Building Information Modelling, Lean and Sustainability: An integration framework to promote performance improvements in the construction industry.

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Highlights

- The construction industry is known for its impact on the environment.
- BIM, lean and sustainability improve processes whilst enhancing sustainability.
- The linkage has been suggested but comprehensive frameworks are still missing.
- An integration framework of BIM, lean and sustainability (BLS) is proposed.

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Abstract

The construction industry is known for its fragmentation, poor performance and negative impacts on the environment. In recent years, Building Information Modelling (BIM), lean principles and sustainability concerns have emerged as trends in the industry, since they aim to improve how buildings are delivered throughout their entire lifecycle. Value aggregation and efficiency in operational and environmental terms are major concerns by stakeholders and wider society. Integrating these practices would yield better project outcomes. However, majority of studies are focused on these elements in isolation or in pairs and there are no comprehensive frameworks suggesting an integration. This study researched, analysed and articulated existing work on a possible integration framework of BIM, lean and sustainability principles (BLS) to promote performance improvements. Current proposals were analysed along with drivers, benefits, barriers and challenges for integration. Academics and industry practitioners will benefit from this framework as it looks into future requirements of the industry, which is aiming to achieve better efficiency and enhancement of sustainability outcomes.

Keywords: Building Information Modelling, lean, sustainability, construction

1. Introduction

The rise in information and communication technologies (ICT) and its benefits have been used as a way to respond to the complex nature of the construction industry (CI) and the effects on performance. This rise in ICT for the construction industry has been reflected in the development of Building Information Modelling (BIM) as the new Computer Aided Design paradigm (Succar, 2009), which can contribute to reduction of costs and errors (Bryde *et al*., 2013) and as an enabler for performance improvements. The BIM trend has increased over the past years. A review study from Abdal Noor and Yi (2018) on BIM in the CI found that most of the research in this topic comes from the USA with 786 articles on the topic, followed by China, the UK, South Korea, Australia, Germany, Canada, Taiwan, Italy and Finland. From those articles, the diversity on the topics researched is vast confirming the range of possibilities of the BIM domain and most of the research were carried out by universities. Barlish and Sullivan (2012) measured the benefits of BIM implementation based on the investments and returns of BIM utilisation with positive results. A study on the same topic with similar results were also conducted by Giel and Issa (2013). Chen *et al.* (2014) analysed the level of maturity of BIM implementation by analysing key factors for measuring BIM maturity in construction projects. Liu *et al.* (2010), analysed the factors influencing the adoption of BIM in the AEC industry grouping them in three categories namely perceived benefits, external forces and internal readiness. A different study by Du *et al.* (2014) proposed a benchmarking application to automatically collect BIM performance data from BIM users to allow companies applying BIM, comparing their performance against best practice. Becerick-Gerber and Rice (2010) performed a survey to determine the perceived value of BIM in the American building industry focusing on benefits and costs regarding BIM use at the project

level and concluding that BIM use is still at early stages and the true value of BIM application is yet to be achieved. Won *et al.* (2013) analysed critical success factors for BIM implementation obtained from international experts. A different approach of BIM analysing retrofitting strategies was studied by Hammond *et al.* (2014) to promote sustainability. Similarly, Zhou and El-Gohary (2018) also studied BIM to promote sustainability looking at regulatory information on energy codes. Other examples of BIM application include Moreno *et al.* (2019) on BIM in education facilities, Chen *et al.* (2018) and Boroujeni and Han (2017) on BIM in construction performance. Finally, more technical applications of BIM include earthquake assessment (Anil *et al*., 2015), laser scanning (Xiong *et al.*, 2013), digitisation of existing buildings (Mellado *et al.*, 2020) and application in other areas such as the mechanical construction industry (Boktor *et al.*, 2014).

Similarly, lean principles have been applied to the CI, aiming to reduce waste and improve construction processes (Koskela, 2000). Waste has negative impacts on the environment and leads to poor efficiency. Concepts such as waste-to-resource and waste-to-energy have appeared as a better solution towards waste, however, it also generates added issues to the environment and leads to extra project costs (Pan *et al.,* 2015). Lean construction has also increased its implementation and use over the past years. A review study from Babalola *et al.* (2019) found that the leading countries in the lean construction area are the USA, the UK and Brazil. Notable works in this field include Howell (1999) on concepts lean construction, Ballard (2000) on the development of The Last Planner System of Production Control, Koskela *et al.* (2002) on the foundations of lean construction and Ballard *et al.* (2002) on lean construction tools and techniques. Whelton *et al.* (2002) proposed a knowledge management framework for project definition of capital facility projects based on lean principles Zimina *et al.* (2012) introduced the target value design concept to reduce construction cost by applying

collaboration and lean approaches. Hamzeh (2009) studied the improvement of lookahead planning and other Last Planner System indicators. Most recently, lean construction has been integrated with other practices such as BIM due to its synergistic nature of improving construction processes and reducing waste (Nguyen and Akhavian, 2019).

Research has demonstrated that improvements in the operational, technological and cleaner production fields are still unexplored in the CI (Saieg *et al.*, 2018). There is great potential to increase productivity and efficiency that are related with BIM and lean goals, whilst also improving sustainability. However, there are few studies focusing on this aspect and there are no frameworks suggesting an integrated management framework. Koskela *et al.* (2010) and Enache-Pommer *et al.* (2010) suggested synergies between BLS and most recent developments on the field have been made by authors such as Ahuja *et al.* (2016) and Saieg *et al.* (2018) but the application on real scenarios remains a challenge and barriers are still under exploration. In this sense, the benefits of full BIM adoption are still unexplored (Walasek and Barszcz, 2017) and the slow adoption of lean is a major hurdle (Djokoto *et al.*, 2014) and sustainability in the construction industry is still focused on the environmental and economic part, neglecting the social aspect (Det Udomsap and Hallinger, 2020). Therefore, reaching for a balance is still an important barrier for wider adoption. Organisations in the CI have the opportunity of changing the way on how they conduct their businesses by integrating BLS practices into their core because it essential to count with their commitment to adopt BLS for the integration to be successful. The synergistic nature of the aspects under study can provide opportunities for improvements and an even stronger synergy when integrated by committing the entire organisation as a starting point.

The aim of this study is to research, analyse and articulate existing work on BIM, lean and sustainability to study the elements that would compose an initial conceptual framework aiming to integrate BIM, lean and sustainability (BLS) to promote performance improvements. The linkage among these three aspects has been suggested but not presented as an integrated framework to demonstrate specific components for their integration. This study structure starts with background on performance in the CI and how it is related with BIM, lean and sustainability principles. Next, the research method is explained and the proposed framework's components such as drivers and barriers, existing frameworks and models, critical success factors (CSFs), integrated project delivery (IPD), impacts of BLS on project performance, are discussed. Finally, research gaps and conclusions are presented. The main contribution of this study is to provide an alternative trichotomy of a BIM-Lean-Sustainability (BLS) framework to promote performance improvements in the CI.

2. Research background

Performance in the CI has been a common topic among practitioners; despite evolution of the CI, projects are still failing to meet success criteria. Traditionally, performance is viewed as meeting quality, time and cost constraints, also known as the 'Iron Triangle'. However, these success measures are being criticised as new projects are becoming more complex to manage to be only measured by the traditional three parameters (Mellado *et al.*, 2019); similarly, other aspects have also been considered but they have mainly been used for benchmarking purposes but not to control project performance (Toor and Ogunlana, 2010). In this sense, including other aspects to assess performance means in the near future, projects may be measured based on different criteria according to the construction industry evolution

such as government's plans for BIM and carbon emissions reduction and how these impact on performance evaluation (Edwards et al., 2019). Major changes related to innovation and collaboration, have been occurring aiming to improve productivity, efficiency and sustainability such as digitalisation in the form of BIM that is considered an innovation tool to achieve efficiency and improved communication which is set to become an integration enabler to adopt other practices due to its synergistic nature with performance improvements (Horta *et al.*, 2010).

Construction projects are by their nature complex, consequently, effective management linked with successful integration of tools and methodologies is crucial to comply with project requirements. Collaboration and communication are key to promote improvements and the lack of them is regarded as one of the main reasons that construction projects still fail. By adopting integrated approaches project outcomes can be improved, and improved overall performance can also be achieved. Efforts have been made by practitioners to study and analyse effective integration of management concepts; for example, a study by Demirkesen and Ozorhon (2017) on integration management and its impact on performance demonstrated a lack of a comprehensive understanding between these two concepts which are crucial in the successful management of construction projects, and also, suggested the integration of different methodologies and tools in different construction project phases such as BIM and lean principles. The study, concludes that integration of practices is a key element of successful project performance and that the CI is still in search of effective practices and strategies. As a result, there are some studies proposing integrating BIM, lean and sustainability in pairs or in isolation (Sacks *et al.*, 2010; Mahalingam *et al.*, 2015; Tauriainen *et al.*, 2016). However, comprehensive frameworks are still missing. For these reasons, it is

hypothesised in this study that by adopting an integrated approach of these three major drivers, construction projects would be more efficient throughout their life cycle because project stages are strengthened. BIM processes have been accepted as an enabler by the CI to improve performance through the project life cycle, but they have not yet reached their full potential. At the operational phase, lean methodologies are used to produce safer, faster and cost-effective projects due to its aim of reducing waste and maximise effectiveness. Furthermore, the CI has targeted the reduction of carbon emissions and to become more environmentally friendly (UKGBC, 2017), which is synergistic with what BIM and lean principles promote. The final outcome is to produce a product which complies with the standard of time, cost and quality but also considering the environment and the process on how the final outcome is reached. Thus, by proposing and integrated approach, the performance of projects and the industry can be improved (Mellado *et al.*, 2019). The exploration of BIM, lean practices and sustainability in terms of performance, synergies, and integration as a single approach is still in early stages, therefore more research needs to be carried out in this area (Saieg *et al.*, 2018).

3. Research method

The aim of this study is to explore the theoretical integration of three current relevant areas to the evolution of the construction process to deliver more efficient and sustainable projects throughout their entire lifecycle, on the belief that these would achieve synergies when integrated, thereby reaching increased levels of performance. The first objective is to identify and evaluate the current state of the literature related to BIM, lean and sustainability to later classify the articles found to identify gap areas and opportunities for new research. This

approach is taken to achieve a better understanding of new topics (Easterby-Smith *et al.*, 2002); and to structure the information which will be used to propose a BLS framework. The literature step is of utmost importance to establish the current state of relevant knowledge and to discover new areas that need further development (Webster and Watson, 2002). This structured process is carried out to obtain an effective literature review and it is done by defining the unit of analysis, classification of the context, evaluation of material and publications collection and field delimitation (Saunders *et al*., 2008).

Insert Table 1 and figure 1

The literature search that was conducted covered the period from 2000 to 2018 to represent the proposed ideas in the new era of construction after the report presented by Egan (1998) proposing a new way of working in the CI and the start of a new century. Furthermore, a new production paradigm presented by Koskela (2000) has become more matured since it was first mentioned in 1992.

Insert figure 2 and 3

Figure 2 and 3 demonstrates the distribution per year of each individual driver and their synergies to show the analysis per year throughout the entire period under study, starting from 2000 onwards and the first relevant paper within the scope of this research was found in 2001. There has been a clear increase in journal papers being published in the three areas of interest, however, research into their comprehensive integration as proposed in this research appears to be non-existent so far.

Insert figure 4

The research streams as presented in Figure 4 show that the majority of the papers are related to BIM in isolation (28%), followed by sustainability (16%) and lean (15%) whilst the synergies between the three drivers are very low (2%). From this analysis, it can be deduced that BIM is growing in importance because it has reached an appropriate level of maturity and acceptance by the industry which could be caused by the requirements set by governments among other benefits encountered. The other drivers, especially lean, have decreased in terms of published research. However, the combination in pairs such as lean/sustainability (LS), BIM/sustainability (BS) and BIM/lean (BL) are still an important part of research.

4. Proposed conceptual framework

A conceptual combination is proposed, aiming to promote performance improvements in the construction industry. This proposed framework is also intending to create a system in which continuous improvement could be reached in a well organised and efficient way. The literature suggested that the same restrictions on lean and sustainability when considered in isolation have been encountered when integrating them (Cherrafi *et al.*, 2016). The proposition of including BIM with lean and sustainability should overcome this issue as they are complementary (Ahuja *et al.*, 2016); thus, each strategy is capable of reducing the limitations of the others.

The framework considers the reasons for adoption (drivers), as well as barriers (for instance, cultural and technological) that can affect integration. The proposition is that organisations in the CI should consider the BLS integration aiming to improve efficiency, environmental, economic and social performance of their construction activities with BIM methodologies as a catalyst. In addition, the potential barriers that could prevent integration need to be assessed for this process to successfully work. As the framework is intended to be applicable in general terms, cultural and technological aspects could be considered as potential barriers; for example, training and education could be an important factor, since implementing new management practices require a level of knowledge prior to the implementation in systematic routines and working practices (Blackler, 1995). Setting a new integrated framework would bring expected benefits and synergies which can be measured through the common indicators adopted by the industry related to BLS. Similarly, integrating complex practices could lead to potential issues which are prevented by including specific tools, methods and techniques which if not considered, successful implementation could be affected, causing limitations (Cherrafi *et al*., 2016). For example, sustainability has its own complexities in terms of processes, making it different to traditional construction practices (Ansah *et al.*, 2019).

The proposed framework components would be based on criteria found in the European Foundation for Quality Management Excellence model (EFQM) which assesses both organisational and operational performance and it is one of the most popular frameworks along with the Balance Scorecard Sheet (Bassioni *et al.*, 2005). The reason for using the criteria from this model is that it allows a clear vision of both management and processes to be established and also because of their focus on performance in the long term. In this sense, it also allows a foundation for sustainable excellence considering the whole organisation and

the ability to track and measure progress (Vukomanovic *et al*., 2014). The BSC model was not considered in this framework because of its over simplicity (Kagioglou et al., 2001). Lean focuses on waste identification and reduction, but it does not consider sustainability aspects therefore, several organisations have included sustainability in their practices to overcome this shortcoming (Ng *et al.*, 2015). There are studies proposing the integration of lean and sustainability principles to help reduce unnecessary waste in environmental and social processes; however, organisations applying those concepts have not achieved top sustainability performance but the inclusion of BIM may help fulfil this goal. The resulting BLS framework is proposed to take advantage of the strong connections between the BIM (B), lean (L) and sustainability (S) management systems considering drivers, barriers and challenges and benefits of the integration. The arrows on the model show the strong connections between the framework elements that work combined as an integrated framework aiming to promote performance improvements in the CI, increasing efficiency and enhancing sustainability as well as identifying strengths and promoting continuous improvement.

Insert Figure 5

5. Discussion of framework components

5.1 Integration drivers

BLS implementation is motivated by drivers and barriers to their adoption; therefore prior to their integration, an assessment is required to ensure a proper evaluation. The analysis considers both internal and external drivers.

Insert Figure 6

There are shared internal and external drivers (Figure 6) (Kleindorfer *et al.*, 2009). For example, costs of resources are frequently rising due to high demand, therefore, forecasting them may be difficult so accomplishing resource efficiency is necessary to obtain better performance results (Wong and Wong, 2014). It is acknowledged that sustainability principles must be in balance and each principle has the capacity of impacting the others. Similarly, the application of environmental drivers is viewed as an improvement of financial performance which is seen as brand image improvement (Wadhwa, 2014), therefore, organisations are looking to those aspects to positively impact in the market (King and Lenox, 2001). In this regard, improving environmental performance is positively viewed as part of corporate social performance (Pagell and Wu, 2009). Companies of all sizes are driven by external forces to constantly evaluate and adapt their processes to improve their performance, also, people are more environmental aware which makes them consider more sustainable options (Xie *et al.*, 2017). Social performance linked to sustainability is also a major consideration to banks, investors and shareholders, making it even more important to companies involved in the industry (Kadry, 2013). In the case of BIM, Eadie *et al.* (2013b) reported that non-BIM users consider government pressure, competitive and client pressure as the most important drivers, whereas, BIM users classified those same drivers at the bottom of their priorities. BIM users found that clash detection, cost savings through reduced rework and improving design quality are the most important drivers for adoption.

5.2 Integration barriers and challenges

Walasek and Barszcz (2017), suggest that the full application of BIM has not been exploited yet which can lead to problems of trust and difficulties in the adoption. Other challenges include the cost of adoption, learning curve and individual commitment that need overcoming if the application intends to be successful (Lee *et al*., 2015). According to Dave *et al.* (2016), communication frameworks that systematically tackle information flow requirements through the construction project lifecycle are still missing. In this sense, the integration of lean methodologies and ICT, such as BIM alongside with environmental outcomes would help overcome this issue by presenting a system considering the entire project lifecycle. However, adoption of lean practices itself has proven to be difficult (Sarhan and Fox, 2013). Despite these hindrances, organisations that have implemented lean are more likely to adopt environmental indicators (Mollenkopf *et al.*, 2010).

Insert Figure 7

When considering the adoption of integrated lean construction and sustainable practices organisations have found the integration difficult despite the strong synergies between them and literature shows that the implementation has been poor and slow (Ng *et al.*, 2015; Djokoto *et al.,* 2014); also sustainability driven projects are more complex than traditional methods due to more specialised and bespoke processes that lead to more complex construction (Ochoa, 2014). On the idea of sustainability integration with social and environmental aspects, Simboli *et al.* (2014) states that this idea will work only when there is a clear increase in economic value by organisations and the idea of improvement in

environmental and social performance is still believed to be a hurdle in achieving economic growth (Fond, 2009).

5.3 Interactions benefits

Gains in efficiency, waste reduction, added value, rework reduction and performance improvement in projects are some of the reported benefits of BIM, which are directly related to lean principles (Table 2). Improved flow and overall time reduction by applying clash detection, visualisation and collaborative planning are practical benefits of the BIM contribution towards lean goals. Table 2 shows examples of BIM and Lean applications confirming the strong synergy between these two methodologies.

Insert Table 2

Similarly, the construction industry worldwide is under pressure not only to reduce waste and to increase low levels of material recycling (Liu *et al.*, 2011), but also to comply according to specific environment requirements established by governments and by international treaties. For example, the UK government has set out specific targets for new domestic and commercial buildings to reduce carbon emissions (Heffernan *et al.*, 2015); these targets have arisen as a need to comply with successive Energy in Buildings Directives and associated legislation. In this respect, BIM methodologies are established as a catalyst for change, with sustainability improvement being a major benefit obtained from its application. Table 3 shows some examples of BIM and sustainability applications, confirming the strong synergy between these two methodologies.

Insert Table 3

In recent years, BIM and sustainability practices have been growing and have been adopted in the built environment (Wong and Kuan, 2014); because the CI is urged to adopt sustainable strategies to tackle the existing concerns regarding CO_2 emissions and dependency on fossil fuels, being the use of BIM methods a powerful tool that allows the use of the design data for both sustainable design and performance analysis (Wu and Issa, 2015). Efforts have been made in studying BIM to promote sustainability outcomes in areas such as energy performance simulation, lighting analysis, construction and demolition waste analysis (Lu *et al.*, 2017). Most of the studies focus on the development of applications to integrate sustainability analysis into design, construction and operation processes. Different management aspects of BIM adoption and sustainability have also been studied, such as economic benefits and organisational adoption barriers. Lean and sustainability are usually two separate and independent concepts targeting to improve economic standards and environmental objectives, respectively. Even though this difference in objectives exists, both share the same goals, mainly towards waste reduction, resource optimisation and process improvement which make them to a significant extent interdependent (Al-Aomar and Weriakat, 2012), therefore, maximising performance and enhancing construction not only in economic aspects, but also in social and environmental terms is of major importance (Abreu *et al.*, 2017). The main advantage of applying lean principles is their ability to identify waste as well as other benefits such as shortened lead times, reduced material waste, quality improvement, reduced carbon emissions and improved value chain which can be accrued by LS integration (Peng and Pheng, 2010). Table 4 shows some examples of Lean and

Sustainability application which illustrate the strong synergy between these two methodologies and hence, their potential for integration

Insert Table 4

5.4 Critical success factors (CSFs) for implementing BLS

The integration of BLS is a complex process whose considerable potential benefits are not easy to accomplish. Thus, identifying critical success factors (CSFs) is an important part of the framework since they give an outlook on the efforts that need to be taken to increase the chance of successful implementation and identify areas for further improvement (Lou and Alshawi, 2009).

Insert Table 5

From Table 5 it could be said that the CSFs deal with human and management aspects rather than technical issues. According to Shub and Stonebraker (2009) these aspects (Human resource management, top management support and leadership, people involvement, teamwork, training and education, as well as culture and communication) are important since they are more regenerative and enduring as competitive advantages. The BLS framework should consider the same CSFs since the three components could be considered as complex management systems, therefore, depending on the type of industry, their CSFs are similar with strong attention on technological components which in this case would be the BIM aspect. However, validation is still required and proposed as a further research suggestion.

5.5 Integrated project delivery (IPD)

A collaborative approach is required for the BLS framework to work such as integrated project delivery (IPD) which is a system that promotes collaboration by aligning incentives and project team goals through shared reward and risk and also promotes early involvement of the parties (Ma *et al.*, 2018). The key is to establish clear contractual relationships as well as well-established project goals and team conformation from the beginning which are important features for IPD success. Other factors for IPD success are clear scope of works, well-defined roles, relationships and responsibilities (Kent and Becerik-Gerber, 2010). Therefore, it is seen that successful integration processes are in accordance with IPD.

5.6 Existing frameworks and models

Different models for integrating the approaches under study in isolation or in pairs have been found in the literature. In total, 16 models and frameworks were studied as shown in Table 6. In order to work properly, the models, frameworks, methodologies need active involvement from the organisation, leadership, people involvement and a certain maturity level regarding the BIM, lean and sustainability areas. Abreu *et al.* (2017) found that lean-sustainability (LS) models applied to the CI are still missing in the literature and that there are few models integrating these two principles published from 2012 onwards and certainly none of those were related to the CI The ones that indeed are related to the CI had waste reduction as their main priority. The aim of the models found in the review was to improve productivity in their respective areas whilst reducing the impacts of their activities to the environment. In general, by integrating sustainable practices with lean principles is an approach which will yield a

greener industry. Finally, it is established that the field of study is emerging due to the strong relationship between lean principles and sustainability, demanding an integrated approach. BS frameworks are mostly related to environmental analysis, BL models are emerging, but it was difficult to find papers from 2010 onwards analysing BIM other than the interactions described in previous sections.

Insert Table 6

5.7 Impacts of BLS on project performance

The interactions explained in previous sections show the strong synergies between BLS which on their own improve the performance of construction projects but with different emphasis depending at what stage of project life cycle they are applied.

Insert Table 7

BIM can be used throughout the entire project life cycle, in the planning stage, BIM allows potential reduction of waste and re-planning (Gibbs *et al.*, 2015); design by improving coordination among project participants (Singh *et al.*, 2011). The construction stage by forecasting project cost and schedule, reducing errors and omissions and improving productivity (Wang *et al.*, 2014); Operations and maintenance stage by using a virtual environment to provide regular maintenance (Chong *et al.*, 2014) and refurbishment and demolition by supporting the appropriate method for refurbishment and demolition (Yun *et al.*, 2014). However, it is currently mostly used in the design stage of projects with less emphasis on later stages (Eadie *et al.*, 2013a). Sustainability approaches are generally

focused on the design and operation project stages, whereas lean principles are focused typically on the construction stage (Kurdve *et al.*, 2015). By bringing them together in a unified system, the focus of improvement would be the entire project life cycle as a whole which would be the main advantage of combining them.

The use of materials is directly correlated with sustainability in the environmental dimension by simulating testing of materials in a 3D BIM environment tools are also used to perform energy simulation analysis such as heating conditions, ventilation, air conditioning and lighting. BIM, lean and sustainability have different tools that improve how construction projects are delivered. Table 8 shows a list of tools that contribute towards performance improvements. These tools are also a part of the proposed framework shown in figure 5. Tools and techniques nearly always require extra investment to implement and maintain them properly. Therefore, it is necessary that this return of effort is reflected in every dimension.

Insert Table 8

It is seen that each driver in isolation brings performance improvements which in an integrated approach would yield better project outcomes as proposed in the BLS theoretical framework. There are similarities in performance improvement from the drivers which suggest that integrating them does not result in conflicts from a performance improvement point of view. Current needs in terms of efficiency in the processes and environment make it necessary to adopt more productive and efficient systems to tackle the challenges the industry faces. The way these three drivers are seen is in terms of innovation in production (lean principles), product representation (BIM) and product requirements (sustainability)

which promote collaboration. Therefore, by integrating and implementing them, combined benefits will be obtained and most importantly, the performance for the construction industry would improve as well as the quality of the constructed facilities, bringing benefits to both stakeholders and society.

6. Research gaps

Despite the importance of BIM, lean and sustainability for the CI there is currently no published research on how the integration would benefit performance in projects. This paper is part of ongoing research where the framework has been established from the available literature, therefore the next logical step is validation. One of the main gaps is that every aspect of performance was researched individually. There have been improvements by applying BLS in projects as shown in the review but integrating management systems such as the ones proposed poses difficulties and complexities therefore, there is still an unknown outcome which is yet to be obtained.

Another gap is the lack of models and frameworks to compare the proposed BLS framework against. For example, in the sustainability model and frameworks are usually related to energy, neglecting the social aspect, therefore, there is no balance among the sustainability components, emphasising one over the others. The BL based models and frameworks are applied to specific contexts and scenarios and may not be applicable across different processes and project stages; thus, a more general view is still missing. In this sense, systematic frameworks and methodologies are needed which can be applied to real scenarios for validation and applicability assessment. This way, their constant feedback and improvement will be ensured. Most of the frameworks encountered are developed for

specific purposes and their applicability is under those circumstances. Developing a validated integrated model is desirable.

It is suggested that the validation and application process is performed within the small organisations context since they are of utmost importance in the global economy, contributing to economic growth, employment and innovation. Furthermore, the challenge for those type of organisations is to comply with the industry requirements where BLS could play an important role to achieve success. The BIM, lean, sustainability adoption in isolation for small organisations is a major challenge, let alone in an integration manner mainly due to the different factors to be considered such as high cost and lack of reported benefits. It is important as well to promote integration at a stakeholder level which, from the review, is one of the most important aspects to consider when implementing new practices. Achieving a successful BLS integration and implementation is part of a successful social change within the industry, however, results showed a lack of social integration, therefore there is an unexplored area for research which needs a more comprehensive understanding. Finally, BLS integration could also bring negative effects that are yet to be explored.

7. Conclusion

BIM, lean and sustainability are major current trends on its own that are being addressed by the CI and recently it has been proposed that they work better when integrated rather than treated in isolation, however there are no comprehensive frameworks suggesting an integration. The starting point to understand this issue and fill this gap is by suggesting an integrated framework based on theoretical elements analysing different variables. A literature review of 215 journal papers published from 2000-2018 was carried out, and the

results show that in terms of the interactions between BIM and lean the main focus is on waste reduction, between BIM and sustainability are the solutions focused on improving specific environmental aspects such as energy and lighting and between lean and sustainability the focus was on improving environmental aspects by reducing waste. Coordination, collaboration, training, early involvement, commitment, qualified staff and organisation culture were the shared critical success factors between BIM, lean and sustainability. Existing studies on BLS integration only accounted for a 2% out of the total papers reviewed. Finally, in terms of performance improvements the BLS components have great opportunities to improve individual KPIs but in an integrated manner BLS only share a few in theory. The limitation of this study is that the framework presented in this research was proposed as a conceptual integrated model which requires validation. To do so, a small sized enterprises approach is suggested. In this era where requirements such as BIM plans and sustainability goals are making organisations consider new ways of working to adapt to the evolving nature of the industry and the difficulties and challenges presented, this extra pressure to fulfil those requirements makes the adoption of a BLS framework a totally plausible scenario.

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Figure

List of figures.

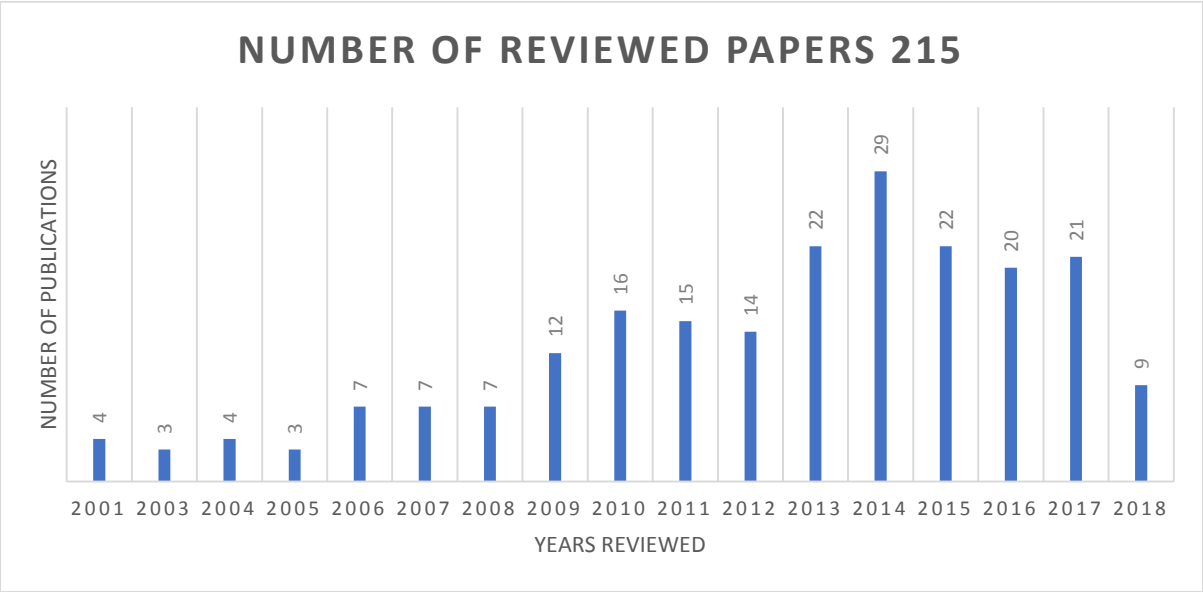

Figure 1: Number of reviewed papers

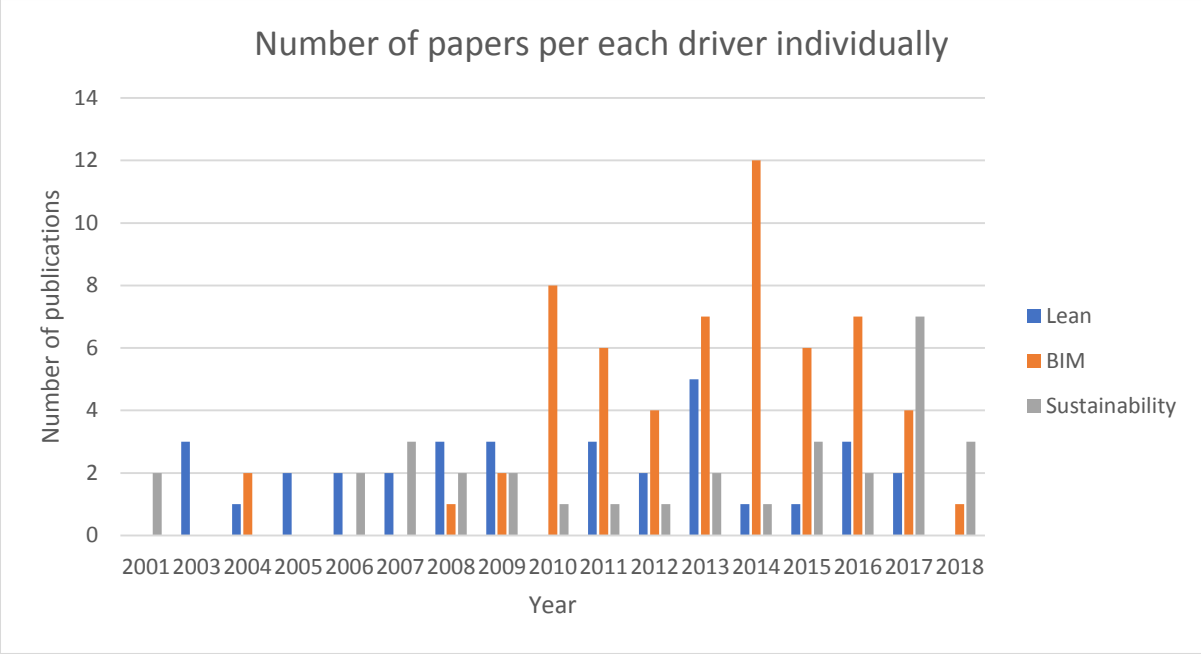

Figure 2: Number of papers per each driver individually

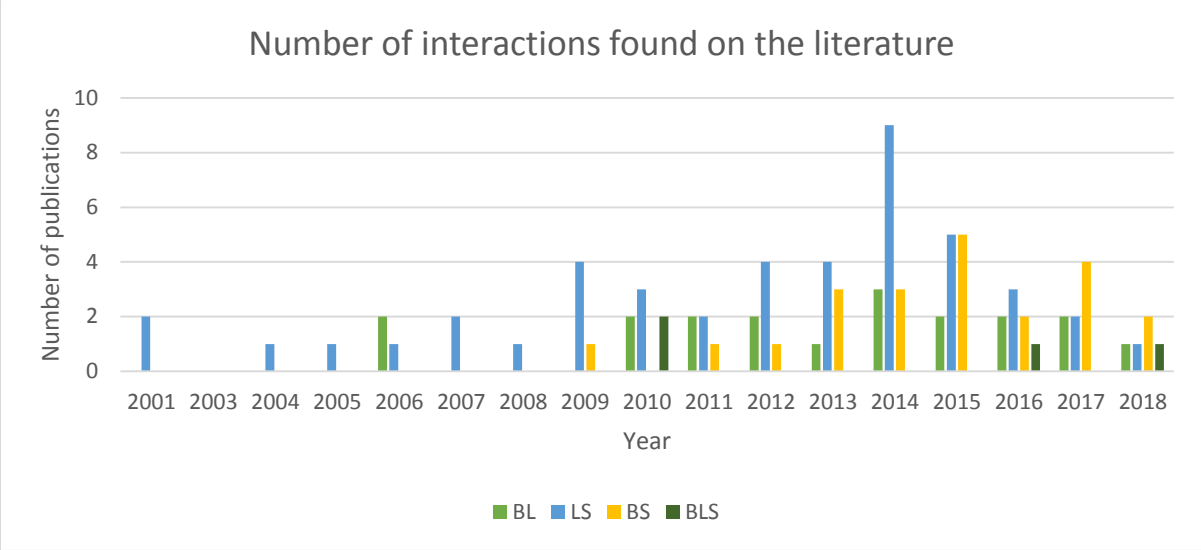

Figure 3: Number of interactions found on the literature

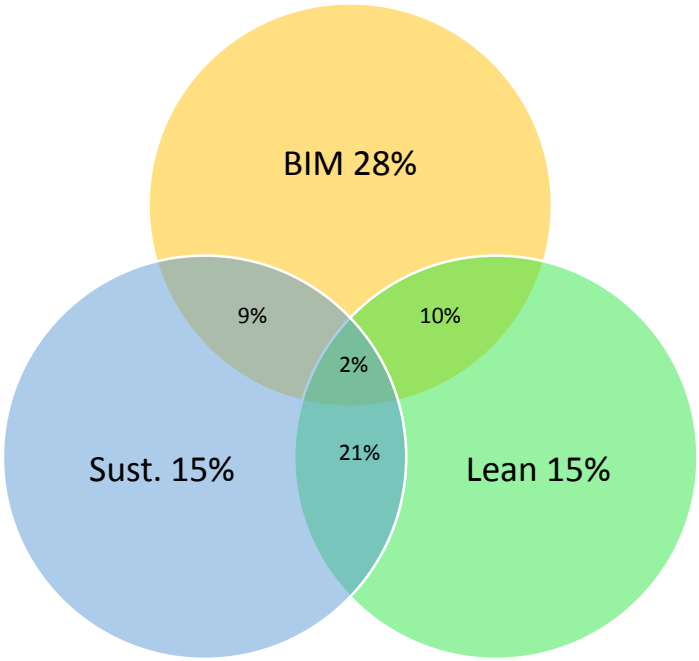

Figure 4: Percentage of research synergies

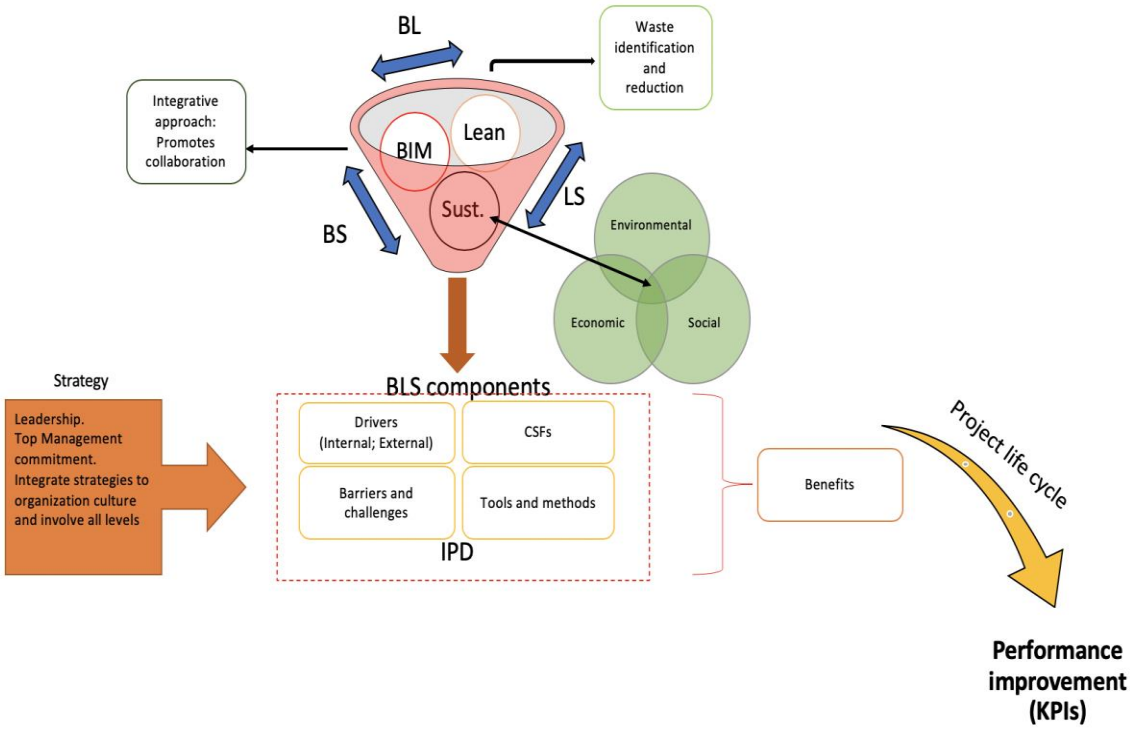

Figure 5: BLS theoretical framework and its components

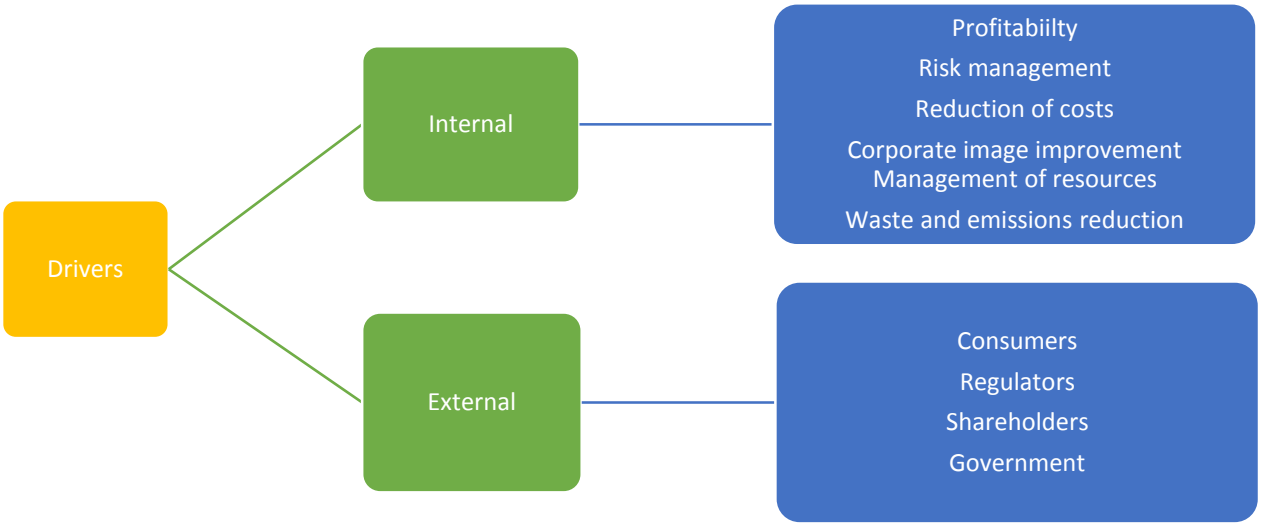

Figure 6: Integration drivers

BIM	Lean	Sustainability
• Interoperability • Lack of skills/experience • Low return of investment • Lack of knowledge from within organisations • Lack of client demand • Resistance to change • Cost of investment • Lack of extra project finance to fund BIM • Unwillingness to share information • Projects that have used BIM not having shown immediate benefits • Legal aspects regarding model ownership	• Structural and cultural barriers • Lack of adequate Lean awareness and understanding • Lack of top management commitment • Cultural and human attitudinal issues	• Lack of environmental awareness • Perception of higher costs • Disconnect between environmental and continuous improvement decisions by organisations

Figure 7: Integration barriers