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毕业设计(论文)外文资料翻译

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附件 1：外文资料翻译译文

结构项目与 BIM 范式的整合：文献综述

摘要 建筑信息模型（BIM）是 AECO 工业向工业 4.0 转变的核心内容之一。BIM 的自动化、互用性和可持续性在这一变化中发挥了关键作用。本文对 BIM 应用的相关文献进行了综述。本综述的目的是明确了解 BIM 方法在结构分析领域的实施现状。同时涉及这两个主题的论文，BIM 和结构分析，在过去的 10 年中选出的文献从两个不同的方面用两种不同的方法进行了分析。首先，采用文献计量分析的方法，对这一课题进行研究。其次，选择和分析了 81 篇具有代表性的论文，确定了专题领域通过聚类分析。文章还根据结构生命周期及其目的进行了几种分类。最后，对所得数据进行 SWOT 分析创建一个完整的框架，显示结构项目的集成状态 BIM 环境和可能的未来发展和风险。这组研究显示设计工具和新建筑的趋势。近年来，自动化和计算机辅助设计已成为研究的一个趋势，但 BIM 在既有建筑和历史建筑结构分析方面的研究还存在一定的差距，这表明 BIM 能够提高既有建筑的分析和维护水平。

关键字：BIM 结构工程 建筑性能 文献综述 生命周期

1 项目介绍

1.1 概述

传统上，建筑、工程、建设和运营行业(AECO)是一个缓慢变化的业务，不会受到很大的变化。然而，在过去的几年里，出现了一些技术和程序，它们正在使其发生变化，采用工业 4.0 标准的数字化。第四次工业革命通常与制造业有关。可持续性、自动化、风险管理和生产力是当今竞争企业的几个需求。亚太经合组织需要不断发展，将它们纳入其中，并提高其在数字革命中的竞争力。一些技术，如研究和发展的生命周期分析，以考虑到新的参数，并使用它们作为设计的中心点。还有其他一些新参数正在研究中，如项目的社会可持续性，该参数基于其对社会的影响，考虑到基础设施与其环境的相互作用。

在这些新方法中，建筑信息模型(BIM)和虚拟、数字和混合双胞胎是数字技术与 AECO 产业之间的纽带，也是这一变化的主要力量。他们允许专业人士面对这些新的挑战并处理

影响行业的问题。此外，它使控制项目的每个维度变得更容易。它还通过云技术减少了协调问题和错误，提供了一个通用的工作场所。BIM 环境带来了新的功能和新的视角，并在行业中开创了数字化转型。

由于 BIM 创建了一个 n 维模型，它是一个理想的工具，可以为建筑项目添加新的发展层，并将新的需求整合到它上。BIM 的能力是相当大的，已经有研究围绕它们开发不同的领域。我们主要关注的是结构项目，以及如何将其整合到 BIM 中来改善它。BIM 提供的新资产打开了一个新的可能性世界，从设计阶段考虑可持续性参数，到施工阶段的风险管理，并使用优化算法来降低成本，也利用拆除废物建造新项目。回顾不同的文章，了解使用 BIM 开发结构项目的优点、缺点和风险是必要的，以了解哪些已经研究，哪些需要进一步研究，并指出在不久的将来可以遵循的新路径。

建设信息能力是如此广泛，尽管它已经受到了十多年的关注，但还没有一个一致的定义。对 BIM 的理解取决于专业人士如何使用和看待它。在本体论上，它可以被理解为一个或多个东西，一个方法论，一个产品，或一个方法。基于这种方法和定义，BIM 的定义被整合在一起。BIM 是一项与 AECO 相关的基于项目三维参数化模型制作的技术，但它不止是数字模型的制作。此外，这些模型必须具有沟通、修改和分析自己的能力。模型中的所有内容都是实时更新的，并使用元素之间链接的参数来共享它们的属性。因此，BIM 技术允许我们创建一个项目的 n 维模型，可以在任何时间修改任何维度，同时保持参数的链接和更新。

在未来的几年里，BIM 将成为在 AECO 行业中具有竞争力的一项基本技能，这将是该行业成员的强制要求。大学需要将 BIM 应用到他们的课程中，否则这将成为年轻工程师的培训缺口，并影响他们的就业能力。研究项目需要发展，并将管理和行政纳入他们的能力，以达到员工寻求的水平。将 BIM 融入工程项目将为行业面临的新挑战创造所需技能的专业人员。这种渐进式的整合必须在几个步骤或层中完成，沿着 BIM 实现不同的技术，以实现工业建筑 4.0 的。

企业正努力变得越来越有竞争力，并投资于创新。BIM 的相关性并不局限于学术工作，因为它有直接的专业应用。一个公司开始使用 BIM 有很多不同的原因，例如，它可以节省 10% 的成本和 7% 的平整时间。尽管有其他难以量化的好处，如减少错误、减少 40% 未编入预算的更改时间、更高的准确性和更容易得到成本估算。AECO 公司越来越多地要求 BIM 知识作为招聘新雇主的要求。

世界各地的政府也对 BIM 的标准化产生了兴趣。欧盟早在 2014 年就制定了 2014/24/EU

指令，目标是在 2021 年将 BIM 引入欧洲。这导致一些国家为 BIM 的采用设定了目标。英国在 2018 年全面采用了 BIM 方法，西班牙正在遵循 2020 年全面实施该方法的路线。其他欧洲国家也在致力于从 BIM 中获益的策略和资源的创造。在欧洲以外，政府也有兴趣。马来西亚从 2016 年开始要求使用它，并从 2020 年开始强制使用。为了能够实现这一目标，一些国际组织已经成立，如 Building SMART，它在几个国家运作，分析 BIM 的状态，并提出正确植入它的方法。

标准化是 BIM 环境的关键，并赋予其跨不同专业人员、工具和分析的互操作性。一些机构，如国际标准化组织 (ISO)，正试图创建规范，以标准化 BIM 方法的规定，如 ISO 19650。

1.2 研究问题

该研究的主要目的是具体确定结构项目在 BIM 方面的发展水平，以及目前通过先进的方法已经取得的成果。还需要确定结构项目的实际趋势和障碍，充分整合结构项目，研究其目前的优势和需要进一步研究的点。本文主要要回答的问题有：

BIM 环境下结构项目的发展水平是什么？

该领域目前的研究领域和研究趋势是什么？

BIM 环境对结构项目的贡献是什么？如何进一步改进？

为了回答这些问题，本文回顾和研究了目前为此目的而发展起来的研究的书目、趋势和优势。由于这一分析，可以创建一个框架，以全面的方法暴露整个结构-BIM 图片。通过这项研究，将建立该领域的研究空白，从而确定未来的研究方向。

使用该框架，可以建立 BIM 结构项目的技术水平，并进行“优势、劣势、机会和威胁”分析，确定其趋势和风险。并在现有的研究路线中发现了不同的不足，发现了研究的空白或主要课题。这将显示出研究和扩展 BIM 能力的新领域。

2 方法论

BIM 在 AECO 行业中得到了广泛的应用，在整个项目的生命周期中，它被证明具有管理项目的的能力，并为项目提供了一定的优势。在本文中，对 BIM 在结构项目中的应用进行了全面的现场观察，理解它在结构的生命周期中是连续的。它的目的是研究在 BIM 方法中的结构项目的实际发展，并进一步了解未来的趋势、研究差距和预期。进行了系统、客观的审查，以寻求已取得的进展和需要加强注意的弱点。为了实现这一目标，采用了五阶段结构。第一阶段是问题的公式化，在前一节中已经完成了。第二阶段是确定数据收集策略，

第三阶段是评估检索到的数据，第四阶段是分析和解释文献，最后，第五阶段是提出结果问题。

2.1 数据采集策略

数据收集是基于使用国际公认的书目数据库 SCOPUS 进行的检索。之所以选择该数据库，是因为它的覆盖深度和按年过滤结果的能力，以及从引文中向前和向后搜索的能力。以 SCOPUS 数据库为主要数据库，随后又对 Web of Science、ScienceDirect、谷歌 Academics 等补充数据库进行了评审，以确保对数据库的全面了解。为了对 BIM 和结构项目的研究工作有一个大致的了解，我们使用了两种搜索算法。使用关键词 BIM 对 SCOPUS 数据库进行第一次搜索算法，对该领域的研究工作有一个大致的了解。结果有 10.519 篇文章。第一次搜索从 2004 年开始受到限制，在今年“BIM 大辩论”会议后，BIM 这个术语获得了更多的关注，并可以被视为一个起点。

执行第二种检索算法以收集数据库中的任何文章，使用关键词“BIM”和“结构项目”，并使用搜索引擎的布尔工具“AND”获取与这两个术语相关的参考文献。时间段限定为 2010 年至 2021 年，以选择可能的最新研究。第二次检索得到的原始集共包含 1.905 份文件。图 1 示出了在数据库的搜索引擎中使用的查询串；根据研究范围对专题领域进行了筛选。

- a) TITLE-ABS-KEY(BIM) AND PUBYEAR > 2003 AND PUBYEAR < 2022 AND (LIMIT-TO (DOCTYPE,"ar") OR LIMIT-TO (DOCTYPE,"cp") OR LIMIT-TO (DOCTYPE,"re")) AND (LIMIT-TO (SUBJAREA,"ENGI") OR LIMIT-TO (SUBJAREA,"COMP") OR LIMIT-TO (SUBJAREA,"MATE"))
- b) TITLE-ABS-KEY(BIM) AND TITLE-ABS-KEY(STRUCTURE PROJECT) PUBYEAR > 2003 AND PUBYEAR < 2022 AND (LIMIT-TO (DOCTYPE,"ar") OR LIMIT-TO (DOCTYPE,"cp") OR LIMIT-TO (DOCTYPE,"re")) AND (LIMIT-TO (SUBJAREA,"ENGI") OR LIMIT-TO (SUBJAREA,"COMP") OR LIMIT-TO (SUBJAREA,"MATE"))

图1 a) BIM 在搜索引擎中的查询字符串 b) BIM 和结构项目的搜索引擎查询字符串

2.2 过滤和扩展工程

收集数据后，应用一个过滤器，从所有结果中选择最适合的研究。该过滤器的第一步是排除那些关键词与主题无关的文章(例如与空气流通或医学相关的术语)。最后一个过滤是通过阅读不同文章的主体来删除那些尽管与该研究有关但被认为不是其核心部分的文章。从那里，选择 60 篇文章的初始语料库来完成分析和确定技术水平。

为了完成这个初始语料库并改进数据集，我们又包括了 21 篇文章，创建了共有 81 篇

论文的扩展集。这些文档是在对初始语料库中的参考文献进行回顾并使用来自研究小组的先前知识之后添加的。新增的论文被认为是对该领域的全面了解的基础，因为它们已被用作几种研究的参考文献。有些论文超出了开始时考虑的时间差距，但由于其重要性仍在使使用。为了有一个更广泛的主题选择，它避免选择一个作者超过一篇文章，这样可以考虑到不同的研究小组。选取的文章在参考文献中显示，选取过程如图 2 所示。

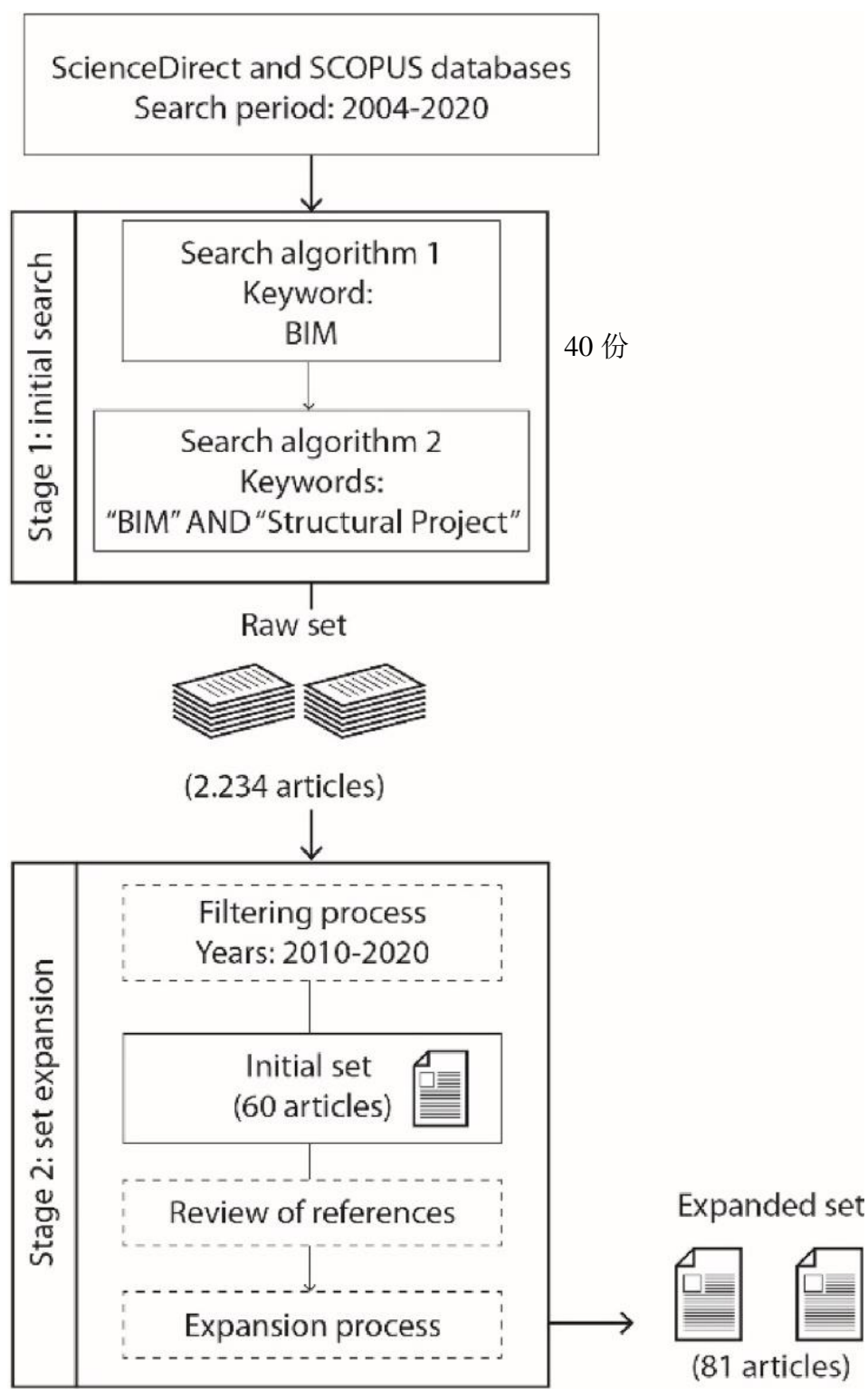


图 2 数据采集策略

2.3 数据评估

该数据库将用于执行两组分析。首先，采用原始集的信息方法，将所有 BIM 已发表的研究考虑在内。其次，采用扩展集的定性方法，并基于其内容、趋势和意图。图 3 包含了研究过程中遵循的不同步骤的流程图。

第一个分析用于通过文章数量研究 BIM 兴趣的演变，并创建整个框架及其特征的基于时间的概述。第二次分析的时间跨度被限定在 2008 年到 2021 年，用于研究 BIM 的实际趋势和发展。第二个跨度的文章用于进行定性分析，因为它们将给予有关当今研究趋势的信息。

扩展集的分析分为两项不同的研究。通过对标题和摘要中的数据进行分类分析，我们能够发现正在研究的不同主题领域和研究趋势。随后，通过对每一篇文章根据范围和内容进行分类，贯穿结构的生命周期。有了这对分析，我们能够从两个不同的角度来看待扩展集的数据，并精确地确定知识差距。

在对两个数据集进行研究之后，将进行基于 SWOT 类型分析的讨论，将结构项目中的 BIM 技术的现状放在一起，突出其优点和缺点。SWOT 分析被用作一种战略方法来评估与项目计划相关的优势、劣势、机会和威胁。它有其局限性，但它是一种可靠的方法，可以设置起点，并以可理解的方式收集和总结信息。将其压缩成目标或趋势，从而创建一个将所有方面都考虑在内的框架。自 60 年代以来，这种方法已被用于多项研究，并取得了巨大的成果。

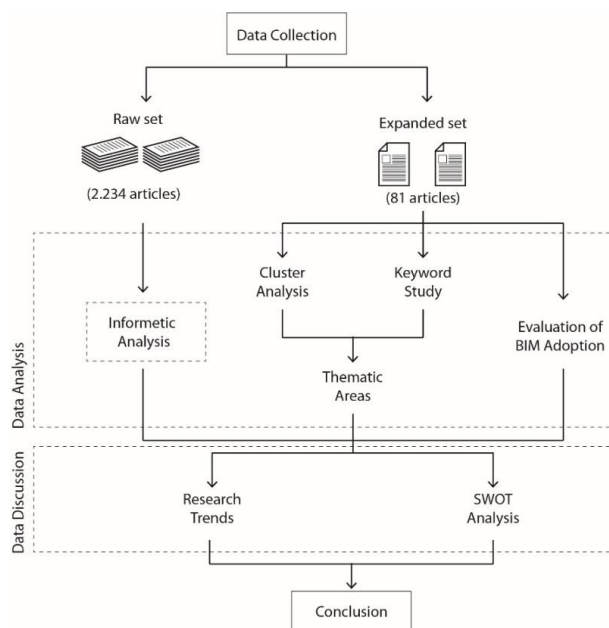


图 3 所进行的研究流程图

3 结果和讨论

3.1 定量分析

2007 年后，关于 BIM 的研究出版物呈指数趋势增加[图 10]。今年后 98.80% 的出版物。到目前为止，出版物数量最多的一年是 2020 年（BIM 出版物为 1500 篇，BIM 和结构项目为 297 篇），这意味着人们的兴趣仍在增长，并且可能出版物的数量将继续增加，因为到 2021 年 12 月出版的文章数量将遵循过去几年的趋势，出版的文章数量越来越多。这些年来，共发表了 10,519 篇关于 BIM 的文章，1,905 篇关于 BIM 和结构项目，占总数的 18.11%。与 BIM 和结构项目相关的文章总数也在逐年增加，但增长率即使也是指数级的，也不如只谈论 BIM 的数量高。从 2017 年开始，增长速度有所放缓。对期刊文章进行的信息计量分析涵盖了根据 ScienceDirect 数据库发表在该主题前 10 大出版期刊上的论文，并涵盖了 2004 年至 2019 年间发表的 55% 的文章。如表 1 所示，第一篇发表的文章于 2004 年发表在“建筑自动化”上，直到 2007 年才在这些期刊上发表。正如我们在表 1 中所看到的，这些年发表了一些论文，但没有在研究的期刊上发表。除了 2017 年。《建筑自动化》是发表论文最多的科学期刊，占该主题总产量的 27%，其次是《Procedia Engineering》，占总产量的 7%，2017 年共发表了 61 篇论文，此后再无论文发表。2020 年发表的文章数量最多，共 378 篇，其中 103 篇发表在“建筑自动化”中。

从 2013 年起，可以观察到期刊数量的增长，这种进步表明，尽管 BIM 在早期在该领域的一些特定期刊上引起了兴趣，但其他期刊也对该主题产生了兴趣，因为它呈现了更多的协同作用和更广泛的观点。这也是因为，尽管只进行了分析，但出版物数量和 55% 的论文数量排名前 10 位的期刊，即“建筑与环境”，“建筑环境杂志”，“可持续城市与社会”和“能源程序”，各自出版了 1% 的产品，并且所有这些期刊都在 2013 年或之后开始发表关于 BIM 的文章。有新的期刊发表关于 BIM 的论文。《建筑工程杂志》是对该主题兴趣增长最大的期刊，从 2019 年起，它每年至少发表 17 篇论文，是过去几年中第三大出版期刊。表 2 通过比较前 10 种最常发表的期刊中包含的文章数量与发表的文章总数，显示了不同期刊中发表文章的分布。这一百分比表明了这些主要期刊上浓缩的研究比例。较高的百分比意味着他们发表了最多的论文，并集中了研究工作。我们可以把研究的时间段分为三个部分。第一个时期从

2004 年开始，直到 2008 年，在出版物中的集中度较低，但它的增加，因为它从期刊中包含的文章的 10%增长到 29%。在此期间，文章主要发表在十大期刊中的两个“建筑自动化”和“高级工程信息学”。这一事实在 2009 年至 2013 年的第二个时期也是如此，这两个期刊不仅是 BIM 和结构的主要出版商，而且还利用了该主题的大部分研究，占科学成果的 60%。从 2014 年开始，这些期刊的工作集中度已经降低到大约 55%，正如我们在表 2 中所示，其他前 10 名期刊的产量有所增加。这表明对这一专题的关注和重视有所增加。

附件 2：外文原文

1. Introduction

1.1. Research questions

The main purpose of the study is to specifically determine the level of development of the structural project on BIM and what has been achieved nowadays via a state-of-art approach. There is also the need to determine the actual trends and obstacles to get full integration of the structural project and study the advantages obtained from it at the moment and the points in need of further research. The main questions to answer in this paper are:

- What is the level of development of the structural project on BIM environments?
- Which are the current thematic areas and research trends on the topic?
- How BIM environments have contributed to the structural project and how can this be further improved?

To answer these questions the bibliography and the trends and strengths of the researches developed nowadays for this purpose are reviewed and studied. Thanks to this analysis a framework can be created where the whole structural-BIM picture is exposed with a comprehensive approach. By performing this research, the research gaps on the field are going to be established and in consequence future research lines will be determined.

Using this framework, the state-of-art of structure project in BIM can be established and a “Strengths, Weaknesses, Opportunities and Threats” analysis will be carried out, determining its trends and risks. Also, different deficiencies in the current research lines, the research gaps or main topics are found. This will show new areas to research and expand the BIM capabilities.

2. Methodology

BIM has been widely adopted in the AECO Industry and it has proven more than capable to administrate the projects and granting some advantages to them during the whole project's life-cycle. In this paper, a full field view on the adoption of BIM for the structural project is presented, understanding it as continuous during the structure's life cycle. It is intended to study the actual development of the structural project in the BIM methodology and further understanding future trends, research gaps, and expectations. A systematic, objective review is done to seek the progress achieved and the weak points that need more focus. To accomplish this a five-stage structure has been adopted [32].

The first stage is the formulation of the problem and has been performed in the previous section. The second stage deals with the determination of the data collection strategy, the third stage revolves around evaluating the retrieved data, the fourth stage points to the analysis and interpretation of the literature and finally, the fifth stage presents the resulting questions.

2.1. Data collection strategy

The data collection is based upon a search performed using the internationally-recognized bibliographic database SCOPUS. This database was chosen due to its depth in coverage and its ability to filter the results by year and search forward and backward from a citation. The SCOPUS database was the main one used, but later on, complementary databases such as Web of Science, ScienceDirect or Google Academics were also reviewed to be sure to get the whole picture. To have a general view of the research effort regarding BIM and the structural project two search algorithms have been used. The first search algorithm was conducted on the SCOPUS database using the keyword BIM to have a general idea of the research effort in the field. It gave a result of 10.519 articles. This first search was limited from 2004 onwards as at this year the term BIM gained more attention after the conference “The Great Debate BIM” [62] and can be considered a starting point.

The second search algorithm was conducted to collect any article within the database for this the keywords “BIM” and “structure project” and the Boolean tool “AND” of the search engine were used to get the references that were related to both terms. The time period was limited to the years from 2010 to 2021 to select the latest research possible. This second search resulted in the Raw Set containing a total of 1.905 documents. Fig. 1 shows the query strings used in the databases’ search engines; the thematic areas were filtered according to the scope of the research.

2.2. Filtering and expansion processes

After having collected the data, a filter was applied to select the most fitting researches among all the results. The first step to this filter was to exclude those articles with keywords unrelated to the topic (with terms related to air ventilation or medicine for example). A final filter was applied to erase those articles that despite being associated with the research were deemed to not be part of the core of it, this was done by reading through the different articles’ main body. From there, an initial corpus of 60 articles was selected to complete the analysis and determine the state of art.

To finish this initial corpus and improve the dataset we have included 21 more articles, creating the Expanded Set with a total of 81 papers. These documents were added after performing a review of the references among the initial corpus and with previous knowledge from the research groups. The new papers have been added as they have been considered basic for the complete understanding of the field as they have been used as references on several kinds of research. Some of these papers are outside the time gap considered in the beginning but are still being used due to their importance. To have a more widespread thematic selection, it has been avoided to select more than one articles per author so different research groups can be taken into account. The selected articles are shown in the bibliography and the selection process is summarized in Fig. 2.

2.3. Evaluation of the data

The database is going to be used to perform two sets of analyses. First, an informetric approach that will take into account all of BIM published research, using the Raw Set. Second, a qualitative approach, using the Expanded Set and based on its content, trends, and intentions. Fig. 3 contains a flowchart with the different steps followed during the research.

The first analysis is used to study the evolution of BIM interest through the number of articles and to create a time-based overview of the whole framework and its characteristics. The second analysis has a span of time that has been limited from 2008 to 2021 and is used to study the actual trends and development of BIM. The articles in this second span are used to perform the qualitative analysis as they will give information about the research trends nowadays.

The analysis of the Expanded set is divided into two different studies. By using cluster analysis on the data in the title and abstracts we are able to find the different thematic areas that are being studied and research trends. Later on, by classifying each one of the articles based on the scope and content through the life cycle of the structure. With this pair of analyses, we are able to view the data from the Expanded set from two different points of view and determine precisely the knowledge gap.

After the two datasets have been studied a discussion based on a SWOT-type analysis will be performed, where the state of the art of BIM in the Structural project will be put together highlighting its strong and weak points. The analysis SWOT is used as a strategic approach to evaluate the strengths, weaknesses, opportunities, and threats related to project planning. It has its limitations but it is a solid methodology to set

starting points and gather and summarize information in an understandable way. Condensing it into objectives or trends and thus creating a framework where all the aspects are taken into account. This methodology has been used since the 60s in several studies with great results.

3. Results and discussion

3.1. Quantitative analysis

The publication of studies about BIM increased after the year 2007 with an exponential trend [Fig. 4], after this year 98,80% of the publications were made. The year with the highest number of publications so far has been 2020 (1.500 publications for BIM and 297 for BIM and Structure Project), meaning that the interest is still growing and presumably the number of publications will keep increasing as the number of articles published until 2021 December is following the trend of past years with an increasing number of articles published. A total of 10.519 articles have been published during these years regarding BIM and 1.905 regarding BIM and Structural Project, a 18,11% of the total.

The total number of articles related to both BIM and Structural Project is also increasing each year, but the growth rate, even being also exponential, is not as high as the numbers speaking only about BIM. From 2017 onwards there has been a slowdown in the growth rate.

The informetric analysis conducted on journals articles covers the papers published in the top 10 most publishing journals of the topic according to ScienceDirect database and covers a total of 55% of the articles published between 2004 and 2019. As Table 1 summarizes the first published article was published in 2004 in 'Automation in Construction' and there were no more publications until 2007 in these journals. As we have seen in Table 1, there were papers published in those years, but not in the studied journals. With the exception of 2017.

'Automation in Construction' has been the scientific journal that has published more papers with an of 27% of the total production on the topic, followed by 'Procedia Engineering' with 7% of the production and who published a total of 61 papers in 2017 and none since then. The higher number of articles published in a single year has been 2020 with a total of 378 articles, 103 of which were presented in 'Automation in Construction'.

From 2013 onwards a growth can be observed in the number of journals, such an advance indicates that, although BIM received interest in the early years in some specific journals on the field, other journals have gained interest in the topic as it presented more synergies and a broader view. This is also seen because despite having analysed only, the top 10 journals in the number of publications and 55% of the papers, the journals ‘Building and Environment’, ‘Environment Journal of Building’, ‘Sustainable Cities and Society’ and ‘Energy Procedia’ have each a 1% of the production published and all of them started publishing about BIM in 2013 or later. There are new journals publishing papers about BIM. ‘Journal of Building Engineering’ presents the biggest growth in interest in the topic, as from 2019 it has published at least 17 papers per year being the third publishing journal in the last years.

Table 2 shows the spread of publications among different journals by comparing the number of articles included in the top 10 most published journals with the total of articles published. This percentage indicates the fraction of research condensed in these main journals. A higher percentage means that they have published the highest number of papers and concentrated the research efforts. We can divide the studied period of time into three sections. The first period starts in 2004 until 2008 and shows less concentration in the publications, but an increase in it, as it grows from 10% of the articles contained in the journals until 29% of them having been published. In this period the articles were published mainly in two of the top 10 journals ‘Automation in Construction’ and ‘Advanced Engineering Informatics’. This fact is also true during the second period from 2009 until 2013, where these two journals not only are the main publishers of BIM and structures but also capitalize on them most of the research of the topic with 60% of the scientific production. From 2014 the concentration of work in these journals has been reduced to roughly 55% and as we have shown in Table 2 the other top 10 journals have increased their production. This shows an increase in the attention and importance given to the topic.