Acta Technica *62* (2017), No. 6B, 1073–1084

Design of BIM-L platform considering effective configuration

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Abstract. Under the new normal, the quantity and quality of the skilled workers in the regional construction industry showed a downward trend. At the same time, the sluggish real estate industry has also brought changes in the types of employment. Faced with this situation, how to guide Skilled Workers' development has become the core of vocational training informatization for the local government. And the promotion and application of BIM provides a new solution to this problem. This paper, after an extensive investigation, established the BIM—L database and got the configuration standards of Skilled Workers firstly. Then it has focused on how to use the BIM to draw a path for the shortage development and demonstration development of Skilled Workers. It's in order to provide useful guidance for Supply-Side Reform of Skilled Workers in regional construction industry.

Key words. Skilled Workers, BIM, Shortage development, Demonstration development

1. Introduction

At present, there are totally four types [1] of employment mode of Chinese engineering including professional engineering subcontract, labor operation subcontract, engineering team of total contract organization, shift labor of total contract organization, etc. No matter for which employment mode, professional technological workers are listed as groups of maximum mobility, maximum employment gap, the worst ensuring. With popularity of higher education, supply number of professional management personnel has tended to be stable, but number of professional technological personnel tends to reduce. On one hand, technological workers of the old generation gradually exit construction market; one the other hand, backwardness of professional technical education and insufficient reserve of young technological workers cause reduction of technological workers year by year. These cause serious supply insufficiency of professional technological personnel, especially high-level technological workers, leading to the fact that labor cost of this part in construction

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industry reaches upper bearing limit of enterprises. Meanwhile, employment types of area construction present new trends. With the fact that gold period of real estate is gone forever, construction task amount of industries related to it significantly reduces, while infrastructure, public facility, fabricated architecture, etc will become main aspects of future construction labor using. In this situation, original popular labor types possibly tend to be ordinary, and extensive low-level workers will be gradually eliminated, while high-level technological workers in highly shortage will become core force accelerating industrialization of construction.

2. Research overview

Supply-side research of human resource of construction industry at home and abroad is mainly on two aspects of configuration and development.

Specifically, there are many researches in aspect of human resource configuration. On micro-level, discussing configuration problem of human resource of a single project in perspective of construction enterprises has been long, and the content is rich. A part of scholars research core factors affecting configuration of project personnel. For example, K.R.Persad et al(1995) predicted work time of a single project work via establishing regression analysis model, and he thought project cost and project type are key factors [3] predicting human needs of project to realize optimal configuration of personnel. A part of scholars applied mathematical planning method to solve optimal configuration problem of human resources. For example, Bassett (2000) emphasized to allocate projects and work tasks via recursion method and heuristic algorithm, and he proved that this method could effectively raise skill use efficiency of workers and reduce human cost [4]. Drezet L. & Billaut J.(2008) comprehensively considered function of multi-ability factor of personnel in human resource configuration of projects, then he constructed integer programming model under this constraint and got the solutions [5] with greedy algorithm and taboo search method. In recent years, some scholars started to introduce theories in other fields into human resource configuration of projects. For example, Wang Xiaojing (2013) discussed the relationship of knowledge reuse level and dispatching efficiency of human resource. Personnel could reduce relying on professional personnel of high technologies and ability threshold of key work posts via knowledge reuse, thus expanding usability and efficiency [6] of human resources. On medium level, researches related to human resource configuration of project group continually increase. Its core is to solve optimal configuration problem of human resource in multi-objective decision and multi-project environment with mathematical models in perspective of system. For example, Kolisch(2000) researched dispatching problem [7] of personnel, equipment, etc of multi-assembly project. Japanese scholar Yoshimura Masataka et al(2005) applied a kind of project optimization system to find optimal allocating way [8] of maximum project group and human resource of total revenue in this type of group. Ren Xiu, Xia Shaogang (2009) introduced method of key chain to solve conflict management problem of shared human resource in parallel multi-projects, and they constructed a kind of human resource balancing model of project group to relieve supply-demand contradiction, providing a kind of new quantitative method

[9] for shared human resource. Certainly, some scholars also researched configuration problem of technological workers in an area on macro level, but the researches were few. For example, Zhao Bin, Lin Shitong (2015) analyzed types of technological workers of construction enterprises and main factors affecting number configuration of technological workers at background of construction market in Chongqing. They constructed number configuration model of professional technological personnel of common civil house construction project on basis of dividing project types, and they verified [10] it with data of Chongqing.

Vocational training of technological workers is mostly basic content of research on construction industry in aspect of human resource development. In it, some scholars discussed optimization strategy of all parties for technological workers in development process in construction industry. For example, Ling Zishan, Li Zhaozhong (2010) proposed to improve development efficiency [11] of technological workers via improving local laws, increasing fiscal support, establishing scientific training model in perspective of government on basis of analyzing training status and existing problems of peasant-worker. Ren Jie (2011) proposed specific measures [12] to strengthen human resource development and management competitiveness in perspective of enterprises aiming at existing problems and their formative reasons of construction enterprises in human resource development at present. Other scholars were fascinated in looking for new models of human resource development and operation. For example, Li Yanfei, Xu Zihua (2004) proposed models of talent cultivating and rent of human resource development in construction industry at the background of economics, and they proved feasibility [13] of this model in China on theoretical level. Xu Hongbin (2013) established a kind of new, multi-level, all-round model [14] of human resource development aiming at features of human resource in small and medium-sized construction enterprises.

Comprehensively, present researches are equipped with the following features: firstly, most of them are in perspective of enterprises rather than government; secondly, there are many researches on human resource configuration, while there are few on human resource development; thirdly, connotation description on human resource is general, and research of configuration and development of professional technological workers in serious shortage is insufficient; meanwhile, there is no research on supply-side reform of technological personnel in perspective of area with BIM technology. It is mainly because government's mastering on specific situation of technological workers in the area is insufficient, and it is short of accurate data; employment form of construction enterprises makes its development on professional technological personnel lack activeness; And application of BIM to configuration and development of technological personnel in construction industry lacks theoretical support and practical experience. In fact, with acceleration of industrialization process of construction and increasing maturity of BIM technology, realizing effective configuration and system development of technological workers under support of government and enterprises in area scope is also worth exploration and trial. The author discusses feasible ways of BIM in effective development of technological workers on macro level at the background of area construction industry in this thesis, so as to provide theoretical basis for application of BIM in aspect of human resources.

3. Construction of BIM-L data base and configuration standard analysis of technological personnel based on supply-demand relationship

3.1. Selection of supply-demand indexes and establishment of BIM-L data base

Supply-demand relationship of professional technological personnel in construction market is affected by two aspects including features of project and quality as well as quality of technological personnel. Considering that house construction is an industry including maximum types and number of workers in construction industry, the author researches configuration standard of professional technological personnel in area construction industry with examples of house construction in this thesis. It can be referred for other industries such as installation project, municipal project, landscaping project, etc.

In perspective of self features of a project, project type, project scale, project cost, structural form, mechanical degree, technological complexity degree, construction period, construction site environment, etc can all affect configuration level of technological workers in the area. Specifically, project cost can comprehensively reflect other factors on condition of determined project type, and project scale is usually presented by building area. Structural form can be subdivided factor of project type, and technological complexity degree is usually affected by construction site environment, while mechanical degree is closely related to area construction technology level in certain period, so related personnel can simplify above influence factors. According to prediction model of Wong J M, etc on labor needs of construction industry, four factors affecting need amount mostly are respectively: project type, project cost, technological complexity degree, construction site environment [15] . The author regards project type, building area, project cost, technological complexity degree as main factors at the time of recognizing project features in this thesis. Considering development trend of fabricated building in recent years, the author can increase project fabrication ratio as another main factor. Among them, project type and project fabrication ratio decide types of professional technological personnel, and building area as well as project cost decide project quantity and personnel amount, and technological complexity degree decides personnel quality.

In perspective of types of professional technological personnel, according to *Work Type Catalog of Identification Norm of Vocational Skills* issued by Ministry of Construction in 2012 and on-site research, types of technological workers of house construction project include woodworker, plastering worker, painter, brick layer, bar placer, concreter, form fixer, scaffolder, waterproof worker, plumber, electrician, electric welder, prestress worker, assembler, etc, and they also include rigger, tower crane driver, driver of lift or elevator, installation and dismantling worker of tower crane or lift, installation and dismantling worker of basket, excavator driver, driver of hanging drilling machine, etc closely related to construction machinery. Meanwhile, workers of skill grades are divided into five types including primary worker, medium worker, senior worker, technician, senior technician. To better sum and reflect construction situation of technological workers and merge common work types

where a single person takes charge of many work types, and remove minor work types in types of successive operation by a team at present, all work types can be divided as primary type, medium type, senior type for only few workers are of grades of technician and senior technician.

So there is no need to collect all information of past projects at the time of constructing BIM-L. In perspective of house building project, it is ok when indexes such as project type, building area, project cost, technological complexity degree, fabricating ratio, etc are obtained by project features; for technological worker type, it can be primarily determined according to woodworker, plastering worker, brick layer, bar placer, concreter, scaffolder, waterproof worker, plumber, assembler, earth-moving machining operator, machining operator of vertical transportation, etc. The author obtains related data of project features and technological work types in past years from bidding documents, settlement documents, documents of final settlement via area survey and initially constructs BIM-L data base.

3.2. Configuration model of professional technological personnel

Comprehensively considering above indexes, the author can present average labor number of certain work type of certain project as:

$$M = f \times (S \times R)/T\,. \tag{1}$$

Average labor quality of certain work type of certain project can be presented as:

$$\beta_m = M_h/M\,. \tag{2}$$

Among them, S is building area of this project, m^2; R is labor number of certain work type of unit square meter, workday/m^2 or (person ·d)/m^2; f is adjustment coefficient of differentiation; T is construction period, dβ_m are ratios of high technological workers in technological workers; M_h is average labor amount of senior workers, technician, senior technician of certain work type; M is total average labor amount of certain work type.

S and T of the project in the area during certain period are determined, and R needs to be measured firstly to obtain average labor amount M and quality β_m of certain work type of certain project. Survey and collection of historical data of construction site in the area and establishment of BIM high-volume database are needed for calculation of R, and interval value of R can be obtained via conclusion, summarizing and contrastive analysis. Value range of R can be continually updated according to real-time monitoring of BIM. Calculation formula of R is:

$$R = F_r/P_r\,. \tag{3}$$

Among it, F_r represents labor cost of certain work type in unit area of sample construction site, yuan/m^2; P_r represents daily average salary of workers of certain work type in sample construction site, yuan (person. d).

3.3. Configuration standard analysis of all technological personnel

The author obtains basic data via providing questionnaires for enterprise personnel of project cost and authorized departments of construction of local government with example of single project of house building project. Totally 200 questionnaires are sent out, and practical recycling number is 186, and 178 questionnaires are effective. R value of brick layer in certain area is as follows according to result of statistic analysis:

Note: ①Project type of this table is prepared in reference to division standard of *Design Rule of Civil Construction* in combination of area structure type.

② This table is based on partial survey data (2010-2016), and labor amount in unit area is average interval value of this area (remove the highest and the lowest).

Secondly, differentiated adjustment coefficient f and average labor amount M_h of professional technological personnel of high technology shall be determined. Time difference, technological level difference, etc among project items shall be comprehensively considered for value of f, and it can be deduced according to experience and sample data. Reference value of M_h is mainly obtained relying on survey data.

In process of constructing BIM-L, personnel can use coding technology to code project type, technological work type, and collect, arrange past data one by one according to coding. In process of using BIM-L, personnel can find similar projects and correct it to current state via f by searching and contrast.

4. Operation way of effective configuration and system development for non-professional technological personnel in area construction of BIM

4.1. Vacancy development way of professional area technological personnel based on prediction background of BIM

Projects under construction, projects to be started and projects possibly started in certain period of future in an area are recorded in related departments. Personnel can know about total amount of project item, ratio and feature of all kinds of projects, etc of an area in short, medium or even long term via typing these records into BIM-L for analysis after summarizing. On this basis, personnel can predict value range of R of work types in all kinds of projects with BIM-L high-volume data base according to configuration standard of professional technological personnel in last area in construction industry. Meanwhile, personnel can apply BIM to conduct real-time monitoring on area project item, and predict average labor amount and quality of all work types in key chains of various projects in certain period at present and in the future via continually updating value R. So personnel can provide accurate direction for vacancy of professional technological personnel in area construction industry. Vacancy development procedure of professional technological personnel in the area is shown in Fig. 1.

Table 1. Summary of Masonry Works' Number per unit area of Building Engineering in Certain Region (man-day) /m^2

Labor number m^2(person. d) /m^2 Project type		Single party of brick layer					
Floor number	Structural type	Building area S	Construction period T (Starting time)	Project cost F	Labor cost of unit area for brick layer F_r	Daily average salary of brick layer P_r	Labor amount of unit area of brick layer R
Lower floor 1-3	Masonry structure						0.28-0.32
	Frame structure						0.21-0.24
	Others						
Multiple-floor 4-6	Masonry structure						0.23-0.27
	Frame structure						0.14-0.16
	Shear wall structure						0.08-0.12
	Others						
Mid-high floor 7-9	Frame structure						0.15-0.18
	Shear wall structure						0.07-0.12
	Frame-shear wall structure						0.13-0.16
	Others						
High floor 10-40	Frame-shear wall structure						0.09-0.13
	Shear wall structure						0.04-0.09
	Tube structure						0.04-0.11
	Others						
Super-high rise structure 41-70	Frame-shear wall structure						0.14-0.21
	Shear wall structure						0.06-0.11
	Tube structure						0.06-0.15
	Others						
Others							

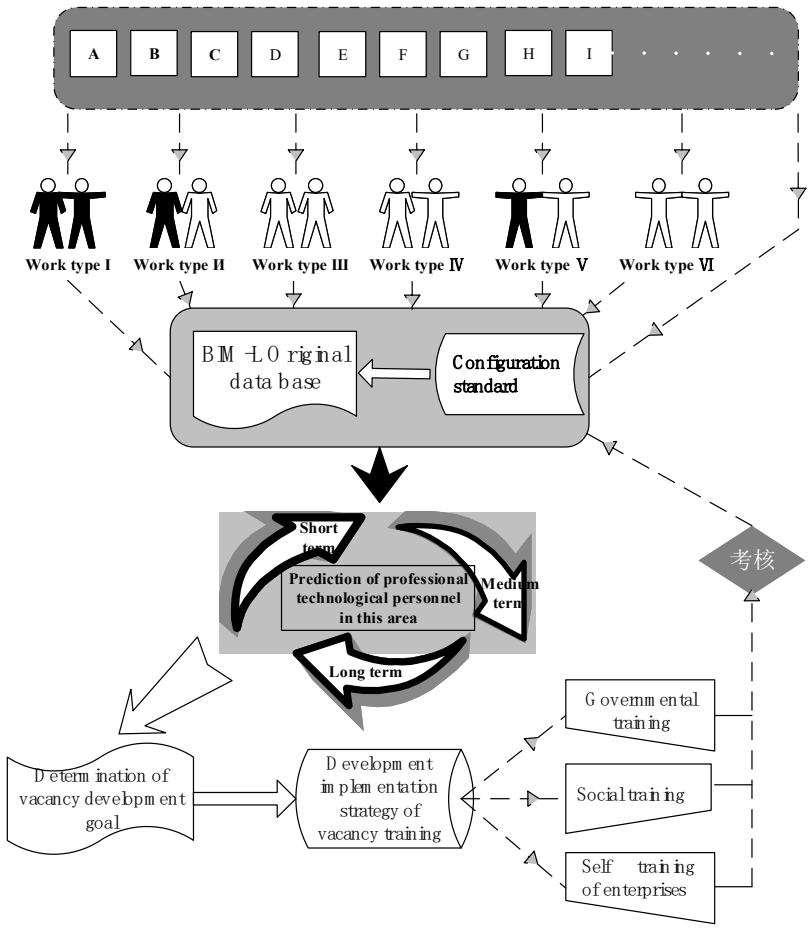

Fig. 1. The flowchart of shortage development for skilled workers in certain region

After determining vacancy development goal, personnel need to formulate specific implementation strategy. On one hand, local government shall use financial aiding fund to provide free vocational training of construction workers, and realize promotion and supply of work types of serious shortage for new construction craft on emphasis. On the other hand, enterprises shall exert their dominant role of vocational training, and adopt ways of self-training and entrusted training. Enterprises of total contract can commonly develop vacancy development of construction workers via withdrawing training expenses and long-term co-operational enterprises of professional subcontract and labor subcontract, and they can also entrust social power such as social organizations, vocational institutes, professional training agencies, etc to undertake training of professional technological workers of high level according to marketization requirements. In vacancy development process of professional technological personnel in the area, the most core problem is to establish and improve dynamic mechanism of supervision and examination. Personnel can normalize ex-

amination process via three-dimension monitoring technology of BIM-L, and find the most effective vacancy training method via collection and analysis of dynamic data of BIM-L, and establish training information system to manage training archive of all technological workers.

4.2. Exemplary development way of professional technological personnel in the area based on background of BIM monitoring

(1) Formulate determined principle of typical project item in the area and establish dynamic monitoring system

There are many types of and plenty project items in the area, and there is no doubt that personnel will add operation cost of the whole system if they conduct monitoring with BIM technology. So personnel need to tease projects in the area, select representative items as typical construction sites. Personnel can adopt ABC analysis method for many times step by step until they capture "key minority". Firstly, personnel can classify project items in the area based on methods mentioned above, and find main project type in this area; secondly, personnel can regard different project items of the same type as object, and find typical construction site of all main project types. In the process, building area, project cost, etc can be selected as accumulated frequency indexes. It is shown in Fig. 2.

After determining typical project item in the area with above methods, personnel need to apply real-time monitoring technology to realize operation monitoring pf professional technological workers in all key working faces on BIM platform. Personnel can select different time periods to start monitoring. Personnel can set monitoring points according to different work types. Personnel shall monitor operation procedure, work efficiency and result quality of different operation personnel in all working faces on emphasis, and transmit documents such as related video, pictures, etc to BIM platform for data handling and analysis in cycles.

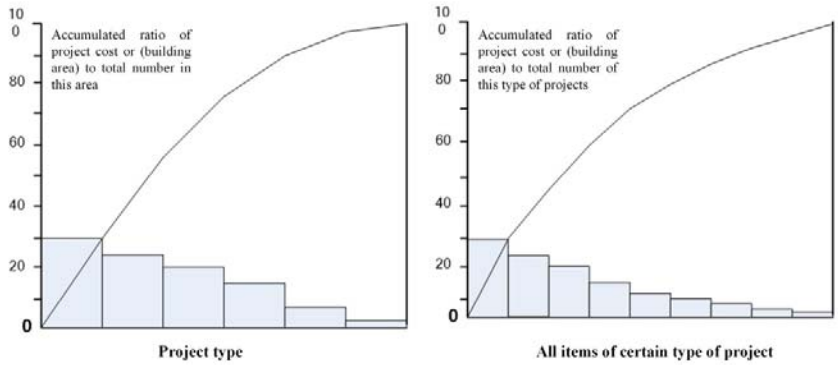

Fig. 2. The method of identifying the typical project

(2) Exemplary development procedure of professional technological personnel in the area

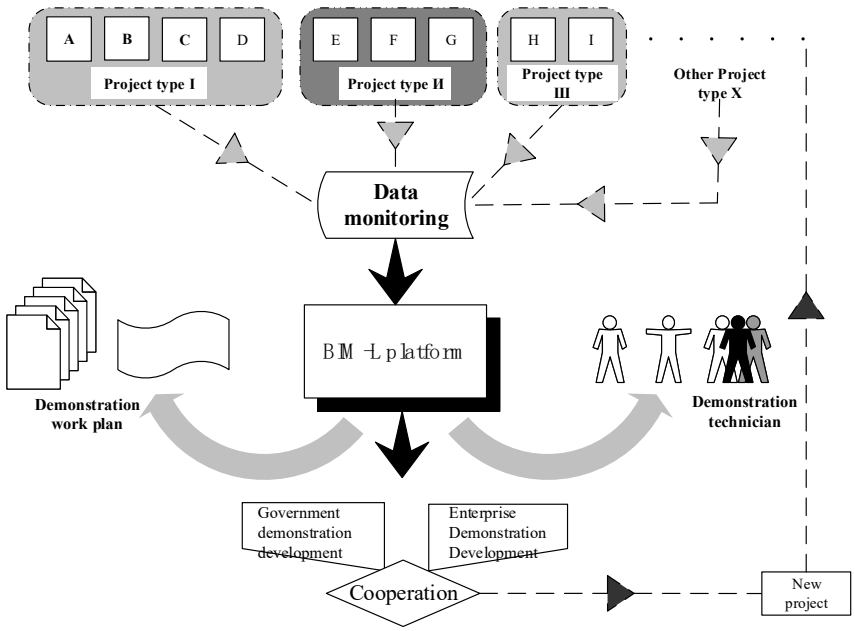

Fig. 3. The flowchart of demonstration development for skilled workers in certain region

Personnel can obtain optimal operation scheme and optimal technological personnel of all work types of all kinds of project items via operation monitoring of all work types in typical construction site and processing and analysis of related data on BIM platform. These operation schemes and technological personnel can exert exemplary effect on other items in the area. For optimal operation scheme, personnel can disintegrate it after handle it with BIM technology, and formulate exemplary text easy to learn as exemplary development course for professional technological personnel in the area; for optimal technological personnel, related personnel can train other personnel of lower technological level via ways of demonstration or even teaching. In specific operation, government will strong support it based on the goal of increasing employment quantity and quality in the area, and provide policy inclination, financial aiding, etc to guide perfection of this development system; enterprises will also actively participate in exemplary development of professional technological personnel based on saving of labor cost and optimization of work progress and quality, accept monitoring and provide first-hand data. Its exemplary development procedure is shown in Fig. 3.

5. Conclusion

In new normal conditions, to solve supply-side difficult problem of professional technological workers of area construction industry, mutual cooperation of local gov-

ernment and construction enterprises is needed, and it can be realized via effective configuration and system development. In this process, application of BIM platform is vital. At present, Chinese construction industry has defects such as different standards, insufficient systematicness, etc on BIM, but promotion and use of BIM are the trends. This thesis is right a trial to effectively associate BIM and human resource development. The author discusses how to predict quantity and quality of personnel configuration of work tasks in all key chains of items, explore vacancy development way applying BIM platform on emphasis; how to capture actual work efficiency and finished product quality for professional technological personnel in all working faces, explore exemplary development ways applying BIM platform. The author aims to accelerate supply-side reform of professional technological personnel in Chinese construction industry to advance in the direction of professionalism and informatization.

In the following research, the author will conduct system and scientific planning on specific construction process of BIM-L platform. The author will conduct deeper research on embedded model when local government and construction enterprises are establishing the platform commonly. The author will also propose practical and feasible schemes for supervision and examination of professional technological personnel after development. In short, the author has established theoretical frame for professional technological personnel configuration and development way of area construction industry under BIM platform in this thesis, but specific implementation scheme and guarantee measures need further improvement.

Acknowledgement

Shaanxi Provincial Department of Education key base project (15JZ035).

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Received May 7, 2017