https://dx.doi.org/10.22161/ijaers.5.5.45 ISSN: 2349-6495(P) | 2456-1908(O)

Development of a Computational Tool for the Analysis of Hydro-Sanitary Designs

Rafael de Medeiros[1], Ana Maria Pallaoro[2], Silvio Edmundo Pilz[3], Claudio Alcides Jacoski[4], Marcelo Fabiano Costella[5]

[1]Universidade Comunitária da Região de Chapecó, Brasil
Email: rafaelmedeiros@unochapeco.edu.br
[2]Universidade Comunitária da Região de Chapecó, Brasil
Email: anam_pll@unochapeco.edu.br
3Universidade Comunitária da Região de Chapecó, Brasil
Email: silvio@unochapeco.edu.br
[4]Universidade Comunitária da Região de Chapecó, Brasil
Email: claudio@unochapeco.edu.br
[5]Universidade Comunitária da Região de Chapecó e Faculdade Meridional IMED, Brasil
Email: costella@unochapeco.edu.br

Abstract— *The high demand for hydro-sanitary designs to be analyzed by the public system, in addition to the long time it takes to complete such analyses, reveals that the employed verification methodology and bureaucratic procedures are obsolete. The main objective of this work was to develop a computational tool for releasing and analyzing hydro-sanitary systems, seeking to automate the process. The methodology was initiated with the creation of an electronic archive of the rules and laws pertinent to the subject, followed by the identification of the work routines for hydro-sanitary designs, the programming of the tool, the creation of an electronic repository for objects and, finally, the validation of the software through testing. As a result, the computational model will automatically retrieve project data in the BIM platform and assess information of designs developed in CAD. Based on this work, the conclusion can be drawn that the automation of the release and analysis processes of hydro-sanitary designs is possible and achievable.*

Keywords— BIM, Design Automation, Hydro-Sanitary Designs, IFC, Information Modeling.

I. INTRODUCTION

Currently, the parameterization of hydro-sanitary systems is a coherent measure to reduce the time to release design information and also for the development of the detailed design. It is hard to think of a way of improving the outdated processes in the construction industry without applying information technology. Azambuja and Antonello (2014) point out that the multiple practices and activities in the productive cycle of civil construction, characterize it as a non-homogeneous element.

The bureaucratic procedures in public bodies and the deadlines for the analysis of hydro-sanitary designs - in addition to the architectural and other complementary designs - are costly and outdated. This is due to the high amount of designs that need to be analyzed and also the methodology applied by the analysts. Each design is analyzed individually based on the drawings submitted with the legal documentation. The intrinsic information of the design contained in its electronic files is disregarded at this time. It is therefore necessary to search for automated means to provide consistency between the filed designs and their examination procedures.

BIM (Building Information Modeling) has become a central topic for the improvement of the AECOO (Architecture, Engineering, Construction, Owner and Operator) industry throughout the world (BRADLEY et al., 2016). Because of the importance of the already developed documentation, the quickly maturing technology for the construction of information modeling provides an object-oriented information integration platform (Park; Cai, 2017). However, most AEC (Architecture, Engineering and Construction) domains store their information about a design in text documents or use object-related or oriented XML formats, which makes it difficult to integrate information (Niknam; Karshenas, 2017).

The main objective of this work was to develop a computational tool for releasing and analyzing hydro-sanitary systems, seeking to automate the process. Based on this model, a Design Science Research sought to create a software containing the normative guidelines that interpreted the information of designs developed in CAD

https://dx.doi.org/10.22161/ijaers.5.5.45 *ISSN: 2349-6495(P) | 2456-1908(O)*

and automatically extracted data from the designs in the BIM platform.

II. THEORETICAL FRAMEWORK

2.1. Design development in civil construction

The application of computing in design development was a great milestone in the history of civil construction in the 1990s. Nunes and Amorim (1998) address the introduction of IT culture in the design sector at this time, which brought new demands and significant changes in the profile of its professionals. The lack of specific knowledge relating to organization, management and strategy was notorious, among other production shortcomings. Along with the productivity gains, therefore, the need for employee training and investments in equipment upgrades also grew.

Kurak Açici and Sönmez (2014) emphasize that the existence of this technology is one of the most important inventions of recent years. The introduction of computers in the design process and the CAD (Computer Aided Design) concept has created new demands for the training of professionals and consequently enabled their qualification. Despite the limitations, Grau and Wittchen (1999) already proposed alternatives to expand and improve the interactions between design elements based on this technology. These extensions would be possible through the compilation of basic technical information for the production of new elements. The CAD tools therefore proved to be drivers of the design development reality, with a high potential for improvement.

The reference in this context of computerization of civil construction is CAD. Originating in 1950, it is an automated foundation for the release of graphical design elements, which are manipulated and interpreted by the computer operator. Together, this information constitutes the entire drawing representation of an engineering design. Nunes and Amorim (1998) emphasize the interactive capabilities of the graphics information in CAD systems.

The lack of mechanisms of a human and operational nature to ensure consistency between what is represented in the computer and what the design represents in technical and quality terms, was notorious. According to Santos (2014), design companies need a modeled system for product development that allows for a global vision of this product. BIM modeling, described below, presents itself as a consistent alternative for the reduction of errors in design interfaces.

According to Eastman et al. (2008), BIM is a modeling technology combined with a set of productive, communication and analysis procedures of a certain construction model. Through this technology, it is possible to design and operate three-dimensional and interactive constructions. It is, therefore, the advance of information technology combined with the design process.

Meira (2016) indicates that, along with BIM, a revolution has emerged in the business standards of the civil construction industry. All operations for the study of a design are treated in a competing manner, i.e., the design becomes more than a drawing of a 3D model and becomes an iterative process in the parallelization of tasks. Mueller (2009) explains that the integrated design development practice guaranteed by BIM, transfers effort and complexity to the initial design phases. This not only improves efficient decision-making capabilities, but also improves the timeline as design changes now have lower costs. This comparison is presented by the graph of Figure 1.

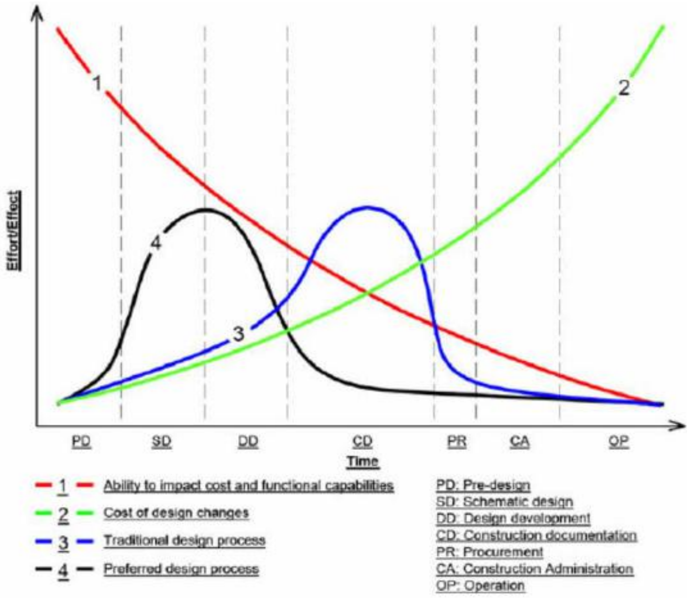

Fig. 1: Application of the BIM process and the timeline of a project.

IFC (Industry Foundation Classes) is a scheme designed to define an extensible package of consistent data representations, which is used for the construction of the information shared between AEC software. All IFC models provide an organizational structure of the design elements, enabling their layout and construction elements to be accessed (Eastman et al., 2011).

Still, according to Eastman et al. (2011), all the object information is organized in a hierarchy of: Design → Environment → Construction → Paving → Space. Each upper-level spatial structure is an aggregation of the lower levels, and also of all elements that comprise the lower-level classes. In a simplified perspective, this hierarchy allows the elements of a building to be grouped in terms of greater and lesser scope, in addition to enabling the identification of the links between them. This information not only characterizes the objects with a high level of detail, it also allows for an analysis of the structure and properties of a design as a whole or in part based on the criteria and the requirements defined by the user.

https://dx.doi.org/10.22161/ijaers.5.5.45 ISSN: 2349-6495(P) | 2456-1908(O)

The representation of IFC models in the XML language seeks to enable extraction and the validation of the IFC specification structure. According to the author, some of the objectives of the use of this language are: enable the exchange of IFC files alternatively as documents defined in XML, allow the reuse of XML content in data exchange and sharing structure by the construction industry (Jacoski, 2003).

Each one of these XML schemes is different and sets its own entities, attributes, relationships and rules. They work well to support the work of software organizations that develop applications around them. Each XML scheme, however, is different and incompatible (Eastman et al., 2011).

"The scope of IFCXML is based on the extrapolation of the currently described IFC definitions according to ISO 10303 (in the Express language) to serve as a specification scheme employing XML" (Jacoski, 2003, p. 139).

The software characterized as BIM still have inconsistencies regarding interoperability. However, initiatives to overcome these weaknesses are being developed. Sun et al. (2015) indicate that the IFC files generated from different systems often contain a huge amount of redundant information. This problem greatly limits storage based on IFC, in addition to the exchange of data.

2.2. Hydro-Sanitary Designs

Since this study was carried out in Brazil, the current regulatory framework of the ABNT (Brazilian Association of Technical Standards) was used to ensure a detailed support with regard to the sizing, operation and maintenance of hydro-sanitary installations. As discussed earlier, these standardized requirements can be compiled and applied in a design methodology.

With regard to cold water building installations, NBR 5626 (ABNT, 1998) determines their requirements, which are similar to those applied in other physical structures in the sanitation sector. This design specialty is portrayed as the connection between the public water supply and the final consumer. The standard covers the current technique and its recommendations for a successful implementation.

NBR 15527 (ABNT, 2007) presents the necessary requirements to take advantage, for non-potable purposes, of the rainwater from roofs in urban areas. The standard indicates which uses can be given to rainwater after the proper treatment. It also provides guidance on how the rainfall system should be designed, including the design of reservoirs.

With respect to effluent treatment systems, NBR 7229 (ABNT, 1993) is used for the design, construction and operation of septic tank systems. The standard sets the conditions, including those for the treatment and disposal of sewage and settled sludge. NBR 13969 (ABNT, 1997) is also used, which deals with septic tanks, complementary treatment units and the final disposal of liquid effluents.

The amount of designs included in the Brazilian bureaucratic system has increased significantly in recent years. Currently, the civil construction sector has shown extensive development and as a result, its methodological rules for validation are quite advanced. Manzione et al. (2011) shows that the inefficiency of the design process in civil construction reveals the need for improving management processes. The author also points out that BIM emerges as a solution, but it is necessary to ensure that this advance solves existing problems in the current design management configuration.

Battesini (2014) reports that projects submitted to the Sanitary Surveillance agency should include the mandatory requirements for health licensing, which focus on minimizing the risks arising from the building facilities. He also shows that the scope for the development of these designs can be expanded through the systematization of their legal requirements.

When this is related directly to the case of water storage and wastewater treatment systems, care must be taken as to the appropriate design, followed by the operation and maintenance, of these elements. All this information, therefore, must be properly specified in the designs and specifications of the building.

2.2.1. Filing and Approval Systems of Conservative Designs

As can be seen in table 1, a comparative study between three Brazilian cities (Rio de Janeiro/RJ, Florianópolis/SC and Chapecó/SC) reveals that the analysis of hydro-sanitary designs is carried out primarily through its physical documentation, such as drawings, specifications and calculation spreadsheets. Although the city of Florianópolis requires electronic files, one can see that this measure is only applied for the storing of documents and not for the evaluation of the design aspects contained in virtual platforms.

Documentation for the evaluation of hydro-sanitary designs the municipalities of Rio de Janeiro, Florianópolis and Chapecó.	
Rio de Janeiro	Descriptive file of the venture;
	Copy of the IPTU (land tax) bills;
	Copy of the ownership or property rights document;

https://dx.doi.org/10.22161/ijaers.5.5.45 ISSN: 2349-6495(P) | 2456-1908(O)

	Copy of the personal documents of the owner;
	A copy of the engineering license (CREA) of the responsible professional;
	Copy of the Technical Responsibility Statement (ART) for the development of the design;
	Aerophotogrammetric blueprint of the IPP with the marking of the lot;
	General or situational blueprint;
	A copy of the design of the sanitary sewer system (comprising blueprints printed on writing paper, complete specifications and hydraulic design spreadsheets printed in the A4 format);
	A copy of the blueprint for the building's sewage installations, including the rainwater network;
	Statement of the possibility for water supply provided by the local utility;
	Approved project of pluvial water grids and galleries (only for ventures with internal roads);
	A copy of the approved (or in process of approval) land parceling project;
	Registration of the sanitary sewer system;
	Statement of compliance for the implementation of the building installations, in accordance with the standardized model.
Florianópolis	Application;
	A copy of the receipt of payment of the analysis fee;
	Technical Responsibility Statement (ART/CREA) or Record of Technical Responsibility (RRT/CAU);
	03 copies of the calculation log (both physical and digital in pdf, recorded on cd);
	03 copies of the hydro-sanitary design (both physical and digital in pdf, recorded on cd);
	01 copy of the approved architectural design.
	Consultation of the feasibility of water supply issued by the company responsible for the sanitation services, or water analysis report for regions not connected to the drinking water supply network;
	Consultation of the feasibility of connecting to the sewer network (when applicable);
	Environmental installation license or statement of environmental compliance (in cases provided for by the competent environmental body).
Chapecó	Application for the assessment of the design, provided by the health surveillance agency;
	01 copy of the complete architectural design.
	02 copies of the complete hydro-sanitary design.
	02 copies of the complete specifications of the hydro-sanitary design;
	Technical Responsibility Statement (ART/CREA) or Record of Technical Responsibility (RRT/CAU);
	Consultation of the feasibility of connection to the water and sewage network from the local utility (sewers only in places where there is a sanitary sewage network).

Tab. 1: Requirements for the evaluation of hydro-sanitary designs in three Brazilian municipalitie

The diagram in Figure 2 represents the analysis and approval logistics of hydro-sanitary designs in Chapecó/SC. The documentation is filed with the municipal health surveillance agency and the analysis of the drawings and complete specifications occur individually and personally. If approved, the design is withdrawn in person along with its certificate of approval and follows for implementation; if rejected, the project is withdrawn in person together with the technical opinion of rejection and filed again after correction.

https://dx.doi.org/10.22161/ijaers.5.5.45 *ISSN: 2349-6495(P) | 2456-1908(O)*

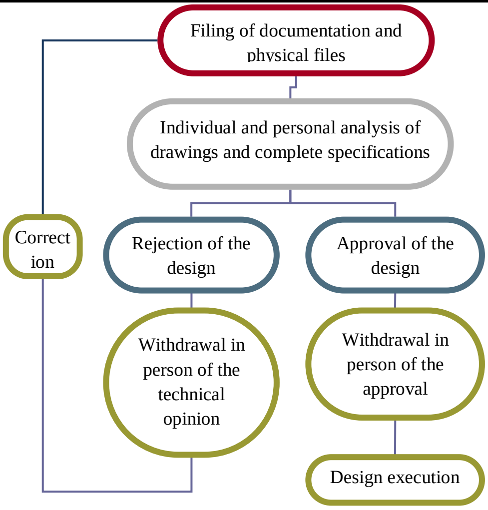

Fig. 2: Analysis and approval logistics diagram of hydro-sanitary designs in Chapecó/SC.

2.2.2. Filing and Approval Systems of Innovative Designs

There is a clear trend to incorporate innovations in the construction industry. The review of outdated procedures is combined with the application of new technologies for the development of more effective designs. In this subsection, the evolution of the Information Technology applied to the design process is presented.

The BIM Protocol of the State of Ohio was conceived to serve as a guide for the development of designs. It makes it easier for owners to apply and establish standards for the use of BIM. The protocol considers the final use of the model, allowing the owners to select the model usage category and the levels of development of the specific building components that support their buildings and the management requirements after construction. Additionally, the approval requirements during the design are reviewed (Ohio Das, 2013).

The British government is at the forefront of the development of web systems and in the leadership in the use of BIM system. It works with individual assets for their incorporation into the design and management of intelligent cities. It aims to engage partners of the European Union for the coordinated adoption of BIM. It also wants to use its leadership position to contribute to the creation and development of standards and practices (HM Government, 2012).

The 900-year-old Chapter House was chosen by the British Institute of Facilities Management (BIFM, 2015) as a pilot project to demonstrate the benefits of the BIM process for existing buildings. The historic room was transformed into a 3D model. The model will help the functioning of a world-famous, well-visited and large location and the conservation and protection of an ancient monument. The design demonstrates how digital building technology can improve efficiency in the management and operation of buildings through the transition from traditional facilities management procedures to the use of digital information and 3D models to provide greater value to the institution.

According to Wong, Wong and Nadeem (2009), in Singapore, a design submission system is being offered called "e-submission", which is part of the integrated plan verification system. This initiative is controlled by the Construction and Real Estate Network (CORENET), the main organization involved in the development and implementation of BIM in governmental projects. The construction industry in Singapore uses the technological standards of the International Alliance for interoperability.

Yang and Song (2015) summarize the role of BIM as a powerful tool for sharing information. This is done throughout the life cycle of the project, from the planning and design of the building until its construction processes. Currently, the evolution of designs in civil construction can't be conceived without the use of BIM tools. This technology covers numerous aspects required for the industrialization of the sector.

III. RESEARCH METHOD

Characterized as a Design Science Research, this study has a qualitative profile. The gathering of the information relevant to the development of the computational tool took place based on direct observation. How the effects of this application appear on the environment under study, was also observed. This way the results were obtained.

For Rocha et al. (2012), alternatively, Design Science Research is developing scientifically substantiated solutions that are able to solve real-world problems. As such, it establishes a link between theory and practice, strengthening the relevance of academic research. According to Lacerta et al. (2013, p.1), "it is in this context that a robust research method becomes indispensable to success in conducting a study".

The study was developed based on an analysis of the interaction between design development platforms, legislative parameters and literature references on the design of hydro-sanitary facilities. The proposed analyses include water storage and wastewater treatment systems for commercial and residential buildings. Treatment systems for specific sewage waste, such as agricultural or industrial waste, were not modeled.

The steps required for the development of the research will be properly described and explored in the course of this item in a chronological order. In short, however, they are related to the creation of a technical and methodological archive to create the computational tool, validate it and subsequently evaluate the obtained results.

2.3. Compilation of ABNT Standards and Municipal Laws

The first step to develop the research was the creation of the electronic archive of ABNT standards related to the

https://dx.doi.org/10.22161/ijaers.5.5.45 ISSN: 2349-6495(P) | 2456-1908(O)

design and evaluation of hydro-sanitary projects. After the gathering of these documents, they were listed in the literature review, monitored according to their contributions to design calculation parameters for water and wastewater treatment systems.

2.4. Work Systems and Design Methodologies

Next, the work routines required for the development of hydro-sanitary designs on CAD tools and BIM platforms were listed. These work structures were taken into account to assess the improvements brought about by the technological advances resulting from the use of BIM.

2.5. Modulation of the Calculation and Design Sequence of the Systems

The calculation assumptions and design guidelines gathered from the ABNT standards were organized in a chronological sequence of operation in a digital spreadsheet for subsequent inclusion in the software. In this format, key information was identified for the consistency between the standardized information and the design of the hydro-sanitary systems.

This information is entered by the user of CAD techniques in the computational tool, or it is extracted from the designs developed in BIM. This concentration in BIM occurs based on the intrinsic information of the objects in the IFC format, which allows for the reading of such aspects as shape, volume, material and other elements that constitute these objects. In the possession of the IFC data, the software evaluates whether the design is in compliance with the design parameters and standardized guidelines.

2.6. Structuring of the Tool

In order to structure the programming of the computational tool, first, the calculation routines were released, combined with the design information in the electronic spreadsheet format. The purpose of this phase was the validation of the results before the development of the program.

Next, the most important methodological step was taken, the development of the computational tool in the PHP language for web. The interactions between the application and the design files will be laid out further in this work. The tool was identified as BuildScanner, in reference to its function of scanning building projects. Its website was registered in the global domain.

2.7. Creation of an Electronic Repository

The availability of an electronic repository of hydro-sanitary equipment proved to be the most consistent measure in terms of the interoperability limitations between BIM systems. As such, the creation was proposed of an electronic library with objects of prearranged volumes, which could be read in the ifcXML language and also be classified at LOD (Level of Development). These files will be entered by users in their designs developed in any BIM software that reads files in this language. The computational tool validates whether these object choices are compatible with the calculation routines described earlier in this work.

Within each library objects, there is a geometric figure representing its usable volume, each figure received a *Pset* identification to check if it is one of the figures available in the repository. This identification also verifies if their dimensions weren't changed.

At the time of the uploading of a design for analysis, an alert screen is presented to the user to change the proportions, measurements and properties of the objects available in the repository. This warning also appears in the complete specifications generated by the tool, in addition to mentioning that, at the time of inspection of the built building, the volume will be checked according to the *Pset* code of the hydro-sanitary equipment.

2.8. Validation of the Tool

Civil engineering and architecture designs were used to test the effectiveness and applicability of the computational tool. At this time, the tool had its final interface for use by the designers. Interactions were performed between CAD designs and the information entered by the user. The automatic extraction of the intrinsic data of BIM designs was also performed.

IV. RESULTS AND DISCUSSION

3.1. Creation of an Electronic Repository

The BIM repository is made available on the website of the computational tool. Its objects were developed according to the design criteria and LOD breakdown. Drinking water reservoirs, rainwater reservoirs, septic tanks, anaerobe filters and sinks are available for download, as can be seen in Figure 3, which were ordered according to their volumes in the IFCxml format, enabling their operation in any BIM software.

This concentration in BIM occurs based on the intrinsic information of the objects in the IFC format, which allows for the reading of such aspects as shape, volume, material and other elements that constitute these objects. In the possession of the IFC data, the software evaluates whether the design is in compliance with the design parameters and standardized guidelines.

Fig. 3: BIM Repository

https://dx.doi.org/10.22161/ijaers.5.5.45 ISSN: 2349-6495(P) | 2456-1908(O)

3.2. Validation of the Tool

Three main environments will be made available to the user accessing the tool: "Designs", "Settings" and "Account". In the "Designs" environment (Figure 4), the options of a new analysis, a search tool and also a list of already analyzed designs are offered, which may be ordered according to their own information, location, building area, technical manager and status (approved or rejected).

The "Settings" environment allows the user to change criteria for the design of his systems, such as per capita consumption according to the type of occupation, cleaning interval of the sewage treatment system, temperature ranges of the design site and current municipal or national regulations. In the "Account" environment the user can change his personal information, such as his name, email and password reset.

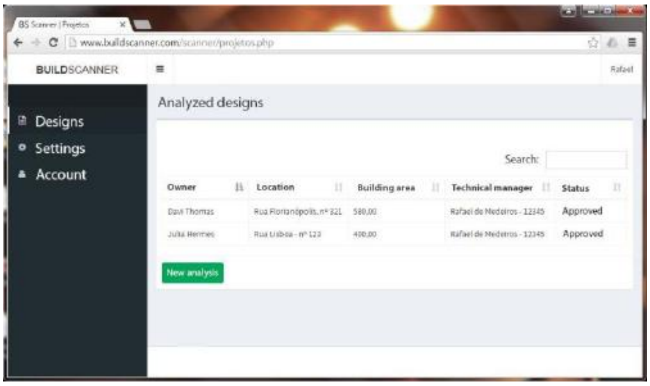

Fig. 4: Designs environment

The new analysis environment follows the model presented in the materials and methods item, and on the screen "Building Identification" entered by the user: owner name, building location, building area and technical manager with the indication of his license and registration number.

Next, on the screen "Building Information", the user can enter: land, largest floor and roof areas, in addition to the soil infiltration coefficient and the technical fire reserve, when applicable. And on the screen "Contributor Information", the user indicates the number of contributors for each type of occupation the building has.

Once this basic information has been entered, the user is directed to the selection of the type of analysis he wishes to perform, Figure 5, which are: Scanning BIM Design; Pre-design (generate results) and Printed or CAD Designs (insert measures). Then, the user determines which aspects he wants to analyze: Drinking Water Reservoir, Sewage Treatment System and Rainwater Installations.

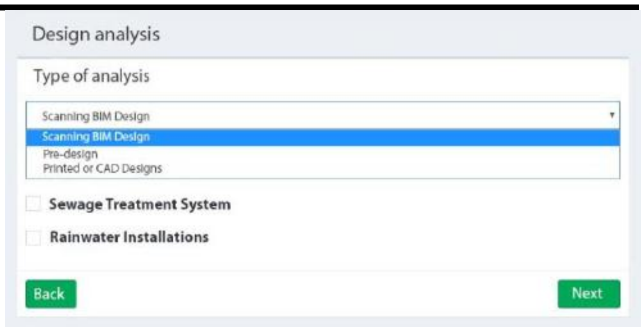

Fig. 5: Selection of the type of analysis.

3.2.1. Scanning BIM Design Panel

By selecting the Scanning BIM Design option, the user uploads the design file in the IFCxml format and informs the total area of rainfall infiltration. The other design aspects are extracted and analyzed automatically by the computational tool.

It is worth noting that the design files will be using the objects available in the BIM repository. The user includes the files in the ifcXML format in his hydro-sanitary project developed in any BIM software. He is alerted to not change its dimensions or properties, bearing in mind that the identification of the objects by the software occurs through their *Pset* codes and that this will be enforced during building inspections during and after its execution.

As a result, the user is shown a screen with the approval or rejection of each aspect of the hydro-sanitary design (Figure 6). If all objects are approved, it is possible to print the complete specifications. If there are rejected objects, the software determines the expected values for each one and prevents the printing of the complete specifications.

3.2.2. "Pre-design (generate results)" Panel

The results, in this case, are the minimum values required for each hydro-sanitary design item. The user can therefore use the objects in the BIM repository compatible with the required demand or design the elements in CAD.

In the current format, the tool does not provide the user with the possibility of adding new compatible objects in the BIM Repository. However, this is an improvement proposal for this paper.

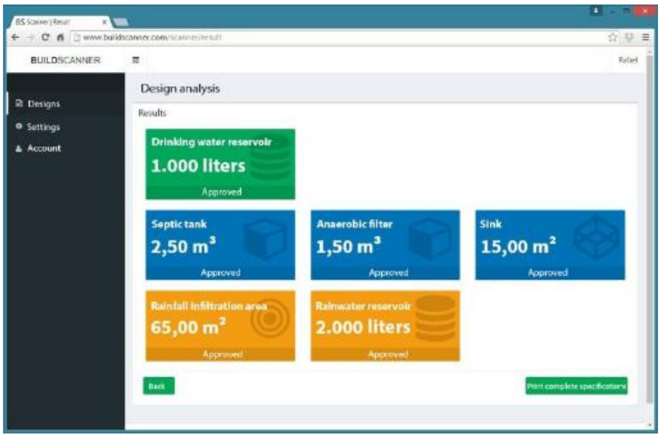

Fig.6: Result of an approved design.

3.2.3. Printed or CAD Designs (insert measures) Panel

When selecting the option insert measures, the user is shown a screen with fields to enter the useful dimensions of each object to be analyzed. If the proportions of objects are not in accordance with the ABNT guidelines, an alert for the non-compliant objects is shown.

The user can then correct this information or continue with the analysis of the design. Once the measurements have been entered, this is followed by the scope described in the item for BIM designs scanned by the computational tool.

3.3. Evaluation of the Tool

The integrated environment of the calculation logs, graphical representation verification and technical document generation decreased the margin for incompatibilities in designs of the CAD platform. The same happened for BIM, in addition to reducing the timelines of the projects, since the tool performs the automated reading of the design files.

The computational tool generated reports for the acceptance or rejection of the designs in a consistent and accurate manner. In conjunction with the approved designs, the complete specifications were also made available electronically. This way, the consistency between the software's interpretations and the user's interactions with his design is made clear.

The following can be highlighted as improvements in future versions of the computational tool:

The use of future enhancements of the IFC structure for greater extraction of information, automating the manual processes that are still necessary for the current format of the BuildScanner tool.

The inclusion of an automatic evaluation of materials and construction systems applied to the objects under analysis.

The possibility of printing acceptance or rejection reports as PDF files, for users that only analyze designs. In the current model, the caveats and approvals are presented only on the screen to the user.

Possibility for the user to add new designs to the BIM repository. Even though these objects pass through an assessment and *Pset* identification for their correct handling and interpretation in the designs.

After selecting the "Generate Results" option, the logistics could be more efficient if there was an automatic redirection of the user to the BIM repository or the "Insert Measurements" screen. This way he can continue his interactions with the tool without interruptions.

Following this research, a business plan will be developed in the technology park and the tool will be adapted to the potential peculiarities of design offices and public agencies that may adopt it, and its commercial release will be prepared.

V. CONCLUSION

Currently, the civil construction design sector is growing. Such a scenario exposes demands for the improvement of procedures and constant technological advances. Hydro-sanitary designs, in particular, are still poorly explored in terms of innovation.

Through this study, a computational tool was developed to improve in an automated way the outdated evaluation methodologies behind the launch and analysis of these systems. The results reveal ways of improving the work methodology in offices and public bodies. As a result, an electronic archive was generated of the normative guidelines and municipal laws for the design of water storage and wastewater treatment systems for commercial and residential buildings.

The tool allows for the update of the laws and legal guidelines added to the system, in addition to adjustments to the laws of other states and/or countries, which provides a universal character to the tool.

As shown, the computational tool has met the objectives proposed in its design. Means were provided for the improvement of the analysis of hydro-sanitary designs in offices and the responsible public bodies. Its ability to automate design release and analysis procedures were also demonstrated.

Based on this work, the conclusion can be drawn that the automation of the release and analysis processes of hydro-sanitary designs is possible and achievable. The scope of interaction and evaluation of designs was structured for its constant expansion, both for hydro-sanitary designs and other specialties, such as architectural, structural and electrical designs. Based on the obtained results, it becomes possible to explore the use of computational tools for other civil construction specialties.

REFERENCES

[1] Associação Brasileira De Normas Técnicas (1998). NBR 5626: Instalação predial de água fria. Rio de Janeiro, RJ.

[2] Associação Brasileira De Normas Técnicas (1993). NBR 7229: Projeto, construção e operação de sistemas de tanques sépticos. Rio de Janeiro, RJ.

[3] Associação Brasileira De Normas Técnicas (1997). NBR 13969: Tanques sépticos - Unidades de tratamento complementar e disposição final dos efluentes líquidos - Projeto, construção e operação. Rio de Janeiro, RJ.

[4] Associação Brasileira De Normas Técnicas (2007). NBR 15527: Água de chuva - Aproveitamento de coberturas em áreas urbanas para fins não potáveis - Requisitos. Rio de Janeiro, RJ.

[5] Azambuja, S. R. S., and Antonello, C. S. (2014). As práticas de trabalho e o processo de aprendizagem de trabalhadores da construção civil à luz da estética organizacional. Revista Brasileira de Gestão e Inovação, 2(1): 1-30.

[6] Battesini, M. (2014). Modelo conceitual para projetos de instalações produtivas sujeitas à Vigilância Sanitária. Vigilância Sanitária em Debate, 2 (3).

[7] Bradley, A., Li, H., Lark, R., and Dunn, S. (2016). BIM for infrastructure: An overall review and constructor perspective. Automation In Construction, Elsevier BV, 71(1):139-152. http://dx.doi.org/10.1016/j.autcon.2016.08.019.

[8] British Institute Of Facilities Management. (2015). BIM Case Studies For Asset and Facilities Management. [Online exclusive]. Time. Retrieved from http://www.time.com/time/health <https://www.google.com.br/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0ahUKEwia35CohqbRAhWMD5AKHRXrDUwQFggaMAA&url=http%3A%2F%2Fwww.bifm.org.uk%2Fbifm%2Ffilegrab%2Fbifm-casestudy-bimx3-v11-final-25.9.pdf%3Ftype%3Ddocuments%26ref%3D5709&usg=AFQjCNH9QjzTXukTGnkThWLQyrYMjLZbYA&sig2=5r5RqEasfpH9uyNGfi5u7Q&bvm=bv.142059868,d.Y2I>.

[9] Eastman, C., Teicholz, P., Sacks, R., and Liston, K. (2011). BIM handbook: a guide to building information modeling for owners, managers, designers, engineers, and contractors, 2. Ed, Hoboken: John Wiley & Sons, Inc., 650 p.

[10] Grau, K., and Wittchen, K. B. (1999). Building design system and cad integration. In: BUILDING SIMULATION, 6., Kyoto. Proceedings... [Online exclusive]. Time. Retrieved from <http://www.infohab.org.br/acervos/abstract/codigo_biblio/31151/cod/1>.

[11] Hm Government (2012). Industrial Strategy: Government and Industry in Partnership – Building Information Modeling. 2012. [Online exclusive]. Time. Retrieved from <https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/34710/12-1327-building-information-modelling.pdf>.

[12] Jacoski, C. A. (2003). Integração e interoperabilidade em projetos de edificações: uma implementação com IFC/XML. 218 p. Tese (Doutorado em Engenharia de Produção) – Programa de Pós-Graduação em Engenharia de Produção, Universidade Federal de Santa Catarina, Florianópolis, 2003.

[13] Lacerda, D. P., Dresch, A., Proença, A., and Antunes Júnior, J. A. V. (2013). Design Science Research: método de pesquisa para a engenharia de produção. Gestão & Produção, 20(4): 741-761. http://dx.doi.org/10.1590/s0104-530x2013005000014

[14] Kim H., Anderson, K., Lee, S., and Hildreth J. (2013). Generating construction schedules through automatic data extraction using open BIM (building information modeling) technology. Automation In Construction, 35 (1): 285-295. http://dx.doi.org/10.1016/j.autcon.2013.05.020.

[15] Kurak Açici, F., and Sönmez, E. (2014). The Place of Hand Drawing and Computer Aided Design in Interior Design Education. In: Cyprus International Conference on Educational Research, 3. North Cyprus. Proceedings… Trabzon, Dis. [Online exclusive]. Time. Retrieved from <http://ac.els-cdn.com/S1877042814043985/1-s2.0-S1877042814043985-main.pdf?_tid=ecf2fe36-f019-11e4-996400000aacb35d&acdnat=1430495666_356a2bab6db48f159e895e3a626a6918>.

[16] Manzione, L., Abaurre, M. W., Owen, R., and Melhado, S. B. (2011) Desafios para a implementação do processo de projeto colaborativo: análise do fator humano. In: Encontro de Tecnologia de Informação e Comunicação na Construção, 5. Salvador. Proceeding... [Online exclusive]. Time. Retrieved from: < https://eprints.qut.edu.au/71036/1/2011_projetocolaborativo-tic.pdf>.

[17] Meira, A. A. N. (2016). Desenvolvimento de ferramentas compatíveis com modelação em BIM para análise do custo da habitação social. 91 f. Dissertação (Mestrado) - Curso de Mestrado Integrado em Engenharia Civil, Departamento de Engenharia Civil, Faculdade de Engenharia da Universidade do Porto, Porto, 2016.

[18] Mueller, V. (2009). Conceptual Design Tools: Establishing a framework for specification of concept design tools. Digitizing Architecture: Formalization and Content. In: Arab Society for Computer Aided Architectural Design, 4. Proceedings… [Online exclusive]. Time. Retrieved from: <https://www.researchgate.net/publication/30873251_Conceptual_Design_Tools_Establishing_a_framework_for_specification_of_concept_design_tools>.

[19] Niknam, M., and Karshenas, S. (2017). A shared ontology approach to semantic representation of BIM data. Automation In Construction, 80 (1):.22-36. http://dx.doi.org/10.1016/j.autcon.2017.03.013.

[20] Nunes, R. C. P., and Amorim, S. R. L. (1998). A implementação de sistemas CAD nos escritórios de projeto na região do Rio de Janeiro: Benefícios e Dificuldades na Implantação de Sistemas CAD. In: Encontro Nacional de Tecnologia do Ambiente Construído, 7. Florianópolis. Proceedings... [Online exclusive]. Time. Retrieved from <http://www.infohab.org.br/acervos/resumo/codigo_biblio/18803/cod/1>.

[21] Ohio Das, State Of Ohio Building Information Modeling Protocol. Ohio, 2013. [Online exclusive]. Time. Retrieved from <http://das.ohio.gov/Portals/0/DASDivisions/General Services/SAO/ pdf/SAO-BIMProtocol.pdf>.

[22] Park, J., and CAI, H. (2017). WBS-based dynamic multi-dimensional BIM database for total construction as-built documentation. Automation In Construction, 77 (1):15-23. http://dx.doi.org/10.1016/j.autcon.2017.01.021.

[23] Rocha, C. G., Formoso, C. T., Tzortzopoulos-fazenda, P., Koskela, L., and Tezel, A. (2012). Design science research in lean construction: process and outcome. [Online exclusive]. Time. Retrieved from <https://www.researchgate.net/publication/289761791_Design_science_research_in_lean_construction_Process_and_outcomes>.

[24] Santos, G. S. (2014). Como a compatibilização de projetos pode diminuir custos, gastos e retrabalhos na Construção Civil. Revista Online IPOG Especialize, Goiânia, 1 (9).

[25] Sun, J,, Liu, Y-S., Gao, G., and Han, X-G. (2015). IFCCompressor: A content-based compression algorithm for optimizing Industry Foundation Classes files. Automation In Construction, 50 (1): 1-15. DOI: 10.1016/j.autcon.2014.10.015.

[26] Wong, A. K. D.,Francis KW., and Nadeem, A. (2009) Comparative roles of major stakeholders for the implementation of BIM in various countries. In: Proceedings of the International Conference on Changing Roles: New Roles, New Challenges, Noordwijk Aan Zee, The Netherlands, p. 5-9.

[27] Yang, R., and Song, W. (2015). BIM for Building Water Supply and Drainage Design. In: International Conference on Automation, Mechanical Control and Computational Engineering, Ji'nan. Proceedings... Chengdu. [Online exclusive]. Time. Retrieved from <http://scholar.google.com.br/scholar_url?url=http://www.atlantis-press.com/php/download_paper.php%3Fid%3D20392&hl=pt-BR&sa=X&scisig=AAGBfm3Eqq4IBczOwhJaYx7S4oawu8CpLw&nossl=1&oi=scholaralrt>