Current Overview of CMMS Operationality: Brazilian Scenario

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Abstract

Currently, the impacts of Industry 4.0 are observed in the construction industry, commonly referred to as Construction 4.0, emerging linked to technological innovations. Construction 4.0 presents a standardized model for smart cities and buildings, with the existence of some important points being essential, such as the capacity for adaptation, improvement and efficiency of resources and connections for everyone involved. As a result, new technologies and applications have been emerging that directly impact building maintenance activities, enabling increased efficiency and productivity in this sector, which reduces the risk of errors, failures and defects by maintenance managers. One of these applications is the use of computerized maintenance management systems (CMMS), which is a software solution designed to simplify building maintenance processes, in addition to improving the management of organizations' assets. In this sense, the present work aims to evaluate the CMMS available in the Brazilian scenario, showing the current panorama in which this technology has been presented to the market. To this end, we carried out a survey of the CMMS used by Brazilian maintenance companies using the *snowball method* to list the CMMS to be analyzed. The research carried out in 16 maintenance companies identified 9 CMMS, which were evaluated using the method proposed by Roscoff; Costella; Pilz (2020), which evaluates CMMS functionalities and activities. As a result, the sample analyzed presents heterogeneity in the results linked to CMMS functionalities and activities. In short, the registration items, a basic function, were met by all CMMS analyzed. However, advanced functions that are linked to the principles of Industry 4.0, such as interoperability, virtualization, real-time and service orientation, present disparities in results. Because among the nine CMMS evaluated, only three reached the levels proposed in the methodology.

1. Introduction

In the contemporary scenario, this dynamic appears linked to the search for a product capable of meeting the demands and functions of buildings and their users, be they: work, industrial, housing or governmental (GONÇALVES *et al.*, 2021; SANTOS; ALVES; PINHEIRO, 2021; SILVA, 2022). In this way, it is understood that a building must effectively guarantee durability and functionality throughout its life cycle. And for this, building maintenance activities are essential for constructions (VIANA *et al.*, 2022).

The focus on the need to preserve buildings is old and has been recorded with special importance over time. As an example, in the Roman Empire there was the figure of the *aedile*, the name of the ancient magistrates who carried out inspections and managed the conservation and maintenance of public buildings (MENDES *et al*., 2022).

According to NBR 5674, building maintenance is an important tool for maintaining the functionality and habitability of buildings and can be characterized as any and all interventions carried out on the building and its constituent parts, with the purpose of conserving or recovering its functional capacity (ABNT, 2012; MENDES *et al*., 2022).

However, it is observed that although there are guidelines on the subject, many buildings have problems arising from inadequate maintenance. In this regard, the main deficiencies in maintenance management have been: lack of a maintenance plan for buildings, lack of preventive maintenance, excessive corrective maintenance, shortage of trained or specialized personnel, insufficient budget and/or material resources, low quality of services performed and deficiencies in the project (VIANA *et al*., 2022).

However, according to studies carried out by Shrestha; Shrestha; Kandie (2014) in Kenya and Kalumbu; Mutingi; Mbohwa (2016) in Namibia (South Africa), these deficiencies tend to be mitigated when analogue management is replaced by computerized maintenance management. Silva (2022) highlights that the search for improvements in processes and technological innovations, new tools and methodologies, such as computerized maintenance management systems (CMMS), are being increasingly applied in organizations.

A *CMMS*, or computerized maintenance management systems, is a software solution designed to simplify building maintenance processes, in addition to improving organizations' asset management. Allowing maintenance managers to efficiently schedule, track and analyze the entire workflow involved, from work orders, inventory, maintenance tasks, budgets, etc. In this way, when using a *CMMS*, organizations can reduce downtime, extend the useful life of building systems, machines and equipment, optimizing work resources and improving maintenance operations in general (BLEASDALE *et al.*, 2022).

At a global level, research demonstrates positive cases in the use of *CMMS*, such as: the incorporation of the concept of multilayer architectures, in this way the management of assets, maintenance and operation are all encompassed through a digital twin *(Digital Twin - DT)* (QIUCHEN LU *et al*., 2020), automation of the needs described in the building maintenance plan and the management of cash flow (current revenue used to pay for operations and maintenance), which in turn affects various financial metrics, such as cash operational availability and the debt coverage ratio (BAIRD; JOLY, 2022), data mining and sharing for decision making based on proposed *insights* (JOHANNES *et al*., 2021), machine learning to improve the relationship with users (ASSAF; AWADA; SROUR, 2020).

In this sense, the present work aims to evaluate the CMMS available in the Brazilian scenario, showing the current panorama in which this technology has been presented to the market.

2. Building Maintenance and Construction 4.0

2.1 History, Concepts and Principles of Construction 4.0

Over time, the world has been going through a process of industrialization, through technological advances that resulted in the breaking of paradigms, a concept known as the industrial revolution. Table 1 presents a schematic summary of the four industrial revolution processes.

Table 1. Comparison between Industrial Revolutions

Revolution	Period	Pioneer country	Characteristics	Main technologies	Impacts on Civil Construction
1st Revolution	1760 / mid-20th century. XIX	England	Use of steam power, coal was used as the main source of energy	Mechanical loom and steam engine	Optimization of transport and diffusion of iron use
2nd Revolution	End of the century. 19th / mid-20th century. XX	USA	Practical use of electrical energy, mass production and oil was used as the main source of energy for machinery	Explosion engine and filament lamp	Optimization of transport, widespread use of steel and emergence of reinforced concrete
3rd Revolution	1950s /1970s	USA	Use of information technology, process automation and beginning to use sustainable energy sources	Computers, robots and the internet	Industrialization of the production of construction materials and the production process
4th Revolution	2011 / currently	Germany	Digitization and communication of processes, human-machine cooperation, production rationalization	CPS, IoT, AI, Big Data and smart factories	Increased digitalization and data integration, improved control and execution of services

Source: SAKURAI; ZUCHI (2018); ALALOUL *et al*., (2018) – adapted by the author

The fourth industrial revolution, also known as Industry 4.0, emerged in Germany through the development of technology projects aimed at the development of industry (SAKURAI; ZUCHI, 2018), covering the basic concept of machine connectivity, through automation and information technology to means of production, creating intelligent networks throughout the entire chain, leaving the factory agile, autonomous, predicting maintenance and failures, and even making adaptations and changes in production (SILVA *et al.,* 2019).

According to Schwab (2016), the impacts of Industry 4.0 have been changing the dynamics of production/consumption, through changes in customer expectations, the emergence of smarter and more productive products, new forms of collaboration and partnerships, transformation of the operational model and conversion in digital model.

These impacts of Industry 4.0 are observed in the construction industry, commonly referred to as Construction 4.0, emerging linked to technological innovations such as techniques such as construction site automation, 3D printing and project management through software (GRESSLER et al., 2020). According to Douglas, Kelly and Kassem (2021), the construction sector started to adopt these innovations motivated by the need to reduce production costs, stricter environmental legislation and the increasingly demanding consumer market.

According to Hermann, Pentek and Otto (2016) and FIRJAN (2016), in a systematic view, it is possible to identify some principles linked to the implementation of the Construction 4.0 concept, which are highlighted in Table 2.

Table 2. Construction Principles 4.0

PRINCIPLES OF CONSTRUCTION 4.0	
Interoperability	cyber -physical systems and between them and people.
Virtualization	The cyber -physical system is capable of monitoring physical processes through simulation and the creation of copies of real elements fed by data obtained through sensors.
Real time	More than the ability to collect data, it is the ability to work in real time, making decisions based on new findings or predictions.
Service Orientation	The use of service-oriented architectures and software combined with the concept of the Internet of Things (Internet of Services);
Modularity	Which makes factories more flexible and adaptable to necessary changes with the use of modular equipment systems and production lines
Decentralization of controls in processes	The ability to make decisions is distributed and independent, not centralized, increasing the ability to solve problems as they arise, where they arise. As a result, the operating environment guarantees flexibility

Source: Hermann, Pentek and Otto (2016); FIRJAN (2019)

2.2 Pillars of Construction 4.0

Construction 4.0 presents a standardized model for smart cities and buildings, with the existence of some important points being essential, such as the capacity for adaptation, improvement and efficiency of resources and connections of all those involved, ranging from the process of creating value until strategic application (SILVA, 2019).

To achieve this concept, Construction 4.0 has technologies that involve nine pillars, having as key points: big data, artificial intelligence, robotics, simulation, internet of things (IoT), cyber security, cloud computing, additive manufacturing, systems integration and augmented reality.

These are the technologies that will make Construction 4.0 more efficient, with the nine pillars of this new industrial revolution extremely connected, exchanging information to achieve greater agility in processes, data transmission and automation, making production stages more efficient and autonomous (GROSSI, 2021). These pillars are defined as:

- **Big Data and *Analytics*** : capture and processing of gigantic databases, analyzed using AI and correlation systems to obtain greater process optimization performance, rationalization in the consumption of inputs in general and seek production quality ;
- **Automatic Robots:** used in traditional industry, now gaining new functions with the help of other technological pillars, becoming more productive, more autonomous and interacting with the entire production line;
- **Simulation:** in Construction 4.0, computer simulation will be used together with plant information, bringing the physical and virtual world closer together. This tool helps companies develop and improve their products and processes. With the help of the computer, professionals carry out different analyzes in real time, detecting errors and helping with solutions, increasing productivity;
- **Industrial Internet or Internet of Things (IoT):** connectivity between machines (fixed or mobile) through electronic devices allowing data collection and exchange with Big Data;
- **Cybersecurity:** with increased connectivity, it is necessary to have an information protection system, as cyber threats increase due to the use of integrated systems. Therefore, security becomes essential, helping to manage sophisticated systems, identity and access of machines and users;
- **Cloud Computing:** sharing data and applications beyond a company's physical servers, generating great flexibility, performance and cost reduction compared to the physical model immobilized on its premises.
- **Additive Manufacturing:** also known as 3D printing, it helps in the production of parts from overlapping layers of materials, allowing the production of complex and personalized shapes directly from the virtual environment, generating input savings.
- **Integration System:** basically a manager of integrated systems to provide a single platform, where everyone has access. Construction 4.0 proposes greater harmony between all pillars, ensuring an integrated and automated system;
- **Augmented Reality:** the main feature of this technology is computer-assisted visualization.

2.3 Construction 4.0 Applications in Maintenance Management

Initially, it is important to highlight that, according to SENAI (2019), the impact of these applications requires changes in the technical skills of construction professionals, predicting the emergence of new professions, such as: building automation and maintenance system integrator, construction technician seca, automation and building maintenance technician, logistics manager, automation and building maintenance system installer. Some practical applications of Construction 4.0 in maintenance management are: BIM platform, Augmented Reality (AR), Drones, Smart Sensors and CMMS.

2.3.1 BIM Platform in Maintenance Management

To carry out a project, it is necessary to carry out several essential projects, such as: electrical, structural, architectural, hydrosanitary, geotechnical, foundation, fire fighting, etc. In the past, these projects were developed using specific software, without communication between them, which in many cases generated incompatibility, execution errors and loss of productivity in a sequential manner (AZEVEDO, 2021).

With the aim of solving this problem, the BIM platform was developed, which is nothing more than a set of programs that address the IFC extension to become compatible. Such a platform follows a fundamental principle of Industry 4.0, which is interoperability with supposed digitalization and integration of data, since a project can be opened in different programs (RIBEIRO, 2019)

Through the BIM platform it is possible to analyze all aspects of a construction in three dimensions, such as: the geometry of the structure, the type of material, thermal and acoustic efficiency, energy performance, aesthetics, installation details, security, maintenance and useful life of the work (LIMA, 2018).

Therefore, the BIM platform covers the entire life cycle of the building, from its conception to its renovation. In the initial design phase, BIM helps by detailing the project, ensuring greater compatibility between systems and simulating interactions. In the construction phase, BIM assists in construction logistics, in the manufacturing of building components and in its planning, cost and deadline. Furthermore, it also contributes to the use and operation phase of the building, in addition to its renovation and maintenance (RIBEIRO, 2019; PRUSKOVÁ, 2020). Figure 01 presents the applicability of BIM in the building's life cycle.

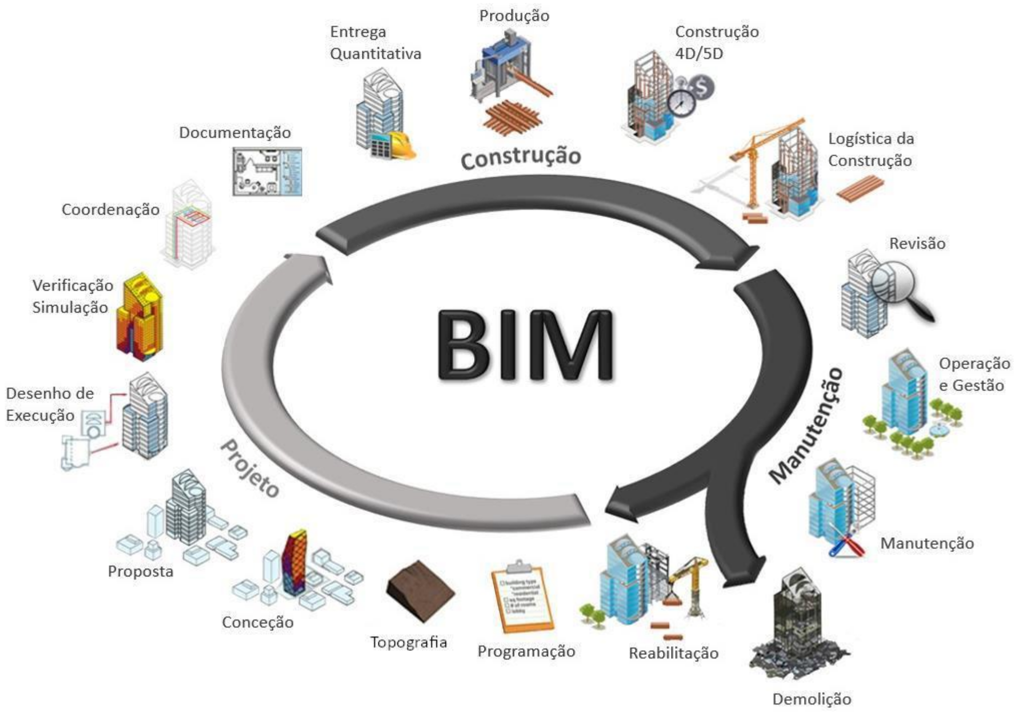

Figure 1. Areas of activity of the BIM platform

Source: Barata (2022)

In the past, production was only carried out in two dimensions in CAD. However, currently, BIM production has several dimensions, which expand as the tools to be integrated into projects increase (GARIBALDI, 2020), as shown in Figure 2.

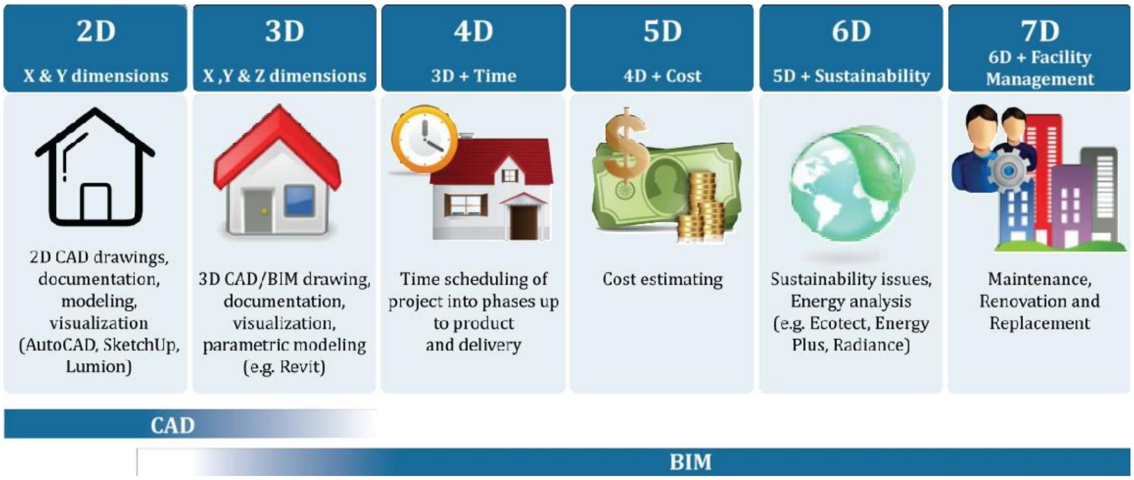

Figure 2. Dimensions in BIM

Source: Semantic Scholar (2018)

Therefore, Dimension 6D deals with the sustainability of the work, including information about manufacturers, maintenance schedules and expected useful life, making it possible to make decisions taking these aspects into account and plan maintenance activities in advance. Furthermore, maintenance management encompasses part of the

7D Dimension, which is focused on the operation and management of a building's facilities, including important asset information such as status, operation manuals, warranty information and technical specifications, all in a single easily accessible location (GARIBALDI, 2020).

However, for better efficiency in the application of BIM in maintenance management, it is necessary to associate other technologies. Success stories point to good use of BIM associated with Augmented Reality, which will be discussed in the next topic.

2.3.2 Augmented Reality in Maintenance Management

AR consists of a technology that integrates virtual content into a real scenario using cameras, allowing elements to be superimposed. In maintenance management, AR can be associated with BIM or 3D Scanner technology to optimize access to building information, such as: specification, manufacturer information, parts costs, dates for maintenance services and others. This way, there is a reduction in service execution time (BORRELLI; SCHEER, 2022).

A better understanding of the project has made it easier to carry out maintenance services efficiently. A practical example would be the need for maintenance of building installations that are above a removable plaster ceiling, with AR visualization the professional can choose which plaster plates need to be removed to carry out the service. Examples of AR technologies can be cited:

- **AR Sketchwalk:** It is a tool that allows, using a tablet, to position the project on the plane where the maintenance service will be carried out, and walk through it, observing how it will look after it has been carried out.
- **DAQRI Smart Helmet:** It is a helmet that allows the user to access the BIM model through the visor and see the project in the field of vision. With it, it is possible to visualize the water pipes, electrical boxes, steel structure, etc., making it easier to detect errors and make decisions for the engineer *on site*.
- **GAMMA AR:** Following the same idea of visualizing the BIM model *in situ*, the GAMMA AR application allows the user to compare the reality of the building with the project via tablets or *smartphone.*
- **Fologram:** Using augmented reality glasses, such as Microsoft HoloLens, the program transforms virtual 3D models into life-size service instructions. In other words, it projects the environment where the service will be performed and the method for execution.

2.3.3 Drones

Drones are unmanned aerial vehicles (UAVs) and are controlled remotely by remote control. In maintenance management, drones assist in aerial mapping, sensing, aerial photos, and building inspections, with the benefits of low cost and speed in performing services on roofs, facades, and upper reservoirs (RODRIGUES, 2023).

Such equipment makes it possible to inspect high places, which are difficult to access, replacing human action, reducing the risks of work accidents and the costs of personal and collective protective equipment, cranes, ropes, etc. Technical applications are due to the drone's ability to attach to devices such as cameras, infrared sensors, thermal sensors, radars, lasers, GPS, among others. When associated with thermography, images can be collected with detailed levels that show the difference in thermal radiation, improving the accuracy of diagnoses of pathological manifestations (MENDES *et al.*, 2022).

2.3.4 Smart Sensors

With the emergence of smart objects linked to IoT, data integration has become real-time, helping the operations and maintenance of buildings. Through the integration of sensors with BIM, it is possible to collect information continuously and share and communicate this information through IoT with other smart objects or with the maintenance management team (TANG, 2019), thus bringing several benefits from monitoring the building in various aspects.

IoT provides ways for facility managers to automate building maintenance and operations processes, building performance management, energy management, and developing failure response strategies (PISHDAD-BOZORGI et al., 2018).

Using IoT devices platforms can be created that support building operation and maintenance practices, such as, for example, access to real-time data, maintenance checks, creation and updating of a digital building platform; space management (TANG, 2019) and security alert through wireless devices, algorithms and software (ABRUZESSE *et al.*, 2020). In addition to the introduction of IoT in building performance management, where it is possible to increase performance in data management, as well as monitoring the quality of the internal environment and improving user comfort (TANG, 2019).

2.3.5 Computerized Maintenance Management Systems (CMMS)

Currently, maintenance companies have been adapting to constant changes and technological demands to maintain quality and competitiveness in the market. Because before Construction 4.0, maintenance management was carried out analogously, which creates a lack of control over service requests, which can generate divergences in internal communication, in addition to generating delays, losses and user dissatisfaction (SACRAMENTO; RIBEIRO, 2020).

CMMMS arise to mitigate these problems, as through them managers can access service costs, material records, work orders and schedules in an agile and precise way, monitoring the progress of maintenance, inspections and inspections in real time, obtaining greater control of processes, in addition to assisting in planning tasks, maintenance control and team performance, always pointing out productivity gains and losses (DE PAULA; CORRÊA, 2020).

In some CMMS it is possible to interact with users, who have a different level of access than managers, making it possible to call meetings and assemblies, evaluate services, carry out votes on subjects and issues raised in meetings, publish documentation and data, among other activities, all in a connected way.

Functions such as recording budget spreadsheets, service orders, materials used, labor values, preparing accounts, transparency of expenses, maintenance history, generation of reports, inspection checklist, service checklist, performance indicators and /or performance of the equipment used, facilitate the management of activities in an integrated and connected way. It is important to highlight that this technology can also interact with applications such as IoT, BIM, Augmented Reality, Cameras, Smart Sensors and GPS.

3. Methodology

To better understand the current situation regarding the use of CMMS, a market survey was carried out using the snowball method, also known as chain sampling. This is a non-statistical method with the aim of extracting from a random sample of interviewees indications or suggestions that can answer a question (LOBO, 2020).

To this end, a preliminary survey was carried out in newspapers and on the internet, with basic information on the different maintenance companies operating in Brazil that use *CMMS* as a tool in maintenance management.

As a result of the previous survey, 16 companies were identified and selected because they are linked, directly or indirectly, to the provision of building maintenance services. All companies agreed to participate in the interview, which were kept anonymous, being identified as company 1 to 16. Four (4) questions were asked during the interview, namely:

- If the company uses a CMMS as a maintenance management tool?
- What CMMS is used by the company?
- The company's level of satisfaction with the CMMS used? The indicators are evaluated: Excellent, good, regular and bad.
- If the company would recommend any CMMS for use, in addition to what it uses.

As a result of the final survey, it was found that 14 (fourteen) of the 16 (sixteen) companies interviewed use some *CMMS*. Between use or indication, the CMMS most cited in the interview were: SIENGE PLATFORMA – SIENGE (6 citations), followed by ADMINISTRAND CONDOMINIOS – ACOLWEB (3 citations) and OPTIMUS – CONSTRUMARKET (2 citations), FRACTTAL ONE – FRACTTAL (2 citations), INFRASPEAK (2 citations), ENGEMAN® – ENGEMAN (2 citations), YOUBIM (2 citations). The other CMMS obtained only one citation in the search result, as shown in Table 3.

Table 3. Research carried out with maintenance companies in Brazil

Maintenance Companies	Do you use any CMMS?	Which CMMS do you use?	Satisfaction Level	Indication of another CMMS
Company 1	Yes	MANAGING CONDOMINIUMS – ACOLWEB	Good	SIENGE PLATFORM – SIENGE
Company 2	Yes	SIENGE PLATFORM – SIENGE	Good	OPTIMUS – CONSTRUMARKET
Company 3	Yes	SIENGE PLATFORM – SIENGE	Excellent	-
Company 4	Yes	ENGEMAN® – ENGEMAN	Good	FRACTTAL ONE – FRACTTAL
Company 5	Yes	ENGEMAN® – ENGEMAN	Good	-
Company 6	Yes	OPTIMUS – CONSTRUMARKET	Good	SIENGE PLATFORM – SIENGE
Company 7	Yes	FRACTTAL ONE – FRACTTAL	Excellent	SIENGE PLATFORM – SIENGE
Company 8	Yes	INFRASPEAK	Good	MANAGING CONDOMINIUMS – ACOLWEB
Company 9	Yes	SIENGE PLATFORM – SIENGE	Good	MANAGING CONDOMINIUMS – ACOLWEB
Company 10	Yes	INFRASPEAK	Good	-
Company 11	Yes	YOUBIM	Good	-
Company 12	Yes	LEANKEEP	Regular	-
Company 13	Yes	SISPRED	Regular	-
Company 14	Yes	YOUBIM	Good	-
Company 15	No	-	-	-
Company 16	No	-	-	-

Source: Author.

The CMMS mentioned in the interview were evaluated according to the method proposed by Roscoff; Costella; Pilz (2020). The investigation of these was carried out using free versions, explanatory videos of the software and meetings with sales consultants, allowing us to identify their main characteristics and point out deficiencies. The method presents two evaluation phases: screening, following the requirements described in Table 4 and analysis of the activities and functionalities available in the software, as described in Table 5.

Table 4. Requirements for CMMS analysis

AREA	REQUIREMENT
Accessibility	Have access via the web
Scope	Scope focused on preventive building maintenance
Operability	Have a responsive system (adapt to smartphone screens)
Communication	Have a version in Portuguese (Brazil)

Source: Roscoff; Costella; Pilz (2020).

Table 5. CMMS Analysis: Activities and Functionalities

ACTIVITIES	FUNCTIONALITIES
Register	Multiple users, System/equipment, Third parties and suppliers, Users with different access levels.
General features	Management of multiple buildings by registration, Building visualization (Form, Plan, Sensors or BIM)
Documents	Floor plan, Contracts, Financial statement, Owner's/manager's manual
Maintenance schedule	Manually created, Template sourcing
Order of Service	Possibility to attach photo, Registration via smartphone, Contact with the supplier, Request for approval, Registration by owners.
Operation and maintenance	List of equipment/materials, List of employees, Performance history.
Reports	Custom Reports

Source: Roscoff; Costella; Pilz (2020).

4. Results Obtained

All software was validated against the requirements listed in the screening stage described by Roscoff; Costella; Pilz (2020), as shown in Table 6. Nine CMMS are mentioned, as shown in Figure 3.

Figure 3. CMMS analyzed

Source: Author

Table 6. Software screening according to Roscoff requirements; Costella; Pilz (2020)

REQUISITOS	SOFTWARES								
	ACOLWEB	SIENGE	ENGEMAN	OPTIMUS	FRACTTAL	INFRASPEAK	YOUBIM	LEANKEEP	SISPRED
Acessibilidade	x	x	x	x	x	x	x	x	x
Escopo	x	x	x	x	x	x	x	x	x
Operabilidade	x	x	x	x	x	x	x	x	x
Comunicação	x	x	x	x	x	x	x	x	x

Source: Roscoff; Costella; Pilz (2020) – Adapted by the Author

In a prior analysis, it can be reported that CMMS Administrando Condomínios is a SaaS platform specialized in condominium engineering, based on different concepts of usability and navigation, being able to assist, in a simple, objective and transparent way, the needs of the property manager. and condominium administrators. The platform stands out for presenting real-time reports, multiple *uploads*, different types of customizations, in addition to adapting to different types of screens and electronic devices. However, the "building visualization" function does not integrate graphics, sensors or BIM technology.

SIENGE's CMMS is a platform made up of several software with different functionalities, in the construction industry its portfolio provides solutions from pre -work to post-work, from cost composition, quotation and purchase of materials, LEAN planning, feasibility studies, between others. However, the available software does not have specific functions for managing building maintenance. The "building visualization" function is integrated with BIM technology, but in an interface for construction management.

ENGEMAN is routine automation software for the maintenance sector. In this way, it helps maintenance managers with asset management, reporting, unexpected downtime, high expenses, loss of information and lack of updating, among other problems. Even so, it lacks important functions linked to the activities of "Documents", "Maintenance schedule", "Service order" and "Operation and maintenance".

OPTIMUS is a platform specialized in intelligent *facilities management* and building maintenance for various types of projects, presenting routine and periodic functions for all construction systems and their components and equipment. Furthermore, OPTIMUS has a real-time management function for mobile teams through GPS and the use of intelligent sensors to monitor environments and equipment.

FRACTTAL is a specific platform to assist managers, planners and technicians in managing building maintenance for various types of projects. Its features use intelligent sensors to monitor environments and equipment.

INFRASPEAK aims to guarantee maintenance managers full, real-time visibility over their buildings, equipment, technicians and customers. In this way, it provides functions such as preparing maintenance plans, scheduling tasks and creating activity summaries, ensuring legal compliance and extending the life of assets. In addition, it has a system for interacting its platform with IoT sensors or Building Management Systems (BMS) to monitor the status of its assets.

YOUBIM allows the user to monitor corrective maintenance and plan predictive maintenance, being able to view them in a calendar format. Checklists can be attached to routines so technicians can understand the exact steps to get the job done correctly. However, even with the integration with BIM, YOUBIM lacks important functions linked to the activities of "Documents", "Maintenance schedule", "Service order" and "Operation and conservation".

Finally, the LEANKEEP and SISPRED software have almost all the functionalities linked to maintenance management activities, they have the "building visualization" function only by plan, without using sensors or BIM. Table 7 presents the complete analysis of CMMS in accordance with the method proposed by Roscoff; Costella; Pilz (2020).

Table 7. CMMS Analysis: Activities and Functionalities

ACTIVITIES	FUNCTIONALITIES	SOFTWARE								
		ACOLWEB	SIENGE	ENGEMAN	OPTIMUS	FRACTTAL	INFRASPEAK	YOUBIM	LEANKEEP	SISPRED
Register	Multiple users	x	x	x	x	x	x	x	x	x
	System/equipment	x	x	x	x	x	x	x	x	
	Third parties and suppliers	x	x	x	x	x	x	x	x	
	Users with different access levels.	x			x	x	x			
General features	Management of multiple buildings per registration	x	x	x	x	x	x		x	
	Building visualization (Form, Plan, Sensors or BIM)	Form	BIM	Form/Plan	Form / Sensors	Form / Sensors	Form / Sensors	BIM	Plant	Plant
Documents	Blue print	x		x	x	x	x	x	x	x
	Contracts	x		x	x	x	x		x	x
	Financial statement	x			x	x	x		x	x
	Owner/manager manual	x			x	x	x			
Maintenance schedule	Manually created	x	x	x	x	x	x	x	x	x
	Model supply				x	x	x			
Order of Service	Possibility to attach photo	x		x	x	x	x	x	x	x
	Registration via smartphone	x			x	x	x		x	
	Contact with the supplier	x	x	x	x	x	x		x	x
	Request for approval	x	x	x	x	x	x		x	x
	Registration by owners	x			x	x	x			
Operation and maintenance	Equipment/materials relationship	x	x	x	x	x	x	x	x	x
	Employee relationship	x			x	x	x		x	
	Performance history	x		x	x	x	x	x	x	x
Reports	Custom Reports				x	x	x		x	

Source: Roscoff; Costella; Pilz (2020) – Adapted by the Author.

In short, of the nine software analyzed, OPTIMUS, FRACTTAL and INFRASPEAK stood out positively, which meet all the functionalities listed in the method proposed by Roscoff ; Costella ; Pilz (2020).

In relation to the others, it was possible to observe that, despite the functionalities present, they are not designed for the preparation of the automated Owner/Manager Manual, they do not provide editable maintenance plan models, in addition to being inefficient in managing resources (financial, human and materials).

5. Final Considerations

All civil construction sectors are directly linked to socioeconomic development regionally and nationally. However, it is necessary to adapt production processes to the principles and pillars of Construction 4.0, which are the result of the fourth industrial revolution.

Through the literature review, presented in item 2.0, it is possible to become aware of the technological advances that impact building maintenance activities. The range of applications of new technologies makes it possible to increase efficiency and productivity in this sector, which reduces the risk of errors, failures and defects by maintenance managers.

The sample analyzed presents heterogeneity in the results linked to CMMS functionalities and activities. In short, the registration items, a basic function, were met by all CMMS analyzed. However, advanced functions that are linked to the principles of Industry 4.0, such as interoperability, virtualization, real-time and service orientation, present disparities in results. Because among the nine CMMS evaluated, only three reached the levels proposed in the methodology.

This fact is worrying, as with the levels of user demand and market competitiveness it becomes practically impossible to promote good maintenance management without the implementation of an efficient CMMS.

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