A web-based system for quality inspection and defect management of industrial building construction

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ABSTRACT: Quality inspection and defect management in industrial building construction is one of the major factors that general contractors have to consider for improving customer satisfaction and gain competitive advantage.
This paper describes a web-based system for quality inspection and defect management (SIDEM). The system is derived from the elements of ISO 9001 standard, and assist management in tracking of inspection/test results, defects management, non-conformities analysis, preventive and corrective measures, etc.
A Quality Inspection database and a relational database structure were devised to effectively interconnect the essential information such as facility, trades, trade contractors, materials, and defect types required for a computerized quality inspection and defect management for industrial building construction.
In SIDEM, all collected and analyzed information is stored into the database of the central server system allowing general contractors to effectively monitor and statistically analyze the statuses and results of the quality inspection and defect management in real time.

1 INTRODUCTION

Quality is a fundamental issue in the construction sector. It is increasing in importance not only in economic terms, but also from the social and environmental perspective.

Currently, to satisfy customers' needs, general contractors have paid more attention than before to complete quality inspection and defect management until final acceptance of a project is made by the customer.

According to Young et al (2008) regardless of this effort, however, many deficiencies and discrepancies are still identified near the completion of a project. The problems are due to:

- the lack of number of on-site staff for quality management,
- too much workload for crews to meet deadlines,
- non-unified traditional checklists and a number of documents to manually fill out,
- poor communications among project participants, and
- complicated and labor-intensive interior finishing work process.

These problems require additional work to correct the defects that often result in the delay of project close out.

To efficiently cope with such problems, there has been a strong need to develop a management system which helps site quality managers promptly identify and correct defects on finishing materials and facilities, and assure their quality.

The primary objective of this paper is to define a conceptual model for the quality management so as to detect, place, hold responsible and properly solve the defects generated in the execution phase of an industrial construction project. This model is then implemented in a web-based tool to facilitate the access to the stored information (SIDEM).

The system can collect defect data on site, and effectively manage the statuses and results of the corrective works performed.

The proposed SIDEM can provide a structured repository of data where various project participants can place and maintain the data in real time for seamless information acquisition and prompt decision making for corrective actions when problems are found.

2 LITERATURE REVIEW

2.1 *Quality inspection*

'Quality' is defined as "the characteristics of a product or service that bear on its ability to satisfy stated or implied needs" (American Society of Quality, 2006). Therefore, quality inspection is the overall process to assure that final products fulfill the requirements and specifications assigned by the customer. When final products do not meet the required quality, it is defined as a defect.

Different types of quality inspection can be made:

- on site quality inspection. It is conducted by several site project managers and engineers whenever necessary until a project is closed
- third party inspection which is an intensive and focused inspection conducted by managers and engineers from a general contractor's main office and construction sites
- external quality inspection, which is carried out by quality control entities or laboratories to control basically materials.

2.2 *Defect management*

Defect management is the process to correct and manage defects found through the quality inspection processes described above. The main purpose of conducting quality inspection and defect management is to maximize product quality and prevent defects until the project is finally transferred to the customer with the satisfaction of his/her demand for final products.

2.3 *Problems in current quality inspection and defect*

According to Young et al (2008), problems in current quality inspection and defect management practices are identified as follows:

- A number of data collected manually with checklists must be retyped to a Personal Computer (PC), by which the data input process is duplicated and such a time-consuming process makes it possible to make input errors in both site office and third party inspections.
- Non-unified or non-formatted data recording system (e.g., checklists, notes, post-it, photos, and spreadsheet) often yields data losses and damages.
- After work orders for correcting defects, it is not easy to find and monitor whether the defects have been properly corrected at an acceptable level or not. Thus, both inspection tasks are often superficially performed in spite of their importance.
- It is also difficult to make prompt corrective actions when defects are found. They are due to lack of the number of on- site staff to handle quality and defect management, excessive management practices workload for crews to meet a project completion date, a number of documents to manually fill out, inefficient communication, poor quality assurance process.
- In case of the third party inspection, it is very difficult to collect defect data and monitor and manage current corrective statuses and results because it is intensively conducted and enormous data are created during a short period of time.
- Poor communication exists especially among on-site quality managers, trade contractors, and their crews in managing and correcting defects. The poor communication is also caused from the tools such as phone, radio, fax, post-it or verbal instruction.
- There is no formal process or computerized system to analyze and verify the causes of defects by statistically monitoring defect rate of construction materials used and trade contractors involved in real time.
- No standard repository of data and feedback systems are available to reuse the lessons learned from the past which recur from a project to other similar projects.

2.4 *Industrial building construction*

Regardir Euroconstruction report (2007), the tendencies of the different construction markets (residential, non-residential, civil engineering and rehabilitation) are sbstantially different.

Currenty, the residential construction is decreasing due to the finantial crisis, while other edification fields such as the industrial building construction is still increasing.

Therefore, taking into account this situation, it seems necessary to start developing tools and norms to promote a quality and arranged edification construction (which includes the industrial building construction) which majoritary it is not the focus of tools and services development.

There are huge amount of standards and codes available for residencial construction, however, few codes are oriented to industrial building construction. Therefore, there is a need to:

(1) consolidate industrial building standards and codes;

(2) develop in-house database using existing standards and codes, and lesson-learned from defects gathered by property managers; and

(3) to apply this knowledge to eliminate latent defects from future design.

2.5 *Quality management systems*

In the construction sector, different systems have been developed for the quality management. Focusing on quality inspection and defect management many approaches for apartment housing projects were created (Young et al (2008), Battikha, (2002) Oh, H.J. et al (2004), K. Lam, S. Ng, (2006), among

others. Relating to industrtial building construction any system has been created.

3 SYSTEM APPROACH

In construction, the origin of differents errors, risks and defects is located in different stages of the life cycle of the project. Furthermore, these defects can appear once the construction stage is finished, i.e. during the occupation stage and are called latent defects. Therefore, it is obvious that a tool to register and manage de defects during al the life cycle of a project can improve the subsecuent occupation and maintenance stage and its facility management.

The main objectives of this tool are:

- To avoid defects coming from the initial stages of the project such as the design phase,
- To assist management in tracking of inspection/test results, defects management, non-conformities analysis, preventive and corrective measures, etc. during the execution phase,
- To help the future owners or endusers maintain and use the building in proper conditions, by putting at their disposal all the tracked and registered incidences occurred during the execution phase to.

This system is derived from the elements of ISO 9001 standard, including checking output for defects, with appropriate and corrective action where necessary and facilitating continual improvement.

The system can collect defect data at site, and effectively manage statuses and results of the corrective works performed.

A Quality Inspection database and a relational database structure were devised to effectively interconnect the essential information such as facility, trades, trade contractors, materials, and defect types required for a computerized quality inspection and defect management for industrial building construction.

SIDEM database is categorized into the following three sub databases: 1) Building database, 2) Trade Contractor database, and 3) Defect Type database.

From this information an electronic checklist is provided and various statistical analysis results can be effectively generated.

The on-site quality inspectors simply inspect the defects using the checklist and all the documentations relating to the defect management are automatically produced for project participants with no additional data input or analysis efforts, thus significantly improving the work efficiency of project participants.

In SIDEM, all collected and analyzed information is stored into the database of the central server system allowing general contractors to effectively monitor and statistically analyze the statuses and results of the quality inspection and defect management in real time.

Therefore, the system would significantly improve communication efficiency among the related stakeholders. It will also help quality managers systematically manage inspection and defect data and accumulate useful information to improve quality management for future projects.

4 ARCHITECTURE DESCRIPTION

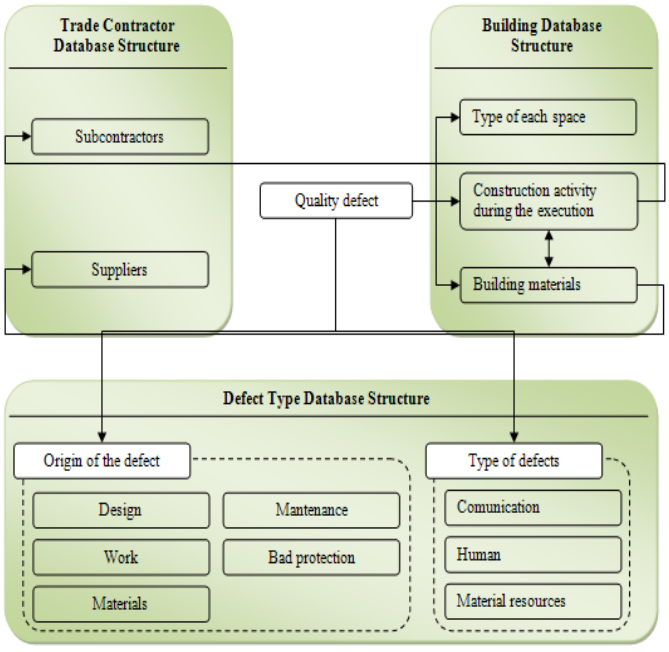
The system architecture must facilitate traking inspection/test results, defect management, non-conformities analysis, etc. and communication among stakeholders.

SIDEM has been implemented using FileMaker Pro, which is compatible with Mac OS X and Microsoft Windows. Users can share the database simultaneously by using the web applications. Filemaker Pro also provides configurations for mobile devices.

5 DATABASE STRUCTURE OF SIDEM

The most important and critical task required to design the proposed SIDEM is to devise a database structure which can effectively interconnect the information of facilities, trade contractors, materials, and defect types related to quality inspection and defect management. Since construction materials and their corresponding defect types vary in contractor by contractor and project by project, the flexibility is a key factor in designing the data breakdown structure for quality inspection and defect management. Fig. 1 shows a unique Quality Inspection Database Structure (SIDEM) proposed in this paper.

SIDEM is categorized into the following three



sub-databases structures:

Figure 1. Database structure

1) Building Database Structure which incluyes the building materials and units, the type of spaces and size (m2) of space, space elements and their attributes and the construction activity where to use an specific material.

2) Trade Contractor Database Structure including the information of each subcontractor and the relation among the contractor and subcontractors. It also incluyes the suppliers of the materials.

3) Defect Type Database Structure.

Some structures are already prefixed. To define all the terms, standard structures are being used.

For the Building Database Structure prefixed fields are:

- The Type of each space. In this research the spaces standard of industrial building have been generated (Heredia, 1981). This task has been complicated due to the fact that industrial buildings can be very different. However, all of the have a production area, administrative area, a boiler room, a room for electrical devices, a warehouse, etc.
- The construction activity during the execution, such as foundation, structure, etc. This structure is obtained from ITEC (www.itec.cat.)
- The building materials where also predefined. They are obtained from CCOC (www.ccoc.es).

All these substructures are defined because of their importance when classifying incidencies (defects) that cause quality problems and can be key elements when determining critical phases during the execution stage.

Therefore, the spaces allow to locate the defects in the specific area of the building, the construciton activities allow to locate the defect temporally and the materials and/or products help to relate the defects with the subcontractor, supplier, etc.

Another important structure to define is the defect's classification (Wai-Kiong Chong, and Sui-Pheng Low, 2006).

First, defects are clasified depending on the origin or cause of the defect (defect derived from the design, from work, from materias, from maintenance or from bad protection). These defects can also be concreted defining specific cause of the defect.

Then, defects can be classified depending on the type of defects: human error or managerial errors such as comunication, human and material resources management.

6 DEVELOPMENT OF A WEB-BASED SYSTEM SIDEM

This tool is orieted to improve the quality managmeent system during the execution phase of a industrial building construction, concretely to register a manage the detected incidences during the exectuion phase.

Figure 2 shows the functioning of the system and the system strcture.

For the moment, we have developed a prototype which is being tested. From the main page (Figure 3), the different types of users (on-site quality managers, third party inspectors and expternal quality inspectors) can choose among 4 different actions:

1) Register a project
2) Database of registered projects
3) Suppliers
4) Results search

From the incidences registered from other projects, the system can obtain preventive and corrective actions to be used in the current project.

Figure 2. System structure

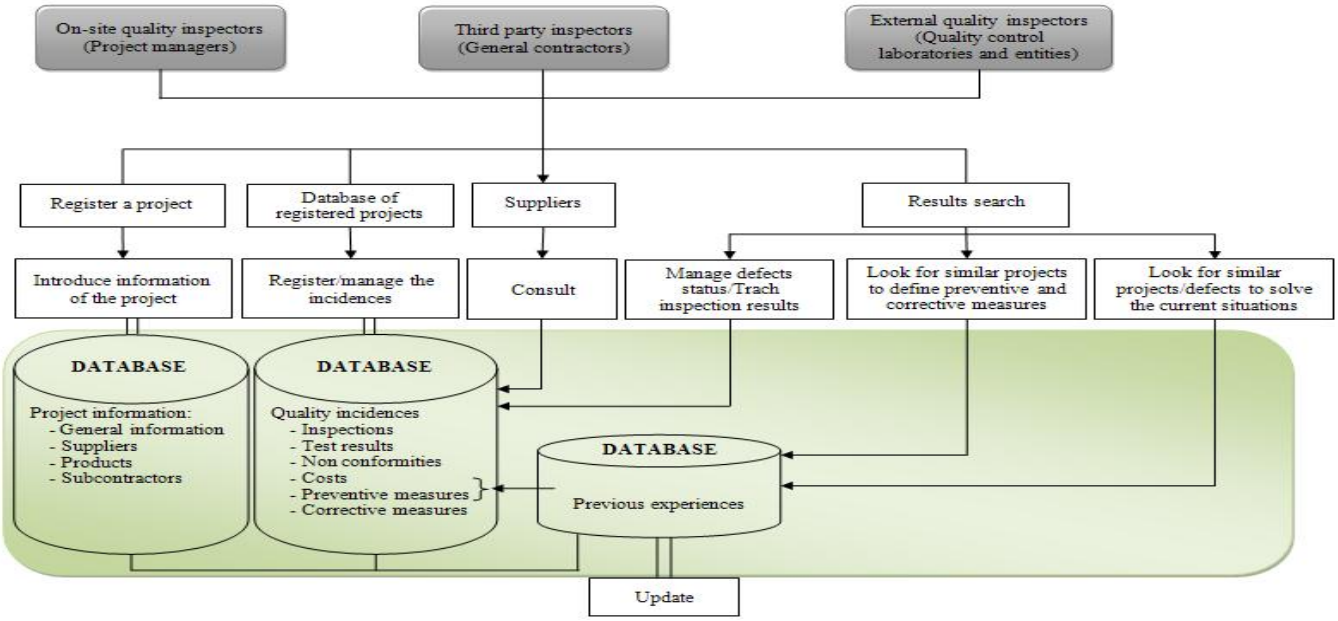


Figure 3. Main page of SIDEM

Figure 5. Registration of a new project. Actors

6.1 *Register a project*

In this section, the project manager can register a project introducing the following information:

- General information: address, location (map), agents (client, desinger, safety and health manager, quality maanger, suppliers, general contractor, etc.)
- Building characterisitics: spaces of the building, area of each space, planification of the execution of the different construction activities.

Figure 4 and Figure 5 show two examples of how to register some of these information:

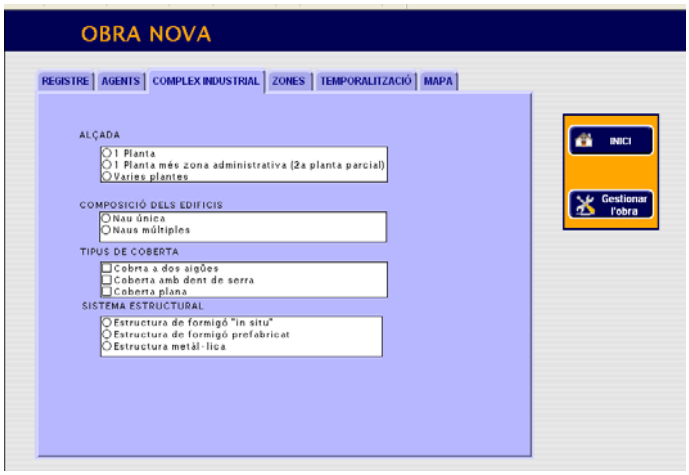


Figure 4. Registration of a new project. Building characteristics

6.2 *Database of registered projects*

Once the project is registered, to proceed with the quality inspection and defect management, the project manager should get into the *Database of registered projects*.

In this section, the incidences can be tracked and managed. To do so, information about subcontracting chain and building materials related to a incidence should be registered.

To register the building materials the previous explained database is used. Then, the material supplier should also be included. When including the company name, the system gets all the information of the company and links it to the supplied material.

The next figure shows how to register an incidence:

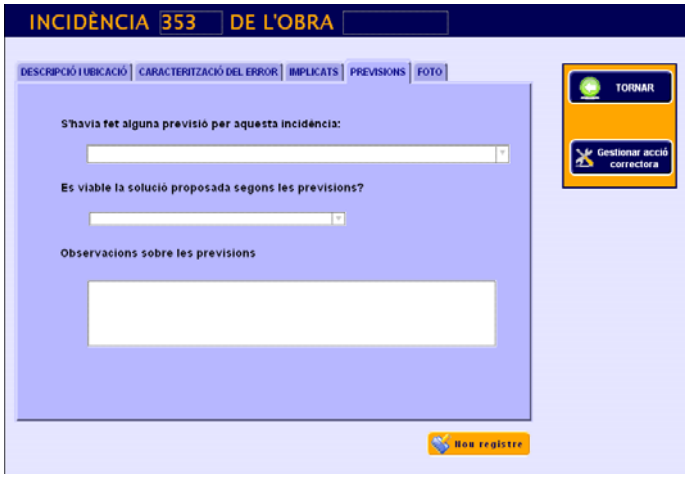


Figure 6. Registration of preventive actions to mitigate an incidence

As explained before, the space of the building where the deffect is located can be registered using the Building Database Structure.

The construction activity can be also registered using this database structure.

Finally, the type of defect can be registered from the Defect Type Database Structure.

As an example, the following figures show how to register an incidence and the types of defects.

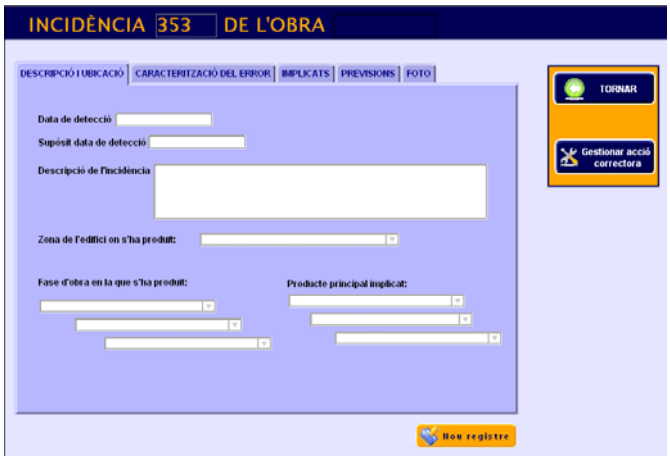


Figure 7. Registration of an incidence. Type of defect

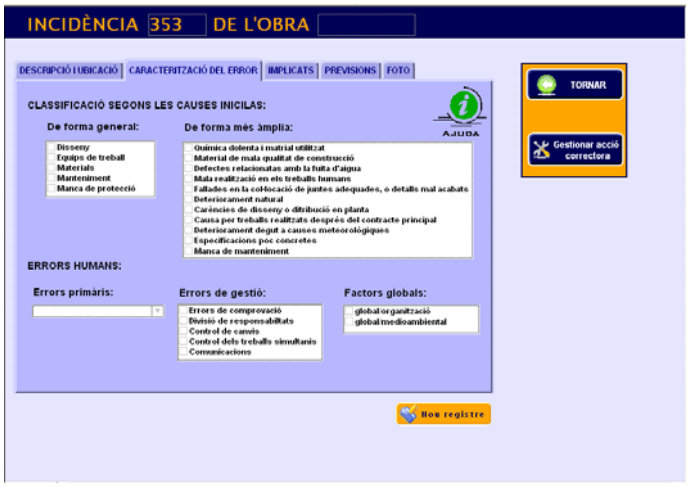


Figure 8. Registration of an incidence. Type of defect

In this section, not only incidencies can be registered but also the forecast incidences and risks management defined during the design phase whith the aim to avoid or minimize the consecuences of the deffects and evaluate the acomplishment level can also be registered. Moreover, preventive and corrective measures related to an incidence or defect can also be included.

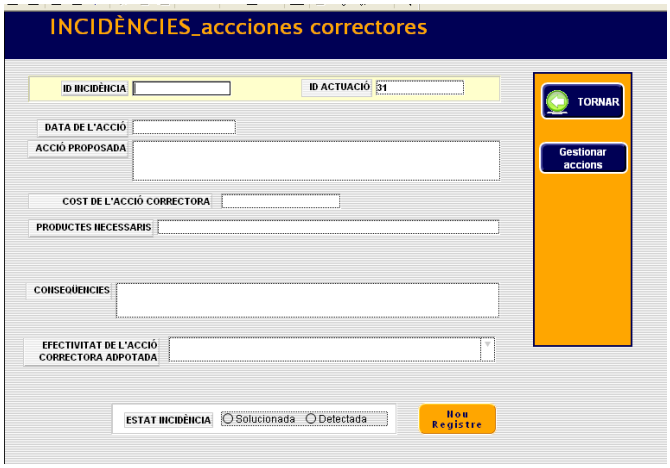


Figure 9. Registration of corrective actions to solve an incidence

Relating the corrective actions, the system provides the possibility to register the cost of this corrective action so as to obtain a global cost of non quality, evaluate the efectiveness of providing extra resources to prevent other defects and suggest possible actions for later projects.

6.3 *Suppliers*

This section is both for the project manager and for suppliers.

Basically, in this section, suppliers can view information about the incidences and defects related to the materials and/or services they are providing.

6.4 *Results search*

In this section, autorised end users can search information of the current project and from previous projects so as to find similar incidences to the one they are dealing with and try to avoid or prevent these incidences by adopting some preventive and/or corrective actions from previous projects.

Once the project is finished, end users can track all the incidences and defects of the project, locate the activity with major incidences, locate the supplier that has caused the most of the delays in the execution phase, analyse the non quality costs of the project, etc.

The following figure shows the screen for searching and printing the results.

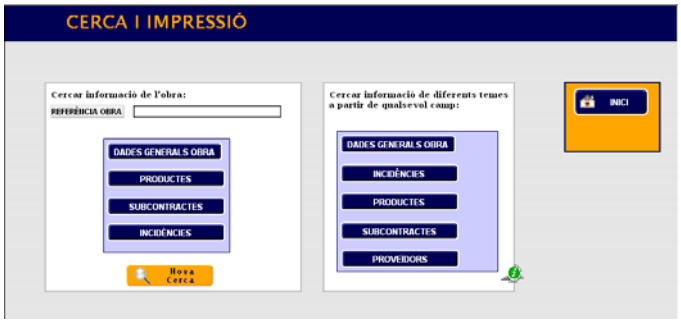


Figure10 Search and printing screen

7 CONCLUSIONS

The web-based system (SIDEM) described in this paper assist management in tracking of inspection/test results, defects management, non-conformities analysis, preventive and corrective measures, etc.

The system collects defect data at site, and effectively manage statuses and results of the corrective works performed. Therefore, it helps site quality managers promptly identify and correct defects on

finishing materials and facilities, and assure their quality.

Quality inspectors can inspect defects using the checklist and all reports interested for the related parties are automatically produced. Therefore, work efficency improves.

All collected and analyzed information is stored into the database of the central server system allowing general contractors to effectively monitor and statistically analyze the statuses and results of the quality inspection and defect management in real time.

Indirectly, the system improves communication efficiency among the related stakeholders. It will also help quality managers systematically manage inspection and defect data and accumulate useful information to improve quality management for future projects.

This system aims at creating a unified data recording system so as not to lose project information, to easily find and monitor whether the defects have been properly corrected at an acceptable level or not.

It also improves the implemention of corrective actions when defects are found.

8 LIMITATIONS AND FUTURE RESEARCH

For the moment we have developed the prototype in a local server. We are planning to create a web application and a PDA application to improve the introduction of data in real time.

This system is focused on quality inspection and defect management based on the principles of ISO 9000 but it is not integrated with project the general management. A deeper analysis of the integration of different aspects of the project such as chang orders, Safety&Health, costs, planning, etc. should be done and integrated in the system.

This system can be used to analyse problematic site phases, activities, suppliers, etc. which provoque the most quality problems. Then, from this information, future projects can be reoriented or modified and preventive measures can be included.

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