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LEAN CONSTRUCTION AND BUILDING INFORMATION MODELING (BIM) IN DESIGN MANAGEMENT: SURVEY RESULTS FROM FRENCH COMPANIES

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ABSTRACT

Lean and BIM integration in the design phase may help achieve better design deliverables on the planned time and cost and consistent with the client's needs and requirements. With the absence of enough studies about lean-BIM integration in France, this study reports the results from a survey about lean-BIM integration in French design firms. The results of the study showed that lean is still not routinely adopted in these firms, and more than 95% of the firms do not provide training on lean. The evaluation of lean-BIM integration was neither high nor low; with a mean of 3.73 out of 5.00. Additionally, the results showed that BIM has still not delivered its full potential in the studied firms. The analysis of the results showed also a positive and significant impact of lean-BIM integration on design performance.

KEYWORDS

Lean construction, Building Information Modeling (BIM), Design Management, Construction, Lean construction 4.0, France.

INTRODUCTION

It is widely believed that decisions in the design phase of construction projects result in changes that cannot be adjusted without affecting the time, cost, and/or quality of the project (Haponava & Al-Jibouri, 2009; Sweis et al., 2008). As a result, design management is believed to be a critical factor that affects the success of construction projects (Chaize et al., 2022; Hattab & Hamzeh, 2013).

Design management refers to the planning, organization, and management of processes, people, knowledge, and information flow during the design phase to meet the client's needs and requirements (Herrera et al., 2020, 2021). During this phase, specialists from different disciplines work to translate the value proposition by the clients, meet their expectations, comply with the standards and avoid making errors in the design (Hattab & Hamzeh, 2013; Tauriainen et al., 2016). Nevertheless, achieving all these objectives is still questionable in the presence of weak and traditional design practices (Tauriainen et al., 2016).

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Traditional design management can be understood as a linear process that includes a set of tasks done by designers who work fragmentedly to deliver the design based on a predetermined schedule and due dates (Khan & Tzortzopoulos, 2015). In this understanding, collaboration and interrelations between design teams are unappreciated (Tauriainen et al., 2016). It also indicates that design continuous improvement is not the focus. This is due to the understanding that the linear design process helps to achieve higher productivity in design and the iterative approach, which normally contributes to improving value and innovation, is wasteful (Abou-Ibrahim & Hamzeh, 2016; Khan & Tzortzopoulos, 2015). Another consequence of this understanding is the neglect of the flow of information between the right people at the right time, which may result in design errors (Hattab & Hamzeh, 2013).

The presentation of Building Information Modeling (BIM) and lean thinking to design management is expected to solve these problems. The use of BIM offers opportunities to collaboratively work on a "live" version of the design between stakeholders and helps to increase transparency and information flow between all the stakeholders (Hattab & Hamzeh, 2013). The features of BIM allow for achieving numerous improvements in the design phase such as the decline in design errors and clashes, increased visualization, quicker and easier design alternatives, reduced design cycle time, improved coordination, and easier cost estimation (Herrera et al., 2021; Rojas et al., 2019; Tauriainen et al., 2016).

Nevertheless, BIM as a technology is not sufficient to ensure successful design management. Lean construction, with its principles and tools, helps to facilitate the generation of the value of the client and improve the social system during the design process. For instance, the presentation of the Last Planner System (LPS) during the design process can contribute to improving transparency, communication, trust, efficiency, and quality of the design (Chaize et al., 2022; Hamzeh et al., 2009; Khan & Tzortzopoulos, 2015). Big room/iroom/co-location is also effective to increase collaboration, decreasing design errors, and reduce latency in decision-making (Tauriainen et al., 2016) and Design structure matrix (DSM) is helpful to improve planning for the entire design phase (Rosas, 2013).

Therefore, the lean-BIM integration has been topical in many research works and applications (Abou-Ibrahim & Hamzeh, 2016; Bolpagni et al., 2017; Dave et al., 2013; Hattab & Hamzeh, 2013; Herrera et al., 2021; Mollasalehi et al., 2016; Rojas et al., 2019; Sacks et al., 2010; Tauriainen et al., 2016; Uusitalo et al., 2019). In France, a limited number of investigations have been carried out about this integration. Additionally, there is still some missing information about the adoption of both concepts in all phases of the construction despite different calls to adopt them (Chaize et al., 2022; Joblot et al., 2017; PLANBIM, 2022; Tranchant et al., 2017). Additionally, despite the global efforts to study lean-BIM integration, there has still insufficient studies that link between lean-BIM integration and design performance. Aiming at increasing the understanding of lean-BIM integration in France and its impact on design performance, the current study tries to achieve the following two objectives:

1- To investigate the levels of lean and BIM adoption in French design companies.
2- To study the impact of lean-BIM integration of design performance.

RESEARCH METHODOLOGY

To achieve the two objectives of the study, a survey to collected quantitative data was developed based on studies from the literature. The use of survey is very common when the researchers try to get quantitative insights about the personal perceptions and the organizational policies and practices (Albalkhy & Sweis, 2022). The survey included four main sections as follows:

1- Section 1: general information about the company and respondents (three questions; participants' experience, company size, and role in the company).
2- Section 2: was about BIM purposes and uses. This section included 12 questions that were adopted from the studies of Bolpagni et al (2017) and Herrera et al (2021). The

questions were about the experience of BIM adoption and training, purposes of BIM, and frequency of BIM uses on a five-point Likert scale from 1 (refers to never) to 5 (refers to always).

3- Section 3: was about lean principles and tools and was based on lean adoption and training and used tools. The section included three main questions that were adopted from the study of Bolpagni et al (2017).

4- Section 4: was about lean-BIM integration in design and evaluation of design performance. The section was based on eight questions adopted from the studies of Dave et al (2013) and Herrera et al (2021). For the lean-BIM integration, the questions were based on a five-point Likert scale where 1 (refers to never) to 5 (refers to always), while for the performance, the scale was from 1 (refers to strongly disagree) to 5 (strongly agree).

The survey was translated into French and developed using Microsoft forms. It was then distributed using emails and LinkedIn was filled by respondents from design and engineering studies firms in France. The analysis of the results was done using Microsoft Excel 2019.

ANALYSIS OF THE RESULTS

Participants and company profile

49 participants answered the questions of the survey. The analysis of the results showed that the vast majority of the respondents had a long experience in construction design and studies as 40 participants had more than 10 years of experience in the field. The roles of the participants ranged between directors, project managers, BIM managers, heads of departments, architects, engineers, and one lean manager.

Concerning the companies' profile, the participants represented the different sizes of companies as 21 participants were from companies with more than 100 employees, 7 were from companies with 50-100 employees, 13 were from companies with 10-50 employees, and 8 were from companies with less than 10 employees. The participants were also from companies with different areas of work including architecture, public and infrastructure projects, residential and real-estate projects, industrial buildings, commercial buildings, hotels, and renovation projects.

BIM adoption and uses

The responses regarding BIM adoption showed an acceptable range of BIM adoption as most of the participants stated that BIM had been applied in their companies for at least five years (38 respondents). Only one participant in the study stated that BIM was still not adopted in the company. Two other participants stated that BIM was new to their company and its adoption started less than one year ago. 38 respondents (78%) declared that their companies were offering training on BIM.

Regarding the purposes of BIM implementation, architectural purposes (n= 38 respondents), structural (n=25), mechanical (n=25), and plumbing (n=25) works were the most found motives for BIM adoption in the studied companies. BIM was also used to manage and develop electrical works, maintenance and alarm systems, facades, environmental studies, and others.

Concerning the BIM applications in the design phase, Figure 1 shows that 3D coordination (mean=4.16), code validation (mean=3.76), and cost estimation (mean=3.02) are among the most frequent uses of BIM in the studied firms. While 4D planning (mean=1.96) is the least frequent use of BIM.

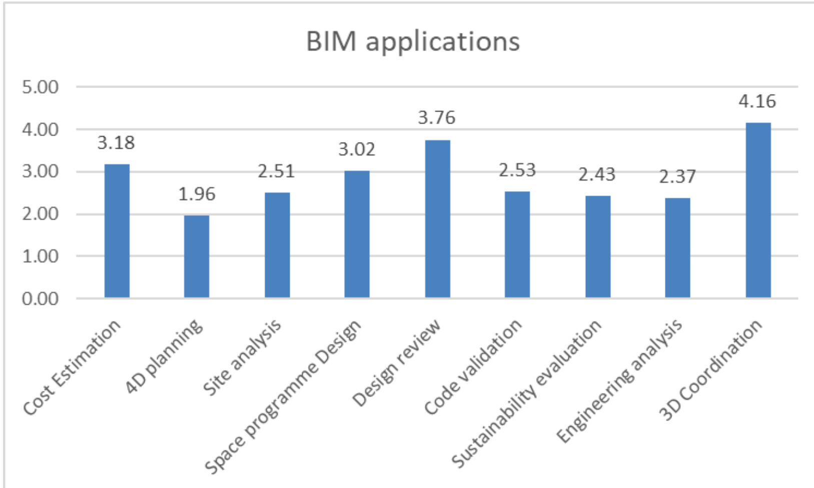

Figure 1: BIM uses in the design phase

Lean adoption and lean tools

The adoption of lean was significantly less in comparison to BIM. This is because only 11 participants (22.45%) stated that lean was adopted in their firms. Among them, only one firm was adopting lean for more than ten years and eight firms were adopting lean for 1-5 years. Additionally, only two participants stated that their companies provide training on lean.

Nevertheless, despite the lack of a declaration of lean as a whole philosophy, some participants believed that their companies use some tools that might facilitate the future implementation of lean. More specifically, as illustrated in Figure 2, the participants showed that the most applied tool/practice is the A3 problem-solving reports (n=13), then Big room or co-location to improve collaborative planning and design (n=12), and then the last planner system (LPS) (n=10). Other tools such as design structure matrix (DSM), plan-do-check-act (PDCA), value stream mapping (VSM), and 5S were less implemented. The least implemented tools/practices were the target value design (TVD), which was implemented by two companies, and the integrated project delivery (IPD), which was implemented by only one company.

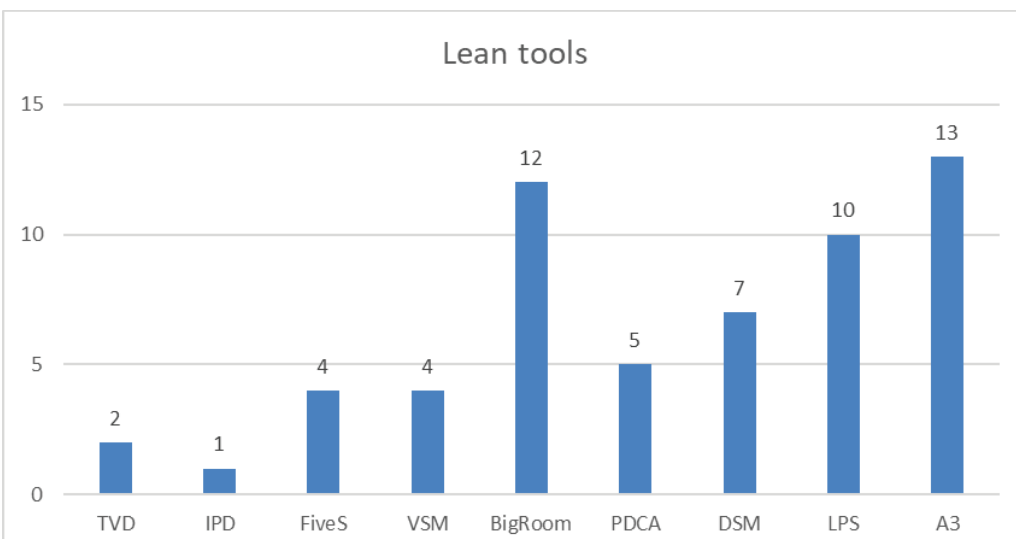

Figure 2: Applied lean tools/practices

Lean-BIM design management

Lean-BIM design management in this study refers to the integration between lean and BIM and the use of BIM models to support lean principles. Table 1 shows that the overall evaluation for lean-BIM integration was neither very high nor low as the mean was 3.73 out of 5.00. The highest evaluation was for the client value (mean= of 3.77), while the lowest was for the early involvement of construction stakeholders (mean= of 3.09). In this regard, it is apparent that other stakeholders (e.g. contractors and suppliers) are not involved early enough before the end of the design phase.

The results also show that design firms try to continuously evaluate and refine the design aiming at satisfying the needs and requirements of the client (mean=3.98). Nevertheless, the use of early BIM models for this purpose is still insufficient (mean=3.55). Concerning BIM as well, BIM models do not seem to be fully implemented to facilitate improving constructability in the later phases (mean=3.29). They are better used for visualization and assessment of design alternatives (mean=3.69) and for collaborative planning among the design teams (mean=3.8).

Table 1: Lean-BIM design management

Dimension	Item	Mean (std. dev)	Dimension means (std. dev)
Client value	Instead of one brief of requirements by the client, the early design is developed iteratively. In each iteration, the requirements of the client are evaluated and the design is refined	3.98 (1.051)	3.77 (1.010)
	BIM models are used to develop the early design to help evaluate the requirements of the client	3.55 (1.385)	
Set-based strategy	Designers consider sets of alternatives from the start of the design process rather than developing one alternative at the beginning	3.65 (1.200)	3.67 (0.927)
	BIM is used to enable rapid visual creation, communication, and assessment of project alternatives	3.69 (1.158)	
Early-involvement of stakeholders	Major project stakeholders (e.g. contractors, suppliers…) are involved early in the design process	2.90 (1.177)	3.09 (1.024)
	BIM models are used in the design phase to help stakeholders plan and construct the building virtually	3.29 (1.275)	
Collaborative planning	BIM models for all design teams can be combined periodically for collaborative working and analysis	3.80 (1.190)	3.64 (0.930)
	The client regularly participates in meetings to support decision-making and problem-solving	3.49 (1.063)	
Overall Mean	**Lean-BIM design**	**3.73 (0.890)**	

Design performance

The analysis of the results showed that the overall performance of the design in the studied firms was neither high nor low as the mean was 3.66 out of 5.00. As shown in Figure 3, the highest evaluation was for the indicators related to the client; specifically, for understanding the needs and requirements (mean=4.22) and then for achieving the client's satisfaction (mean=4.06). As the results showed, participants believed that they could also avoid future change orders (mean=4.04).

The figure also shows that the lowest evaluation was for clash detection (mean=2.76), and then for engaging design teams (mean=3.00), the flexibility of decision-making (mean=3.02), and easiness of dealing with design changes (mean=3.04). The results also showed that delivering the design in compliance with the planned time and budget was not easy (means= 3.10 and 3.18 respectively).

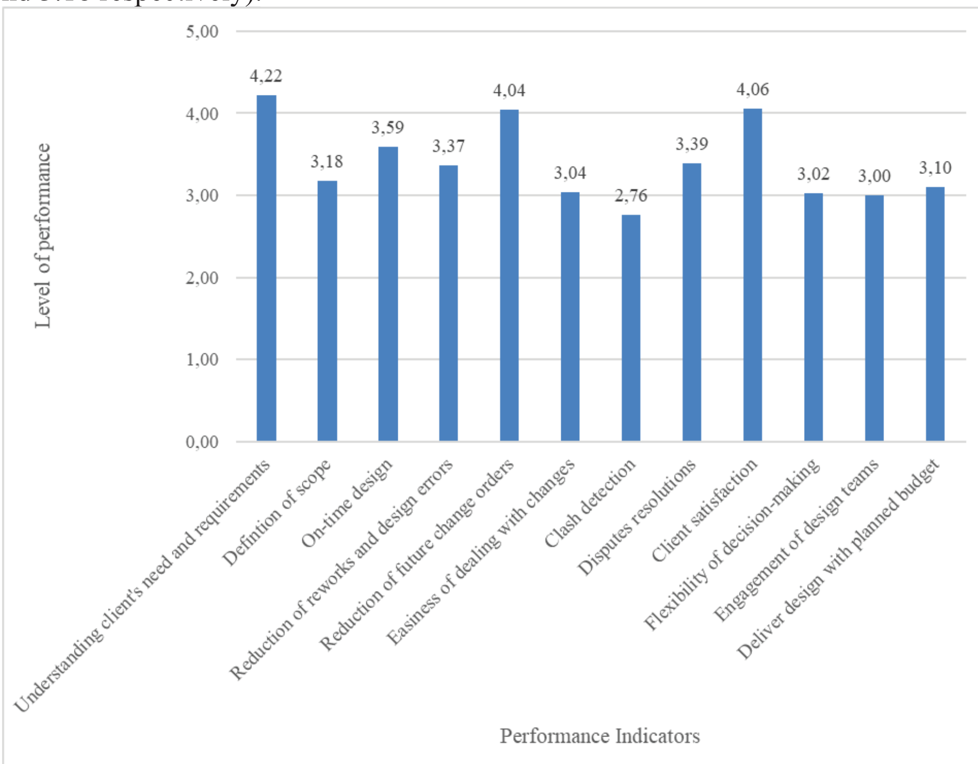

Figure 3: Design performance evaluation

To study the relationship between lean-BIM integration and design performance, a simple linear regression analysis was conducted. The regression test (as shown in Figure 4) revealed that at a significance level of (α=0.050), there is a positive and significant impact (P-value= 0.020) for lean and BIM integration in the design phase on design performance. The coefficient of correlation for the relationship is (r=0.44) and the coefficient of determination is (R-square= 0.194). This means that 19.4% of the change in the design performance can be explained by the change in the lean-BIM integration. Despite the significance of the relationship, it is worth mentioning that the the relationship needs to be investigated and validated using different and larger sample sizes and using other regression analyses.

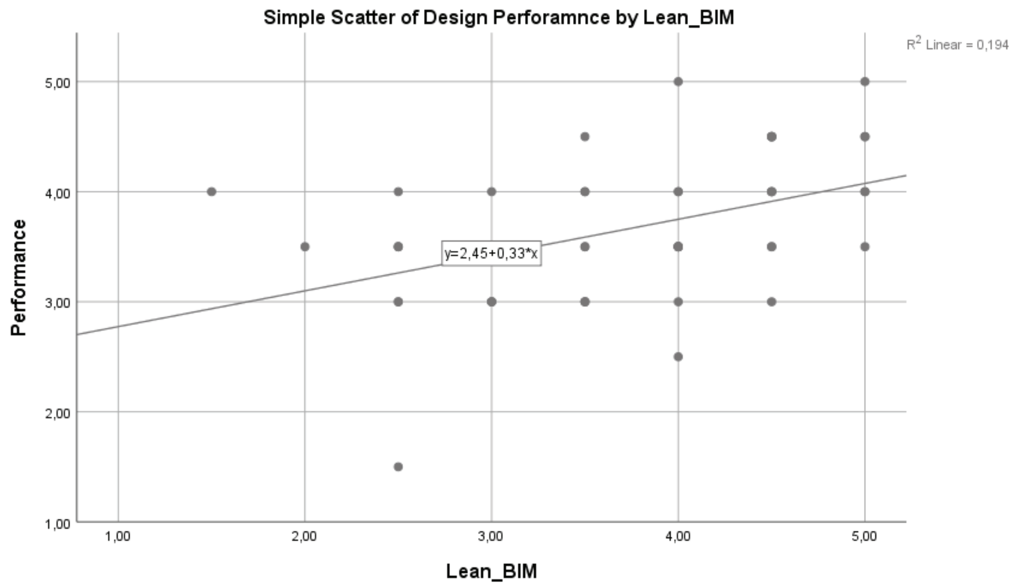

Figure 4: Relationship between Lean-BIM integration and design performance.

DISCUSSION AND CONCLUSIONS

Lean construction and BIM have been considered as two important concepts to create positive changes in the construction industry and along the different phases of construction projects (Sacks et al., 2010). Though, despite the increasing interest in lean and BIM and the numerous efforts to study the synergies between them, the implementation of lean principles jointly with BIM is still overlooked (Likita et al., 2022). Especially in design management (Herrera et al., 2021). Additionally, the levels of lean and BIM adoption are still unknown in different locations around the globe. The current study investigated the levels of lean and BIM adoption in France and the impact of lean-BIM integration on design performance. These objectives were achieved following the analysis of survey results filled by practitioners from different design firms in France.

The analysis of the results showed that BIM is more adopted in the studied firms in comparison to lean. This is unsurprising, especially with the increased interest in BIM due to the recognition of its different benefits and wide implementation around the globe to the limit that it was described as the "biggest change" that happened recently in the AEC industry (Tauriainen et al., 2016). The case for lean is a little bit different. While lean was labeled by some practitioners as the philosophy that can provide "revolutionary" improvements to the AEC sector, its adoption is still facing different barriers among them the lack of awareness and knowledge about it (Albalkhy et al., 2021; Albalkhy & Sweis, 2021). Additionally, for years, BIM has been a mandatory requirement in the construction sector in many countries (Bolpagni et al., 2017; Tranchant et al., 2017), which is not the case of lean despite the different calls and initiatives to increase its adoption.

Despite the greater adoption of BIM, the results of the study showed that it has not delivered its full potential and is not regularly practiced for different purposes in French design firms. More specifically, the results showed that some companies still do not adopt BIM, and others started its adoption less than a year ago. These results are consistent with another study conducted in 2017 about BIM adoption in 206 Small and Medium-Sized companies (SMEs) from the French construction industry that showed BIM adoption was not very high despite increasing (Tranchant et al., 2017). The same study reported complicatedness in the transition toward BIM by the surveyed companies and felt that BIM would not present improvements in terms of cost and time savings for the companies. This might be an explanation for the absence of the full implementation of BIM in the studied firms in this study. Another explanation might be that BIM is not yet a mandatory practice in France.

Concerning lean adoption, the results of the study are consistent with some claims in the literature that lean is not fully or routinely adopted in France (Chaize et al., 2022; Dakhli & Lafhaj, 2017). Nevertheless, due to the lack of studies about the challenges facing lean adoption in France, it is difficult to define the exact reasons behind this result. However, the lack of training on lean in the vast majority of the studied firms might indicate the presence of two serious barriers to adopting lean, which are the lack of support from top management and the lack of skills and knowledge (Albalkhy & Sweis, 2021).

Despite the lack of full implementation or adoption of lean, the current study investigated the presence of some lean tools, as in some cases, these tools might be implemented but without a full adoption of lean. The results showed that co-location or big room and A3 problem-solving are the most adopted tools. This might show some orientation toward collaboration to find solutions for design problems and improve the design. However, the implementation of these tools is only found in around 25% of the companies and there is no evidence that these tools are implemented routinely or perfectly. The lack of lean implementation in the design may cause losses of opportunities to improve trust, communication, collaboration, cost saving, and on-time delivery of the design (Chaize et al., 2022; Khan & Tzortzopoulos, 2015).

Despite the absence of full BIM and lean adoption, the results of the study showed some promising, but not full, results regarding the use of lean-BIM integration in design management. This was due to the acceptable evaluation for the overall lean-BIM integration (mean= 3.73 out of 5.00). This may show the opportunity to benefit from both concepts even if they are not fully adopted to improve the design. The results show that the client value is the most appreciated dimension while considering lean-BIM integration. While studying the design performance, similar results were found as the highest evaluation was for client satisfaction, understanding of the client's needs and requirements, and ability to cope with the changes. This may show an achievement of one of the principles of lean, which is the focus on the client (Albalkhy & Sweis, 2022). However, collaboration is still not enough; may be due to the contracting methods.

Studying the impact of lean-BIM integration showed that the latter significantly affects design performance. This is consistent with many studies in the literature that showed that lean and BIM together can work together to improve design deliverables, achieve higher client satisfaction, improve the quality of the design, and avoid delays (Bolpagni et al., 2017; Herrera et al., 2021; Tauriainen et al., 2016). Nevertheless, due to the small sample size in the study, this result needs to be validated in further investigations and with larger and different samples from different locations around the globe.

The small sample size is one of the limitations of this study, which hinders the full understanding of the overall evaluation of the studied variables. Future work with larger samples is recommended. Additionally, while this study uses the survey to achieve its objectives, further investigations can be conducted using other data collection methods such as interviews and case studies. Finally, while the survey included questions about the adoption of lean tools, further investigations based on the assessment of maturity levels with these tools might be conducted.

The current study aims to provide an understanding of the current situation in terms of lean-BIM integration in France. The results of this study are helpful to provide insights into the needs for these concepts. While lean-BIM integration was found to affect the design performance, this result might be helpful to achieve better design outcomes due to the adoption of lean and BIM. For researchers, the current study tries to fill the gap concerning the limited resources for the joint implementation of lean and BIM, especially in the design phase. The used tool in this study might be applicable in other locations.

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