Maturity Evaluation on Safety Standardization in Hydropower Construction: Methodology and Case Study

CHEN Shu, YU Di, ZHENG Xiazhong*

***Abstract*--Safety standardization is considered to be a promising solution of improving serious safety situation in hydropower construction, so maturity evaluation on performance of safety standardization is an appropriate response and one of the most critical operations. Accordingly, this article aims at developing a maturity evaluation method by using the maturity evaluation framework of software capability for reference. Firstly, the performance maturity of safety standardization is divided into five grades according to the practical effect and the key technological capability in process standardization. Secondly, a safety standardization evaluation index system is built and evaluation criteria are established with special reference to the "interim measures of evaluation and management on hydraulic safety production standardization". Furthermore, the hierarchical weighted method is used to quantify the quantitative maturity level of safety standardization system through a survey. And a maturity cobweb model of safety standardization system is constructed to analyze the principal factors which may influence the evaluation. Finally, the feasibility and validity of this approach are illustrated by the case study of Xiang Jiaba Dam. The presented maturity evaluation approach will effectively provide additional tool to promote and to improve safety standardization of the system for supervisors and engineers.**

***Index Terms*— safety management, maturity evaluation, safety standardization, hydropower construction, assessment criteria**

I. Introduction

Hydropower construction system has more influencing factors, such as unique geological landform conditions, complex construction environment, extensive external connection, and more random disturbing factors in operation process. In practice, most disastrous failures occurred in construction period may impose considerable economic losses and even result fatalities[1]. Due to this high degree of uncertainty and potential destruction, there is a growing interest to develop and to introduce safety standardization technologies recent years. The application of safety standardization is considered to be a promising solution especially for the serious safety situation in hydropower construction[2]. Safety standardization system will be established gradually in all hydraulic engineering projects in China. When the safety standardization system put into thorough implementation, maturity evaluation on performance of safety standardization is an appropriate response and one of the most critical operations in the hydropower construction[3]. Furthermore, evaluating the maturity of safety standardization accurately and reliably is a sequential and conceptually concise approach, which gives step wise insight into each phase of a project[4].

Construction industry, as high-risk industries not only in China, but also in the world, attracted many scholars attention preventing accident[5]. The basic assumptions of safety management that safety should be a management responsibility is present in the classical works of Heinrich[6]. Due to the status change of people in the production process, human errors are considered to be a prime cause of accidents[7, 8]. The field of safety management has certainly evolved since the publication of Peterson's book in 1978. Most practical efforts(e.g. Abu-Khader[9]; Wang[10]) to manage safety still seem to be based on this assumption, and consequently, that the control of employee behavior is a key objective of safety management.

Safety standardization proved to be a useful tool in safety management in preventing incidents and accidents[11]. There are now signs that companies are taking further steps towards standardization[12]. Standards can be seen as generalized and formalized rules that serve to prescribe and document efficiency and control within and across organizations. The term standardization can broadly be defined as the process of "rendering things uniform"[13]. In many ways, the logic of standardization is an integral part of the very notion of organization[14]. Standards have been among the supreme expressions of rationality. The doctrines of scientific management, can be seen as one of the earliest manifestations of standardization within organizational science[15]. As already indicated, we see the key principles of safety management as expressions of standardization[16].

Internationally there is a growing interest in the application of safety standardization in production. On account of its wide application, Moran[17] et al., Antonsen[18] et al. analyzed both advantages and disadvantages in management practice of safety standardization system. In order to evaluate process risk consistently and

Manuscript received December 16th, 2013; revised April 22nd, 2014. This work was supported in part by the National Natural Science Foundation of China under Grant No. 51379110, and the Science Foundation of China Three Gorges University under Grant No. KJ2013B073.

CHEN Shu is with the College of Hydraulic & Environmental Engineering, China Three Gorges University, Yichang 443002,PR China(e-mail: chenshu@whu.edu.cn).

YU Di is with the College of Hydraulic & Environmental Engineering, China Three Gorges University, Yichang 443002,PR China.

ZHENG Xiazhong is with the Collaborative Innovation Center for Geo-Hazards and Eco-environment in Three Gorges Area, China Three Gorges University, Yichang 443002, PR China(Tel: 08618986836111; e-mail: zhengxz@126.com).

systematically, Stavrianidis et al.[19] discussed a process safety compliance framework (PSCF) which assesses the compliance of the process to existing standards and provides opportunities to improve the management of technological risk. By using systematic and scientific modeling approach and optimization technique, Yue-Cheng et al.[20] put forward main factors of safety standardization and established overall frame of its operation mechanism. Meanwhile, Ting-Ting et al.[21] comprehensively applied fuzzy comprehensive evaluation theory and analysis hierarchy process (AHP) and set up a grade evaluation model of safety standardization. Xin-Feng et al.[22] stated the importance of using safety standardization in hydraulic power plant, and then they comprehensively summarized experience of safety standardization based on Ertan Hydropower Station's. Then through management practice of construction safety standardization in Nuozhadu Hydroelectric Station program, Xi-Bin et al.[23] showed that construction safety standardization has practically elevated safety management efficiency and safety control ability. It has boosted the establishment and evaluation efficiency of safety standardization.

Great efforts which was made to tackle construction safety problem effectively during recent years, provide us examples and reference to promote safety standardization in hydropower construction. But the traditional approaches mainly focus on basic stages like establishment procedure, implement issues, evaluation mechanism, information platform construction and so on. Thus they lack dynamic analysis and evaluation on overall operation and development tendency of safety standardization system from a systematic prospective[24].

Base on the concepts of systematic theory and process improvement, this study discusses an index system of construction according to the structure of safety standardization and attempts to propose a maturity evaluation method for hydropower construction by using the maturity evaluation framework of software capability for reference. Thereafter, we will demonstrate the use of maturity evaluation method by using an example taken from Xiang Jiaba Dam, a hydropower project under construction in the southwest of China.

II. Maturity Grading

Safety standardization is to establish safe construction responsibility, safety management system and operation procedures. It is not only to troubleshoot potential problems, monitor major hazard sources and establish preventive mechanism, but also to regulate construction behaviors, ensure each construction procedure be confirmed with relevant safety laws and regulations and keep persons, machines, materials and environment all in good construction status. Therefore, we should strengthen construction safety standardization continuously.

Proactive maturity evaluation for construction safety of hydropower can measure the conformity of pre-scheduled performance standards and achievement degrees of a specific safety standardization performance objectives. It cannot be considered as an autonomous goal. The purpose is oriented to finding and solving the problems in order to uphold the spirit of achieving performance targets and to continue improvement[25].

To fulfill a good operation, standardization system will experience adjustment, amendment, and continuous improvement from its initial creation. While based on hierarchical promotion frame of process improvement principles[26], the maturity model method can provide an improved path to evaluate and hierarchical improve the standardization system for construction safety of hydropower. In accordance with its main features of each stage, maturity grading is set as following:

1) Maturity Grade 1 is the initial grade. It's the lowest grade of standardization system for construction safety of hydropower: it only carries out some basic requirements of safety standardization, and there is certain arbitrariness whether it performs or not. The safety management mainly depends on habits and experience.
2) Maturity Grade 2 is the planning grade. In this grade, it focuses on structured process and criteria: attention will be paid to work of safety standardization, plans will be made, and manual, material and financial supporting measures will be provided. It will gradually standardize the implementation process of safety standardization, and its execution program is stable and repeatable.
3) Maturity Grade 3 is the standard grade. In this grade, it emphasizes organizational standards and institutional process: works of safety standardization will be put into standardization process and it will blend in daily work of safety production. There will be specific targets of safety standardization. The supporting system construction will be relatively complete and programmed working procedures will be well formed during its implementation.
4) Maturity Grade 4 is the control grade. It's an integration process in this grade: it will quantify the effectiveness and efficiency of system operation. That is, through safety performance monitoring and surveillance, to establish quantitative evaluation index, thus to analyze the results of system operation and to take appropriate control measures to improve the system's operational effectiveness.
5) Maturity Grade 5 is the continuous improvement grade. This grade is the highest grade in safety standardization system. It's an ongoing process of optimization in this grade: it can review and make quantitative analysis of system operation results. Based on feedback and changes, it can timely improve the system in a dynamic manner. It will continuously optimize the system, and then essentially improve construction safety level of hydropower engineering.

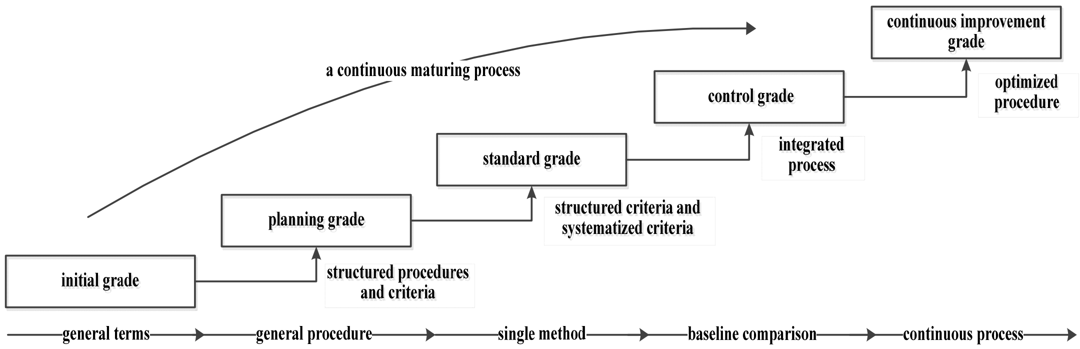

Fig 1 Maturity level

III. Evaluation Elements and Standards

A. Evaluation Elements

Maturity evaluation on safety standardization in hydropower construction is a complex process that entails the consideration of many parameters, which are difficult to quantify[27]. For meeting the core requirements of the "basic norms for work safety standardization of enterprises" (AQ/T 9006-2010), Ministry of Water Resources issued "hydraulic safety production standardization evaluation management interim measures" to serve as technical evaluation standards for safety standardization in hydropower construction[28]. This system includes 13 first-grade elements and 45 secondary-grade items. Safety standardization system maturity is mainly measured by the performance of these elements. Therefore, the evaluation model of safety standardization system evaluation model takes these core elements as first-grade evaluation index, and related secondary-grade items as secondary-grade evaluation index, to create a safety standardization evaluation index system, as shown in Table 1.

B. Assessment Criteria

To make a comprehensive evaluation upon the establishment of safety standardization system, evaluation criteria of each evaluation index are yet to be made. Evaluation criteria are the basis for a comprehensive evaluation, and each index in each maturity grade has corresponding features[29]. For results of first-grade indicators evaluation is determined by secondary-grade indicators, the secondary-grade indicators evaluation criteria are the only aspects to make sure. For space limitations, we will take the reporting of occupational hazards as an example, to establish evaluation criteria of maturity grade, as specified in Table 2 below; other indicators evaluation criteria will not established then.

TABLE 1
EVALUATION INDEX SYSTEM

First-grade indicator	Secondary-grade indicator
Safety construction target(S_1)	Target-setting; target implementation; target supervision and assessment
Organization and responsibility(S_2)	Security gear; staffing; security responsibility
Safety construction input(S_3)	Safety construction expense management; security costs expenditure
Laws, regulations and safety management system(S_4)	Laws, regulations and standards; safety regulations; safety procedures; evaluation; amendment; file management
Training (S_5)	Training management; security management personnel training; job operating personnel training; other personnel training; safety culture establishment
Construction equipment management(S_6)	Equipment basic management; equipment operation management; equipment scrap management
Construction safety(S_7)	Site management and process control; operating behavior management; warning signs; interested party management; change management
Hidden danger investigation and risk management(S_8)	Hidden danger investigation; risk management; forecast and early warning
Major hazard sources monitoring(S_9)	Identification and assessment; registration and filing; supervising and management
Occupational health(S_{10})	Occupational health management; occupational hazard informing and alerting; occupational hazards reporting; industrial injury insurance
Emergency rescue(S_{11})	Emergency response administration and personnel; emergency plan; emergency facilities, equipment and supplies; emergency response training; emergency rescue
Incident reporting, investigation and management(S_{12})	Incident reporting; accident investigation; accident handling
Performance assessment and continuous improvement(S_{13})	Performance assessment; continuous improvement

TABLE 2
EVALUATION CRITERIA FOR DECLARATION OF OCCUPATIONAL HAZARDS

Secondary-grade indicator	Maturity grading				
	Initial grade	Planning grade	Standard grade	Control grade	Continuous improvement grade
Occupational hazards reporting	Occupational hazards undeclared	Major occupational hazard factors declared, but incomplete	Occupational hazard factors reported properly	Occupational hazard factors reported accurately	Occupational hazards timely and truthfully reported , and supplementary report made immediately after changes

IV. Maturity Assessment Methods

Safety standardization system maturity grading is evaluated according to hierarchical weighted method[30].

1) Firstly, we assign a certain weight to the importance of each secondary-grade indicators.
2) Secondly, we score each secondary-grade indicators through questionnaire and work out the weighted scores of secondary-grade indicators by multiplying its average score and weighted value.
3) Finally, sum up scores of all first-grade indicators to find out an aggregate score of maturity model, which determines their respective grades according to maturity classification criteria.

A. Indicator Weights

The Ministry of Water Resources of PR China issued “Standardized evaluation criteria of safety production in water conservancy and hydropower construction enterprise (for trail implementation)", which gives each secondary-grade indicator different scores, the score of each first-grade indicator is the sum of all the scores of its secondary-grade indicators[31]. Corresponding to this evaluation index system, the weights of secondary-grade indicators are the total scores of all the factors and sub-factors in this evaluation criteria. If the aggregate score in this evaluation criteria is 1000 points, then the weights of secondary-grade indicators is:

$$\omega_{ik} = \frac{T_{ik}}{1000} \qquad i = 1, 2, \cdots, 13 \qquad k = 1, 2, \cdots, m \tag{1}$$

In this format, T_{ik} stands for the scores of secondary-grade indicators in this evaluation criteria; m means the number of all the secondary-grade indicators included.

B. Maturity Grading

Evaluate the maturity through questionnaire, which is designed based on evaluation system of safety standardization system maturity. It includes the first-grade indicators, secondary-grade indicators and the evaluation criterion that all together form the evaluation system of safety standardization system maturity model. And each indicator will be marked according to Likert5 Marking System.

Suppose there are n effective questionnaires, a secondary-grade indicator has got a score of s_l, then the average score of the questionnaire is:

$$\overline{s_{ik}} = \frac{1}{n}\sum_{l=1}^{n} s_l \qquad i = 1, 2, \cdots, 13 \qquad k = 1, 2, \cdots, m \tag{2}$$

The weighted score of the secondary-grade indicator is:

$$s_{ik} = \overline{s_{ik}}\,\omega_{ik} \tag{3}$$

The weighted score of first-grade indicator S_i is the sum of all the weighted score of secondary-grade indicators that are included:

$$S_i = \sum_{k=1}^{m} s_{ik} \tag{4}$$

Thus the total score of safety standardization system maturity is the sum of weighted scores of 13 first-grade indicators:

$$P = \sum_{i=1}^{13} S_i \tag{5}$$

According Likert5 marking principle, the maturity grades are divided into five specific grades, as shown in Table 3.

C. Maturity Cobweb Model

The first-grade indicator gets the maximum when each questionnaire score of secondary-grade indicator is 5:

$$S'_i = 5\sum_{k=1}^{m} \omega_{ik} \tag{6}$$

Then the scoring rate of each first-grade indicator:

$$r_i = \frac{S_i}{S'_i} \tag{7}$$

The indicator which has higher scoring rate also makes greater contribution to maturity. When we select 13 first-grade indicators as evaluation dimension, and link the scoring rate of each first-grade indicator from beginning to the end, then we can get the maturity cobweb model of the safety standardization system.

V. Case Study

A. Engineering Data and Surveys

Xiang Jiaba is a hydropower project under construction in the southwest of China. It is a huge-sized hydropower project which mainly focuses on electricity generation. At the same time it has the function of flood control, sediment deduction and improving the overall efficiency of the downstream shipping conditions. To evaluate the establishment of safety standardization, questionnaire survey is applied to evaluate the maturity of it.

The questionnaire covers directors of safety and technical section, safety managers, construction managing staff, operating personnel and other safety engineering and construction-related personnel. A total of 420 questionnaires were distributed and a total of 383 questionnaires recovered. After excluding 10 invalid questionnaires, 373 questionnaires were valid. The valid recovery rate reached 80.8%, as shown in Table 4.

TABLE 3
GRADE CLASSIFICATION STANDARDS OF MATURITY

Grade	Initial grade	Planning grade	Standard grade	Controlling grade	Continuous improvement grade
P	（0,1]	(1,2]	(2,3]	(3,4]	(4,5]

TABLE 4
LIST OF THE RESEARCH SAMPLE RECOVERY PROFILE

Representative number of sampling	The number of samples recovered	Recovery rate	Effective number of samples	The valid recovery rate	Invalid number of samples
420	383	91.19%	373	88.81%	10

TABLE 5
INDICATOR WEIGHTS

First-Grade Indicator	Weights	Secondary-Grade Indicator	Weights
Safety Construction Target	0.030	Target-Setting	0.006
		Target Implementation	0.008
		Target Supervision and Assessment	0.016
Organization and Responsibility	0.050	Security Gear	0.010
		Staffing	0.010
		Security Responsibility	0.030
Safety Construction Input	0.050	Safety Construction Expense Management	0.025
		Security Costs Expenditure	0.025
Laws, Regulations and Safety Management System	0.070	Laws, Regulations and Standards	0.012
		Safety Regulations	0.019
		Safety Procedures	0.018
		Evaluation	0.004
		Amendment	0.004
		File Management	0.013
Training	0.070	Training Management	0.010
		Security Management Personnel Training	0.010
		Job Operating Personnel Training	0.030
		Other Personnel Training	0.012
		Safety Culture Establishment	0.008
Construction Equipment Management	0.120	Equipment Basic Management	0.030
		Equipment Operation Management	0.075
		Equipment Scrap Management	0.015
Construction Safety	0.280	Site Management and Process Control	0.130
		Operating Behavior Management	0.090
		Warning Signs	0.025
		Interested Party Management;	0.025
		Change Management	0.010
Hidden Danger Investigation and Risk Management	0.080	Hidden Danger Investigation	0.035
		Risk Management	0.035
		Forecast and Early Warning	0.010
Major Hazard Sources Monitoring	0.080	Identification and Assessment	0.020
		Registration and Filing	0.010
		Supervising and Management	0.050
Occupational Health	0.060	Occupational Health Management	0.030
		Occupational Hazard Informing and Alerting	0.008
		Occupational Hazards Reporting	0.006
		Industrial Injury Insurance	0.016
Emergency Rescue	0.050	Emergency Response Administration and Personnel	0.006
		Emergency Plan	0.012
		Emergency Facilities, Equipment and Supplies	0.012
		Emergency Response Training	0.010
		Emergency Rescue	0.010
Incident Reporting, Investigation and Management	0.030	Incident Reporting	0.010
		Accident Investigation	0.006
		Accident Handling	0.014
Performance Assessment and Continuous Improvement	0.030	Performance Assessment	0.015
		Continuous Improvement	0.015

B. Reliability Analysis

The reliability of a scale is regarded high if consistency is created after the subjects of the same group were measured with the scale of the same nature and same purpose. The stability of a scale is regarded high if it results in little difference when subjects of the same group receive the same measurement of the same scale at a different time[32]. In this study, the reliability and stability of the sample is tested by SPSS 12.0 and reliability analysis is primarily Cronbach's Alpha coefficient. The Cronbach's Alpha coefficient of the result turned out to be as high as 0.931, indicating high internal consistency of the questionnaire with high reliability.

C. Questionnaire Analysis and Statistics

With the score distribution analysis of secondary-grade indicator in the "Standardized evaluation criteria of safety production in water conservancy and hydropower construction enterprise (for trail implementation)", the weights of secondary-grade indicators are calculated by formula (1). Then, the weight of each first-grade indicator is accumulated all the weight s of its secondary-grade indicators, as shown in Table 5.

Through the statistics of 373 valid questionnaires, the characteristic values are analyze such as mean, standard deviation and coefficient of variation, as showed in Table 6. Questionnaire statistics show that questionnaire discrete level is not high and the highest coefficient of variation is only 0.2284.

TABLE 6
CHARACTERISTIC VALUES OF THE SAMPLE

Secondary-Grade Indicator	Average score	Standard deviation	Coefficient of variation
Target-Setting	3.689	0.7354	0.1993
Target Implementation	3.747	0.7465	0.1992
Target Supervision and Assessment	3.718	0.7154	0.1924
Security Gear	3.750	0.7684	0.2049
Staffing	3.800	0.6975	0.1836
Security Responsibility	3.790	0.6849	0.1807
Safety Construction Expense Management	3.572	0.7254	0.2031
Security Costs Expenditure	3.588	0.7134	0.1988
Laws, Regulations and Standards	3.640	0.7048	0.1936
Safety Regulations	3.660	0.7132	0.1949
Safety Procedures	3.620	0.7289	0.2014
Evaluation	3.650	0.7377	0.2021
Amendment	3.610	0.6686	0.1852
File Management	3.645	0.6984	0.1916
Training Management	4.032	0.7377	0.1830
Security Management Personnel Training	4.065	0.6883	0.1693
Job Operating Personnel Training	4.050	0.7358	0.1817
Other Personnel Training	4.020	0.6841	0.1702
Safety Culture Establishment	4.011	0.7321	0.1825
Equipment Basic Management	3.761	0.7145	0.1900
Equipment Operation Management	3.740	0.7068	0.1890
Equipment Scrap Management	3.750	0.7317	0.1951
Site Management and Process Control	3.600	0.6788	0.1886
Operating Behavior Management	3.590	0.7210	0.2008
Warning Signs	3.550	0.7353	0.2071
Interested Party Management;	3.530	0.7158	0.2028
Change Management	3.556	0.7086	0.1993
Hidden Danger Investigation	3.740	0.6982	0.1867
Risk Management	3.700	0.7136	0.1929
Forecast and Early Warning	3.720	0.7328	0.1970
Identification and Assessment	3.850	0.7153	0.1858
Registration and Filing	3.931	0.6985	0.1777
Supervising and Management	3.911	0.7149	0.1828
Occupational Health Management	3.179	0.7262	0.2284
Occupational Hazard Informing and Alerting	3.180	0.7187	0.2260
Occupational Hazards Reporting	3.198	0.6852	0.2143
Industrial Injury Insurance	3.175	0.7178	0.2261
Emergency Response Administration and Personnel	3.810	0.6858	0.1800
Emergency Plan	3.817	0.7326	0.1919
Emergency Facilities, Equipment and Supplies	3.770	0.7379	0.1957
Emergency Response Training	3.784	0.7153	0.1890
Emergency Rescue	3.776	0.7001	0.1854
Incident Reporting	3.890	0.6972	0.1792
Accident Investigation	3.930	0.7243	0.1843
Accident Handling	3.937	0.7014	0.1782
Performance Assessment	3.728	0.7185	0.1927
Continuous Improvement	3.712	0.6956	0.1874

According to formula (4), the final practical score is summarized by the practical score of second-grade indicators contained by first-grade indicator. And then the biggest index value of first-grade indicator are acquired by formula (6). What's more, the scoring rate of each first-grade indicator are calculated according to formula (7), as detailed in Table 7.

TABLE 7
STATISTICS OF QUESTIONNAIRE RESULTS

First-grade indicator	S_i	S_i'	r_i
Safety construction target	0.1116	0.15	0.7440
Organization and responsibility	0.1892	0.25	0.7568
Safety construction input	0.1790	0.25	0.7160
Laws, regulations and safety management system	0.2548	0.35	0.7280
Training	0.2828	0.35	0.8080
Construction equipment management	0.4496	0.60	0.7493
Construction safety	1.0037	1.40	0.7169
Hidden danger investigation and risk management	0.2976	0.40	0.7440
Major hazard sources monitoring	0.3118	0.40	0.7796
Occupational health issues	0.1908	0.30	0.6360
Emergency rescue	0.1895	0.25	0.7580
Incident reporting, investigation and management	0.1176	0.15	0.7840
Performance assessment and continuous improvement	0.1116	0.15	0.7440

D. Maturity evaluation

According to the statistics in Table 4, maturity score of safety standardization system which is calculated by formula (5):

$$P = \sum_{i=1}^{13} S_i = 3.6896$$

This shows that maturity of construction safety standardization system in this project is at the third grade, namely the standard level. This indicates that in this project safety standardization is well processed and applied into its daily safety construction, and that the objectives of safety standardization in this project are quite clarified. At the same time, it shows that the support system in this project is well organized and it has formed systematic working procedures in implementation.

E. Discussion of Verification results

Then the maturity cobweb model diagram of safety standardization system is drawn based on scoring rate of indicators, shown in Figure 2. This model diagram can visually demonstrate each indicator's scoring rates.

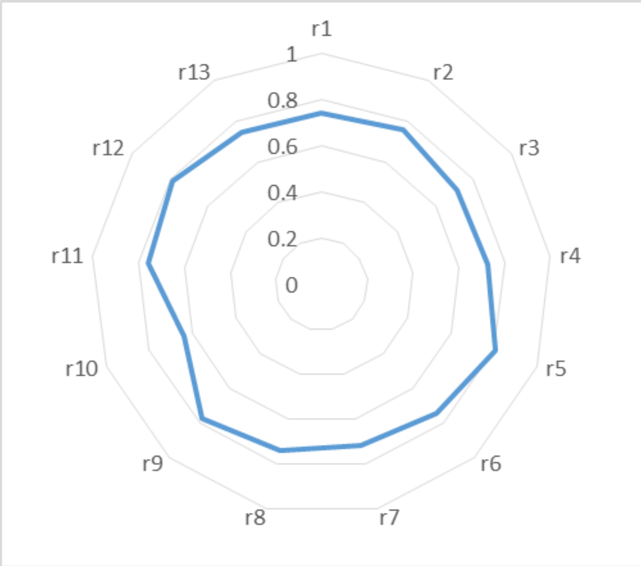

Fig.2 Maturity cobweb model diagram

1) The lowest scoring rate of occupational health means a weak indicator performance. That is not only a major factor which reduced the overall level of maturity, but also where we need to pay attention to and make improvement.
2) The highest scoring rate of training indicates has good performance and should continue to maintain.
3) The other indicators are relatively balanced and appropriate effort should be made to improve and perfect them.

VI. Conclusion

The performance of safety standardization was divided into five stepladder evolution maturity grades according to key features of safety standardization implementation in hydropower construction. A safety standardization evaluation index system was built to make a quantitative evaluation on implementation of safety standardization according to the evaluation criteria, thus to judge which maturity grade it belongs to.

The maturity cobweb model diagram was drawn to analyze the main factors that influence the maturity grade of the safety standardization system, it helps us to find out the weak links in safety standardization system.

The applicability of the proposed model was demonstrated by maturity evaluation on Xiang Jiaba Dam. The results reveal that the method is effective and feasible in hydropower construction and provides a stepwise development frame for safety standardization system.

Acknowledgements

In guest editing this Special Issue, we wish to acknowledge the help and support from several quarters. We would also like to thank our colleagues QIN Ai-Rong and LIU Qian for their support in data assimilation and table processing. Last, but not least, we are very grateful to the anonymous reviewers for their essential contribution in enhancing the quality of this issue and for discharging their work so effectively.

References

[1] Shu Chen, Zhi-Gen Hu. Construction progress risk of hydropower engineering under the condition of earth-rock overtop cofferdam[J]. Systems Engineering —Theory & Practice, 2013, 33(6): 1622-1627.
[2] Horaska D. D., San Juan C. M., Bonnivier B. M., Dickinson A. L., Conaway J. L. Safety-management programs and standardized application equipment minimize risks of nonconventional chemical usage[J]. SPE Projects, Facilities and Construction, 2011, 6(4): 192-204.
[3] Sato Hiroyuki, Ohashi Hirofumi, Tazawa Yujiro, Sakaba Nariaki, Tachibana Yukio. Safety evaluation of the HTTR-IS nuclear hydrogen production system[J]. Journal of Engineering for Gas Turbines and Power, 2011, 133(2): 22902.
[4] Zheng Xia-Zhong, Shen Qiao-Ling, Chen Shu, U Bin-Feng H. Safety assessment method for hydropower construction based on rough set[J]. China Safety Science Journal, 2011, 21(1): 82-86.
[5] Leu Sou-Sen, Chang Ching-Miao. Bayesian-network-based safety risk assessment for steel construction projects[J]. Accident Analysis & Prevention, 2013: 122-133.
[6] Heinrich Herbert William. Industrial accident prevention[M]. New York: McGraw-Hill, 1979.
[7] Petersen Dan, Petersen D. Techniques of safety management[M]. McGraw-Hill New York, 1978.
[8] Lai J., Zhang L., Duffield C. F., Aye L. Engineering reliability analysis in risk management framework: Development and application in infrastructure project[J]. IAENG International Journal of Applied Mathematics, 2013, 43(4): 242-249.
[9] Abu-Khader M. M. Impact of human behaviour on process safety management in developing countries[J]. Process Safety and Environmental Protection, 2004, 82(6): 431-437.
[10] Wang Zhentao, Schittenhelm Rudolf Sebastian, Borsdorf Matthias, Rinderknecht Stephan. Application of augmented observer for fault diagnosis in rotor systems[J]. Engineering Letters, 2013, 21(1): 10-17.
[11] Jansen John. Production-line testing: A 100% solution to product safety[J]. Compliance Engineering, 2002, 19(2): 46-48.
[12] Davenport Thomas H. The coming commoditization of processes[J]. Harvard Business Review, 2005, 83(6): 100-108.
[13] Timmermans Stefan, Berg Marc. The gold standard: The challenge of evidence-based medicine and standardization in health care[M]. Temple University Press, 2003.
[14] Timmermans Stefan, Almeling Rene. Objectification, standardization, and commodification in health care: A conceptual readjustment[J]. Social Science & Medicine, 2009, 69(1): 21-27.
[15] Mintzberg Henry. Structure in fives: Designing effective organizations.[M]. Prentice-Hall, Inc, 1993.
[16] Taylor Frederick Winslow. The principles of scientific management[M]. Harper, 1914.
[17] Moran George, Spanner Jack. Importance of standardization[J]. Materials Evaluation, 1996, 54(8): 901-904.
[18] Antonsen Stian, Skarholt Kari, Ringstad Arne Jarl. The role of standardization in safety management–A case study of a major oil & gas company[J]. Safety Science, 2012, 50(10): 2001-2009.
[19] Stavrianidis Paraskevas, Rennie John. Improving management of technological risk: Reliability certification of safety systems[J]. Isa Transactions, 1996, 35(2): 127-136.
[20] Yue-Cheng Huang, Yun Luo, Xiao-Qiao Wang, Feng-She Xia, Ming Xu, Hong-Tao Zhang. Study on modeling work safety standardization operation mechanism and optimization[J]. China Safety Science Journal, 2013, 23(4): 159-166.
[21] Ting-Ting Luan, Zhen-Hua Xie. Work safety standardization grade evaluation model and system development of Bauxite mines[J]. Procedia Engineering, 2011, 26: 1927-1933.
[22] Xin-Feng Yang, Feng-Hui Wang. Discussion on experience of standardization construction of safety production of large hydropower plant[J]. Journal of Safety Science and Technology, 2012, 08(5): 207-209.
[23] Xi-Bin Ouyang, Cheng-Liang Dai, Zheng-Fei Wu, Minghua Ao. Standardized management practices on construction safety of Nuozhadu hydropower station project[J]. Water Power, 2012, 38(9): 16-18, 30.
[24] Shu Chen, Xia-Zhong Zheng, Di Yu. Evaluation on standardization system for construction safety of hydraulic engineering[J]. Journal of Safety Science and Technology, 2014, 10(02): 167-172.

[25] Pinto Abel. QRAM a Qualitative Occupational Safety Risk Assessment Model for the construction industry that incorporate uncertainties by the use of fuzzy sets[J]. Safety Science, 2014: 57-76.
[26] O Regan Gerard. The Capability Maturity Model[M]. A Practical Approach to Software Quality, Springer New York, 2002, 129-167.
[27] Ao Tianyong, Chen Pan, He Zhangqing, Dai Kui, Zou Xuecheng. RDCC: A new metric for processor workload characteristics evaluation[J]. IAENG International Journal of Computer Science, 2013, 40(4): 274-284.
[28] The Ministry of Water Resource of the PRC. Interim measures of evaluation and management on hydraulic safety production standardization[S]. 2013.
[29] Wilson J. R. Standards for product safety design: a framework for their production[J]. Applied Ergonomics, 1984, 15(3): 203-210.
[30] Aminbakhsh Saman, Gunduz Murat, Sonmez Rifat. Safety risk assessment using analytic hierarchy process (AHP) during planning and budgeting of construction projects [J]. Journal of Safety Research, 2013: 99-105.
[31] The Ministry of Water Resource of the PRC. Standardized evaluation criteria of safety production in water conservancy and hydropower construction enterprise (for trail implementation)[S]. 2013.
[32] Hsu I. Yuang, Su Teh-Sheng, Kao Chen-Shan, Shu Yi-Liang, Lin Pei-Ru, Tseng Jo-Ming. Analysis of business safety performance by structural equation models[J]. Safety Science, 2012, 50(1): 1-11.