Blockchain-based E-tendering Evaluation Framework

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Abstract –

Tendering & Bidding generally involve many construction units participating in a project bidding. The purchaser selects the best bidder with a short construction period, low cost, high quality, and good reputation. There are huge economic benefits and points of concern behind it. However, tendering suffers an increased risk of data tampering due to the centralized database architecture, resulting in huge financial losses and unnecessary consumption of human resources. Blockchain technology has gained increasing attention in the construction industry because of its high transparency, information traceability, non-repudiation, and non-tampering characteristics. Initial explorations have been carried out to discuss blockchain benefits in the e-tendering process. However, existing studies are limited to conducting qualitative analysis or proposing conceptual frameworks. A workable blockchain-enabled solution that supports basic functions in the e-tendering process still lacks. Therefore, as an initial exploration, this paper presents a secure blockchain-based framework for tender evaluation. Besides, technical components such as tendering smart contracts are developed to support framework functionalities. The framework feasibility is validated in a tendering evaluation example. Results show that the proposed framework guarantees secure tender evaluation by keeping data traceability and immutability.

Keywords –

E-Tendering & Bidding; Blockchain; Smart contract; Tender transaction

1 Introduction

Tendering and bidding refer to a type of business in which many construction units participate in project bidding. By selecting the best, the project task is assigned to a company with low price, good quality, short construction period, or relevant experience. On this basis, the purchaser unit and the bidding unit will sign a contract. Digitalization (or e-Tendering) is a trend in tendering process to solve low efficiency and unfairness problems [1]. However, most of the current e-tendering systems rely on a centralized database, suffering cybersecurity risks especially data tampering, as all data are controlled in one sector. For example, authorized personnel can modify the bidding data, which will cause the authenticity and traceability of the data to be lost in the bidding process.

Blockchain technology has the characteristics of high transparency, non-tampering, non-repudiation, and traceability. Blockchain is a shared, unchangeable ledger that facilitates recording transactions and tracking assets in a business network. From the initial cryptocurrency to the current smart contract, the application feasibility of blockchain in the construction industry has been analysed. For example, Penzes B et al. [1] proposed the determination to reduce disputes and optimize storage, as well as the retrieval analysis and framework design of key areas by Li, J et al. [2] etc. Meanwhile, the feasibility of blockchain has been verified in the AEC industry. For example, Li H et al. [3] proposed saving database overhead in the Internet of Things technology. Chang S et al. [4] applied the tracking process in the supply chain.

Some initial explorations have investigated the benefits of applying blockchain in e-tendering. For example, Ambegaonker et al. [5] proposed a blockchain-based e-tendering system case designed to include analysing its security, and Li, et al. [6] explored the feasibility analysis of its data processing performance. However, these studies mainly focused on qualitative analysis or conceptual models' development. A solution that can be applied in practice has not been designed.

Therefore, this paper aims at designing a blockchain-based e-tendering system that can be practically applied. The objectives are: (1) to develop a blockchain-based e-tendering system framework, (2) to design technical components (transaction data model & smart contract) required by the framework, (3) to test the feasibility of the framework in an e-tendering example. In addition, this paper discusses the potential uncertainty that may arise in the actual situation.

2 Blockchain in E-Tendering

As a point-to-point distributed data structure, the blockchain records all transaction data in chronological order and stores it safely. The blockchain is essentially an encoded digital ledger, which can be stored on a computer on a public or private network [7]. The current hash in the blockhead of each block is calculated from all other information in the entire block. If the data in transaction is changed, this block's real current hash value will be changed. The previous hash value in the next block corresponds to it, as shown in the Figure 1.
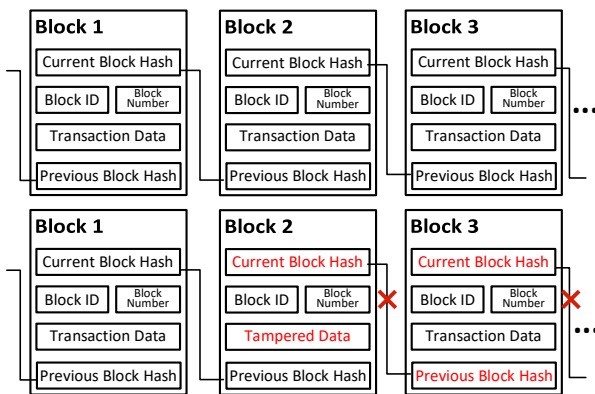

Figure 1. Blockchain Structure

In the transaction process of the blockchain system, each block needs to hash the previous block and link the newly calculated block with the previous chain. A block will contain blockhead, transaction data, timestamp, and last block hash in this process. The blockhead includes the block height (the number of the block) and the current hash of this block. The data or information stored in it has the characteristics of "unforgeable," "fill traces," "traceable," "open and transparent," and "collective maintenance" [8]. Based on these characteristics, blockchain technology has laid a solid foundation of "trust" and created a reliable "cooperation" mechanism. Because of these advantages, the application of blockchain technology in the e-tendering system is promising.

In the past research in the e-tendering system, most of the information exchange methods used were centralized databases [9][10]. Centralized databases often cause information loss or tampering because the only data storage location is attacked. Persons with authority to the central database can easily enter it. Once the information obtained by bid-base or other bidders is acquired through illegal means, it will give them an unfair advantage. According to the analysis of the bidding framework of the credible third-party model adopted in the past research, it is prone to some mistakes that lead to economic losses and bidding failures. One of the most representative is data manipulation.

The tendering system in the trusted third-party (TTP) mode is currently the most mainstream build model. Its organization provides certification for bidders and purchasers who need to access the database and determines that other people cannot access the contents of the centralized database. However, suppose a member of the bidders or purchaser unit uses illegal means to tamper with the information in the database due to economic interests. In that case, the third party cannot guarantee the security of the file.

In the application of tendering, because of the complexity and security requirements of the process itself, many scholars have carried out a blockchain-based design in this regard. Because the laws and institutions of many countries have higher requirements for confidentiality in tendering, Hardwick, Akram, & Markantonakis [11] have designed a bidding framework for government procurement. In addition, Ambegaonker et al. [5] proposed some suggestions for improvement of the Blockchain-based e-Tendering System.

In these similar studies, the consideration of the bidding process has been simplified. The main proposals are conceptual frameworks. There is no analysis for special procedural requirements; for example, verifying the submitted information in the "prequalification" link and the information exchange in the "clarification" link is omitted.

3 Blockchain-based E-tendering Evaluation Framework

3.1 Development of Framework

Because of the complexity of the tendering evaluation stage, the system framework adopts the parallel mode of blockchain system and centralized database. This type of "public service platform" is filed by the government's market supervision unit, and it is also the mainstream method of bidding for large-scale projects. Although there are many resources used to protect the security of the database, it still has the structural flaws of a centralized database.

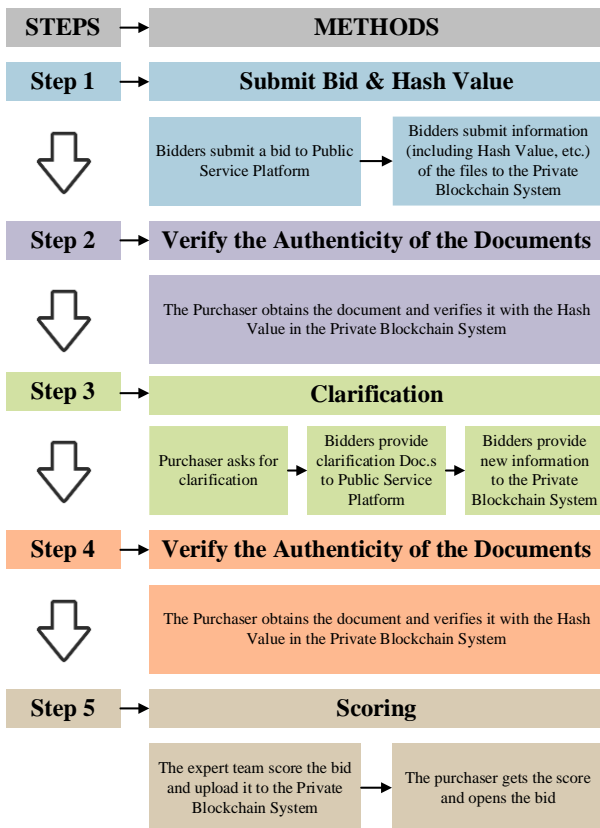The framework mainly consists of the following steps:
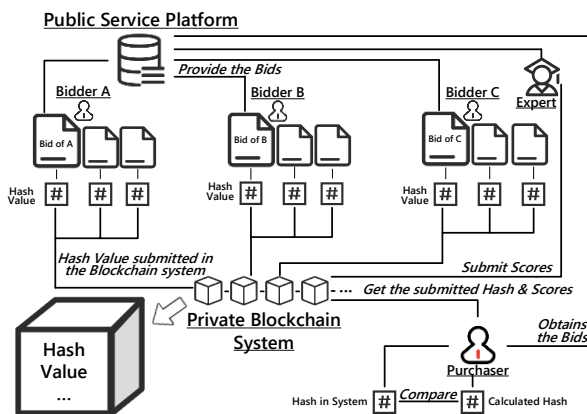
Figure 2. Framework Steps

Figure 3. Blockchain-Based E-Tendering System of Tendering Evaluation

Figure 2 illustrated the framework that mainly consists the process from submitting bid to scoring. Especially for the critical "clarification" step, the framework designed in this article plans for bidder's need to update information.

For the clarification stage, in the actual project, there are often many clarifications. Each clarification may be aimed at different bid parts, such as the business part, price part, etc. During a clarification process, you may be

asked to provide information multiple times. Therefore, in the design process, the two stages of "clarification" and "verify and clarify the authenticity of the documents" will be carried out many times by the actual situation until the change step is completed.

After the "clarification" section is over, follow the process to score the bidder's files. The scoring results should be sorted according to the scores of all bidders. Choose the three (or more) with the highest scores as candidates for advertising. And after the advertising period, the final bidder is determined among them, generally the bidder with the highest score.

In this framework, the expert group needs to score documents in the private blockchain system. Therefore, the expert group should obtain all bidder documents (including bid and all clarification documents) from the "Public Service Platform" or from the purchaser.
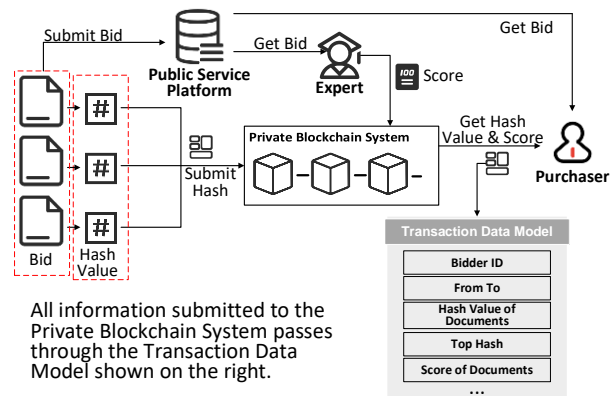

Figure 4. Framework Design of Scoring Part

Whether the bidders or an expert group are uploading information to the private blockchain system, it should be compared to the transaction data model designed for Tendering Evaluation intended in this article.

3.2 Development of Transaction Data Model

For information transmission and acquisition in smart contracts, the transaction data model should be adopted. This article is aimed at the tendering stage, and a dedicated data model is designed. This model can summarize the information that a bid should have. A qualified bid should have a business part, a price part, and a technology part among the implemented specifications. In addition, all communications between the purchaser and bidder should be added to the bid in the clarification process. There are corrections and supplements to the original information in the information required to be provided subsequently.

Each part of the bid should meet the requirements of the project. If there is a bid base, it should be checked at the bidding base. If some rigid requirements cannot be met,

the bid shall be invalidated. In addition, after the clarification is over, the purchaser should blindly select the members of the expert group. Those who have a deep understanding of the technology and the project score the documents. The expert group obtains the authority from the purchaser, accepts all the documents, and divides parts into bid scores. In this transaction data model, the score of each item is set to 100 points, and the total score is 300 points. In addition, the clarification document is a supplement to the above three parts and will not be scored. The transaction data model is represented in Table 1.

Table 1 Transaction Data Model

ATTRIBUTES	VALUES
Bidder ID	002s0001
Bidder Name	ZHANGSAN
From To	002 to 001
Hash of Business Part	bd4674b81fcd40…
Hash of Price Part	4489a0052b40f4…
Hash of Technology Part	85d56bb4cebd08…
Hash of Clarification Doc	NULL
Top Hash	fe2245a47443aa6…
Score of Business Part	NULL
Score of Price Part	NULL
Score of Technology Part	NULL
Score of Bid	NULL
Clarify Number	0
Date	04-15-2021

Because the blockchain system cannot transmit large files, the hash value of each part of the file should be calculated in advance. This design uses SHA256 to encrypt documents.

For a message of any length, SHA256 will generate a 256-bit hash value called a message digest. This summary is equivalent to an array with a length of 32 bytes, usually represented by a hexadecimal string with a length of 64. The purchaser can place large documents through the bidding service platform. Calculate its hash value after obtaining the document. In addition, for the "Top Hash" item in the model.
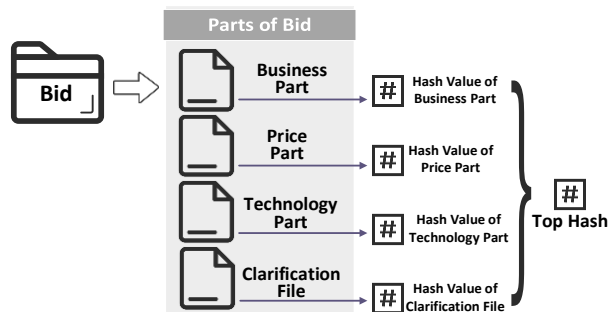

Figure 5. Top Hash

Top hash is derived from the four hash values in the document, which are calculated through SHA256 again. When users want to verify the document's authenticity, they can first verify the value of Top Hash. If the corresponding data is correct, it can be considered that the document has not been tampered with. If the data is different, you can check the four sub-items. This process can reduce the time for verification and save related costs.

As shown in Table 1, the transaction data model contains the bidder's name, bidder ID and submission date, and other related information. The purpose of bidder ID is to make it more convenient to query transaction records. The submission time is only accurate to the date because a block will have its timestamp. The timestamp will be stored in the block with a time accurate to the second, and authorized users can query the data. It is not necessary to express in the model.

For scoring items, because the ID of the expert group set in the framework is different from other users (Expert ID: 000) when querying the score, the result will not be affected by other incorrectly entered data.

Because the business part, price part, and technology part cannot be changed after the first submission (you can make changes in the clarification file), the value will not be altered in different submissions. But the top hash will vary with the data of the clarification file.

3.3 Development of Smart Contract

The designed blockchain-based tendering system framework and transaction data model develop the smart contract, as shown in the Figure 6. The smart contract is based on the Go language. The main functions are installing, instantiation, upgrade, etc., that come with Hyperledger Fabric, and three other functions are also designed.

Figure 6. Smart Contract Design

As can be seen from Figure 6, Smart Contract: "RecordTest" has three main functions: (1) Save Function, (2) Query Function, and (3) History Query Function.

The two functions of save and query are important requirements in the bidding process that requires frequent communication. In the design of this article, information such as time, bidder, hash value and score of the file, etc., are all carried out through these functions.

In the survey, the actual situation of tendering evaluation, data storage is also an essential item. All documents in the bidding process (bidding documents, bids, clarification documents, confirmation letters, etc.) need to be kept appropriately for a possible eventual inspection for possible inspection. Based on this fact, the function can be designed to query all historical information submitted in the past.

4 Illustrative Example

This article designs an experiment based on the e-Tendering System in the Tender Evaluation phase and the smart contract used above. The design and experimental scenarios are as follows: one purchaser (No.001), one bidder (No.002), and one expert group (No.000).

The bidders submit bids and clarification documents according to the process. The purchaser makes queries in order. After the clarification is completed, the bid will be scored by the expert group. Finally, check the score. The function of querying historical information is also set up.

The whole process is mainly divided into four steps, omitting the repetitive steps of the intermediate process. This is to verify whether the completed e-Tendering System can work normally. The framework is based on Hyperledger Fabric 1.4. Specific information about the above three scenarios is also shown below.

4.1 Scenario Ⅰ : Initial Submission of Information

Bidder submits information about the bid for the first time; the ID of the Purchaser is 001. The ID of this bidder is 002. Therefore, the query code is set to 002001. When Purchaser searches for "002001", all the latest information provided by the bidder can be obtained. The hash value calculated from the files obtained from the "public service platform for tendering and bidding" database can be compared with the information obtained from the blockchain system.

In general, the three main steps in the bid: Part of Business, Part of Price, and Part of Technology, will not be changed during the clarification process. So, the purchaser needs the bidder to submit clarification documents.

Figure 7 shows the validation results in Hyperledger Fabric, transaction data for Step 1, and the current blockchain status after Step 1 are displayed.
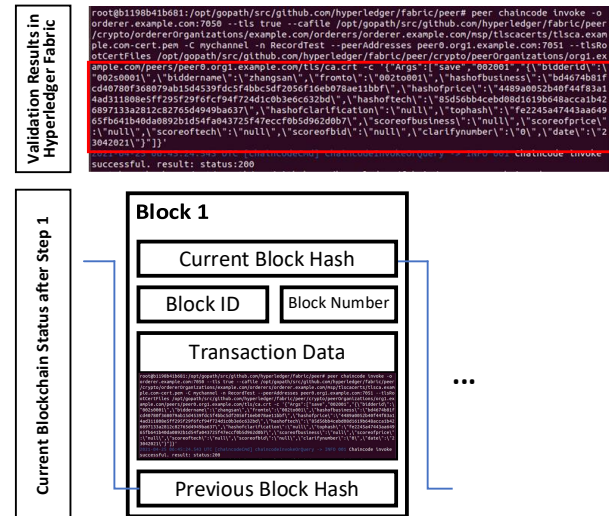

Figure 7. Scenario Ⅰ : Initial Submission of Information

4.2 Scenario Ⅱ : Update Submitted Data

This scenario shows two updated information of No.002 bidder, respectively, in the first clarification (second submission) and the fourth clarification (fifteenth submission). The content submitted for the fifteenth time is the final information submitted by the bidder. The two submission dates are April 23, 2021, and May 23, 2021, respectively, and the hash value and top hash of the clarification information in the content have also been updated.

Because of the complexity of the tendering and Bidding process itself, the purchaser often requires multiple clarifications. In each clarification work, the bidder will also be required to provide corrections/additional information as required. In the verification experiment, the intermediate steps were omitted as shown in Figure 8. However, in the application, there may be multiple submissions of information in each clarification. So, there will be a fourth clarification, but the number of submissions is 15, as shown in Figure 9.
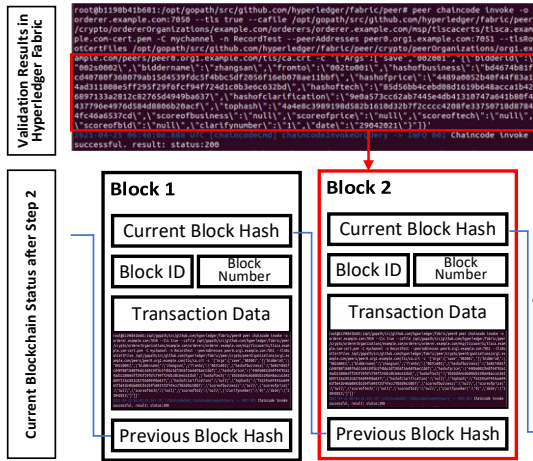
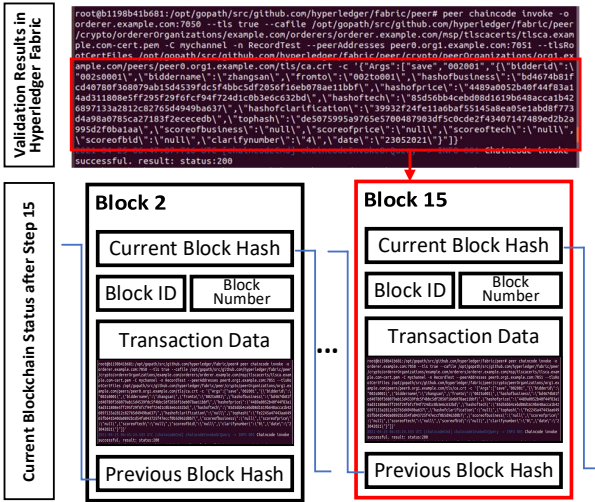Figure 8. Bidder Submits Information for Second Time

Figure 9. Bidder Submits Information for Fifteenth Time

4.3 Scenario Ⅲ: Scoring Bid

After the whole clarification part is over, the expert group needs to score the bids submitted by each bidder. Scoring the business part, the price part, and technology part, respectively.

As shown in Figure 10, the scores given to the bidder are as follows. The business part score is 93, the price part score is 97, and the technical part score is 91. The total score (score of bids) is the sum of the above three items, 281 points. The total score of this scene-setting is 300 points, and the total of each item is 100. The query result is also the score transmitted by the expert group to the system and the relevant information of the bid.

The ID of the expert group set in the experiment is 000. Therefore, in the input and query, the ID of bidder number 002 should be set to 002000. The ID (002000)

can coexist with 002001 (the ID used when the bidder enters information) in the smart contract. So, there is no need to update the chaincode.

The input data corresponds to the data obtained by the query. Since then, the blockchain-based e-Tendering System of the entire tender evaluation process has been experimentally verified and succeeded.
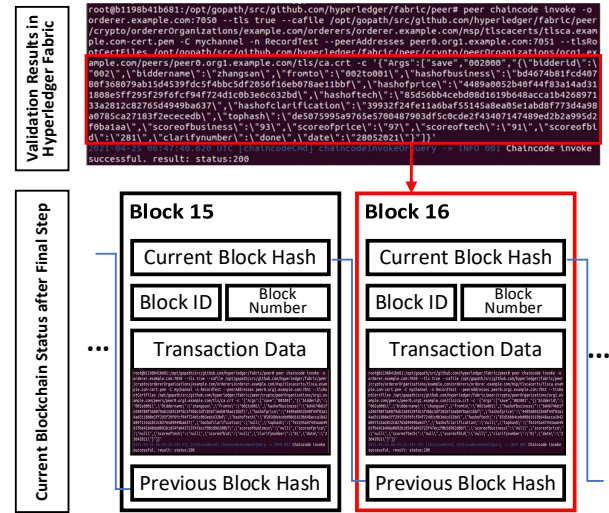

Figure 10. Scenario Ⅲ: Scoring Bid of No.002 Bidder

According to the information inquired by the purchaser, the ID required for the query is 002000. The result is the latest submission. The experiment of this step is finished.

Because a large amount of data needs to be stored in tender evaluation, the documents submitted in each clarification work need to be properly held for future inspection and verification if necessary. The smart contract "RecordTest" designed in this article also has a historical query function. In the experiment, all the information submitted by bidder No. 002 was extracted, and the results are shown in Figure 11.
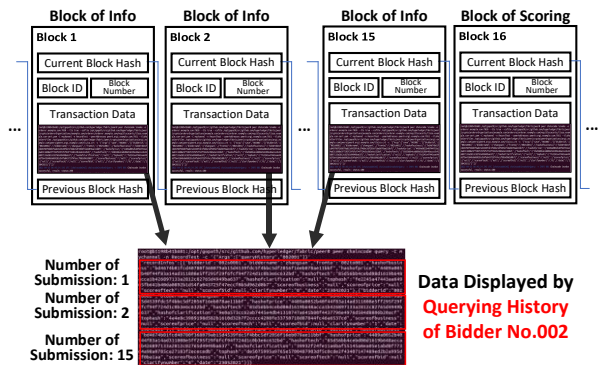

Figure 11. Query Historical Data of No.002 Bidder

Because the format of the input information used in the scoring stage is different, when querying the historical information of the bidder, the content related to the score

is not displayed in the result. As shown in in figure 11, because the verification design omits the repeated steps in the middle, only the three entered information is displayed. They are the first submission (submission of bid), the second submission (first clarification), and the fifteenth submission (fourth clarification).

5   Conclusion

This study proposes a Blockchain-based E-tendering Evaluation Framework for enhancing data security in electronic biddings. The framework proposes a transaction data model to realize the information exchange in tendering. A smart contract is proposed to complete the interaction between the transaction data and the blockchain system.

The framework has been verified in three scenarios: "Initial submission of information," "Update submitted data," and "Scoring bid." The verification results show that it can provide a more secure e-tendering collaboration.

However, there are still limitations in research: (1) The framework only tests some limited scenarios. (2) This design only considers tendering evaluation under standard conditions. Some special requirements, such as quality assessment, have not been validated.

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