ICIC Express Letters
Part B: Applications
Volume **9**, Number **9**, September **2018**

ICIC International ©2018 ISSN 2185-2766
pp. **961–968**

QUANTITATIVE ADMINISTRATION OF SCADA PROJECT FOR INTEGRATED WATER RESOURCES MANAGEMENT

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Received March 2018; accepted June 2018

Abstract. *SCADA (Supervisory Control and Data Acquisition) projects for IWRM (Integrated Water Resources Management) are very important since they deal with the infrastructure of national or local governments. These projects often take long time, and are large in scale and complexity. Therefore, there are high risk of failure arising from the size and complexity of such projects. However, there is not much knowledge or experience shared due to the lack of systematic researches on this area. IWRM project usually involves both IT and construction sector while spending lots of resources and time, so it is very important to develop a quantitative system for successful management. In this study, authors have presented two quantitative indicators for successful management of IWRM project which are PSI (Project Success Index) and RE (Risk Exposure). The PSI calculated by weighing the CSFs (Critical Success Factors) of the IWRM project has been applied to the 31 completed IWRM projects so that it can be used with some reference values for the management of future IWRM project. The relative frequency of CSF that is evaluated not satisfactory after the project is used to define the risk likelihood of that CSF, and then the RE is calculated by factoring that risk likelihood with the importance of that CSF. It is expected that quantitative management of IWRM projects will be more effective if relevant data using PSI and RE are accumulated sufficiently.*
Keywords: Integrated water resources management, Project management, Risk exposure

1. **Introduction.** As the imbalance in the supply and demand of water resources increased both globally and domestically, the importance of effective management of water resources grew as well. Since the integrated management of water resources has large scale and causes a powerful ripple effect, it is mainly carried out as a public project of local government or national level. However, project for IWRM (Integrated Water Resources Management) usually requires a lot of resources over a long period of time, and it is very difficult to administer since it has a mixed nature of IT and construction project internally. Although many SCADA (Supervisory Control and Data Acquisition) projects for IWRM have been carried out in various countries, detailed information on those projects has not been shared to the public due to their inherent nature like national security issues and protection of key knowledge. Systematic research for this specific sector has not been actively conducted in academia, either. Details on successful cases of the SCADA projects for IWRM are not well known to outside, and even the definition of success is very ambiguous [2,3,5-7]. Kim et al. conducted an AHP study reflecting expert opinions for the

DOI: 10.24507/icicelb.09.09.961

successful management of SCADA project for IWRM and presented 82 CSFs (Critical Success Factors) within the hierarchical structure of systematical, managerial, directional and environmental dimension [3-5,8]. Although their study is significant in that it is the first quantitative approach for systematic management of the IWRM SCADA project, additional research is still needed on how to use those CSFs to the actual project management. In this study, authors have used those 82 CSFs of the IWRM project to quantify the prospect of project success and assess its exposed risk. By analyzing the PSI (Project Success Index) values over 31 IWRM projects that were carried out by K-water, authors have suggested practical references to comprehend PSI value of ongoing project. Now, with the suggested PSI method, project administrator can rather sturdily guess the mode of project success or failure. In addition to this, authors have suggested a way to measure the risk of IWRM project by assessing the RE (Risk Exposure) of individual CSF. Suggested RE analysis allows quantitative identification of potential risk factors for IWRM projects. With the PSI and RE approaches proposed in this study, it is expected that more quantitative and effective management of the IWRM project will be possible.

The rest of this paper is organized as follows. Section 2 briefly summarizes related works on management of IWRM SCADA project. In Sections 3 and 4, PSI and RE are explained in detail. Finally, in Section 5, conclusion and contribution of this paper are briefly described.

2. **Project Management for IWRM.** Researches on general project management have been actively addressed for a long time, and various factors that influence project success have been identified with their relative importance. Many of the variables that constitute the CSFs of a project are usually organized into a hierarchical structure, and nowadays individual CSF system is studied and presented for various application domains [1,5-9]. These works generally consist of AHP (Analytic Hierarchy Process) studies to combine expert opinions with literature review. Research on CSFs of ICT projects has also been actively conducted, and 18 CSFs with four dimensions are proposed by Subiyakto and Ahlan [5]. Kim et al. have further extended those 18 CSFs into 82 factors while studying SCADA projects for IWRM in K-water as is given in Figure 1 and Table 1 [3].

Table 1 summarizes the weight of those 82 factors in a percentage value. The top 21 factors are shown in bold letters. It can be seen that many factors from the 'quality (S_Q)' variable of systematical dimension are among the top 21 factors. In the managerial dimension, factors from the 'utilization (M_U)' and 'close down (M_E)' rank in higher positions compared to the other factors. It is quite interesting that all factors from directional dimension are positioning within the top 21. Finally, in the environmental dimension, it is seen that only one factor from the 'deliverable level (E_D)' variable belongs to the top 21. Grasping the relative importance of those CSFs through the weight values is meaningful

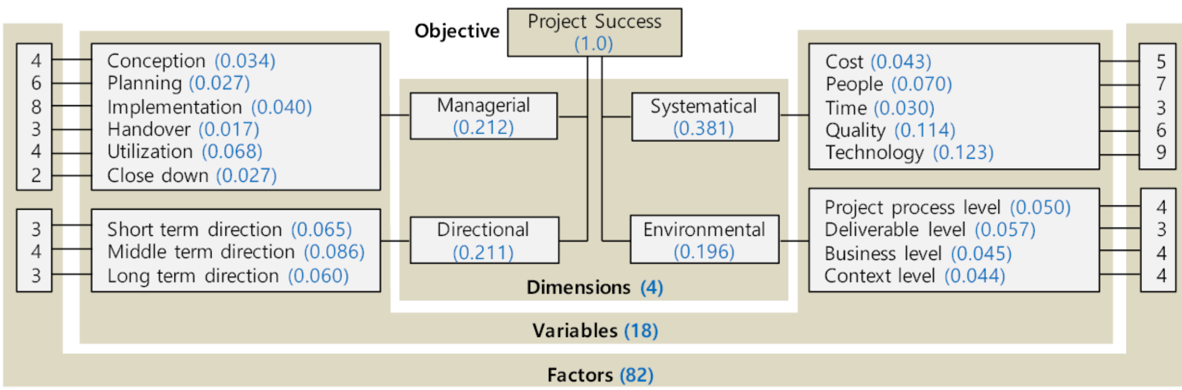

FIGURE 1. AHP evaluation model of the CSFs and their weight values [3]

Table 1. Weight values of 82 factors for IWRM project [3]

	Factors (Weight in %)
S_C	Proper budgeting (1.2), To avoid the lowest bid (0.9), Cost management (0.6), Risk minimization of new development (0.9), Construction cost information management (0.7)
S_P	Technician ability (1.3), Project organization (0.7), Project manager (0.9), Authority and responsibility (0.7), Provider selection (1.2), Ordering organization supervisory service (1.2), Operation and maintenance personnel (1.0)
S_D	To eliminate unreasonable delivery schedule (0.7), Schedule (0.8), Process management (1.5)
S_Q	Establishment and compliance of the quality control procedure (1.1), Set of work standards (1.1), **Quality control of the equipment (2.0)**, **Construction quality management (2.2)**, **Selection criteria of application techniques (1.8)**, **Standardization and systematization of the system configuration (3.2)**
S_T	HMI selection and management (1.2), Network selection (1.1), Data management (1.2), Creating software (1.4), Open architecture (1.2), **Ensure the reliability of the lower level equipment (2.2)**, **RCS(TM/TC) selection (1.9)**, Improvement of duplicated or distributed control level (1.2), Information security (0.7)
M_C	Range setting (1.1), Set of success criteria (0.7), Requirement definition (0.9), The definition of the proposal and contract (0.7)
M_P	Site investigation (0.5), Requirements analysis (0.7), Well-designed construction documents (0.3), Project launching (0.3), Establishment of emergency measures (0.4), Commissioning test plan (0.5)
M_I	Simulation (0.3), Change management (0.4), User (stakeholder) participation and management (0.5), PDCA cycle execution (0.4), Attitude of the ordering party (0.4), Attitude of the contractor (0.5), Communications management (0.8), Conflict management (0.6)
M_H	Commissioning test (1.0), Completion inspection (0.4), Education and training (0.3)
M_U	**Alarm management (1.9)**, **Early detection and corresponding of emergency (2.0)**, Maintenance (1.0), **Operation and management (1.9)**
M_E	**Stabilization of the system (2.2)**, Sharing and management of knowledge (0.6)
D_S	**Integrated operation management of the entire process of the supply of water (2.4)**, **Construction of integrated water information platform (2.1)**, **Construction of integrated flood disaster management system (2.0)**
D_M	**IWRM-based integrated water management (1.7)**, **Smart Water Grid-based supply of healthy water (2.9)**, **Real-time monitoring of the entire basin water circulation (2.0)**, **Sophistication and the joint use of the integrated water management technology (1.9)**
D_L	**Future growth power generation through innovation paradigm of water management (1.7), Realize the public value of public enterprises such as national water welfare (2.4)**, **Through the improvement of productivity and efficiency, provide services that meet the public's point of view (1.9)**
E_P	Efficient allocation of water reserved (1.5), Demand customization water supply (1.2), Taking into account the facility utilization efficiency and energy (1.3), Optimization of facility utilization rate (0.9)
E_D	Switching how to manage the water from the hardware manner to soft method of using ICT (1.5), Emergence of new technologies in the field of water management such as Smart Water Grid (1.3), **Systematization for integrated management of water quantity, water quality, ecology, environment (2.9)**
E_B	Water-related comprehensive service industry (1.4), Globalization and specialization (1.3), Privatization and decentralization (0.4), Wide-area and integration (1.4)
E_C	Stable water resources (1.3), Smart water resources management (1.0), Safe river to disaster (1.1), Sustainable river (0.9)

(Glossary)

S_C = cost, S_P = people, S_D = time, S_Q = quality, S_T = technology

M_C = conception, M_P = planning, M_I = implementation, M_H = handover, M_U = utilization, M_E = close down

D_S = short term direction, D_M = middle term direction, D_L = long term direction

E_P = project process level, E_D = deliverable level, E_B = business level, E_C = context level in that it tells us which factors to be carefully managed. Project manager will possibly use above CSFs to get an aggregated value by calculating a weighted sum of all factors. However, to understand the status of current IWRM project by calculating such value, some references that can be used to interpret the meaning of the result are needed. In this study, authors have analyzed the success or failure of past IWRM projects based on the CSFs presented above. If project manager refers to these analyzed results, it can be helpful to quantitatively judge the current status of IWRM project.

3. **Assessing the Prospect of Success with PSI.** After assigning values to above 82 CSFs, calculating a weighted sum will be the most natural way to aggregate the result to quantitatively determine the current state of the project. The project success index presented in this study is also the weighted sum of CSFs and summarized in Table 2. Four PSI measures (PSI_S, PSI_M, PSI_D and PSI_E) are defined for each project dimension and one PSI is defined for top-most project level.

Table 2. PSI formula for IWRM project

(*Scope*) **PSI Formula**
(*Project*) **PSI** = Total sum of [weight × evaluation score] for all factors = **Systematical Dimension** $(0.043 \cdot S_C + 0.070 \cdot S_P + 0.030 \cdot S_D + 0.114 \cdot S_Q + 0.123 \cdot S_T)$ + **Managerial Dimension** $(0.034 \cdot M_C + 0.027 \cdot M_P + 0.040 \cdot M_I + 0.017 \cdot M_H + 0.068 \cdot M_U + 0.027 \cdot M_E)$ + **Directional Dimension** $(0.065 \cdot D_S + 0.086 \cdot D_M + 0.060 \cdot D_L)$ + **Environmental Dimension** $(0.050 \cdot E_P + 0.057 \cdot E_D + 0.045 \cdot E_B + 0.044 \cdot E_C)$
(*Systematical Dimension*) $\mathbf{PSI_S} = 0.113 \cdot S_C + 0.185 \cdot S_P + 0.080 \cdot S_D + 0.299 \cdot S_Q + 0.322 \cdot S_T$
(*Managerial Dimension*) $\mathbf{PSI_M} = 0.159 \cdot M_C + 0.125 \cdot M_P + 0.188 \cdot M_I + 0.078 \cdot M_H + 0.321 \cdot M_U + 0.128 \cdot M_E$
(*Directional Dimension*) $\mathbf{PSI_D} = 0.307 \cdot D_S + 0.409 \cdot D_M + 0.284 \cdot D_L$
(*Environmental Dimension*) $\mathbf{PSI_E} = 0.255 \cdot E_P + 0.290 \cdot E_D + 0.232 \cdot E_B + 0.222 \cdot E_C$

To better understand the status of project for specific PSI values, 44 project managers were asked to evaluate 31 IWRM projects performed by K-water. 31 managers out of 44 replied to the questionnaire. Table 3 summarizes the basic information for those project managers. All of the participants have more than 5 years of experience in IWRM projects, and more than 70% of the participants have more than 10 years of experience. Table 4 summarizes the basic information of 31 IWRM projects evaluated through questionnaire. The most projects are of the type of water supply facility, and 49% of the projects are above the $860,000 in project amount.

Table 3. Work experiences and positions of the 31 participants

Experience / Position	5 to less than 10 years	10 to less than 20 years	More than 20 years	Total
Manager	6	1		7
Senior Manager	3	13	8	24
Total	9	14	8	31

Table 4. Project amount and types

Amount (unit USD)	Instances (%)	Type of project site	Instances
less than 170,000	3 (10%)	Water supply facility	24 (77%)
170,000 to less than 860,000	13 (42%)		
860,000 to less than 2,580,000	7 (23%)	Water resources facility (weir, dam, ...)	7 (23%)
More than 2,580,000	8 (26%)		
Total	31 (100%)	Total	31 (100%)

Participants were asked to categorize the degree of success for 31 IWRM projects into five types, and the performance of 18 variables in Figure 1 was also assessed on a 5-point Likert scale. Table 5 shows the number of projects classified according to their degree of success. A project with Type I is the total success, while Type V indicates total failure. It can be seen that all the projects are rated to have more than Type III degree of success.

TABLE 5. Evaluation result for the degree of project success

Type	**Description for the degree of success**	**Instances**
I	The project is successful in both construction and operation.	12 (39%)
II	The project is successful in construction, but requires a little improvement in operation.	8 (26%)
III	The project requires a little improvement in both construction and operation.	11 (35%)
IV	The project requires a lot of improvement in both construction and operation.	0 (0%)
V	The project has failed.	0 (0%)
Total		31 (100%)

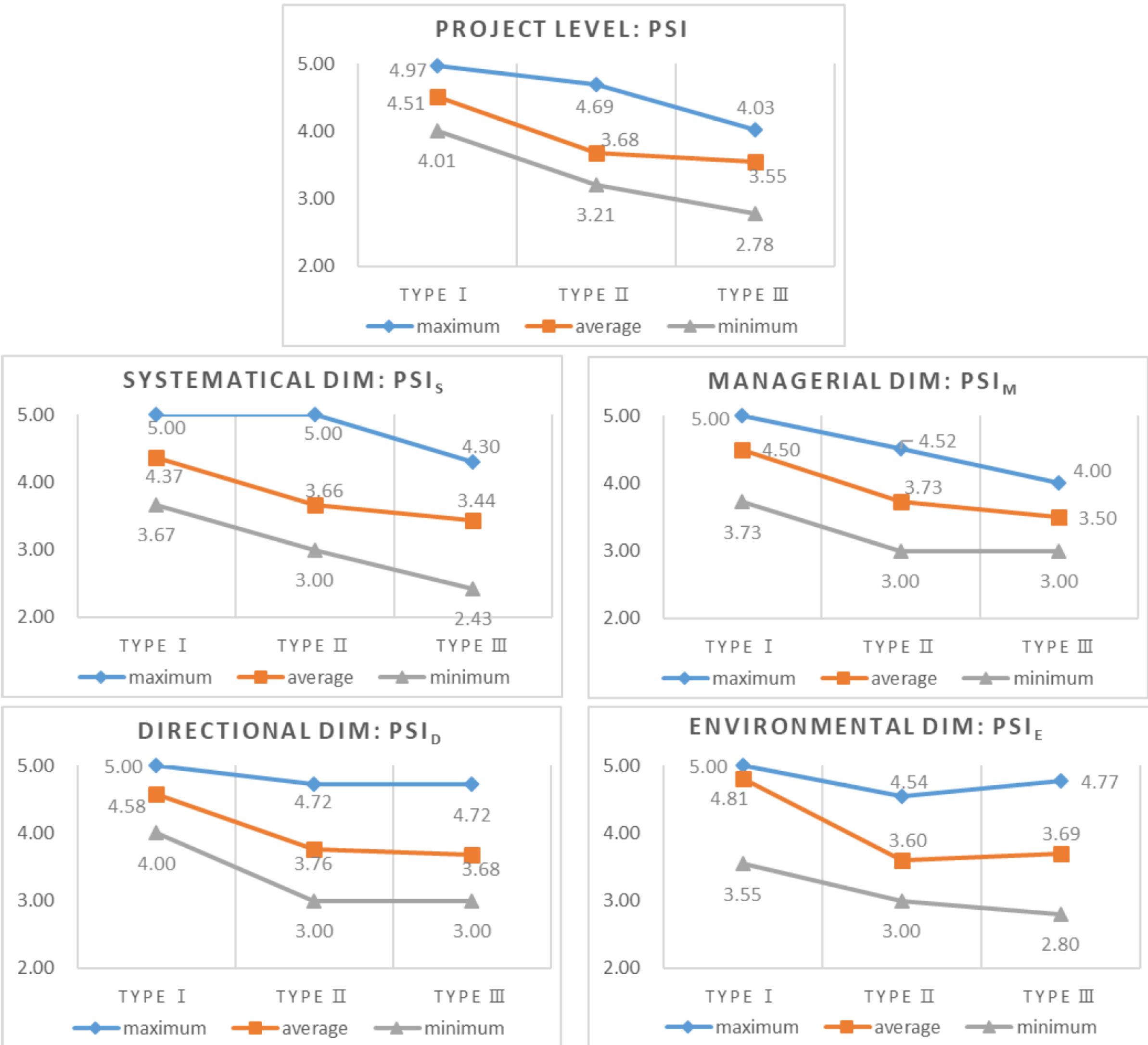

FIGURE 2. PSI values for IWRM projects in K-water

The results of participants' evaluations for 18 variables are summarized into PSI values for each success type of project in Figure 2. Since all PSI values tend to decrease from Type I to Type III with an exception for the PSI value of environmental dimension (PSI_E), one can guess the degree of project success by calculating the PSI value of that project. In case of PSI_E where the values are reversed between Type II and Type III, additional study is needed to further clarify the result. One possible reason for this inversion on environmental dimension can be attributed to homogeneous survey pool that includes only the internal experts who are rather insensitive to outside environmental issues.

4. **Assessing the Risk with RE.** According to the PMBOK (Project Management Body of Knowledge), project risk is an uncertain event or condition that may cause a negative or positive result in one or more project objectives [10]. Such things can be considered as risks like requirement change, introduction of new constraints, and occurrence of unexpected circumstances. These risks are caused by uncertainties that may arise during the course of the project. Project risk management is the process of identifying, monitoring and controlling the risk factors to mitigate unwanted events. The success of project requires effective identification and control of such risk factors as well as systematic management of the CSFs. In general, the extent to which a project is vulnerable to risk is proportional to the number of risk occurrences and the impact of such risks. Following Equation (1) shows how to calculate the Risk Exposure (RE) of a project.

$$\text{RE (Risk Exposure)} = \text{RL (Risk Likelihood)} \times \text{RI (Risk Impact)} \tag{1}$$

For risk management to be quantitative, RL and RI should be derived quantitatively. In this study, authors have combined the analysis of past data and the CSFs of the project to systematically calculate the RE of the IWRM project. The relative number of occurrences, in which a certain CSF was not fully satisfied in the past projects, was used to estimate the RL value. The value of RI was used as the weight value of the corresponding CSF, since it explains the significance of that factor. All participants of the survey are required to answer the number of times that a specific CSF was not implemented enough in the project. By dividing the replied number with the total number of projects (31 projects), authors have defined the RL values of IWRM project in K-water. Of the 57 factors in the systematical and managerial dimension, 48 factors were answered as they were not fully implemented at least once in the past project. Table 6 lists the final RE values of those 48 factors in descending order.

5. **Conclusions.** This study is concerned with quantitative management for IWRM project. By utilizing the CSFs of SCADA implementation project for IWRM, authors have presented two quantitative measures which are PSI and RE. The significance of this study is as follows. First, expert surveys on 31 completed IWRM projects have showed that suggested PSI can be a useful mean to assess the degree of project success. Second, the risk likelihood of the project is defined by using the relative frequency of CSFs that were not fully implemented in the past projects. This RL value is multiplied by the weight of the corresponding CSF to calculate the risk exposure of that factor. With the suggested PSI and RE methods, more effective and quantitative project management will be possible.

Further research directions can be as follows. Due to the inversed PSI_E values between the Type II and Type III project at the environmental dimension, more analysis is needed to clarify the reason. In the present study, only the systematical and managerial dimensions have been studied to calculate the RE, but in the near future directional and environmental dimensions can also be investigated similarly. If sufficient data are available for PSI and RE, further studies may be possible to examine the statistical significance of such values.

Table 6. RE for factors of systematical & managerial dimension in IWRM project

Factors	Cases (RL%)	Weight (RI)	RE (‰)
Early detection and corresponding of emergency	11 (35%)	0.020	7.10
Standardization and systematization of the system configuration	5 (16%)	0.032	5.16
Stabilization of the system	5 (16%)	0.022	3.55
Technician ability	6 (19%)	0.013	2.52
Set of work standards	7 (23%)	0.011	2.48
Schedule	9 (29%)	0.008	2.32
Creating software	5 (16%)	0.014	2.26
Requirements analysis	9 (29%)	0.007	2.03
Open architecture	5 (16%)	0.012	1.94
Proper budgeting	4 (13%)	0.012	1.55
Requirement definition	5 (16%)	0.009	1.45
Process management	3 (10%)	0.015	1.45
Range setting	4 (13%)	0.011	1.42
Commissioning test	4 (13%)	0.010	1.29
Provider selection	3 (10%)	0.012	1.16
Sharing and management of knowledge	5 (16%)	0.006	0.97
The definition of the proposal and contract	4 (13%)	0.007	0.90
To avoid the lowest bid	3 (10%)	0.009	0.87
Establishment of emergency measures	6 (19%)	0.004	0.77
Cost management	4 (13%)	0.006	0.77
Communications management	3 (10%)	0.008	0.77
Establishment and compliance of the quality control procedure	2 (6%)	0.011	0.71
Construction quality management	1 (3%)	0.022	0.71
Ensure the reliability of the lower level equipment	1 (3%)	0.022	0.71
Education and training	7 (23%)	0.003	0.68
Construction cost information management	3 (10%)	0.007	0.68
Project organization	3 (10%)	0.007	0.68
To eliminate unreasonable delivery schedule	3 (10%)	0.007	0.68
Set of success criteria	3 (10%)	0.007	0.68
Site investigation	4 (13%)	0.005	0.65
Operation and maintenance personnel	2 (6%)	0.010	0.65
Quality control of the equipment	1 (3%)	0.020	0.65
RCS(TM/TC) selection	1 (3%)	0.020	0.65
Alarm management	1 (3%)	0.019	0.61
Operation and management	1 (3%)	0.019	0.61
Risk minimization of new development	2 (6%)	0.009	0.58
Conflict management	3 (10%)	0.006	0.58
Change management	4 (13%)	0.004	0.52
Attitude of the contractor	3 (10%)	0.005	0.48
Well-designed construction documents	4 (13%)	0.003	0.39
PDCA cycle execution	3 (10%)	0.004	0.39
Ordering organization supervisory service	1 (3%)	0.012	0.39
Improvement of duplicated or distributed control level	1 (3%)	0.012	0.39
Authority and responsibility	1 (3%)	0.007	0.23
Project launching	2 (6%)	0.003	0.19
Simulation	2 (6%)	0.003	0.19
Commissioning test plan	1 (3%)	0.005	0.16
User (stakeholder) participation and management	1 (3%)	0.005	0.16

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