Identifying uncertainties toward sustainable projects

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Abstract

Building Information Modeling (BIM) is an evolutionary idea designed to ensure performance is evaluated continuously over the whole life of a given asset. Over the last decade significant emphasis has been placed on the design and management of construction projects by using the 7 layers, or dimensions (D), of BIM (3D Modeling, 4D Time, 5D Cost, 6D Procurement and 7D Sustainability). Moreover, it has been argued that the 7th dimension (7D) that is related to sustainability could impact the other six dimensions of the BIM concept. Sustainability indicates the relationship between economic, social and environmental considerations. The relative sustainability of any building will in part be dependent on the nature of these three considerations over its whole life. However, economic, social and environmental characteristics are likely to be subject to change over time, the precise nature of which cannot be predicted. Consequently, any such changes can introduce vulnerabilities in terms of performance. Hence, the hypothesis of this research is that the pre-identification of economic, social or environmental uncertainties within a BIM platform could help reduce performance vulnerabilities during the project management life cycle. This necessarily includes consideration of the post-occupancy phase. Therefore this study aims to explore uncertainties within the 7D of BIM that could influence and impact the other six dimensions of BIM and vice versa. The study uses secondary data to establish which social, economic and environmental data have to be mined using advanced techniques and technologies to identify key uncertainties that could help project stakeholders to make early, efficient decisions. In other words, project stakeholders could pre-identify those uncertainties in order to avoid vulnerable results during the project management life cycle (from the design phase to the post-occupancy phase) during the application of BIM philosophies.

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1. Introduction

The need to reduce the gap between design intent and in use performance in the built environment, thereby delivering the required whole life performance, is widely recognised. Building Information Modeling (BIM) is an approach designed to address this issue by ensuring performance is evaluated continuously over the whole life of a given asset. BIM comprises 7 dimensions: enhanced design drawing details (3D), delivery time (4D), cost (5D), procurement strategy (6D) and sustainability (7D). Successful examples of the implementation of BIM can be seen in the USA and many European countries. Moreover, the UK Government obliges contractors to use BIM from 2016 onwards for projects with a value of more than £50K, and a European directive officially requires public procurement to use BIM (volume 57, 2014). The biggest challenge in the implementation of BIM is the need to ensure it actually helps deliver built assets that perform effectively with minimum impact over their whole life. The sustainability analysis in the 7th dimension of BIM should be at the heart of any such evaluation. However, traditional approaches adopt a very static perspective whereby the prevailing economic, technical, social and climatic conditions remain constant over the asset lifetime. In reality these conditions are likely to change in ways that are uncertain and difficult to predict. Such uncertainties can have a significant impact on whole life performance and relative sustainability and therefore should be included systematically as part of assessment. For example, UK climate projections suggest some building types might overheat in the future, thereby increasing the cooling load and raising economic and environmental concerns. They also have the potential to affect decisions made at different phases of construction which in turn could impact other stages of the BIM process. For example, the need to adapt to a particular climate condition might favour certain construction types with the concomitant impact on delivery time, cost and procurement (4D, 5D and 6D above). While much emphasis is currently placed on the development of a global BIM standard, the analysis of uncertainties within the 7th dimension does not form part of its scope. This potentially significant omission raises the risk of BIM solutions not delivering built assets that perform effectively over their whole life. Therefore this study aims to explore uncertainties within the 7D of BIM that could influence and impact the other six dimensions of BIM and vice versa.

2. 7D in Building Information Modeling

“Project information” refers to the universe of models, drawings, emails, markups, submittals, transmittals, meeting minutes, images, contracts, specifications, change orders and other documentation created in the course of designing, building and operating large facilities including constraints, surveys imposed restrictions. In order to measure building performance, data need to be gathered so as to simulate how the final product will perform. This process will show how the building will perform under certain conditions where economic, social and environmental characteristics are likely to be subject to change over time, the precise nature of which cannot be predicted. Hence, 7D in Building Information Modeling (BIM) could help to reduce performance vulnerabilities during the whole life cycle of an asset, including the post-occupancy process.

Inevitable Building Information Modeling (BIM) is an evolutionary idea [5] to maintain project performance at a high level [10]. However, this concept does not justify clearly from where data will be retrieved/collected in order to ensure the design and development of sustainable projects as stated in the 2050 United Kingdom green strategy report.

Sustainability is defined as a function of social, economic, technological and ecological constraints [8]. On the contrary Cato indicates the relationship between the "three pillars of sustainability", which are economy, society and environment, where the first two are constrained by environmental limits [2]. Paradoxically, project design, development and viability are also affected by the above factors. Consequently, in order for BIM to become a revolutionary idea in Architecture, Engineering and Construction (AEC) clients are required to meet sustainability requirements. This will assist project stakeholders to meet the 2050 UK Government Target, including the real philosophical meaning of BIM within the contemporary management of construction projects.

Therefore, by collecting and analysing primary data from the economy (micro and macro level), environment, politics and cultures, the design project process will occur in a more protective environment. Henceforth, the mind-
set and attitude of stakeholders will be changed and their behaviour will become more proactive and reactive. In particular, this data will be related to pre-identifying any uncertainties and assumptions, including implications that could put the project at risk. Moreover, the identification of these uncertainties will be during the project life cycle (from design to handover stage), during the building life cycle (virtual post-occupancy and physical post-occupancy) and disposal of the asset [6],[7]. In order for this to be achieved the design and development of integrated collaborative environments and their technologies (7D BIM) will give the competitive advantage to stakeholders to foresee any sustainable uncertainty, to measure quantitatively the degree of influence and to identify the implications of these uncertainties on project performance [9]. The 7D of BIM provisionally seems to be the most important element due to the capacity of influencing a number of unknown uncertainties that could make a project vulnerable in terms of design (3D), Time (4D), Cost (5D) and Procurement (6D). Hence, identification of factors that could impact on the design process is required.

According to James the factors fall under three sustainable pillars [8]. The economic domain is defined as the practices and meanings associated with the production, use, and management of resources, where the concept of ‘resources’ is used in the broadest sense of that word. The political is defined as the practices and meanings associated with basic issues of social power, such as organization, authorization, legitimation and regulation. The ecological domain is defined as the practices and meanings that occur across the intersection between the social and the natural realms, focusing on the important dimension of human engagement with and within nature, but also including the built-environment.

In order to review aforementioned factors researchers choose those that impact on project performance considering the Key Performance Indicators published by the United Kingdom Government (2013): time, cost, quality, health safety and environment, business performance, change orientation and client satisfaction [10]. The factors that meet the above requirements are: Production and resourcing (PR), Exchange and transfer (ET), Technology and infrastructure (TI), Organization and governance (OG), Law and justice (LJ), Enquiry and learning (EL), Materials and energy (ME), Built-form and transport (BT) and Emission and Waste (EW). Considering the aim of this paper the methodology is initially to identify key factors of sustainability within a BIM platform followed by a critical analysis of the vulnerabilities in project performance. The limitation of this study is that no validation has been taken at this stage.

Identification of further factors, unknown external factors or uncertainties that could impact project building performance in a Building Environment (BIM) environment is required. The factors could influence both the project and business strategy. Therefore, the PESTLE framework will be applied within the management of construction projects to scan and identify macro factors that could impact and influence project cycles (conceptual design/detailed design, construction and dispose off) [11]. PESTLE acronym stands for Political, Economic, Social, Technological, Legislation and Environment framework and will be used to group uncertainties within the economic, social and environmental factors of the sustainability dimension (7D) and to understand their vulnerabilities within a BIM environment.

3. Uncertainties in 7D

This section aim to group uncertainties on the basis of the PESTLE model. Moreover considering PESTLE framework and sustainability factors regardless then set of hypotheses has been drawn. At the end each group of uncertainty a discussion of potential impact and influences on the design of 3D 4D, 5D and 6D in a BIM Environment has been conducted.

3.1. Uncertainties that arise in economic factors

A political environment consists of factors or uncertainties as defined in this project that could affect businesses in areas such as: tax policy, labour law, environmental law, trade restrictions and political stability [3]. Further to this are the quality of services/products that a government offers to residents and businesses which influence the design and development on the health, education and infrastructure of a nation. Therefore, in order to be able to design and apply innovative solutions in a project, combining prosperity and resilience of an area would be advantageous. This will motivate local communities to be involved in the design (3D) of local construction projects where they can
comment on design preference or project needs/requirements or actively participate in artwork additions and on the actual design process. Social problems could engage local government to act accordingly, and hence design drawing details (3D) could be affected too. Moreover it would be useful, if not mandatory (in some councils contractors need to use local resources), to utilise human and physical resources. This could drive toward three directions: a) enhancing local economy and prosperity; b) using local physical resources; and c) engaging and motivating local community. Furthermore use of local manufactures and fabrication would allow for prevention and elimination of relevant costs (5D), such as product transportation and storage. This could be visualised on an integrated system where governors and stakeholders could make a decision as to which product(s) would be used for a certain part of the asset, as well as seeing further environmental perspectives that could affect the order, design, production and delivery process (5D).

Moreover, inflation rate, interest rates, general taxation, international trade and efficiency of financial markets are among key economic uncertainties that could impact and influence the design of 3D, 4D, 5D and 6D in a BIM Environment [3]. This phenomenon influences the quantification of objects (5D) of a BIM model. The situation of an economy reflects on how exchange and transfer will be operated, while a non-stable cash flow, for instance, from a client perspective, will impact on how the project will operate and hence time of key milestones/programmes (4D) cannot be reached as agreed (6D). This could be a breach, depending on the contract and constraint that the client sets on ITT, Volume 2 and works. In addition, the lack of provision of accurate information between departments would cause a project to be inoperational, with the danger of either stopping a project or causing certain delays that could affect its actual construction, which can be presented in 3D.

From a social perspective demographic details, employee education, culture and attitudes; ethical issues and branding could reflect the design of a project [3]. Primarily, from an architectural perspective, where end users will be citizens or residents of a society, drawing details (3D) and product (6D) specifications can be affected in a (3D). Moreover labour rates, education, culture and attitudes could map on the qualities where an employee will be recruited. This will support the identification of budget costs (5D) and hence orders (6D) will be gathered based on employees’ capacity to apply each construction and building technology or product or service regardless. Furthermore, social uncertainties could be gathered and predicted by enhancing society’s knowledge and understanding of the value of the asset in the community’s sustainability.

Recent technological developments; technology and cost and process optimisation; data and information analysis; technology access and intellectual properties are among the key technological uncertainties presented [3]. Moreover, this reflects design, process, access and evaluation of production and resources for a project (6D). Hence, changes in products costs (5D) will incur that clients or contractors are not willing to pay for. Therefore, the pre-identification of which technologies - including alternative solutions – should be used could help the prevention of the future of unknown costs of a product (5D and 6D) including delivery and availability options (4D). This rationale will allow dynamic interventions in the design process (3D) of a project. In addition, technological uncertainties will not help manufacturers to meet government’s requirements in terms of product details (6D). This reflects the supply chain and procurement process (6D).

Legislative uncertainties are hidden notably in corporate law, contract and procurement law, design standards codes, codes of practise, design manuals, eurocode, tax law and import–export law [3]. The biggest threat for a business is to face constant changes in legislation, which could drive the business and the project towards the inability to comply with the relevant regulations. In a 3D environment the project team could identify and foresee technical vulnerabilities that could cause further problems in project execution. This cost (5D) would be converted in project programme delays (4D) and that could lead to increased costs (5D). This occurs due to lack of access to correct information or insufficiently capable employees that could contribute to project delivery. Moreover, changes in tax could reflect final product prices and therefore it would be impossible to estimate project costs (5D) “accurately”. Henceforth, monitoring and reflections between stakeholders would allow for constructive feedback.

Environmental uncertainties arise in production and resources based on the principle of reducing CO₂ emissions and carbon footprint [3]. Moreover, whether a building product or goods as products are designed, team stakeholders need to evaluate whole life cycle performance in terms of CO₂ emissions generation in the environment
or not (7D). In addition to this, the project team, with assistance from key project stakeholders, needs to create an environment that can test safety assessments to ascertain whether or not these products meet the above requirements. In addition, certain construction and building software programmes have been developed to assess the impact of a product (environmental chamber) or the building (IES virtual environment), excluding the financial impact (5D). Moreover, any inefficiency in conducting these exercises (3D) could lead to project delays (4D).

3.2. Uncertainties that arise in social factors

A political environment consists of factors or uncertainties as defined in this project that could affect businesses in areas such as: tax policy, labour law, environmental law, trade restrictions and political stability [3]. Therefore, where bureaucracy is involved this could cause task delivery delays (4D) which could be translate to a relevant cost (5D). Moreover if planning permission requires further changes in a model (3D) and relevant is application not submitted on time for review by the relevant governmental organisation, drawing changes will be required (3D). These changes may not be cost effective for the client (5D) and hence the need to make changes to an order could be a consequence (6D). In addition storage, access and analysis of project data between stakeholders could cause conflicts. Conflicts are a phenomenon that is observed within a project due to the involvement of opposing parties that have different targets (business level). These conflicts could happen at any stage of the project management life cycle and could halt project progress. Moreover implications could result at any stage of the whole life cycle performance due to arguments between stakeholders. Therefore collaboration is required where a BIM environment could help in the development of the appropriate attitude between team members. Furthermore, the design and execution of construction projects could be affected by political uncertainties, such as change of terms and conditions, actions, type of contracts that could cause certain delays to projects (4D) and costs (5D). Consequently procurement strategy (6D) will not be able to be executed.

Economic uncertainties arising in organisations and governance could be related to transparency and administration [3]. For instance, in the case where a government is moving to budget cuts this could be an indicator for contractors to submit competitive offers (5D). Hence, this could cause schedule changes (4D) and changes in drawing details (3D). Furthermore data security is an element that could primarily cause changes in the design of drawings (copyrights) and their sharing among team members (if stolen then privacy conditions are broken and project details will be in non-owners’ hands). A country’s economic execution plan could cause changes in tax levels. This impacts on final product prices (5D) and hence the contract (6D) will be affected too.

Social uncertainties such as demographic details; employees education, culture and attitudes; ethical issues and branding could reflect on the design of a project accordingly [3]. Moreover, knowing the educational levels of residents will help the client to have a better understanding of the type of projects required. If this is not clear the architect will not meet the client’s expectations. Branding uncertainties would influence what products should be purchased and what strategy is to be developed (6D). The first and the second example are more than enough to cause further delays (4D) in project commencement as long as the project work information (brief) cannot be prepared. If Works Information and or design/drawing are not clear, then deficiencies will be caused in terms of the delivery of the task (4D) and consequently the project (5D).

Recent technological developments; technology and cost and process optimisation; data and information analysis; technology access and intellectual properties are among the key technological uncertainties presented [3]. These uncertainties could influence the administration and bureaucracy process as well as transparency of the procedures. Where those uncertainties occur, it would be difficult to visualise and map them in an organisational and project environment. Moreover, the lack of presenting and visualising key organisational and governance activities will cause project design (3D) deficiencies. Therefore, if team members cannot understand how an organisation operates, with lack of access and analysis of project information and lack of privacy and sharing of project information, then it will be extremely difficult to pre–identify project requirements, including delivery time (4D), project cost (5D) and procurement strategy (6D). Furthermore, with a lack of understanding of how technological uncertainties impact on supporting accuracy and transparency, the BIM environment and philosophy cannot inspire project stakeholders.

Legislative uncertainties are hidden, notably in corporate law, contract and procurement law, structural eurocode,
tax law and import–export law. These uncertainties could impact in defining budgeting (5D) and delivery time (4D) accordingly [3]. Furthermore, continuous changes in planning regulations and contracts could cause problems in designing and drawing details. Moreover the lack of compliance with legislation uncertainties will block data and information flow in the project and hence the BIM environment cannot be sustained as initially planned.

**Environmental** uncertainties arise in organisation and governance based on the principle of reducing CO₂ emissions and carbon footprint [3]. Environmental law and environmental data need to be taken into consideration by the architect and the client, as well as the contractor. If this is not happening then the likelihood of financial penalties (5D) is high due to not applying relevant regulation(s). Furthermore, these product details cannot be drawn (3D) and hence order requirements (6D) will not be accurate. Therefore, it will be more difficult to cost these uncertainties (5D) to the client. Moreover, lack of providing access and data analysis to contractors may cause deficiencies in project execution, having a detrimental effect on the contractor’s reputation.

### 3.3. Uncertainties that arise in environmental factors

A **political** environment consists of factors or uncertainties as defined in this project that could affect businesses in areas such as: tax policy, labour law, environmental law, trade restrictions and political stability [3]. According to low carbon regulations, countries need to comply with the related environmental law with action on reducing CO₂. The main principle of the political uncertainties in materials and energy; emission and waste and built form and transport is to oblige contractors to comply with the above requirements. Moreover, the first implication of non-appliance of the aforementioned regulations is to request more changes in drawing details (3D) and hence more time (4D) spent, which will translate into a cost (5D). Furthermore, building performance in terms of environmental factors cannot be simulated and hence, imperfect building performance will be presented.

Moreover inflation rate, interest rates, general taxation, international trade and efficiency of financial markets are among key **economic** uncertainties that could impact and influence the design of 3D, 4D, 5D and 6D in a BIM Environment [3]. Economic uncertainties in the price of materials and energy could impact on products used in the actual construction product orders (6D) and costs (5D). Moreover architectural drawing (3D) details will be affected accordingly as long end users will not be able to visualise whether product materials are fit for purpose, including access to relevant costs (5D).

**Social** uncertainties such as demographic details; employee education, culture and attitudes; ethical issues and branding could reflect the design of a project [3]. Materials and energy will affect end user behaviour due to the fact of how occupants use the space in order to keep it warm and consume considerable amounts of energy. So in fact, how materials and energy are used supports human wellbeing. Moreover, a better understanding of the neighbourhood makes project stakeholders and architects feel more confident of project requirements, including residents’ inclusion in a live city. This will impact emission and waste accordingly, where if it is not measurable during the 3D process then it will be difficult to calculate end user living costs. Hence, in a few years’ time clients need to take into consideration these calculations and then move toward to refurbish the (non) domestic project. A similar case applies for built–form and transport.

Recent **technological** developments; technology and cost and process optimisation; data and information analysis; technology access and intellectual properties are among the key technological uncertainties presented [3]. If stakeholders do not invest in technologies and data/information analysis then they will not be able to gather more detailed data and simulate them so as to visualise consequences in the short and long term (3D), e.g. materials behaviour in pre and post occupancy; energy consumption; emission and waste usage and built–form and transport access. This inconvenience does not allow stakeholders to prevent relevant costs (5D) via different scenarios. **Legislative** uncertainties are hidden notably in corporate law, contract and procurement law, design manuals, codes of practise, design codes, design standards, national annexes, regulations, national annexes, tax law and import–export law [3]. In particular these uncertainties derive from how a contract or a project is designed and executed (3D and 6D). Within contracts there are terms and conditions that oblige clients and contractors to follow international standards. Where they do not comply with the suggested terms and conditions then they will not be able to design 3D, 4D, 5D and 6D of a BIM environment.
Environmental uncertainties arise in production and resources based on the principle of reducing CO₂ emissions and carbon footprint [3]. Stakeholders need to consider those uncertainties that keep CO₂ emissions and carbon footprint at a high level and thus impact on the design of a BIM environment. In summary the hypotheses are generated considering uncertainties that arise in factors of sustainability and thus impact and influence the design of 3D, 4D, 5D and 6D in a BIM Environment, as illustrated in figure 1.

**ECONOMIC**
- If a Political uncertainties arise in Production and resources (PR), Exchange and transfer (ET), Technology and infrastructure (TI), these could have an impact and influences on the design of 3D, 4D, 5D and 6D in a BIM Environment.
- Economic uncertainties arise in Production and resources (PR), Exchange and transfer (ET), Technology and infrastructure (TI), these could have an impact and influences on the design of 3D, 4D, 5D and 6D in a BIM Environment.
- Social uncertainties arise in Production and resources (PR), Exchange and transfer (ET), Technology and infrastructure (TI), these could have an impact and influences on the design of 3D, 4D, 5D and 6D in a BIM Environment.
- Economic uncertainties arise in Production and resources (PR), Exchange and transfer (ET), Technology and infrastructure (TI), these could have an impact and influences on the design of 3D, 4D, 5D and 6D in a BIM Environment.
- Legislative uncertainties arise in Production and resources (PR), Exchange and transfer (ET), Technology and infrastructure (TI), these could have an impact and influences on the design of 3D, 4D, 5D and 6D in a BIM Environment.
- Environmental uncertainties arise in Production and resources (PR), Exchange and transfer (ET), Technology and infrastructure (TI), these could have an impact and influences on the design of 3D, 4D, 5D and 6D in a BIM Environment.

**SOCIAL**
- Political uncertainties arise in Organization and governance (OG), Communication and critique (CC), Law and justice (LJ), these could have an impact and influences on the design of 3D, 4D, 5D and 6D in a BIM Environment.
- Economic uncertainties arise in Organization and governance (OG), Communication and critique (CC), Law and justice (LJ), these could have an impact and influences on the design of 3D, 4D, 5D and 6D in a BIM Environment.
- Social uncertainties arise in Organization and governance (OG), Communication and critique (CC), Law and justice (LJ), these could have an impact and influences on the design of 3D, 4D, 5D and 6D in a BIM Environment.
- Economic uncertainties arise in Organization and governance (OG), Communication and critique (CC), Law and justice (LJ), these could have an impact and influences on the design of 3D, 4D, 5D and 6D in a BIM Environment.
- Legislative uncertainties arise in Organization and governance (OG), Communication and critique (CC), Law and justice (LJ), these could have an impact and influences on the design of 3D, 4D, 5D and 6D in a BIM Environment.
- Environmental uncertainties arise in Organization and governance (OG), Communication and critique (CC), Law and justice (LJ), these could have an impact and influences on the design of 3D, 4D, 5D and 6D in a BIM Environment.

**ENVIRONMENTAL**
- Political uncertainties arise in Materials and Energy (ME), Emission and waste (EW), Built-form and transport (BT), these could have an impact and influences on the design of 3D, 4D, 5D and 6D in a BIM Environment.
- Economic uncertainties arise in Materials and Energy (ME), Emission and waste (EW), Built-form and transport (BT), these could have an impact and influences on the design of 3D, 4D, 5D and 6D in a BIM Environment.
- Social uncertainties arise in Materials and Energy (ME), Emission and waste (EW), Built-form and transport (BT), these could have an impact and influences on the design of 3D, 4D, 5D and 6D in a BIM Environment.
- Economic uncertainties arise in Materials and Energy (ME), Emission and waste (EW), Built-form and transport (BT), these could have an impact and influences on the design of 3D, 4D, 5D and 6D in a BIM Environment.
- Legislative uncertainties arise in Materials and Energy (ME), Emission and waste (EW), Built-form and transport (BT), these could have an impact and influences on the design of 3D, 4D, 5D and 6D in a BIM Environment.
- Environmental uncertainties arise in Materials and Energy (ME), Emission and waste (EW), Built-form and transport (BT), these could have an impact and influences on the design of 3D, 4D, 5D and 6D in a BIM Environment.

Figure 1: Hypotheses considering uncertainties that arise in factors of sustainability

Uncertainties and factors which could impact and influence on the design of 3D, 4D, 5D and 6D in a BIM Environment are presented in figure 2. Therefore, it appears that there are relationships within the seventh dimension and other six dimensions that could impact and influence on the design of the whole life cycle. The challenge is how to model them in a way that makes sense of these data so stakeholders are influenced and consequently make efficient decisions.

Where abbreviations as bellow:

(PR) Productions and resources
(ET) Exchange and transfer
(TI) Technology and infrastructure

(ME) Materials and Energy
(CC) Communication and critique
(LJ) Law and justice

(EW) Emission and waste
(OG) Organisational and governance
(BT) Built-form and transport
4. Discussion

Considering the above it is clear that environmental, social and economic factors need to be pre-identified, since their inner elements could prevent performance vulnerabilities in the whole life cycle of an asset. Hence it is vital to try to investigate further these uncertainties by developing an integrated and interactive platform where end users could use simulative and gamification technologies to observe their living and working space. This will allow stakeholders to model and map uncertainties by using UML (Unified Modeling Language) and, in association with BIM, to understand explicitly the impact of uncertainties within the whole life cycle of buildings. In order for this to be achieved special mechanisms need to be developed in order to gather, store, analyse and distribute data among project stakeholders.

In particular simulation technologies will help to visualize and assess uncertainties in different conditions; gamification technologies will be used to engage project stakeholders to collaborate and share project data/information so to make efficient design decisions. More details how simulation and gamification technologies will be presented extensively in another paper.

5. Conclusions and further studies

Currently, bespoke solutions have been designed and developed that aim to measure quantitatively the above factors. However, they have yet to be integrated within an “environment” that bridges data and information among social, environment and economic filters. This incapacity prevents stakeholders from identifying uncertainties that could cause reduced vulnerabilities performance during the whole life cycle. Hence, there is a need to reconsider the integration of all three of the aforementioned factors so as to prevent unforeseen uncertainties that could impact key design decisions. Therefore, project risk investments could be reduced significantly and uncertainties that reduce performance vulnerabilities during the Project Management Life Cycle could be prevented. Further studies need to be conducted in order to validate whether the above factors apply to real projects and hence whether an integrated platform could be designed and developed that will incorporate social, economic and environmental factors so as to identify and map uncertainties by using BIM environments and its technologies. This will be the initial stage of changing the way of thinking in project design by engaging end users to be part of the design of their living and working space.

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