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Review Article

Do Building Information Modelling Applications Benefit Design Teams in Achieving BREEAM Accreditation?

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Using building information modelling (BIM) within a design team allows for integration of sustainability analysis such as daylighting analysis, water harvesting, and thermal assessment whilst capturing the data which can be used for BREEAM assessment. Therefore, the availability of data compared to traditional methods can be used to design teams, stakeholders, and environmental assessment bodies' advantage. Since BIM boasts extensive building performance analysis capabilities, design teams should be provided with standard methodologies and guidance into successfully achieving certain BREEAM criteria. This paper highlights gaps in the existing theory to develop a solid understanding for further research in order to achieve BIM integrated BREEAM design team protocol. Further to this and running parallel to the protocol and guidance, an internal conceptual framework existing within BIM software could be instigated from future research. This will require detailed and innovative solutions to link the credits with the software both from an IT and from a software coding perspective; also, there is great merit into analysing design teams' cultural and behavioural factors towards sustainable design through the BIM model.

1. Introduction

The UK Government has singled out the built environment as an essential influence in helping the UK economy accelerate out of the recession. Statistics from the government's industrial strategy show that the construction sector accounts for 7% of GDP (gross domestic product). In addition, the UK Government's Construction Strategy 2011 indicates a 20% reduction in the cost of assets by 2016 in the public sector as the areas cost accounts for 40% of construction sector spending [1].

Recent investigations into sustainability are increasing due to requirement for low embodied energy buildings required by employers, clients, governments, and organisations. Azhar et al. [2], Autodesk Inc [3], and Biwas et al. [4] indicate that as a result local authorities, clients, and green building bodies are demanding low carbon energy efficient buildings from the construction industry due to the fact that 40% of the EU energy consumption is used in the construction sector [5]. This is seen as a major opportunity to implement sustainability practice with effective tools such as BIM to deliver an energy efficient structure.

The construction industry is experiencing rapid modification in the methods used when buildings are designed and, as a result, project teams and constructors face the difficult task of adapting to these new methods whilst still applying sustainable systems to designs [6].

By 2016, all government procured projects are required to supply the design works using BIM. As a result, building information modelling (BIM) has been one of the most talked about topics in the construction industry increasingly in the last 5 years due to its attributes such as improved project quality and delivery methods by means of important data and analysis. The tool provides accurate real time estimations to the construction works and can generate the information needed by facilities managers in the running and ongoing maintenance of the building after handover [7].

In the UK, environmental assessments such as the Building Research Establishment Environmental Assessment Methodology are used to align the sustainable practices with the building design works along with the use of the construction in the buildings' lifecycle. BREEAM is used with projects to assess the performance of buildings and is used as a benchmarking tool in order for a rating to be specified

by a qualified BREEAM assessor (BREEAM accredited professional). The code for sustainable homes (CSH) has similar criteria for housing only and it is compulsory to achieve a certain level of the code on new builds in Wales particularly. Some criteria identified in the guidelines provided by these two documents could be achieved and managed more easily through the incorporation of BIM with sustainability criteria required from sustainability assessments (BRE online).

Documents BS1192 and PAS1192-2:2013 (publicly available specification) identify the approaches and standards to implement and exploit during a BIM project. Both documents set certain standards that must be met and contain best practice guidance to the design teams. There has yet to be solid protocol or guidance for the integrated immersion of sustainable design through BIM for use in design teams adopting BIM.

Great effort has been applied in the use of BIM within a design team; however, implementation of sustainability methods using the BIM process compared to traditional design and sustainability measures is a grey area for design teams. According to Bynum et al. [8], sustainability was not thought to be the main use of the BIM tool but instead the virtual building model and the 3D visuals it can create along with the collaborative workflow and simultaneous working mind-sets within design teams. This highlights the need for structured guidance to the design teams.

An investigation into how BIM will support sustainable design and systems is essential in this paper to deliver useful information to design teams and green design bodies to demonstrate how the two systems integrate with each other from review of desk study literature and exploratory research. To do this, various aims and objectives must be identified from the following desk study research. Further to this literature review, the BREEAM documentation must be critically analysed and the relationship between BIM and the BREEAM criteria must be evaluated to develop standardised methodologies to be adopted by the design teams.

Current studies have suggested areas of enquiry due to the emerging development of techniques such as BIM and the existing government objectives in sustainable design. The purpose of the research was to investigate the current implementation of BIM with the application of sustainable design methods. As a result, reviewing and evaluating BIM's capabilities as a tool for project delivery, incorporating sustainable systems and policies, and testing the software were used to produce building performance analyses [9].

2. Building Information Modeling Overview

BIM is a method that involves the management and input of data utilising an integrated design process. Using BIM allows for 3D representations compared to traditional methods of 2D drawings that have no real meaning or construction specific information contained in the building elements [10]. From the 3D parametric model, documents are automatically prepared as the model is federated to enable for quicker more efficient decision making between clients and design teams at early conceptual stages. Azhar and Richter [11] identify that AECs using BIM for sustainability analysis are noticing considerable time and cost savings utilising BIM based sustainability analysis.

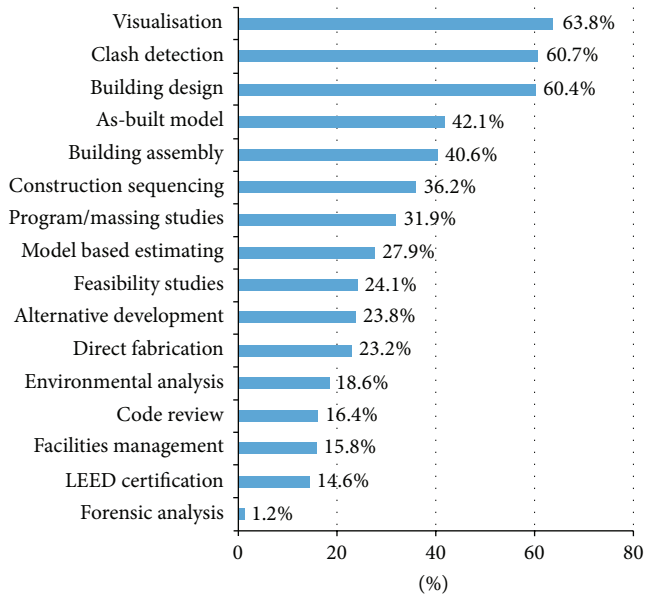

Figure 1: Most popular tasks using BIM [6].

The information is issued using data drops at certain points in the project cycle as shown in the information delivery cycle diagram in PAS 1192. This information is required by the government for construction operations building information exchange (COBie) data drops and can be used to support the management of the facility through detailed information provided by the design team such as equipment locations and spaces [12, 13].

There are considerable advantages of the design teams utilising the BIM process including the ability to create 3D visuals for presentation and supporting information to deliver schedules for quantity take-off and 4D models. In addition the 3D model could be used for building performance analysis, structural design and cost estimating of a building. [14]. Figure 1 shows the most popular uses of BIM. These advantages overall allow for shorter programmes delivery of a project; one reason for this is the use of the common data environment (CDE) which is a central store for any project files for use by multidisciplinary teams to transfer information to facilities' managers from design teams [15].

3. Environmental Assessment Method

Environmental assessment boards are primarily put in place to set standards to the design teams on new and existing construction projects to responsibly design their buildings, by a set of obtainable standards for assessment at design stage and after construction [16].

The nondomestic buildings account for 18% of the total carbon emissions in the UK Carbon Trust [17]. BREEAM is the pioneer sustainability assessment used in the UK for sustainable design practice following through to the construction and life cycle of the building [18].

Table 1: BREEAM credits and weighting overview.

Section topic	Number of credits available	Section weighting	Number of minimum standard BREEAM issues
Management	22	12	3
Health and well-being	10	15	2
Energy	30	19	3
Transport	9	8	0
Water	9	6	2
Materials	12	12.5	1
Waste	7	7.5	2
Land use and ecology	10	10	1
Pollution	13	10	0
Innovation (additional)	10	10	N/A

The method of the assessment is as follows; an overall percentage is given to the building at design stage and then reassessed after construction. The percentages are classified as follows: less than 30% unclassified, pass 30% or more, good 45%, very good 55%, excellent 70%, and outstanding 85% [18].

The categories of the assessment criteria include management, health and well-being, transport, water, materials, energy and waste, pollution, and land use and ecology. Credits are scored in each section; for example, in ENE 1, there are 15 credits available. To achieve a BREEAM rating, the minimum percentage must be achieved if that particular credit requires minimum standard; see Appendix section; therefore, the minimum amount from the 15 credits available from ENE 1 must be achieved [19]. The assessment criteria are split into 9 weighted sections and one additional section for innovation; see Table 1.

4. Building Information Modelling in Design Teams

Using BIM in design teams is the most effective way to fulfil the tools' potential. AECs may choose to work alone; however, this works against BIM's integrated design strategy. Deutsch [20] conveys the idea to use the time to learn and advance skills in the technicality of the software, the application of analysis upon construction, and BIM theory so users would be equipped for integrated project delivery (IPD).

Deutsch [20] advises pilot projects for design teams new to BIM and integrated project delivery. This method allows for sustainable design techniques to be analysed along with sustainability analysis tools compatible with BIM software.

Information and data collected by the AECs are managed and integrated by the design team into the BIM model. The process allows the design team and anyone involved in the phasing to extract product information, parametric statistics, and details of construction to build up the BIM model. In addition, the model can be used to assess the buildings structure and flag up any construction defects during the design process [8]. Figure 2 taken from PAS 1192-2:2013 shows the BIM design workflow.

The building information model (BIM) is used as the central tool and hub of data to a BIM project and is the principal instrument for design teams. BIM objects hold all the metadata and parametric information for that specific element. Manufacturer's products are available from BIM libraries dependent on their availability and competency with the BIM process [21]. Additionally, design teams may produce specific custom families which can be created in a project if required. Essentially, this means that any custom components can be used for future projects.

However, there are possible risks and limitations. Integrating a traditional system such as sustainability theory with an advanced technological tool such as BIM that is predominantly data driven means that the integration issues must be approached effectively. The method of project delivery should be agreed upon between organisations to ensure that the design team is technically competent and has the capabilities to approach the projects integration with BIM efficiently [22].

5. The BIM Model Applications to Sustainable Design

BIM allows architects and engineers to produce a 3D model that contains information rich BIM objects in a computer generated model; the 3D model is the key system for use by design teams.

There are evidently clear advantages of design teams using the model. However, a faster more efficient process is inoperable if the BIM model data is not accurate enough to provide valuable information. Krygiel and Nies [10] justify that the BIM model is dependent on data; therefore, if the data input into the model is incorrect or no longer practical, then this will have possible knock-on effects when carrying out sustainability analysis at later stages in the design. Additionally, a study by Becerik-Gerber and Kensek [9] noted that the accuracy of the as-built models is required to be of high quality to ensure a sustainable building after handover. This highlights the requirement for a working model that is up to date and informative.

The BIM model is an important factor from as early as the conceptual stage in the design. Outlined in the RIBA BIM overlay to the plan of work, the concept design stage requires outline proposals for environmental strategies. The guidance recommends the consideration and initial development of sustainable design strategies at the earliest possible stage once the massing model has been produced [13].

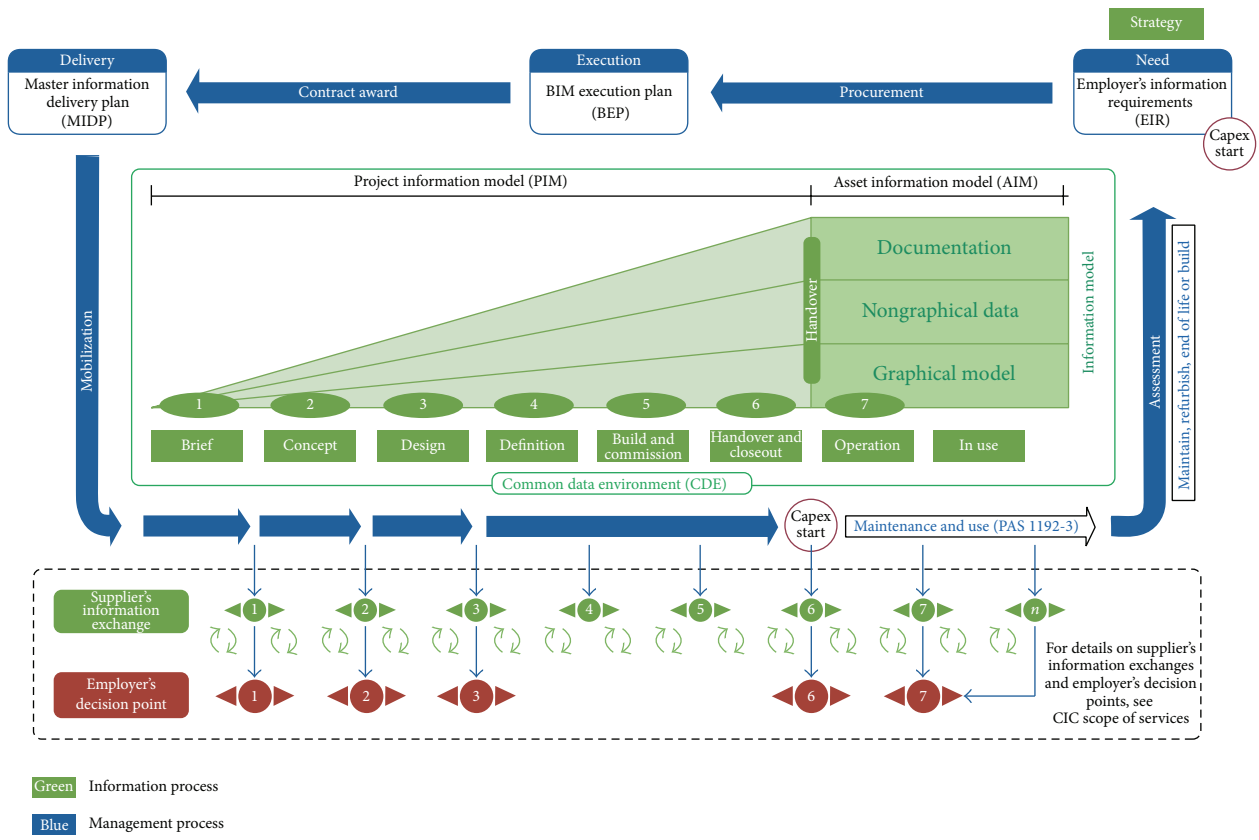

Figure 2: The information delivery cycle (PAS-2 : 2013).

The massing model as described in Krygiel and Nies [10] and Cho et al. [23] can be used to incorporate several sustainable design criteria from an early stage. These include volume and areas allowing stakeholders to compare materials properties and estimate the potential cost of the design. Moreover, the positioning and orientation on the site to establish site specific coordinates could be done. Sun paths for analysis of the conceptual mass in relation to the world coordinates could be done to assess solar gain inside buildings. This could be done along with assessing the suitability of heating, ventilation, and air conditioning (HVAC) systems for design consideration.

Eastman et al. [21] suggest the importance of the initial energy analysis in the BIM model at the conceptual design phase determining factors such as assumptions of HVAC costs using BIM's concept building mass modelling, orientation on the site, and its building shell design and volume.

6. BIM Integrating Sustainability Practice

As more AEC practices adopt BIM and utilise the primary tools available, the idea behind BIM is becoming more apparent [8]. In effect, the areas of sustainable design will become more fundamental to design teams in key areas of the project programme.

When building up the BIM model, the most important process with sustainability implementation is at the design and preconstruction phase to ensure that the building meets requirements after construction and during the buildings' life cycle, relying on architects, engineers, and construction managers to know how the BIM tool and green design tie together. This leads on to how BIM assists with the implementation of sustainable approaches to design (see [9, 20]).

BIM based sustainability analysis is one of the critical areas to successful integration of the two systems. Various pieces of software are available to the design teams including Autodesk Ecotect, Green Building Studio (GBS), and Virtual Environment (IES), which all have similar building performance analysis capabilities. However, building information modelling software such as Revit only includes basic building performance analysis. Bynum et al. (2013) identify that there are interoperability issues between the BIM software and the external performance analysis tools and suggest that BIM must improve its environmental analysis methods to establish future benchmarks for the design teams to work towards.

Alternative to exporting the data to green building analysis software such as Ecotect, simple building analysis can be performed on the conceptual mass as Revit has implemented this facility so users do not need other software packages to carry out concept design. Exporting the 3D model may result in interface issues with the user; so, improving the analysis software in Revit is crucial to align BIM and the sustainability methods as one operational tool [21]. However, energy analysis plugins such as Green Building Studio and integrated environmental solutions plugins (IESVE) can be directly loaded into use with Revit [24].

7. Connection between BIM Centred Sustainability Analysis and Environmental Assessment Criteria

BIM's ability to analyse a building's performance at the design stage offers an opportunity for the design teams to integrate their model data to potentially achieve certain BREEAM credits. BIM and its ability to manipulate building data and performance statistics can influence the BREEAM assessment process. Significantly, BREEAM assessments need to recognise the growing use of BIM and the advantages such as those that performance data and building element information have upon design teams and stakeholders to make key decisions to ensure the efficiency of the building prior to site handover to contractors. These evident characteristics will provide clear advantages to the BREEAM assessment process [18].

Azhar et al. [25] developed a conceptual framework of a project case study to establish any underlying links between the sustainability analysis in the BIM software and the LEED rating system which is the pioneering sustainability construction organisation in the USA with similar criteria to BREEAM. A table was devised to enable the LEED credits to be compared against sustainable design related investigation types and to decide which stage of the project had direct relationship with the analysis types.

The energy analysis was the most related one to the LEED criteria at the design stage, as previously discussed; this verifies the importance of energy analysis by design teams at the conceptual stages to integrate data results to the aim to achieve environmental assessment credits particularly in energy.

The material documentation was also a predominant successful link between the two fields, with certified wood being one of the criteria related to the sustainability analysis at the construction stage [25].

The study put into perspective the link between BIM based analysis and the environmental assessment criteria; however, a future system to diminish BREEAM's interoperability issues with BIM is currently being developed. The development of such frameworks will benefit design teams if a clear interface between the two is established.

Due to the demand, BRE have instigated research into the development of an IT infrastructure because the input of information through use of BIM allows for an opportunity to integrate the output of building data information and strategies and combine with BREEAM performance criteria to develop a clear relationship between the exchange of BIM data and the success or failure in meeting the BREEAM objectives [18].

8. Issues Faced by Design Teams Using BIM Based Sustainability

Due to the fact that building information modelling is a relatively new tool, there may be some problems with compatibility with sustainable design measures [8]. The current practice by design teams enabling the use of sustainable design in BIM delivered project is to export the data to external simulation packages underlined earlier in the paper. The main issue with this process is the risk for errors due to multiple data entries and the transfer of accurate information into other software platforms [26].

In addition, Azhar et al. [27] suggest a possible solution to the integration issue between the two systems required for the BIM model and the sustainability analysis to take place in a single BIM platform to reduce errors during the building performance analysis. Additional issues being faced by design teams suggest the lack of a simple method to change the BIM model to meet the required building performance from the energy simulation results. Greater integration is needed to allow precise elements to be highlighted that require modification in order for the criteria to be met on the next performance assessment [28].

In relation to the above issue discussed, the research of Bank et al. [29] provides a possible solution proposed by combining the BIM model from, for example, Revit, with a system dynamics (SD) modelling program which is a tool for decision making. The dynamic system model integrated with the model in Revit would automatically update the BIM model from highlighted modifications shown in the SD analysis results.

There may also be issues with the collaboration between parties both externally and internally via the CDE that is seen as one of the revolutionary advantages of switching to BIM. The CDE may only be local (internal CDE) or cloud based including external parties depending on the size of the organisation. This will have an effect on the data control and may lead to data integrity issues if managed poorly. Users may be reluctant to share information with issues relating to design liability when multiple parties are manipulating its geometric data and publishing the data back to the author. Many AEC practices have been reluctant to share their BIM models externally because they are not fully aware of the model control and management that BIM software is capable of, such as model permissions and work-sharing management. These issues can easily be overcome given that more advanced training is implemented with reference to modifying work-sharing settings in Autodesk Revit, providing a good example of this feature [30].

Design teams may also experience hardware issues due to hardware power demands that designing for sustainability, performance analysis, and BIM requires. For example, at conceptual mass modelling stages, the integrated building performance analysis runs smoothly on building masses with low complexity data, which is only when the model becomes populated with high detailed components and building elements such as structural walls, windows, and floor, whereas less powerful hardware struggles to perform the task. There are obviously cost implications of meeting the hardware demands so AEC practices may have a different level of users within design teams such as power users to perform the more complex task, which also helps with the capital cost of being BIM compliant [31].

Table 2: Minimum BREEAM standards by rating level.

BREEAM issue	Pass	Good	Very good	Excellent	Outstanding
Man. 01: sustainable procurement	One credit	One credit	One credit	One credit	Two credits
Man. 02: responsible construction practices	None	None	None	One credit	Two credits
Man. 04: stakeholder participation	None	None	None	One credit (building user information)	One credit (building user information)
Hea. 01: visual comfort	Criterion 1 only	Criterion 1 only	Criterion 1 only	Criterion 1 only	Criterion 1 only
Hea. 04: water quality	Criterion 1 only	Criterion 1 only	Criterion 1 only	Criterion 1 only	Criterion 1 only
Ene. 01: reduction of CO_2 emissions	None	None	None	Six credits 1	Ten credits 1
Ene. 02: energy monitoring	None	None	One credit (first submetering credit)	One credit (first submetering credit)	One credit (first submetering credit)
Ene. 04: low or zero carbon technologies	None	None	None	One credit	One credit
Wat. 01: water consumption	None	One credit	One credit	One credit	Two credits
Wat. 02: water monitoring	None	Criterion 1 only	Criterion 1 only	Criterion 1 only	Criterion 1 only
Mat. 03: responsible sourcing	Criterion 3 only	Criterion 3 only	Criterion 3 only	Criterion 3 only	Criterion 3 only
Wst. 01: construction waste management	None	None	None	None	One credit
Wst. 03: operational waste	None	None	None	One credit	One credit
LE 03 Mitigating ecological impact	None	None	One credit	One credit	One credit

BREEAM minimum standards, available online at http://www.breeam.org/BREEAM2011SchemeDocument/Content/03_ScoringRating/minimum_standards.htm.
Date accessed 29/01/2014.

9. Conclusions

The implementation of BIM in design teams and the process of undergoing BREEAM assessments unquestionably have a positive impact in relation to government zero carbon objectives. The frameworks devised by the existing studies only provide an indicator for further research or have drawn conclusions that relate back to interoperability in the existing software or lack of environmental assessment user friendly interfaces integrated into BIM software.

There are feasible methods to directly link BIM to achieve certain BREEAM criteria. As discussed, many applications of BIM are highly linked to BREEAM credits especially in the energy section, with the BIM model being a key factor in achieving the credits. Therefore, there is an opportunity for guidance to be developed for use by the design teams. As a result of the exploratory research, it has been concluded that the main BIM input by a design team is through the BIM model such as building performance analysis. There is limited knowledge of how BIM can benefit a design team to achieve certain BREEAM credits; therefore, standards are required to be implemented to standardise methods in order to apply and input data into the BIM model to directly achieve BREEAM credits.

Currently, the software frameworks specifically developed for achieving BREEAM credits through BIM software require the BIM model to be exported in various formats, such as gbXML, to an external ribbon or software window; this can result in data loss and is not the most efficient and effective way that BREEAM could be integrated into the modelling of buildings and implementation of sustainable design methods. With data and the model interchanging through differential file formats driven by BIM's power for interoperability, this means that the file may become inaccurate and corrupt, resulting in data loss and inaccurate building performance analysis and data production that would be required by the assessor to meet particular BREEAM credits.

Architectural, engineering, and construction practitioners lack best practice guidance that takes into consideration cultural and behavioural factors linked with achieving credits through BIM; if these guidelines are not put in place, the benefits to the design teams from the use of BIM integrating sustainable design may not be recognised. In addition to this, it would be a great benefit for an internal software tool that enables key analysis and performance modules to run parallel to the guidance within the BIM software, proving that the chosen software has a customizable API facility to do this.

The IESVE navigator provides an IT solution for 42 of the BREEAM credits; however, the same issue exists where the BIM model has to be exported externally creating a readable format. Perhaps more credits could be achieved if the modules existed within the BIM software as an internal platform; researchers may also be inclined to further push the boundaries of certain credits that are limited by the software application so there could be room for improvement to the design application itself to provide the user with all the sustainability tools they need to make the process more manageable and efficient.

Appendix

See Table 2 [32].

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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