

# Computer Aided Quality Evaluation of Dwellings

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## Summary

The evolution of computer related technologies allows for the construction of increasingly complex applications. On the other hand, the house building industry calls for an organised approach to quality assurance, which should be based on an integrated view of the dwelling life cycle: design, construction, use and, eventually, demolition. A framework for the evaluation of the quality of dwelling designs, named QDF (Quality Dwelling Framework), has been developed, focused on the evaluation of the quality of dwelling designs. In order to experiment with QDF, a computer prototype has been implemented, following the object-oriented approach to software development. The work is progressing in the line of extending QDF to support the need for computer aided evaluation of the quality of dwellings, after construction. The relevance of the object oriented approach in modelling complex products like buildings, also adopted in Product Modelling, is briefly referred to.

Keywords: quality evaluation, certification, dwellings, object oriented programming.

## 1. Introduction

At UTAD, Universidade de Trás-os-Montes e Alto Douro, situated in the region of Trás-os-Montes e Alto Douro, in the North East of Portugal, a Construction Observatory has been created, named Observatório da Construção de Trás-os-Montes e Alto Douro. It involves public and private institutions, namely city councils, public administration institutions, banks, companies, business associations and real estate agents.

The Observatory's main mission is to provide information related to the sector of construction to the various local and regional organisations, that will allow them to make decisions related to their technical, administrative, economic and financial activities. These activities are related with a broad range of sectors, such as urban planning, financing or execution of housing projects, and evaluation and certification of the quality of dwellings.

Two basic objectives are associated to this mission:

- To create an instrument of analysis, evaluation and prediction of the regional dynamics of civil construction, mainly of housing;
- To conceive and implement an evaluation and certification system for the quality of dwellings.

This evaluation and certification system, in a first stage, is aimed at certifying some aspects of recently built dwellings (e.g. thermal behaviour, sound insulation, and dampness). In order to identify the aspects that are more relevant to the users, a set of inquiries is being carried out.

Previous work led to the establishment of a framework for the evaluation of the quality of dwellings named QDF (Quality Dwelling Framework). This framework, while very wide, has been focused on the evaluation of quality at the design phase.

QDF is being extended, in the scope of the Observatório da Construção, in order to support the need for computer aided evaluation of the quality of dwellings, during and after construction. This dimension will lead to quality certification (and eventually assurance). This aspect is of great importance to raise quality standards in Trás-os-Montes e Alto Douro, a region where traditional construction techniques have been



almost abandoned (in part due to the high costs) and where new techniques and materials are frequently adopted without careful analysis.

The paper is organised as follows. In the next section, QDF is briefly presented, as well as a computer prototype of QDF, implemented in the programming environment KAPPA, following the object-oriented paradigm. The certification process under development is presented in section 3. Section 4 contains the discussion, focused on the evaluation of quality during the dwelling life cycle. Finally, section 5 contains the conclusions.

## 2. Computer Aided Quality Evaluation of Dwellings

Previous work has led to a new approach for the evaluation of the quality of dwellings named QDF (Quality Dwelling Framework) [1]. Because it is difficult to model a complex product using a simple model, QDF is complex and calls for an adequate methodology in order to make it suitable for computer implementation.

The methodology used to develop QDF is based in the systems approach and uses a human body analogy [2]. This is justified by the fact that a human body is perhaps the most sophisticated and highly developed form on earth. A comprehensive set of systems for modelling the quality of dwellings has been proposed, by drawing a parallel with the human body systems. The quality of a dwelling is evaluated by analysing the quality of its systems. The regular structure of the holons (objects) across different levels of the hierarchies makes the framework suitable to be implemented using object-oriented techniques and tools [3].

It is important to stress the relevance of the OOP (Object Oriented Paradigm) in modelling complex products. This aspect has been carefully studied in the area of Product Modelling [4].

QDF can be compared with models proposed in the context of Product Modelling for buildings (e.g. the RATAS model and the AEC building systems model). These models have a higher degree of abstraction. On the other hand, having been defined without a specific purpose, they tend to be too abstract for easy application. QDF is concerned with the evaluation of the quality of a dwelling. This requires a lot of information to be analysed, but with a well-defined purpose.

Important aspects of this approach, which follow the object-oriented approach to software development [5][6], are:

- **Composition:** a dwelling is a complex system recursively composed of subsystems and elements (composition hierarchies, which are based in a-part-of relations);
- **Inheritance:** each element of the dwelling is modelled as an instance of a class, with characteristic attributes and behaviour; classes are organised in hierarchies (classification hierarchies, which are based in a-kind-of relations). To develop and present these hierarchies the graphical notation defined by Rumbaugh was used (Figure 1).

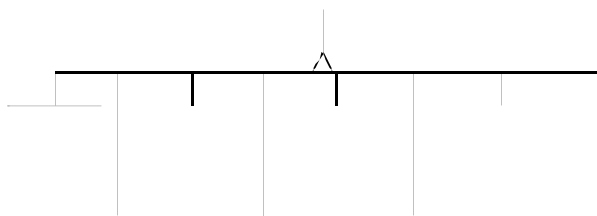


Fig. 1 The dwelling systems hierarchy.

It benefits, as well, from other aspects of the object-oriented approach to software development. These, although not so important in themselves, are important components of an object-oriented system. As with any system, the emergent properties of an object-oriented system result from the interactions between its components and go beyond the individual properties of the components (the object-oriented approach to software development is a systems approach). This is the essential property of a systems approach to

It is usual in engineering practice to divide a complex problem in simpler sub-problems in order to make it easier to solve. This is the key idea behind modularity in software engineering, which is behind the success of the object-oriented approach to software development. Object-oriented methodologies are centred on software objects, which are responsible for the services they offer to their clients, and provide a convenient way to build and maintain modular programs. QDF was developed having modularity in mind and following an object-oriented methodology.

modelling as distinct from the reductionist approach. There is no other approach to software development known to the author which can model the extremely complex relations and interactions of the elements of a complex system like a dwelling in a satisfactory way for computer implementation.

A computer prototype of QDF has been implemented using the programming environment KAPPA® [7], after a comparative analysis of available software platforms. The following reasons influenced the decision of choosing KAPPA® for experimenting with QDF:

- To be object-oriented;
- To have persistent objects;
- To be an integrated development system, not only a programming language;
- To have good interfacing facilities with Microsoft Windows and with the C programming language;
- To have the possibility of being used for procedural programming as well as for declarative (rule based) programming;
- To have good facilities to develop a user-friendly interface;
- To be very user-friendly;
- To be relatively simple to learn;
- To be available for more than one platform (Windows and UNIX);
- To be a mature tool.

The components of the dwelling are modelled using software objects. All the information about the systems of a dwelling is modelled using a set of attributes and a set of procedures (methods), stored inside the objects involved in the functions performed by those systems. Each attribute describes a state of nature of the component and each procedure models the behaviour of the component.

Program functionality includes the evaluation of the quality of different dwelling designs and alternative solutions for these designs. The use of the program has demonstrated that it is friendly to use, and a helpful tool in the evaluation of alternative design solutions. In order to illustrate the type of output, a computer screen is shown in Figure 2, corresponding to the evaluation of the close environment aspects of a flat in Gaia, Portugal.

### **3. Quality Certification of Dwellings in Trás-os-Montes e Alto Douro**

As part of the activities of the Construction Observatory of Trás-os-Montes e Alto Douro (TMAD) [8] a quality certification of dwellings adapted to the TMAD reality is being developed.

The improvement of the quality of a product or service is not usually dissociable from its certification. The importance and the need to create mechanisms to assure the consumer that a dwelling is built according to a set of requirements, that defines a certain level of quality, it is nowadays in the fields of construction and rehabilitation of dwellings.

The difficulties connected with the implementation of a system of quality certification are related with a vast number of circumstances. These circumstances can go from the difficulty to determinate a significant number of criteria that are comprehensive enough, to the implementation of these requirements by the agents involved in the construction process.

The certification system under development follows previous work that has been developed in the fields of thermal behaviour of buildings, and the evaluation of their quality [2][3][9]. This system is based on other studies and experiments been developed in Portugal and other countries.

Close Environment Quality Evaluation		
Flat1 Gaia		
Criteria	Weight	Satisfact. Degree
<b>Possibility of choice</b>		
choice regarding dwellings in the same environment	17	3.33
choice regarding dwellings in the same building	17	2.67
<b>Circulations</b>		
car parking	12	2.00
entrance of the building	15	1.40
distribution of spaces in the building	10	0.86
access to the building	18	4.00
<b>Building equipment</b>		
storage places outside	17	1.00
bicycle parking places	11	0.00
laundry and drying places	18	2.00
multi-purpose common facilities	19	2.00
<b>Outside equipment</b>		
toddlers playground	8	2.67
children playground	14	2.67
vegetable gardens and animal breeding	10	0.00
Use-Value (UV)		374.46
		Close

Figure 2 Close environment - first floor flat in Vila Nova de Gaia, Portugal.

A strategy of implementation of a system of quality certification of dwellings, adapted to the TMAD reality, is being planned. It is important to keep in mind the complexity of the product that will be certified and the need to promote the co-operation of the various agents involved in the construction process. In order to take informed decisions to implement the certification process, the following methodology was defined:

- To critically analyse existing evaluation and certification methods of quality of dwellings;
- To characterise the more relevant aspects that influence the decision to acquire a new dwelling;
- To study the occurrence of pathologies in the housing real estate of TMAD;
- To define the certification model to be adopted;
- To define aspects to be certified and certification methods to be adopted;
- To organise actions that will lead to sensitisation of the users and all other parts involved in the construction process to the relevance of the certification of the defined aspects;
- To use QDF to implement a computer program, and use this program to test the certification process in a small universe.
- To progressively enlarge the certification process to a wider geographical universe as well as to a wider range of aspects to be certified.

Quality, being related to the satisfaction of the users, must be defined taking into account social and cultural aspects. This justifies the need for the characterisation of the preferences of the users. To characterise the preferences of the users, inquiries were made to the state agents and the builders / promoters, in eight cities of TMAD. These inquiries helped in having a better understanding of the preferences of the users, and in establishing the first contacts.

## 4. Discussion

Quality evaluation should consider the life-cycle of the dwelling, i.e. design, construction, maintenance, exploitation and demolition. The present version of QDF is focused on the design phase.

Quality evaluation of the design should take into account the implications of ageing in design decisions. The present version of QDF evaluates the quality as it is previewed soon after construction.

The first aspect involves an extension of the quality assessment to the various phases of the life of the dwelling. The second aspect is closely related with the estimation of maintenance, exploitation and demolition costs, although it involves another aspect, which is the prevision of the evolution of quality standards (e.g. 5 years after construction, 10 years after, etc.).

In the present version of QDF the temporal dimension is not explicitly modelled, i.e. the objects represent the state of a dwelling at a given moment in time. QDF can be extended to take the temporal dimension into account by modelling a dwelling at sufficiently close time intervals.

At present quality evaluation is focused in the design phase, and it is assumed that the dwelling will be well built and maintained. Furthermore no distinction is made between two design solutions which are expected to last for different periods of time.

QDF is appropriate for computer aided evaluation of quality after construction. Work is still needed in order to identify and validate the criteria to be used in the evaluation of quality after construction, and for quality certification.

## 5. Conclusions

An important objective of the Construction Observatory of Trás-os-Montes e Alto Douro is to conceive and implement an evaluation and certification system for the quality of dwellings. This work follows previous work in the area of quality evaluation of dwellings, namely the development of the Quality Dwelling Framework, QDF.

While attention is being given to the careful characterisation of the universe of dwelling users, in order to define a strategy for the implementation of the certification method, QDF is being extended in order to support the evaluation of quality of dwellings, after construction.

QDF is proving to be an adequate framework for development of computer programs that implement quality evaluation methods. These computer programs will be used to help in the promotion of a quality evaluation culture. They are expected to play an important role in the implementation, and adoption by the various actors, of a quality certification method in the region of Trás-os-Montes e Alto Douro.

## 6. Acknowledgements

I would like to thank Prof. David Blockley (University of Bristol, UK) and Prof. Artur Bezelga (Universidade do Minho, Portugal) for their support and guidance. I would also like to thank the colleagues at UTAD involved in the “Observatório da Construção”, for their encouragement and support.

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