

Identifying Critical Success Factors for Data Quality Management through a Delphi Study

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II. LITERATURE REVIEW

Abstract—Organizations support their operations and decision making on the data they have at their disposal, so the quality of these data is remarkably important and Data Quality (DQ) is currently a relevant issue, the literature being unanimous in pointing out that poor DQ can result in large costs for organizations. The literature review identified and described 24 Critical Success Factors (CSF) for Data Quality Management (DQM) that were presented to a panel of experts, who ordered them according to their degree of importance, using the Delphi method with the Q-sort technique, based on an online questionnaire. The study shows that the five most important CSF for DQM are: definition of appropriate policies and standards, control of inputs, definition of a strategic plan for DQ, organizational culture focused on quality of the data and obtaining top management commitment and support.

Keywords—Critical success factors, data quality, data quality management, Delphi, Q-Sort.

I. INTRODUCTION

THIS paper describes a study that intends to answer the following research question: What are the CSF for DQM? To answer this question a literature review was performed, followed by a Delphi questionnaire with the Q-Sort technique, supported by an online questionnaire. The CSFs identified in the literature review were presented to a panel of experts with the objective of obtaining consensus regarding their ordering by degree of importance.

Although data and information mean slightly different things, for reasons of simplicity the terms are often used interchangeably [4], [21]. Organizations are increasingly working with enormous volumes of information that is a fundamental asset and a differentiating factor if it has quality. The CSFs for DQM are a relatively unexplored issue that will be considered in this work [4].

In [5], Boynton & Zmud define CSFs as those aspects that must go well to ensure the success for a manager or an organization, and are vital for the company's operational activities and its future success. In [23], Rockart categorized the CSFs in two groups: monitoring and building. The CSFs in the former group serve, as the name implies, to monitor the current results, and the CSFs in the latter one are oriented towards building for the future.

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A. DQM

According to the Data Management Association [30, p.43], cited by Lucas [17], DQM consists of applying the concepts and practices of Total Quality Management (TQM) to improve the quality of data and information, involving the definition of policies and rules, assessment of DQ (including auditing and certification), data analysis, cleaning and correction, DQ improvement and education.

Reference [11] goes further and considers that DQM should incorporate the creation and implementation of roles, policies, responsibilities and processes related to the acquisition, maintenance, organization and distribution of data, requiring alignment between the technologies and the business. The Data Warehousing Institute estimates that DQ problems cost US companies more than \$600 billion a year [7].

Table I summarizes the impact of poor DQ according to organizational levels.

TABLE I
IMPACT OF POOR DATA QUALITY [22, p.82]

Organizational levels	Impact of poor DQ
Operational	Reduces customer satisfaction
	Increases costs
	Decreases employee satisfaction
Tactical	Makes decision making less accurate and more time-consuming
	Makes it difficult to implement data warehouses
	More difficult to reengineer
Strategic	Increased organizational mistrust
	More difficult to set and to execute the strategy
	Contribute to issues of data ownership
	Compromise ability to align organizations
	Divert management attention

B. CSF

Forster & Rockart [8] argue that the concept of CSF has decades and reported that Aristotle, almost two thousand years ago, expressed the idea that leaders should create a few simple goals for their organizations and noted that those organizations that did so fared better than those that did not.

CSFs are essential elements for an organization or project successfully achieve its mission or objectives with success [15] and should be identified in a limited number of key sectors of the company, in order to ensure a competitive and successful performance [23].

Table II summarizes the CSF for DQM identified and defined through the literature review.

As the issue of CSFs to DQM is poorly treated in the literature, that was decided to search the CSFs in more mature areas, such as Knowledge Management Systems; Business

Performance Management; Data Management; TQM; Management; Enterprise Resource Planning; Data Aligning IT and Business Objectives, Business Process Warehousing; and Accounting Information Systems Quality.

TABLE II
CSFS

CSF	REFERENCE
1. Physical environment: Conducive physical working environment	[2], [35], [36]
2. Evaluate cost/benefit tradeoffs: Tracking costs and benefits and identifying the critical point where a more centralized business initiative is justified. Identification of costs caused by poor DQ. Have systematic cost/benefit analysis of DQ controls and activities in order to maximize benefits at minimum cost.	[6], [35], [36], [42]
3. Top management commitment and support: Recognition by the top management of the importance of DQ. Authorization to support activities related to DQ and attribution of rewards to employees. Change in the work environment to enable employees to accept the importance of DQ. Implementation of measures aimed at motivating people in the organization to support the DQ initiative and the inherent organizational changes. Obtaining necessary operational resources such as financing and personal competences.	[1], [3], [7], [13]-[15], [29], [32], [34]-[36], [38], [41]
4. Middle management commitment and support: Acceptance of responsibility for DQ performance by middle managers. Effective procedures at middle management level.	[7], [36]
5. Communication: Sharing knowledge and communication between different departments, within departments and among different professionals. Sharing between employees needs a strong, reliable culture and also transparency throughout the organization.	[1]-[3], [6], [14], [15], [19], [20], [36]
6. Input controls: Quality assurance of data loading. Certification of external data sources. Certification of existing data. Implementation of robust validation routines in data collection. Controlling the way internal data is generated.	[2], [13], [35], [36], [41]
7. Organizational culture with a focus on DQ: Perception of the importance of DQ. Coherence in the way DQM processes are applied in the organization. Involvement with the academic environment. Focus on consumers. Market and law analysis. Compliance with contractual obligations. The quality of the data should be seen as a critical issue of the business and dealt continuously and proactively. Development of a culture of motivation, trust and respect.	[1], [2], [4], [9], [14], [35], [36], [41]
8. DQ policies and standards: Implementation of a standard methodology. Standardizing codes, rules, and definitions. Reformulation of the data model, when necessary.	[2], [6], [13], [18]-[20], [31], [35], [36]
9. Production of a strategic plan for DQ: Strategic alignment with the business. Knowledge of maturity level of the organization. DQ vision articulation with business.	[1], [3], [6], [7], [13]-[15], [18]-[20], [31], [38]
10. Education and Training: Acquisition of new competences covering the entire organization, from the top and intermediate management to the collaborators. Providing effective and appropriate initial and continuous training to employees.	[1], [2], [4], [6], [7], [12]-[14], [20], [31], [32], [35], [36], [41], [42]
11. Documentation: Elaboration of adequate and sufficient documentation, both at the user and the data administrator levels. Documentation of all data items.	[4], [12], [15], [42]
12. User Focus: User engagement. Focus on users ' needs and quality requirements. Active participation of users in order to ensure and improve DQ.	[2], [3], [34]-[37], [41]
13. Architecture Management: Appropriate Software and Hardware acquisitions. Update applications. Adequate technological capacities. Minimization of interfaces. Data integration. Implementation of Data Warehouse.	[1], [4], [7], [13], [18], [20], [29], [34], [41]
14. Change Management: Change in organizational processes and behaviors. Adapting the rules of data integrity considering the changes in business processes and requirements. Existence of organizational competencies to manage internal and external changes. Reengineering and process integration. Change of culture at all levels of the organization.	[1], [2], [4], [7], [13], [15], [18]-[20], [31], [32], [35], [36], [38]
15. Storage Management: Policies of Backup and retention. Implementation of a Repository of Meta Data. Selection, preservation and management of digital data, in order to facilitate the current and future discovery and recovery of this data. Implementation of reuse practices and data preservation.	[1], [4], [18], [12], [19]
16. Risk Management: Identification, analysis, monitoring, prioritization and categorization of Risks. Implementation of risk mitigation procedures.	[4], [35]-[37], [42],
17. Continuous improvement: Institutionalization of continuous improvement of DQ. Identification and troubleshooting. Perform data cleansing. Monitor progress towards DQ objectives by holding periodic presentations and communications meetings Projects to improve the quality of data should be part of the company's budget.	[2], [4], [13], [15], [31], [35]-[37], [42]
18. Internal and external monitoring and evaluation: Implementation of ETL and DQ tools. Identification of problems such as missing data, incorrect values, duplicates records, and violations of business rules. Establishment of service level agreements. Implementation of results measurement. Performance evaluation. Implementation of benchmarking techniques. Implementation of statistical process control. Definition of metrics.	[4], [7], [12], [18], [19], [36]
19. Appointment of managers and definition of roles: Definition of responsibilities for DQ. Identification of Owners and the Custodians. Appointment of Data Stewards and a Data Champion. Appointment of a specialist or a group of experts as managers of DQ.	[3], [4], [6], [7], [13], [15], [29], [34], [36], [38]
20. Conducting regular audits: Identification of problems such as missing data, incorrect values, duplicate records, and violations of business rules. Identification of opportunities, deficiencies and gaps. Ensuring that the appropriate controls are in place.	[1], [4], [7], [12], [13], [35], [36]
21. Sufficient resources: Allocation of sufficient resources: technical, monetary, people, competencies and time.	[3]
22. Effective relationship with employees: Empowerment and participation of employees as part of the organization. Satisfaction, workplace safety and career development.	[2], [14], [19], [31], [35]-[37]
23. Security and internal control: Access control and permissions. Implementation of appropriate internal controls to systems and processes, including security control. Analysis of logs of user activities. Control of data privacy violations. Controls at people level, such as segregation of functions.	[2], [4], [12], [13], [18], [19], [35], [36]
24. Teamwork: Definition of a team for DQ. Centralization of competencies, both technical and the interpersonal, in a team of excellence.	[2], [3], [7], [34]-[36]

III. DATA COLLECTION AND METHODS

It was decided to use the Delphi method with Q-Sort, because according to Linstone [16] cited by Yousuf [40] there

are two situations in which the Delphi method is appropriate:

- The question is not consistent with a precise technical analysis, but can benefit from subjective judgments on a collective basis;

- People who need to interact cannot meet face-to-face due to time or cost constraints.

A. Delphi Method

The original Delphi method was developed in the 50s by Dalkey of RAND Corporation for a military project and is defined by Gallego & Bueno [10] as a method that, through the availability of questionnaires, allows organizing and sharing opinions of experts, being one of the best known and used techniques in new areas of knowledge.

There is no single type of Delphi method because the method is modified to suit the circumstances and the research question [26] and because it is a flexible method being used by researchers in the area of Information Systems and Technologies (IS/IT).

In a Delphi study, an expert should be a specialist in the area of knowledge in which the study is conducted and each questionnaire should correspond to a round, making as many rounds as necessary to obtain a consensus or the confirmation that the consensus is not possible.

Landeta & Barrutia [43] and Gracht [44] cited by Gallego & Bueno [10] characterize the Delphi method, independently of the type of variant and format, through four characteristics: anonymity, iteration, controlled feedback and statistical analysis of group responses.

B. Q Method

The Q method was developed by Stephenson [28] cited by Santos [25] and provides grounds for the systematic study of subjectivity. The distinctive feature of the Q-Sort technique, a component of Q method, is that the panel members are required to order the questions provided under a predefined distribution, usually approximately normal.

The Q-Sort technique is usually preferred on a Likert scale when one wants an order and not just a weighting.

For the analysis and interpretation of the results, the e-Delphi tool with Q-Sort provided by the University of Minho was used. Developed specifically for the Delphi method, this tool automatically calculates some statistical data and orders the CSF in tables generated by the application itself [24].

In order to identify consensus, non-parametric statistical tests were performed. The IBM SPSS Statistics tool was used to calculate the Kendall's concordance coefficient and the Spearman's correlation coefficient.

C. Delphi Method and Q-Sort

24 CSFs identified and defined through the literature review were presented to the panel of experts using an online questionnaire.

Specialists with deep knowledge of DQ were invited to respond to the questionnaire, which is crucial for the final quality of the research. Fig. 1 illustrates the distribution by professional area of the 45 experts who accepted to participate in this study.

D. First Round

For the first round, 45 participants were invited to order the 24 factors that were presented in alphabetical order, according

to the procedures of the Q-Sort methodology. 30 responses (66,67%) were received.

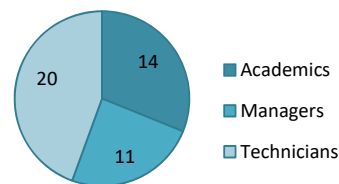


Fig. 1 Experts by profession area

At the end of the first round, experts chose the five most important factors: organizational culture focused on DQ, the definition of appropriate policies and standards, the definition of a strategic plan for DQ, commitment and support of top management and input controls.

In addition to the mean, variance and standard deviation, the Kendall's coefficient was calculated to determine the agreement within the ordering of factors. The value of this coefficient (0.178) shows that there is no strong correlation between the responses, so it was necessary to perform a second round, with the objective of improving the degree of convergence.

At the end of the first round, two of the experts presented 3 apparently new factors, but only one of them was added to the list in position 25. The other two factors were deemed to be covered by the already existing CSFs.

The new factor "data governance" is defined as the set of essential actions to ensure data compliance with organizational strategies.

E. Second Round

For the second round were only invited the respondents of the first round. Table III presents the results of the first and second rounds and in second round the first 5 CSFs are the definition of appropriate policies and standards, the input controls, the definition of a strategic plan for the DQ, the organizational culture with a focus on DQ, and top management commitment and support.

The Kendall's W coefficient (0.227) rose slightly and according to Schmidt [27], this is still a low value that remained practically stabilized and indicates that it will be difficult to improve the agreement with a new round.

The Spearman's coefficient that measures the convergence between the ordering of the first and second rounds was 0.425, which reflects a moderate agreement. In view of the result obtained, it was decided not to proceed with a new round for the following reasons:

- The Kendall's coefficient remained virtually identical in the two rounds;
- The Spearman's coefficient obtained reflects a moderate convergence between the answers of the first and second rounds;
- The research question has not yet reached a reasonable degree of maturity in the academic and professional communities;
- There were difficulties related to the time of the year in

- which the survey was conducted;
- There were difficulties regarding the availability of experts to continue to participate;
- There was little time available for research.

F. Final Results

The results obtained after the two rounds are summarized in Table III, where the first CSF is “definition of appropriate policies and standards”. This factor consists of the implementation of a standard methodology, standardization of codes, rules and definitions and reformulation of the data model, when necessary.

The second position is the “input controls” which means to ensure the quality of data loading, to certify external sources and existing data, to implement validation routines in data collection, and to control how data are generated.

It should also be noted that the five first factors maintained their positions in the two rounds, having only changed their order, which shows concordance of opinions.

TABLE III
 RESULTS OF THE TWO ROUNDS

1st round		2nd round		Question
sum of points	Position	sum of points	Position	
209	2	176	1	Appropriate policies and standards
258	5	180	2	Input controls
225	3	183	3	Definition of a strategic plan for the DQ
183	1	184	4	Organizational culture with a focus on DQ
254	4	195	5	Top management commitment and support
n/a	n/a	200	6	Data governance
343	7	248	7	Continuous improvement
387	10	262	8	Internal and external monitoring and evaluation
382	9	309	9	Change management
406	15	323	10	Conducting regular audits
398	13	324	11	Architecture Management
378	8	336	12	User Focus
324	6	342	13	Education and training
394	12	343	14	Appointment of managers and definition of roles
436	19	356	15	Documentation
390	11	357	16	Communication
408	16	359	17	Middle management commitment and support
440	20	359	18	Teamwork
454	21	359	19	Security and internal control
455	22	365	20	Risk management
401	14	374	21	Sufficient resources
430	17	376	22	Storage Management
431	18	398	23	Cost/Benefit Assessment
513	24	427	24	Effective relationship with employees
501	23	465	25	Workplace environment

The two least important factors also maintained their positions in the two rounds. Thus it would seem that the workplace environment and all that is entailed by effective relationships with employees – empowerment and participation in the organization, satisfaction, job security and career development – are not considered relevant to DQM.

These results are in line with the literature review.

IV. DISCUSSION

DQM includes policies, processes and procedures that contribute to the improvement of DQ, so it is in the interest of the scientific and business communities to identify the CSFs that influence data quality management.

This study identified the five most important CSFs influencing DQM: the definition of appropriate policies and standards, the input controls, the definition of a strategic plan for DQ, the organizational culture focused on DQ and the top management commitment and support. These results are in line with previous studies. References [36], [33] and [2] are unanimous regarding the importance of top management support, as well as the input controls [36].

The involvement of the users and the focus on their needs and requirements pointed by [33] and [2], as well as the acquisition of new skills and initial and continuing training were classified in position 12 and 13 in last round, so they were not considered by the experts of this study as very important for DQM. The most important CSF in this work "definition of appropriate policies and standards" is not among the top 10 CSFs identified by [36] and [2] and ranks in the ninth position in [33].

The study also identified the importance of data governance, defined as a set of essential actions to ensure data compliance with organizational strategies. This CSF was proposed by one of the experts and although it is not mentioned in the literature, it was placed in the sixth position, thus demonstrating the convergence of opinions regarding its importance. The subjects Data Governance and DQM, though distinct, are related, for DQM's pursuit of collaboration between business and IT implies cultural change. Such change can only be achieved with leadership, authority, control and resource allocation, which, in turn, implies data governance [17].

V. CONCLUSION

The present study used the Delphi method with Q-Sort technique to order the CSFs for the DQM identified in the literature review. The CSFs were evaluated and ordered by a panel of experts in the area.

Although there was no convergence of opinions, the study shows that DQM requires the implementation of a methodology, the definition of policies and the standardization of codes and rules, as well as the implementation of measures for data control and validation. The need for a strategic plan, the commitment to an organizational culture focused on DQ, and the top management commitment, control and support are also relevant, according to the panel of experts.

VI. LIMITATIONS AND FUTURE WORK

The study suffers from a few limitations concerning its implementation. First, due to the low degree of maturity of this subject in academic and professional communities, it was difficult to find experts willing to participate. Second, there

were limitations related to the time of the year in which the investigation was carried out, and the available period for the investigation. Finally the literature notes several limitations associated with both the FCS and the Delphi method with Q-Sort.

Davis [6] cited by Guynes & Vanecek [12] identified several issues related to the approach of the CSFs, specially the difficulty of human beings in constructing simplified models that reflect real-world situations.

There are other limitations related to the difficulties in using the method and in the ability of the researcher, Boynton & Zmud [5] indicate that the approach is feasible and useful with adequate training.

Regarding the application of the Delphi method there are some limitations like Santos & Amaral [25] mentioned, this method has been criticized for lack of guarantee of confidence in relation to the results obtained, being necessary, especially when using the Q-sort technique, to pay attention to the time spent collecting data and the effort that is requested from the expert panel, although these limitations can be reduced using a web tool.

Despite using one online tool, e-Delphi, it was considered unintuitive by some experts, requiring some effort to understand.

Some CSFs, due to their complexity, have some overlap regarding its definition, that perhaps have hampered the response of the experts, since a good understanding of the CSFs could lead to a faster consensus.

This study suffers from the limitations of the qualitative research methodology used. As a result, it only allows analytical generalization, generalization to the theory, and not generalization to the population [39]. On the other hand, it is an exploratory study about a poorly studied subject, whose objective was to understand the phenomenon and to explore the research question: What are the CSF for DQM?

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