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Trusted Evidences on the Digital Transformation of Classic Cars Restoration

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Abstract

Classic automobiles are a crucial component of the automotive industry, representing specific eras' historical, and technological accomplishments. However, to be regarded as masterpieces, these must be conserved in mint condition or restored following strict guidelines applied by expert services. Therefore, all data about restoration processes, and other relevant information about these vehicles, must be rigorously documented to guarantee its auditability and immutability. This paper reports on our ongoing research to properly provide such features to the classic car ecosystem.

We are developing a blockchain-based solution that facilitates the adequate recording of classic car information, restoration procedures applied, and all associated documentation by ensuring this data is immutable and trustworthy, while also promoting collaboration between interested entities.

Our proposed solution aims to be advantageous for all automotive entities involved. Additionally, it will be feasible to assess the impact of our system and its key technology, blockchain, applied to this particular domain.

Keywords: Blockchain; Smart Contracts; Classic Cars Restoration; Digital Transformation

1. Introduction

Classic automobiles are much more than old cars and are sometimes considered true works of art due to the materials used in their original construction, the craftsmanship involved, and their historical significance. As with other pieces of art, these vehicles are often collectible items and can fetch high prices when sold. However, to be considered masterpieces and associated with a high price tag, most vintage cars must be meticulously preserved or undergo strict restoration processes. This involves expert restoration services that adhere to national and international guidelines, such as the 'Charter of Turin Handbook' [9] published by *FIVA*. The restoration process can significantly

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impact the automobile's price and overall quality, so it is essential to document and record all activities performed during each process. This documentation can be used for certification or evaluation by classic car owners, workshops, and certification institutions.

The lack of trust and transparency and the necessity to provide rigorous information in the classic car sector is the problem we are trying to tackle with our work, offering a unique solution using blockchain technology, to document immutable information about restoration procedures, with all related pieces of evidence, like media files or any other type of vehicle documents, together with an appropriate access control mechanism and policy, capable of effectively handling diverse scenarios within the classic car industry, as different stakeholders may require different access levels, achieving an immutable and trustworthy portfolio of the car's history.

Our proposed work aligns with an ongoing project [10, 7] that aims to digitally transform a classic car shop by developing a platform dedicated to tracking the progress of classic car restorations. This web platform enables customers to monitor the progress of their vehicles and access documentation generated throughout the restoration process. To minimize human intervention, the system uses machine learning algorithms and sensors to automatically identify the type of restoration activities conducted on the vehicles, together with input provided manually by a plant shop manager using a Workflow Editor to create Business Process Model and Notation (BPMN) and Decision Model and Notation (DMN) models that represent the restoration processes supporting the guidelines from *FIVA*'s Charter of Turin [9], this way naming this platform as *Charter of Turin Monitor*. Additionally, the platform facilitates video conference sessions with remotely controlled cameras. It is important to mention that the *Charter of Turin Monitor* is in continuous use at the workshop and obtained valuable feedback from Museu do Caramulo and *FIVA*. Please refer to the cited papers for additional information about this project.

We adopted a Design Science Research Methodology [11], which consists of a scientific and systematic outcome-based approach aiming to acquire and develop the necessary knowledge to provide an innovative solution to our problem, offering identified guidelines for evaluation. This methodology involves iterative design, development, and evaluation cycles to create a practical and valuable solution. The initial phase of this methodology involves identifying the research problem, which, in our case, revolved around the need for enhanced transparency and the necessity to provide minute and credible information regarding vintage cars. Subsequently, we formulated our suggestion: to explore blockchain technology and its unique attributes to address this problem. The third step consists of developing the necessary artifacts aligned with our proposal. The fourth and fifth steps consist of evaluating our solution and results through various methods and highlighting the significance and impact of the work developed, respectively.

We anticipate two significant contributions as a result of completing this project. The first is a decentralized, trustworthy blockchain-based platform to adequately register all the procedures and documentation associated with classic car restorations, assuring that this evidence is tamper-proof, immutable, and auditable. This platform must be integrated with the existing system at the mentioned classic autoshop, where the digital transformation is actively underway. The second is a practical product for all the interested stakeholders of the classic cars sector, from vehicle proprietors to restoration shop administrators and authentication regulators, streamlining their tasks and adding significant value, positively influencing the digital transformation of classic vehicles and associated processes.

The rest of this paper is organized as follows: in section 2, some insight into important concepts to the work being developed is provided; section 3 presents previously developed projects with similar objectives and research questions; then, in section 4, the proposed platform and its architecture are detailed; in section 5, we present the corresponding validation efforts; finally, in section 6, we present our conclusions and prospects for future work.

2. Background

Blockchain technology is often described as an exceptional solution for the longstanding challenge of establishing trust among humans [2]. It is a decentralized and distributed digital ledger that allows the recording and verification of transactions without a central authority. It is a distributed system that stores, manages, and shares data among all participants in the network, maintaining a continuously growing list of transaction data records, which are cryptographically secured to prevent tampering and revision.

Blockchain technology was first proposed in a white paper published by Satoshi Nakamoto in 2008 and was introduced as the underlying technology for the Bitcoin cryptocurrency [15]. This paper detailed a peer-to-peer (P2P)

online payment system that, by establishing an immutable, decentralized public ledger that records all transactions and forbids double-spending, eliminated the need for banks.

Understanding blockchain requires familiarity with its key technologies. Though not new, their combination makes blockchain unique. These include:

- **Cryptography** plays a crucial role in securing digital data and is essential for almost every application that runs on the Internet. It establishes secure digital identities for each network participant and verifies transactions through cryptographic hashing and digital signatures, ensuring authentication, non-repudiation, and data integrity;
- **Distributed Ledger Technology** makes it possible to maintain information securely and decentralized by logging asset transactions on a shared database;
- **Consensus Protocols** determine how a network agrees on the state of a ledger and validates transactions. After an update on the ledger, all the nodes in the network must have a single and accurate copy of the ledger, but this is only possible after the nodes reach a consensus on which version of the ledger is correct. The higher the number of nodes in the network verifying and validating the transactions, the more secure the network. The most popular consensus protocols are the *Proof-of-Work (PoW)* which was introduced to the blockchain technology with Bitcoin's creation, *Proof of Stake (PoS)*, which consists of a viable alternative to PoW and which the *Ethereum* blockchain recently adopted, and *Crash Fault Tolerance (CFT)* and *Practical Byzantine Fault Tolerance (PBFT)*, consensus protocols widely used in permissioned blockchains.

Together, the presented technologies and their noteworthy development make blockchain a technology with unique and distinctive characteristics that have been gaining interest and relevance among several sectors all around the globe. These characteristics are decentralization, immutability, persistency, transparency, traceability, and integrity in trustless environments. An additional crucial technology that has significantly contributed to the widespread acceptance of blockchain is **smart contracts**. Basically characterized as code deployed and operational within the blockchain, smart contracts also provide the ability to automate the execution of specific functions when predefined terms and conditions of an agreement are met, regardless of the level of trust between parties involved [5].

Depending on the use, requirements, and access permission levels, blockchain systems can be categorized into three types: public, private, or consortium. Each type has unique features, characteristics, advantages, and disadvantages.

Public or **permissionless** blockchains are typically open source and available to anyone worldwide without restrictions. Network participants can read, write, and participate in the consensus process, validating transactions and blocks to be added. This blockchain type provides economic incentives for users to participate in the consensus process to attract more participants to join the network. *Bitcoin* blockchain is the first and most notorious implementation of a public blockchain. Another extremely popular public blockchain is *Ethereum*. However, this platform can be enhanced to offer useful applications for enterprise-focused industries.

A **private** blockchain is a digital ledger that provides proprietary networks where a central organization can grant access to the potential participants. Within an organization, a specified group of users holds centralized write permissions, whereas read permissions can be restricted or available to the public. Industries specifically design this kind of blockchain for their internal and commercial due to its effectiveness and auditability. *Ethereum* and *Hyperledger Fabric* are the most commonly used platforms to deploy and maintain private blockchains.

A **consortium** or **hybrid** blockchain is derived from the two previously mentioned types. As the name suggests, a group of organizations collaborates to maintain the network in this blockchain category. In contrast to writing permissions, which are only given to verified and acknowledged participants representing the associated organizations, read permissions can be public or restricted. This type of ledger is best suited for inter-organizational collaboration. As in private blockchains, the most popular and well-suited platforms for consortium blockchains are *Ethereum* and *Hyperledger Fabric*.

Table 1 depicts a comparison between the blockchain environments presented.

Table 1. Comparison between public, private and consortium blockchain networks

	Public blockchain	Private blockchain	Consortium blockchain
Network join permission	Open	Restricted	Restricted
Consensus determination	All block generators	Selected nodes from one organization	Selected nodes
Transaction visibility	Public	Public or restricted	Public or restricted
Permission	Permissionless	Permissioned	Permissioned
Decentralized	Full	No	Partially
Trust in the network	Not required	Required	Required
Data privacy	Low	High	High
Efficiency	Low	High	High

3. Related Work

We now present the results of our literature review to identify, examine, and evaluate available findings and analyses of other authors on our topic, providing the necessary background about the available technologies and limitations in current research.

3.1. Blockchain-based Documentation Solutions

Several solutions in the literature present a novel implementation using blockchain technology to facilitate, store, and generate trustworthy documentation, although applied in different industries, such as healthcare and supply chain, but with similar requirements.

Zhong et al. [18] proposed a framework that uses blockchain technology to manage the impact of hospitals during the COVID-19 pandemic by tracking infection control measures. The framework ensures an immutable, tamper-proof record of events and authenticates records. *Hyperledger Fabric* is the selected platform to implement the blockchain network. The blockchain is a consortium blockchain, where different organizations with different permission levels interact. The framework is supported by off-chain cloud data storage to store larger data files unsuitable for blockchain storage.

Another solution proposed by authors in the healthcare sector in [12] is a lightweight blockchain architecture for managing healthcare data. A PBFT protocol is used to achieve consensus on the ledger. As patient data is sensitive, the authors opted for a permissioned blockchain network that limits network participation to authorized members. However, this architecture does not support smart contracts, a significant limitation compared to *Hyperledger Fabric* or the *Ethereum* platform. While this solution offers several benefits, such as reduced computational energy consumption and increased transaction throughput, its inability to support smart contracts limits its potential applications.

Zhang et al. [17] propose a system architecture based on blockchain technology to track and store data of all the operations involved in the entire grain supply chain to guarantee food quality and safety. The authors designed a multimode storage mechanism to improve blockchain storage efficiency. The blockchain network, developed with *Hyperledger Fabric*, ensures that the information is traceable and credible and supports the execution of smart contracts. Moreover, each of the blockchain's nodes also has an off-chain database component to solve the problem of blockchain's insufficient storage capacity when there is the need to store large amounts and varied types of data or when the data to be stored does not need a consensus to be reached.

In [8], the authors proposed a smart contract-based supply chain framework using a permissioned blockchain network. This framework was optimally designed to be applied to the US beef cattle industry but can be adapted to other supply chains with minimal modifications. The system ensures that all operations along the supply chain are recorded in the blockchain to guarantee that the generated data is immutable, confidential, and tamper-proof. The proposed solution is based on the *Ethereum* blockchain platform and presents a P2P network, where each node contains not only the blockchain but also needs a local database service to store raw farm data.

3.2. Blockchain-based Vehicle Documentation Solutions

Several commercial projects have a scope similar to ours, for instance, *VINchain* and *carVertical*. Both present a solution to transparently and securely record important information about vehicles using blockchain technology. In both cases, the information about a specific vehicle is retrieved using its VIN (Vehicle Identification Number). However, it is necessary to pay to obtain the desired information. Both solutions do not implement efficient data access management mechanisms since anyone with access to the vehicle's VIN and willing to pay to get the associated data will have it. In contrast, even the vehicle owner would have to pay to get information about his vehicle, and to the best of our knowledge, both do not seem to have been receiving recent and recurring updates.

Another commercial implementation using blockchain, in this case, specifically geared towards the classic vehicles sector, is *The Motor Chain*. However, it primarily focuses on a basic timeline of events of a classic car, e.g. exhibition events and summaries of restoration procedures, and does not follow the guidelines and best practices expressed in *FIVA*'s Charter of Turin, providing thorough details of the vehicles and its restoration procedures. To the best of our knowledge, this system lacks the capability to incorporate other types of media evidence besides photos, and there is insufficient information accessible on the access management mechanism. Furthermore, due to its proprietary nature, there exists no accessible means to verify the actual usage of blockchain technology.

While searching the published literature, we realized that blockchain technology is being applied in several areas of the automotive industry beyond the scope of our research, such as in facilitating communication in autonomous vehicles. Those other applications are not reviewed here.

Regarding the studies using blockchain technology to store and secure trustworthy information about vehicles, our focus of interest, we left out those not peer-reviewed, oversimplified, without practical use, or using outdated blockchain platforms or technologies that no longer work due to discontinued components or developer abandonment. Notwithstanding, some relevant research explores blockchain technology in securing immutable vehicle documentation, as follows.

Y. T. Jiang and H. M. Sun [13] proposed a blockchain-based system to create a trusted source of vehicle data for the second-hand vehicle market. The system uses a consortium blockchain network built on the *Ethereum* platform and utilizes the *Proof of Authority* (PoA) consensus protocol. The PoA protocol verifies and combines transactions in blocks through selected credible entities, similar to the Practical Byzantine Fault Tolerance protocol. The system provides access control management, allowing different entities, such as car dealers, repair shops, and government branches, to interact with specific data stored on the ledger. Each vehicle is identified by its unique VIN, and a token provided by the car dealer is required to access its data record. Since the system uses *Ethereum*, recording data on the ledger incurs a transaction fee in the native cryptocurrency *Ether*. The cost of transactions may vary based on fluctuations in the cryptocurrency market.

In [3] and [4], from the same authors, a vehicle data and process ledger framework was proposed to facilitate collaboration and secure sharing of vehicle data and maintenance history among multiple stakeholders over a consortium blockchain. This system aims to furnish a transparent record of a vehicle's history throughout its life cycle, starting from the original automotive manufacturer and ending with the car owner, by documenting all relevant operations and data, such as repairs, maintenance, and accidents. Access to a vehicle's data is restricted first to the manufacturer, car owner, and brand official repair shops. This access can also be granted to other entities, such as third-party maintenance shops or insurance companies. This solution mixes blockchain technology and classic databases for storage purposes. The authors chose *Quorum* as the blockchain platform for this implementation. *Quorum* enables control nodes to access the ledger using a whitelist, validates blocks using a specially designed consensus protocol that does not require mining, and removes the cost of executing transactions on the blockchain. However, it is worth noting that Quorum's requirement for smart contracts to be written in *Solidity* may limit its applicability in specific scenarios, as compared to other blockchain platforms such as *Hyperledger Fabric*.

In [14], the authors proposed a blockchain-based smart contract application to avoid some of the common challenges of the automotive industry, such as tampering with vehicle information and falsification of mileage. With the proposed solution, the vehicles' data is transparent, and immutable while also offering the possibility to streamline some processes, which leads to an increase in trust among customers and improved efficiency in the vehicle registration process while minimizing the need for paperwork and reducing costs. This solution's blockchain network implementation consists of *Hyperledger Fabric*. To the best of our knowledge, the proposed solution is a proof of concept, and

there was no validation or analysis of the results performed by the authors. However, the authors performed interviews with several stakeholders of the automotive industry and surveys to collect information and opinions that corroborate the need for our research, namely the lack of trust towards sellers and the general agreement that blockchain technology would represent a substantial enhancement to the sector, that the interested entities are willing to endorse.

Another relevant solution was introduced by G. Subramanian and A. S. Thamp [16]. The authors proposed a consortium blockchain solution, similar to the ones already presented, but focusing on the electric car market, where the major actors consist of the vehicle manufacturer, charging station, and battery manufacturer. Since electric vehicles and their charging stations have more software support, smart IoT sensors can be used to enable automatic interaction with the blockchain and the overall system, such as recording vehicle mileage during charging. *Ethereum* serves as the blockchain platform for this solution, with each transaction incurring an associated cost.

3.3. Discussion of the Research

Through our literature review, we identified and understood the technologies and tools needed to tackle similar issues, enabling us to draw certain conclusions. Even though certain literature examined was used in various fields and not specifically relevant to the automotive industry, it is vital in understanding cutting-edge technologies and can serve as a source of inspiration for our work. We concluded that consortium is the network type preferred in systems to record reliable documentation and that *Hyperledger Fabric* and *Ethereum*, or derivations from it, are the favored platforms.

Some relevant studies, projects, and initiatives specific to the automotive sector aim to preserve vehicle data, documentation, and overall history using blockchain technology. However, none of these have been adequately adapted or tailored to meet the specific needs and demands of the classic automobile context. These solutions primarily target the conventional automotive market, and the recorded data is typically plain and straightforward, like maintenance logs. The solution most tailored to the classic vehicle industry is *The Motor Chain*, however, it offers only a relatively limited timeline of events with no minute details and presents other issues identified previously. Both the owners of classic cars and the certification authorities, along with the restoration procedures, require a higher level of meticulousness, namely a precise and detailed record for every stage of the restoration process. Proper documentation outlining each step of the restoration process and associated evidence, grants authenticity that, as for most works of art, is highly considered for determining the market value.

The lack of trust and transparency and the necessity to provide rigorous information in the classic car sector is the problem we are trying to tackle with our system, offering a unique solution to record every restoration procedure, with all related pieces of evidence, like media files or any other type of vehicle documents (e.g., inspection reports), together with an appropriate access control mechanism and policy, capable of effectively handling diverse scenarios within the classic car industry, to benefit all the entities involved and streamline their tasks. As expected, addressing these problems in this sector entails specific challenges, which is something that this work aims to overcome, namely how to best structure and configure the blockchain network for the most valuable performance achievable and to align seamlessly with the classic car ecosystem.

4. Proposed System Overview

4.1. Requirements

To ensure a comprehensive system design, requirements elicitation drew upon the valuable expertise of industry specialists. This included renowned classic vehicle collectors, managers from reputable restoration shops, and key stakeholders within the automotive sector. Additionally, the knowledge acquired by all the participants throughout the rest of the project's progression was also vital for this purpose.

As previously stated, our goal with this project is to develop a decentralized solution using blockchain technology to enhance transparency, credibility, and immutability of records and documentation throughout the various stages of classic car restoration. This solution will require integration into the existing system in operation described in [10, 7].

Initially, we identified the entities with distinct stakeholders, which have different roles, requirements, and different levels of access to the system. Although we did not use formal techniques for stakeholder mapping, we relied on the

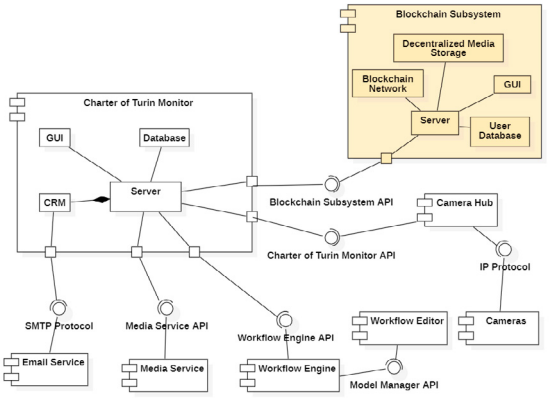

Fig. 1. Component Diagram of the proposed system's architecture, as an extension (in yellow) to the one proposed in [7].

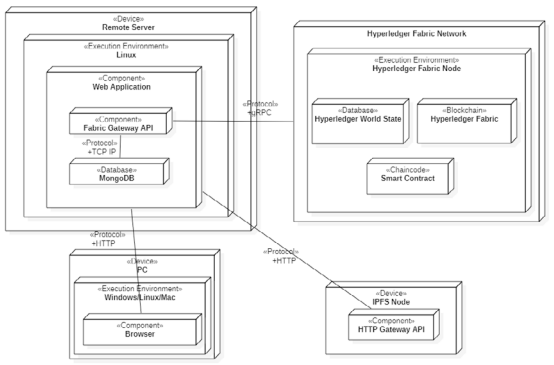

Fig. 2. Deployment Diagram of our solution.

extensive expertise and experience of the classic car shop's personnel where the project is based to identify these stakeholders. The stakeholders identified, their priorities and requirements are as follows:

1. **Classic Car Owners**: can register themselves as new users in the system; register a new classic car resorting to a certified restoration shop or certification authority; view the documentation of its vehicles; add documentation to its vehicles when desired to add legal documents, or individually perform a minor recondition or repair activity; grant permissions to other entities, such as view permissions to potential buyers or modification permissions to other restoration shops or certification authorities; finally, can change the ownership of its vehicles' records to another user;
2. **Certified Restoration Shop Administrators**: The restoration shops will be responsible for most of the restoration and conservation procedures, so they need to have the required access to modify the documentation of the vehicle;
3. **Certification Regulators**: Certification regulators of classic cars are responsible for proper certification of the vehicle after its restoration or repair. For this purpose, they require permission to check vehicle documentation. They will also need permission to mark the documentation as certified by the authority;
4. **Potential Buyers**: As previously mentioned, possible buyers of a classic vehicle can be granted permission to check the documentation of that car to verify its authenticity and procedures made to restore it, and ultimately, if the buyer decides to buy the car, he gets complete access to the car's history, while the original owners get his permissions revoked.

4.2. Architecture

The component diagram in Figure 1 is an overview of the current system's architecture. It is an upgraded version of the initial component diagram for the system used at the classic restoration shop [7]. This project involves developing various artifacts, identifiable by their colored components and parts. Although the component diagram depicts them as a subsystem integrated into the repair shop platform, they can function as an independent system for other entities. The integration of the system will add restoration evidence to the car's blockchain ledger automatically. Our solution is divided into several components:

1. **Blockchain Network**: To securely and immutably preserve data about every detail of all the documentation of restoration processes, such as procedures, materials, tools used, and the hash of other generated pieces of evidence, such as images and videos. Smart contracts are used to record the data.
   For this purpose, the chosen technology was ***Hyperledger Fabric***. Fabric is a consortium-oriented blockchain platform that is highly configurable, increasing scalability and performance. Fabric allows for the creation of

organizations comprising different users for entities connected to the network. These entities include restoration shops, certification authorities, and car owners. It also supports the creation of channels and enables private data collections and attribute-based access control for selected network members to communicate with data isolation and confidentiality. Other benefits of choosing Fabric are that no transaction costs are associated, and smart contracts can be written in general-purpose programming languages. The vehicles are identified by their VIN and all operations pertaining to vehicles rely on this attribute.
The programming language chosen for the smart contracts was ***Go*** due to being the most optimized language and, therefore, the most adopted among developers of Fabric's community.

2. **Web Server**: A Linux web server connects users with all other components. It accepts HTTP requests from the client app and communicates with the blockchain network and the rest of the components. These requests granted through a middleware *REST API* implemented with the ***Express*** framework for ***Node.js***.
3. **Decentralized Media Storage**: As our system is based on blockchain, it is also important to store media files associated with classic cars decentralized. However, blockchain is not suitable for high-volume data storage. To address this issue, ***InterPlanetary File System*** (***IPFS***) is used as off-chain media storage. *IPFS* is a decentralized, P2P file storage system that provides redundant, efficient, and permanent storage for different types of files.
4. **User Database**: To facilitate user registration and, consequently, authentication on the system with typical credentials, besides the registration within the blockchain platform that records the user as an entity of the network, attributing it a public and private key, the user is also automatically registered in ***MongoDB*** database. This ensures that the user can be authenticated in the system with credentials, such as email and password. Still, when interacting with the blockchain network, it uses the expected certificates.
5. **GUI**: A Graphical User Interface (GUI) is necessary for the web application of this system, allowing users to interact with different functionalities based on their roles. The vehicles' information is displayed as a portfolio with all the relevant data that can function as an Identification Card of the vehicle, which we called *Vehicle Card*. We decided to use ***Angular*** for our front-end since the software available at the repair shop where our solution is being integrated uses this technology as its front-end.

The component diagram of our system's architecture and the technologies employed were combined to generate the deployment diagram in Figure 2.

5. Results and Validation

In a Design Science Research methodology, evaluating the solution is crucial. Therefore, it is vital to use precise and thorough methods to assess its impact, quality, and performance.

5.1. Performance Evaluation

Performance tests were conducted to simulate real users making requests using the Web app by employing Bash Shell scripts to communicate with the Web server via a REST API. This evaluation's goal was to collect data about the duration of each specific type of request. We must acknowledge that our work is still in development, so the blockchain network may suffer some topological modifications in the future, which consequently can affect the performance of the system. Our blockchain is currently deployed on the cloud, with *Kubernetes* being used as our container management platform for deploying and managing the network, which is composed of 4 organizations: one running the ordering service with three orderer nodes and the other three organizations running two peers each. This way, we can obtain significant results for our work promptly.

Table 2 displays the minimum, average, and maximum duration times, in seconds, for specific requests that were expected to be among the most frequently utilized, with each request being executed 30 times. Requests marked with an asterisk (*) refer to instances of that request with notable alterations, such as increased data to be uploaded or retrieved.

We observe that the requests involving the registration of information on the blockchain exhibit similar execution times between them, averaging around 2.2 seconds. However, when there are additional media files to process, the duration of these methods experiences a notable increase, sometimes exceeding 15 seconds, as seen in request 6, which

Table 2. Performance Evaluation: platform request's duration, in seconds.

Request	Minimum	Average	Maximum
1) Register a new user on the system	0.812	0.930	1.283
2) Login a user	0.133	0.139	0.177
3) Get the classic cars owned by a specific user	0.103	0.111	0.133
3*) Get the classic cars owned by a specific user (more cars)	0.294	0.314	0.473
4) Register a new classic car	2.268	2.299	2.397
6) Add a new restoration procedure	2.293	2.324	2.375
6*) Add a new restoration procedure (with 1 or 2 media files)	4.077	6.436	9.237
6) Add a new restoration procedure (with more than 5 media files)**	13.121	14.823	22.225
7) Get the information of a specific classic	0.091	0.098	0.104
7*) Get the information of a specific classic (more information)	0.247	0.262	0.296
8) Get the history of a specific classic	0.193	0.233	0.255
8*)Get the history of a specific classic (more history updates)	6.265	8.398	12.141
8) Grant/Revoke access permissions to a specific vehicle	2.229	2.361	2.451
5) Change a classic's owner	2.210	2.462	2.703

will definitely be noticeable to an end-user. This is due to the fact that each media file needs initially to be uploaded to *IPFS*, followed by retrieving the resulting *Content Identifier (CID)* to subsequently record it on the blockchain.

Alternatively, the methods that solely read a relatively low amount of data from the blockchain typically demand significantly less time, spanning from 0.2 to 0.5 seconds. Nevertheless, similar to in write request, this duration significantly increases as the data to be retrieved increases, potentially exceeding a 10-second duration, as evident in request 8.

5.2. Usability Evaluation

A comprehensive usability evaluation has been planned, and it is anticipated that the usability evaluation will be carried out shortly after the completion of the GUI. For GUI validation, we anticipate analysis from the viewpoint of each user role (car owner, workshop worker, certification administrator, and buyer) since each will have other interactions with the platform due to the required permissions levels.

To validate the users' interaction with the system, we plan to use an interview approach with the help of surveys. Ideally, none of the users should need any prior knowledge. We intend to use two metrics in these interviews. The first is the Customer Effort Score (CES) [6], which consists of users rating how difficult it was to perform specific tasks. In addition, the System Usability Scale (SUS) [1] is also going to be employed to assess the participants' overall experience by having them rate ten questions on a scale of 1 to 5, where one represents Strongly Agree, five denotes Strongly Disagree.

6. Conclusions and Future Work

In this paper, we described our ongoing effort to develop and validate our blockchain-based solution to adequately record all the data and documentation involved in classic car restoration processes and to make all this information available to interested entities in a transparent, secure, and immutable manner. Furthermore, a review of the available literature was conducted to confirm the relevance of this research.

Besides extending the capabilities of the available platform at a classic car restoration shop, it also reifies a valuable solution for application in other contexts in the classic car industry. The platform mentioned and its underlying technologies have gathered interest from several classic car restoration industry players, classic car owners, other workshops, and certification entities. We anticipate our work will increase their interest and participation, significantly improving the platform and validation procedures.

As future work, we will continue developing and refining our blockchain-based solution, improving our web application and blockchain network while conducting rigorous testing and validation, with a pronounced focus on usability, to ensure its effectiveness and reliability. Additionally, we will focus on integrating our solution with the shop's

platform. We aim to develop an efficient and integrated system that will benefit all parties engaged in the classic automobile restoration process by increasing transparency, security, and efficiency. It will also be feasible to evaluate the suitability and influence of blockchain technology, along with its distinctive attributes, within the domain of classic automobiles.

Since our work is still under development, certain elements related to the mentioned technologies and implementation remain subject to potential modifications or replacements. The primary areas identified for consideration include the adaptation of the blockchain network structure to better suit the classic car domain and the potential replacement of decentralized media storage due to performance-related factors.

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