APPLICATION OF AUTOMATED CODE CHECKING IN BRAZILIAN BUILDING REGULATIONS

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ABSTRACT

Nowadays Architecture, Engineering and construction (AEC) companies and governments have effective opportunities to use automated checking of design data due to the increase of development and use of Building Information Modeling (BIM) based applications. These applications make the verification work possible because they are based in models containing non-geometric data in addition to the three-dimensional data. Another advantageous feature is that a BIM application can gather information of any sort from a project, once a comprehensive set of information is an attribute of a well-structured BIM model.

This paper presents possible ways to use automated code checking in the process of design approval of new buildings in Brazil. Experiences occurring abroad, such as Singapore, Australia and the USA are used as reference for this work. One item of the São Paulo city building code is taken as an example (the verification of the minimal width of elevator halls) and adapted to be used in other state capitals of the country. The result shows that the effort required for the automation can be shared between cities. Among the benefits of using automated checking are the reduction of verification time along the design elaboration and the government approval phase.

Keywords: BIM; code checking; automation; building code

1. BIM MODEL FOR AUTOMATED CODE CHECKING

The search for automated checking tools is older than the so called Building Information Modeling (BIM). The idea has emerged with the usage of computer for design purposes, which has begun in the 1960´s (Eastman, 1991). The initial studies where focused in structural analysis and fire scape regulations. Some examples where published in technical journals in the USA (Saouma, Doshi and Pace, 1989; Dym et al., 1988).

The development of the building information model concept has facilitated the extraction of useful information of the model, as can be seen in figure 1. This occurs because the model may contain non-geometrical data, as well as geometrical data. Nowadays, the information in the model is based in the construction industry and no longer in pure geometry. A door is a building object that has specific characteristics and behavior towards other elements and not just lines grouped together. This results in more organized and therefore more accessible information.

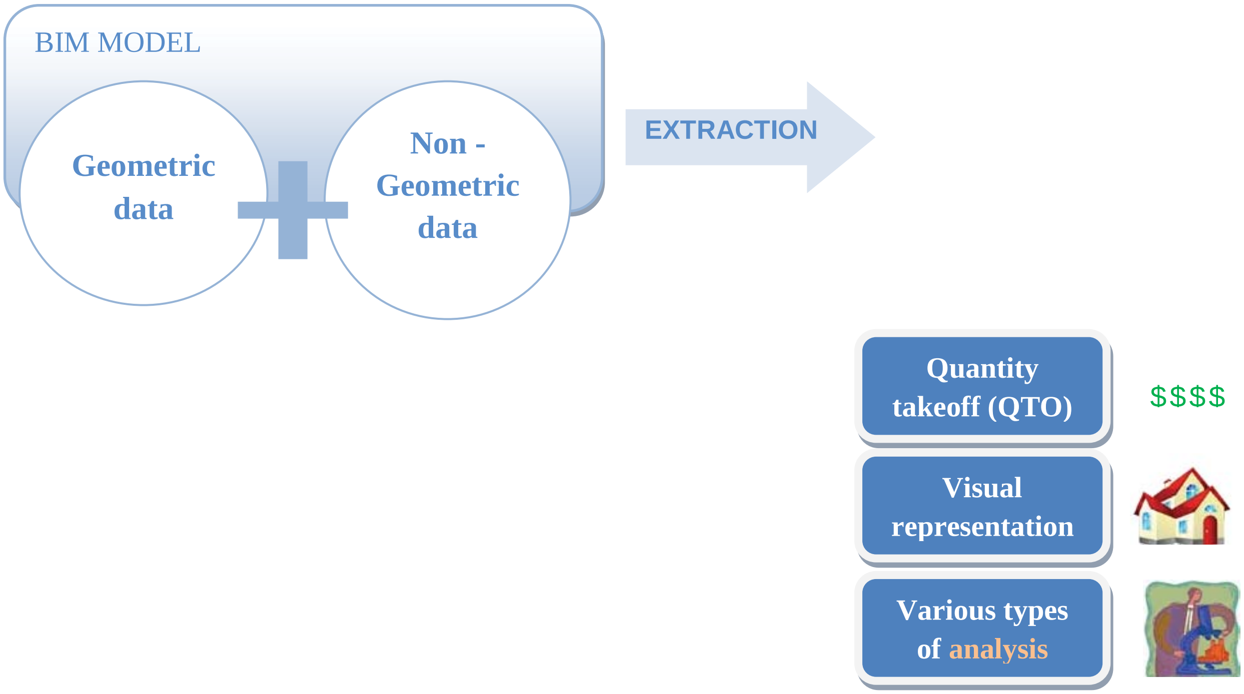

Figure 1: Some products extracted from the BIM model

The benefits of the BIM concept applied to the automated code checking are consequence of the three characteristics listed below:

1. The tridimensional model allows verification in the three axis (X, Y and Z), at the same time;
2. Although it is not always possible, it is intended to be a single model, containing all the information regarding a building. This prevents and diminishes errors caused by redundancies or incompatibilities;
3. The association of non-geometric information allows other types of verification, beyond space validation.

Also, the initiative of the International Aliance for Interoparability (IAI), currently known as BuildingSMART, cannot be ignored. It has developed the IFC (Industry Foundation Classes) model, which is one of the most known exchange model for the BIM tools that is open to the public. The IFC is an organized model which arranges the information in order to facilitate exchange, minimizing the errors. The model is in constant review and its capabilities of representation and information storage are growing (Ferreira, 2005).

This is an important effort regarding automated code checking because it allows models made by any BIM tool to be exported in a format that can be used by analyzing tools, such as SolibriModelChecker or Jotne EDModel Checker.

Examples from countries like Singapore, Australia and United States are briefly described in the next item.

2. OTHER COUNTRIES EXAMPLES

Three experiences related to automated code checking were selected to be described and to be analyzed below: Singapore and its COREnet program, Australian tests for automated code checking of the code 1428.1 and the American experiences of the General Services Administration (GSA). The selection has taken into account the phase of development of each experience and the literature available. Eastman et al. (2009) have a broad explain of five efforts in the area.

The first significant government investment in a program of code checking automation came from Singapore. This effort was part of the so called Construction and Real Estate Network (COREnet) program, which was a part of a greater initiative in the IT area. The CoreNet was officially launched in 1995. A part of the program focused in the development of automated code checking verification through the e-Plan Check system (Khemlani, 2005). The goal of the project is to check models for inconsistencies regarding the building codes and general code compliance. Some examples of checking are listed in (Eastman et. al., 2009).

In the beginning of COREnet, initial studies were made using “feature based computer aided design” (Khemlani, 2005), but in 1998 the IFC was adopted as the building information model used for project development (Eastman et al., 2009). The e-plan check program uses software specially developed for the program, called Fornax, which adds more information to IFC objects (Eastman et al., 2009; Khemlani, 2005). This was needed because not all the information required to perform the rule checking was available through the IFC model.

After about ten years of study and development, the COREnet has been tested between the years of 2004 and 2005, being finally put in use for some building types after 2006 (Lin, Fatt, 2006). Today it offers an online verification tool which gives back results of the checking through a report in the website of the e-plan check program (Eastman et al., 2009) for registered architects and professional engineers (Lin, Fatt, 2006).

According to information provided in the study performed by Eastman et al (2009), approximately 92% of the building code rules and 77% of the general code compliance is verified through the program, stating its amplitude.

In Australia the experience was divided into two phases and funded by the Cooperative Research Centre for Construction of Australia, with the participation of other local entities (Eastman et al, 2009).

During the first part of the project, the selection of the software to be used in the project was made. The Solibri Model Checker and the Jotne EDModelChecker were evaluated and the latter was chosen due to its more flexible editing and writing of new rules (Eastman et al, 2009).

The intention of the Australian initiative is to automatize the verification of the Australian accessibility code: 1428.1 – General requirements for access – new building work. Due to this objective, it was named DesignCheck. The second phase of the program consisted in writing the software based on all the contents of the code. Today it can also be used to check the compliance to the “New draft access code for buildings. Part D – Access and egress” (Ding et al. 2006) which was, in 2006, released for public comments.

The program uses the IFC building data model, which is imported in the EDM base software and then transformed in a Design Check internal model. This is necessary because the IFC model database does not have all the objects required for the code checking.

The report is generated in a user interactive page, which allows the selection of the report by clause and facilitates the analysis by the user (Ding et al, 2006).

Until 2010 the project was still in test phase for implementation (Greenwood et al. 2010) in private and public design organizations.

In the USA, the effort made by the General Services Administration (GSA) is of great interest. The agency is responsible for assisting the administrative services of the federal government of that country. Its Public Building Services (PBS) is in charge of the public buildings maintenance.

The GSA has been studying automated code checking since 2003, through its BIM study project called 3D-4D Building Information Modeling (Eastman et al, 2009). One of the projects, called Spatial Program Validation, is the development of a tool for automatic verification of space compliance in courthouses according to requirements of the PBS Business Assignment Guide. The program uses the Solibri Model Checker software as its base.

One of the goals of the Spatial Validation Program is to check the area in accordance with the directives of the guide. The program uses the names of the spaces in accordance with the Business Assignment Guide definition and the program first scan the models to verify if there could be problems related to modeling and naming definitions (Eastman et al, 2009) and then start the checking of spaces.

More information can be found in the GSA BIM Guide Series 02 (GSA-USA, 2007). Since 2007, all the new projects submitted for approval of the PBS must pass through the Spatial Validation Program check (Eastman et al, 2009; GSA-USA, 2007).

Another important project is the Design Guide Checking, which checks the spaces validating circulation and security organization through its Design Assessment Tool (DAT) and it is based in best practices available in the US Courts Design Guide (CDG). The analysis is based on graphs generated in the model and crosschecked with the needs of the CDG. This program has been applied in most of the Courthouses projects analyzed in US and is about 90% automated (Eastman et al, 2009).

Brazil is also developing a project for the electronic integration of information and necessary services regarding the approval of engineering and architectural projects called Construction Licensing System (Sistema de Licenciamento de Obras – SILO) (Grupos de Estudos Urbanos, 2012). The program was started in 2009 with the prevision of end of its test phase in 2010. Although the program has the support of the Ministry of Development, Industry and Exterior Commerce, until the conclusion of the present paper there were no reports on its progress.

3. APPROVAL PROCESS IN SÃO PAULO CITY

For a better understanding of Brazilian reality, in this item some steps for the project approval process in São Paulo city are listed and commented.

Nowadays, the approval process in the São Paulo city municipality is done by submitting the printed design documentation and other documents to the Edifications Approval Department, a section of the Secretariat of Habitation and Development. If one wants to get started in the procedures of the approval process, there is a guide with the steps to pursue in the department´s webpage in order to guide the public (Prefeitura de São Paulo, 2012).

The main activities and procedures in each step are as following:

- Step 1: gathering of the documentation of the plot, including the title of property and also the “matrícula”, a document which contains the description of the plot limits and localization;
- Step 2: definition of the activity (residential or non-residential) or use for the plot, according to the 45.817 municipal decree (Prefeitura de São Paulo, 2005);
- Step 3: based on the definition of the activity, one should verify the legal urban restrictions that may apply. These restrictions are mainly based on the city zoning law and the type of road in which the plot is located. Also is necessary to verify other laws that may apply or the existence of urban operations, which are subject to different regulations;
- Step 4: definition of the type of intervention to be executed (new construction, renovation, regularization, small renovation, and change in use or project amendment). It is recommended in this step to start consulting the city building code;
- Step 5: gathering of other required information data. This represents, in practical terms and for most projects, the solicitation of a technical file, emitted by the city government. In this document there are information regarding the existence of a public improvement project in the area, if the plot is in an environmental protection area, if it is around a protected building or neighborhood, near an airport or in special zones or inside a urban operation perimeter. If one of these conditions apply, then it is necessary to consult other specific legislation;
- Step 6: if a project is defined as special, due to its size, use or impact, some other documents may apply. These projects are submitted to the analysis of other departments, besides the Edification Approvals Department;
- Step 7: presentation of the building design. It is indicated to be in sheets of paper folded in the A4 size (297x210mm). The drawings should contain a planialtimetric survey of the plot and also plans, sections and elevations;
- Step 8: Gathering of all the needed documentation for each type of permit desired and start of the legal approval process.

The time for analysis stipulated by the city building code, represented by the law nº 11.228, of June 25th 1992, is of 90 days (Prefeitura de São Paulo, 1992) but it is known that in practical terms that period is not met for bigger projects, like real estate ventures of more than one tower. The time is prolonged due to various documents called "comunique-se" which could be compared with the "requests for information" used in USA. Each "comunique-se" has an average time of response of one month and there are no limits for its emission by the Edifications Approval Department.

Most "comunique-se" emitted are caused by the lack of or incoherent information presented in the project design. These types of requests for information can be responsible for delays and rework to the government and others involved in the approval process, like architects and owners.

Also, it is important to consider that the approval process in the city requires the knowledge and compliance to more than one law in use. Beyond the city building code, the approval of the municipality include the verification of zoning, environmental, historical heritage and other specific laws.

After these analyses, it is also necessary the validation of the project through, at least, the state fire department and water and power companies, illustrated in figure 2 . Some of the requirements to be fulfilled by the design are the covered by more than one law or guidelines, or have different understandings. Examples of this condition are items 12 (Circulation and security) and 15 (Installation and storage conditions for chemicals, flammable and explosives) of the São Paulo city building code, which are also analyzed by the State Fire Department. There is no official document to indicate, in case of conflict, which should be taken as valid. These types of conflicts are another source of delay in the building approval process.

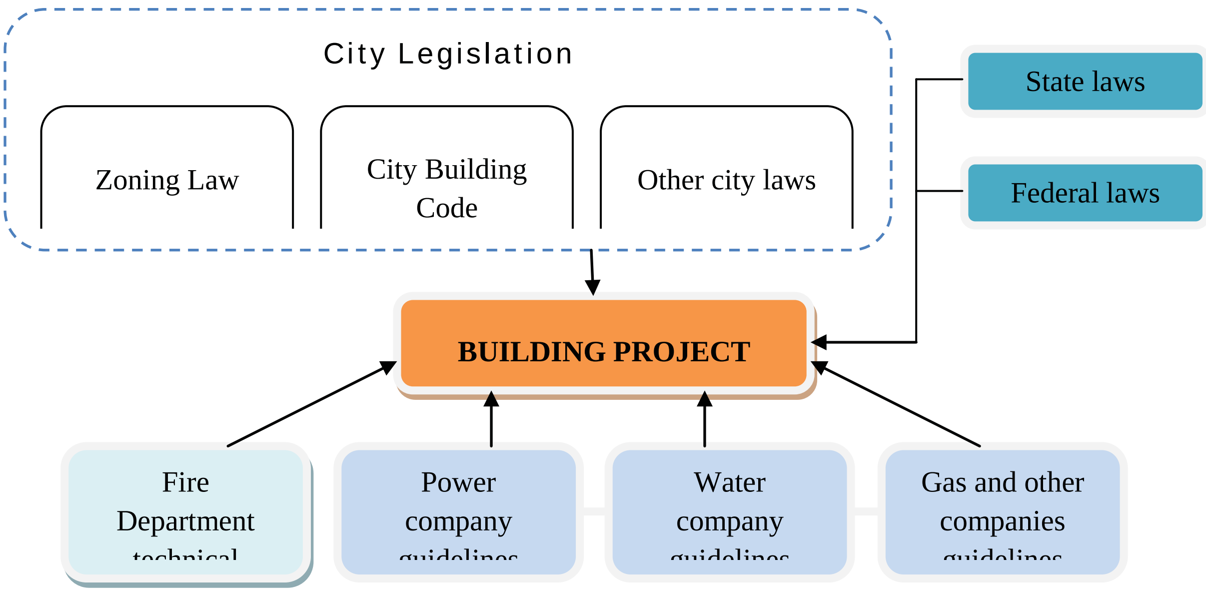

Figure 2 - Scope of analysis of a building project approval process

Although the compliance to national standards is not a direct requirement, São Paulo city building code indicates that they should be attended in the design through the use of references in multiple articles of the law. In this regard, the city of São Paulo has a brief experience with an automated checklist of a Brazilian Standard for accessibility, the ABNT NBR 9050:2004 – Accessibility for edifications and urban furniture, spaces and equipments. The checklist was automated in an application available for download in the municipality online site and is called "Vistoria eletrônica" (electronic survey). The information has to be manually entered in the software, based in the design or existing building space and, after processing the compliance to the code of reference, it generates a report about the accessibility conditions of the analyzed entity. The program was part of an effort to multiply the number of agents to verify the accessibility conditions of various establishments throughout the city. The agents had to undergo a course about the ABNT NBR 9050:2004 standard and, together with the aid of the checklist perform the analysis. After completion, the report generated is submitted to the municipality for providences and documentation.

The city building code is the main reference for the design in a edification project. In São Paulo it is expressed by law nº 11.228, of June 25th 1992 and contains some administrative orientations, regarding the documentation needed for each type of permission, orientations for the construction site and, finally, the design and space configuration necessary for the building. More specifically, the information needed for the design can be found in items 8 through 16 of the code, which are:

- Item 8: use of edifications;
- Item 9: components: materials, constructive elements and equipments;
- Item 10: building site configuration – sunstroke and aeration of buildings;
- Item 11: compartments;
- Item 12: circulation and safety;
- Item 13: parking;
- Item 14: sanitary installations;
- Item 15: installation and storage conditions for chemicals, flammable and explosives;
- Item 16: specific complementary demands.

After analysis performed in the above items of the code, it is clear that some of the articles contain information that could be use for an automated code checking routine. These selected articles have clear and specific information that could be transformed as a rule and applied to the model. Based on this assumption, one article with this characteristic is taken as a case study to be automated and, then, compared with other capital cities of Brazil.

4. EXAMPLE OF AN AUTOMATED ITEM OF THE CODE

To best understand how an analysis of automated code checking works, a practical test, used as a case study, was performed in a modeler. The modeler chosen for this study was Vectorworks™ due to software availability and the familiarity of the authors with its programming language (Vectorscript, which has a Pascal language basis). The item chosen for the study was the 9.5.5 of the São Paulo building code, which reads: “The circulation spaces bordering the elevator doors, in any floor, must have dimension not bellow 1,50m (one and a half meters)” (Prefeitura de São Paulo, 1992). This article was selected because it has clear specifications and the elements involved could be easily defined (elevator, elevator door, hall space).

The study was developed in two phases. The first phase involved the conception and scripting the rule in order to work with simple elements. The second phase consisted in applying the code in a more complex model, to verify the appliance and performance of the script. The model used in this phase is a 4 storey building, with four apartments in each floor and a common hall for the apartments, the elevator and the stairs, as shown in figure 3.

The solution for the automation was based on developing the script on Boolean operations with a 3D volume that could represent the space needed in front of the elevator door. If and interference with the minimal space required is found, a locus is placed in front of the problematic elevator door, as seen in the Figure 4.

The tests performed show that an alternative to analysis software can be achieved, for simple cases, inside the modelers. This can be done by using software development kits and computer programming.

Architects and other designers can benefit of tools, inside modelers or with specific software, to assist in design and space conception decision making, before submitting to government analysis.

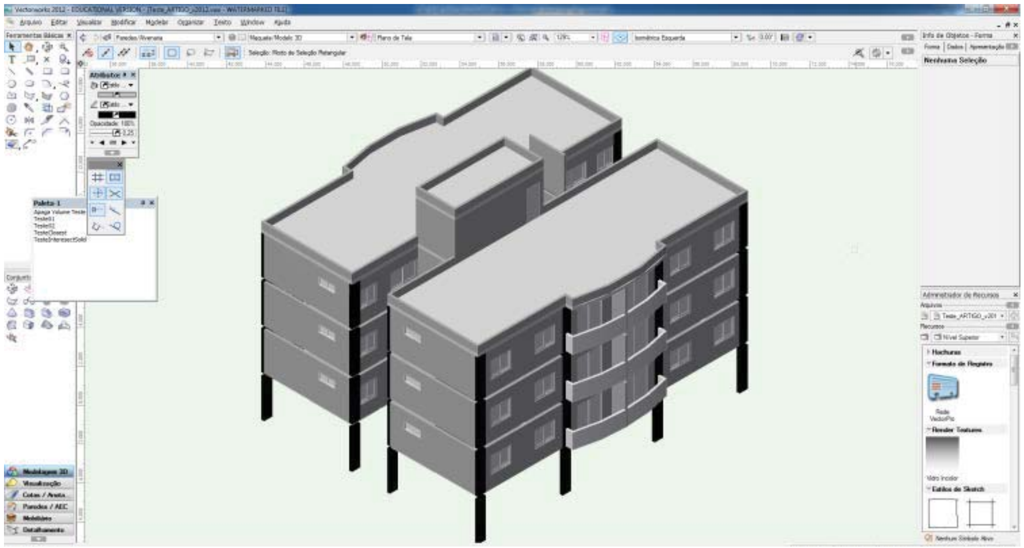

Figure 3 - Model for tests in phase 2 (building perspective)

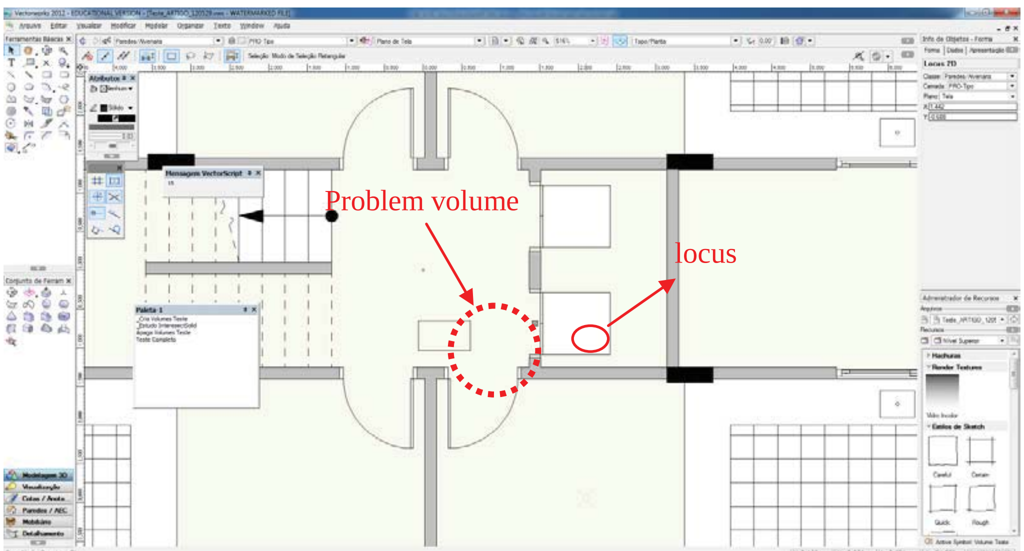

Figure 4 - Test result with a 'locus' in front of the problematic area

Appliance of the automated item using other city codes in Brazil

The effectiveness of automated code checking can be confirmed by the international experiences related in item 2 of this paper. Based on those experiences and after the study of a specific article of the code, a broader analysis of building codes of Brazilian state capitals was performed. This research was conducted to verify the existence of clauses about the elevator hall width, the case of the article studied in the previous item of this paper, among other Brazilian cities. The analysis was performed in the 26 state capitals of Brazil and the federal district and resulted in Table 1. In this compilation the similarities of the city regulations for the analyzed item are clear. All the city building codes used for the research are available online for public download, with the exception of the city of São Luis.

Besides the city of São Paulo, other seven cities (or approximately 26% of the total analyzed) share the same minimal space for elevator hall regulation, one of them (Campo Grande) with some reservations. Therefore, the automation verification developed for one of them can be used by all. Among the other building codes encompassed by the study, it can be identified two variations and one combination of them:

Table 1 - Summary of the building city regulations for minimal space for elevator halls

City / State	Minimal width necessary for elevator halls according to current city legislation				Other considerations
	Commercial		Residential		
	Ground floor	Other floors	Ground floor	Other floors	
Belém / PA	1,50m				
Campo Grande / MS	1,50m				When grouped with stairs the necessary space is augmented
Fortaleza / CE	1,50m				
Macapá / AM	1,50m				
Maceió / AL	1,50m				
Manaus / AM	1,50m				
São Paulo / SP	1,50m				
Vitória / ES	1,50m				
Goiânia / GO	2,00m	1,50m	2,00m	1,50m	
Palmas / TO	2,00m	1,50m	2,00m	1,50m	
Teresina / PI	2,00m	1,50m	2,00m	1,50m	In case of non residential buildings add 30% more space for each extra elevator
Boa Vista / RR	2,00m		1,80m		
Cuiabá / MT	1,50m		1,20m		
Salvador / BA	2,40m		2,00m	1,50m	
Porto Alegre / RS	2,00m		1,50m		
Florianópolis / SC	See other considerations				Minimal dimensions vary according to the area and floor. See specific chart in city legislation
Rio de Janeiro / RJ	See other considerations				Minimal dimensions vary according to the area and floor. See specific chart in city legislation
Aracaju / SE	No direct citation				
Belo Horizonte / MG	No direct citation				
Brasília / DF	No direct citation				
Curitiba / PR	No direct citation				
João Pessoa / PB	No direct citation				
Natal / RN	No direct citation				
Recife / PE	No direct citation				
Rio Branco / AC	No direct citation				
Porto Velho / RO	No direct citation				
São Luis / MA	The state legislation was not available in the city electronic webpage				

Source: City building codes available to public online

- Code variations by building usage;
- Code variations by building floor;
- Code variations by building usage and building floor.

In the case of variations by building usage, some cities stipulate different hall width values for residential and commercial use. To accommodate this change, it can be programmed in the developed script to ask for the building usage before verification. Depending on the answer provided, the routine applied takes a number for parameter, but the bases of the code written may remain the same.

In the case of variations by building floor, the value for some cities varies for the ground floor. This can be justified because of the greater people flow. Here, the script developed for São Paulo city has to identify the ground floor and apply a different detection value. It has to be clear for the user of the application to specify the same name that the script searches for the identification of the ground floor. These cases represent about 11% of the total analyzed.

Other cases are a combination of both variations, that is, the minimal width necessary for the elevator halls varies according to its usage and the floor it is located. For this, the routines applied to the cases described above are used as the basis for a combination of scripts that could encompass both needs: the indication of the usage of the building by the user as a part of the routine and the search for a specific floor. These cases represent about 15% of the total.

The cities of Florianopolis and Rio de Janeiro prescribe a series of charts that represent the needs of the elevator hall width specification. These account multiple variables that may require more careful transcription, so that one does not interfere with others.

Nine of the 27 cities analyzed do not have any specification regarding minimal width for the elevator hall in its city building codes. The building code of one of the cities was not available for electronic download and could not be analyzed in time for the completion of this paper.

Therefore, it can be implied that the routine for automated code checking of the elevator hall width proposed in this article for São Paulo city can be used, with some minor alterations and improvements for the verification of other 14 cities selected for the study. This represents about 55% of the total analyzed and can indicate that the efforts may be divided between cities.

5. CONCLUSIONS

Automatic code verification can be used as means of improving the approval workflow and also as minimizing rework during design and approval phases. Government and public efforts made by Singapore, Australia and USA prove that this intention can be read as a trend. Architects and designers can profit from these type of analysis with the objective of reducing incompatibilities with local regulations and, therefore, rework and delays in the approval process.

The use of automated code checking methods in Brazil is still restricted to some check lists and studies in progress. On the other hand the amount of ventures launched in Sao Paulo city has increased in the past years (SINDUSCON-SP, 2012) and, as a result, the quantity of labor imposed for its analysis has augmented. Also the guidelines and requirements necessary for a project design are spread through diverse agencies, some in conflict with others, causing other delays. The São Paulo city item used as an example is just one of the many items of the code that can benefit with automatic verification technics; this initiative should be considered in order to accelerate the analysis performed by the municipality, along with efforts to simplify and manage the different guidelines and law conflicts.

Finally, through the example of item, it is shown that building code regulations may share similarities among cities in Brazil. These could be used for the development of a common effort to share experiences and, maybe, even the rules and scripts. The combined effort of municipalities can minimize costs and human resources needed to automate at least part of the building codes of a region or a country.

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