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A BIM+Blockchain approach to ensure Transparency in the Strategic Housing Development Planning System

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Abstract – The introduction of the fast-tracking housing regulations in Ireland has modified the dynamics in which democratic participation is deployed in planning decisions. The resulting planning process has favoured inequality phenomena and has strengthened the position of construction lobbies in large-scale developments. This paper enforces citizen engagement in the Strategic Housing Development (SHD) framework using Building Information Modelling (BIM) and blockchain technologies to build digital trust. Digital tools have enormous potential to deliver more transparent planning by establishing proven accountability for building permissions and promoting trusted interactions between citizens and local administrations. This study first describes all the reasoning underpinning the de-democratisation process of Irish planning after introducing SHD regulations. Based on the previous findings, a theory-driven, inductive case study is proposed. The case study offers an integrated framework that combines the improved visualisation properties of BIM with the immutability characters of blockchain. Results indicate that such a methodology successfully addresses the problem of trust and transparency and brings additional intrinsic benefits due to the use of digital solutions in planning.

Keywords – Building Information Modelling (BIM), Blockchain, Planning, Transparency, SHD, Hyperledger Fabric

I INTRODUCTION

Despite the progress made by the Planning and Development Regulations 2001-2020 in clarifying and simplifying the planning procedures, the legislation has not yet completely taken into account the contribution of information technology (Monaghan, 2015). Currently, the application lodgement is characterised by inefficiency and redundancy, requiring multiple hard copies to be posted to the local office and then manually scanned before being uploaded to the relevant Council e-portal. As a result, the administrative process associated with standard planning applications involves cost issues related to the storage of significant amounts of paper and potential risks of losses in the event of a fire (Monaghan, 2015). The current planning process is also perceived to be slow and subject to numerous delays, primarily if requests of information are issued by the PA or in case of appeals to An Bord Pleanála (Lennon & Waldron, 2019). Several studies (Reddy, 2004; Lennon & Waldron, 2019) also agree that inconsistencies and arbitrary interpretations of the planning legislation by the local authorities add additional uncertainties and associated costs for future developments.

For designers, the advent of the fast-tracking legislation has highlighted the importance of providing the right set of information to enable An Board Pleanála to form an opinion around a particular planning decision. In such environment, significant effort is required by designers in the production of detailed drawings ahead of pre-planning meetings. Also, if substantial changes are required to the initial design, this might result in delaying the permission process with serious cost implications (McNally, 2019).

The integration of blockchain solutions with other types of technologies such as BIM is the subject of development and research focus. While the introduction of BIM procedures has emphasised the importance of collaborative processes to create and manage building data, the current practice presents difficulties in assigning liabilities due to the overlapping of roles, guaranteeing intellectual property protection and third-party dependence. In this context, Blockchain is a possible solution to provide "evidence of trust" (Mathews, et al., 2017) which would create value for the AECOO industry and overcome many legal complications that occur in the current BIM practice.

II LITERATURE REVIEW

a) Planning

This section will give a summary of the Irish Planning system and is particularly focused on the dynamics which underlay the recent “Fast-Track” planning process after its introduction by the “Planning and Development (Housing) and Residential Tenancies Act” (2016).

The Planning system in Ireland operates at local, regional and national level. At the highest level, the National Planning Framework and National Development Plan (2018-2027) are merged to form Project Ireland 2040, which supports the government’s long-term strategy under the planning and infrastructural perspective (Williams & Nedović-Budić, 2020). At regional level, there are three Regional Assemblies accountable for the preparation of the Regional Spatial and Economic Strategies (RSES) which prioritise investments to promote the strategic growth of the region, ensuring compliance with EU guidelines and local development plans (Williams & Varghese, 2019). At a local scale, Development Plans represent the primary documents to deliver planning by the local authorities. These policies last for six years and describe between a set of maps and written statements how the local municipality intends to use certain areas along with their development objectives. Development Plans are often accompanied by a significant political debate, and, in most cases, a certain number of amendments are ratified due to public consultation.

The Irish Planning system presents two unique features: the establishment of an independent planning appeal board (An Bord Pleanála) and the possibility of public appeal to a decision issued by the local planning authority. As consequence of this configuration, the right to build and develop is formalised with the grant of a planning permission after the submission of an application to the appropriate City or County Council. The application, to be successful, needs to be assessed against the national planning principles and the appropriate local authority development plan (Lennon & Waldron, 2019). In particular, the Planning and Developments Regulations (2001-2020) establish the steps that must be taken when filing an application or appealing to An Bord Pleanála and the types of exempted developments.

In 2017 the housing crisis resulted in the development of a new “Fast Track” planning procedure, with the attempt to prioritise large student and housing developments (Lennon, 2019). This protocol was introduced by the Planning and Development (Housing) and Residential Tenancies Act 2016 and is also known as Strategic Housing Development (SHD). The SHD is used to streamline housing developments of more than 100 dwellings and student accommodation of 200 or more bed spaces. The relative applications could be lodged for consideration directly with An Board Pleanála with a three stage process (McCarthy, 2018). Initially the prospective applicant is required to initiate a consultation period with the Local Planning Authority; at this stage a meeting is held within four weeks after the date of request and the prospective applicant is required to provide all the appropriate information two weeks prior to the pre-planning meeting for the attention of the PA. The second stage consists of a 9 weeks pre-application consultation period with An Board Pleanála, at the end of which the Board will form an opinion whether the documents submitted constitute a reasonable basis for an application or require further consideration and amendment. During the third and last stage the planning application is submitted to the Board and a decision is to be made within 16 weeks. This could result in a decision being taken within 25 weeks of the process’s commencement. As result, for the first time in Irish Planning history, a decision is guaranteed within a well-defined time limit (McCarthy, 2018). Figure 1 covers in detail the current SHD process including time frames and actions required by the main parties.

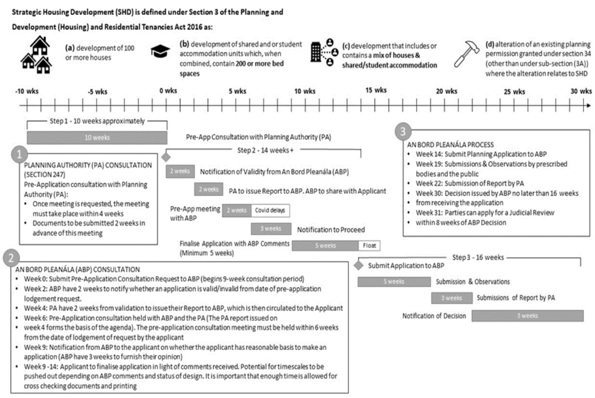

Fig. 1: SHD Planning Framework (Mitchell McDermott, 2021)

However, this approach has been subject to criticism in relation to the reduction of the local authorities’ power stemming from to the centralisation of the planning system and the absence of third-party appeals as a decision-making instrument (Williams & Nedović-Budić, 2020). With third-party appeals, stakeholders can claim protection of property rights but under the new system there is no possibility to appeal a decision being made by An Board Pleanála afterwards. This can be seen as a first degree of de-democratisation of the Irish planning system by putting the interests of developers ahead of public participation (Lennon & Waldron, 2019). Also, under the “fast track” scheme the large residential and student developments are assessed at national level in place of local planning authorities with the result of boosting a process of centralisation that prioritises a certain type of development deemed to be of highly-strategic importance for the economic growth of the nation (Lennon, 2019). According to Lennon & Waldron (2019), this mechanism further reduces public participation in the planning system because it effectively removes the importance of city and county development plans and bypasses a full assessment of an application by the local planners. In this perspective, the local development plans, which represent the democratic expression of a local municipality's intent for land use, are weakened by policies introduced by national politicians rather than local elected representatives. Moreover, An Board Pleanála being an independent body, the decisions under the SHD system are unaccountable to any type of electorate, making the system vulnerable to lobbying, political interferences and corruption (Lennon & Waldron, 2019).

b) Building Information Modelling

In circumstances similar to the fast-track process, where meetings create commitment to quick and irreversible decisions, it is essential to have effective visualisation and decision-making instruments at one's disposal. Kim, et al. (2015) highlighted that in the current practice there is a lack of an integrated method to evaluate multiple scenarios and metrics as well as an absence of a comprehensive representation of such information. This could result in evaluating fewer scenarios with the associated parameters being assessed only at a few points in time based on a fragmented understanding of the project's deliverables. They assert BIM-based workflows could support planners to make timely and more informed decisions, create different scenarios, assess changes on top of simple metrics and visualise over time the results in a more integrated way. The availability of information that a planning body has at its disposal for supporting a planning decision has brought a degree of transparency that was impossible to obtain with a standard 2D process (McNally, 2019). This will also benefit the democratic participation and in particular the ability of third parties to visualise how developments impact the surrounding landscape and buildings. The availability of information based on a 3D representation will consequently make appeals more informed. Consequently, the improved understanding of project deliverables at building and neighbour level might create a collaborative culture among all the stakeholders.

According to Kim, et al. (2020), the adoption of BIM methodologies will have the immediate effect to automate a significant part of the planning process and speed-up the period for granting of permissions. The time required to respond to changes, issue and review drawings by the designers is significantly reduced with the use of BIM software and workflows, bringing a large degree of automation as well better future proofing for the design (McNally, 2019). It is deemed (Ullah, et al., 2020) that in the long-term, the automatization could make the planning application process cost-effective, saving time and resources for both public administration and designers.

The possibility to run computer-based checks on BIM model submissions is a key component of the automation process. The current research around the possibility to provide e-submissions for planning permission suggests a significant benefit in eliminating human error and arbitrary interpretations of the planning legislation, thus strengthening the planning system's transparency. BIM models could be submitted in a central system administered at County or national level at a defined level of development (Monaghan, 2015). Such models are then assessed automatically with an algorithm against the current planning legislation. Other countries such as Singapore (Plazza, et al., 2019), Norway (Hjelseth, 2015), South Korea (Kim, et al., 2020) have successfully developed an e-submission technology system. In Singapore, the e-PlanCheck function of the CORENET system was developed to perform electronic checks against planning and building codes using automated procedures instead of a paper-based process. At present, nearly all the planning applications in Singapore are submitted using the e-submission system. The checks are performed by building additional intelligence from IFC models submissions (Hjelseth, 2015). In parallel, an integrated platform such as KBIM (Kim, et al., 2020) can also be developed to support the electronic submission module. This platform will be capable to gather non-BIM type of planning information including planning and agreement documents. McNally (2019) suggests that a project dashboard built on top of such a platform could improve the collaboration among the planners and the design team. The submission of BIM models will necessarily require establishing a minimum level of detail (LOD) prior the system is developed (Ullah, et al., 2020) so they could correctly conform to a defined checking standard (Kim, et al., 2020).

However, the implementation of such a solution is obstructed by factors that are not just technological barriers or resistance to change, and that partially justifies the fragmented and delayed adoption of these processes at country level. In the first instance, one of the main obstacles is represented by the planning legislation itself, which is specific to country and regional level and requires a significant amount of work to be converted into code. According to Olsson, et al (2018) the planning code is composed of qualitative, quantitative and visual criteria. Quantitative and visual criteria can be supported by a BIM methodology, respectively, with automatic checks and digital representation of models. The qualitative criterion presents more difficulty as it concerns the adequacy of a building in a broader planning context, thus requiring human participation. Another important factor is the choice of file type for the planning submission. While GIS files are capable of covering large areas, BIM files, including IFC format, are suitable for a local and very detailed approach (Van Berlo, et al., 2013). GIS files do not store all information required by planning codes and BIM files cannot manage geographical type of information (Altıntas & Ilal, 2021). Although their interoperability is very limited, more recent literature (Olsson, et al., 2018) has emphasised the potential of integrating GIS data with BIM to enhance more effective compliance checks.

The employability of such solutions in an international planning context is yet to improve. Literature has shown a significant added value in terms of improved transparency, reduced costs and better decision making. In the Irish framework this can justify government investment into this technology for the SHD system; technical evaluations will determine whether to emulate other countries' planning systems or proceed with Ireland-specific solutions.

c) Blockchain Technology

Since the invention of the Internet, Blockchain has been considered the most impactful technology innovation (Cong, et al., 2017). This technology is essentially a decentralised database that enables new digital possibilities without depending on a third entity to store, verify, transmit and communicate network information across its own distributed nodes (Xu, et al., 2021). In its simplest form, blockchain technology validates a set of transactions using a decentralised peer-to-peer network. Once the transactions are verified, they are combined into blocks. A single block is capable of storing the information associated with each transaction in the form of encrypted data. The preceding block's hash is included in the updated block so each block can be traced back to its parent with a complete history of the changes (Safa, et al., 2019).

Since the introduction of blockchain technology, smart contracts have been one of the most sought-after applications. In a blockchain framework, a smart contract is a novel technology that can autonomously negotiate, fulfil, and enforce the terms of an agreement. Smart contracts, unlike real-world contracts, are entirely digital and contain lines of code that triggers computer protocols. Those protocols could be self-executed and self-verified after being created and implemented without the need for human involvement (Xu, et al., 2021). Due to this characteristic, a smart contract can increase trust among parties, lower transaction risk, operational costs, and maximise business productivity. The development of smart contracts lowers the potential for corruption and fraud in distributing and transferring money. Non-currency types of data can also be stored on the blockchain thanks to the recent adoption of smart contract applications by Ethereum (Buterin, 2014). Moreover, users may accomplish seamless and secure peer-to-peer data sharing without worrying about data leaks or manipulation by establishing access rights through smart contracts. One common misconception (Mason, 2019) about smart contracts is that they are difficult to code and understand. The reality is that users do not have to comprehend how smart contracts operate to use them. Following the example of the most widely used mobile applications, people will just be engaged with foreground functionalities in a user-friendly environment.

For its nature, blockchain is particularly useful in addressing problems related to the centralisation of information, trust, and transparency. With an authorisation system based on blockchain smart contracts, it is possible to allow decentralised and democratised authorisation delegation without relying on a central authority. This can only happen if a trust system is built around the network itself, making the 3rd party facilitators obsolete. According to Nawari & Ravindran (2019), trust derives from the network's capacity to validate data transactions, and it can only be achieved when shared/distributed ledgers handle transaction and ownership. This means that all construction and design activities under the form of "value transactions" are recorded into a ledger, timestamped and via consensus enclosed into a block (Mathews, et al., 2017). These data are accessible to all users and thus become visual evidence of trust. The trust model is consequently altered when new players join the network and implement a new blockchain application.

Safa, et al. (2019) emphasise that blockchain technology is not meant to substitute BIM, but it can be seen as innovating the existing BIM processes. This is reinforced by Mason (2019), who asserts that smart contracts are a "complementary" technology, which might be the key for BIM to succeed. Andersen, et al. (2018), had shown the potential of blockchain in the facility maintenance phase for the safe storing of sensitive sensor data acquired by building operating systems (BOS). In construction payments, it was shown (Ye, et al., 2020) that it is possible to achieve automatic and simple payments during the construction phase by using a combination of BIM model-driven data and smart contracts. Turk & Klinc (2017) Implemented an architecture for managing BIM information in the form of files through a blockchain enhanced BIM server. The idea behind this solution is to store construction files in an unchained scheme. While files are saved in the cloud or a cold server, the associated metadata or the fingerprints is stored in the blockchain. In this way, all stakeholders can retain a copy of the blockchain with the proof of existence of a file at a certain point in time. Dounas, et al. (2021) designed a BIM+Blockchain approach that does not rely on trust to deliver a design project because trust is automatically assigned to an underlying system based on the idea of the DAO (Decentralised Autonomous Organisation). The DAO acts as an entity that sets design problems as a smart contract through the Ethereum blockchain. Through the DAO, any stakeholder can participate in the design optimisation by staking tokens using their own Ethereum address. This approach guarantees a complete record of all design attempts, contributing to a more transparent and efficient design based on cryptographic records. A similar role to the DAO was assigned by Mathews, et al (2017) to Oracles. On this occasion, the consensus mechanism was provided by singular entities who possess specialised knowledge to execute smart contracts.

In the planning context, Nawari & Ravindran (2019) developed a complete BIM+Blockchain workflow based on Smart Contracts and automatic code checking techniques to speed up the permission process in post-disaster recovery. It was demonstrated that principles of decentralisation, privacy and transparency were successfully achieved, leading to significant savings in paperwork and time needed to issue planning permission. In this instance, achieving more trust and transparency was an essential deliverable due to the possibility of malicious individuals taking advantage of the emergency's nature and urgency. The author believes that similar conditions, such as timely and transparent building permit grants, could represent a basic need for the Irish planning to develop BIM+blockchain alternatives.

III RESEARCH METHODOLOGY

This research is conducted as a case study and adheres to the case study research approach according to (Yin, 2013). As opposed to multiple case studies, single cases may permit the creation of more complex theories since single case researchers can adapt their theory perfectly to the many characteristics of a given case (Eisenhardt & Graebner, 2007). Due to the scarcity of theory driving BIM and Blockchain application in planning, an inductive case study technique was employed as it is deemed the most suitable methodology for developing insights around a new subject (Eisenhardt, 1989). Generally, qualitative research methodologies, and inductive case studies, start with extensive observations of the reality. These in-depth observations will be used as the initial point for learning more about blockchain technology and BIM capabilities.

For the construction of this case study and the collection of published data sources, secondary data is used with a multiple-cases and multiple-investigators approach. The data for this study was acquired from public sources, including whitepapers, experts' review reports, blockchain community sites & social media sources and developers websites. These resources enabled the researcher to triangulate findings from various pieces of information to gain a better knowledge of the subject (Yin, 1994) and enhance the validity of the case study (Yin, 2013).

Firstly, a literature review was conducted to offer basic knowledge of the study's conceptual framework and identify existing research gaps. TUD Dublin library, along with Google Scholar, was the primary database utilised to acquire information. The examined literature mainly consisted of peer-reviewed papers to avoid material that may not be accurate, trustworthy or prejudiced.

The second part of this research is an inductive case study. A reference architecture for the planning practice was developed using an approach similar to that described in Grosskurth & Godfrey (2005). Because of the limited adoption of BIM+Blockchain approaches in planning, the proposed conceptual architecture was derived using two reference case studies. The first proposed by Dounas, et al., (2021) presented a public blockchain architecture based on Ethereum platform in order to solve engineering design problems. The second case study, on the contrary, designed a blockchain-based planning system supported in a private blockchain. The analysed case studies were compared to find common traits and differences using observations, logic models and cross-case synthesis (Yin, 2013). Based on the results of the previous phase, an optimal architecture was derived for the planning domain.

IV PROPOSED FRAMEWORK

a) Defining the infrastructure – Hyperledger Fabric

To address the issues of SHD planning in building a more democratic system, this paper proposes an integrative BIM+Blockchain approach. This section will first evaluate the appropriate blockchain for storing planning data and introduce the associated platform that will host the blockchain network.

A blockchain network can be of two types: permissioned or permissionless. Anyone can join and start submitting transactions in a permissionless network (or public network) such as Bitcoin and Ethereum. Most of the market's digital currency is currently powered by permissionless blockchain networks (Zhou, et al., 2019). They enable users to generate unique addresses under wallets and engage with the network by processing transactions and adding data to the ledger. The transactions are verified with mining protocols either by staking tokens as collateral (POS) or by using computational power to solve complicated mathematical problems (POW). Permissioned blockchain networks (or private blockchains) on the other hand, are distinguished by the fact that they need authorisation protocols to enable users to join the network. They are typically employed by centralised organisations such as public authorities, businesses and consortiums. These blockchains are usually more versatile than permissioned ones by giving the participants a significant degree of customisation and privacy (Castro & Giraldo, 2020).

In the construction management framework, while there are arguments (Dounas, et al., 2021) sustaining permission-less blockchain as an instrument to assign trust to the technical system instead to the network members, the tendency is to believe that permissioned types of blockchain are best suited for purpose (Nawari & Ravindran, 2019; Mathews, et al., 2017). A permissioned blockchain is a method of protecting data transfers between members of organizations who share a common purpose but have intellectual property rights that they must safeguard when sharing information between the network. Also, the high degree of confidentiality in the AEC industry requires that only permissioned members are allowed to join the network and exchange data while a strict number of users with specific technical knowledge can trace back or audit transactions. If a permissionless approach was used in a planning framework, experts and non-experts might give equal contributions to the planning process. This might result in eroding the knowledge and decision-making capacity of the experts. These privacy and control access requirements will suggest a permissioned blockchain to be an optimal solution for the planning system.

Between private blockchains, one of the most adopted architecture is the Hyperledger Fabric (Zhou, et al., 2019), and this will be used for the purpose of this research. In particular, Hyperledger Fabric (HLF) is chosen for its properties of scalability, privacy and access control over the planning data, reducing the time to store and share information, improving trust and lowering the overall costs. Hyperledger is a private blockchain initiative of the Linux Foundation. Since its creation, it has become a popular platform attracting the attention of big corporations such as Microsoft and IBM. Among Hyperledger projects, "Fabric" is the most popular. With the first version launched in 2018, HLF presented a permissioned blockchain structure for running smart contracts. It is particularly suited for a group of identified individuals who have common objectives but lack trust in each other. Unlike the execute-order structure, typical of traditional blockchain platforms, Fabric presents an "execute-order-validate" architecture with a pluggable Byzantine-fault tolerant consensus protocol (Manevich, et al., 2021). Under this scheme, the transaction flow is divided into three steps: firstly, a transaction or smart contract executed and endorsed by a subset of peers; the outputs of the execution are then ordered via a customizable consensus protocol by the ordering nodes who group transactions into blocks and broadcast to the validator nodes; transactions are then validated in the third and last phase against a specific system policy and finally added to the ledger.

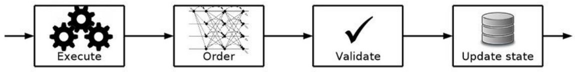

Fig. 2: Execute-order-validate architecture of Fabric (Colyer, 2018)

This transaction flow is usually initiated by a client. In the HLF framework, a client is an application which proposes a transaction over the network on behalf of an individual. The roles that run the system are mainly Peers and Ordering Service. Peers, who can be endorsers or committers, keep track of the network status and retain a copy of the ledger. On the other hand, the ordering service receives approved transactions, organizes them into blocks, and distributes the blocks to the committed peers. As mentioned, there are two different roles for peers: endorser peers simulate and endorse transactions while committer peers validate transaction outcomes before committing to the blockchain. Although this difference, there is an overlapping of roles because the system is designed to make a peer always committer. Other main functionalities that distinguish Hyperledger Fabric from traditional blockchains are:

- Smart Contracts (chaincode): In Hyperledger "chaincodes" are the equivalent of Smart Contracts. They are essential for the network's routine operations, defining how assets are exchanged or manipulated. As per Smart Contract, chaincodes assume the form of computer programs containing certain logic to perform transactions. They are expressed in Go or eventually in Java language.

- Membership Service Provider (MSP): The MSP is the system that provides the rules for validating and authenticating users' identities. This component manages users IDs and grants access to the network by giving credentials to customers to request transactions.

- Channels: Channels enable organisations to share the same network while keeping separate blockchains. Transaction details are visible only to the member of the channel where the transaction was initiated. This is possible because each peer belonging to a given channel can retain multiple ledgers.

The next section will focus on the technical aspects of solving the trust problem in the SHD housing. A case study will be presented implementing the high-level framework described in this section. This example is designed not to revolutionise the current SHD process but to modernise the current practice with a BIM+Blockchain approach. Since the objectives are to speed up and bring more transparency to the fast-track planning legislation, the following structure will be proposed: a BIM model-checking module which will substitute the pre-consultation phase with the local's planning authority and a document management module which will provide proof of trust among the parties in the consultation stage with An Board Pleanála.

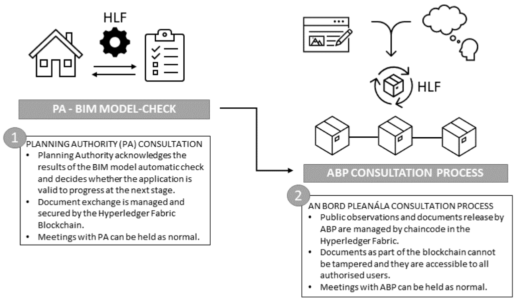

Fig. 3: Model-checking and document management module overview

b) Automatic Model Checking Transaction Flow

As discussed by Nawari & Ravindran (2019) it is possible to achieve a model code-checking compliance by using HLF in a BIM workflow. The idea behind this strategy is to keep both planning code and BIM models "off-chain" and invoke a chaincode capable of acting as a model checker. In order to do this, a smart contract (chaincode) needs to be able to process into computer language the planning rules written as ordinary pieces of legislation. Another study proposed by Nawari (2019) showed that such an approach could be possible by employing a Transformation Reasoning Algorithm (TRA) that transforms standards and regulations into computer language and run code compliance based on BIM models' object extractions via ifcXML. This alghorithm can be written as smart contract, or if all the planning legislation terms are not supported, it can be expressed directly in a scripting language and then be invoked by a chaincode. For simplicity, at the time of the model submission, it is assumed that the planning code is accessible as a scripting language and stored in an off-chain database. The structure of the checking mechanism is presented as follows:

1. The first step consists in storing the BIM model data off-chain. This will allow the invoked chaincode to access read/write key-value pairs in the dataset and perform the function of code-checking in the following phase. The BIM model is exported into a ifcXML by the client's application and distributed into the authorised peers' side storage via gossip data dissemination protocol. The hash of the file could be retained in the main ledger as non-tampering proof.

2. A model checker in the form of a smart contract is invoked with a transaction in the HLF. The model data are then verified against the translated rules, and a report is generated with an appended smart contract to notify the client of the results. two models use a similar approach following the Hyperledger Fabric blockchain transaction flow and can be implemented independently from one another based on the exigencies of the planning network or due to technological barriers.

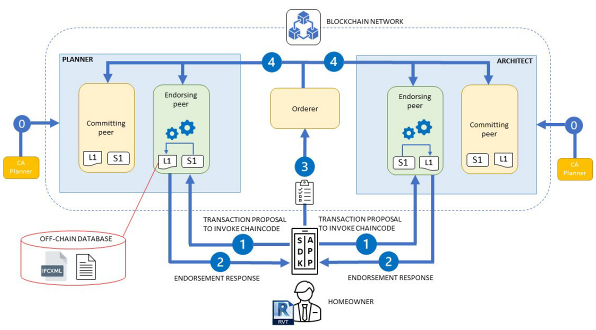

Fig. 4: Model-checking typical transaction flow

In the HLF planning network, such transaction flow will follow this structure:

1. The homeowner or architect is sending a request to the planning authority under the SHD housing scheme. This request includes a BIM model as part of the pre-checking stage previously described. The request is processed by the Software Development Kit and translated in a proper format to create a data exchange proposal. Essentially this proposal consists of a request to invoke a smart contract that will read/write key-value pairs in the ledger. A digital signature is generated using the cryptographic credentials of the user. This part corresponds to number (1) in the Figure above.

2. In part (2), the endorsing peers verify that the proposal is well formulated, it was not previously submitted and that the client's signature is correct by checking the certificate authority (CA) previously released by the MSP. Then the nodes simulate the transaction by running the invoked chaincode, which reads the key-values associated with the BIM model and planning legislation. Note that there are no updates to the ledger at this stage.

3. The peers' response arrives to the application (3). The response includes the data read results and the peers' signature. At this point, a chaincode present in the application, previously encrypted and discretised into blocks, performs the functions of code-checking. Since this program could consist of several chaincodes it is executed by a separate code-checking service application and expressed in C# or Java. Finally, the model's key-values are checked against the translated planning rules, producing code-compliance results.

4. The checking results are passed to the ordering service that validates transactions, group them into blocks, and (4) transmit blocks to all network peers. The blocks will be appended to all nodes of the planning network, and an event is invoked from the application to notify the client that results are available.

This approach should provide a record of every code-checking transaction that happens in the planning network. Also, the computational mechanism is designed to perform as many operations as possible off-chain, leaving only the transactions metadata stored in the primary ledger. This ensures a fast and reliable code-checking performance with the advantages of discretisation and privacy offered by a blockchain methodology.

c) Automatic code compliance checking (ACCC)

Achieving automatic code compliance checks is a crucial requirement to ensure that the principles of cost-effectiveness and design efficiency are implemented in the planning practice. As previously mentioned, there is an increasing research interest in implementing ACCC processes in the planning practice, yet the proposed solutions are not suitable for a generalised framework using Industry Foundation Classes (IFC) data standard. However, a recent study by Nawari (2019) aims to develop a Generalised Adaptive Framework (GAF) for IFC models that enables effective ACCC techniques. The concept behind this approach is to develop an object-based representation of the building rules (Malsane et al., 2015) obtained from the transformation of the written code into computable, semantic-rich information. Secondly, a design review is processed by invoking algorithms that access and link BIM and regulations using ifcXML format. An overview of the ACCC methodology is proposed in the following figure.

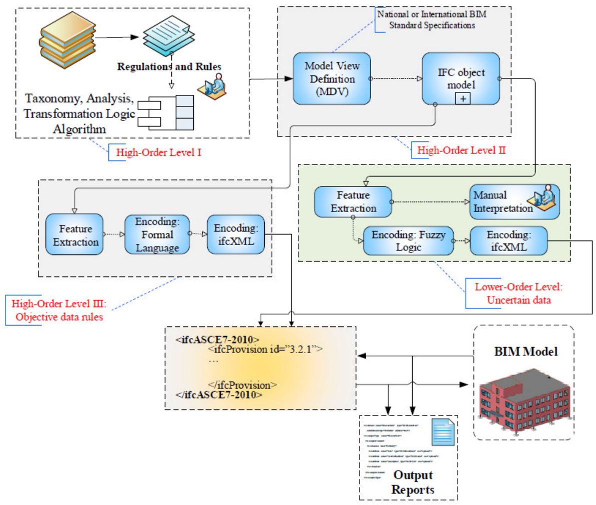

Fig. 5: ACCC Architecture (Nawari, 2019)

The proposed architecture defines initially standardised extraction protocols for the translation of the code requirements from textual rules into computable language. This phase is also known as the "Tranformation Reasoning Algorithm" (TRA) (Zhang & El-Gohary, 2015). Under TRA, the regulation clauses are classified into four categories: contents (descriptions), provisory (explicit rules), dependent (on provisory clauses) and ambiguous (fuzzy logic). These groups are automatically formed using computer code after data analysis, splitting and categorising the regulation language. Subsequently, the produced knowledge is used to develop a Model View Definition (MVD) standard that supports a specific IFC data schema. The following phases employ extraction algorithms intending to build the ifcXML data object model. This is undertaken under a higher-level order (unambiguous data) or lower-level order (ambiguous data). The final part of the framework includes a compliance check handled with Language-integrated Query (LINQ) programs. These algorithms can access and confront the information obtained from the BIM model on one side and regulations expressed in ifcXML on the other side. As a result of these checks, reports are produced in 3D or 2D format showing the objects that are not compliant with the current building regulation.

The main advantage of this approach is the adaptability provided by the TRA algorithms to handle different building codes as opposed to "Black Box" or "Grey Box" techniques (Nawari, 2019). These offer hard coding rules suited for a specific purpose that in many cases are deemed to be costly to maintain and inflexible to change due to the absence of a generic framework for modelling building rules and regulation (Nawari, 2019). GAF could bring considerable benefits to the AEC industry in automatic code compliance checking. However, the degree of complexity of such methods is very high, and the implementation cases are limited to simple buildings spaces assessed with few different building codes (Nawari, 2019). Thus, more research is needed to assess this technology under various designs and regulations properly.

d) Document Management in HLF

This section aims to democratise the SHD planning by building trusted relationships within the Hyperledger Fabric protocol. Immutability is one of the main proprieties of blockchain technology, and this implies that the data in the ledger can never be altered (Dounas, et al., 2021). With this logic, trust among parties could be enforced by building a blockchain-based document database that keeps cryptographic proof of the existence of documents at a given time. This platform could be built on top of an existing project dashboard allowing authorised users to securely access documents and automatise various tasks by employing smart contracts. The main functionalities of such a scheme are explained in figure 6.

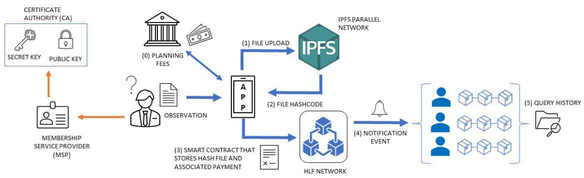

Fig. 6: Document Management in the planning framework

The image shows a typical process of storing planning files in a case of public observation. Any individual who wants to participate in the planning process must firstly prove his identity to the network. Identities are issued by Certificate Authorities which generate a public and private key pair to sign or endorse transactions digitally. The Membership Service Provider (MSP) keeps a record of the peers' public keys that are used to verify the validity of a transaction. In this way the MSP ensures that all identities of the network are trusted without disclosing the peers' private keys.

Once users are verified, a request to submit an observation is made by the client application and a planning fee is processed. Since the capabilities of the Hyperledger Fabric to support token's transactions are under development and there are no built-in cryptocurrencies, users can program their token to be used in conjunction with smart contract solutions (Lee, et al., 2020). Payments using HLF framework are currently the subject of research interest in the electric vehicles charging system (Jamil, et al., 2021; Khan & Byun, 2021). Such solutions employ smart contracts that automatically trigger at the completion of the charging process to generate payment requests and automatically balance the transaction between the parties. Similarly, in the planning context, a chaincode could be initiated by the client requesting the submission of a document to the planning authority. The PA will charge the fees the smart contract that will automatically deduct the tokens from the e-wallet of the owner. After the transaction is made, every participant will get a success notice.

At the payment, the application will initiate the observation upload under the form of a .pdf or .docx file. Since storing large files in the blockchain usually leads to performance issues, storing data in it is necessary to store data in a sideDB or in an off-chain database (IBM, 2018). Only the hash of the file is generated and stored in the blockchain along with other transaction details. According to Desai, et al. (2020) and Ye & Park (2021) Interplanetary File System (IPFS) could be used in combination with HLF blockchain to achieve successful off-chain storage of files. The process involves the previous creation of a parallel IPFS network that will store and encrypt the file. In the given example, the client's application is instructed to upload the file in the IPFS database so that the returned hash is inserted in a smart contract that will store it in the blockchain. Note that this smart contract could be triggered from the precedent chaincode at the event of the fees' payment and could be further developed by inserting time-limit conditions for ABP to respond. Usually, chaincodes owning sub-chaincodes should be preferred for their capability to manage all data in one contract, thus increasing data security (Ye & Park, 2021).

Finally, a new block with the associated transaction details is committed to the ledger, and the SDK executes a peer-based channel event to notify the users. In HLF, an event is a program-detected activity, so when a new block is committed to the peer's ledger, the Fabric client gets informed. This event service can deliver filtered blocks containing a minimal set of information to enhance privacy. Also, further actions could be triggered by the client's application after being notified.

When a transaction is validated and committed to the blockchain ledger, the process is considered complete. The data in any given block cannot be changed retrospectively without affecting all future blocks, which needs the network's majority agreement or the involvement of an Oracle. This characteristic ensures that trust is finally established within the planning network.

In HLF, the block data are arranged as a list of transactions that are packaged and ordered by the ordering service in a well-defined sequence. In a situation where multiple planning applications are processed simultaneously, all transactions referencing different planning permission might be batched in the same block. This happens because the ordering nodes create blocks based on the received transaction in chronological order. From this arises the necessity to dispose of tools that help stakeholders to query data based on specific criteria such as planning ID or submission date. At present, the development status of Hyperledger Fabric allows viewing all ledger's relevant information such as blocks, transactions, and network data in a web application. However, none of the existing tools can perform sophisticated queries on transactions and blocks, nor can they monitor the state's database operational history. Zhou, et al. (2019) investigated the possibility to query blocks or transactions effectively by employing a ledger data analysis middleware. The proposed "Ledgerdata Refiner" framework extracts ledger data from a Hyperledger Fabric-based blockchain network and saves the outputs in a third-party database. As long as a client certification is supplied, Ledgerdata Refiner can be connected to any fabric network peer to synchronize ledger data and parse the relationship between them. This functionality offers an enhanced data view for users by providing schema overview and customizable inquiry on ledger states. Since information is stored in the form of <key,value> in the ledger, in a potential planning framework, anyone could retrieve information about a specific planning application by querying a specific planning ID number (with a given planning ID "00001" the query condition may be like 'PlanningInfo.PlanninngElement.ID="00001").

V RESULTS & DISCUSSION

The first notable finding of this work suggests a positive synergy between BIM and Blockchain to address construction problems and improve the current planning practice. From one side, the literature review has shown that BIM methodologies enable better decision-making and a better understanding of the project deliverables within the SHD context. From the other side, it was demonstrated that Blockchain technologies could solve the problem of privacy and transparency that represented a fault in the current legislation around Fast Tracking.

An inductive case study was developed to validate this theory and demonstrate the compatibility of a BIM+Blockchain approach. The main functionalities of the presented architecture can be summarised as follow:

- Any electronic document (public observations, planners' document release, BIM model files, drawings, etc.) is encrypted, timestamped, and published in the planning blockchain.
- Designers and planners can perform automatic model checks against the current planning legislation using TRA algorithms.
- Users (typically homeowners, architects, and planners) are notified by a smart contract when a new document is released. The same smart contract will enforce a defined timeframe to respond, if relevant.
- At the end of the planning process, a complete history of the application is available to authorised users by using history data retrieval and filtering functions in the Hyperledger Fabric blockchain.

Since Hyperledger Fabric's projects are still in the early stages of implementation or testing, the present research is mostly based on whitepapers and peer-reviewed articles, supplied with other high-quality information sources when available. While the examination of secondary data enables a complete understanding of the subject, they only provide preliminary information on the value of BIM and Blockchain applications in SHD planning. Also, due to the current technological capabilities, the employability of such a framework in a real-case scenario might be consistently limited. Future research may need to simplify and condense the proposed methodology to consider standard planning cases.

VI CONCLUSIONS

Lack of transparency, poor record-keeping, and irregularities have historically characterised the Irish planning system to date. Transparent planning can generate more inclusive and sustainable economic growth by increasing the accountability of communities. Improved accountability ensures that all urban policies are implemented with all demographic groups. It also fosters trust among people and allows for active engagement. If transparency is taken into account in planning developments, cities would be able to provide services and infrastructure more successfully. Trusted relationships between planners and local governments also allow planners to identify the needs of the citizens and deliver better policies.

Through BIM+Blockchain this research has established a digital trusted relationship in the planning system. The proposed architecture is designed to enhance better transparency in the SHD planning by using specific capabilities in the Hyperledger Fabric. Moreover, by exchanging BIM files within the planning network, users can improve their comprehension around a specific planning application, leading to better decisions and reduced errors due to misinterpretation of the design characteristics.

This framework provides a solid theoretical foundation for developing BIM+Blockchain integrated solutions in the SHD Irish planning framework. The presented case study has shown that all the relevant pieces of technology contribute towards a more transparent SHD planning network. Future research is needed to evaluate the feasibility of the proposed framework in a real-world scenario.

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