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BLOCKCHAIN CROWDSOURCED ARBITRATION IN CONSTRUCTION PROJECT DELAY RESOLUTION

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Abstract

A major matter in any industry, especially one with complicated stakeholder relationships like the construction industry, is dispute resolution. Blockchain technology, in the form of crowdsourced arbitration, may assist project stakeholders to conclude a verdict for any conflict including an argument over delay damage responsibility. This paper aims to propose a Blockchain-based methodology to facilitate small and medium project delay resolution demands on a timely and transparent basis. The methodology consists of two implementation stages: (i) A Blockchain-powered crowdsourced arbitration jury to analyze and determine the responsible party and subsequent affairs following predefined conditions of the contract and (ii) Blockchain-based smart contracts to enable automatic implementation of said events including automatic payment of penalty and/or compensation cost. The introduced method is validated by a case study of crowdsourced arbitration using the Rhubarb platform to resolve disputes over who should be responsible for the delay of a garage construction project taken from an academic study on delay analysis techniques. The final verdict was that the contractor must reimburse the client's financial loss following established terms and conditions on liquidated ascertained damages via smart contract operation. The research also underlines the pros and cons of both current decentralized dispute resolution practice and this research proposed model in the construction field for future studies.

Keywords: construction; contract management; liquidated delay damages; the extension of time; contractor's claim; crowdsourced arbitration; smart contract; Blockchain.

1. Introduction

In construction projects, delay can be defined as the period of time overrun beyond a completion date, either of a whole or partially, predefined in a contract [1]. Whatever the reason, delay commonly leads to excessive cost and loss of revenue [1]. Therefore, determination of the responsible party and implementation of applicable indemnity to the opposite party whenever time overrun occurs is a never-ending argument among project stakeholders. Poor dispute management, accelerated by lack of honesty and finger-pointing disturbs the project stakeholder relationships and subsequently overall project success. Usually, a third-party presence is necessary to determine and settle bilateral conflicts.

Generally, there are three dispute settlement instruments: state court litigation, professional private arbitration and crowdsource arbitration (including Blockchain-based dispute resolution method presented in this research) [2]. Conventional state court litigation and professional private arbitration

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observed in the construction industry nowadays suffer from high financial charges, complicated submission of documents and lengthy procedures [2]. It is required that a more cost efficient and simple channel exists so that small and medium construction enterprises with limited resources and access to professional legal services can enjoy hassle-free justice whenever conflicts, including those regarding project delay, occur.

In Vietnam, there have been studies introducing the new concept of selecting a contractor with win-win motive [3], and studies focusing on analyzing contract management techniques on legal perspective [4], however, the authors observe there is a lack of study on dispute resolution, especially disputes over project delays during the construction phase in both academic and practical fields.

In order to resolve existing problems of traditional lengthy litigation and compensation processes in delay resolution, it is recommended that Blockchain technology is applied in both tasks: determination of responsible party and automatic implementation of subsequent contractual events including monetary and non-monetary outcomes. Blockchain's most significant characteristics and applications related to the topic shall be presented in this paper. A conceptual approach using Blockchain as a facilitating a platform to perform delay resolution tasks shall also be proposed and discussed in this study.

Academically, the study contributes to the existing body of knowledge of construction project and contract management by introducing an integrated blockchain-enabled smart contract and crowdsourced arbitration solution to resolve disputes that arise as a result of project delay. Practically, the proposed approach has significant potential to improve the current dispute settlement process in construction projects as it reduces implementation time and litigation charges incurred in traditional state court and professional private arbitration methods.

A typical construction project's life cycle consists of 6 stages: Appraisal; Definition; Design; Construction; Commissioning and Operation [5]. In this research, the authors focus on delay management within Construction stage.

Construction projects usually involve a dynamic group of many parties, including clients, general contractors, subcontractors, suppliers, architects and engineers, etc. who perform tasks of different aspects. As the research focuses on delay settlement, stakeholder relationship in Fig. 1 is examined.

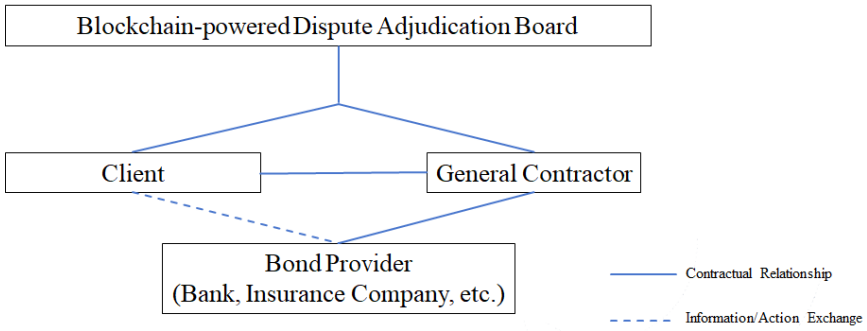


Figure 1. Research Project Stakeholder Relationship

Blockchain is selected as the backbone infrastructure of this research proposed approach. Its definition, operation mechanism and application are presented as follows.

Created in 2008 by a person or an organization named Satoshi Nakamoto, Blockchain technology, a Distributed Ledger Technology is a promising alternative to resolve contractual issues in the construction sector. Blockchain – as the name suggests – is a chain of blocks of information [6]. Unlike

conventional contract management tools where a centralized data server administering all contractual data is prone to malicious attack and overpowering of a single party, commonly client or general contractor, Blockchain technology uses a shared ledger on a peer-to-peer network to store data across several devices, validate the data authenticity and sufficiency to verify transaction. Then, it updates each block with the data from that transaction with a credible timestamp. The embedded information cannot be altered once added to the chain, transforming the chain of transactions into a valid and highly protected record. A blockchain is secured as every block is linked to its previous block through hash values. These are generated by hash functions, which convert a string of data to a new irreversible string that cannot be decoded back to its original value [7]. All transactions are visible to every node in the Blockchain network. Anyone can check the data and track the history through a device on the network to ensure the reliability of information [8]. Mechanism of Blockchain operation [9] is illustrated in Fig. 2.

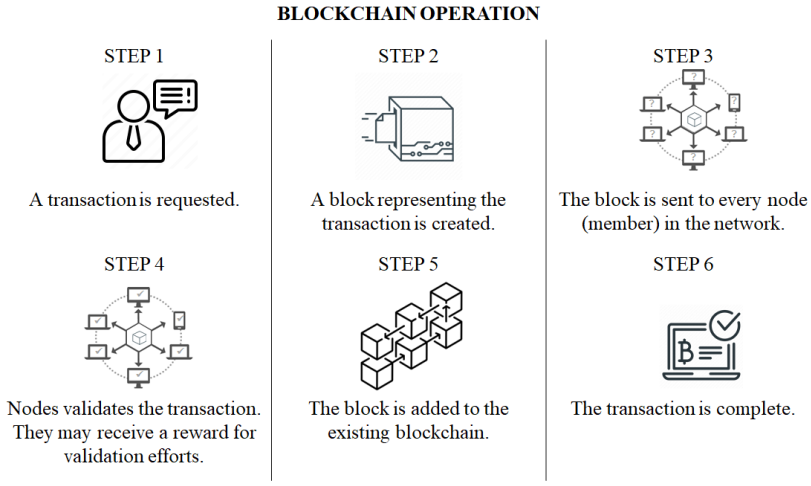


Figure 2. Mechanism of Blockchain operation

A smart contract is executable code operated on the Blockchain to facilitate, execute and enforce the terms of a contract agreement between untrusted parties [10]. Once contract terms and conditions are discussed and agreed, they are encoded onto either public Blockchain platforms like Etherum or permissioned Blockchains with limited access. The contract defines respective parties' lawful rights and obligations. Record of any fulfillment or breach of statutory obligation, partially or entirely, is bounded with reasonable subsequence, including payment, penalty or contract termination. All records of contract implementation are saved in the shared ledger, enabling relevant stakeholders to monitor and audit the proceeding. In the era of Internet of Thing, record of contract fulfillment or violation can be directly verified by authorized persons in the Blockchain, or automatic input by trusted third-party information sources (called "oracle") [11, 12], like national news websites, at-site sensor devices, or even a linked online dispute resolution instrument as presented in this paper. Smart contract execution [13] is presented in Fig. 3.

Currently in construction field, smart contracts are widely applied in building material supply chain and logistics governance as it releases cryptocurrency payments systematically when contract terms are satisfied (for example: on-time material delivery with required inspection proofs) [14]. Smart contracts are also exercised in interim payment procedure to eliminate cash-flow issues as they may settle payment to general contractor automatically using an embedded cryptocurrency fund

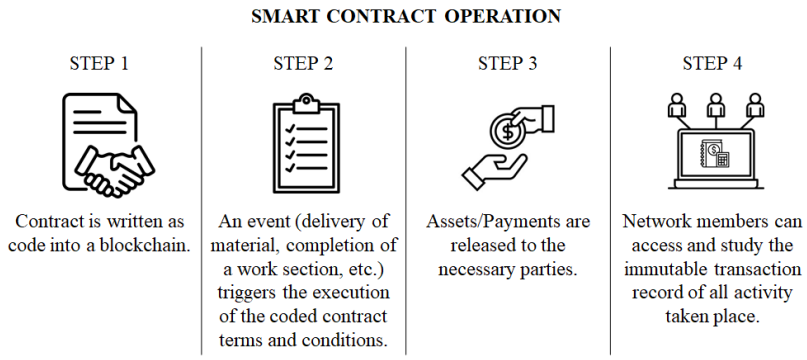


Figure 3. Smart Contract Operation Mechanism

upon validation of payment request by relevant stakeholders (quantity surveyor, supervisors, etc.) [15, 16]. Moreover, smart contracts can be linked to create a "web of payment" [14], once payment is transferred to a general contractor's wallet, associated relevant conditions of smart contracts between general contractor and their agencies (subcontractor or supplier for instance) also trigger automatic payments to these downstream parties as immediately as possible.

[17] has asserted the increasing potential of cryptocurrency usage in Vietnam as a robust market of over 1 million holders in 2021 with expectation to increase approximately 30 times in 20 years.

2. Delay Resolution

Any delay event occurred is analyzed on its three aspects: (i) is the delay excusable or non-excusable, (ii) is it compensable or non-compensable and (iii) does it occur independently or concurrently with other delay(s) in which either of them could cause the impact of work completion date. According to [18], with an excusable non-compensable delay, the contractor is entitled to an extension of time (EoT), with an excusable compensable delay, the contractor is entitled to both EoT and reasonable financial claim, while with a non-excusable delay, the contractor is entirely responsible and subjected to a penalty or liquidated ascertained damages (LAD) . Any of the mentioned types of delay can occur concurrently. Once determination of delay classification is confirmed, associated solutions are suggested (Table 1).

In construction projects, repayment of monetary penalty is usually resulted by performance bond call-on or a verdict of a dispute adjudication board (DAB). The indemnity method of performance bond call-on can be selected provided the contract contains predefined provisions of (i) a specific amount indicated for each delay day in the currencies and proportions in which contract price is payable; (ii) maximum amount of delay damages; and (iii) value and nature of performance bond deposited in a trusted surety, usually a bank or an insurance company. Regarding the nature of the performance bond, depending on whether it is a conditional bond or an unconditional bond [19], the procedures differ slightly. If the performance bond is an unconditional bond, sometimes called on-demand bond, the client may submit to the bond provider an official request for reimbursement considering he is in financial loss caused by the contractor. On the other hand, in order to successfully call a conditional bond, the client must submit additional supporting documents to prove that the contractor is responsible for the project progress failures, and such supporting documents are usually verdicts of a delegated DAB [19].

Table 1. Delay Typology and Proposed Solutions

Code	Delay Typology	Example	Proposed Solution			
			EOT	Claim	LAD	Nil
Stand-alone Delays						
S1	Excusable non-compensable	Extreme weather	×			
S2	Excusable compensable	Late site handover	×	×		
S3	Non-excusable	Late material delivery			×	
Concurrent Delays						
C1	Excusable non-compensable / Non-excusable		×			
C2	Excusable non-compensable / Excusable compensable		×	×		
C3	Excusable compensable / Non-excusable		×	×	×	×
C4	Excusable non-compensable / Non-excusable / Excusable compensable		×	×	×	×

In which:
EOT: Contractor is granted Extension of Time to complete the work(s).
Claim: Contractor is compensated for their prolonged work.
LAD: Contractor is penalized and must recover Client's liquidated damages.
Nil: Neither Client nor Contractor takes any contractually subsequent action.

Generally, there are three dispute resolution models. They are state court litigation, professional private arbitration and crowdsourced arbitration [2]. State courts' main advantage is that the jury's judgement is backed up with the force of state authority, resulting in strong lawful action. However, state court procedures are usually lengthy and costly, hence not favorable among medium and small sized businesses [2]. Professional arbitration services can also be provided by private DAB, for instance, Vietnam International Arbitration Centre (VIAC) in local office, which is normally faster and judgement quality is guaranteed thanks to the knowledge and reputation of the board committees. In recent years, in order to adapt with increasing requisition for fast, fair and cost-effective dispute settlement, private arbitration can be organized on online platforms, like the European Online Dispute Resolution which solved over 36,000 cases in the year 2018 [2].

Unlike the above, crowdsourced arbitration involves untrained juror members instead of competent and professional attorneys. It is a common solution for smaller groups who wish to manage disputes themselves by establishing common ground rules to facilitate community adjudication in a timelier and affordable manner [2]. Crowdsourced dispute resolution can be both offline and online. Blockchain-enabled online dispute resolution service, or "cryptocourt" as termed by [20] is a form of online crowdsourced arbitration). With the advent of Blockchain technology, online Blockchain dispute resolution become an effective tool for solving conflicts with lower risk of manipulation. The philosophy of crowdsourced arbitration is to put disputes in a public vote [21] by either a randomly-selected anonymous board of jurors or assigned well-known legal experts. Platforms like Rhubard

Fund [22] allow users to post a dispute topic on its portal, along with proposed verdict options so that jurors, who must deposit an amount of fixed token in a pool, can vote for the one they consider the most righteous. The solution with most votes is considered the final judgement and jurors who voted for this verdict are rewarded with deposited token on pro-rata basis. Final verdict recorded on Blockchain is transparent. It can be linked with smart contracts and trigger the next contractual events.

On the other hand, jury members with less favorable solutions forfeit their tokens to redistribute to winning jurors. This game-theory based principle is called Schelling Point [21], it prevents voters from making random choices and encourages them to put reasonable efforts in the process of problem solving. Essentially, Schelling Point provides cryptocourts a "mathematical justification" for risk evaluation and abstract decision-making [20]. Other networks like Aragon [23] add another layer of game-theory in the principle of eliminating juror bribery and favoring honest jurors over malicious ones by requiring jury members to enter an agreement to delate the bribing party and vote for the opposite side in the event either party attempts to bribe the jury. If the parties still fail to resolve the dispute upon public judgement, it is possible that a special panel of jurors with higher professionalism and reputation to be set up to further review the evidence, consider arguments before providing their final decision [24]. Apparently, online Blockchain jurisdiction is significantly less costly and more time-effective compared to a physical courtroom arbitration thanks to its less strict facility requirement, incentive mechanism and the power of Internet population.

3. Model Development

A conceptual approach to determine who should be responsible for time overrun between a client and a general contractor using Blockchain platform is proposed and discussed in this section (Fig. 4). Different cases of dispute between any two project stakeholders can be resolved using similar concept.

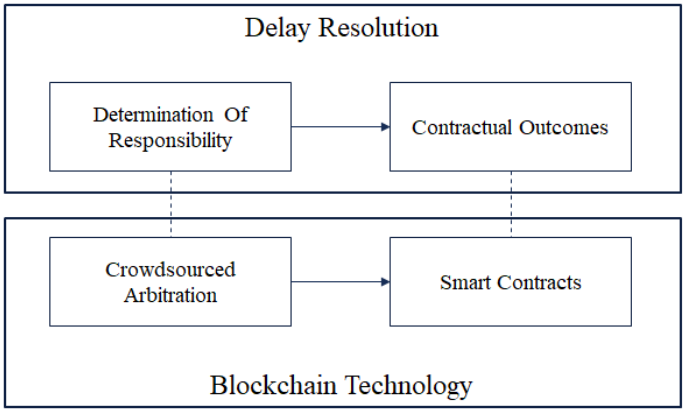


Figure 4. Blockchain-Based Construction Delay Resolution Methodology

The proposed approach consists of two main tasks: (i) determination of responsibility (via Blockchain online crowdsourced jurisdiction platforms) and (ii) automatic implementation of contractual subsequent affairs (including reimbursement of LAD, payment of contractor's claim and notice of EOT, via smart contracts) following below assumptions:

- The study of delay typology should be done (offline) by all project stakeholders, resulting in the shortlisting of a few most persuading arguments with detailed description of accountable party and subsequent events following contract logics like EOT, compensation, contractor's claim, etc.

- In construction projects, repayment of penalty is via either calling-on of performance bond, deduction in a due payment for contractor's work-done or direct payment upon an adjudication of arbitration. As this section focuses on the reimbursement of delay damages, the indemnity method of performance bond calling-on is selected. Therefore, it is necessary that the involved bond provider, either a bank or an insurance company, be assigned as a blockchain system node.

- Smart contracts are used in conjunction with embedded fund of cryptocurrencies, so that payment if any can be implemented automatically and rapidly to prevent impact of both unintentional and intentional delay transfer.

3.1. Blockchain-based Delay Resolution Model

The conceptual flowchart of construction project delay resolution using Blockchain smart contracts and crowdsourced arbitration is illustrated in Figs. 5, 6 and 7. The procedure first starts with checking of performance bond type, whether it's unconditional bond or conditional bond (Fig. 5). Client, for his interests, usually requests that an unconditional bond be procured by Contractor at the beginning of contract implementation period (with an unchangeable specimen captured in past tender requirement). However, conflicting meaning of the words written in the performance bond may provoke arguments among relevant parties whether the bond is either purely conditional or unconditional (on-demand) bond [19], therefore careful selection of words is essential to avoid unwanted confusion and dispute. In the event the performance bond is an unconditional one, beneficiary, which in most cases, the client, shall submit an original of a written demand form and the original of the bond itself to the bond provider before the expiry date and time to request for a payment of LAD for a specific delay period following the predefined contract terms and conditions, with consideration of the maximum advance amount and allowed number of callings (See process P1 illustrated in Fig. 5).

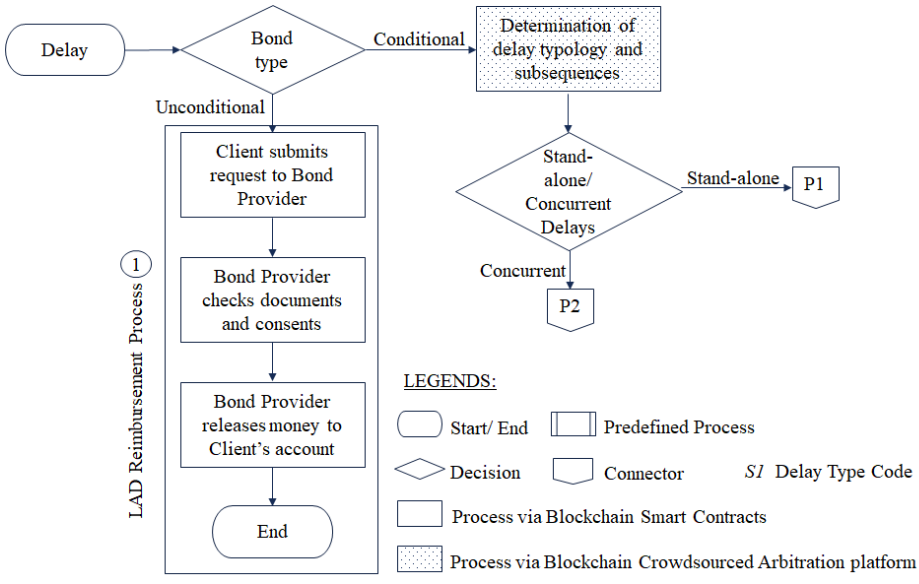


Figure 5. Blockchain-based Delay Resolution Flowchart

On the other hand, if the performance bond is a conditional bond, it is required that final determination of delay typology and subsequent actions following contract logics is conducted, to supplement documents to the bond provider, who has joint responsibility for the performance of the contractor

[19]. As supporting documents are usually results of an arbitration, Blockchain crowdsourced arbitration platforms are recommended. Smart contracts designate a platform as their DAB in case of dispute with specific conditions of court type and number of jurors etc. Accordingly, when a dispute emerges, members of a crowdsourced jury board are randomly selected to study the case evidence and vote for a verdict [25].

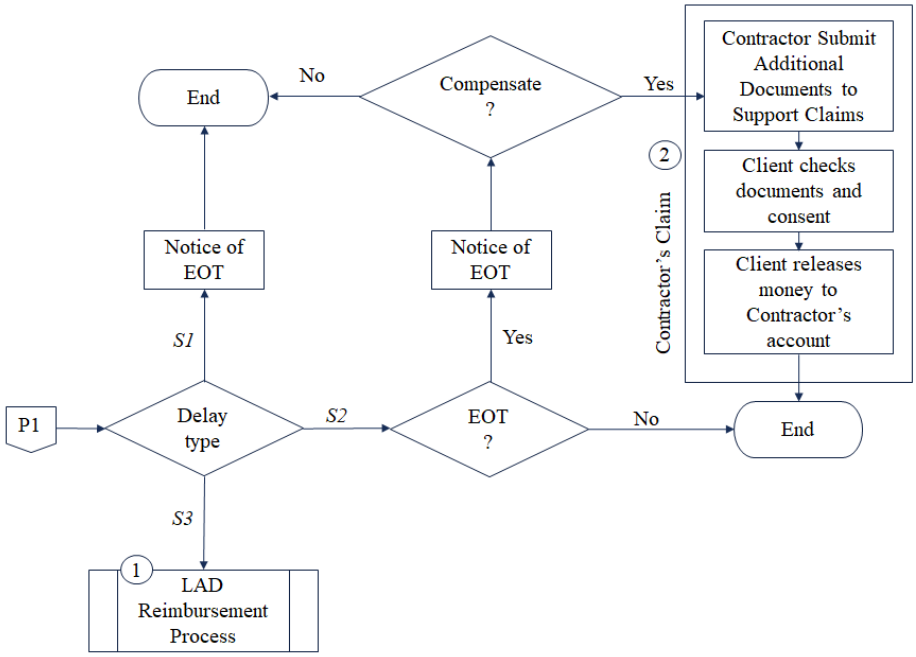


Figure 6. Blockchain-based Project Delay Resolution Flowchart for Stand-alone Delays

Resolutions of stand-alone and concurrent delays are slightly different. For easy comprehension, following procedures in the event delays are stand-alone/concurrent ones shall be presented separately in P1/P2 flowcharts (Figs. 6, 7). In a typical construction project, there are four possible resolving outcomes upon delay is discovered and analyzed and responsible party is determined, including: (i) Notice of EOT; (ii) Payment of Contractor's Claim; (iii) LAD Reimbursement to Client; and (iv) Status quo (neither parties take any action). Decision of solution is relatively simple in case of stand-alone delays since responsibility of a single-party can be pinned down. However, if two or more delays occur simultaneously, apportion of responsibility isn't as simple, resulting in several scenarios that relevant stakeholders may have to choose among and perform accordingly. Therefore, shortlisting of a few most persuading arguments with explicable description of responsible party and relevant event following contract logic must be conducted before final decision is chosen by a third-party crowdsourced arbitration service. It is noteworthy that different delay analysis techniques (DAT) deployed (for example: As-Planned vs. As-Built, Collapsed As-Built and Time Impact Analysis, etc.) might produce different determinations of stakeholders' responsibilities when applied on the same set of project data [26]. Once selected, off-chain data of winning verdict linked to the smart contracts subsequently triggers the outcomes based on established conditions of smart contracts.

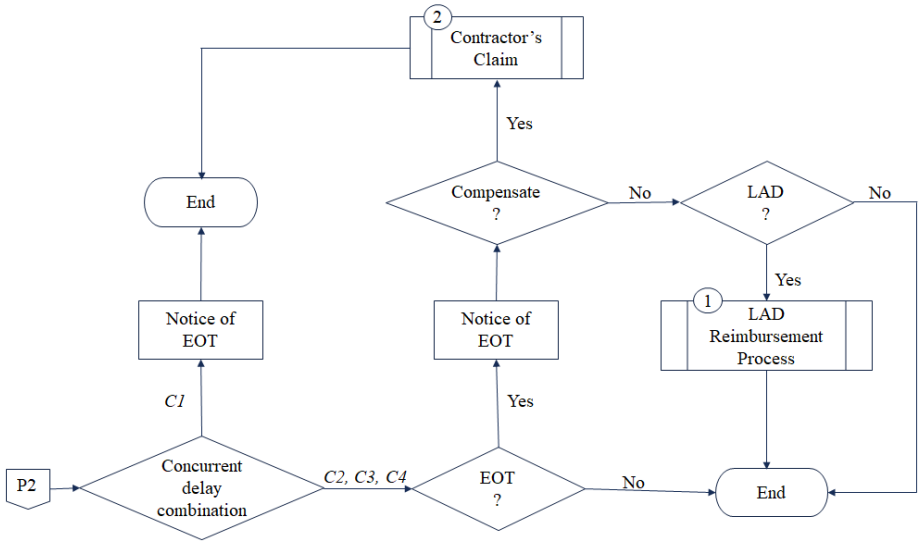


Figure 7. Blockchain-based Project Delay Resolution Flowchart for Concurrent Delays

3.2. Case study

To evaluate the recommended flowchart, a simple case study involving the construction project of a small garage is conducted. The project activity details, planned versus actual progress and various delay scenarios resulting from two delay analysis techniques *As-Planned vs. As-Built* and *As-Planned But for* taken from [26] are presented in Figs. 8, 9 and 10 and Tables 2, 3. Provided the liquidated damages are $300/day up to a maximum amount of $6,000 and contractor is indemnified with the overhead cost amount of $50/day for any delay responsible by the client.

Legend:

NN Non-Excusable Non-Compensable Delay

EC Excusable Compensable Delay

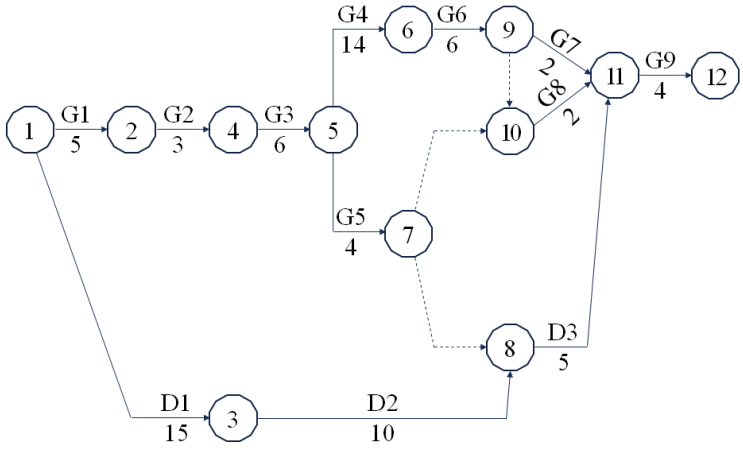


Figure 8. Arrow diagram of the case-study project

Activity ID	Activity Description	Planned Duration
Garage		
G1	Excavate foundation	5
G2	Concrete foundation	3
G3	Brickwork to 1m height	6
G4	Brickwork to roof level	14
G5	Concrete to floor slab	4
G6	Fix roof structure	6
G7	Waterproof roof	2
G8	Fix doors	2
G9	Paint and clean-up	4
Drive-In		
D1	Clear and excavate	15
D2	Hardcore base to drive-in	10
D3	Tarmacadam to drive-in	5

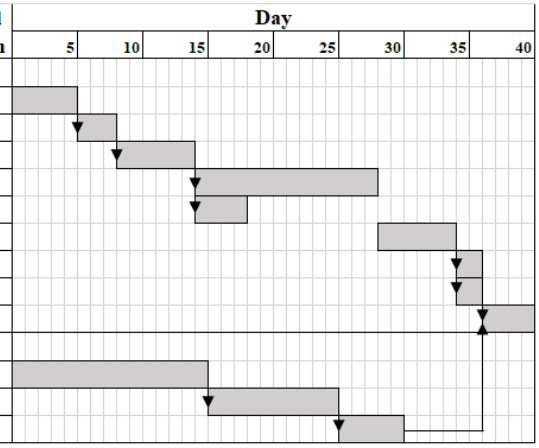


Figure 9. As-Planned Schedule of case-study project

Activity ID	Activity Description	Actual Duration
Garage		
G1	Excavate foundation	5
G2	Concrete foundation	6
G3	Brickwork to 1m height	6
G4	Brickwork to roof level	17
G5	Concrete to floor slab	5
G6	Fix roof structure	6
G7	Waterproof roof	5
G8	Fix doors	5
G9	Paint and clean-up	4
Drive-In		
D1	Clear and excavate	22
D2	Hardcore base to drive-in	19
D3	Tarmacadam to drive-in	9

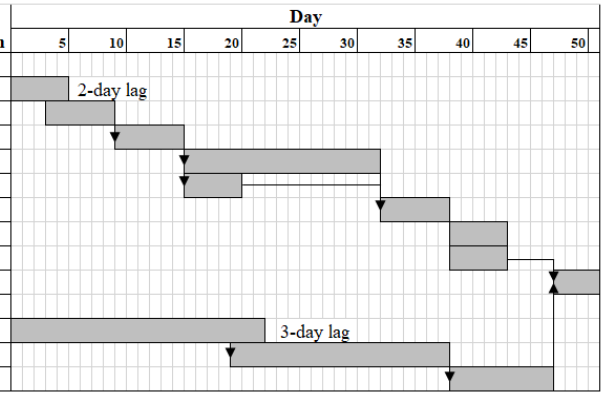


Figure 10. As-Built Schedule of case-study project

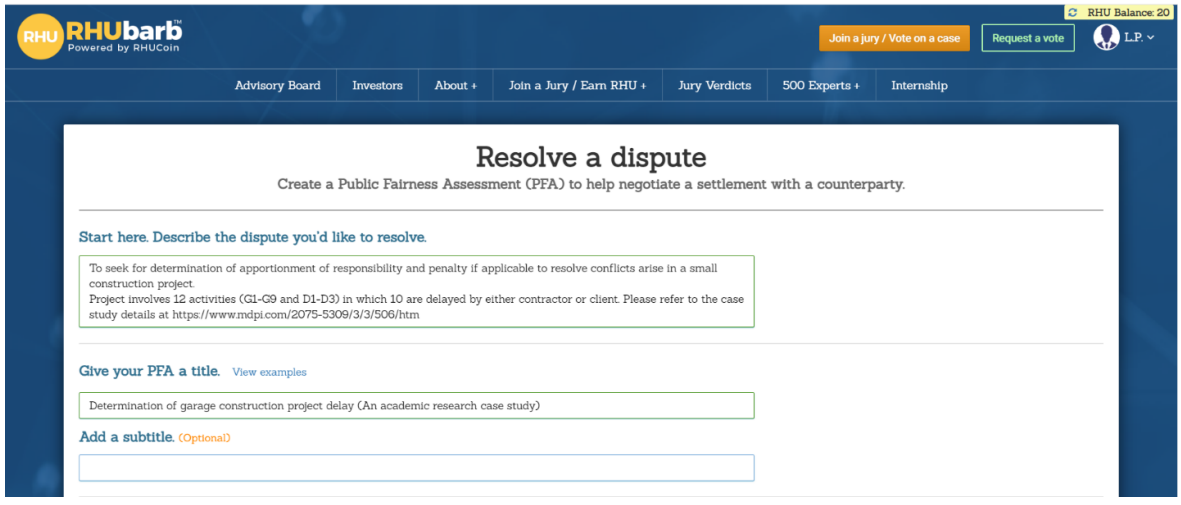
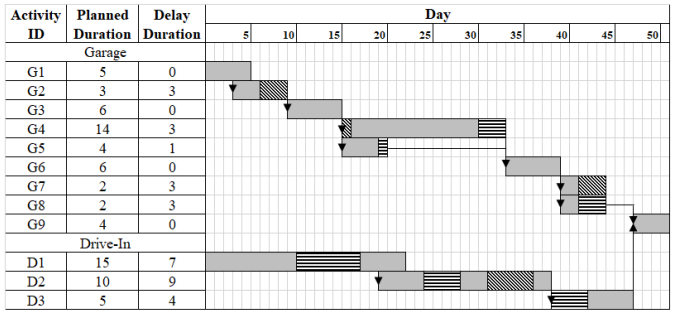
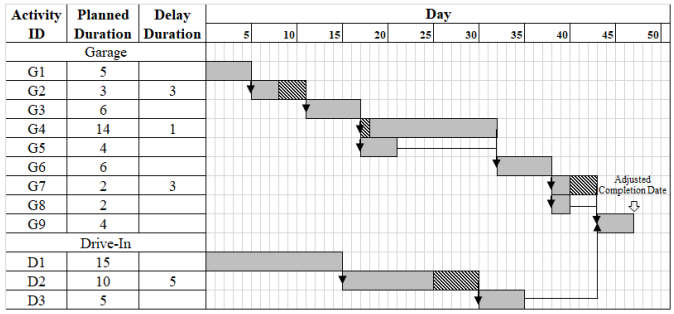
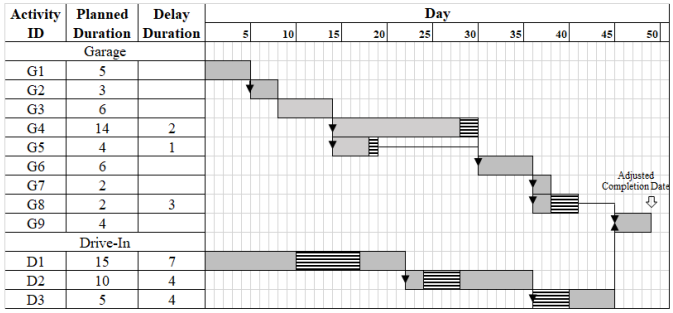


Figure 11. Case-study description

Table 2. Case-study project delay information

Activity	As-planned duration	Order	Delay Information				
			Description	Type	Start date	End date	Duration (days)
Concrete foundations (G2)	3	1	Contractor had a labor problem so it took 3 days extra to complete activity G2.	NN	6	9	3
Clear and excavate for drive-in (D1)	15	2	Contractor encountered unforeseen adverse ground conditions during excavation of the drive-in.	EC	10	17	7
Brickwork to roof level (G4)	14	3	Activity G4 did not start immediately after completion of its predecessor as-planned due to a 1-day delay by the contractor's brick supplier.	NN	15	16	1
Concrete to floor slab (G5)	4	4	Contractor advised the owner on the need to increase the thickness of the floor slab. This change required 1 extra day to accomplish.	EC	19	20	1
Hardcore base to drive-in (D2)	10	5	After 5 days of working on activity D2, the owner suspended works for 3 days as a decision on the suitability of the hardcore material was being made.	EC	24	28	4
Brickwork to roof level (G4)	14	6	The owner ordered the contractor to add an extra window after the completion of G4. This design change caused a 2-day delay.	EC	30	32	2
Hardcore base to drive-in (D2)	10	7	A quality control test revealed that certain sections of the drive-in base were poorly constructed. This defective work resulted in 5 days of rework by the contractor.	NN	31	36	5
Tarmacadam to drive-in (D3)	5	8	There was a 4-day delay by the owner in making available to the contractor an owner-furnished equipment for activity D3.	EC	38	42	4
Waterproof roof (G7)	2	9	It took the contractor 3 more days to complete activity G6.	NN	40	43	3
Fix doors (G8)	2	10	The owner changed his mind on the type of door used for the garage so ordered the contractor to make changes. This caused 3 extra days of work.	EC	40	43	3

Table 3. Case-study project delay analysis

Option	DAT deployed	Outcome Description	Quantitative Outcome
1	As-Planned vs As-Built	 - Sum of contractor-caused delay: (a) 12 days - Sum of client-caused delay: (b) 21 days - Assume (c) 12 days are concurrent delays due to both parties (the lower of the above two). Net delay responsible by client is 21 – 12 = 9 days (d) - Net delay responsible by contractor: 51 – 40 – 9 = 2 days (e)	- Notice of EOT: (d) = 9 days. - Contractor is indemnified with an amount of 50∗(d) = 50∗9 = 450$. - Contractor is penalized with an amount of 300 ∗ (e) = 300 ∗ 2 = 600$.
2	As-Planned But for (Impacts by contractor)	 - Adjusted as-planned schedule considering impacts from contractor's delays is 47 days. - Net delay responsible by client is 51 – 47 = 4 days (a) - Net delay responsible by contractor is 47 – 40 = 7 days (b)	- Notice of EOT: (a) = 4 days. - Contractor is indemnified with an amount of 50∗(a) = 50∗4 = 200$. - Contractor is penalized with an amount of 300 ∗ (b) = 300 ∗ 7 = 2,100$.
3	As-Planned But for (Impacts by client)	 - Adjusted as-planned schedule considering impacts from client's delays is 49 days. - Net delay responsible by contractor is 51 – 49 = 2 days (a) - Net delay responsible by client is 49 – 40 = 9 days (b)	- Notice of EOT: (a) = 9 days. - Contractor is indemnified with an amount of 50∗(b) = 50∗9 = 450$. - Contractor is penalized with an amount of 300 ∗ (a) = 300 ∗ 2 = 600$.

Three proposed delay determination options are presented for public voting of at least 25 jury members on Rhubarb website [22]. Description of the case study and relevant voting options are demonstrated in Figs. 11 and 12. Users can select preferred background of jury members in accordance with the nature of dispute arise. In this case, construction/builder field is picked.

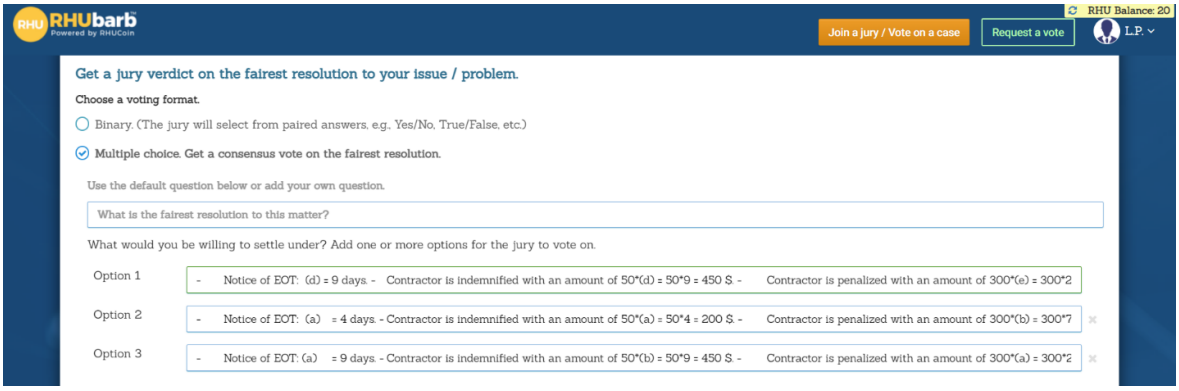


Figure 12. Available voting options for case-study dispute resolution

Option 1 is the most selected one which sets the precedent of contractor's automatic payment of (600 – 450) = 150$ penalty following Predefined Process 1 (LAD Reimbursement Process) in Fig. 5 and Predefined Process 2 (Contractor's Claim) in Fig. 6. It is noteworthy that contract managers can choose to reconcile the balance value of LAD reimbursement amount and contractor's claim amount in order to perform a single payment aftermath either from client to contractor or from bond provider to client to reduce transaction cost, however in this study, the authors intentionally separate the two payment processes for clear demonstration purpose.

Additionally, the proposed resolution method was applied in a community park construction project in Dong Nai, Vietnam (Fig. 13). The total contract value was approximately $1,078,260 and expected time for completion was 150 days. As per agree delay damage clause in the contract, each

Figure 13. Community park case-study project

delay day is worth $1,078.26 (or 0.1% contract value) and total maximum liquidated delay indemnifiable is $107,826 (or 10% contract value). Incentive for early completion isn't available. Note: contract value was in Vietnamese dong, all reported values in US dollar/ETH token are for reference purpose only using present exchange rates.

As-planned and As-built project schedules are presented in Fig. 14 and Fig. 15.

ID	Activity Description	Pred	Dur.
A	Mobilisation and preparation works		15
B	Site clearance and landfill works	A	30
C	Piling works	B (SS=15)	30
D	Underground tanks	C	15
E	Carpark Structure works (Ground slab, column, etc.)	D	45
F	Carpark Finishing works (Roof, tile, asphalt driveway, etc.)	E (SS=30)	30
G	Carpark MEP Works	E (SS=15)	45
H	Lake embankment works	B	45
I	Infrastructure MEP Works	H (SS=15)	45
K	Bridge and deck construction works	H (SS=15)	60
L	Hardscape works	I	30
M	Other works (loose furnitures, signage works etc.)	L (FF)	45
N	Softscape works	L (FF)	45
O	Defect retifying, cleaning and handing-over	F,G,L	15

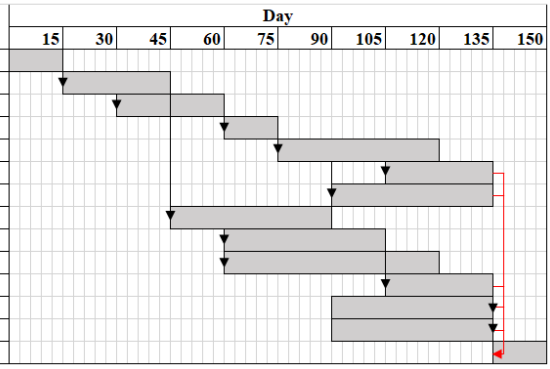


Figure 14. Community Park Project As-planned Schedule

ID	Activity Description	Pred	Actual Dur.
A	Mobilisation and preparation works		15
B	Site clearance and landfill works	A	33
C	Piling works	B (SS=15)	30
D	Underground tanks	C	21
E	Carpark Structure works (Ground slab, column, etc.)	D	42
F	Carpark Finishing works (Roof, tile, asphalt driveway, etc.)	E (SS=30)	30
G	Carpark MEP Works	E (SS=15)	48
H	Lake embankment works	B	45
I	Infrastructure MEP Works	H (SS=15)	45
K	Bridge and deck construction works	H (SS=15)	54
L	Hardscape works	I	30
M	Other works (loose furnitures, signage works etc.)	L (FF)	45
N	Softscape works	L (FF)	45
O	Defect retifying, cleaning and handing-over	F,G,L	15

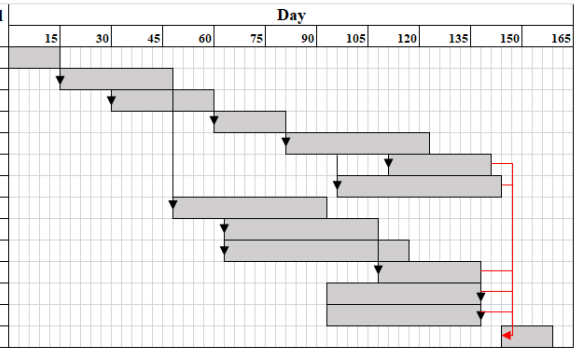


Figure 15. Community Park Project As-built Schedule

The actual total project duration was 159 days. Due to late machinery mobilization, rework of underground septic tank and late firefighting pump delivery, activity B, D and G were delayed for 3, 6 and 3 days respectively. But the contractor had tried his best to catch up, subsequently, activity E and K were shortened by 3 and 6 days respectively. Thus, the contractor argued that he should be penalized for $(3 + 6 + 3) - (3 + 6) = 3$ days only. However, the public jury agreed with the client that the contractor is responsible for all 9-day delay period, and that provision of incentive for early completion was not agreed upon, the penalty amount was subjected to no reduction. Eventually, the contract had to pay $9,704.34 or ETH8.82 including transaction cost via Ethereum public Blockchain network.

4. Conclusions

Research Outcome Summary

The study has proposed a conceptual Blockchain-based method for delay resolution in construction projects exploiting two Blockchain applications, smart contracts and crowdsourced arbitration solutions, respectively to facilitate responsibility apportionment and automatic outcome implementation as a part of an overall contract management procedure. The usage of the proposed approach is expected to reduce settlement time and overhead cost caused by employment of third parties like banks and lawyers; as well as to reduce the risk of injustice and arbitrary thanks to Blockchain's incentive mechanisms and power of Internet population. However, due to jury members' expertise limitation, the proposed approach is recommended for small and medium projects only, in which relevant stakeholders are of constrained financial resources and mean access to professional legal services.

Proposed method is validated by a case study to resolve disputes over who should be responsible and penalized for the delay of a garage construction project taken from an academic study on delay analysis techniques. Blockchain-powered community jurors of Rhubarb crowdsourced arbitration platform concluded the contractor must reimburse the client's financial loss following established liquidated ascertained damages terms and this reimbursement process is done systematically and automatically via Blockchain smart contracts.

Research Limitation and Future Research

However, due to limited resources and current technology available, smart contracts linked to selected dispute resolution platform of presented case study is yet to be coded and refined to perform aforementioned payment process. Future research should focus on developing smart contract prototypes and further assessing their outcomes to test the proposed method's feasibility, scalability and legal significance.

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