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Utilization of BIM in Steel Building Projects: A Systematic Literature Review

José Ignacio Avendaño [1], Sisi Zlatanova [2], Alberto Domingo [1], Pedro Pérez [3] and Christian Correa [3,*]

[1] Department of Construction Engineering and Civil Engineering Projects, University Polytechnic of Valencia, 46003 Valencia, Spain; jo.ignacio.a@gmail.com (J.I.A.); adoming@cst.upv.es (A.D.)
[2] GRID, School of Built Environment, University of New South Wales, Sydney 2052, Australia; s.zlatanova@unsw.edu.au
[3] Department of Civil Works, Faculty of Engineering Sciences, University Católica del Maule, Talca 3480094, Chile; pedro.perez@alu.ucm.cl
* Correspondence: clcorrea@ucm.cl

Abstract: This research aims to bridge the information gap pertaining to the utilization of building information modeling (BIM) in steel building projects. Therefore, a systematic literature review (SLR) was conducted to synthesize the available uses. This research involved three phases—planning, execution, and reporting—according to the PRISMA guide, which includes the main aspects of identification, screening, and eligibility. As a result of the SLR, it is evident how and where BIM facilitates steel building projects, which were grouped into three different categories according to their main BIM topics. One of the uses that stands out as a common denominator across the different processes is "early integration". Early integration allows for optimization of the design based on existing resources, directly affecting the cost and time of steel building projects in a positive manner.

Keywords: building information modeling (BIM); steel project life cycle; project management; communication in steel construction projects

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1. Introduction

Steel is an essential material for the construction industry; as a result, its consumption and production per capita have grown considerably, owing to population growth and increasing demands for industrialization in developing countries, among other factors [1]. Steel offers certain advantages over other construction materials, such as low weight, adequate structural behaviors, a high degree of prefabrication, and increased construction speed [2,3]. Steel construction can be divided into two categories: (1) "concrete building," which is realized using concrete and steel bars (reinforced concrete); and (2) "steel building," where steel is considered the primary construction material [4]. Steel construction involves a wide variety of projects, such as industrial, housing, and non-housing projects, which have lower costs and greater social values than those associated with reinforced concrete [2,3]. A steel building project comprises factory-made components or units transported and assembled in the shop or on-site [5]. The work phases involved are (1) planning, (2) design, (3) fabrication, (4) transport, (5) construction planning, and (6) erection of the structure [5,6]. The efficient completion of these steps maximizes the benefits of working with steel [7]. However, the use of steel as a construction material has increased the complexity of projects, particularly in terms of information management, because it is imperative to ensure quality and timely information for the different actors involved in the workflow. Thus, redoing processes can be avoided, and, consequently, the associated costs and construction time can be reduced. The inefficient use of information results in fragmentation during construction [8]. To cope with such fragmentation, it is necessary to include building information technologies that facilitate collaboration between the different actors involved in the building life cycle [9].

Building information modeling (BIM) refers to a set of processes that improve the deliverables, relationships, and roles of stakeholders in the construction industry [10–12]. These deliverables are framed under the concept of the level of development, which is a reference tool that is aimed at improving the quality of communication between the users of building information models and provides guidelines pertaining to the characteristics and details of the elements in the 3D models. [13–17]. BIM reduces costs and improves management efficiency [18–21], prioritizing the needs of the project, among other things, above each specialty or process. Some of the benefits of using this technology for each actor are as follows:

Principal/Owner: Enables efficient information exchange, streamlines project communications, and generates options that allow for effective changes to achieve the project objective, without sacrificing cost control, budget management, and schedule.

Engineers/Designers: Enables designers to improve their long-term relationship with different stakeholders, owing to better understanding of the different sub-processes for the materialization of the construction project.

Builder/Executing Engineer: Enables the contribution of their knowledge during the design process, or updating of the model during different stages of construction, thereby improving pre-execution and on-site planning, and affording a better understanding of design and building [22,23].

Over recent years, other technologies have been complemented by BIM, such as virtual reality (VR), augmented reality (AR), digital twins, and the Internet of Things (IoT) [24].

Augmented Reality: This computer technology can provide a highly immersive construction experience to different stakeholders, or be used to monitor the construction process [13,25].

Virtual Reality: Contrary to AR, VR is mainly used for planning and simulation in the different phases of construction projects. This technology can be used to reveal limitations from a contractor's perspective because it is considered more akin to an animation, rather than an actual construction representation [26].

Digital Twins: This concept aims to bridge the actual and digital worlds by employing sensor technology for monitoring and analysis, in order to adapt to actual construction or digital plans. Similar to BIM, it can be used across different project stages [27].

Internet of Things: The IoT facilitates interconnect physical entities (such as humans, equipment, devices, and workstations) and collects all data from different processes [13,28,29].

Combining BIM, AR/VR, digital twins, and IoT with actual data from a construction project enables stakeholders to obtain information regarding the predicted state of construction. However, many challenges exist in transferring data between the different software packages to allow for smooth and seamless utilization [25,30].

BIM has been associated with improved productivity and cooperation among teams and different phases; accordingly, BIM has been employed in many applications, such as urban management and navigation [31,32]. However, the benefits of using BIM in the steel building process have not been explored comprehensively [33]. Hence, the objective of this study was to identify the uses of BIM and its benefits pertaining to steel building processes. To this end, a systematic literature review (SLR) related to BIM in steel buildings was conducted.

2. Materials and Methods

Traditional literature reviews lack a transparent and reproducible process that enables others to determine the accuracy of the results [34]. By contrast, systematic reviews of the literature are more informative and scientific when conducted rigorously and are, therefore, well justified [35,36]. Thus, in this work, a systematic review was designed to locate, analyze, and synthesize the evidence available in literature to answer the aforementioned research question [37]. Systematic reviews follow well-defined and transparent steps and always require the following: precision of the question, identification of the available scientific documentation, and summary of the findings [38]. Therefore, an SLR was used to achieve the research objectives, according to the approach suggested by Tanfield [39]. The structure of this research entails three phases: (1) planning, (2) execution, and (3) reporting [40]; this is illustrated in Figure 1.

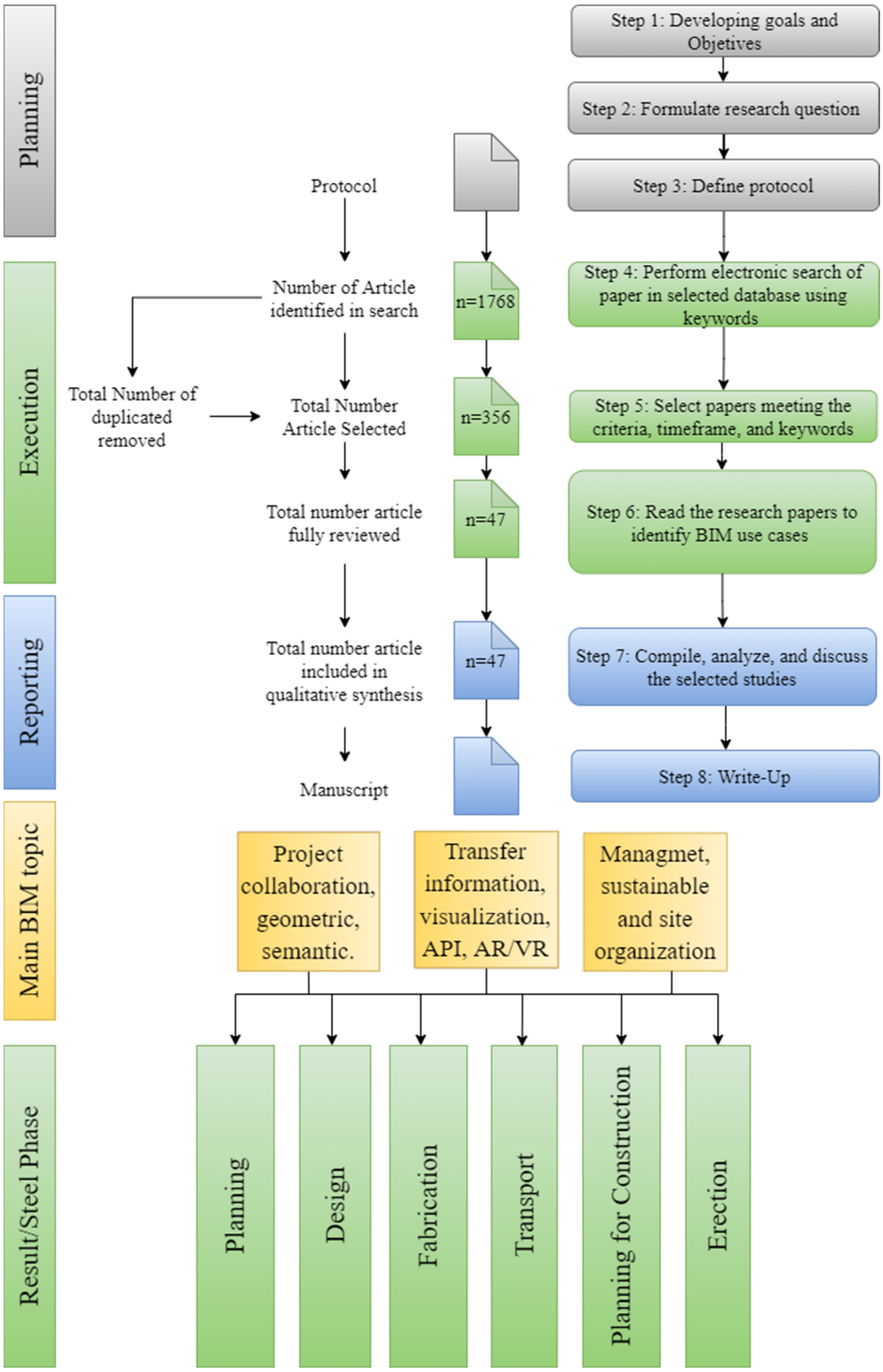


Figure 1. SLR process for this article. (Modified from Kim and Brown) [41].

Protocol establishes searching and evaluating processes regarding information to answer questions and to achieve the objective [42], that is, to identify BIM practices in the steel building project. Subsequently, research questions were formulated based on the provisions of the population, the phenomenon of interest, and context (PIC) elements for qualitative reviews. PIC elements can aid in defining the question, and the inclusion, and exclusion, criteria used to select studies for systematic review [38,43]. Therefore, the following question was formulated.

Research Question: What are the use cases of bim in steel building projects?

To address the issue of article quality, it was decided to primarily include content from peer-reviewed journals, such as the Web of Science (WOS) and Scopus. Between 2012 and 2022, see Table 1, the search strings used were: (a) “Steel”, (b) “Building Information Modeling”, (c) “Detailing”, (d) “Construction”, (e) “Manufacturing”, (f) “Prefabrication,” (g) “Impact business”, (h) “Innovation industry”, (i) “Structures”, and (j) “Projects performance”, see Table 2.

Table 1. Inclusion and exclusion criteria [38].

Criteria	Inclusion	Exclusion
1	Articles that discuss BIM in the steel building project	Articles that do not discuss BIM in the steel building projects
2	Articles that are in WOS and/or Scopus	Articles that are not in WOS and/or Scopus
3	Articles that were published in 2012–2022	Article published before 2012

Table 2. Keyword combinations for BIM practices used in the SLR process.

K1: Steel K2: Building Information Modeling K3: Detailing K4: Construction K5: Manufacturing		K6: Prefabrication K7: Impact business K8: Innovation industry K9: Structures K10: Projects performance
Combinations	**Results from database**	
	WoS	**Scopus**
C1: K1 AND K2 AND K3	118	19
C2: K1 AND K2 AND K4	267	327
C3: K1 AND K2 AND K5	94	64
C4: K1 AND K2 AND K6	12	9
C5: K1 AND K2 AND K7	3	9
C6: K1 AND K2 AND K8	22	6
C7: K1 AND K2 AND K9	420	319
C8: K1 AND K2 AND K10	35	44
TITLE-ABS-KEY	C1: Steel AND Building Information Modeling AND Detailing	
	C2: Steel AND Building Information Modeling AND Construction	
	C3: Steel AND Building Information Modeling AND Manufacturing	
	C4: Steel AND Building Information Modeling AND Prefabrication	
	C5: Steel AND Building Information Modeling AND Impact business	
	C6: Steel AND Building Information Modeling AND Innovation industry	
	C7: Steel AND Building Information Modeling AND Structures	
	C8: Steel AND Building Information Modeling AND Projects performance	

The execution process began with a documentation search of the selected databases. Duplicate articles (present in different databases) were only considered once to avoid counting a previously found article twice. The selected articles were positioned as relevant or irrelevant, according to the magnitude of their titles and abstracts to respond to the research questions [37–42]. Categorization was performed independently by each author [28]. Articles were evaluated using an article quality checklist. This quality checklist form was adapted from PRISMA 2020 and contained 12 items. The most relevant ones are the locality of the research, steel building project description, BIM use name, BIM use description, and performance indicators [44]. Table 3 summarizes the SLR that resulted in a total of 47 articles.

Table 3. Articles that resulted from this systemic search.

Screening Step	Number of Articles in Sample
Original sample	1768
Duplicates removed	643
After cut-off point	356
Unrelated articles removed	309
Articles that could be retrieved	47
Final sample	47

Once the relevant articles were identified, the "Quality assessment" activity was conducted. In this activity, the authors conducted a comprehensive analysis of the relevant articles to select those related to BIM utilization in steel building projects. As in the previous process, a crosscheck of the documentation found was performed [45]. Subsequently, the "Data extraction" activity commenced, which consisted of obtaining information directly related to the question of this work. The systematic classification and evaluation of the evidence in the articles were conducted using the methodological principles of the grounded data theory (TFD); in other words, through constant comparisons, the evidence is collected, coded, and analyzed to generate concepts and groups to discover the relationships between these articles and, thus, obtain decisive evidence pertaining to the questions posed and construct explanations [46]. To minimize errors in the analysis and interpretation of the extracted information, the authors held periodic online meetings to resolve inconsistencies in the interpretation of the results.

In the reporting stage, the results of the research were recorded. In the first stage, we mapped the main elements of the literature, that is, tabulated the results to visualize how many studies met the inclusion criteria. The next step was to combine the BIM use cases into one of the three groups: 1. Project collaboration: Geometric Semantic; 2. Transfer information, visualization API, AR, and VR; 3. Management, sustainability, and site organization. The information/uses analyzed, due to the complexity, were grouped into the following project phases [5,6]: (1) planning, (2) design, (3) fabrication, (4) transport, (5) planning for construction, and (6) erection; this helps explain its application and its relationship with the other phases of the steel building project.

3. Results

Table 4 shows the year of publication, journal, CI, quartile, and impact factor of the journals that published this bibliographical search. The Journal of Conservation and Recycling has the highest impact factor, followed by the Journal of Cleaner Production and the Automation in Construction journal.

Table 4. Systemic search results.

Source	Quartile	Impact Factor
Advanced Engineering Informatics	Q1	6.41
Advances in Civil Engineering	Q3	1.8
Applied Mechanics and Materials	Q2	3.15
Applied Sciences	Q2	2.736
Architectural Engineering and Design Management	Q2	2.19
Automation in Construction	Q1	9.16
Bautechnik	Q3	0.35
Conservation and Recycling	Q1	9.93
ISPRS International Journal of Geo-Information	Q1	2.899
International Journal of Steel Structures	Q2	1.33
Journal of Building Engineering	Q1	5.7
Journal of Cleaner Production	Q1	9.297
Journal of Facilities Management	Q2	2.19
Key Engineering Materials	Q4	0.45
KSCE Journal of Civil Engineering	Q2	1.97
Stahlbau	Q3	0.23
Sustainability (Switzerland)	Q1	3.48
Transportation Research Record: Journal of the Transportation Research Board	Q2	1.81

Figure 2 shows the percentage of ranked journals in the bibliographic data; 66% of the data are from the journals in the first quartile, 23% are from those in the second quartile, 9% are from those in the third quartile, and 2% are from those in the fourth quartile.

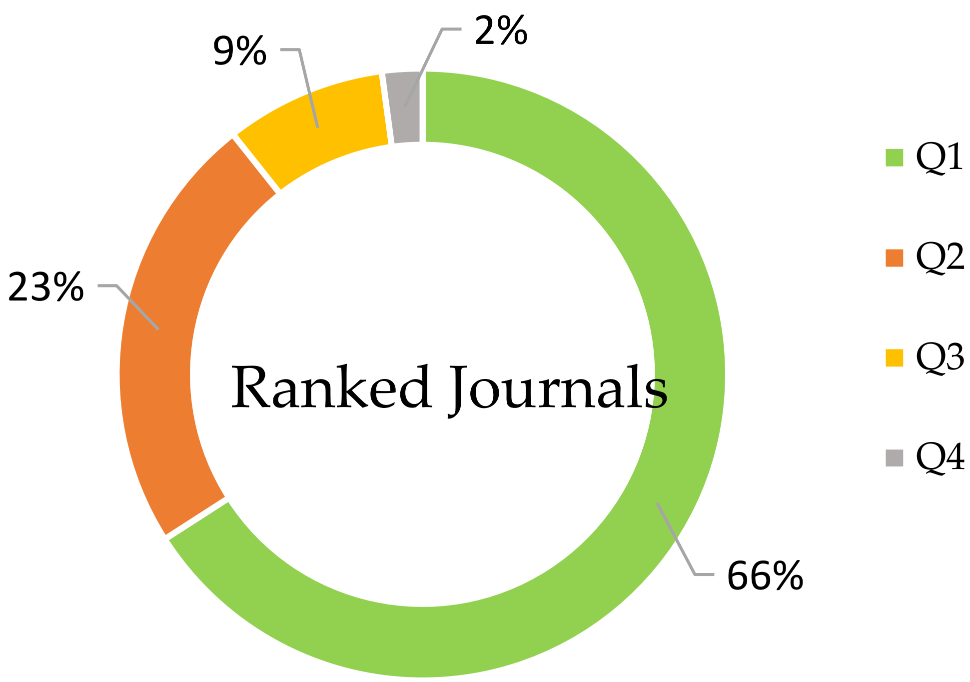


Figure 2. Percentage of ranked journals in the bibliographic data.

Figure 3 depicts the historical literature review, which indicates that the largest number of publications related to this research was presented between 2019 and 2020.

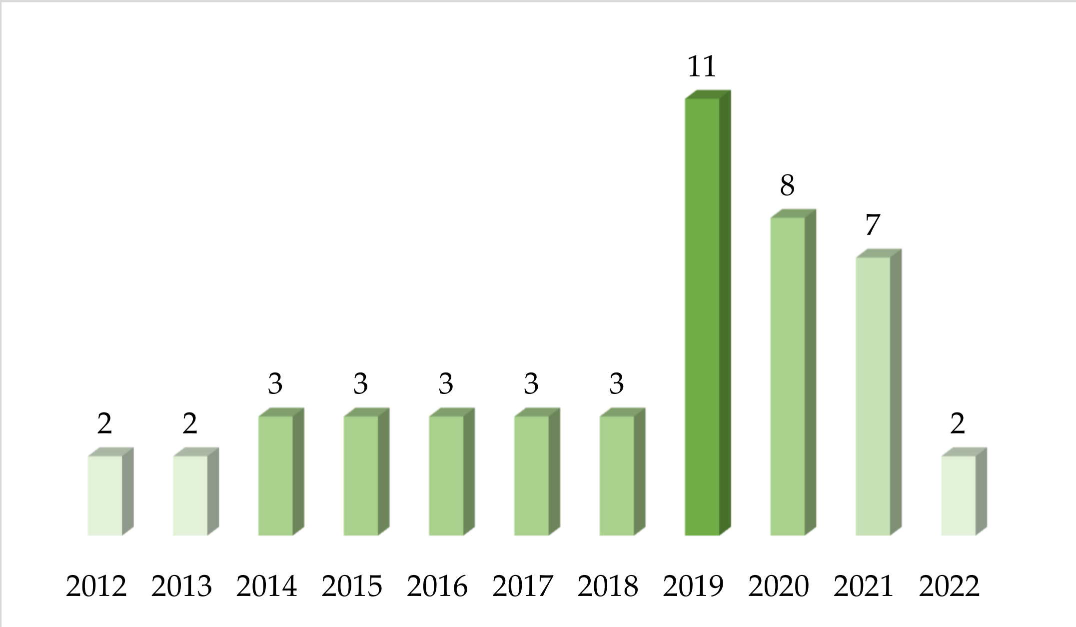


Figure 3. Evolution of the research literature review.

Figure 4 shows the relationship between the journals with the highest number of publications on this topic. The Automation in Construction journal stands out with 21 articles.

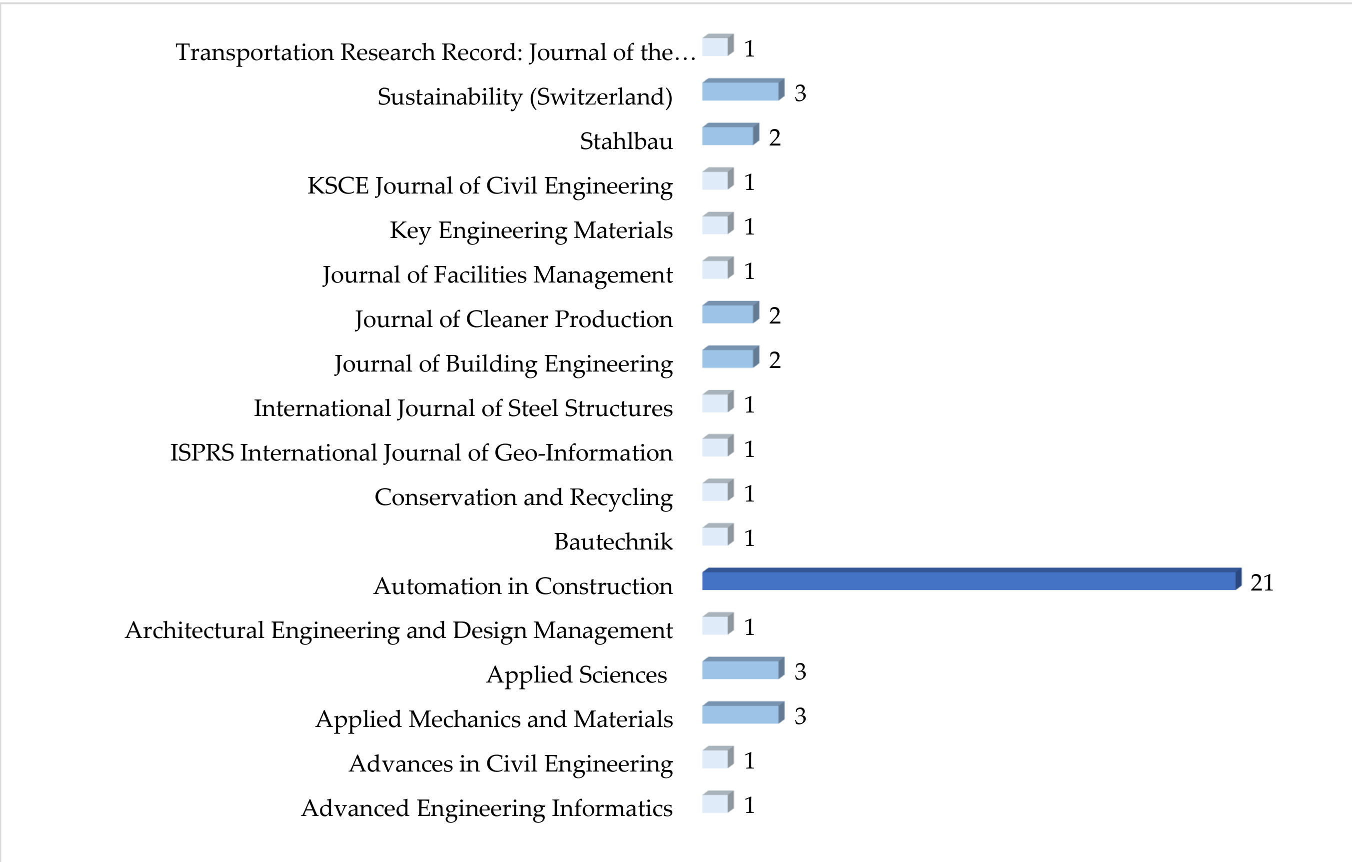


Figure 4. Number of publications per journal.

Figure 5 shows the percent of citations found for the articles included in this review, divided by continent. It indicates that most articles were cited from Asia and North America, followed by Europe, Oceania, and Africa. Authors with more than one publication include Al-Hussein, M., Ahmad, R., followed by Yoo, M., Martinez, P., Wang, Q., Cheng, J., Yu, J. and Park, J.

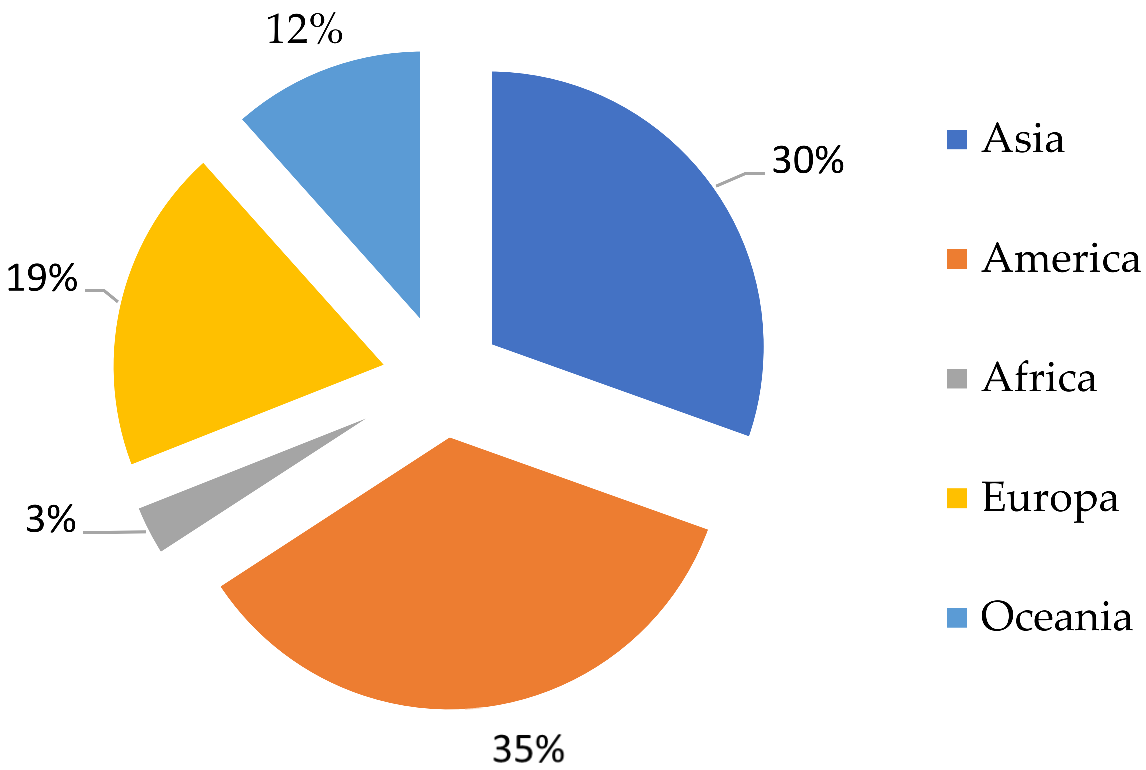


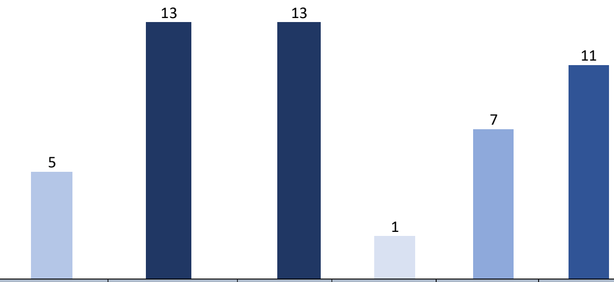
Figure 5. Cites by continent.

Table 5 shows the BIM uses involved in the different stages of the steel buildings project life cycle. These uses were compiled for each phase, as indicated in Figure 6.

Table 5. Number of uses by steel building phases.

Number of BIM Uses by Phases					
Planning	**Design**	**Fabrication**	**Transport**	**Planning for Construction**	**Erection**
5	13	13	1	7	11

Figure 6 summarizes the BIM uses related to the six steel building phases involved: planning, design, fabrication, transport, planning for construction, and erection [5,6]. The sidebars indicate the specific process in which the uses are executed, whereas the upper bars indicate the number of uses involved in each process. In addition, these were grouped under three different categories according to their main BIM topics.



Segment	BU#	BIM USES	Planning	Design	Fabricacion	Transport	Planning for construction	Erection	
			Steel Structure Phases						
Projects collaboration: Geometric, Semantic	1	3D BIM models to visualize and improve steel processes.	1	1	1	0	1	1	5
	2	BIM Collaboration for Structural Engineering and L.O.D.	0	1	1	0	1	0	3
	3	Early integration between design, manufacture, and assembly based on BIM models.	1	1	1	0	1	1	5
	4	Create a BIM modeling prior to fabrication.	0	1	1	0	0	0	2
	5	Traceability of the manufacture and assembly processes using BIM models.	0	1	1	0	0	1	3
Transfer information, Visualization API, AR, VR	6	BIM and virtual/augmented reality.	0	1	1	0	1	1	4
	7	BIM and IoT	0	1	1	0	0	1	3
	8	Use API for non-geometric information transfer.	0	1	1	0	0	0	2
	9	Control Installation through BIM.	0	0	1	0	1	1	3
	10	BIM and Laser scanning data.	0	1	1	0	0	1	3
Management, Sustainable and Site Organization	11	Cost analysis through BIM models.	1	1	1	0	1	1	5
	12	BIM for construction management.	1	1	1	0	1	1	5
	13	Structural health monitoring with BIM models.	0	1	0	0	0	1	2
	14	BIM information to improve site logistics planning.	0	0	0	1	1	1	3
	15	BIM for deconstructability and Identification of reusable steel materials.	1	1	1	0	0	0	3

Figure 6. BIM utilization is related to the six project life cycle phases: planning, design, fabrication, transport, planning for construction, and erection.

4. Discussion

The bibliographic review was analyzed and grouped into three sections: 1. Project collaboration: Geometric Semantic; 2. Transfer information, visualization API, AR, VR; and 3. Management, Sustainable, and Site Organization. This discussion section includes observations of the BIM utilization results (BU).

BIM utilization descriptions:

- *Use of 3D BIM in collaborative steel building projects: Geometric and semantic.*

BU#1: One of the main applications of 3D BIM models is the visualization and improvement of steel processes. This has been the focus of literature to date [33,47–50], highlighting 3D BIM as a comprehensive project engine that will replace 2D drawings with a communication channel that principally works through a 3D model [20,21,50]. The visualization and comprehension benefits of 3D BIM models can be used by people fulfilling various roles in the steel building process, such as owners, welders in the factory, and workers installing structural bolts during the erection stage [51]. Conversely, the exclusion of BIM can impact the level of understanding and stakeholder expectations of the project [47]. Should a 3D BIM model be executed only in certain phases of a project, these phases alone will benefit from the visualization and comprehension provided by the 3D model [52]. Furthermore, excluding 3D BIM models from steel construction will prevent detection of interferences with other mechanical engineering and plumbing MEP disciplines. [50]. BIM use applies to the planning, design, manufacturing, construction planning, and erection phases. This use is not applicable to the transportation phase.

BU#2: From a structural engineering perspective, BIM collaboration in structural engineering, and level of detail (L.O.D), permits interoperability and aims to maximize building model information collaboration to improve work efficiency and structural quality [20]. To implement this, the level of information detail that will be transferred between the different stakeholders must initially be agreed upon [53]. The literature review showed that this utilization was not applied in three of the six building project construction phases: planning, transport, and erection phases were excluded. For example, by not applying this utilization in the planning phase, it would be impossible to determine the steel tonnage to be processed by the manufacturer and assembler, which is essential information for a correct estimate of the project costs by stakeholders, especially the owner [54]. In addition, a lack of guidelines that clearly state the L.O.D required in the BIM models for the erection stage could result in misunderstandings and delays.

BU#3: The early integration between design, manufacture, and assembly, based on BIM models, is a critical utilization in this section, although there is no evidence of it in the transportation process. It is evident from this literature review that the incorporation of BIM models to ensure early integration between the designer, manufacturer, and erector reduces the cost and time of steel building projects [54–59]. This ensures that the resources available to the fabricator and erector are considered in the design process. [54]. In addition, the stakeholder is encouraged to work toward a common, and not an individual, objective [60–62]. Conversely, insufficient information is available to show the beneficial effects of early integration in the transport phase.

BU#4: The creation of BIM models before manufacturing positively impacts the following phases of transportation, planning for construction, and erection. Before manufacturing, the utilization of BIM models primarily takes advantage of the ability of BIM to detail steel structures and automatically generate the 2D drawings required for fabrication [33,54,55]. In addition, the steel detailing software can transfer information from the BIM model to the factory's computer numerical control machinery to optimize cutting, bending, and punching [56]. The exclusion of BIM from the stages preceding fabrication results in delays and a lack of accuracy in the documentation necessary for manufacturing, as these processes are done manually by a draftsman, rather than by BIM software algorithms [62,63]. The 3D BIM model increases the reliability and precision of the results, or deliverables, of each phase of the project.

BU#5: The traceability of the manufacture and assembly processes using BIM models is primarily utilized in the design, manufacture, and erection processes. Similar to the previous BIM utilization (BU#4), the BIM model includes detailing software rich in information with graphical and non-graphical examples of the primary and secondary steel elements. [58]. This information is transferred to the Enterprise Resource Planning (ERP) software to implement production control, and can be directed to a common data environment to share the manufacturing or assembly statuses with the stakeholders [64]. The exclusion of BIM utilization necessitates the manual input of information for fabrication control and assembly, which decelerates the process and exposes it to greater errors because of human interactions and the transfer of information [64].

- *Utilization of BIM information in steel building projects: Transfer information, visualization API, AR, and VR.*

This group of BIM uses facilitates communication and comprehension for defining deliverables, stakeholder decisions, and the coordination between phases and construction professionals. However, the absence of this group of BIM uses in the planning and transportation phases can generate errors in defining the product (building) and a lack of coordination or control between the manufacturing, transportation, and assembly phases.

BU#6: BIM and virtual/augmented reality are notable developments in this section. Combining BIM models with augmented and virtual realities improves the comprehension of stakeholders, such as owners and investors, who are unfamiliar with construction language [64,65]. It has also been incorporated into manufacturing to check the quality of steel components, such as welds and holes, and simulate complex assemblies. This BIM utilization is present in all phases, except planning and transportation.

BU#7: IoT is one of the rarest, but most disruptive, utilization of BIM. The primary purpose of this utilization is to optimize steel construction information by applying data-driven methods and analytics to perform real-time collaborative management, and control of steel elements, manufacturing, and assembly activities [66]. The information obtained from IoT tags and sensors is fed into a centralized database where the average performance of steel activities can be recorded [66,67]. This information allows for faster decision making when deviations or project reorganizations occur. Notably, this utilization is found in the design, fabrication, and erection phases.

BU#8: An API is used for non-geometric information transfer. Programming interfaces (APIs) are useful links that run plugins between the different software involved in the design and manufacturing processes to customize interoperability between BIM models [68]. In addition, it saves time for repetitive tasks within known scenarios related to design [56,68], and it can be programmed to exchange information from the BIM model to the design phase and ERP. This is possible as long as the BIM and ERP software have open API. This BIM utilization occurs primarily in the design and fabrication phases.

BU#9: Controlled installation through BIM is used to monitor and control the erection of steel structures based on the BIM model. One of the main objectives of this utilization is to report, in real-time, the status of the fabrication items, such as painting, welding, assembly, and dispatch, to the stakeholders, and the erector contractor, in particular [53,69] This utilization is present only in the construction planning and erection phases.

BU#10: BIM and laser scanning data: the main characteristic of this utilization in steel construction is the development of a BIM model from real survey data of existing project conditions by importing the information through a point cloud [70,71], which is specially oriented to isostructural development. This information, obtained by a laser scanner, can also be used to prepare complex assemblies and resolve interferences with other specialties [19,72]. This utilization is mainly found in the design, fabrication, and erection phases.

- *Use of BIM in Steel Project Management, Sustainable, and Site Organization.*

This group of BIM uses facilitates project management at a tactical and operational level in each phase. In addition, it is used to incorporate the concepts of sustainability and infrastructure management.

BU#11: Cost analysis using BIM models is one of the largest uses in this segment. The particularity of this use is the addition of non-graphical information to the BIM model, which permits the calculation of the costs of each steel element [54,57,73]. With this use, it is possible to segment the costs according to the type of steel structure (light, heavy, or extra heavy), which allows the total project costs to be predicted with greater certainty [74,75]. This use appeared in all phases except for transport.

BU#12: BIM for construction management is one of the largest uses of BIM in different steel building processes. Here, BIM is used for the different stages of the project, from the cubing of materials to managing person-hours in the field [70,76]. In addition, it allows the reporting of information to estimate possible deviations of the project from an economic perspective. [61]. This use was observed in all phases, except for transport.

BU# 13: Structural health monitoring with BIM models permits automated data and damage visualization module to be created, through which sensor data are interpreted to identify damage or anomalies in the steel structure, and the affected building components are highlighted and labeled in the 3D BIM model [77]. To facilitate the display, damaged or nearly damaged module elements are highlighted in the BIM model through color coding, based on deformation threshold values to be considered by the designer, and facilitates making decisions. This applies to new projects in the development phase and reusable structures in the remodeling phase. This purpose was displayed in the manufacturing and erection phases.

BU# 14: BIM information to improve site logistics planning: the use of BIM stands out as a coordination engine to improve construction planning, considering methodologies, such as just in time, to optimize the limited spaces in the field model [28,63], especially for projects that are conducted in urban areas where the collection space material is limited. With this use, it is possible to simulate different scenarios in the BIM model to reach the best decisions according to the project's needs [78,79]. This use occurs mainly in the transportation, construction planning, and erection phases.

BU#15: BIM is used for de-constructability and the identification of reusable steel materials in remodeling stages, thus allowing the BIM model to identify potential structural elements that can be reused, which decreases project costs and benefits the total cost of the project [80,81]. Existing elements can be modeled with a laser scanner, as shown using BU#10 and structure verification using BU#13. However, with this use, it is possible with the same models to optimize the planning of deconstruction according to the characteristics of the project [82]. This use is presented in the first three phases of a steel project: planning, design, and fabrication.

The BIM uses found do not exhibit continuity throughout the phases of the steel construction project; hence, their benefits are truncated. In other cases, they are developed in the late phases or specifically within a phase. The aforementioned discussion serves as evidence that BIM has been unable to break the fragmentation of the steel construction industry. Therefore, there is a need to investigate, develop, and propose BIM uses that generate continuous communication, coordination, and management between phases and assure deliverables that conclude with a building that meets the requirements established at the beginning of the project.

Table 6 presents the findings of the systematic literature review regarding BIM uses and the software tools in steel buildings; the table shows the bibliographic sources used to summarize each BIM utilization. The studied cases indicated a wide variety of tools used in the steel building process and also revealed how information is exchanged between the tools (IFC format); however, certain trends in the tools used were identified. The prevailing BIM tool is Tekla, which appears in 13 of the 15 BIM applications. Other software tools with more than one use were Revit, Naviswork, MicroStation, and ArchiCAD.

Table 6. BIM uses in application phase and bibliographic resources.

BIM Utilization	BIM use in Application Phase	3D Software Tools	Source
3D BIM models to visualize and improve steel processes.	*Planning, design, fabrication, and planning for construction.*	Tekla, Navisworks, Revit, ArchiCAD, SketchUp.	[20,33,47–52,74]
BIM Collaboration for Structural Engineering and L.O.D.	*Design, fabrication, and planning for construction.*	Tekla, Revit, MicroStation.	[20,53,54,57,70]
Early integration between design, manufacture, and assembly based on BIM models.	*Planning, design, fabrication, planning for construction, and erection.*	Tekla, Navisworks, Revit, MicroStation.	[51,52,54,56–61,83]
Create a BIM modeling before fabrication.	*Design and fabrication.*	Tekla, Revit.	[33,48,50,54–56,62,63]
Quality control and traceability of the manufacture and assembly processes using BIM models.	*Design, fabrication, and erection.*	SolidWorks, Revit, Tekla.	[56,58,64,68,84]
BIM and virtual/augmented reality	*Design, fabrication, and planning for construction erection.*	Revit, Tekla.	[64,65]
BIM and IoT	*Design, fabrication, and erection.*	Revit, Tekla.	[66,67,83]
Use API for non-geometric information transfer.	*Design and fabrication.*	Revit, Navisworks.	[68,85]
Control installation through BIM.	*Fabrication, planning for construction, and erection.*	Revit, Navisworks, Tekla. MicroStation	[53,69,84,86]
BIM and Laser scanning data.	*Design, fabrication, and erection.*	Revit, Tekla, AECOsim, FARO SCENE.	[19,70,71]
Cost analysis through BIM models.	*Planning, design, and fabrication, planning for construction.*	Tekla, MASTAN2, STAAD Pro, SAP2000, Revit.	[54,57,73–75]
BIM for construction management.	*Planning, design, and fabrication, planning for construction.*	Revit, Civil 3D, MS Projet, Navisworks, Tekla, ArchiCAD, Synchro Pro.	[28,29,52,58,60–62,64,69,70,76,82,83,86,87]
Structural health monitoring with BIM models.	*Design and erection.*	Revit, Tekla, ArchiCAD.	[77,85]
BIM information to improve site logistics planning.	*Transport, planning for construction, and erection.*	Revit, Tekla, Synchro Pro, MicroStation	[28,53,59,60,62,63,78,79,87]
BIM for de-constructability and identification of reusable steel materials	*Planning, design, and fabrication.*	Revit, Dynamo.	[65,80–82]

5. Conclusions and Future Research Directions

The literature review identified 15 uses of BIM in the life cycle of steel construction projects, which were then grouped into three categories: 1. Project collaboration: Geometric Semantic; 2. Transfer information, visualization API, AR, and VR; and 3. Management, Sustainable, and Site Organization.

Regarding the first segment, BIM uses with the greatest presence in the steel construction phases were BU#1 (3D BIM model to visualize and improve the steel process) and BU#3 (early integration between design, manufacture, and assembly based on BIM models).

For the second segment, the use of BIM and augmented reality, BU#6 stands out with greater presence; with less presence, it shows the use of APIs for transferring non-geometric information between BIM models (BU#8).

Related to the third segment, the use of BIM with the greatest presence is cost analysis (BU#11) and the use of BIM for construction management (BU#12). Conversely, the least frequent use found for this segment was BU#13 (structural health monitoring with BIM models).

In the steel phase, BIM is mostly used in the design, fabrication, and erection stages. Conversely, planning and transportation have the least number of BIM uses. According to the SLR, most BIM uses for steel construction have been published as research work between Asia and North America; the rest are distributed between Europe and Africa. However, there is no evidence for BIM use cases in South America.

Regarding the historical evolution of scientific publications on BIM uses in steel construction, an evolution was observed between 2012 and 2022, and 2019 was the year with the most publications pertaining to this topic. However, over the last three years, the number of publications has decreased, likely due to the reduction in investments worldwide as a result of the COVID-19 pandemic. This, in turn, has affected drop-in construction projects and, consequently, the potential use cases that can be documented.

Early integration highlights the use of a BIM model as a pivot among the designer, manufacturer, and erector, which reduces the cost and time associated with steel building projects. It is recommended to adopt this early integration in the design stage because it permits collaboration and validation between the different actors involved in the materialization of the project.

Notably, some BIM uses are not widespread in the steel construction industry; these include the combination of BIM for structural health monitoring (BU#13), the use of API for transferring non-geometric information (BU#8 or BU# 15), and BIM for the deconstructability and identification of reusable materials.

Regarding the tools used for BIM modeling, Tekla appears in 87% of the uses, mainly in the design and manufacturing phases; other software, such as Revit, MicroStation, and Naviswork, are frequently mentioned in the design and erection stages.

5.1. Future Research Directions

This section summarizes the potential new areas of research related to BIM and steel construction projects.

5.2. Use of 3D BIM in Collaborative Steel Building Projects: Geometric and Semantic

The review of scientific literature revealed that, in the segment of geometry and semantics, BIM is widely used in the design and manufacturing phases, albeit to a lesser extent than in the fabrication and design phases. No evidence related to transportation was found in this segment. Considering the benefits of BIM, it is recommended that further studies focus on these three phases, which are less prominent in existing literature.

5.3. Utilization of BIM Information in Steel Building Projects: Information Transfer, Visualization API, AR, and VR

In this segment, the transfer of information through the different phases involved in steel construction is widely mentioned. Few reports focus on the transfer of non-geometric information between the BIM models through APIs for steel construction projects. Hence, this topic is recommended to be addressed in future research.

5.4. Use of BIM for Steel Project Management, Sustainability, and Site Organization

According to the bibliographic review of literature, in this segment, all the phases show at least one BIM use. It is noteworthy that, in this segment, where the use of BIM is framed in the costs and logistics of the project, the manufacturing and transportation phases are the ones with the least presence. Therefore, it is recommended that these uses be treated under future research.

According to the SLR, 65% of the uses of BIM for steel construction have been published as research work from Asia and North America, with the rest distributed between Europe and Africa. However, there is no evidence related to BIM use cases in South America. This indicates a gap related to disseminating the uses of BIM in steel construction, which needs to be addressed in future research, especially with reference to this continent.

All these guidelines for future research are recommended to be addressed by the scientific community, with support from the most critical stakeholders and the industry.

5.5. Contribution to Scientific Community

The contribution of this work to the scientific community is the identification of BIM uses for steel projects. Based on this review, it can be determined how, when, and where BIM uses are executed in steel building projects. This answers the previously posed research question regarding the use of BIM in steel building projects. In addition, we identified the uses with greater and lesser disclosures, as well as future research directions.

5.6. Limitations

The study was limited to a specific sector of the steel construction industry, and the search was further limited by summarizing the last ten years of scientific evidence related to the search for information, using the search words indicated in the methodology.

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