Implementation, Performance and Waste Management Analysis of Decentralized Wastewater Treatment Systems Using BIM Technology

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Abstract. Brazil has more than 23 million inhabitants in rural areas without adequate sewage collection or treatment, which corresponds to 75% of the rural population. The absence of adequate sanitary conditions can cause disease and harm the environment. Decentralized wastewater treatment systems are alternatives to ensure the health of the population and at the same time maintain the environmental integrity of these locations. However, several projects in this area do not include important data for the construction, good performance, and operation of these systems. This partially nullifies the benefits of collecting and treating effluents. Currently, the Building Information Modeling (BIM) methodology fits into this scenario as a possibility for technological innovation and progress in productivity and project presentation. However, there are two barriers to the implementation of this technology in the production of hydraulic and sanitary projects: the scarcity of studies related to the management of the design process of these systems and the lack of BIM components that represent decentralized wastewater treatment systems. This work presents the development of a technological artifact with the potential to fill these gaps: a template created in Autodesk Revit software with several components of decentralized wastewater treatment systems available for use in projects. It is not simply a catalog in which the designer can choose the equipment to be used, but components that provide productivity in the project design, learning and flexibility in the construction of the models, fitting to the market standards.

Keywords: Decentralized wastewater treatment system · BIM · Sustainability

1 Introduction

Basic sanitation is defined by law No. 11,445 of January 5, 2007, as the set of services, infrastructures and operational facilities in four areas: drinking water supply, sanitary sewage, solid waste management and rainwater management [1]. In addition to providing important definitions, the law also establishes national guidelines and fundamental principles for universal access to sanitation, a proposal that necessarily involves resolving the situation of isolated communities. On this document, two of the objectives of the Federal Basic Sanitation Policy are: 1) prioritize plans, programs, and

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projects aimed at implementing and expanding basic sanitation services and actions in areas occupied by low-income populations; 2) provide adequate conditions of environmental health to rural populations and isolated communities.

The term “isolated communities” was disseminated by the Brazilian Association of Sanitary and Environmental Engineering (ABES-SP) to designate housing units that are not connected to public basic sanitation services. This isolation can occur due to several factors: technical, economic or political infeasibility, a long distance from the municipality’s headquarters, difficult access, low population density, large dispersion among households or irregular land tenure. In these locations, the water distribution and sewage collection networks do not exist or are insufficient, leading to the adoption of local, single-family or semi-collective solutions [2]. In this regard, it is essential that different strategies have adopted that respect the cultural and environmental diversity of the communities.

1.1 The Universalization of Basic Sanitation, a Distant Goal

Good sanitation practices are essential not only to prevent diseases, especially those of water transmission, but also to promote health, protect the environment and increase the population’s quality of life [3]. The sewer sanitary system can be defined as the set of activities, infrastructures and operational facilities for the collection, transportation, treatment and final disposal of wastewater, from building connections to its final release into the environment [1]. Despite being an essential basic sanitation service for the promotion of the population’s health and for environmental protection, it is estimated that about 2.4 billion people worldwide still live without access to adequate sanitation practices, which represent about 32% of the global population [4].

This is also the reality in Brazil, since, among the national basic sanitation services, the sewer sanitary system is the one with the lowest municipal coverage [5], just over half of Brazilian municipalities have this service (55.2%) [6]. In 2013, a study was carried out by the IBGE, which included 65130 households, in which it indicated that only 63.5% of these are served by wastewater collection systems, with huge disparities between the Southeast Region (88.3%) and North (19, 3%), for example [7].

In Brazilian municipalities, the most common destination for domestic sewage is still rudimentary cesspools (53.17%), with septic tanks (8.03%) and open ditches, direct disposal in water bodies and other forms of incorrect disposal (3.35%) [5]. This situation is more common in small municipalities and districts, with less than 50,000 inhabitants, predominantly rural locations with a more dispersed population [6]. Therefore, if the universalization of sewage services in Brazilian municipalities is still a distant goal, the situation in isolated communities is even more serious.

Currently, about 30 million people live in the Brazilian countryside, which is equivalent to 16% of the country’s population [6]. The IBGE data indicate that only 8% of the rural households surveyed are served by a wastewater collection system and that 13% do not have any type of wastewater treatment system [8]. Among households that have some form of treatment, 58% adopt solutions considered unsuitable for sanitary sewage, such as the use of improperly constructed absorbent pits and other forms of treatment and final disposals such as the discharge of sewage into ditches, water bodies and other locations.

1.2 Decentralized Wastewater Treatment Systems

Despite the low coverage rate of rural areas in Brazil by sewage collection networks, this in itself is not an aggravating factor for sanitary conditions [3, 9]. Decentralized wastewater treatment systems, if well designed, built and operated, are good alternatives to ensure the health of the population and at the same time maintain the environmental integrity of these locations [10]. The decentralization strategy is increasingly complementary and not opposed to the centralization of wastewater treatment in the quest for the universalization of basic sanitation services [11].

In general, decentralized systems are those that collect, treat and make the final disposal or reuse of wastewater in a place close to its generation, unlike what occurs in traditional centralized systems, where wastewater in cities is collected and treated in large sewage treatment plants. Two terms are used to classify decentralized systems: single-family and semi-collective. Single-family systems refer to those that serve a family that lives in one or two very close households. Semi-collective systems are those that treat the wastewater of a small group of houses or spaces destined to commerce or provision of services such as villages, churches, small schools, grocery stores, shops, and rural warehouses [2].

Decentralized systems are gaining more and more attention as they present several benefits widely discussed in the literature, such as the demand for less financial resources in implementation, the contribution to local sustainability [12] and the opportunity to reuse treated sewage in agriculture [13]. Although decentralized systems have some advantages over centralized systems, there are limitations and many challenges that need to be overcome to make their implementation efficient, viable and safe for isolated communities. These points are summarized in a table adapted from Bueno [14] and Tonetti et al. [2], which divides them into four areas: social, economic, environmental and operational (Table 1).

The first challenge in implementing this type of system is choosing the most appropriate sewage treatment technologies for each situation. This is a complex task, which involves evaluating many variables simultaneously. There is a wide variety of technologies available for rural and isolated areas, but there is no consensus on which would be the most technically appropriate. The decision must, therefore, consider local specificities, given that there are significant differences between Brazilian regions regarding their environmental, socioeconomic and cultural characteristics [2].

Therefore, there must be a greater concern in studying and working efficiently with the information related to this type of system in the design stage. The design in civil construction is one of the main stages of work and has a fundamental role in the quality and production of buildings. It is in this phase that the concepts of space organization are defined, as well as the technology to be used, costs, benefits, etc. The project's solutions directly reflect on the entire construction process and on the quality of the product to be delivered to the customer [15, 16].

It is known that sewage treatment is essential for reducing pollution of water resources and improving the health of the population. However, several projects do not include important data for the construction, good performance, and operation of the wastewater treatment system. Fundamental information, such as materials used for construction, destination of the sludge produced, type of treated sewage, type of system, rate of removal of organic matter, the number of people served and the frequency

Table 1. Possibilities, limitations and challenges of using decentralized wastewater treatment systems. Source: Adapted from Bueno [14] and Tonetti et al. [2].

Area	Possibilities	Limitations	Challenges
Social	Contribute to improving the health of the local population	Requires the interest of residents, family and neighbors to understand the functionality of the system	To guarantee the acceptance of the population and their involvement in the technology choice process
	They can generate work and income		
	Can help produce food, contributing to food security	There is not always acceptance by the population in the implementation of the system	
	Adaptable to customs and culture		To guarantee the help of technicians in clarifying doubts and presenting viable options
	They are usually well accepted by the population and inspection bodies	Needs the effective participation of the population served	
	Can help compose the local landscaping		
Economic	The simplest systems have low installation costs	The most appropriate type of system does not always correspond to the economic reality of the population served	To reduce costs by using alternative materials for the construction of the systems (construction rubble, bamboo, green coconut, etc.) or materials that were already available on site and that can be reused (pipes, connections, water tanks, concrete rings, bricks, tires, etc.)
	Consume little energy and external inputs		
	Some by-products of the system have commercial value and can generate income (food, biogas, ornamental plants, etc.)		
	There is savings in fertilizers when using treated wastewater in agriculture		To reduce costs and generate jobs with the use of local labor
Environmental	Single-family systems can be compact	Most systems need a large area for their implementation	To avoid overload and contamination of soils with low infiltration rate or soils with good drainage in very dense places
	Use little inputs and energy in construction and operation	Factors such as climate and soil type can generate large variations in the final quality of treated sewage in some systems	To avoid contamination of water by nitrates, phosphates and pathogens from systems located very close to surface or underground water reserves
	Reduce pollution of soil and local water bodies		
	They can improve local ecological conditions	Very impermeable soils, with groundwater close to the surface, or areas that are frequently flooded do not allow the infiltration of treated sewage into the soil	To avoid eutrophication of surface water bodies
	Promote the reuse of water and nutrients locally		To ensure correct disposal of sludge produced in the system
Operational	No need to build a local wastewater collection system and pumping stations	Some systems have a high frequency of operation and maintenance, which often must be performed by residents	To maintain regularity in the operation and maintenance of the systems (filter material exchange, constant plants pruning, sludge final disposal, etc.)
	Have good operational flexibility		
	Can be extended over time		
	Have low consumption of materials and energy		
	In most cases, treatment is free		To monitor treated wastewater and receiving water bodies and to create an information system, when possible
	Do not require specialized labor		
	Can treat gray and black waters separately		
	Are little influenced by natural disasters		

of maintenance [13], are neglected and replaced by standard components [15, 16], which is often not the best solution for the building or community in question, when it comes to a decentralized process. As a result, the benefits of collecting and treating effluents are partially canceled. The community needs to take this problem very seriously, and, with the help of scientific and technological research, develop safe and feasible alternatives so that sewage does not become a new environmental problem, taking instead the environmental advantages of its disposal [13].

1.3 About BIM Technology

Currently, study methods and standards are being applied to improve civil construction projects production. Strategies of constructive conceptions are researched that present approximation with the reality of the construction sites, or even control over the entire planning, favoring mainly the construction progress [17]. The BIM methodology fits into this scenario as a possibility for technological innovation and progress in the project's presentations productivity. One of the pioneers of the concept was Chuck Eastman [18], a professor at the Georgia Institute of Technology in the United States. According to him, BIM is a work philosophy that integrates architects, engineers, and builders (AEC) in the elaboration of a precise virtual model, which generates a database with topological information and necessary subsidies for budget, energy calculation, and forecast of inputs and actions at all stages of construction.

Developed by Autodesk, Inc., Revit is one of the software with BIM technology available on the market and includes resources for architectural design, mechanical, electrical and hydraulic systems engineering, structural engineering and construction. It also supports a collaborative and multidisciplinary design process, allowing everyone involved to keep up to date on the stages of work [19]. In this software, every virtual model of construction is designed with the modeling and use of families. According to Autodesk [20], a family is a group of elements with a set of parameters (semantic and/or geometric information) and a related graphic representation, they constitute all components of a project.

Elements modeled on BIM platforms are based on representations of the physical and functional characteristics of a component or set of components to be used in the construction of the building. One aspect of BIM is the availability to contain building information, these data are defined in relation to the geometric and non-geometric attributes of the elements [21] (Table 2).

Table 2. Examples of geometric and non-geometric attributes of elements in BIM. Source: Adapted from the Government of SC - Notebook for presentation of projects in BIM [21].

Geometric attributes	Non-geometric attributes
Size	Product performance data
Volume	Technical specifications and standards compliance
Form	Cost
Density	Color, brand, technical details
Area	Classification system (DEINFRA, Uniformat, SINAPI (…))

The Level of Development (LOD), developed by BIMForum, is a specification to clearly articulate the content and reliability of the BIM model in different phases of a project. It is related to the amount of information and details that are present in a component of a virtual design [22]. According to BIMForum [23], a BIM model element is associated with a specific LOD, in which it evolves from LOD 100 (preliminary basic model) to LOD 400, which corresponds to the completed model with all necessary information for the construction. Finally, there is the LOD 500, which characterizes what has been accomplished. In this evolution, each component (family) is increased with geometric and non-geometric parameters and are categorized as follows:

- LOD 100: The model element is represented graphically with generic symbols;
- LOD 200: The model element is converted into an object or set of generic objects with the definition of its basic dimensions;
- LOD 300: The model element is graphically represented as a specific system, object or set in terms of quantity, size, shape, location and orientation;
- LOD 350: The model element presents the vision of the construction and the identification of the interfaces between the specialties;
- LOD 400: It includes the final details of the model element, in order to generate enough information for the perfect characterization of the services to be performed;
- LOD 500: The model element is a field-verified representation in terms of size, shape, location, quantity and orientation (Fig. 1).

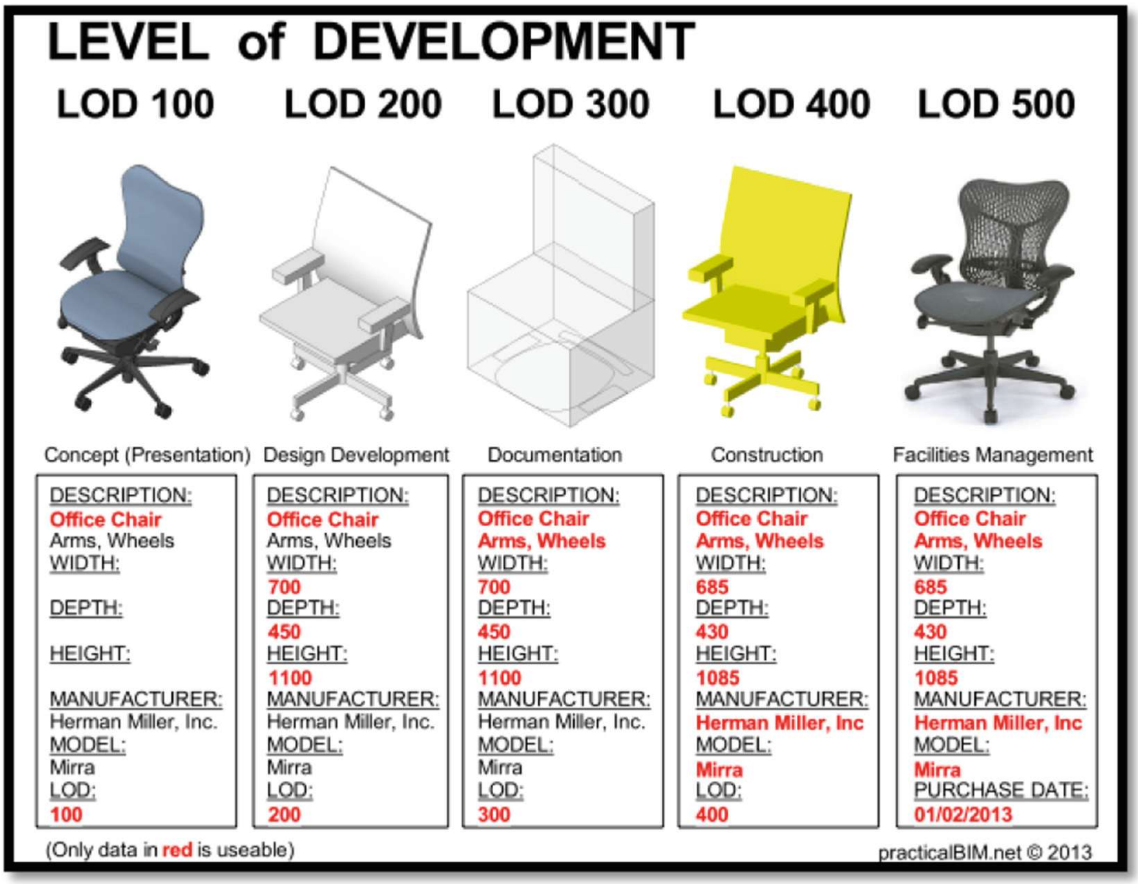

Fig. 1. Level of Development applied to an office chair. Source: PracticalBIM [24].

LOD is sometimes interpreted as a Level of Detail, rather than Level of Development, but there are important differences. The Level of Detail is essentially the amount of detail included in the model element (visual design). The Level of Development is the degree to which the element's geometry and the information attached to it were thought, that is, it is the Level of Detail of the component associated with its Level of Information. That is, the Level of Detail can be considered as an input for the element, while the Level of Development is an output with reliable information attached [23] (Fig. 2).

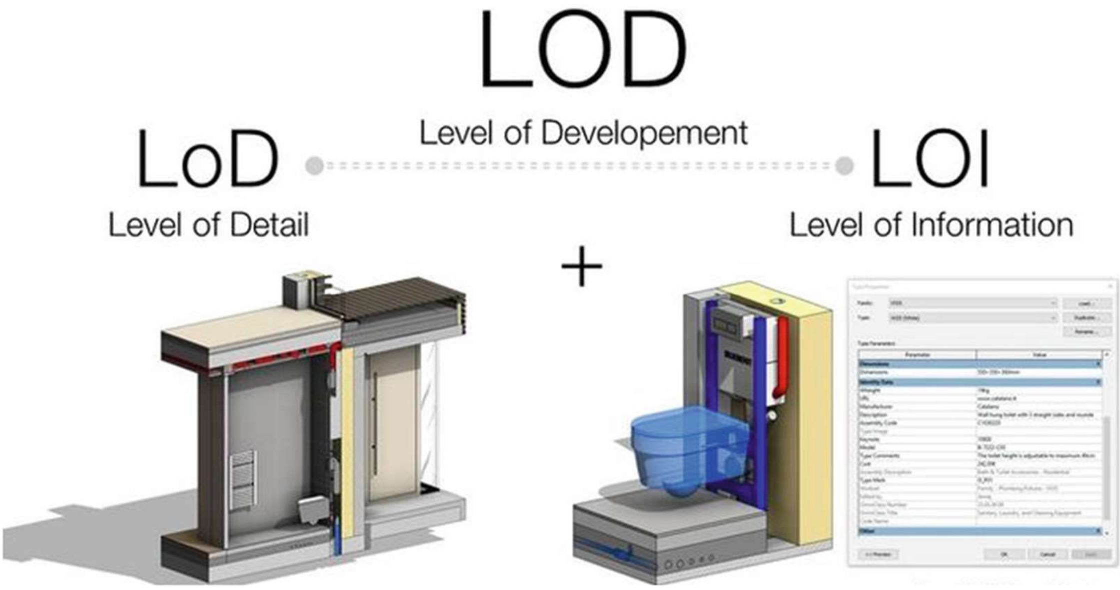

Fig. 2. Level of Development in relation to the Level of Detail and Level of Information. Source: Authors (2020).

Despite recent efforts by software vendors, civil construction organizations, professionals and the government to promote the BIM as the way to define buildings, most projects are still carried out in a traditional way, based on several two-dimensional drawings of each disciplines. Today, although technology exists that can make professional work in most disciplines in the AEC sector more efficient, most professionals are resisting efforts to move towards BIM [15–25].

Bazjanac [25] highlights that after trying briefly to model information and under pressure to meet tight deadlines and without significant additional resources to carry out their work on a given project using the BIM methodology, engineers, and architects come to the conclusion that it is not worth the effort and end up opting for the traditional way of projecting. In this way, professionals already have a well-defined workflow in their offices with ready components to be used in their projects, saving time and money. The lack of BIM components in the market and the difficulty in creating these families, also indicated by Memon et al. [26] and Santos [27], is one of the major barriers to implementing this concept in the AEC sector.

Another issue to be highlighted is that although there are several kinds of research regarding BIM technology, there are still few works that focus their attention on the process of hydraulic and sanitary projects from the management point of view, that is, the relationship of this system with the other project disciplines, the moment this project is elaborated, the pertinent standards, how it will be executed on-site and how the operation and maintenance process works [28]. Ywashima and Ilha [29] also report that this context is reflected in the market, where most offices still work in a segmented manner and the solutions adopted do not always meet the needs of users and the maintenance of the building.

A systematic survey of the articles published in Brazilian scientific congresses focused on the built environment (Fig. 3) revealed the scarcity in research that relates project-based technologies to hydraulic and sanitary systems, where in only two events an article with this approach was published:

1. DARIVA, M. A.; ARAUJO, A. L. Concepção de projetos hidrossanitários com tecnologia BIM: estudo comparativo ao método conduzido em plataforma CAD. In: SIMPÓSIO BRASILEIRO DE TECNOLOGIA DA INFORMAÇÃO E COMUNICAÇÃO NA CONSTRUÇÃO, 2., 2019, Campinas. Anais […]. Porto Alegre: ANTAC, 2019.
2. STAUT, Solange L. S.; ILHA, Marina. S. de O. BIM NO ENSINO DO PROJETO DE SISTEMAS PREDIAIS HIDRÁULICOS E SANITÁRIOS NA ENGENHARIA CIVIL. In: SIMPÓSIO NACIONAL DE SISTEMAS PREDIAIS DESEMPENHO E INOVAÇÃO DE SISTEMAS PREDIAIS HIDRÁULICOS, XIII., 2019, SÃO PAULO. Anais… São Paulo: Escola Politécnica da Universidade de São Paulo, 2019.

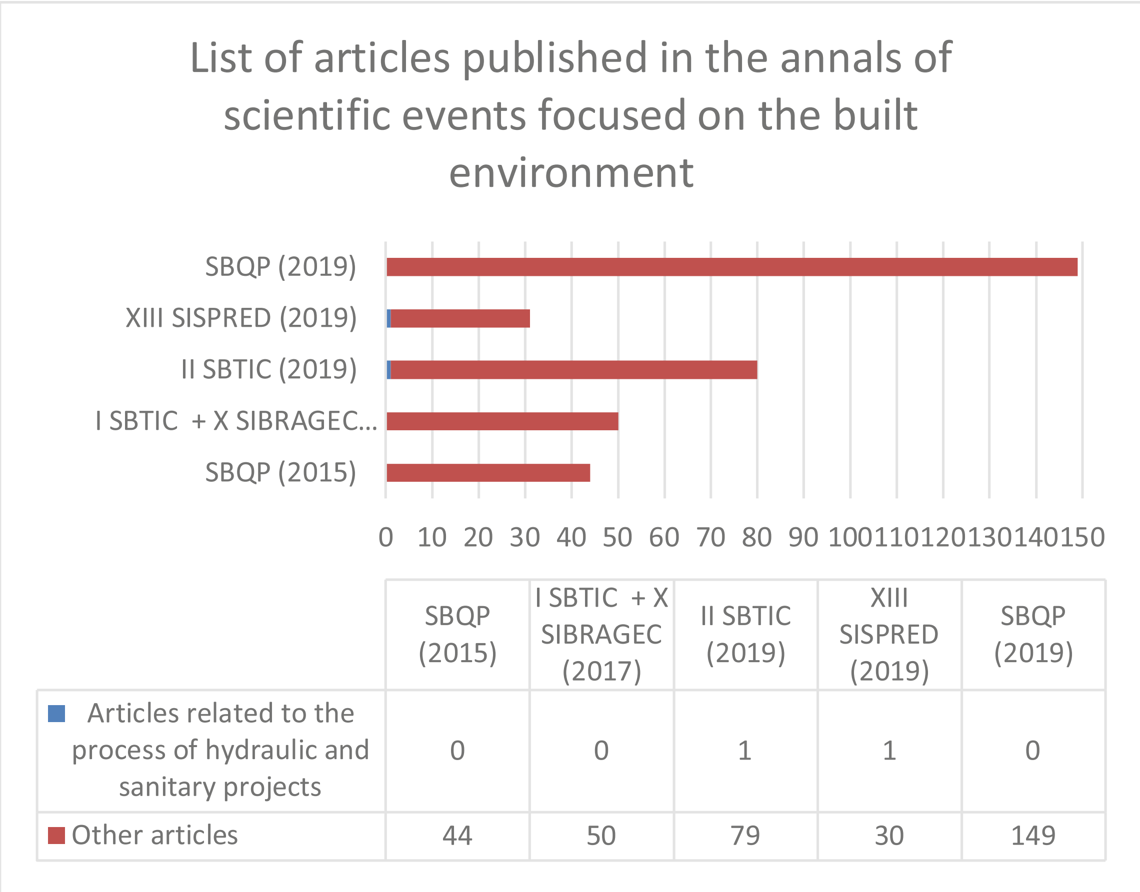

Fig. 3. List of articles published in the annals of scientific events focused on the built environment (comparison between the number of articles related to the design process of Building Hydrosanitary Systems and others from other disciplines). Source: Authors (2020).

In this current academic, market and environmental context, briefly outlined above, some issues challenge the development of decentralized wastewater treatment systems projects by professionals in the AEC area as an alternative to the universalization of basic sanitation:

1. The adequacy to sustainability parameters;
2. The incorporation of the ICT (Information and Communication Technology) concepts;
3. The treatment of adequate and enough information for the correct implementation of the systems;
4. Ensuring learning about the many types of decentralized sewage treatment, its challenges, and its limitations;
5. The easy access to the different components and the possibility to study and choose the best system in the elaboration and presentation of projects.

2 Objective

This work aims to confirm these issues highlighted above by creating families of decentralized sewage treatment systems at a High Level of Development (LOD 400) that enable the study, manipulation, learning and the best choice of the numerous options of this equipment.

3 Methodology

For the development of this work, a strategy of Design Science Research was adopted, whose main characteristic is the production of innovative artifacts aimed at solving problems found in the real world, contributing to the development of the theory of the disciplines in which it is applied, these artifacts can be models, methods, concepts or implementations [30]. Table 3 summarizes the general instructions for the conduct and evaluation of this type of methodology.

Table 3. General instructions for the Design Science Research Conduction/Evaluation. Source: Adapted from Hevner, March and Park [30, p. 83].

Instruction	Description
The relevance of the problem	The objective of Design Science based research is to develop technology-based solutions to important and relevant management problems
Design as artefact	Research based on Design Science should produce a viable artifact in the form of a construct, model, method and/or an instantiation
Design evaluation	The usefulness, quality and efficacy of the artifact must be rigorously demonstrated by means of well executed evaluation methods

(*continued*)

Table 3. (*continued*)

Instruction	Description
Design contributions	Research based on Design Science should provide clear and verifiable contributions in the specific areas of the artifacts developed and present a clear grounding in design fundamentals and/or design methodologies
Design as a research process	The search for an effective and efficient artifact requires the use of means that are available, to achieve the desired ends, while satisfying the laws governing the environment in which the problem is being studied
Research communication	Research in Design Science should be presented to both the more technology-oriented and the more management-oriented audience

3.1 The Relevance of the Problem and Design as an Artifact

First, through the bibliographic survey, the relevance of problems associated with decentralized wastewater treatment systems were verified. It was found that:

- Only 63.5% of households in Brazil are served by a sewage collection system [7];
- The most common destination for domestic sewage in Brazilian municipalities are still considered inadequate solutions, such as rudimentary cesspools (53.17%), septic tanks (8.03%), open ditches and direct disposal in water bodies (3.35%) [5];
- Currently, about 30 million people live in rural Brazil (16% of the country's population) [6].
- Only 8% of rural households are connected to the sewage collection system and 13% do not have any kind of wastewater treatment system [8];
- Among the rural households that have some form of treatment, 58% adopt solutions considered inadequate [8];

From so many alarming data it was conjectured that this problem could also be associated with the issue related to the production of projects, where, through a new bibliographic the survey, it was verified that:

- The use of AutoCAD standard blocks in different projects is a common practice in the market [15, 16]. This factor can represent productivity gains in the project issue [16], however, when it comes to the design of a decentralized wastewater treatment the system, a "fad" in using the same block in different cases can be created, which often does not represent the best solution for the building or the community in question.
- Several projects do not include important data for the construction, good performance and operation of the wastewater treatment system [13].

- The BIM methodology fits into the current scenario as a possibility of technological innovation and progress in productivity and project presentation [18]. However, the lack of BIM components in the market and the difficulty in creating these families are one of the great barriers to implement this concept in the AEC sector [25–27].
- Technological solutions in the area of hydraulics and sanitation have not been consistently studied from a management point of view, that is, related to the project process [28].
- Although there is a wide range of systems available, many professionals in the AEC field are not aware of these possibilities nor of the functionality of some equipment [2].

In view of this, thought was given to the development of an artifact that could resolve these issues. The idea was to create a template in Revit that would include families of decentralized wastewater treatment systems with LOD 400. From these families, it would be possible to extract sufficient information for the characterization and construction at the time of the work, and not only that, but it would also be possible to verify maintenance and operation data of the equipment, final destination of the sludge produced, type of sewage treated, type of system, rate of organic matter removal of and amount of people served. In addition to the non-geometric information, the proposal also aimed to treat geometric information automatically and with a certain degree of flexibility that would allow the professional to choose the best system for the building, but would not allow the use of diameters/sizes outside the market standards. That is, the sizing of the equipment would have to be done automatically from the entry of some information (number of people served, the volume of sewage produced, room temperature, etc.), ensuring productivity in the preparation of the project. Finally, we would have components of decentralized wastewater treatment systems that are self-dimensioned according to commercial diameters/sizes, with sufficient information for construction, operation and maintenance, and that enable not only the best choice but also the learning of the designers.

The first step was to choose the systems, from the literature, that would be modeled. It was based on the systems proposed in the book "Tratamento de esgotos domésticos em comunidades isoladas: Referencial para a escolha de soluções" by Tonetti et al. (2018). Among the several options highlighted in the book, the 7 considered most efficient in the organic matter removal and one for the final disposal of the treated sewage was chosen. These are them:

- Biodigester Septic Tank
- Evapotranspiration Tank
- Wetlands/Garden Filter
- Banana Circle
- Anaerobic Filter
- Sand Filter
- Vermifilter
- Soak Pit

The chosen systems were modeled in the Revit Family Editor, where all parameters were configured very rigorously to guarantee all expected contributions. Each family was configured in order to guarantee the self-dimensioning, flexibility, and analysis of all the information mentioned above. For this, several algorithms were created to be applied to several parameters of the families, as shown, for example, in Fig. 4.

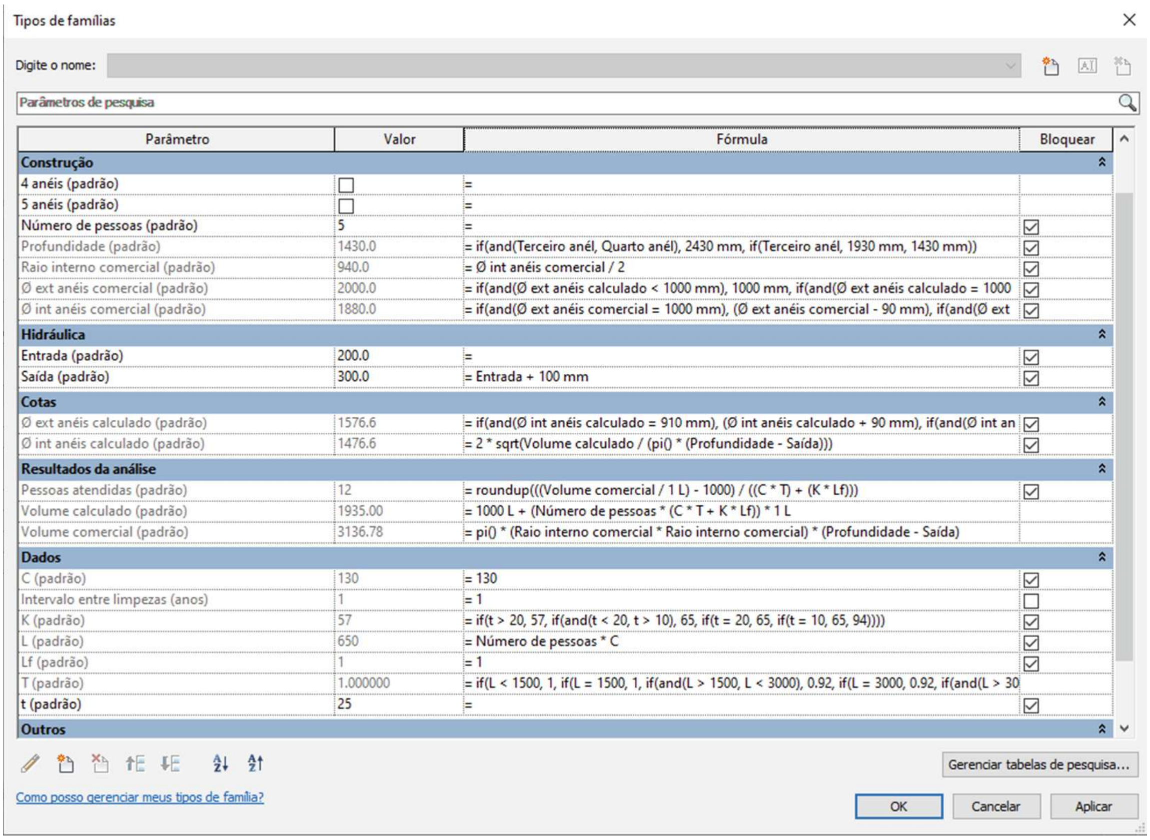

Fig. 4. Table of parameters for the "Biodigester Septic Tank" component in the Revit Family Editor. Source: Authors (2020).

All families were made to this standard of rigor. It was also concerned not to overload the archives with families of the vegetation type, making them heavy. For this purpose, light textures and RPC (Rich Photorealistic Content) type vegetations were added for the Evapotranspiration Tank and Banana Circle systems (Fig. 5). Only in the Filter Garden component was modeled vegetation used in the Revit family editor (Fig. 6). As smaller vegetations are used in this type of system, it would not be interesting to place numerous RPC vegetation families, but only one family representing the type of plant used for sewage treatment.

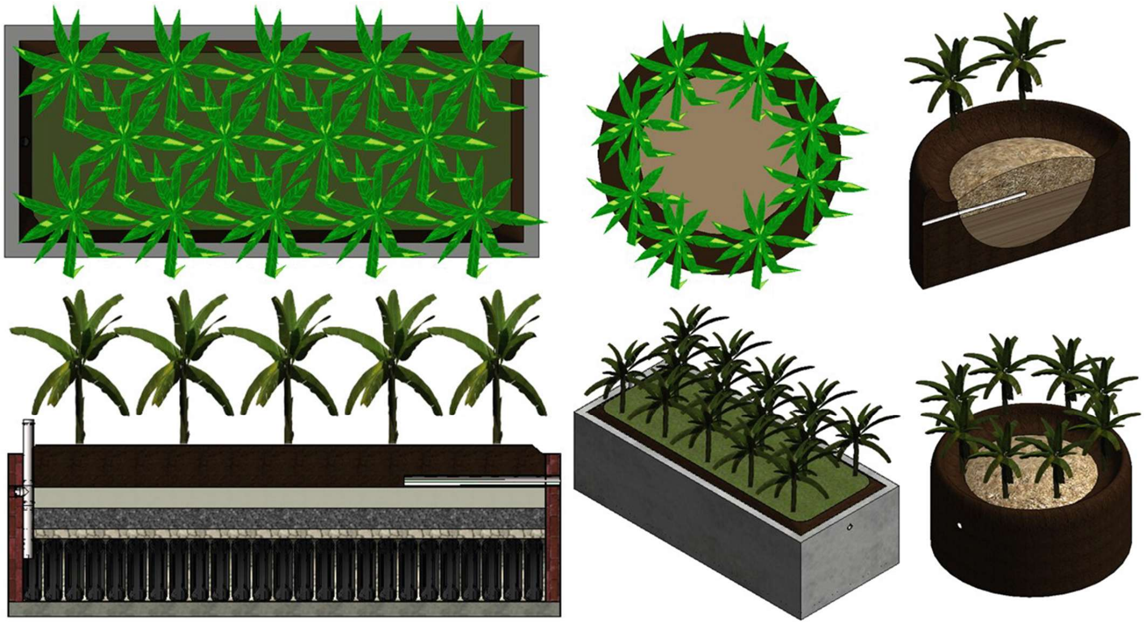

Fig. 5. Views of the Banana Circle and the Evapotranspiration Tank. Source: Authors (2020).

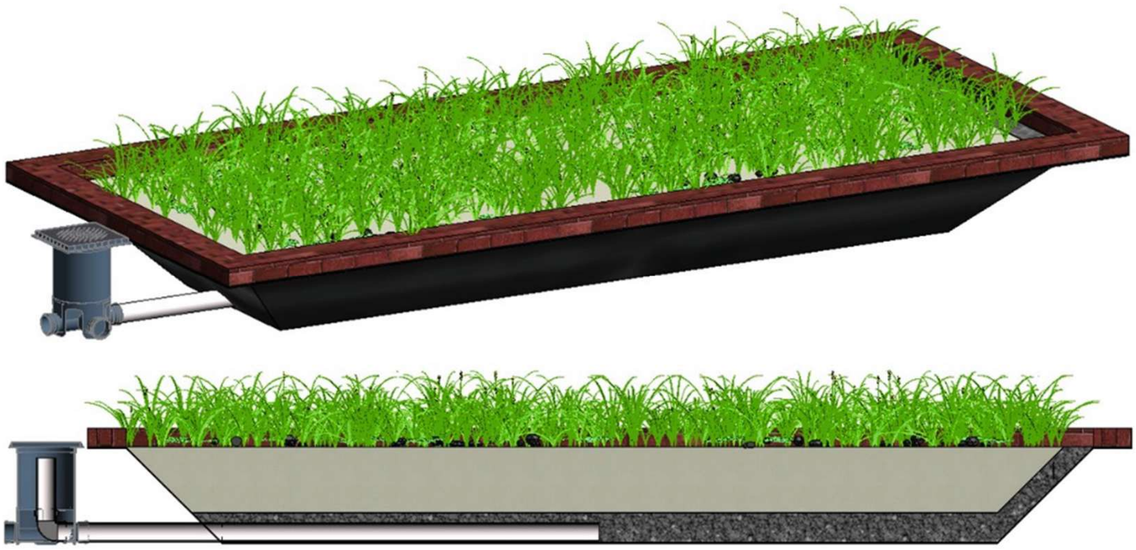

Fig. 6. Perspective and frontal section of the Filter Garden. Source: Authors (2020).

Another concern was the choice of materials, it was chosen to use concrete rings in circular systems because of it is a cheap material and easily found in building material stores. This was the case of the filters (Anaerobic Filter, Sand Filter, and Vermifilter), the Septic Tank and the Soak Pit (Fig. 7).

Fig. 7. Views of Vermifilter, Sand Filter, Biodigester Septic Tank, Anaerobic Filter and Soak Pit. Source: Authors (2020).

Finally, all the created families were grouped in a Revit template that makes it possible to evaluate and study each one of them, to self-size the systems from the input of some data (Fig. 8 and Fig. 9), automatically create tables of quantities (Fig. 10), to analyze information by positioning the mouse cursor on some parameter (Fig. 11) and to identify each of the materials that compose each component (Fig. 12).

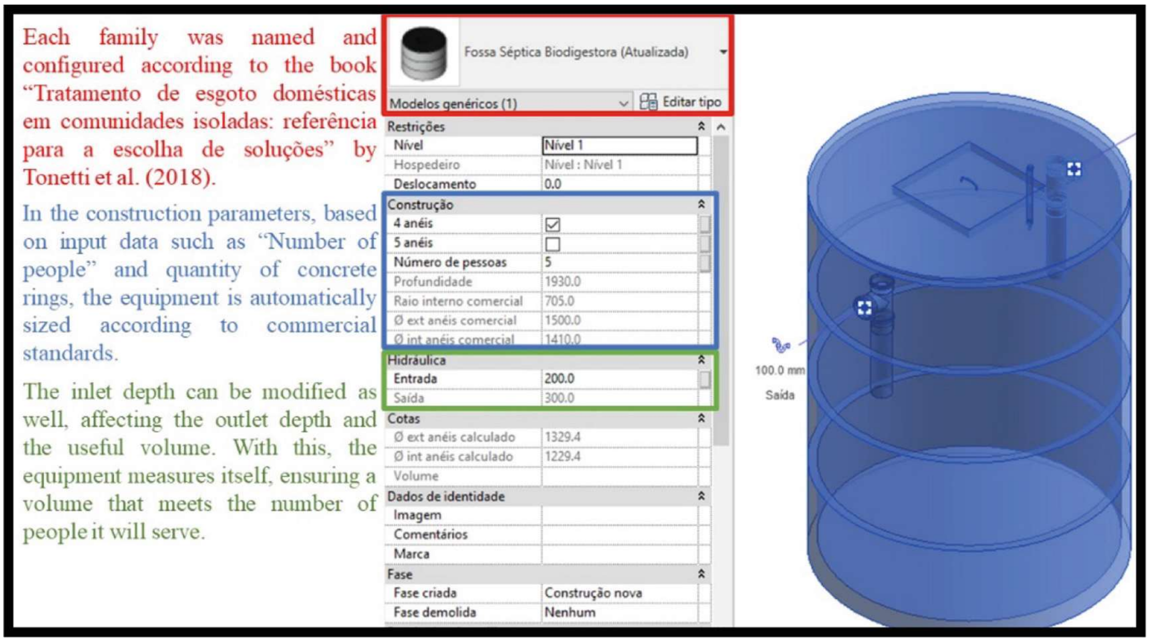

Fig. 8. Procedure for self-sizing of the Biodigester Septic Tank. Source: Authors (2020).

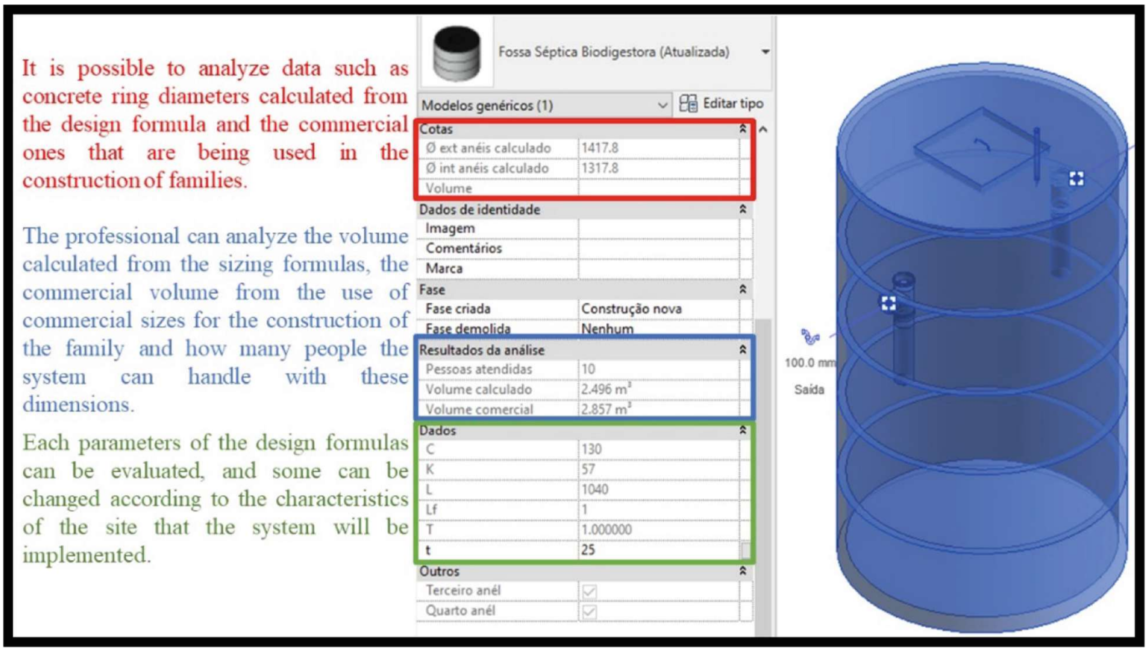

Fig. 9. Parameters assigned for the self-sizing of the Biodigester Septic Tank. Source: Authors (2020).

Kit do Sistema de Tratamento de Esgoto Descentralizado	
Quantidade	Descrição
3	Anel de concreto LISO 1.20 (Ø 1200 mm)
2	Anel de concreto LISO 1.20 (Ø 1200 mm) com FUNDO (70 mm)
1	Anel de concreto LISO 1.20 (Ø 1200 mm) com FUNDO PERFURADO (70 mm)
2	Anel de concreto LISO PERFURADO 1.20 (Ø 1200 mm)
1	Anel de concreto LISO PERFURADO 1.20 (Ø 1200 mm) com FUNDO (70 mm)
2	Camada de Brita N° 4
1	Cap 100mm, Esgoto Série Normal - TIGRE
2	Cap Soldável PERFURADO 20mm, PVC Marrom, Água Fria - TIGRE
4	Luva Simples 100mm, Esgoto Série Normal - TIGRE
1	Tampa circular (Ø 1200 mm) c/ inspeção quadrada (500x500mm)
2	Tampa circular (Ø 1200 mm) c/ inspeção quadrada (500x500mm) - Superfície pintada com tinta preta
4	Tubo de PVC - Série Normal - DN 100
1	Tubo de PVC - Série Normal - DN 100 PERFURADO
2	Tubo de PVC Marrom - Soldável - DN 25 com CAP perfurado de PVC soldável na ponta (Respiro)
4	Tê 100 x 100mm, Esgoto Série Normal - TIGRE

Dimensões				
Quantidade	Descrição	Ø ext anéis (m)	Ø int anéis (m)	Volume Útil
1	Filtro Anaeróbio	1.20	1.11	895.11 L
1	Fossa Séptica Biodigestora	1.20	1.11	1112.84 L
1	Sumidouro	1.20	1.11	870.92 L

Fig. 10. Quantitative tables of materials extracted from the Biodigester Septic Tank. Source: Authors (2020).

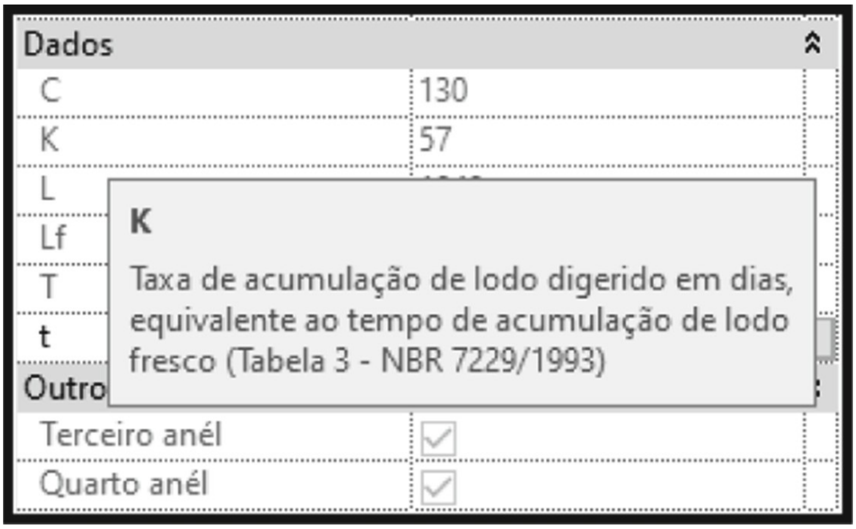

Fig. 11. Demonstration of the information analysis from the positioning of the mouse cursor on some parameters. Source: Authors (2020).

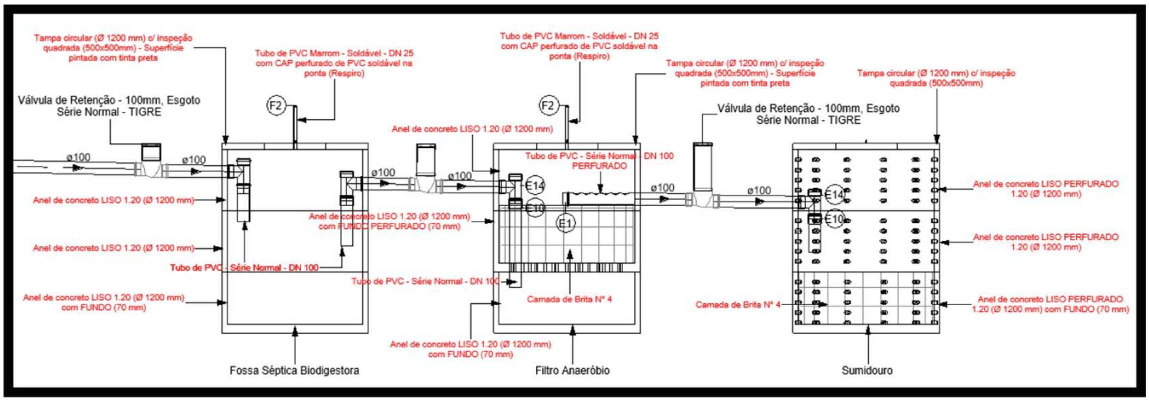

Fig. 12. Example of identification of the materials that compose the families of Biodigester Septic Tank, Anaerobic Filter and Soak Pit. Source: Authors (2020).

3.2 Design Evaluation and Contributions

After the preparation of the families and the template in Revit, it was made available to some professionals in the area of AEC from various locations in Brazil with the families of Biodigester Septic Tank, Anaerobic Filter and Soak Pit available for use in projects. With these families, it was already possible to create an integrated system (Fig. 13) to treat the black water coming from the toilet and to guarantee adequate final disposal for the grey water coming from sinks, washbasins, showers, etc. Some months after that the template was shared, a questionnaire was elaborated in Google Forms with questions that clarify the points highlighted in this work, and it was sent to all professionals who acquired the material (25 in total). This way, it was possible to evaluate the possible contributions that the artifact in question could provide.

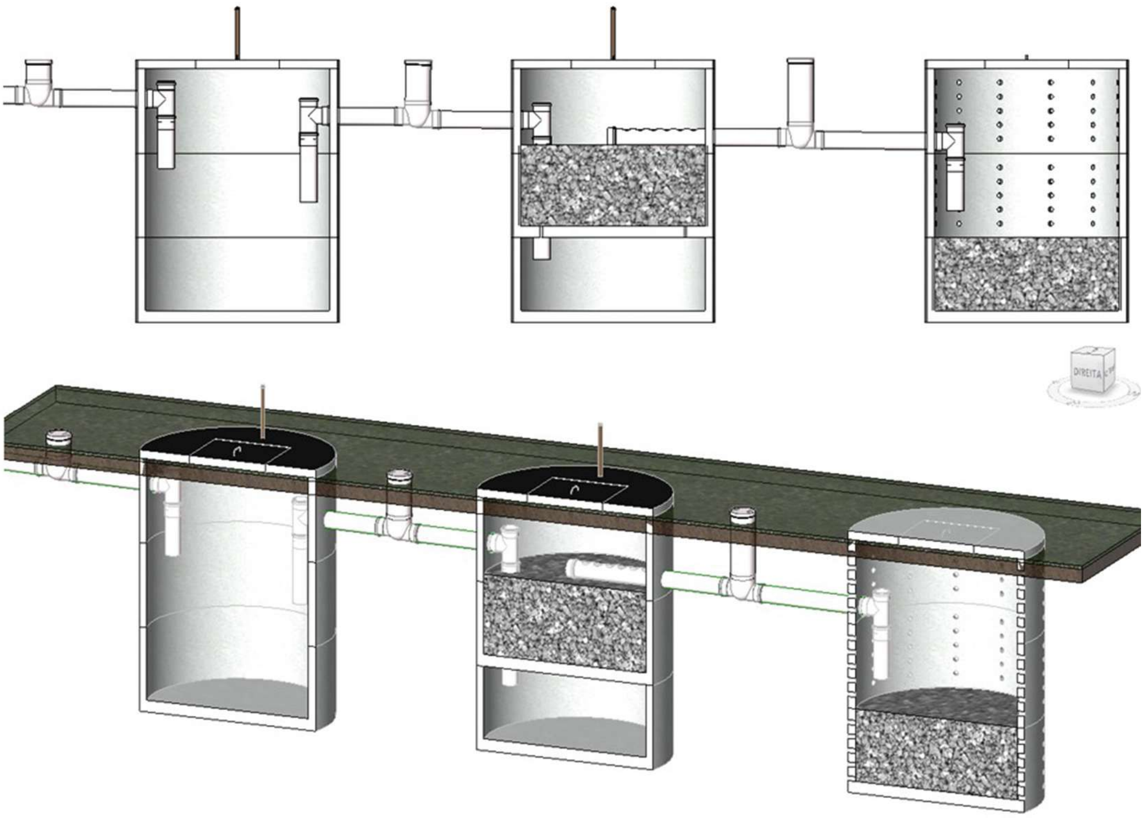

Fig. 13. Frontal cut and perspective of the decentralized sewage treatment system integrated with the families of Biodigester Septic Tank, Anaerobic Filter and Soak Pit. Source: Authors (2020).

Five questions were developed to compose the questionnaire, which had the following configuration:

1. Knowing that in the project stage the Development Level (LOD) evolves from LOD 100 (preliminary basic model) to LOD 400, which corresponds to the model completed with enough information for the construction, how do you classify the Development Level of the families?
2. How do you rate the control of the information available in families?
3. Have the acquired families contributed in any way to learning about decentralized wastewater treatment systems?
4. Before using these families, what other methods were used to represent a decentralized wastewater treatment system?
5. In your opinion, does the lack of components (families) harm, or create resistance, to the implementation of BIM in the AEC (Architecture, Engineering, and Construction) sector?

The results of this research will be presented and discussed in the next topic (Results and Discussions).

3.3 Research and Communication Process

The template created with the families were made available at (www.darivabim.com) where any professional in the AEC area can download the material. Information videos were recorded about each of the components available in the template and posted on YouTube in the channel “DarivaBIM” (Fig. 14), which can be accessed for free through the link: (https://www.youtube.com/channel/UCUyry49-3fD9RGUAJ_xDdcA).

The videos were divided into episodes and present guidelines on how families work, their possibilities and limitations. Thus, the contribution to the participation of professionals in the elaboration of hydraulic and sanitary projects can be more effective when related to situations that require the implementation of wastewater treatment systems.

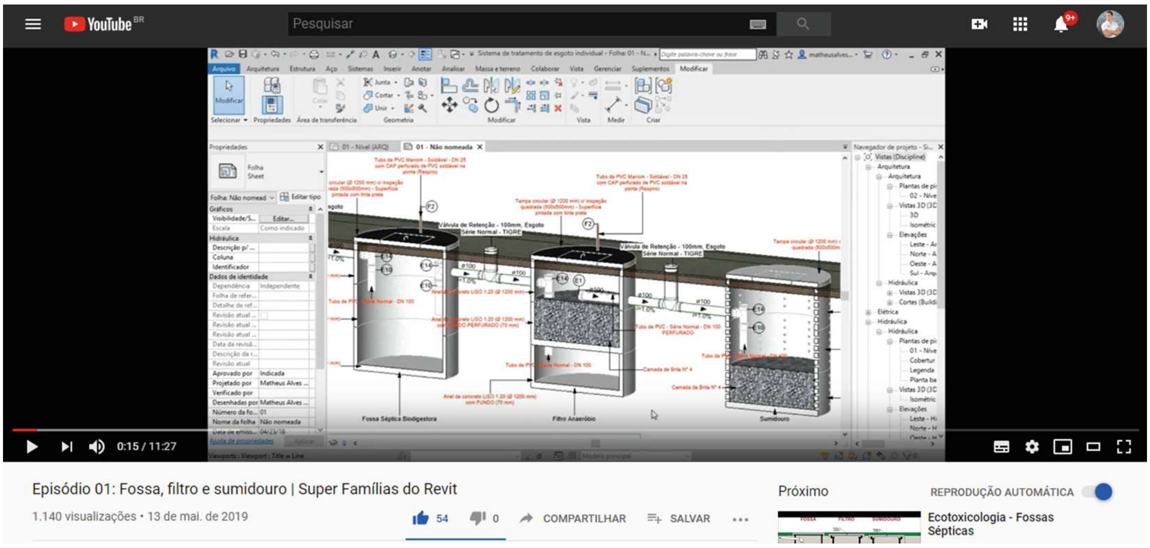

Fig. 14. Episode 01, available on YouTube, of the video series dealing with the components of a decentralized wastewater treatment system. Source: Authors (2020).

4 Results and Discussions

With the evaluation made from the Google Forms questionnaire, it was possible to get an idea of the current context in the market regarding wastewater treatment system projects. It was also possible to obtain qualitative results regarding the level of development of families, i.e. opinions of professionals regarding the details and information contained in the components and whether these data were enough for the construction, good performance and operation of the equipment. Of the 25 professionals requested, 19 answered the questionnaire. The results can be observed below.

In relation to the first question, all professionals replied that the families acquired are designed at a high level of development (LOD 350/LOD 400). For most of them, the information contained in the families is enough for a perfect characterization of the services to be performed (LOD 400), as shown in Fig. 15.

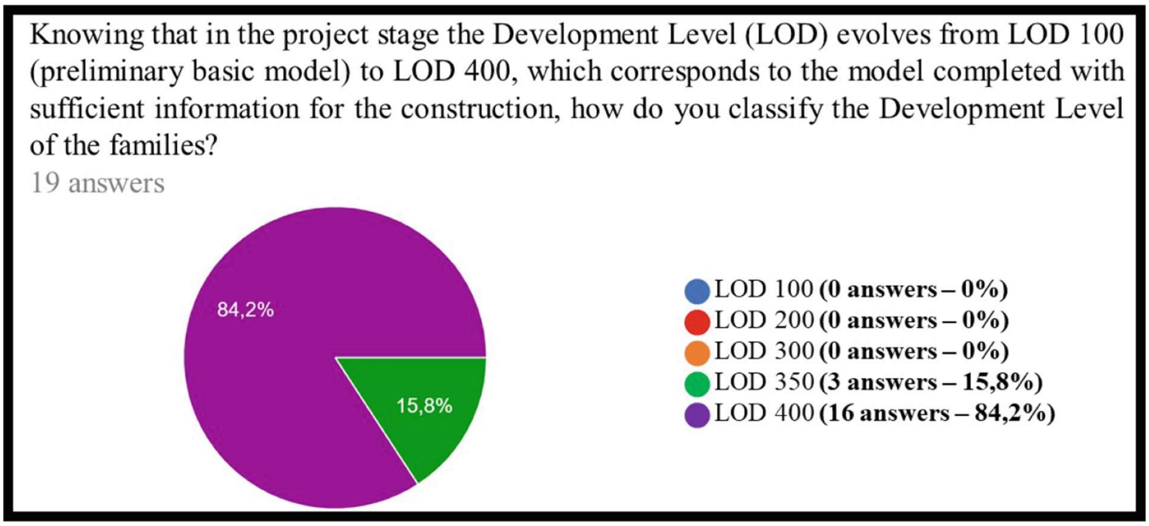

Fig. 15. Result of the first question in the questionnaire. Source: Authors (2020).

The result of the second question (Fig. 16) shows that, for most professionals, the control of the information available in families is great. This means that these professionals have adapted with excellence to the workflow established in the families. As previously mentioned, the flexibility of the components guarantees the automatic sizing of the equipment according to commercial standards, not allowing the use of sizes/diameters outside the market context. In the opinion of the interviewees, this is a factor that guarantees productivity in project development.

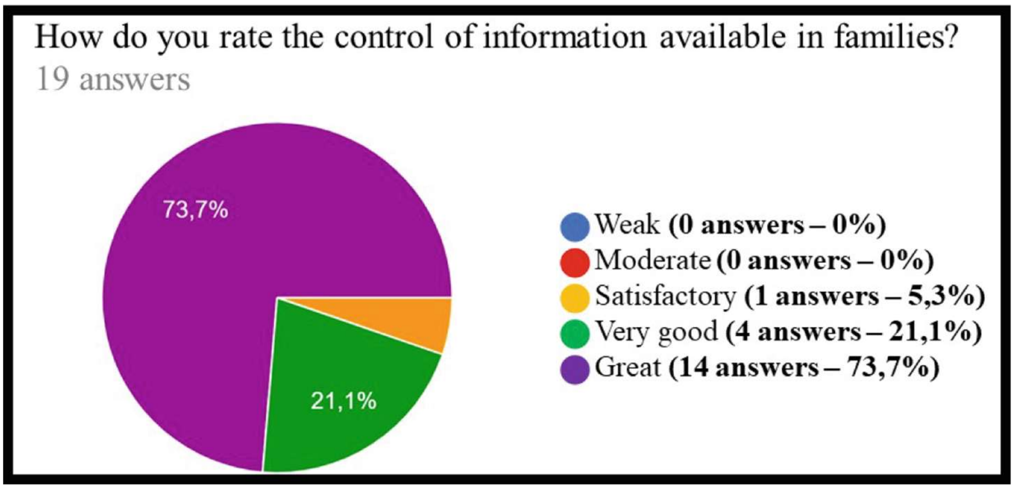

Fig. 16. Result of the second question in the questionnaire. Source: Authors (2020).

For all interviewees, the families contributed in some way to learn about wastewater treatment systems, as shown in Fig. 17. This may represent a paradigm shift, where the project process is also a learning opportunity for the professional, and not only a sophisticated tool for the selection of the best solution for those professionals who hold the heuristic knowledge.

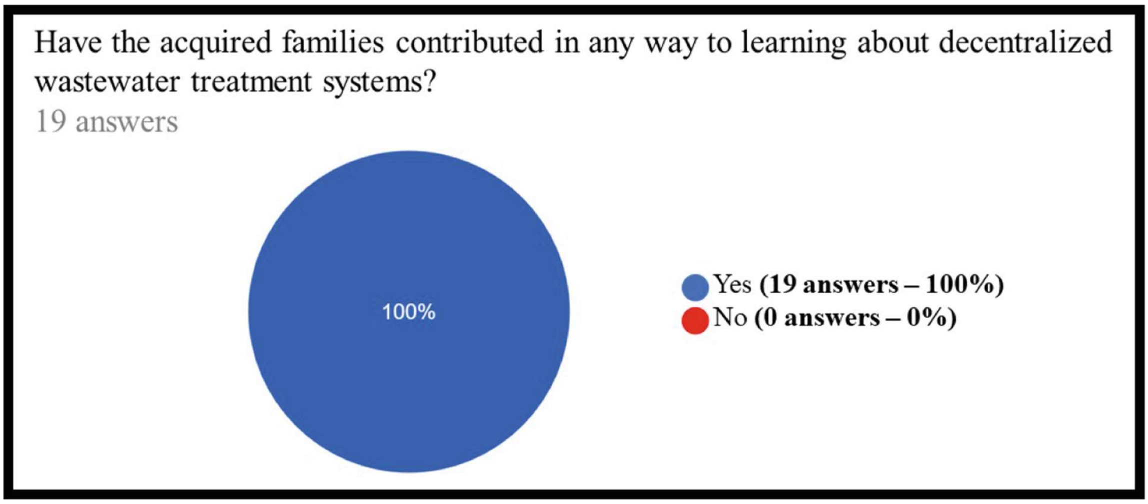

Fig. 17. Result of the third question in the questionnaire. Source: Authors (2020).

As some authors have found [15, 16], the use of AutoCAD standard blocks in different projects are common practice in the market. Observing the result of the fourth question (Fig. 18), this method, besides being common in the market, also extends the use of low LOD families when working with BIM technology. This is a factor that hinders the representation of projects since not enough information is guaranteed for the construction of the systems in question. It is also concluded that this factor can be linked to the difficulty of professionals in creating BIM components or acquiring them in high LOD since there were no interviewees who selected these options. It is interesting to point out that 10.5% of them answered that they did not use this type of system in projects. Some reasons can be deduced from this: the difficulty in finding high LOD components; the lack of knowledge about the possibilities of wastewater treatment systems and the impacts caused by their incorrect disposal; the lack of interest in using this type of system in hydraulic and sanitary projects.

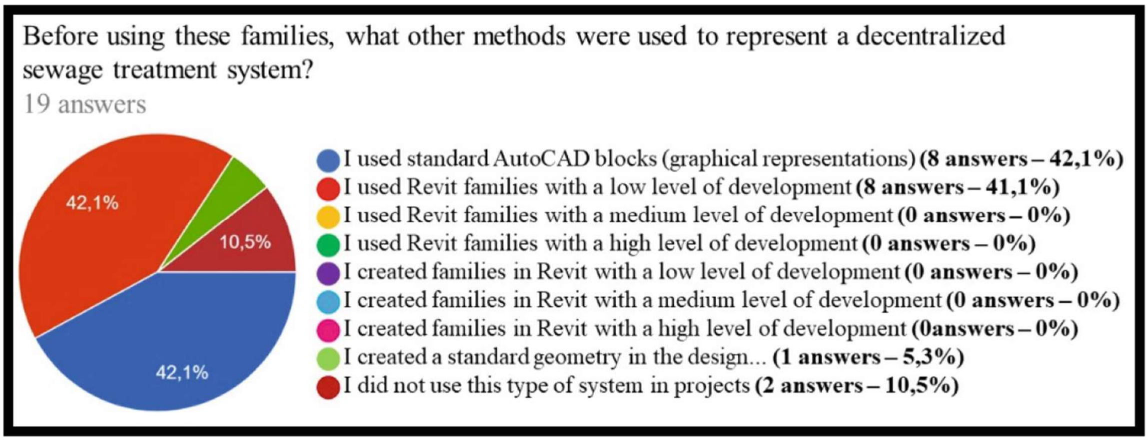

Fig. 18. Result of the fourth question in the questionnaire. Source: Authors (2020).

Finally, as some authors have already observed [15–26], the lack of BIM components available in the market creates a resistance to the implementation of the concept in the AEC sector. This is shown by the results of the fifth question (Fig. 19), where all professionals agree or fully agree with this statement.

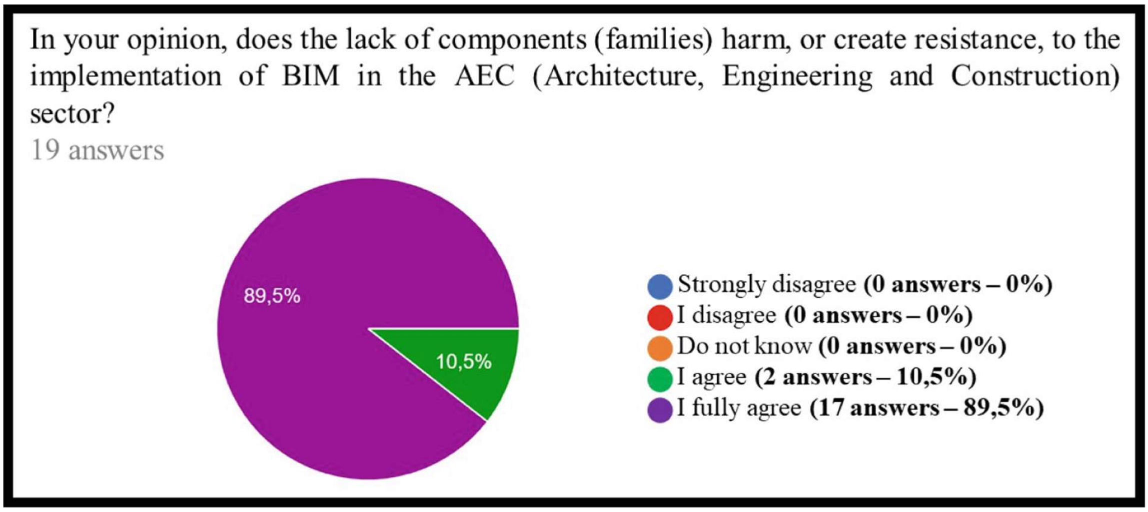

Fig. 19. Result of the fifth question in the questionnaire. Source: Authors (2020).

All questionnaire results are available on the link: (https://docs.google.com/forms/d/e/1FAIpQLScYKvbFiTWAshAk_-s5CWPVH3kIt_35MaznrOVgdL3RUpWVVA/viewanalytics).

5 Conclusion

From the current environmental and market context related to the final disposal of sewage, it was found that the lack of BIM components that represent decentralized systems of wastewater treatment hinders the presentation of these projects. This is a problem that causes damage to the proper functioning of these types of equipment and, consequently, to the environment and the health of the population. The preliminary results indicate that the artifact produced in this work has the potential to fill this gap, providing possibilities of choice by the designers, productivity in the design, learning and a certain flexibility in the construction of the models, which fits the market standards. This may be, in another perspective, the path to a new concept of sustainability in the AEC sector: the ability to accommodate all design disciplines harmonically to produce efficient construction systems from their parameters.

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