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Automated code-checking as a driver of BIM adoption

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Abstract
Information management in the construction industry is inefficient when compared with other industrial activities. Unlike other productive activities, the construction industry is yet to develop standard formats for the representation of its products, which would allow its participants to communicate efficiently and, in some cases, automatically.
Several different information models (BIM) that represent building products partially or as a whole have been developed over the last decades. Their adoption by the community of users has been, however, scarce.
It is believed that the dissemination and adoption of these models throughout the construction industry is hindered by a cooperation problem: the cumulative benefits derived from widespread BIM adoption are clearly larger than those that can be achieved through individual adoption, while the initial direct and indirect costs are considerable. The incentives for single users to change their work processes are therefore modest.
In this context, automated code checking performed upon designs that follow standard representation formats is regarded not as an end in itself, but rather as a demonstration of the immediate benefits that can be obtained by the users who voluntarily adopt this kind of information technology.
In this paper, an information model and an application developed at FEUP are briefly presented. These tools perform automated code-checking of domestic water systems for compliance with the main national regulations.
Automated code-checking should not only provide advantages due to simplified work processes, but it should also motivate users to adopt building information models, especially in the early stages of the construction process.

1 Introduction

According to game theory, in a cooperation problem, all players can benefit by acting consistently according to the interests of the group. Paying taxes or curbing pollution are examples of cooperation problems. A key issue on solving cooperation problems is motivating players to follow a strategy that goes beyond the pursuit of selfish interests. Frequently, the players' actions are restricted by formal

rules (laws) or by incentives. Ideally, it should be commonly understood that all players will follow a cooperation strategy, even in the absence of outside interference. In other words, players should trust all others to follow cooperation strategies too [1].
In this article, the adoption of a standard representation for building products (in particular, Building Information Models, or BIM) is regarded as a cooperation problem. The impact of these models on the work processes in the construction industry is limited considering the potential benefits that could be expected from the widespread BIM adoption. For construction professionals, the risk associated with the adoption of a new representation format is considerable: on one hand, the direct and indirect costs of changing work processes are significant. On the other hand, the current *de facto* standard, the IFC model, is yet to be officially established. In the absence of external influences, the limited adoption rate of these information models is predictable.

2 Information management in the construction industry

2.1 Overview

Productivity in the construction industry is considerably lower than in the rest of the economy [2, 3]. Although the adoption of modern IT solutions has often been suggested to have an important role to play in the reduction of waste in the construction industry [4], the adoption rate of these systems remains scarce. Indeed, the construction industry has been found to be one of the least efficient activities in IT adoption [5, 6]. In Portugal, it has been shown that the use of computers in construction is less prevalent than in the rest of the economy [7].
Interoperability issues throughout the construction process are largely responsible for the inefficient flow of information between its phases (Fig. 1).

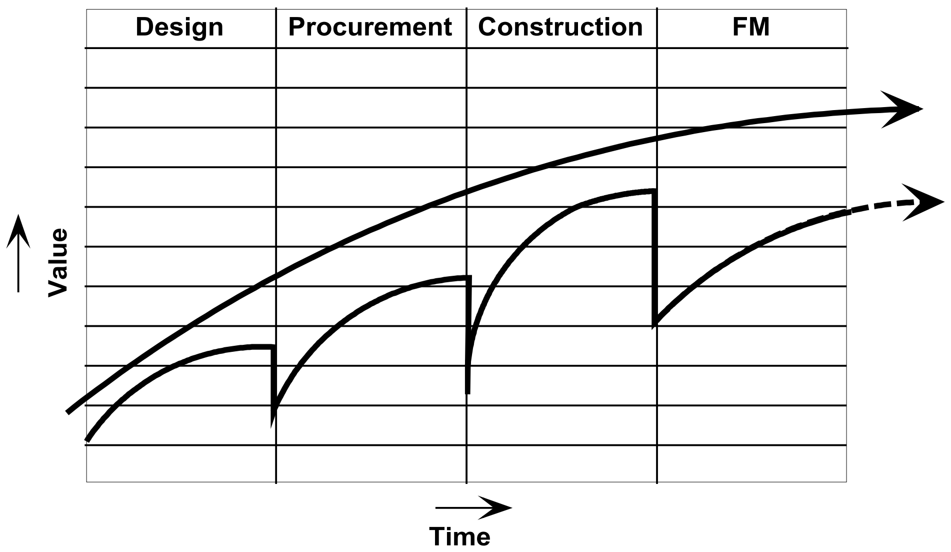

Figure 1: Value loss between phases of the construction process (adapted from [8]).

2.2 Building Information Models (BIM)

An abstraction is a view of a domain of reality where some aspects which are considered unnecessary for its intended purpose, are omitted. An information model is therefore an abstraction of the product it represents.

Construction documents, including design drawings, bills of quantities, planning charts, etc. are no more than specific views of the model. BIM based software applications can use these views as an interface to the model. In other words, the model can be edited through its views.

BIM is the application of the Product Lifecycle Management (PLM) philosophy to the construction industry. These models currently support many construction related software applications, especially building design tools. Many of these tools comply with the international *de facto* standard for representing building products, the Industry Foundation Classes (IFC) model.

According to their scope, models can be divided into “aspect models” and “full models”. Aspect models are built to suit specific requirements that are defined by users (such as structural or energy analysis). Their development usually follows a bottom-up approach [9] and only the information required by the task they are built for needs to be included. These models are therefore usually simple and they are typically evaluated based on empirical criteria: whether they are considered suitable for a specific task or not. Full models, on the other hand, are often large, complex structures that follow a top-down development path. They are developed with one main goal: interoperability. In other words, the model is built to become a representation standard for a given domain that can be used as a common language for users in that area.

The IFC is an example of a full model, the LicA model that is presented in this paper, is an aspect model that has been developed to allow the automated code-checking of domestic water systems’ designs.

Although building information models have shown the potential to address many of the interoperability issues that affect the construction industry, their adoption remains scarce. Furthermore, users who adopt BIM for design purposes, often do so as a CAD tool, not as a repository of other, non-geometrical information.

It can be said that BIM faces the same issues as other aspiring standard formats before they are accepted as such: a cooperation problem. Although all users can expect benefits from adopting BIM, since many of these benefits derive from interoperability issues, they are limited by the rest of the users’ adoption rate. The initial direct and indirect costs are considerable and may hinder BIM adoption while models such as the IFC do not achieve the status of an official standard representation format. It is therefore essential to grant early BIM adopters clear, immediate advantages in order to address this cooperation problem.

It is believed that the adoption of automated code-checking procedures may provide an important incentive to users who voluntarily choose to design according to standard representation formats.

3 Design review

3.1 Overview

The design review stage, included in the building permit application process, is an important milestone in the development of building designs since it is often at this moment that a first formal information exchange occurs from within the group formed by the actors in the early stages of the construction process (promoters, designers, etc.). At this stage, the existence of formal representation rules and procedures for drawings and written documents reduce the diversity of information contents and formats when compared to earlier phases of the design process (Fig. 2). Unlike most of the other phases in the design process, design review is a compulsory stage for new building designs.

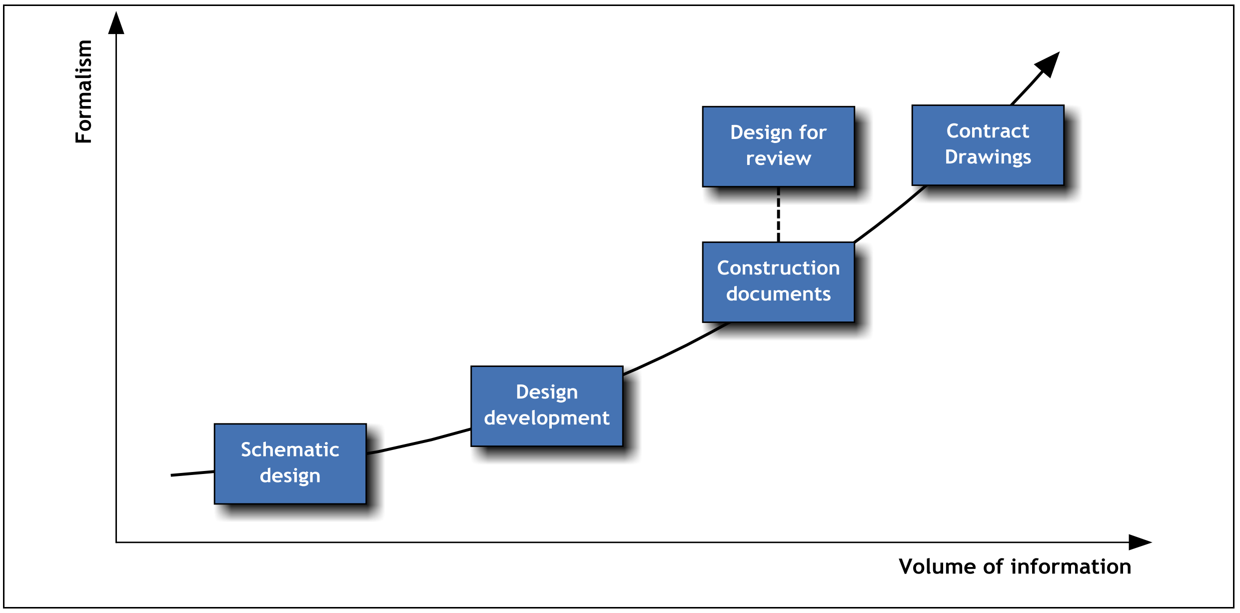

Figure 2: Creation and formalization of information throughout the design process

3.2 The importance of the design review stage in the context of information management

Although most construction projects do not have a main actor throughout the whole of the construction process, all new projects share a stage where the information that has been created must be formalized and submitted in the shape of construction documents: design review.

Many tasks that make up the design review process can be automated through the use of Building Information Models. Naturally, this leads to faster review processes for designs that are submitted according to an adequate format. The traditional alternatives should still be available, so BIM needn't be imposed on users. The advantages that might be expected by the different players in the construction process are clear:

a. Promoters will benefit from a quicker design review process, besides other advantages related to the use of BIM.
b. Designers will avoid the preparation of the documents that are usually necessary for design review (the model itself will suffice). They will also benefit from a transparent review process that can be simulated before the design is submitted.
c. The entity responsible for performing design review will benefit from a simpler, shorter, less human resource-intensive process. The automated procedure needn't be definitive. All computer generated verdicts can be changed manually so that non-compliances that are considered non-critical or that can be solved at a later date can be waved.

It is believed however, that the overall advantages that can be expected from the voluntary adoption of standard representation formats go beyond the efficiency gains that are listed above. Indeed, automated code-checking procedures are viewed, not as an advantage in themselves, but as a catalyst for BIM adoption, particularly in the early phases of the construction process.

The construction industry is composed largely of very small companies that seldom establish durable business relationships amongst themselves. Building projects are generally not supervised by entities that have the power to define the format of the information systems that will support the exchange of information along the construction process. In the absence of such an entity, it is considered that the design review process may play an important role in the definition of representation formats for building products: only designs that comply with standard formats can be accepted for automated review.

Several international initiatives on the automation of code-checking procedures are currently being undertaken, including the SMARTCodes and CORENET projects. The development of a fully automated procedure is an important goal of the BIM community that should not, however, be achieved in the short term [3].

4 LicA

In this chapter, a set of tools developed at FEUP [10] is briefly presented. These tools automate the code-checking process of domestic water systems according to the main Portuguese regulations (DR nº 23/95).
Three important requisites must be met in order to establish a new code-checking procedure:

a. To develop or to settle upon an existing, suitable format for the representation of building products;
b. To develop code-checking algorithms that are compliant with specific building regulations;
c. To develop or to adapt existing graphical user interfaces (GUI) that are compatible with the representation formats.

During the development of the LicA code-checking tools, all three of these requisites were addressed. In this case, the representation format, the code-checking algorithms and the GUI were developed from scratch.
The general outline of the LicA model and its connections to upstream and downstream software applications is presented in Figure 3. These applications can be accessed by different kinds of users, both for designing domestic water systems and for verifying their compliance with national regulations.

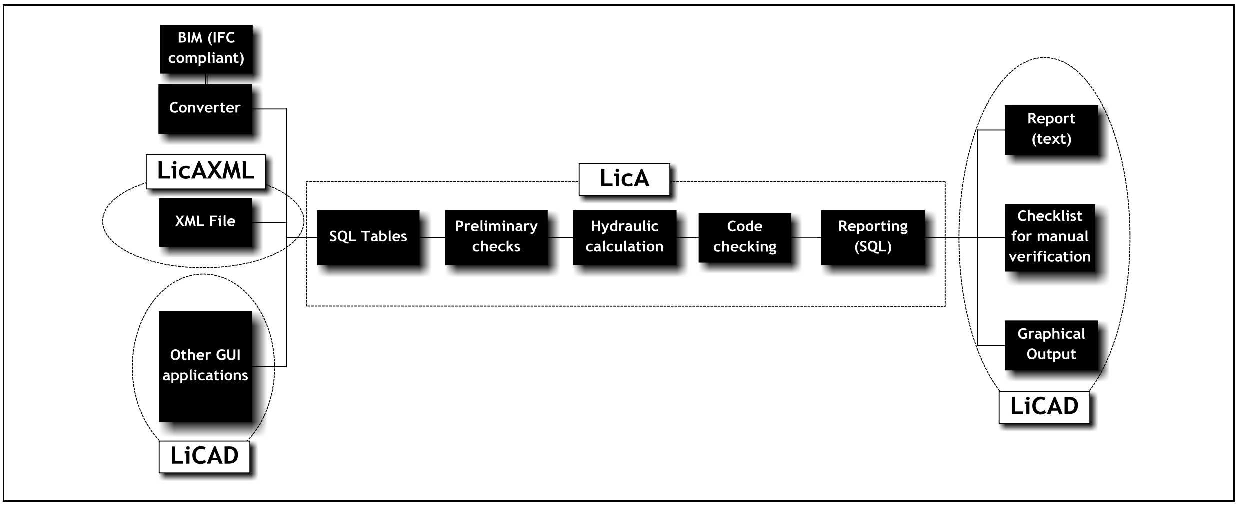

Figure 3: General outline of LicA and its connection to other applications

The LicA database is the main component in the toolset. It contains a set of tables that describe the domestic water system (its physical components and their relevant properties) and modules for hydraulic calculation, code-checking and reporting. All of these items are contained in a single SQL database.
The LicAXML specification has been obtained directly from the structure of the tables in the LicA database. This specification allows the exchange of design information between the designer and the entity that performs the code checking. The submission of design information is performed using the XML standard format.

LiCAD is a graphical interface through which the user can access LicA database functions indirectly, both for designing and for code checking purposes (Fig. 4). In short, besides editing and browsing functions, this application allows designers to check the compliance of domestic water system designs with national regulations before submitting them to the authority having jurisdiction. This application renders graphical representations of the networks, both in 2D (plans, elevations, etc.) and 3D (isometric projections, perspectives, etc.) and other construction documents (bills of quantities, technical specifications, code-checking reports, etc.).

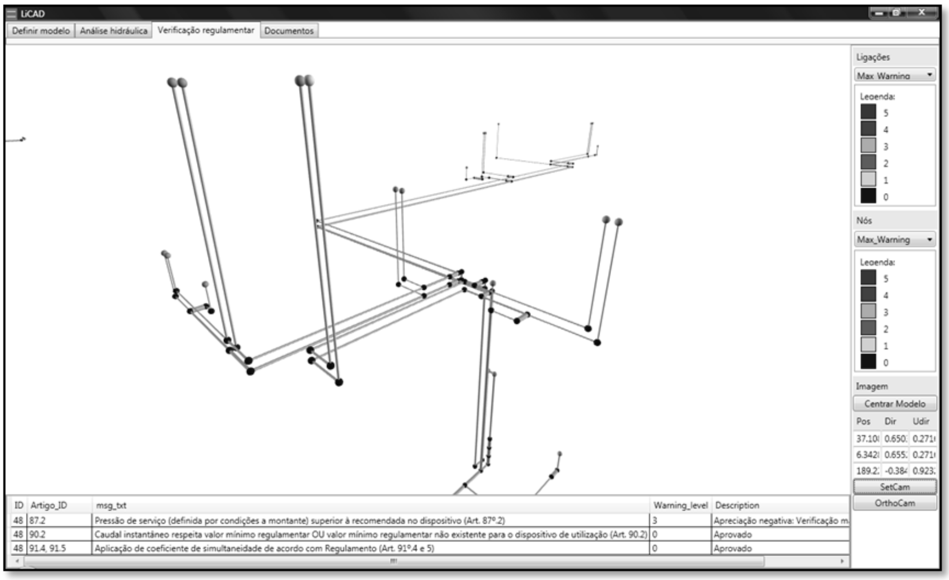

Figure 4: LiCAD. Graphical output of code checking results [10].

A full description of the structure of the LicA database and the LicAXML specification can be found in the original source [10].

The connection of the LicA database to the IFC model is the aim of a study currently undertaken at FEUP. Preliminary conclusions show that the models are only partially compatible and that the IFC model does not contain all of the information required by an automated code-checking process according to applicable Portuguese regulations. Extended compatibility may be achieved through the use of IFC Property sets.

5 Conclusions

The cooperation problem that has delayed the adoption of Building Information Models can be addressed through the use of aspect models designed for specific tasks such as automated code-checking. These models should result in immediate, evident advantages for the users that choose to adopt them voluntarily.

It is believed that the *ad-hoc* standard formats should be complemented with narrower scoped aspect models that aim to address specific information related tasks along the construction process.

The model presented in this paper demonstrates that automated code-checking procedures can be successfully applied to domestic water system designs. These procedures are transparent and auditable. Although automated code-checking of building designs is an ambitious goal, it can be achieved in the short term in some domains.

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