Classifying Audit Results of ISO 9000 in Architectural Design and Engineering Firms

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Abstract
Greater use of ISO quality standards is needed to increase the penetration of South Korean construction companies into foreign markets. There have been significant problems in the stable implementation of ISO 9001 in architectural design and engineering firms, which appear to be caused by lack of recognition and comprehension of standards requirements. This research aims to deduce improvement measures by analyzing nonconformity results published when a certification body audits companies. One hundred and twenty three nonconformity reports from six companies that have been audited periodically from 2000 to 2004 by the certification body have been analyzed and classified. Thirty-four causes of nonconformity were found in 10 areas. The research showed that corrective actions for nonconformity were closely connected with all management activities. Consequently, specific corrective actions should be implemented to achieve ISO 9001 quality standards in architectural design and engineering firms.

Keywords: quality management system; nonconformity; process; certification body

1. Introduction
1.1 Background and purpose of the study
The International Organization for Standardization ISO 9000 was introduced into Korean domestic architectural design and engineering firms to reinforce organizational competence and internal–external competitiveness. Its introduction was inevitable as overseas expansion of the domestic construction industry increased after the establishment of the WTO and Korea's affiliation with the OECD. The ISO 9000 standard has functioned as an important method of enhancing recognition of quality standards among nations and exchange activity. However, after exactly 10 years' experience, quality management activity in architectural design and engineering firms is inadequate. The reasons are considered to be an immature environment at home and abroad at the time of introduction, unsuitability of the standards for the characteristics of the construction industry, and insufficient will and inadequate understanding by top management.

The ISO 9000 standard was transformed entirely in 2000 to be the quality management process model standard applicable for all industries, not just the manufacturing industry. However, many companies are not responding appropriately to this change. There are several obstacles making recognition of the standard and its application to the construction industry difficult. Accordingly, the purposes of this study are to examine the actual condition of the quality management system used in design companies, which are playing important roles in quality management activity in the domestic construction industry, and to suggest improvement measures for quality management activity.

1.2 Scope and method of the study
The study conducted the following research to investigate the operation of the ISO 9000 standard as a medium for construction companies' quality management activity, and to identify improvement measures for quality management activity:
(1) A literature study and collection of data related to the quality management system of the construction industry.
(2) Examination of the conditions for introduction of ISO 9000 certification in the construction industry, and development of basic theory regarding the use of ISO 9001.
(3) Investigation of data on nonconformity reports published at the time of certification, post-management audit, and renewal audit of architectural design and engineering companies, through visits to certification bodies registered at the Korea Accreditation Board (KAB).
(4) Classification of nonconformity reports from certification bodies according to company, year, and standards requirements for ISO 9000;1994 and for ISO 9001:2000.
(5) Classification of nonconformity patterns based on detailed audit criteria and checklists for the construction sector prepared by the KAB; analysis of common nonconformity patterns that occur repeatedly over a long time.
(6) Suggestion of improvement measures for quality management activity to enhance quality level by major nonconformity pattern and cause.
2. Theoretical study of the quality management system

2.1 ISO 9000 types and application

As shown in Fig.1., ISO 9000:1994 was originally a family of standards comprising ISO 9001, 9002, and 9003. Companies could choose the appropriate standard according to their business area and characteristics. An integrated ISO 9001 quality management process model standard has been used throughout the construction industry since its revision in 2000.

2.2 Need for introduction of ISO 9001

Generally, the following are factors supporting introduction of ISO 9001 in the construction industry:

(1) Understanding ISO 9001 standard requirements can help to improve customer or final-user expectations and demands.

(2) Operation of the ISO 9001 standard can contribute to efficiency and transparency of organizational activity.

(3) It is possible to respond to trade and technological obstacles among nations by establishing a mutually acceptable certification system between advanced countries.

(4) Operation of a quality management system can reinforce competitiveness and enhance quality level. It can also help to reach an organization's quality goal efficiently.

(5) It is possible to provide a framework to contribute to organizational growth and development by supporting the implementation of organizational process activity.

2.3 What is process?

As shown in Fig.2., Process is defined as "a group of interaction and relevant activities that transforms input into output" by ISO 9000:2000 in clause 0.2, Process Approach. It transforms input (material, information, and personnel) into output by changing the type and condition of inputs while going through serial stages. In addition, the definition of process is "a group of correlated or mutually reacting activities in converting input to output". Therefore, a process converts certain states or shapes; that is, it takes inputs such as materials, information, and people and goes through a series of stages to convert the shapes and states of the inputs. Fig.3. shows a process-based methodology, operation, and evaluation of the management cycle in an organization in the format of process management.

2.4 Architectural design management business process

Generally, the architectural design management process describes the process of converting input activities, through a work-activity sequence, to an output by correlating each work activity from the commencement stage to the completion stage using the process model of a quality management system as shown in Fig.4.

2.5 What is nonconformity?

Nonconformity is defined as "a condition or circumstance that has a negative influence on quality deviating from prescribed requirements". Prescribed requirements include quality requirement and social requirements. "Quality requirements" mean ISO 9000 requirements, contract requirements, and quality requirements specified by a supplier, while "social requirements" mean obligations such as the law and other considerations such as environment preservation, health, and safety. Fig.5. shows the areas of nonconformity.
3. Present condition of quality certification

As shown in Table 1, 5,274 construction industry companies maintained ISO 9000 certification in 2000, but the number had decreased to 2,465 by 2004. The decrease occurred because construction companies did not meet the standards requirements at the time of ISO 9001:2000, there was no incentive to maintain the certification system, and there was an increase in maintenance and management expenses.

4. Research on nonconformity

4.1 Outline of research

A nonconformity report published at the time of a quality audit for architectural design and engineering companies by a certification body is an important element in measuring quality management activity and quality level. The studies shown in Table 2 were used to analyze inappropriate cases to identify corrective actions and improvement measures for quality management activity, since inappropriate operations affect quality at every stage from planning to completion.

| Stage         | Input Data          | Work Activity Sequence and Correlation                           | Output Data                                                                 |
|---------------|---------------------|------------------------------------------------------------------|----------------------------------------------------------------------------|
| Design stage  |                     |                                                                  |                                                                            |
| Contract stage|                     |                                                                  |                                                                            |
| Completion stage|                   |                                                                  |                                                                            |

Fig. 4. Architectural Design Management Process

Table 1. Present Condition of Quality Certification (February 28, 2005)

| Classification                      | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 |
|-------------------------------------|------|------|------|------|------|------|------|------|
| Number of certifications in all industries | 3,218 | 5,955 | 10,608 | 13,197 | 14,209 | 14,752 | 10,643 | 12,425 |
| Number of certifications in the construction industry | 883 | 2,418 | 5,005 | 5,274 | 4,772 | 4,167 | 2,249 | 2,465 |
| Percentage of construction industry certification against all industries (%) | 27 | 40 | 47 | 39 | 33 | 28 | 21 | 19 |
4.2 Research and analysis target

Fifteen design companies were targeted. As illustrated in Table 2., 646 data sets were gathered. However, data from 1997 to 1999 were excluded because results of document audit and site audit were mixed. In addition, some companies were excluded from analysis because of a lack of continuity in data. Accordingly, 123 data sets from six companies that received nonconformity reports from 2000 to 2004 were used for analysis, as shown in Table 3. below.

Table 3. Present Condition of Nonconformity Research

| Companies | Period certification maintained | Number of audits | Published number of nonconformity reports |
|-----------|--------------------------------|------------------|------------------------------------------|
| A1        | 2000–2003                       | 4                | 20                                       |
| A2        | 2000–2003                       | 4                | 17                                       |
| A3        | 2000–2003                       | 4                | 12                                       |
| A4        | 2000–2003                       | 4                | 32                                       |
| A5        | 2001–2004                       | 4                | 25                                       |
| A6        | 2000–2003                       | 4                | 17                                       |
| **Total** | **24**                          | **123**          |                                          |

4.3 Present state of nonconformity

Table 4. shows the present state of nonconformity report publication by year and company.

Table 4. Present State of Nonconformity Report Publication

| Companies | 2000 | 2001 | 2002 | 2003 | 2004 | **Total** |
|-----------|------|------|------|------|------|-----------|
| A1        | 10   | 4    | 3    | 3    | 20   |
| A2        | 4    | 4    | 4    | 5    | 17   |
| A3        | 4    | 3    | 3    | 3    | 12   |
| A4        | 8    | 8    | 11   | 5    | 32   |
| A5        | 9    | 2    | 10   | 4    | 25   |
| A6        | 5    | 4    | 6    | 2    | 17   |
| **Total** | 27   | 33   | 29   | 27   | 7    | 123       |

5. Pattern and classification of nonconformity

5.1 Nonconformity pattern

Nonconformity patterns published at the time of a quality certification audit by the certification body for ISO 9001:2000 and ISO 9000:1994 are shown in Fig.6. In the case of design companies, many nonconformities occurred in the requirements of the ‘Design and development’ and ‘Production and service provision’ of Product realization, and ‘General’ and ‘Monitoring and measurement’ of Measurement, analysis and improvement. Therefore, activities corresponding to the above are very significant elements in quality improvement. With regard to Product realization, many nonconformity patterns are seen in Planning of product realization, Customer-related process, Design and development, Purchasing, and Production and service provision. And many nonconformity patterns of Measurement, analysis and improvement are also seen in General, Monitoring and measurement, Control of nonconformity, Data analysis and Improvement.

5.2 Classification of nonconformity by pattern

The pattern of the nonconformity reports means the distribution by standards requirements and the corresponding patterns of detail nonconformity reports published at the time of the quality audit by the certification body. Similar nonconformity cases repeated during the target research period were classified by requirement and pattern. The research found that the greatest number of nonconformity reports was published in the requirements of Product realization and Measurement, analysis and improvement among the ISO 9001 requirements. The distribution by standards requirements is illustrated in Fig.7. The two requirements of Product realization and Measurement, analysis and improvement occupied 83% of all nonconformity reports. Therefore, it is necessary to analyze the nonconformity pattern for these two in detail.

5.3 Detailed patterns of nonconformity

In the case of Product realization, the order of published nonconformity reports by pattern was Design and development, Production and service provision, Planning of product realization, and Customer-related process, as shown in Fig.8. Moreover, in the nonconformity reports of the Measurement, analysis and improvement requirement, the order of published reports by pattern was General, Monitoring and measuring, Improvement, Control of conformity, and Data analysis as shown in Fig.9.

Hence, through classification and research of nonconformity patterns, the most nonconformities for Product realization were found in Design and development for design companies, while the most nonconformities were found in Production and service provision for general construction companies. This is because auditors consider characteristics and key businesses of organizations when auditing quality. Therefore, investigation, classification, and analysis of published nonconformity activities for design companies were required.

6. Pattern and causes of nonconformity

The nonconformity pattern for the Product realization requirement can be explained by 19 nonconformity causes in five detailed standard requirements, as shown in Table 5.

The nonconformity pattern for the Measurement, analysis and improvement requirement among ISO 9001 standard requirements can be explained by 15 nonconformity causes in five detailed standard requirements, as shown in Table 6.
7. Quality management improvement activities

As analyzed above, improvement measures for quality management activity to prevent a recurrence of nonconformity notices from quality certification audits and to enhance the quality level in architectural design and engineering firms are as follows:

1. To solve nonconformity in Production and service provision, design companies should develop site supervision implementation plans suitable for the characteristics of the project, approve the construction plan received from the construction company through thorough review in advance, and conduct constant review and feedback at each stage of construction.

2. For improvement of quality in Design and development, design companies should establish a preparation standard and procedures plan suitable for the characteristics of the project, and conduct review, verification, and validation of the design output at every stage of the design. In addition, valid copy and latest copy of design output should always be managed properly.

3. For improvement of quality in Purchasing, design companies should establish and operate associated company management procedures clearly. They should conduct evaluation, re-evaluation, and post evaluation of associated companies, and perform feedback of outcomes.

4. For improvement of quality in Customer-related process and Planning of product realization, it is necessary to collect and manage accurate information on expectations and demands of the customer, and to review requirements before the contract implementation stage. In particular, design companies should review satisfaction of requirements by stage and perform feedback activity.
(5) For improvement of quality in Monitoring and measuring, inspection and testing of plans for the project should be established in terms of the characteristics of the project. Implementation should designate items to be tested in detail including standards, frequency, and inspector.

(6) For improvement of quality in Control of nonconformity, design companies should maintain a rework record of nonconformity design occurring after delivery of the design outcome, and should develop procedures for follow-up actions in case of defects in the design outcome. Information on construction nonconformity should be kept and feedback activity should be executed.

(7) For improvement of quality in Data analysis and Improvement, design companies should arrange and analyze rework records for prevention of design error and should conduct feedback activity.

(8) For improvement of quality in Document and data records, design companies should review, approve, and reply to a shop drawing received from a construction company courteously. Moreover, on a construction site, there should be distinct management of valid and invalid drawings.

8. Conclusion

The current study was conducted to suggest improvements for quality management activity by examining nonconformity reports published at the time of a quality certification audit by the certification body in domestic architectural design and engineering firms. The following were the results:

(1) In a study of 123 nonconformity reports, 83% of nonconformity was found in Product realization and Measurement, analysis and improvement among the ISO 9001 standard requirements. Therefore, more active quality management activity is needed concentrating on nonconformity.

(2) Repetitive nonconformity patterns were observed in 10 areas of the ISO 9001 standard requirements: Design and development, Production and service provision, Purchasing, Planning of product realization, Customer-related process, General, Monitoring and measuring, Control of nonconformity, Data analysis, and Improvement.

(3) Analysis of nonconformity patterns in the 10 areas by cause suggested 68 major causes for nonconformity activity. Accordingly, nonconformity activities commonly appearing, regardless of the characteristics of the construction company, should be rechecked.

Table 5. Nonconformity Patterns and Causes of Product Realization Requirement

| Nonconformity patterns by standard requirement | Sub-total | Number | Cause of main nonconformity activities | Ratio |
|-----------------------------------------------|-----------|--------|----------------------------------------|-------|
| Production and service provision              | 13        | 1      | Site supervision implementation plans are not established | 3 5.76 |
| Design and development                        | 26        | 2      | The characteristics of project are not reflected in site supervision implementation plans | 2 3.84 |
|                                               |           | 3      | Approval of site quality plan, construction plan, etc. are deficient | 3 5.76 |
|                                               |           | 4      | Construction detailed drawing, and feedback of outcome are deficient | 2 3.84 |
|                                               |           | 5      | Inspection of carried-in materials are deficient | 1 1.92 |
|                                               |           | 6      | Site inspection of auditor and feedback of outcome are deficient | 1 1.92 |
|                                               |           | 7      | There is a disparity in process management standard of site and check list used | 1 1.92 |
| Purchasing                                    | 8         | 1      | Preparation standard and procedure of design plan are deficient | 5 9.61 |
|                                               |           | 2      | Design review, verification, feedback of outcome are not implemented | 14 26.92 |
|                                               |           | 3      | Management of valid design output copy and the latest copy is imperfect, and feedback of outcome are deficient | 3 5.76 |
|                                               |           | 4      | Technological connectiveness among participating organizations in design is not guaranteed and duty by responsibility is not clear | 1 1.92 |
|                                               |           | 5      | Renewal of design plan stage is deficient by design change | 3 5.76 |
| Customer-related process                      | 5         | 1      | Procedures of associated companies are not established | 3 5.76 |
| Planning of product realization               | 2         | 2      | Evaluation of associated companies and feedback of outcome is not performed | 2 3.84 |
|                                               |           | 3      | Associated companies that do not meet its selection standard are selected | 1 1.92 |
|                                               |           | 4      | Purchasing management procedure is not established | 1 1.92 |
|                                               |           | 5      | Purchasing documents of associated companies are not prepared and inspection of purchased goods is not implemented | 1 1.92 |

Total | 52 | 100.00 |

Table 5. Nonconformity Patterns and Causes of Product Realization Requirement

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9. Suggestions for future research

It is necessary to conduct a study on the development of a new quality management system model, which can increase efficiency and competitiveness by reinvestigating and analyzing overall operation conditions for quality management activity in the construction industry, and applying quality management systems to construction sites.

A study on the development of integrated quality management activity processes for mutual connectivity is required because design and construction in the construction industry are important elements in the quality of architecture.

Study of the development of a unified project implementation system including procedures, guides, and activities that are mutually connected between the concerned parties participating in the construction project from commencement to completion is needed, taking into account the characteristics of the construction industry.

Notes
1) Korea Foundation for Quality (2002) Understanding and Application of Process Approach Methods, Chapter 2 Process and Procedure, 11-13. (Page 2, right, foot)
2) Dae-Kwon Bae (200) Construction Project Assurance Plan, Gimoondang, Jan., 375. (Page 3, right, foot)
3) The numbers stand for the accumulated number of certification maintenances by year. (Page 4, left, foot)

Table 6. Nonconformity Patterns and Causes of Measurement, Analysis and Improvement Requirement

| Nonconformity Patterns by standard requirement | Sub-total | Number | Cause of main nonconformity activities | Ratio |
|----------------------------------------------|-----------|--------|---------------------------------------|-------|
| General                                      | 30        |        | Test and inspection plans are not established | 6 12.50 |
|                                             |           | 2      | Inspection items, inspection standard, frequency, inspector, etc. are not designated in test and inspection plans, or are unreasonable | 9 18.75 |
|                                             |           | 3      | Characteristics of the construction, customer specification, characteristics of product are not reflected in test and inspection plans. | 3 6.25 |
|                                             |           | 4      | Checklist for inspection activity is not prepared or cannot be used because of disparity | 6 12.50 |
| Monitored and measuring                      |           | 5      | Test plans for correction equipment are not established or propriety is not verified | 4 8.33 |
|                                             |           | 6      | Feedback of site supervision implementation outcome is deficient | 1 2.08 |
|                                             |           | 7      | Internal quality audit is not implemented, or follow-up actions for indication is deficient | 1 2.08 |
| Control of nonconformity                    | 6         |        | Rework record for unsuitable design that occurred after delivery of design is not maintained | 2 4.16 |
|                                             |           | 2      | Disparity between design plan and site construction | 1 2.08 |
|                                             |           | 3      | Follow-up procedure for design defect is not established and information on construction nonconformity is not possessed | 2 4.16 |
|                                             |           | 4      | Demand of auditor's corrective action for nonconformity of site construction is deficient | 1 2.08 |
| Data analysis                               | 12        |        | Arrangement, analysis, and feedback of rework record to prevent recurrence of design defect are deficient | 5 10.41 |
|                                             |           | 2      | Reinspection after rework for nonconformity and improvement measures are deficient | 3 6.25 |
|                                             |           | 3      | Conclusion at the correction stage of indication made by internal audit | 2 4.16 |
|                                             |           | 4      | Conclusion at the correction stage without cause analysis of corrective action and preventive measures of recurrence | 2 4.16 |
| Total                                       |           | 48     |                                        | 100.00 |

References
1) Abdol R. Chini and Hector E. Valdez (2003) ISO 9000 and the Construction Industry, Journal of Management in Engineering, ASCE, Apr, pp. 399-402.
2) Andi and Takayuki Minamoto (2003) Design Documents Quality in the Japanese Construction Industry: Factors Influencing and Impacts on Construction Process, International Journal of Project Management, 21, pp. 537-546.
3) BVQI Certification Center, Audit Nonconformity report (1997-2004).
4) C. W. Jeong and S. Y. Jin (1999) Establishment of Model for ISO 9000 Quality Management System Development at Domestic Construction Sites, Architectural Institute of Korea, Feb., 24.
5) Dae-kwon, Bae (1996) Explanation of Construction Related ISO Certification, Daewoo Publishing, 14.
6) Dae-kwon, Bae (2000) Construction Project Assurance Plan, Gimoondang, Jan., 375-378.
7) Dae-kwon, Bae (2002) Description on Construction Quality Management System, Gimoondang, 75.
8) Dae-kwon, Bae (2003) Construction Quality Management, Gimoondang, May, pp. 34-52.
9) Dae-kwon, Bae (2004) Process Management and Performance Control, Korea Legislation Research Institute, Dec., pp. 40-69.
10) Francisco J. Conca, Juan Llopis and Juan Jos. Tar (2004) Development of a Measure to Assess Quality Management in Certified Firms, European Journal of Operation Research, 156, pp. 683-697.
11) Gregerson, J. (1995) TQM: Is ISO 9000 the next big thing?, Building Design and Construction, Nov., pp. 36-38.
12) International Organization for Standardization (ISO) (2000) The ISO Survey of ISO 9000 and ISO 14000 Certificates, Ninth
Cycle/ISO 9000 and ISO 14000 Certificates Awarded Country by Industrial Sector (CD-ROM), Geneva

13) Jae-young, Lee and Hak-ki, Lee (2000) A Study on the Application and Improvement of the ISO 9000 System in the Domestic Construction Industry, Architectural Institute of Korea, Apr., pp. 399-402.

14) Jong-il, Lee (1994) The Effect of ISO 9000 Certification on Quality, PhD Manuscript, Yeonsei University, Dec.

15) Korea Accreditation Board (2002) Korean Certification Comprehensive Bibliography, KAB News, 37

16) Korea Foundation for Quality (1997-2004) Audit Nonconformity report

17) Korea Foundation for Quality (2002) Understanding and Application of Process Approach Methods, pp. 11-13

18) Mil Terziovski, Damien Power and Amrik S. Sohal (2003) The Longitudinal Effects of the ISO 9000 Certification Process on Business Performance, European Journal of Operation Research, 146, pp. 580-595

19) Pena, M. G., and Fisher, D. J. (1994) Business Reengineering in a South American Oil Company, J. Mgmt., in Engrg., ASCE, Vol. 10, No. 4, pp. 45-51

20) Savido, V. E., and Norton, K. J. (1993) Integrated Design-Process Model, J. Mgmt. in Engrg., ASCE, Vol. 10, No. 5, pp. 55-62