THE APPLICABILITY OF THE QUALITY ASSURANCE REQUIREMENTS OF THE ISO 9000 CONFORMANCE STANDARDS IN CONSTRUCTION

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ISO 9000 compliance is rapidly becoming a prerequisite for construction companies seeking contracts and a competitive position in the construction market. The ISO 9000 conformance standards (ISO 9001, 9002 and 9003) are being used by construction companies seeking ISO 9000 certification. Nearly 35% of the largest construction companies in Portugal are using ISO 9000-based quality systems for 100% of their projects. A fundamental requirement of ISO 9000 quality management/quality assurance standards is that a documented quality system must be present. Each of the ISO 9000 conformance standards requires the consideration of a number of requirements that form the contents of the standard. The most comprehensive model, ISO 9001 requires the consideration of twenty requirements. This paper examines the applicability of the twenty requirements in construction by investigating the use of ISO 9000 by largest companies in Portugal's construction industry. In addition, it addresses how each requirement is implemented in the ISO 9000-based quality systems for construction organisations and projects.

Keywords: ISO 9000, quality, quality system, quality assurance, questionnaire survey.

INTRODUCTION

The implementation of ISO 9000 based quality assurance and quality management systems have received a wide attention in several countries (Serpell, 1999; Watson and Chileshe, 1998; Nee, 1996; Ashford, 1990). ISO 9000 compliance is rapidly becoming a prerequisite for construction companies seeking contracts and a competitive position in the construction market. In addition, owners are increasingly transferring the responsibility for quality assurance to contractors. This situation has forced construction companies to implement ISO 9000-based quality systems and in several cases to seek ISO 9000 certification.

The ISO 9000 conformance standards (ISO 9001, 9002 and 9003) are being used by construction companies seeking ISO 9000 certification. Nearly 35% of the largest construction companies in Portugal are using ISO 9000-based quality systems for 100% of their projects (Ribeiro and Curado, 2000).

A fundamental requirement of ISO 9000 quality management/quality assurance standards is that a documented quality system must be present. Each of the ISO 9000 conformance standards requires the consideration of a number of requirements that form the contents of the standard. The most comprehensive model, ISO 9001 requires the consideration of twenty requirements. The quality management standards (ISO 9004-1, ISO 9004-2, ISO 9004-3) are being utilised to assist in the organisational

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understanding of each quality assurance requirement. However, in the construction industry the application of the quality management requirements and quality management guidelines has been more difficult due to its nature and complexities of organisations and project. Very few studies have examined the application of the ISO 9000 quality assurance requirements in construction projects (Pheng, 1999). As stated by McGeorge and Palmer (1997) the criticism that has been made of ISO 9000 certification may not relate to the systems themselves but to the way they are implemented in construction industry.

The objective of the current study is to obtain feedback from construction and design companies on the implementation of ISO 9001 quality assurance requirements in the context of quality systems.

RESEARCH SURVEY

The objectives of the research were met through an intensive literature review and an in-depth research survey.

The research survey concentrates on two categories of respondents: construction contractor and design and engineering firms. The data collected through the survey were enhanced through further interviews with the original respondent. Thus, a questionnaire was designed and mailed to an equal number of construction contractors and design firms operating in the construction industry in Portugal. These companies represent the largest organisations in the nation according to their annual turn-over.

The primary aim of the survey was to investigate the applicability of the quality assurance requirements that form the contents of the ISO 9000 conformance standards in construction and to examine the impact of each requirement on the quality of construction projects. The questions were based on the existing theory of how ISO 9000 standards should be implemented. The questionnaire includes two sections:

Exploratory questions in relation to the business activities of the respondents and their experience.

A list of 20 quality assurance requirements contained in the ISO 9001 standard enabling respondents to rate each according to their perceived importance, and their impact on the quality of construction projects.

ANALYSIS OF RESULTS

The research analysis is based on 48 positive responses (26 were from construction contractors 22 were from design firm), constituting a 52% response rate within the construction contractors group and 44% response rate within the design and engineering group. This level of response is not unexpected considering that construction industry has lagged behind other industrial sector in Portugal in the issues of quality assurance/quality management. Some of the questionnaires were returned uncompleted by some organisations for various reasons, including lack of knowledge about ISO 9000, lack of time, etc. Uncompleted questionnaires were not included in the analysis.

CHARACTERISTICS OF THE RESPONDENTS

Tables 1 and 2 respectively show the category and the position held by the respondents, and distribution of their experience. The majority of respondents held a position of seniority within their employer's organisation. A majority of the respondents within both groups of organisations are directors, general managers and project managers responsible for strategic decisions, policy development, resources and production.

Table 1: Position held by the respondents

Position held	Category of respondents					
	Contractor		Design and Engineering		Total	
	No.	%	No.	%	No.	%
General director	15	58	7	32	22	46
Head of department	6	23	6	27	12	25
Manager	4	15	2	9	6	12
Adviser	1	4	7	32	8	17
Total	26	100	22	100	48	100

In terms of the construction experience of the respondents, contractors and designers and engineers have almost the same level of experience.

Table 2: Experience of the respondents

Years of experience	Category of respondents					
	Contractor		Design and Engineering		Total	
	No.	%	No.	%	No.	%
0-5	4	15	4	18	8	17
6-10	6	23	5	23	11	23
11-15	3	12	6	27	9	19
16-20	8	31	6	27	14	29
21-25	5	31	1	5	6	12
Total	26	100	22	100	48	100

ANALYSIS OF QUALITY ASSURANCE REQUIREMENTS

The ISO 9001 standard is the most comprehensive model for developing a documented quality system. It requires the consideration of 20 quality assurance requirements. As previously mentioned, one of the major objectives of this study was to find the perceptions of the importance of the twenty quality assurance requirements in construction.

The respondents were asked to rate the level of importance of all quality assurance requirements on a Likert Scale of 1 to 5, where the index number 5 denotes *extremely important* and 1 denotes *not important*. A relative importance index (RII) (after Kumaraswamy and Chan, 1998) was calculated to and the levels of importance divided into three parts, 5 and 4 being of strong importance, 3 being moderate importance and 1 and 2 being weak importance. This analysis (Kumaraswamy and Chan, 1998) provides a basis for ranking the quality assurance requirements within the two groups surveyed: contractors and designers and engineers. The relative importance rankings of the quality assurance requirements within each group from 4.1 to 4.20 are indicated in Tables 3 and 4. These were assigned on the basis of the factor RIIs.

A general conclusion taken from Tables 3 and 4 is that respondents tended to rate the quality assurance requirements which are crucial to their business objectives, as being

most important. For contractors, the most important quality assurance requirements are those that will affect the performance of building works, with process control as being the most important. For designers and engineers, the most important quality assurance requirements are those that will affect the outputs of the design process, with design control ranked as being most important. There is a positive agreement for both groups on the level of importance of the management responsibility requirement ranked (within both groups) as the second most important quality assurance requirement.

Table 3: Contractors' group ranking of RIIs quality assurance requirements

Rank	Quality assurance requirements	<4	3	>2	Total	Relative Importance Index
1	4.9-Process control	18	3	0	21	0.867
2	4.1-Management responsibility	17	3	1	21	0.838
3	4.10- Inspection and testing	16	3	2	21	0.819
4	4.2-Quality system	15	3	3	21	0.790
5	4.14- Corrective and preventive actions	13	6	2	21	0.771
6	4.6-Purchasing	13	5	3	21	0.762
7	4.13-Control of nonconforming product	13	5	3	21	0.743
8	4.18-Training	11	7	3	21	0.724
9	4.12- Inspection and test results	8	5	8	21	0.689
10	4.17-Internal quality audits	10	6	5	21	0.676
11	4.3-Contract review	10	6	3	21	0.667
12	4.5-Document and data control	9	6	6	21	0.648
13	4.8-Product identification and traceability	7	6	8	21	0.590
14	4.4-Design control	4	7	10	21	0.505
15	4.11-Control of inspection, measuring and test equipment	4	4	13	21	0.467
16	4.15-Handling, storage, packaging, preservation, and delivery	2	7	12	21	0.457
17	4.19-Servincing	2	5	14	21	0.419
18	4.7-Control of customer-supplied product	0	6	15	21	0.381
19	4.16-Control of quality records	3	6	12	21	0.362
20	4.20- Statistical techniques	0	4	17	21	0.238

Table 4: Designer and engineers' group ranking of RIIs quality assurance requirements

Rank	Quality assurance requirements	<4	3	>2	Total	Relative Importance Index
1	4.4-Design control	13	2	0	18	0.878
2	4.1-Management responsibility	15	2	1	18	0.856
3	4.9-Process control	16	2	0	18	0.856
4	4.10- Inspection and testing	15	1	2	18	0.811
5	4.2-Quality system	13	4	1	18	0.800
6	4.14- Corrective and preventive actions	13	3	2	18	0.789
7	4.5-Document and data control	11	4	3	18	0.733
8	4.13-Control of nonconforming product	9	6	3	18	0.711
9	4.3-Contract review	8	6	2	18	0.622
10	4.8-Product identification and traceability	6	6	6	18	0.600
11	4.18-Training	7	5	4	18	0.533
12	4.17-Internal quality audits	4	4	10	18	0.511
13	4.19-Servincing	7	4	10	18	0.500
14	4.12- Inspection and test results	3	5	10	18	0.467
15	4.7-Control of customer-supplied product	3	5	8	18	0.444
16	4.16-Control of quality records	2	3	13	18	0.400
17	4.11-Control of inspection, measuring and test equipment	0	3	15	18	0.356
18	4.15-Handling, storage, packaging,	0	5	13	18	0.356

	preservation, and delivery					
19	4.6-Purchasing	0	3	15	18	0.344
20	4.20- Statistical techniques	0	2	16	18	0.311

The weighted average of RIIs for each of the 20 quality assurance requirements from each group surveyed was next computed (Table 5). Table 5 provides a means of identifying overall the most important quality assurance requirements for construction projects.

The ten most important quality assurance requirements within table 5 are associated with process control, management responsibility, inspection and testing, quality system, corrective and preventive actions, control of nonconforming product, document and data control, product identification and traceability, design control, and contract review. The five most important quality assurance requirements in table 5 were ranked for each group.

The consistently least important quality assurance requirement overall and within the groups is associated with associated with statistical techniques.

Table 5: Weighted average of relative importance indices (RII) of quality assurance requirements for both groups surveyed

Rank	Quality assurance requirements	Contractors (RII)	Designers/Engineers (RII)	Weighted average
1	4.9-Process control	0.867	0.856	0.862
2	4.1-Management responsibility	0.838	0.856	0.846
3	4.10- Inspection and testing	0.819	0.811	0.815
4	4.2-Quality system	0.790	0.800	0.795
5	4.14- Corrective and preventive actions	0.771	0.789	0.747
6	4.13-Control of nonconforming product	0.743	0.711	0.728
7	4.5-Document and data control	0.648	0.733	0.687
8	4.8-Product identification and traceability	0.590	0.800	0.687
9	4.4-Design control	0.505	0.878	0.677
10	4.3-Contract review	0.667	0.622	0.646
11	4.18-Training	0.724	0.533	0.636
12	4.17-Internal quality audits	0.676	0.511	0.600
13	4.12- Inspection and test results	0.689	0.467	0.587
14	4.6-Purchasing	0.762	0.344	0.569
15	4.19-Servincing	0.419	0.500	0.456
16	4.11-Control of inspection, measuring and test equipment	0.467	0.356	0.416
17	4.15-Handling, storage, packaging, preservation, and delivery	0.457	0.356	0.410
18	4.7-Control of customer-supplied product	0.381	0.444	0.410
19	4.16-Control of quality records	0.362	0.400	0.380
20	4.20- Statistical techniques	0.238	0.311	0.272

IMPACT OF QUALITY ASSURANCE REQUIREMENTS ON THE PRODUCT QUALITY

As previously mentioned, one of the major objectives of this study was to find the perceptions of the impact of the twenty quality assurance requirements on the product quality.

The respondents indicated perceived impact of quality assurance requirements on product quality on a Likert Scale of 1 to 5, where the index number 5 denotes *extremely high impact* and 1 denotes *very low impact*. A relative significance index (RSI) (after Kumaraswamy and Chan, 98) was calculated to and the levels of

significance divided into three parts, 5 and 4 being of strong significance, 3 being moderate significance o and 1 and 2 being weak significance. This analysis (Kumaraswamy and Chan, 98) provides a basis for ranking within the two groups surveyed: contractors and designers and engineers.

The relative significance rankings of the impact of the quality assurance requirements on the product quality within each group from 4.1 to 4.20 are indicated in Tables 6 and 7. These were assigned on the basis of the factor RSIs.

Table 6: Contractors' group ranking of RSIs of quality assurance requirements on product quality

Rank	Quality assurance requirements	<4	3	>2	Total	RSI
1	4.1-Management responsibility	17	2	2	21	0.848
2	4.9-Process control	6	7	8	21	0.829
3	4.10- Inspection and testing	4	5	12	21	0.781
4	4.14- Corrective and preventive actions	5	5	11	21	0.771
5	4.2-Quality system	13	4	5	21	0.752
6	4.6-Purchasing	3	4	14	21	0.695
7	4.17-Internal quality audits	3	5	13	21	0.676
8	4.18-Training	0	3	18	21	0.629
9	4.13-Control of nonconforming product	2	3	16	21	0.610
10	4.11-Control of inspection, measuring and test equipment	8	5	8	21	0.581
11	4.3-Contract review	5	6	10	21	0.543
12	4.16-Control of quality records	8	6	7	21	0.524
13	4.4-Design control	4	5	13	21	0.495
14	4.5-Document and data control	1	4	16	21	0.486
15	4.12- Inspection and test results	14	5	2	21	0.476
16	4.19-Servincing	4	5	12	21	0.457
17	4.8-Product identification and traceability	13	6	2	21	0.429
18	4.15-Handling, storage, packaging, preservation, and delivery	10	7	4	21	0.400
19	4.7-Control of customer-supplied product	16	3	2	21	0.390
20	4.20- Statistical techniques	10	7	4	21	0.314

Table 7: Designer and engineers' group ranking of Relative Significance Index (RSIs) of quality assurance requirements on product quality

Rank	Quality assurance requirements	<4	3	>2	Total	RSI
1	4.4-Design control	15	2	1	18	0.844
2	4.1-Management responsibility	14	2	2	18	0.822
3	4.9-Process control	13	3	2	18	0.800
4	4.5-Document and data control	13	3	2	18	0.789
5	4.2-Quality system	12	3	3	18	0.778
6	4.13-Control of nonconforming product	12	3	4	18	0.767
7	4.10- Inspection and testing	11	4	3	18	0.756
8	4.18-Training	11	3	4	18	0.722
9	4.3-Contract review	8	6	4	18	0.667
10	4.7-Control of customer-supplied product	8	5	5	18	0.667
11	4.14- Corrective and preventive actions	10	5	3	18	0.656
12	4.17-Internal quality audits	7	5	6	18	0.622
13	4.19-Servincing	9	5	4	18	0.533
14	4.8-Product identification and traceability	2	4	11	18	0.444
15	4.11-Control of inspection, measuring and test equipment	3	4	10	18	0.444
16	4.12- Inspection and test results	6	5	7	18	0.433
17	4.6-Purchasing	1	6	11	18	0.422
18	4.16-Control of quality records	0	3	15	18	0.356
19	4.15-Handling, storage, packaging, preservation, and delivery	0	3	15	18	0.344
20	4.20- Statistical techniques	0	2	16	18	0.333

A general conclusion taken from Tables 6 and 7 is that respondents tended to rate the impact of the quality assurance requirements on the product quality which are paramount to their market position, as being most important. For contractors, the most important quality assurance requirements is management responsibility. For designers and engineers, the most important quality assurance requirements are those that will affect the outputs of the design process, with design control ranked as being most important.

The weighted average of RSIs for each of the 20 quality assurance requirements from each group surveyed was next computed (Table 8). Table 8 provides a means of identifying overall the quality assurance requirements with most impact on the quality of construction projects.

Table 8: Relative significance indices (RSI) of the impact of quality assurance requirements on product quality

Rank	Quality assurance requirements	Contractors (RSI)	Designers/Engineers (RSI)	Weighted average
1	4.1-Management responsibility	0.848	0.822	0.836
2	4.9-Process control	0.829	0.808	0.819
3	4.10- Inspection and testing	0.781	0.756	0.769
4	4.2-Quality system	0.752	0.778	0.764
5	4.14- Corrective and preventive actions	0.771	0.656	0.718
6	4.13-Control of nonconforming product	0.610	0.767	0.682
7	4.18-Training	0.629	0.722	0.672
8	4.4-Design control	0.495	0.844	0.656
9	4.17-Internal quality audits	0.676	0.622	0.651
10	4.5-Document and data control	0.486	0.789	0.626
11	4.3-Contract review	0.543	0.667	0.600
12	4.6-Purchasing	0.695	0.422	0.569
13	4.11-Control of inspection, measuring and test equipment	0.581	0.444	0.518
14	4.7-Control of customer-supplied product	0.390	0.667	0.518
15	4.19-Servincing	0.457	0.533	0.492
16	4.12- Inspection and test results	0.476	0.433	0.456
17	4.16-Control of quality records	0.524	0.356	0.446
18	4.8-Product identification and traceability	0.429	0.444	0.436
19	4.15-Handling, storage, packaging, preservation, and delivery	0.400	0.344	0.374
20	4.20- Statistical techniques	0.314	0.333	0.323

The ten most important quality assurance requirements within table 8 are associated with management responsibility, process control, inspection and testing, quality system, corrective and preventive actions, control of nonconforming product, training, design control, internal quality audits and document and data control.

The consistently least important quality assurance requirement overall and within the groups is associated with associated with statistical techniques.

CONCLUSIONS

Contractors and designers in Portugal have been using ISO 9000 standards for less than six years. However, only few of them have obtained the certification of their company. ISO 9000 standards represents a cultural change in the way construction industry firms implement their projects.

Several results emanated form the analysis of the survey. The respondents tend to rank most highly those quality assurance requirements that are crucial for the performance

of their projects. Contractors focused on quality assurance requirements with major impact on the performance of construction processes such as process control, management responsibility, inspection and testing, purchasing, etc.

Designers and engineers focused on quality assurance requirements which affect the outputs of the design process such as design control, management responsibility, process control, inspection and testing, etc.

The questionnaire survey in this study also revealed differences in perceptions as to the importance of quality assurance requirements as well as to their impact on product quality by the main groups of project participants. It is suggested that these apparent collective biases of different industry groups are a result of the fragmentation of roles that characterise the construction process. However, it is expected that the revealed perceptions on ISO 9000 series may change in the future with wider use of ISO 9000 quality systems in construction.

The expected new ISO 9000 series will replace the existing quality assurance standards (ISO 9001, ISO 9002, ISO 9003). It will introduce alterations in three areas: management responsibility, customer satisfaction and continual improvement. The new ISO 9000 series, in fact, will clarify the implementation of the quality assurance requirements.

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