# A multidimensional longitudinal meta-analysis of Quality Costing Research

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**Abstract**

*Purpose* –The present paper examines the longitudinal evolution of Quality Costs measurement, depicted in 99 real-data studies of the last thirty years. A meta-analysis of these articles is conducted, in order to highlight the evolution of the variables that have been used for the study of Quality Costing, in relation to the date of publication, business sector and geographical origin of each paper.

*Methodology* - The analysis of the cost components has been conducted with the use of Multiple Correspondence Analysis, which is a useful tool for the exploration of the interrelations among all elements, aiming at the identification of the dominant and most substantial tendencies in their structure.

*Findings* – Our findings suggest that the level of analysis of Quality Costs is related to the date of publication, the business sector and the origin of each research. Furthermore, it is pointed out that the most prominent Prevention Costs are related to suppliers' assurance, internal audit and new product's design and development.

Appraisal Costs are mostly defined by quality audits and procurement costs, while Failure Costs by defect/failure analysis, low quality losses, complaint investigation and concessions and warranty claims.

*Originality-Value*– The present paper is a longitudinal meta-analysis of Quality Cost papers that have been published in the last 30 years. It explores the evolution of research in Quality Costing, not only in relation to the variables in use, but also in terms of date of publication, business sector and geographical origin of the studies.

**Keywords**: Quality Costing, Cost Components, PAF Model, Multiple Correspondence Analysis, Meta-Analysis.

## 1. Introduction – Theoretical Background

Quality Costing was first introduced in Literature by Juran (1951) and Feigenbaum (1956), in an attempt to define both the costs that are related to the quality of products and also the costs that emerge when quality is not achieved. Numerous complimentary definitions have been proposed by researchers (Mitra, 2016; Yang, 2008; Schiffaeurova & Thomson, 2006; Campanella, 1999, Crosby, 1979). Ittner (1996) claims that 'quality costs are all expenditures associated with ensuring that products conform to specifications or with producing products that do not conform' (p. 114-115). Crosby (1979) interestingly suggests that 'Quality is conformance to requirements' and that 'the nonconformance detected is the absence of Quality'. Consequently, 'the Cost of Quality is the expense of nonconformance, the cost of doing things wrong' (p. 17-18).

The most widely used Quality Costing classification originates from Juran's original trade-off model, which emphasizes on the opposite behavior of prevention and appraisal costs on one hand, and the failure costs on the other (Trehan et al, 2015; Ayati and Schiffaeurova, 2014; Juran and Gryna, 1988; 1993). It categorizes costs under three major categories, Prevention-Appraisal (conformance costs) and Failure costs (non-conformance costs). Failure costs are further analyzed into Internal and External Failure costs. Under the 'Prevention Costs' category, the costs are associated with quality planning and development expenses, quality training, supplier assurance etc. 'Appraisal Costs' include, among others, the costs surrounding the inspection and testing of incoming parts and materials, sampling and laboratory analysis and production quality audits. 'Internal Failure Costs' are basically related to the re-inspection and re-testing of materials, parts and components that fail to conform to quality requirements, while the 'External Failure Costs' mainly investigate the cost of

dealing with returned defective products or components and the costs incurred as a result of a loss of customer goodwill or loss of sales.

Although a number of alternative views, additions and criticisms on Cost of Quality theory have been suggested in literature (Plewa et al, 2016; Kerfai et al, 2016; Freiesleben, 2004; Juran and Gryna, 1988; 1993) since the appearance of the original model, the above cost categorization in Prevention-Appraisal and Failure Costs seems quite clear. However, the component costs that can be included in each category are numerous. Furthermore, it can rely upon the objectivity of the researcher, whether some costs will be 'classified' under the one or the other category. Consequently, the main objectives of this paper are:

- to depict the quality costs that have been measured in 99 international quality costing research papers. It is an attempt to describe which cost components have been used the most and under which cost category they are reported in the papers.
- to point out and analytically present specific demographic characteristics. It would be interesting to examine whether the level of analysis of Quality Costs is dependent upon a) the date of publication of each paper, which emphasizes the longitudinal evolution of quality cost analysis, b) the business sector and c) the country-continent where each research has taken place, in order to approach the role that different cultures may play in the process.
- to highlight, with the use of Multiple Correspondence Analysis, possible relationships between the demographic characteristics and the quality cost components. Since, to the knowledge of the authors, no similar analysis has previously taken place, we choose not to formulate any hypotheses in advance, but rather let the data "talk for themselves".

A detailed presentation of the 99 papers and their analysis can be found in the Appendix.

## 2. Research Methodology

Keyword searches were performed using the online Google Scholar, to identify articles published between 1985 and 2016, concerned with the topic of Quality Costing. The initial results were then sifted through, to identify articles specifically dealing with Quality Costing research, either in the form of field or individual case studies. These articles were obtained and read by the authors. Each of the articles was examined to ensure that its content was relevant to Quality Costing research. Only field and case studies with 'real' recorded research data were taken into consideration, excluding any theoretical or modelling/simulation papers, which provided either theoretical contributions or laboratory test results.

Literature suggests that there is some evidence that geographical, political, historical, and economic proximity play a role in the configuration of cultural values (Liñán, F. & Fernandez-Serrano, 2014) and that culture is not permanent, even though it changes only slowly, over long periods of time (Mcgrath et al. 1992). The research criteria that we chose to examine, therefore, are the date of publication, the geographical area and the business sector, since they seem to be connected with culture and the entrepreneurial activity, which jointly help characterize the level of economic development and quality management.

## 2.1 Date of Publication

Although the theoretical framework of Quality Costing has been formed since the 1950s by Juran (1951) and Feigenbaum (1956), it was not earlier than 1980 that it started to attract intense attention by the scientific community. Rarely have scientists conducted relevant field research before, basically due to the limited knowledge of Quality Costing among practitioners and managers. The seminal work of Crosby (1979) has been one of the first attempts to bridge the gap between theory and practice and show the world of business how Quality Costing can bring about positive results. Our research, therefore, focuses on a 30-year period and on papers that have been published from year 1985 until year 2016. This period has been separated into 3 decades (Y1: 1985-1995, Y2: 1996-2005, Y3: 2006-2016), according to Table 1.

**Table 1: Date of Publication**

| VARIABLES | Dates of publication | no. of research papers |
|---|---|---|
| Y1 | 1985-1995 | 8 papers |
| Y2 | 1996-2005 | 32 papers |
| Y3 | 2006-2016 | 59 papers |
| | **TOTAL** | **99 papers** |

It is interesting to note that the number of published papers increases, as time proceeds. The distribution of papers highlights the increasing emphasis that the scientific community places on Quality Costing throughout the three decades. Although the use of the Internet and of digital data has almost been nonexistent before 1995, which would in part justify the very limited number of papers in that period, there was an undeniable 'burst' of relevant research in the second half of the tricennial. The date of publication is one of the demographic variables that were taken

into consideration in the present review, in order to examine its possible interrelations with specific cost of quality components in the papers under research.

## 2.2 Business Sector

The business sector of companies has proved to be relevant to the extent of Quality Costing implementation (Trigueros Pina and Selles, 2008; Rapley et al, 1999). It is for this reason that we focused on the business sector of the companies that have been analyzed in the published surveys/case studies. Table 2 shows the distribution of studies in business sectors. It is obvious that the majority of surveys have taken place in the manufacturing sector by a percentage of 63%, while construction and food industry is less frequent (16% and 10% respectively). The Business sector has also been used as a variable in our research, in order to highlight its relationship with specific quality cost components

**Table 2: Distribution of papers in Business sectors**

| VARIABLES | Sector | no. of papers |
|---|---|---|
| S1 | MANUFACTURING[a] | 63 |
| S2 | CONSTRUCTION | 16 |
| S3 | FOOD | 10 |
| S4 | OTHER[b] | 10 |
| | **TOTAL** | **99** |

[a] **MANUFACTURING** includes: footwear company, electrical parts and appliances, automobile companies, auto parts, etc.

[b] **OTHER** includes: medical and pharmaceutical companies, telecommunications, flower wholesale, water laboratory etc.

## 2.3 Geographical characteristics

The geographical area was also included in the analysis of the 99 papers. The literature review further highlighted an interesting distribution in relation to the country where each survey/case study has taken place. Tables 3,4,5,6,7 present the most 'popular' countries among the papers of our sample, with UK being the most energetic in the field, covering 16% of the published papers.

**Table 3: Asia**

| ASIA | no. of papers |
|---|---|
| India | 11 |
| Turkey | 7 |
| Iran | 4 |
| Malaysia | 4 |
| Japan | 6 |
| Thailand | 4 |
| China | 2 |
| Hong Kong | 2 |
| Pakistan | 2 |
| Bahrein | 1 |
| Dubai | 1 |
| Israel | 2 |
| South -East Asia* | 1 |
| **TOTAL** | **47** |

* country not clearly identified

**Table 4: Europe**

| EUROPE | no. of papers |
|---|---|
| UK | 16 |
| Slovakia | 2 |
| Spain | 2 |
| Sweden | 2 |
| Denmark | 1 |
| Europe* | 1 |
| Germany | 1 |
| Greece | 1 |
| Italy | 1 |
| Lithuania | 1 |
| Portugal | 1 |
| Romania | 1 |
| Serbia | 1 |
| **TOTAL** | **31** |

* country not clearly identified

**Table 5: Southern and Northern America**

| AMERICA | no. of papers |
|---|---|
| US | 7 |
| Canada | 1 |
| North America* | 1 |
| Argentina | 1 |
| Brazil | 1 |
| Latin America* | 1 |
| **TOTAL** | **12** |

**Table 6: Africa**

| AFRICA | no. of papers |
|---|---|
| Morocco | 1 |
| Libya | 1 |
| Sub-Saharan Africa* | 1 |
| Tunisia | 1 |
| Zimbabwe | 1 |
| **TOTAL** | **5** |

* country not clearly identified

**Table 7: Australia**

| AUSTRALIA | no. of papers |
|---|---|
| AUSTRALIA | 4 |

Although the above analysis provides interesting data about the number of surveys that have taken place in each country, we chose to form smaller groups for our research, for brevity purposes. The geographical variables that have been used in the analysis are presented in Table 8, where the various countries have been grouped under Continents. It is obvious that Asia is the most 'productive' Continent in terms of published papers, as the majority of surveys/case studies (47%) have taken place in its area.

**Table 8: Geographical variables**

| VARIABLES | Continents | no. of papers |
|---|---|---|
| C1 | Asia | 47 |
| C2 | Europe | 31 |
| C3 | America | 12 |
| C4 | Africa | 5 |
| C5 | Australia | 4 |
| | **TOTAL** | **99** |

## 2.4 Quality Cost Indices

The Total Quality Cost Indices (QCIs) are the typical ratios of total quality costs as a percentage of sales revenue, value added, direct material/labour costs etc. (Malik et al, 2016; Mitra, 2016; Djekic et al, 2014; Lupin et al, 2010; Shah & Mandal, 1999; Zugarramurdi, 1995; BS6143-2, 1990) and are defined as follows:

$$\frac{TOTAL\ QUALITY\ COST\ X\ 100}{BASIS}$$

According to our data, 'sales revenue' is the most common basis in the calculation of QCIs among the surveys/case studies under research, followed by 'production cost' and 'turnover'. However, almost half of the papers do not report any Quality Cost Index or do not specifically mention which basis is used (Table 9).

**Table 9: Bases of Quality Cost Indices**

| Quality cost bases | frequency |
|---|---|
| sales revenue | 23 |
| production cost | 12 |
| turnover | 8 |
| value | 7 |
| material/labour | 4 |
| profit | 2 |
| not identified | 47 |
| | **103 *** |

* The sum (103) exceeds the number of papers under research (96), as some studies use more than one basis in their analysis.

## 2.5 Cost components

Out of the 99 papers that were reviewed, only 45% proceeded to a detailed analysis of the cost components that were included in the reported Total Quality Costs. Almost 37% of the studies did not mention any analytic costs, but rather provided a general sum of each cost category (Prevention-Appraisal-Failures). A further 17% focused only on poor quality (Failure) and did not expand on details concerning Prevention and Appraisal Costs (Table 10).

**Table 10: Analysis into cost components**

| Cost components | no. of papers |
|---|---|
| analysis into quality costs components | 45 |
| no analysis into cost components | 37 |
| emphasis on poor quality | 17 |
| **TOTAL** | **99** |

Among the 45 papers that conducted an analysis into quality cost components, it is interesting to note that the majority of them was written during the third decade (years 2006-2016). Table 11 demonstrates the increasing focus on the analysis of the general 4 quality cost categories into cost components, as time proceeds.

**Table 11: Analysis into cost components in relation to the date of publication**

| VARIABLES | Dates of publication | no. of papers |
|---|---|---|
| Y1 | 1985-1995 | 3 papers |
| Y2 | 1996-2005 | 12 papers |
| Y3 | 2006-2016 | 30 papers |
| | **TOTAL** | **45 papers** |

Out of the 45 papers, the most commonly used cost components were first gathered, in an attempt to investigate the essence of Quality Costs and better depict

the *individual* components of each quality cost category. As it is clearly shown in Table 12, the most commonly used Prevention Costs are 'quality training', 'equipment preventive maintenance' and 'quality planning and development'. Appraisal Costs are mainly analyzed in 'inspection costs', 'testing costs' and 'equipment calibration and testing'. 'Total rework' and 'total scrap cost' mostly characterize the Internal Failure Costs category, while 'cost of returns' and 'complaint investigation' are the most commonly used costs for External Failure Costs.

**Table 12: More commonly used cost components**

| | **cost components** | **frequency** | **% of 45* papers** |
|---|---|---|---|
| Prevention costs | quality training | 32 | 71% |
| | preventive mainentance | 28 | 62% |
| | quality planning and development | 26 | 58% |
| | supplier assurance | 19 | 42% |
| | products's design and development | 17 | 38% |
| Appraisal costs | inspection costs | 30 | 66% |
| | testing costs | 27 | 60% |
| | calibration and testing | 26 | 58% |
| | receipt and control of incoming material | 24 | 53% |
| | sampling and laboratory analysis | 19 | 42% |
| Internal Failure costs | total rework | 29 | 64% |
| | total scrap cost | 25 | 56% |
| | re-testing and re-inspection | 20 | 44% |
| | defect/failure analysis | 19 | 42% |
| | repair cost | 18 | 40% |
| External Failure Costs | cost of returns | 24 | 53% |
| | complaint investigation | 19 | 42% |
| | warranty adgustments | 15 | 33% |
| | penalties/liabilities claim | 15 | 33% |
| | repair/replacement cost | 15 | 33% |

* The percentage is calculated for the 45 papers that conduct an analytic research of cost components. The sum of percentages exceeds 100, as each study analyses multiple costs.

Given the fact that the total number of cost components that were originally collected was excessive (58 cost components -see Appendix), we chose to create the following groups as shown in Tables 13,14,15,16. This way, 5 groups of cost components were built for the categories of Prevention, Appraisal and External Failure Costs respectively, while 6 groups of cost components were built for the Internal Failure Costs category.

**Table 13: Prevention Costs Category**

| | PREVENTION COSTS | |
|---|---|---|
| | COST GROUPS | COST COMPONENTS |
| P1 | QUALITY PLANNING & DEVELOPMENT | site staff salaries |
| | | quality training |
| | | quality planning and development expenses |
| | | marketing |
| P2 | PROCESS QUALITY | preventive mainentance |
| | | purchasing prevention costs |
| | | ISO/HACCP related expenses |
| | | operations prevention costs |
| | | hygiene and sanitation |
| P3 | INTERNAL AUDIT | analysis and reporting of quality data |
| | | internal audit |
| P4 | NEW PRODUCT'S DESIGN & DEVELOPMENT | new product's quality |
| | | new product's design and development |
| | | determining customer demands |
| P5 | SUPPLIER ASSURANCE | suppplier assurance |

**Table 14: Appraisal Costs Category**

| | APPRAISAL COSTS | |
|---|---|---|
| | COST GROUPS | COST COMPONENTS |
| A1 | INSPECTION & TESTING | inspection costs |
| | | testing costs |
| | | equipment calibration and testing |
| | | quality control staff's salaries |
| | | training of the quality control staff |
| A2 | PROCUREMENT COSTS | receipt and control of incoming material |
| | | stock evaluation |
| | | purchasing appraisal costs |
| | | operations appraisal costs |
| A3 | QUALITY AUDITS | sampling and laboratory analysis |
| | | production quality audits |
| | | analysis and reporting of inspection results |
| A4 | QUALITY AUDITS OF SUPPLIERS | quality audits of suppliers |
| A5 | REGULATORY APPROVALS | regulatory approvals |

**Table 15: Internal Failure Costs Category**

| | INTERNAL FAILURE COSTS | |
|---|---|---|
| | COST GROUPS | COST COMPONENTS |
| IF1 | RE-TESTING & REPAIR | re-testing and re-inspection |
| | | total rework |
| | | repair cost |
| IF2 | SYSTEM FAILURE | spares and consumables |
| | | purchasing failure costs |
| | | operations/system failure |
| IF3 | DEFECT/FAILURE ANALYSIS | defect/failure analysis |
| IF4 | PRODUCTION LOSS | production design failure cost |
| | | production loss |
| | | total scrap cost |
| | | uncotrollable material loss |
| | | low labour productivity |
| | | non productive/idle time |
| | | rescheduling/overtime |
| IF5 | SUPPLIER FAULTS | suppplier faults |
| IF6 | DEVIATIONS & CONCESSIONS | deviations |
| | | consessional approvals |

**Table 16: External Failure Costs Category**

| | EXTERNAL FAILURE COSTS | |
|---|---|---|
| | COST GROUPS | COST COMPONENTS |
| EF1 | REPAIR & REPLACEMENT | cost of returns |
| | | repair and replacement costs |
| | | damaged products |
| | | external services (travelling expenses) |
| | | shipping costs of returned products |
| EF2 | LOW QUALITY LOSSES | discounts due to low quality |
| | | loss of customer goodwill |
| | | loss of sales |
| EF3 | COMPLAINT INVESTIGATION | complaint investigation |
| EF4 | CONCESSIONS & WARRANTY CLAIMS | warranty adjustment |
| | | penalties/liability claims |
| EF5 | IMPROVEMENTS | adjustments and improvements to meet quality standards |

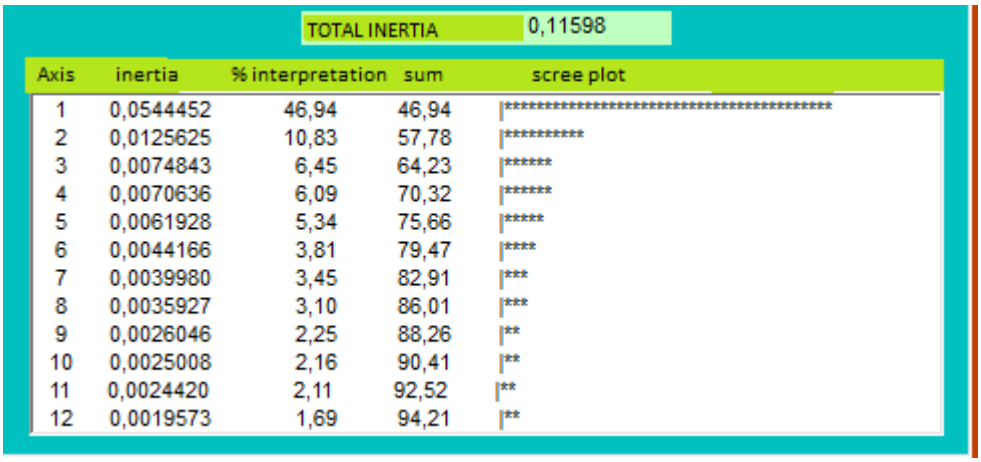
## 3. Analysis of Data

Multiple Correspondence Analysis is an exploratory methodology of the Data Analysis field, which constitutes a holistic approach of the phenomenon under research and explores the interaction and interrelations among all nominal data, resulting in the identification of the dominant tendencies in their structure. It assumes no distribution for the data and is graphically putting forward possible trends that exist in the data, treating rows and columns equivalently (Moschidis 2015; Moschidis, 2009; Greenacre, 2007). Furthermore, it is also used to highlight potential issues and questions that have not been previously identified.

A basic characteristic of the method is the visualization of the results, which provides the optimum visualization in matrixes of multiple dimensions, i.e. multiple rows and multiple columns. This multidimensional character of the data lies in the

core of these methods, and constitutes their competitive advantage against the methods of Classical Statistics. Through the available data, Multiple Correspondence Analysis was mainly used in the present research as the most suitable tool for highlighting correspondences between the demographic variables of the papers (date of publication, business sector, geographical area) and the quality cost components that were analyzed in each survey. The data was transformed into a BURT matrix, which is the symmetric matrix of all two-way cross-tabulations between all categorical variables.

According to Figure 1, it becomes obvious that by analyzing the three factorial axes we have a 64.23 percent interpretation of the total inertia, while only the first axis covers 46.94 percent of the available information.



TOTAL INERTIA 0,11598

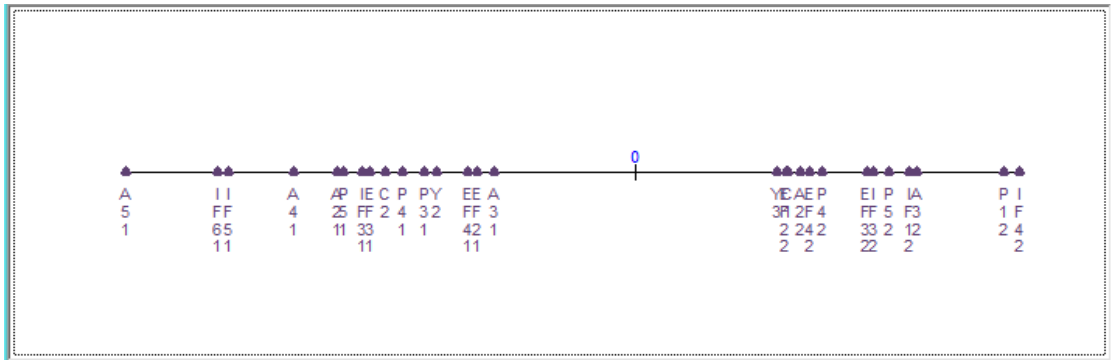
| Axis | inertia | % interpretation | sum | scree plot |
|---|---|---|---|---|
| 1 | 0,0544452 | 46,94 | 46,94 | \|********** |
| 2 | 0,0125625 | 10,83 | 57,78 | \|********** |
| 3 | 0,0074843 | 6,45 | 64,23 | \|****** |
| 4 | 0,0070636 | 6,09 | 70,32 | \|****** |
| 5 | 0,0061928 | 5,34 | 75,66 | \|***** |
| 6 | 0,0044166 | 3,81 | 79,47 | \|**** |
| 7 | 0,0039980 | 3,45 | 82,91 | \|*** |
| 8 | 0,0035927 | 3,10 | 86,01 | \|*** |
| 9 | 0,0026046 | 2,25 | 88,26 | \|** |
| 10 | 0,0025008 | 2,16 | 90,41 | \|** |
| 11 | 0,0024420 | 2,11 | 92,52 | \|** |
| 12 | 0,0019573 | 1,69 | 94,21 | \|** |

**Figure 1 : Eigenvalues and Intertia**

After the use of Multiple Correspondence Analysis, we took into account the variables that had the highest contribution indicator (CTR). The points with high CTR emphasize the importance of each variable through the axes construction process. Axis 1 presents the dominant tendency of the data.

### 3.1. Axis 1 – The first dominant tendency

From the analysis of the first dominant tendency, which is described by Axis 1 (Fig.2), it can be concluded that there is strong diversification among the quality cost components. On the one hand, there are papers that have been written between 1985 and 1995 (Y1) and focus on Appraisal and Internal Failure Costs. In particular, the Appraisal Costs that stand out in this period are 'regulatory approvals' (A51) and 'quality audits of suppliers' (A41), while the most dominant Internal Failure Costs are 'deviations and concessions' (IF61) and 'supplier faults' (IF51).




| | | | |
|---|---|---|---|
| Obvious | P12 | A51 | IF42 |
| Hidden | C5 | Y1 | A12 |

**Figure 2: First dominant tendency – Axis 1**

On the other hand, there are studies that have been conducted between 1996-2005 (Y2) in Europe (C2) and seem to highlight a wider range of quality cost components. All P-A-F costs are reported and analysed, with an emphasis on 'supplier assurance' (P51), new product's design and development (P41) and 'internal audit' (P31), as far as Prevention Costs are concerned. Appraisal costs are characterised mainly by 'procurement costs' (A21) and 'quality audits' (A31), while 'defect/failure analysis' (IF31) covers Internal Failure Costs. Finally, 'low quality losses' (EF21),

‘complaint investigation (EF31) and ‘concessions and warranty claims’ (EF41) are the most prominent Failure Costs.

Finally, there are papers limited to years 2006-2016 (Y3), which have been conducted in Australia (C5). These are quality costs components that have NOT been monitored or reported in this period. As far as Prevention Costs are concerned, it seems that not much emphasis has been put on ‘new product’s design and development’ (P42) and supplier assurance (P52). Equally, Appraisal Costs have not been analysed in terms of ‘inspection and testing’ (A12), ‘quality audits (A32) and ‘procurement costs (A22). Finally, Failure Costs did not include ‘re-testing and repair’ (IF12), ‘defect/failure analysis’ (IF32), ‘production loss’ (IF42), as well as ‘low quality losses’ (EF22) and ‘complaint investigation’ (EF32).

### 3.2 Axis 2 – The second dominant tendency

The analysis of the second dominant tendency, depicted by Axis 2 (Fig. 3), presents two further characteristics that correspond with certain quality cost components. Business sector ‘Construction’ (S2) and continent ‘Africa’ (C4) characterise a group of papers that do NOT focus on ‘process quality’ (P22) and on ‘system failure’ (IF22). The rest quality cost components that appear on this Axis have a low CTR index, which means that their contribution to the construction of Axis 2 is not as intense. It is for this reason that they are not taken into consideration at this stage.

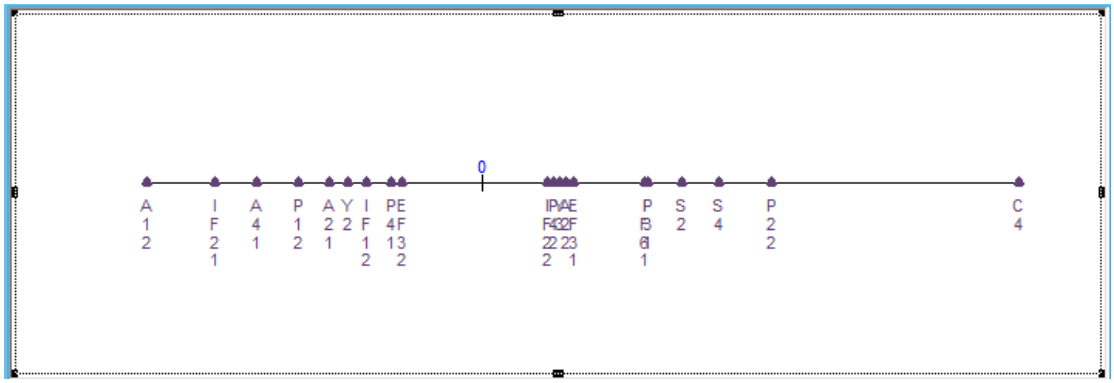



**Figure 3: Second dominant tendency – Axis 2**

### 3.3. Axis 3 – The third dominant tendency

From the analysis of the third dominant tendency, graphically displayed by Axis 3 (Fig.4), it can be deduced that there is a strong diversification among quality costs, especially between papers written in 'America' (C3) on the 'Food' sector (S3), which highlight only one External Failure Cost 'repair and replacement' (EF11) and papers that belong to the 'Manufacturing sector (S1) (which includes a footwear company, electrical parts and appliances, automobile companies, auto parts, etc.), as well as to the 'Other' sector (S4) (which includes medical and pharmaceutical companies, telecommunications, flower wholesale, water laboratory etc). These papers do NOT report 'repair and replacement' (EF12) External Failure Costs. The above-mentioned comment on the rest quality cost component applies in this tendency as well. Since they have a low CTR index, their contribution to the construction of Axis 3 is not as intense, so they are not taken into consideration at this stage.

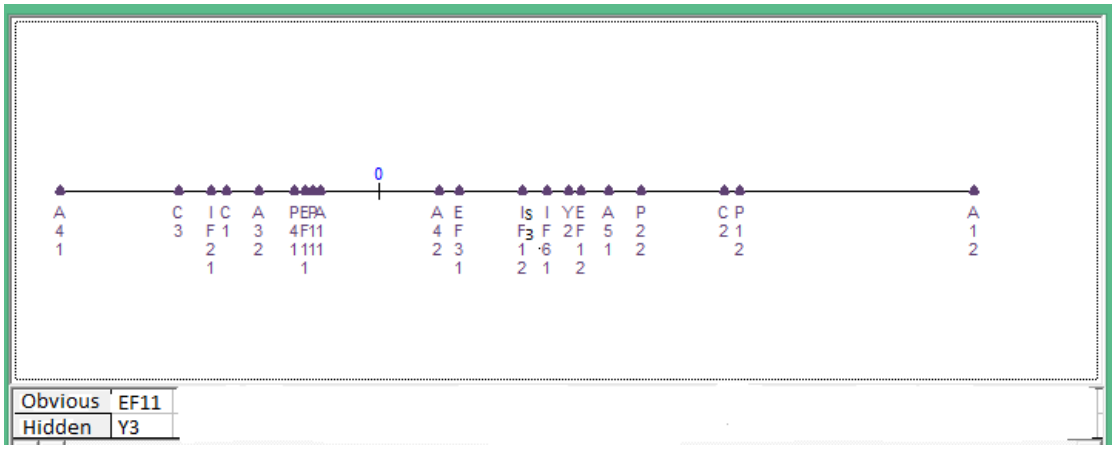



**Figure 4: Third dominant tendency – Axis 3**

## 4. Conclusions

The main objectives of the present paper are the longitudinal depiction of quality costs from 1985 until year 2016 and the identification of the most prominent cost categories and cost components, in relation to the date of publication of each study. Equally, the role that the business sector and the origin (country-continent) of each paper is also of great interest, as well as any possible relationships between the above demographic characteristics and the quality cost components.

The analysis produces the following results:

The descriptive statistics show that, out of the 99 research papers that have been analyzed, only 45 do actually proceed to a detailed measurement and reporting of the various cost components. 37 papers deal with Quality Costing on a general level, by measuring Total Quality Costs as a sum of Prevention-Appraisal and Failure Costs, with no further analysis of cost components. Finally, 17 papers focus on the measurement of Poor Quality, with little or no reference to conformance costs. The majority of studies took place in manufacturing environments, followed by construction and food companies. Although UK (Europe) is the country with the most

published papers on Quality Costs, Asia exceeds the rest of the continents by almost 10%. Various bases have been used among the studies, in order to calculate the Total Quality Cost ratio. Sales revenue, along with production cost, are the most typical bases of Total Quality Cost Index. However, almost half of the papers do not report any Quality Cost Index or do not specifically mention which basis is used.

As far the publication date is concerned, the first decade 1985-1995 emphasizes on Appraisal and Internal Failure Costs. In particular, the most prominent groups of Appraisal Costs of years 1985-1995 are quality audits of suppliers and regulatory approvals, while the most dominant groups of Internal Failure Costs are deviations and concessions and supplier faults. During the next decade (1996-2005) Quality Costs of all cost categories are monitored. Prevention Costs are related to suppliers' assurance, internal audit and new product's design and development. Appraisal Costs are mostly defined by quality audits and procurement costs, while Failure Costs are characterized by defect/failure analysis, low quality losses, complaint investigation and concessions and warranty claims. Table 17 depicts the most prominent cost component groups in terms of publication date, as a result of the above analysis.

**Table 17: Most prominent groups of cost components**

| MOST DOMINANT COST COMPONENT GROUPS | | |
|---|---|---|
| DATE OF PUBLICATION | COST CATEGORIES | GROUPS OF COMPONENTS |
| 1985-1995 | Appraisal Costs | quality audits of suppliers<br>regulatory approvals |
| | Internal Failure Costs | supplier faults<br>deviations and concessions |
| 1996-2005 | Prevention Costs | internal audit<br>new product's design and development<br>suppliers' assurance |
| | Appraisal Costs | procurement costs<br>quality audit |
| | Internal Failure Costs | defect/failure analysis |
| | External Failure Costs | low quality losses<br>complaint investigation<br>concessions and warranty claims |
| 2006-2016 | Prevention Costs | quality planning and development<br>suppliers' assurance<br>new product's design and development |
| | Appraisal Costs | inspection and testing<br>quality audit<br>procurement costs |
| | Internal Failure Costs | repair and retesting<br>production loss<br>defect/failure analysis |
| | External Failure Costs | complaint investigation<br>low quality losses |

* Grouping of cost components according to Tables 13,14,15,16.

The multidimensional longitudinal analysis confirmed that the level of analysis of quality costs is dependent upon the date of publication of each paper. In particular, it seems that through the 30 years, there has been a change of focus, as far as the use of quality cost elements is concerned. The date of publication determines to a great extent the depth of analysis of the quality cost components. Results show that the earlier a study has been conducted, the simpler the analysis of quality costs. It is

evident that in the first decade under research (1985-1995) only 8 relevant papers have been published, with an emphasis mainly on Appraisal and Internal Failure Costs. During the second decade (1996-2005), 32 research studies have been conducted, aiming at a wider range of costs and covering multiple aspects in more detail, such as failure/poor quality costs, external costs etc. Finally, the last decade (1996-2016) proved to be the most productive, as 59 research papers analyzed not only the quality costs in general, but also more specific issues in the area of maintenance costs, warranty claims, etc.

In terms of the geographical area (continent), it is concluded that it also plays an important role in the analysis of quality costs. There is an extended analysis of all quality cost categories (Prevention-Appraisal-Failure) in the studies published in Europe from 1996-2005, which coincides with the economic evolution of Europe in the 90s. It is obvious that there is an emphasis on Quality Costing as time proceeds, resulting from the realization of managers and practitioners that it may lead to a reduction of total costs and to continuous improvement. Africa and America also have a strong presence in the analysis. The case of Australia is, however, striking: although some of the costs that constitute the most dominant trend throughout the second decade (1996-2005) are measured and analyzed in detail in Europe, results show that they are *the least* monitored through the next decade (2006-1016) in Australia. Almost one for one, these costs seem NOT to be reported among the studies in Australia, which may denote a shift of quality cost focus in that part of the world.

Finally, in relation to the business sector, there seems to be a connection between business sector and quality costs analysis. Construction, Manufacturing, Food and other sectors all appear to have a direct relationship to the extent of quality cost analysis. What is interesting to note is the fact that focus is placed only on

Prevention and Failure Costs, in contrast to Appraisal costs, which do not seem connected with the 'business sector' variable.

## 5. Limitations, Practical Influence and Future Research

The above findings are in accordance with the basic premises of Quality Cost theory. Firstly, theory proposes that the strategy for using quality costs is mainly to 'attack' failure costs and to invest in the right prevention activities. Furthermore, appraisal costs are to be reduced and prevention efforts to be continuously evaluated and redirected (Campanella, 1999). Our findings support that from 1996 onwards, emphasis has been placed by researchers on the proper analysis of cause and effect. The role of failure costs has been examined, in an attempt to identify root causes which can be permanently eliminated. Moreover, it has been realized that the later a failure is discovered, the more expensive it is to correct. Consequently, it is observed that extensive examination of prevention and appraisal costs is conducted among the analyzed papers.

Furthermore, our results affirm that many companies are driven by the primary objectives of Quality Cost theory into evaluating quality costs (Juran and Gryna, 1988). Objectives such as 1) quantification of the size of the problem, 2) identification of major opportunities for cost reduction, for reducing customers dissatisfaction and other associated threats, 3) expansion of budgetary and cost controls and 4) stimulation of improvement through publication of cost data (Juran and Gryna, 1988, p. 4.3), seem to have made it necessary among most companies to monitor and measure Quality costs in great detail. Although companies may not be formally aware of the theoretical aspects of Quality Cost theory, it can be deduced from the studies

depicted in the present paper, that experience and effective reflexes have lead them towards the implementation of quality programs, especially since the last decade of the twentieth century.

Given the fact that Quality Costing has been a popular topic of research since the 1980s, the present analysis focuses on internationally published research papers from 1985 until 2016 from all around the world. The collected studies, which included only field and/or case studies (and not theoretical contributions or modelling/simulation articles), claim that the use of Quality Costing may lead to cost reductions and to continuous improvement. However, only 45 out of 99 papers present detailed analysis of quality cost components, while 54 papers either focused only on poor quality or did not mention any analytic costs, but rather provided a general sum of each cost category (Prevention-Appraisal-Failures). This observation leads to the assumption that the process of collecting Quality Costs in practical situations can be, apart from extremely interesting and unpredictable, also quite uncertain and complicated. Not every organizational environment is appropriate for a detailed Quality Cost analysis, since the identification and categorization of cost components can be quite an expensive, subjective and impractical process. This limitation also applies to External Failure Costs in particular, since they are experienced by both the company and the customer, with all the potential damaging implications. External failure costs are also the most costly to correct. 'The cost of finding a faulty partτ is likely to far outweigh the cost of the part itself' (Dale and Plunkett, 1999).

Despite the above limitations, the existence of a considerable amount of literature on Quality Costs and their practical implementation in companies all over the world, means that certain obstacles may and can be overcome. Opportunities are

provided, therefore, for further research on the costs presented in Table 17, which protrude in the present analysis. Since these costs stand out among the studies that were analyzed in the last 30 years, it can be assumed that they provide reliable and accepted results, which confirm the basic premise of Quality Costing.

The present work constitutes, moreover, a useful guide for quality-oriented companies, who wish to create a quality costing program. In an attempt to facilitate the quality process and reduce overall costs, the present paper can serve as reference for companies, since it highlights the most dominant cost elements and cost categories. The most commonly used quality cost components can be combined with the different business sectors or geographical areas and provide a flexible framework in the hands of the companies (see Appendix). Depending on the special traits of each interested company, its individual characteristics and needs, its business sector or origin, the framework can serve as an effective tool towards the monitoring and measuring of the most crucial cost categories, cost components and quality cost bases, which may achieve higher quality level or reduction of quality costs.

Furthermore, it would be interesting if the present research could be expanded with a more detailed analysis of the geographical and sector variables. It is suggested that a specific examination of the way that quality cost components interact among *countries in the same continent* would provide useful information. Towards the same direction would be a detailed analysis of the interrelations of quality costs among *companies in the same business sector*. The field of Quality Costs never stops to provide new interesting aspects, waiting to be further explored.

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