analysis, the design / development, the licensing, the manufacture (i.e. the construction, properly speaking) and the after-selling services. Finally, such procedures are often misunderstood or ignored, because of the great amount of information needed to accomplish Quality Control without a computer-aided support. In fact, we admit that the use of computerised tools will help an easier application of Quality Procedures.

As far as construction is concerned, we observe few evolutions in Quality Evaluation procedures, particularly in Portugal, although the Quality Evaluation is important in the whole construction process: the best design looses its values if poorly constructed. That is why in our opinion, we should implement Quality Evaluation Procedures not only at the design stage, but also at least during the construction stage, in order to reach the goals of a Quality Policy.

This paper presents a computer-aided methodology for Quality Management and Evaluation during building's construction, based on the follow up of several building works. Since the use of this kind of methodology, in our opinion, might be more efficient if it is applied by the building's owner (whether public or private), the present work's scope is restricted to the owner's point of.

## 2. The Quality Evaluation and Management, during the Construction Stage

Apart from quality's organisation and control aspects, like Control's System, Nature, Type, Placement and Mode (we consider this one very useful since it allows statistical quality control), we also emphasise the use of Inspection and Test Plans (I.T.P.), to control construction elements. Their development and application in the construction industry have shown some improvement lately; their implementation should be properly planed, within a Quality Plan that must be developed at the beginning of each and every construction.

On the other hand, as a result of the present study, we developed a Quality Indicators Board (Q.I.B.), which expresses and values several aspects indirectly associated with Construction Quality, each one being represented by an indicator. The indicators result from specific ratios, which were established according to a quality control to be performed from outside the production team; so, they were designed as a quality management tool in the owner's perspective. In opposition to an inner control (internal and external) performed inside the production by the contractor's personnel, an outer quality control can be undertaken by a management team, currently hired by the owner, which may also be responsible for the works surveillance and management.

Therefore, the systematic use of this Quality Indicators Board could be associated with a set of actions oriented to the development of a housing policy, since the adoption of quality evaluation rules will allow such policy to be more efficient.

### 2.1. The Evaluation's Points of View

The Construction Quality Evaluation results from the integration of two points of view, which value two distinctive aspects of quality control, as depicted in Figure 1.

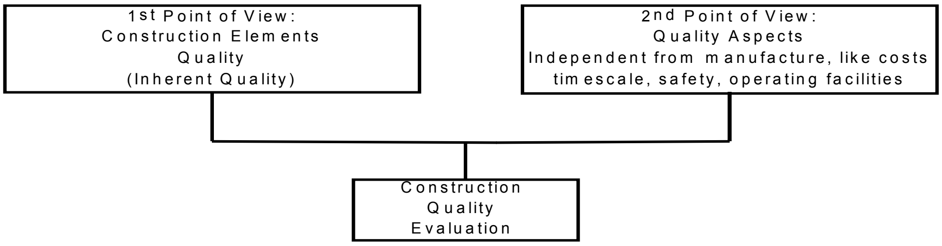



Fig. 1 – The two distinctive quality control areas integrating the construction quality evaluation

The first point of view values the construction's elements inherent quality, meaning the quality of the construction elements manufacture. The second one values the important aspects indirectly associated with the construction's final quality, as indicated earlier: these aspects are related to costs, time-scale, safety, equipment operating facility (having in mind the use of the product, that is the after-selling stage), etc.

### 2.2. The Structure of the Construction Quality Evaluation System

The inherent quality can be valued by an individual evaluation of elementary parts of the construction, based on the quality control of the work, which enables an appreciation of their quality in a quantitative way. In order to establish what elements to appraise during building process, we use a Construction's Standard Elements List, which helps us to set up a Works Specific Elements List. The ones to control are chosen according to the Quality Management Level established for the building and according to the Elements Quality Control Level, of each specific element; this level also defines the weight of the elements. Thus, we propose to quantify, over the works, the Individual Rates (IRi) of some construction's elements, leading to the Elements Global Rate (E.G.R.), which results from the Individual Rates weighted mean.

The second point of view is a complementary quality evaluation, based upon the Quality Indicators Board (Q.I.B.). Having defined a weight for each indicator, we established an Indicators Global Rate (I.G.R.) which is given by the Indicators weighted mean.

The Element Individual Rate (Iri) result from its Frequency of Pathologies Occurrence (FPO), Pathology's Repercussion (PR) and the Elements Importance (EI) in a numerical scale (1 to 3) - the three parameters needed for the Elements Quality Control Level (EQCL). The FPO and the PR are in the Construction's Standard Elements List; the third one – EI results from the Requirements Importance (RqI) and the Economical Importance (EcI), as follows.

| **Elements Importance (EI)** | Economical Importance (EcI) | | |
|---|---|---|---|
| Requirements Importance (RqI) | 1 | 2 | 3 |
| 1 | 1 | 2 | 2 |
| 2 | 2 | 2 | 3 |
| 3 | 2 | 3 | 3 |

Procedures were implemented, in the Data-Base Application, to calculate EI (as a function of RqI and EcI) and the Elements Quality Control Level (EQCL):

$$\textbf{EQCL} = \begin{cases} 1, & \text{IF } 3 \le (FPO + PR + EI) < 5 \\ 2, & \text{IF } 5 \le (FPO + PR + EI) < 7 \\ 3, & \text{IF } 7 \le (FPO + PR + EI) \le 9 \end{cases}$$

The E.G.R. and the I.G.R. are to be calculated when suitable (at least once a month). These interim evaluations – with the data collected up until that moment – should be the guidelines that lead the **Quality Management** actions. During and at the end of the works, we evaluate the Construction Quality Rate (C.Q.R.), given by the following expression:

**CQR = EGR ∗ IGR**, in which the abbreviations are the ones above-mentioned.

The evaluation method of the Elements Global Rate, has the flow-sheet shown in Figure 2.

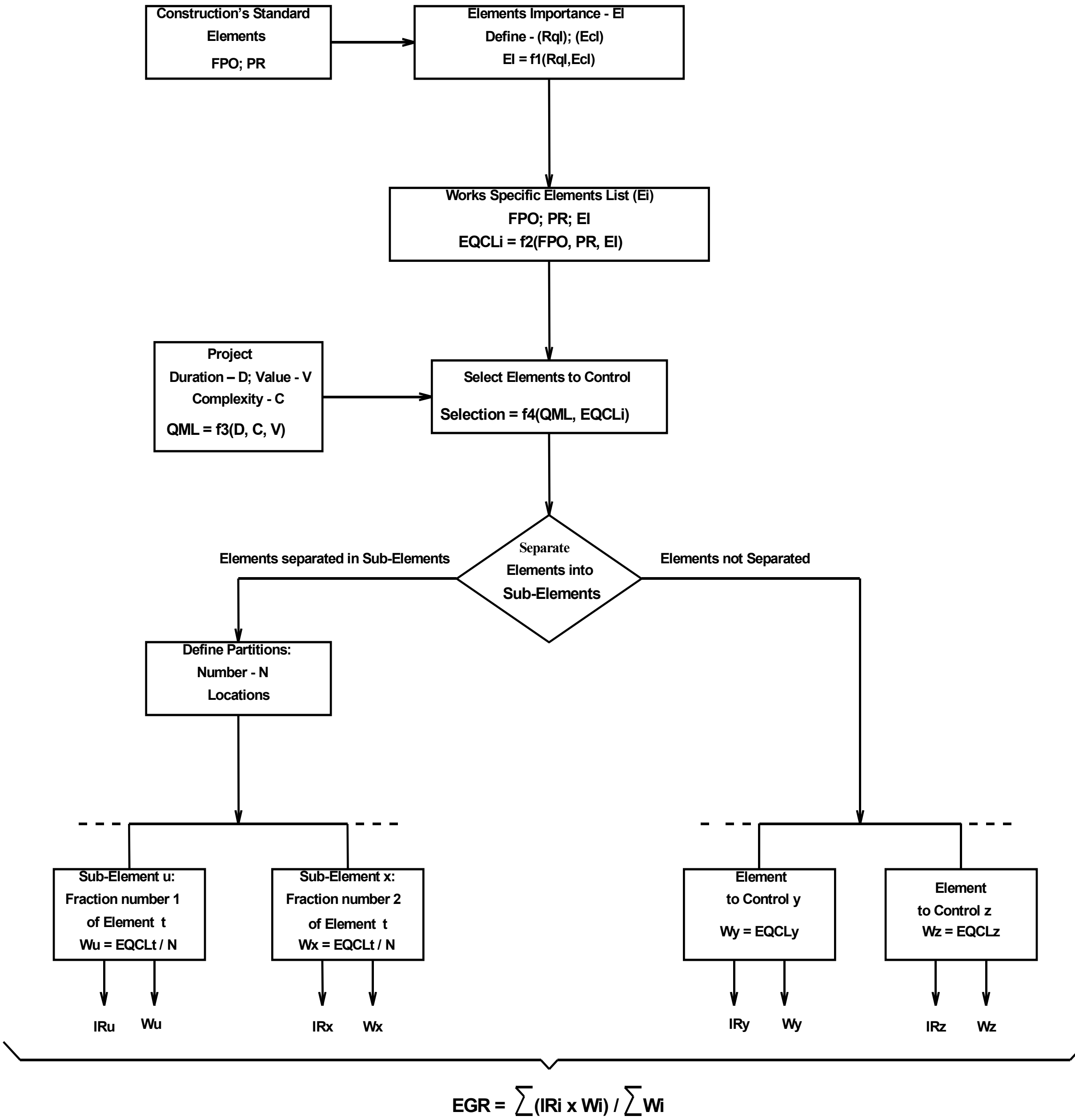



Fig. 3 – Elements Global Rate evaluation – Flow-sheet

## 2.3. The Quality Indicators Board (Q.I.B.)

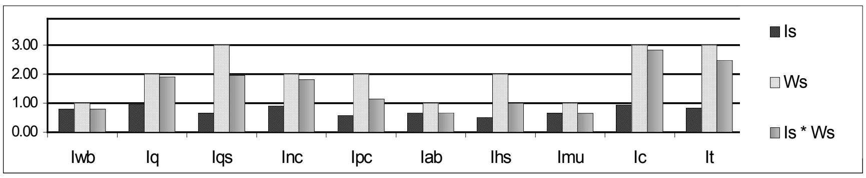
The Quality Indicators Board is shown in Table 1. It has 3 Initial Indicators, calculated at the beginning of the works and 7 Progress Indicators, which unfold along the works, being periodically evaluated (monthly, for example).

Table 1 – Quality Indicators Board (Q.I.B.); sample

| | | |
|---|---|---|
| | **QUALITY INDICATORS BOARD** | Page: 1/1 |
| | **Project :** | Mounth / Year Fev-97 |
| | **Owner:** | Number |
| | **Works Quality Management Level:** | Map ref.: QM02V01 |

| Nº | QUALITY INDICATORS - description | | Indicator's Parameter IPs | Indicator's Value Is | Weight Ws |
|---|---|---|---|---|---|
| 1 | **Inicial Indicators** | | | | |
| 1.1 | Winning Bid Indicator | 0.40 ≤ **Iwb ($/$)** ≤ 1.20 | 0.8 | 0.800 | **1** |
| 1.2 | Quantities Indicator | 0.30 ≤ **Iq (%)** ≤ 1.00 | 1.25 | 0.950 | **2** |
| 1.3 | Works Quality System Indicator | 0.30 ≤ **Iqs (degree)** ≤ 1.00 | 2 | 0.650 | **3** |
| 2 | **Progress Indicators** | | | | |
| 2.1 | Nonconformity Indicator | 0.10 ≤ **Inc (measureless)** ≤ 1.00 | 0.02 | 0.900 | **2** |
| 2.2 | Personnel In Carge Indicator | 0.20 ≤ **Ipc (men/leader)** ≤ 1.00 | 20.7 | 0.573 | **2** |
| 2.3 | Absenteeism Indicator | 0.10 ≤ **Iab (absents/not absents)** ≤ 1.00 | 0.043 | 0.667 | **1** |
| 2.4 | Health and Safety Indicator | 0.00 ≤ **Ihs (rec./mouth/worker;accident;type)** ≤ 1.00 | 0.042 | 0.500 | **2** |
| 2.5 | Maintenance / Usage Indicator | 0.20 ≤ **Imu (measureless)** ≤ 0.80 | 2.5 | 0.650 | **1** |
| 2.6 | Costs Indicator | 0.20 ≤ **Ic ($/$)** ≤ 1.00 | 1.065 | 0.940 | **3** |
| 2.7 | Time-scale Indicator | 0.20 ≤ **It (days/days)** ≤ 1.00 | 1.138 | 0.824 | **3** |
| INDICATORS GLOBAL RATE | | 0.20 ≤ **IGR** ≤ 1.00 | | **0.76** | **20** |

Indicators Graphic




| | |
|---|---|
| Issued By: | At: 20-04-1998 |

We established the QIB Indicators to use accumulated values, each indicator reflecting the aspect it traces, until the time the evaluation is being held. At the QIB bottom, a graphic of the Indicators, the Weights and the product - Is*Ws - helps a quick approach to the Board.

## 2.4. Quality Indicators calculation

The QIB Indicators result from the Indicators' Parameters (IPs values). We developed abacus for each Indicator, to obtain their values according to the Parameters values (defined in $\Re$). Below, we present three examples of Quality Indicators calculation.

**The Wining Bid Indicator - $I_{wb}$**

This Initial Indicator is meant to express an usually underestimated aspect: low cost contracts may influence works quality; this is, however, an acknowledged quality factor. The following expression, calculated at the beginning of the works, gives the Indicator's Parameter:

$$P_{Iwb} = \frac{W.B.V.}{B.A.V.} (\$/\$),$$ being:

W.B.V. - The Wining Bid Value, in escudos;
B.A.V. - The Bids (accepted) Average Value, in escudos .

To define the Indicator $I_{wb}$ we adopted the solution shown in Figure 3.

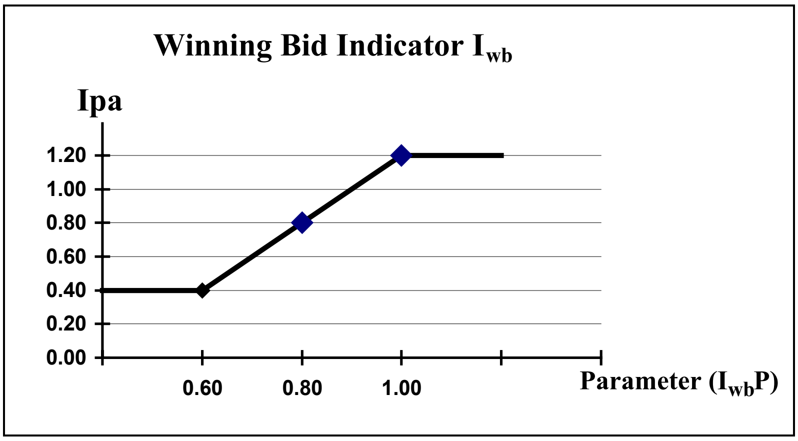



Fig. 3 – The calculation curve for the Wining Bid Indicator - $I_{wb}$.

**The Personnel In Charge Indicator - $I_{pc}$**

We use this indicator to obtain quantitative information about an important aspect of the production organisation, concerning the efficiency and capacity of its hierarchic control, which is a relevant piece of the quality control implemented by the contractor. We evaluate this aspect by a ratio between the total number of workers, at the building site, and the number of workers in charge.

The Indicator's Parameter does not result from values occurred in a period of time, but from the accumulated values, since the beginning of the works; it is given by the following expression:

$$P\,I_{pc} = \frac{A.D.W.L.}{A.D.P.C.}\ (\text{men/leader}),\ \text{being:}$$

W.L.D.A. – The working load daily average, at the building site (i.e. the average of workers, by day), from the starting date until the date the analysis is tacking place, excluding the workers with leading functions;

P.C.D.A. - The personnel in charge daily average, at the site, in the same period;

To define the Indicator $I_{pc}$ we adopted the solution shown in Figure 4.

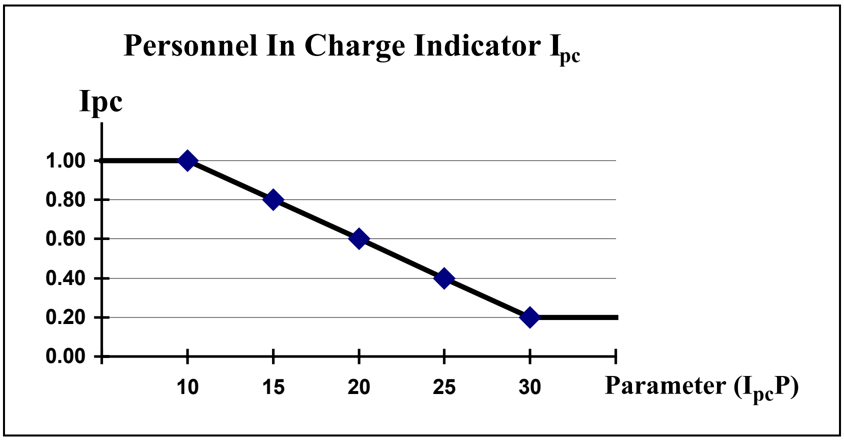



Fig. 4 – The calculation curve for the Personnel In Charge Indicator - $I_{pc}$.

**The Costs Indicator - $I_c$**

Cost deviations, in a building process, are Non-Quality, within nowadays conception of quality. In addition, the cost control is one of the main functions committed to the construction management, from the owner's perspective. Therefore, apart from the works invoice control, it is very important to control the building final cost forecast, correcting regularly the contract total costs with the results of new financial agreements, settled out since the start-date up to the date each evaluation is tacking place.

Bellow, there is the Indicator's Parameter expression; the Indicator $I_c$ is defined in figure 4.

$$P\,I_c = \frac{F.C.F.}{I.T.C.C.}\ (\$/\$),\ \text{being:}$$

F.C.F. - the final cost forecast of the works already agreed (contract included), in escudos;

I.T.C.C. - the initial total costs on the contract, in escudos .

In order to define the Indicator $I_c$ we adopted the solution shown in Figure 5.

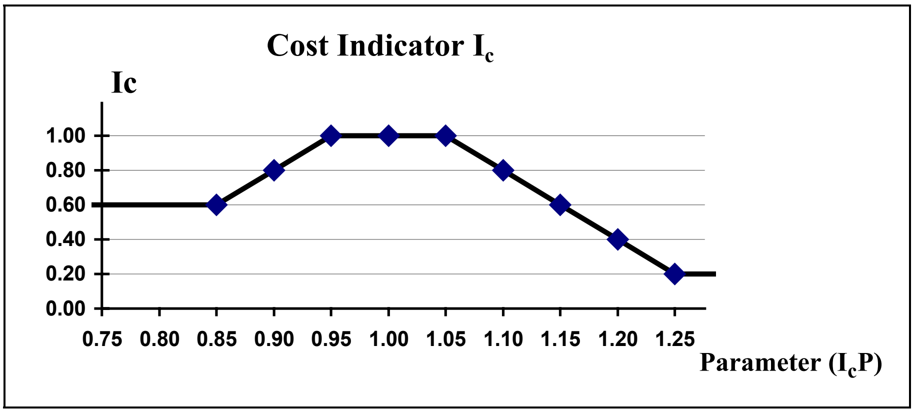



Fig. 5 – The calculation curve for the Costs Indicator - $I_C$.

## 3. Data Base Models and Applications Developed

### 3.1. Data Bases for the Computer-Aided Implementation of the Building Quality Management and Evaluation Methodology

We developed a computer solution for an easier implementation of the methodology, which is supported by a specific *Data Base Management System* (DBMS). At the time this work was initially issued, a well-known DOS application was used to establish the Data Base needed – the dBase III plus, whilst the programs for the methodology implementation were written in Clipper (again, a DOS users well-known language). On one hand, the DBMS used wasn't a recent one, but on the other hand, the software solution was based on widespread applications among compatible micro-computers users, which is the most current hardware, in the Portuguese construction related firms (contractors, surveillance and management firms, design firms, owners, etc). But, above all, this solution doesn't require high hardware capacity, which is a relevant feature, particularly on building sites.

Nevertheless, we can use others DBMS to build the Data-Base needed and develop a software solution using it, since the Data Base created respects the rules of the Relational Data Base Model. We defined a set of *Entities* and *Attributes*, originating 9 *Tables*, after the normalization of this set of relations. This model does not depend, therefore, upon the software used and it can be implemented in any DBMS, running on different computer architectures. In the description bellow, only the important data-base field names were adapted to english.

The Data-Base design is a very important activity, which must be done carefully, before all the steps required for its implementation and use, that is way that first step, being somewhat gloomy, it is often hastened. It shouldn't be done that way, once tfunctionality of the application that manipulates the information stored in the Data Base depends, mainly, on its model, carried out by the former study of the information attributes and there relations.

The normalized model issued the following Entities and corresponding Attributes:

i. The Entity Groups of Standard Elements

It describes the information related to the groups of standard construction elements (example: foundations, pavements, outside walls, flat roofs, etc). It is based in the list of distinctive groups of standard construction elements, as proposed by other authors (Bezelga and Ribeiro). The information in the Table corresponding to this Entity has been stored at the same time as the data base application was developed, meaning that this Table will not, currently, be modified, but only in the case of being added a new group (new constructive solutions or the unfolding of existing groups). The Table has the following format:

| **Attributes** | **Data Base field** | **Type** |
|---|---|---|
| Standard Elements Group Code | GroupCode | Number |
| Group Name | GroupName | Text |

ii. The Entity Standard Elements

It describes the information related to the standard construction elements, as presented in the list proposed by Bezelga and Ribeiro (example: direct foundations, deep foundations, flat roof water proofing system, flat roof insulating material, flat roof cement cover protection, outside walls of ceramic bricks, outside walls of prefabricated panels, outside walls of expanded clay bricks, etc). This Entity also includes the degrees, in a numerical scale (1 to 3), of the two first parameters needed for the Elements Quality Control Level (EQCL): the Frequency of Pathology's Occurrence (FPO) and the Pathology's Repercussion (PR). As in the former case, the information in the Table corresponding to this Entity has been stored at the same time as the Data-Base application was developed. It only should be modified in the case of new standard construction elements, like new constructive solutions or materials.

| **Attributes** | **Data Base field** | **Type** |
|---|---|---|
| Standard Elements Code | StandElmCode | Number |
| Standard Elements Group Code | GroupCode | Number |
| Standard Element Name | StandElmName | Text |
| Frequency of Pathology's Occurrence | FPO | Number |
| Pathology's Repercussion | PR | Number |

We can obtain the Construction's Standard Elements List, with the information stored in the two tables above.

iii. The Entity Projects

It describes the information about each project, that is each construction (ex. buildings):

| **Attributes** | **Data Base field** | **Type** |
|---|---|---|
| Project Code | ProjCode | Text |
| Project Name | ProjName | Text |
| Owner's Name | Do | Text |
| Place | Local | Text |
| Starting Date | Dataini | Date |
| Term | Prazodu | Text |
| Project Manager | Coord | Text |
| Situation (in construction / ended) | Sit | Text |

iv. The Entity Specific Elements

This Entity is aimed to store the information about the specific elements of each construction. Their study and identification is the source of information to store in the corresponding Table. This Entity also includes the degree, in a numerical scale (1 to 3), of the third parameter needed for the Elements Quality Control Level (EQCL): the Elements Importance (EI).

The information to store in this Table should be defined during the development of the Quality Plan of each construction, which must be done in the early stage of the works and should include a control plan. In order to help that definition of the Works Specific Elements List, the software application has a module to introduce the information needed. The former two Tables described are currently the base to present Table (i.e. the Specific Elements Table is built upon the first two Tables). It has the following format:

| **Attributes** | **Data Base field** | **Type** |
|---|---|---|
| Construction Code | ProjCode | Text |
| Specific Element Code | SpecifCode | Number |
| Standard Element Code | StandElmCode | Number |
| Element's Requirements Importance | RqI | Number |
| Element's Economical Importance | EcI | Number |

An example of a particular construction's Specific Elements List, obtained with the information stored in the three Tables presented up to now, might be as follow (it is one of the reports offered by the software application developed):

| Elements Code | Group Code | Group of Elements | Standard Element | FPO | PR | RqI | EcI | EI | EQCL |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | Foundations | Direct | 3 | 3 | 3 | 3 | 3 | 3 |
| 2 | 2 | Foundations | Deep | 1 | 3 | 3 | 3 | 3 | 3 |
| 3 | 6 | Hearth pavement | Drainage and Waterproofing | 2 | 3 | 2 | 2 | 2 | 3 |
| 4 | 9 | Structure | Concrete pillars and beams | 1 | 2 | 3 | 2 | 3 | 2 |
| 5 | 12 | Structure | Resistant masonry | 2 | 2 | 1 | 1 | 1 | 2 |
| 6 | 16 | Outside walls | Ceramic Bricks | 3 | 2 | 1 | 1 | 1 | 2 |
| ... | ... | .... | ... | ... | ... | ... | ... | .. | ... |

v. The Entity Specific Sub-Elements to Control

This Entity enrols the sub-elements (fractions of an element) which are to be submitted to registered control, as settled in the Quality Plan developed; it may happen that a Specific Element can be controlled in the whole and in such case it will not be separate into fractions to be controlled. The definition of such sub-elements is done in correspondence to the Elements Quality Control Level – EQCL. This definition should not be executed automatically by the software application; on the contrary, it is better that the selection of the sub-elements to control result from the study of the Standard Elements List, firstly developed. That is way, the software has a menu to insert the

information needed, on the present Table, through a separate operation, with a window which presents all the Specific Elements previously introduced.
We also must specify, for each sub-element to control, its location in the construction, once the distribution (in space and time) of a specific element, to be executed in different locations, is mostly the reason that motivates its partition into fractions (the sub-elements); for instance, during the construction of a seven stages building, to control and evaluate the execution of the Specific Element "Outside walls in ceramic bricks" it is perhaps better to separate it into, at least, seven sub-elements, one for each stage. In the table, besides this attribute we have a short reference of the location, too.
On the other hand, the Table has a set of fields to introduce the information needed to the quality evaluation of the execution, as a result of the evaluation of each Sub-Element. Those fields are: the Total Number of Control Points; the Total Number of Failures Detected; the Total Number of Parts Controlled; the Acceptance Date (that is the date of the last check). Finally, the Table has a field to store an evaluation of Sub-Elements related to equipment or installations; those facilities should be easy to operate and to support, that is way we appraise their operation's level (in a 1 to 3 scale), which will integrate the valuation of the QIB Maintenance / Usage Indicator.

| **Attributes** | **Data Base field** | **Type** |
|---|---|---|
| Construction Code | ProjCode | Text |
| Controlled Sub-Element Code | CtlCode | Number |
| Specific Element Code | SpecifCode | Number |
| Sub-Element's Location (space / time) | Localelm | Text |
| Location's Short Reference | Locabrev | Text |
| Total Number of Control Points | Totpc | Number |
| Total Number of Failures Detected | Totfalha | Number |
| Total Number of Parts Controlled | Totverif | Number |
| Acceptance Date (last check) | Datad | Date |
| Equipment's Operation Level | Noei | Number |

vi. The Entity Nonconformity Forms

This Entity describes the data related to the Nonconformity Forms, opened as a writing support of the Nonconformity Actions, which shell be set to every and each Element or Sub-Element where failures were detected, as a result of their execution's control. Towards a better performance of the control actions and having in mind the data-base implementation, each Form must concern only one Element or Sub-Element controlled. As we will see further, the next Entity solves the problem of a Nonconformity Action, related to one failure concerning more than one Sub-Element.
The Table of Nonconformity Forms has the following format:

| **Attributes** | **Data Base field** | **Type** |
|---|---|---|
| Construction Code | ProjCode | Text |
| Nonconformity Form Code | NCFormCode | Number |
| Nonconformity Form's Opening Date | Dataabt | Date |
| Solving Term Settled (weekdays) | Prazoduc | Number |
| Nonconformity Form's Closing Date | Datafc | Date |
| Nonconformity Headings | N_Ctopic | Text |

vii. The Entity Nonconformity Assignments

It describes the information about the Nonconformity Actions, during the works. It relates the data concerning the Elements or Sub-Elements, stored in the corresponding tables, and the data stored in Nonconformity Forms, where the evolution of the failure has been followed: since the detection, the search of the causes and the correcting actions taken.
This Entity results from the possibility of occurring a Nonconformity, followed through a Nonconformity Form, which can be related to more than one Sub-Element controlled. As stated above, a Nonconformity Form can be developed because of a fault or a failure, occurring on more than one Sub-Element. In that case, those Sub-Elements should be wrote down in that Nonconformity Form (they can be referred in the field Nonconformity Headings); therefore, two or more records would be added to the Table of Nonconformity Assignments, each one relating the Nonconformity Form with each faulty Sub-Element. The Table has the following format:

| **Attributes** | **Data Base field** | **Type** |
|---|---|---|
| Construction Code | ProjCode | Text |
| Controlled Sub-Element Code | CtlCode | Number |
| Nonconformity Form Code | NCFormCode | Number |

viii. The Entity Initial Indicators Evaluation

This Entity points to another kind of information, apart from the control of the execution; it is oriented to the 3 Initial Indicators of the Quality Indicators Board, which are stored separately, because they are evaluated only once, at the construction's start. In fact, to avoid redundancy in the data-base, they cannot be introduced to the same table of the other indicators, which will origin progressive evaluations to be stored in individual records. The Table has following structure:

| **Attributes** | **Data Base field** | **Type** |
|---|---|---|
| Construction Code | ProjCode | Text |
| Evaluation Date | EvalData | Date |
| Winning Bid Indicator | WBI | Number |
| Quantities Indicator | QI | Number |
| Woks Quality System Indicator | QSI | Number |

ix. The Entity Progress Indicators Evaluation

It concerns the information about the remaining Indicators of the Quality Indicators Board: the Progress Indicators, which should be periodically evaluated (monthly, in general). Each last evaluation, more correct, will be introduced in the Table, in order to be used in Construction Quality Evaluation.

| **Attributes** | **Data Base field** | **Type** |
|---|---|---|
| Construction Code | ProjCode | Text |
| Evaluation Code | EvalCode | Number |
| Evaluation Date | EvalDate | Date |
| Nonconformity Indicator | NCI | Number |
| Personnel In Charge Indicator | PCI | Number |

| | | |
|---|---|---|
| Absenteeism Indicator | AbI | Number |
| Health and Safety Indicator | HSI | Number |
| Maintenance / Usage Indicator | MUI | Number |
| Cost Indocator | CI | Number |
| Time-scale Indicator | TI | Number |

x. The Relational Data-Base Model, in a graph presentation

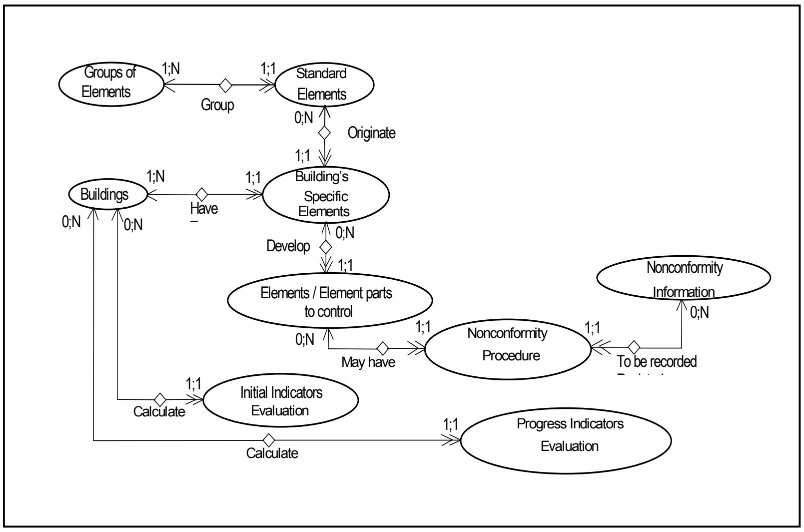



Fig. 6 – The Data Base Model generated after normalization.

xi. Keys

The keys of the tables presented above are as follows; often, the keys are composed of more than one field, as the type indicated:

| **Tables** | **Keys** | **Type** |
|---|---|---|
| Groups of Standard Elements | Groupcode | Single key |
| Standard Elements | StandElmCode | Single key |
| Projects | ProjCode | Single key |
| Specific Elements | ProjCode; SpecifCode | Double key |
| Specific Sub-Elements to Control | ProjCode; CtlCode | Double key |
| Nonconformity Forms | ProjCode; NCFormCode | Double key |
| Nonconformity Assignments | ProjCode; CtlCode; NCFormCode | Triple key |
| Initial Indicators Evaluation | ProjCode; EvalDate | Double key |
| Progress Indicators Evaluation | ProjCode; EvalCode | Double key |

## 3.2. The Software for a Computer-Aided Implementation of the Quality Management Methodology

There were built 2 independent programs to explore the Data Base created.

The first one actuates on the data concerning the Construction's Standard Elements, stored in the first two tables – the Groups of Standard Elements Table and the Standard Elements Table. As said, those tables are already supplied with information based on the data proposed by other authors (Bezelga and Ribeiro). The reason to built this separate program for the use of those tables is because their data rarely will be modified. The query of this data is neither currently necessary, as the second program was coded with a window to display that data, helping the user to prepare the Specifics Elements data.

The second program helps creating and processes a Specific Elements Table, as well as all the information about the construction evolution, to be stored in the other tables, namely the Initial and Progress Indicators of the Quality Indicators Board; it also issues the Quality Evaluation of each construction. Therefore, this program has five modules, corresponding to each entry proposed by its initial menu:

- a module to access the construction's Specific Elements information;
- a module to access the construction's Specific Sub-Elements information;
- a module to develop the Quality Management and Evaluation operations, which includes the introduction and modification of the QIB Indicators;
- a module to access the Projects information;
- a module to elaborate a Report of the construction's actual situation, concerning its quality, in result of the information processed by the first three modules.

It should be referred that the information related to the definition and calculation of the QIB Indicators was not computerised within the programs above. Indeed, while developing this methodology, we used simple worksheets (like MS-Excel, for instance) to calculate the Parameter's Indicators and we proposed to evaluate the Indicators with the different abacus indicated earlier. Even the Quality Indicators Board presented above was implemented in a MS-Excel worksheet, using its graphs facilities to format the graphic in the bottom of the QIB. The Indicators Values though calculated are then introduced in the data-base, using the module to develop the Quality Management and Evaluation.

Nevertheless, it would be worthwhile to include the Indicators Data Management in the data-base software developed, in order to have the whole data treatment in only one application. This software could have, eventually, the possibility to export the results of the QIB Indicators Evaluation to a Worksheet, if justified.

# 4. Conclusions

## 4.1. Summary of the main aspects concerning the use of this methodology

In the first place, we have to point out that it is rather difficult to fully experiment any quality related model, in a short term. Nevertheless, during the development of the methodology presented in this paper, some tests were accomplished, on the field, to separate parts of its Evaluation and Management Structure. Those tests also revealed that such a Data-Base and software was easy to use and it helped strongly the storage of a great amount of information, necessary to the Quality Management and Evaluation, in Construction.

A second issue to remark is the methodology's usage perspective: as indicated previously, it was developed from the owner's point-of-view. The owner should lead its implementation, since he would benefit from contracting a management team, to control, among other features, the building quality. In fact, the Quality Evaluation and Management is based in a Quality Control that will be functioning as an inner control of the owner's production, although it will be an outer quality control to the contractor (outside its production). This is likely to happen currently, but in particular it should occur if the owner is somehow involved with Quality Goals.

We also must refer some considerations about the use of this Quality Evaluation and Management tool. On one hand, it is widely recognised that Information Systems on site should be improved to give better reporting of construction's progress. Furthermore, the ISO 9000 series of standards and the certification of companies are important recent developments, causing the need for documentation to grow rapidly. The use of computer-aided solutions (built upon Data Bases, as a logical rule) to handle this vast volume of data seems vital, regarding the actions needed for controlling and documenting quality. Within this study, we developed a feasible solution for such software, in order to help the methodology's implementation. Secondly, this methodology does not replace the adoption and the implementation of Quality Systems based on the ISO 9000 standards; this methodology might otherwise be a tool to evaluate and prove the efficiency of a Quality System in use.

### 4.2. The use of such kind of methodologies: some aspects

First of all, we should focus on the advantages of Quality Management and Evaluation aided by the use of such methodologies and the ways to achieve this. We report the following ones.

- As a result of being involved in practical situations of Project Management, the authors also have noticed that the particularly sensitive area of undertaking cost control, is one of the main sources of the information circulating among professionals related to a set of construction investments. Once this kind of information must be thoroughly analysed and carried on, owners management teams, leading several investments that generate a set of construction works, have to constantly watch undertaking costs, as one of their main objectives. While that issue might decay the attention to Quality Goals, the cost control is an important issue, also related with the Quality Indicators Board proposed above. Then, it would be interesting to improve the storage and treatment of that amount of information; in addition, this possibility would match the evaluation of some Indicators proposed in the Quality Indicators Board, mainly the Cost Indicator (depending on the solution to develop, it could simplify also the calculation of some other indicators).
  Therefore, as an attempt to solve some management difficulties observed in real situations, a model was developed, once again on a Data-Base solution, for Cost Control in Project Management. This tool is to be developed for a particular large set of construction works, which are now being prepared, that is way the Data-Base model has some particularities. A draft of this model, implemented in a current Data Base Management System (MS Access), is shown at the end of this paper.

- The implementation of this kind of methodologies, simplified by the use of computer-aided tools, is one the reasons that might influence other aspects, like the stimulation resulting from the market's supply and demand behaviour, and like the increasing attention of owners to Final Quality Indicators.

- This kind of model might easily integrate the development of Project Management computer-aided tools, where costs and time-scale control ought to be linked to quality, safety and health, maintenance, tracing quality evaluation during after-sales services, etc.

- We also realise that the teaching of quality related matters may certainly benefit from such study, mainly as a result of the well-known students' higher motivation generated by the use of computer resources, such as the programs presented on heading 3.

Finally, we must emphasise some expected consequences of this methodologies systematic usage, which would help to meet the goals of a quality oriented Housing Policy. On one hand, with the results found in several buildings, trend analysis of the Quality Indicators might be performed. On the other hand, the results of this Quality Evaluation, particularly the QIB Indicators, will give us the possibility to compare the quality of different buildings. Thirdly, those results will give us a way to compare different contractors, and even to rank them, in order to allow an organization (private, public and namely the State) to introduce Quality Requirements in later. Furthermore, the methodology results enable an organization to compare contractors' quality, independently of their Quality Systems.

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Appendix - A Data-Base Model for Cost Control, in a particular Project Management situation, involving a large amount of Projects.