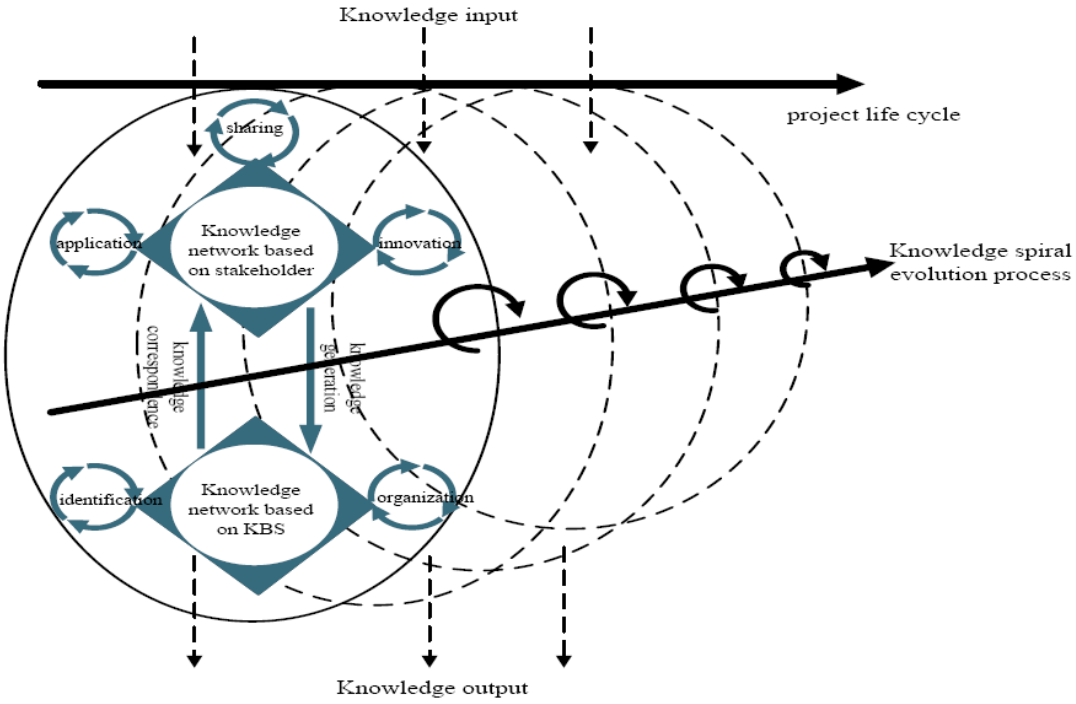

FIGURE 9. The evolution path of general contract knowledge system

knowledge in the project activities. On the other hand, the stakeholders in various stages of the project, as the carriers of knowledge storage and application, constitute a network, which is the main platform for knowledge sharing, learning and innovation. In the process of knowledge integration, stakeholders in each stage of the project life cycle acquire knowledge and accumulate experience and skills through a specific path and affect the constitution of ontology and relationship through a process of ceaseless externalization of implicit knowledge and the creation of new knowledge, leading the evolution of the ontology network. Instead, the ontology network evolution affects the network knowledge activities of the stakeholders further. The continuous enrichment of the content and optimization of the relationship between network nodes by the synergy is conducive to the process of integration and utilization of knowledge.

The process of collaborative evolution of SKN and knowledge network, covering the entire process of identification, management, organization, sharing, application and innovation of knowledge, makes the general contract knowledge system present the entire spiral evolution process, shown in Figure 9.

As with the complex organizational system in multiple stages and fields of EPC, the knowledge spiral evolution mechanism is capable to dynamically interpret the process of knowledge organization and coordination in the various stages of the project, improves the efficiency and management effectiveness of EPC and ultimately contributes to perfect the regulation and specification of the organization, to establish a corporate knowledge system supporting the EPC and to achieve the sustainable development.

As for the firms launching EPC projects, this paper has several implications.

Firstly, it is very important for firms to find out the knowledge that will be used in their projects before integrating the knowledge, so break down the knowledge is the first step for knowledge integration of EPC projects. As knowledge is fully decomposed to the smallest unit of knowledge package, it is easier to integrate knowledge in different fields based on the concept and attribute of knowledge package. The understanding of the links between knowledge packages helps in border management between different life cycles.

Secondly, good breakdown is only for better integration. When firms finish the identification of a knowledge package in the project, they can integrate knowledge in different business areas with the integration basis which is the concept of knowledge, attributes and their relationships. In other words, a knowledge package may cover multiple areas of knowledge, and to complete the knowledge integration in project areas needs to integrate the knowledge of the same field in different knowledge packages. For example, in the construction projects, the work package of painting the house contains all the tasks for completing the work. In order to clarify the work in detail, the knowledge package of this work describes the progress management knowledge of time estimating and arrangements, the quality requirements knowledge and the knowledge of material and cost estimating. The knowledge integration at field level is to integrate the progress management knowledge of painting the house, paving brick, installing doors and windows and other tasks together into the knowledge of progress management of construction projects, and the same thing for the quality management and cost management.

Finally, firms must be clear that personnel are always the most important factor in knowledge management, as knowledge exists in the mind of the person who is responsible for the work. In the practice of building the knowledge network of EPC projects, it only makes sense if the path of knowledge integration among staffs is confirmed. Knowledge exchange in an effective way corresponding to the knowledge network may be the critical thing to the knowledge integration of EPC projects. Who are the knowledge agents in knowledge network? Which is a strong connection between the knowledge agents, which is the weak link? Therefore, firms should pay attention to the efficiency and effectiveness of communication among the EPC project team to strengthen a weak connection in knowledge integration.

5. **Conclusions.** EPC projects are the future direction of the mainstream, and it is the effective knowledge management that is the key factor to carry out EPC project management well. This paper explores the issues of knowledge integration of EPC projects, hoping to attract attention to the knowledge management of EPC projects. Based on the analysis of the characteristics of EPC projects, it is proposed that the unique framework of knowledge integration in the EPC project management, which contains the knowledge breakdown on the basis of work breakdown and a clear grasp of the project work packages according to the work breakdown structure.

Research on knowledge integration of EPC projects belongs to the intersection of project management and knowledge management areas. However, the problem coming from the enterprise management practice is able to provide an effective theoretical guidance for the domestic integration management of EPC, and an indispensable reference for the practical management of EPC in China, as follows.

For one thing, from the level of knowledge management, integration based on the knowledge networks promotes the exchange and externalization of the knowledge and improves the knowledge learning and innovation efficiency of individual, then to enhance the development of organizational knowledge systems and affect the effectiveness of knowledge integration directly or indirectly by the differences of knowledge body in the aspects of knowledge ability, social relationship, etc. Therefore, knowledge integration model built in this paper provides methods and tools for knowledge integration in dynamic path for EPC knowledge management and the basic conditions for the achievement of knowledge integration.

For another thing, in the business application level, with the support of research on structural attributes of a knowledge network, EPC manager can study the quality, cost, schedule and other fields of expertise in the management process and figure out dynamic

knowledge integration paths in the business fields such as procurement and design through the identification of the nodes in the knowledge network and the strength of the relationship. On the premise that knowledge at each stage of the project can be transferred and collected on time, the cross-stage and multi-field rapid integration of project management activity is realized by continuous adjustment and path reconstruction. Then the communication efficiency is improved under dynamic conditions and the management risk is lowered, eventually achieving the project objective.

While these insights are to advance our thinking in the new direction, this paper outlines the basic framework for knowledge integrating in EPC project management. To deepen our understanding of the implementation mechanism, further study with enterprise practice cases is needed. To this extent this study only provides a first but valuable step in this field.

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REFERENCES

[1] K. T. Yeo and J. H. Ning, Integrating supply chain and critical chain concepts in engineer-procure-construct (EPC) projects, *International Journal of Project Management*, vol.20, pp.253-262, 2002.
[2] S. Zhang, L. Zhang and Y. Gao, On the integration of indicators of bid evaluation under design-build/EPC project delivery approach, *Journal of Tianjin University (Social Sciences)*, vol.2, 2005.
[3] E. W. L. Gray and F. Clifford, *Project Management: The Managerial Process-5/E*, 2011.
[4] J. R. Meredith and S. J. Mantel Jr., *Project Management: A Managerial Approach*, Wiley, 2011.
[5] J. Gido and J. P. Clements, *Successful Project Management*, CengageBrain, 2012.
[6] R. M. Grant, Prospering in dynamically-competitive environments: Organizational capability as knowledge integration, *Organization Science*, vol.7, pp.375-387, 1996.
[7] J. Swart and N. Kinnie, Sharing knowledge in knowledge-intensive firms, *Human Resource Management Journal*, vol.13, pp.60-75, 2003.
[8] F. Chirico and C. Salvato, Knowledge integration and dynamic organizational adaptation in family firms, *Family Business Review*, vol.21, pp.169-181, 2008.
[9] M. Alavi and D. E. Leidner, Review: Knowledge management and knowledge management systems: Conceptual foundations and research issues, *MIS Quarterly*, pp.107-136, 2001.
[10] J. C. Huang and S. Newell, Knowledge integration processes and dynamics within the context of cross-functional projects, *International Journal of Project Management*, vol.21, pp.167-176, 2003.
[11] J. Swart and N. Kinnie, Knowledge-intensive firms: The influence of the client on HR systems, *Human Resource Management Journal*, vol.13, pp.37-55, 2003.
[12] H. M. Kim, Enabling integrated decision making for electronic commerce by modelling an enterprise's sharable knowledge, *Internet Research*, vol.10, pp.418-425, 2000.
[13] M. C. Becker and F. Zirpoli, Organizing new product development: Knowledge hollowing-out and knowledge integration – The FIAT auto case, *International Journal of Operations & Production Management*, vol.23, pp.1033-1061, 2003.
[14] R. Andreu and S. Sieber, Knowledge integration across organizations: How different types of knowledge suggest different 'integration trajectories', *Knowledge and Process Management*, vol.12, pp.153-160, 2005.
[15] Z. Wang, Knowledge management in project management, *China Civil Engineering Journal*, vol.3, 2003.
[16] A. Tiwana and E. R. Mclean, Expertise integration and creativity in information systems development, *Journal of Management Information Systems*, vol.22, pp.13-43, 2003.
[17] V. L. Mitchell, Knowledge integration and information technology project performance, *MIS Quarterly*, pp.919-939, 2006.
[18] S. Newell, J. Huang and C. Tansley, ERP implementation: A knowledge integration challenge for the project team, *Knowledge and Process Management*, vol.13, pp.227-238, 2006.

[19] S. Kujala, K. Artto, P. Aaltonen and V. Turkulainen, Business models in project-based firms – Towards a typology of solution-specific business models, *International Journal of Project Management*, vol.28, pp.96-106, 2010.

[20] A. Keegan and J. R. Turner, The management of innovation in project-based firms, *Long Range Planning*, vol.35, pp.367-388, 2002.

[21] R. C. Hicks, R. Dattero and S. D. Galup, A metaphor for knowledge management: Explicit islands in a tacit sea, *Journal of Knowledge Management*, vol.11, pp.5-16, 2007.

[22] H. Hoang and F. T. Rothaermel, Leveraging internal and external experience: Exploration, exploitation, and R&D project performance, *Strategic Management Journal*, vol.31, pp.734-758, 2010.

[23] J. Yang, Knowledge integration and innovation: Securing new product advantage in high technology industry, *The Journal of High Technology Management Research*, vol.16, pp.121-135, 2005.