A Decision Support System for Blockchain Platform Selection

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Abstract— **The blockchain technology is a new innovation with the potential to disrupt the world as we currently know it, despite several limitations and challenges to overcome. One of these challenges for software producing organizations is selecting the right technology for their case. In this research we identified this selection process as a multi-criteria decision making problem. Based on this we created a Decision Support System which aids developers during the technology selection process of blockchain platforms. Contemporary solutions to this problem were only rather simplistic decision-models which struggle with complexity and adaptations. The novelty of this Decision Support System lies in being a feature-based artifact which incorporates ISO software quality standards and feature prioritization based on the MoSCoW-technique. This Decision Support System was evaluated in three different case-studies with organizations creating blockchain-based solutions.**

Key words: Blockchain, Technology Selection, Multi-criteria Decision Making, Decision Support System

I. INTRODUCTION

The blockchain technology has received a massive increase in attention the last few years. Conceptualized by the release of the Bitcoin cryptocurrency [6], the fundamental technology behind it might rise to even higher peaks than Bitcoin itself. The blockchain technology can be best described as a distributed ledger technology that solves the double-spending problem [7], [6] through cryptography. The double-spending problem is a potential flaw in digital cash transactions, in which the same digital value can be spent more than once through duplication or falsification. Currently this double-spending problem is dealt with by trusted third-parties, such as banks, notaries, escrow agents or key distribution centers (KDC). The blockchain technology has the disruptive potential to completely replace these trusted third-parties for solving the double-spending problem. Although the initial domain of application of the blockchain was the payment sector, the blockchain technology has the potential to disrupt a tremendous amount of business processes in other industries such as healthcare, logistics and supply chain management [8]. Despite all the potential the blockchain technology offers for implementation, it is at present not fit to replace these business processes with a blockchain-based solution yet. With the blockchain technology still being in its infant-stage technical challenges such as scalability, privacy and security [9]. Another argument for not using a blockchain is that occasionally the blockchain technology has no real value proposition over a more centralized solution such as a Database-Management System (DBMS) [10].

Once established a blockchain-based solution is the right underlying technology, a software producing organization (SPO) faces the challenge selecting one the blockchain platform alternatives available on the market. Succeeding the Bitcoin-blockchain, more sophisticated and feature-rich blockchains with the possibility to develop decentralized-applications (dApps), create cryptographic tokens or other blockchains began to emerge. This selection process for a SPO is complicated because many factors, such as security and market positioning, have to be considered. In this study, the Blockhain Platform (BP) selection process is modeled as a multi-criteria decision-making (MCDM) problem that deals with the evaluation of a set of alternatives, and taking into account a set of decision criteria [11]. This study introduces a Decision Support System (DSS) to help decision-makers with MCDM problems, in this specific case BP selection. The DSS is a tool that can be used over the full life-cycle and can co-evolve its advice based on evolving requirements. The DSS applies the six-step decision-making process [12] to build maintainable and evolvable decision models for MCDM problems, and makes the knowledge acquisition more reliable and trustful. In our previous work [1], [2], [3], we built decision models for the database technology selection problem [2] and one for the cloud-service provider selection problem [1]. In both these studies we conducted several case studies to evaluate the DSS. The final results showed that these DSSs performed well to address the DBMS and CSP selection problem for software-producing organizations. The novelty of the DSS lies in utilizing the MoSCoW prioritization technique (MoSCoW) [5] to assess criteria weights and reduce uncertainty, in introducing assessment models to measure the values of non-boolean criteria, and in using ISO/IEC quality aspects to indicate the relationship among criteria according to domain experts knowledge.

This paper has the following structure. Section 2 describes the design science method followed and the exploratory theory testing case studies that have been performed. Section 3 describes related literature of software technology selection and the traditional approaches to solving decision-making problems. Section 4 outlines the details of the proposed decision support system and emphasizes the usage of novel techniques such as ISO qualities and the MoSCoW-technique. Section 5 illustrates an application of the DSS to address the BP selection problem, using three case studies to evaluate and emphasize the significance of the approach. Section 6 presents an analysis of of the case studies results Section 7 elaborates on the limitations and constraints of the DSS, alongside the conclusion. Finally, Section 8 offers directions for future studies based on this research.

II. RESEARCH METHOD

Blockchain platforms allow for rapid prototyping, development and deployment of new decentralized blockchain applications (dApps) [15]. These blockchain platforms are mostly open sourced and available for most to participate and use. Each of this blockchain platforms is designed with specific goals, which dictate its features. Should a company decide they want to develop a blockchain application they have to select the right blockchain platform for their case. Not every blockchain platform offers the same features (due to different goals) which are required for a specific case. Software-producing organizations typically are not knowledgeable in the problem domain, which is finding the most suitable alternative for their businesses based on their requirements and priorities. The knowledge regarding the problem domain does not make any difference in the selection process, because the right selection requires regular studying and tracking available alternatives in the market. This research proposes the Blockchain Platform Decision Support System (BPDSS) which incorporates the six-step decision-making process [12] with the goal of finding suitable alternatives that support a set of domain feature requirements for a SPO.

The research approach for creating this DSS is the Design Science Research method [14]. Design science addresses research through the building and evaluation of artifacts designed to meet the identified business need [14]. The business need for an artifact for SPOs has been elaborated on in Section 1. According to this Design Science cycle first the required knowledge is gathered, then the artifact is built in an incremental process and finally evaluated. The knowledge required for the creation and evaluation of the BPDSS was gathered during two series of interviews and applied during the evaluation in another interview. Ten blockchain experts (four researchers from Dutch research institutes, two blockchain-developers and four blockchain consultants/public-speakers) participated in this research.The domain experts were pragmatically selected according to their expertise and experience that they mentioned in their professional profile. Each of the interview series followed a semi-structured interview protocol. Data collected during one interview, would typically be propagated to the next, to incrementally build and validate the knowledge base. The knowledge base was sent to the interview participants afterward for final confirmation.

The efficacy, generality and validity of the DSS were evaluated through three exploratory theory-testing case studies. The unit of analysis is a unique BP selection for a Software Producing Organization. We performed three such case studies at software producing organizations to evaluate the DSS. The case studies typically consisted of (1) defining the domain feature requirements, (2) prioritizing them, and (3) comparing the DSS feasible solutions with their solutions.

III. RELATED WORK

This research utilized the snowballing method[21] to identify the approaches and techniques used by other studies to solve MCDM-problems for SPOs. In addition to this snowballing method we'll also discuss some approached identified in our previous work [1], [2] to amplify the importance of our chosen approach. Examples of other MCDM methods are *Analytic Hierarchy Process (AHP), Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), Machine Learning (ML) and Fuzzy based decision making* [22]. However the problem with many of these methods is that they use pairwise comparison to assess the weight of criteria, which becomes rather time-consuming and complicated as the number of criteria increases [23]. These MCDM approaches were mainly identified and explained within research related to our previous work for which the technology domain differed compared to this research. Within the MCDM-domain of Blockchain selection the *Binary Decision Diagram (BDD), Case-based Reasoning (CBR) and the Simple Multi-attribute Rating Technique (SMART)* were contemporary approaches. The *BDD* is a data-structure that is used to represent a boolean function. They can be considered as a compressed representation of sets or relations. The output of these BDDs is always binary. Within the other studies and decision tools for blockchain selection [17], [18], [19] the BDD approach is utilized in the initial stage of decision-making whether a blockchain-based solution is appropriated or not. Following this binary decision, these studies either utilized *CBR* [17], [18] or *SMARTS* [19]. *Case-based Reasoning* is the process of solving new problems based on the solutions of similar past problems. Similar to *Machine-Learning* and *rule-induction algorithm* approaches, *CBR* starts with a set of cases or training examples; it forms generalizations of these examples, albeit implicit ones, by identifying commonalities between a retrieved case and the target problem. However, one of the drawbacks of this approach is the reliance on anecdotal evidence rather then being backed by statistical relevance. Quite often this is the result of data-scarcity, which in line with the immaturity of the blockchain domain is comprehensible but not ideal. A *Multi-Attribute Utility Theory* based function is used to represent the preferences of an agent over bundles of goods either under conditions of certainty about the results of any potential choice, or under conditions of uncertainty. The most general situation is that there are both multiple attributes and uncertainty when the decision has to be made. *SMART* is one of the simplest *MAUT*-based methods, however it struggles with more uncertainty and complexity than more advanced *MAUT* approaches such as *AHP* and *TOPSIS* [24].

The DSS method provides a substantial number set of criteria to support decision-makers. As concluded in our previous work the DSS-method deals well with a large number of criteria and alternatives, and doesn't struggle with complexity or adaptations because it is an evolvable and expandable model-based approach that splits down the decision-making process into four maintainable phases.

Furthermore, it utilizes the ISO/IEC 25010 as a standard set of quality attributes [13]. These quality standards are domain-independent software quality models and provide reference points by defining a top-down standard quality

TABLE I

THIS TABLE COMPARES SELECTED MCDM METHODS FROM LITERATURE TO ADDRESS TECHNOLOGY SELECTION PROBLEMS. THE SECOND COLUMN (PROBLEM DOMAIN) POINTS OUT THE PROBLEM DOMAIN. THE THIRD COLUMN (MCDM) DENOTES THE MCDM APPROACH. THE FOURTH COLUMN (PAIRWISE COMPARISON) INDICATES WHETHER THE APPROACH APPLIES PAIRWISE COMPARISON AS A WEIGHT CALCULATION METHOD OR NOT. THE FOURTH COLUMN (QUALITY ATTRIBUTES) DETERMINES THE TYPE OF QUALITY ATTRIBUTES. THE SEVENTH AND EIGHTH COLUMNS (CRITERIA AND ALTERNATIVES) SIGNIFY THE NUMBER OF CRITERIA AND ALTERNATIVES THAT WERE CONSIDERED IN THE PROBLEM DOMAIN.

Authors	Domain	MCDM	Pairwise Comparison	Quality Attributes	Criteria	Alternatives
[1]	Cloud Service Provider	DSS	No	ISO/IEC 25010 EX. ISO/IEC 9216	300	40
[2]	DBMS	DSS	No	ISO/IEC 25010 EX. ISO/IEC 9216	307	73
[16]	Product Development Partner	FAHP FTOPSIS	Yes	Domain specific	16	6
[20]	Software-as-a-Service product selection	AHP	Yes	Domain specific	57	3
[17]	Blockchain Comparator	CBR BDD	Yes	Domain specific	5	8
[18]	Blockchain	CBR BDD	Yes	Domain specific	6	4
[19]	Blockchain Platforms for IoT and Edge Computing	BDD SMART	Yes	Domain specific	6	6
This paper	Blockchain Platform Selection	DSS	No	ISO/IEC 25010 EX. ISO/IEC 9216	75	29

model for software systems. The DSS utilizes the MoSCoW-technique [5] to assess the importance of criteria and reduce the uncertainty, moreover it introduces assessment models to measure the values of non-boolean criteria, such as the maturity and popularity of the alternatives. The studies mentioned in this section and relevant approaches have been summarized in Table 1.

IV. MULTI-CRITERIA DECISION-MAKING

The Blockchain Platform selection process is modeled as a multi-criteria decision-making (MCDM) problem that deals with the evaluation of a set of alternatives, and taking into account a set of decision criteria [11]. The artifact proposed to solve this MCDM problem will be the 'Blockchain Platform Decision Support System' (BPDSS) with all the fundamental components of a standard DSS [25]. A Decision Support System is a tool that can be used over the full life-cycle and can co-evolve its advice based on evolving requirements. In our previous work [2] we have introduced a model-based DSS for technology selection problems (Figure 1). In our CSP-selection research [1] we have extensively described the different components of our DSS and how they interact according to the study by Sage. This section will discuss it briefly in the context of the blockchain technology as well. According to this model several sets of data played an important role in the creation and utilization of the DSS. This data can roughly be divided into several sets: *Quality aspects, Domain Features, Domain-Alternatives* and the *Domain-feature requirements*. The Domain-Alternatives are the blockchain platforms available on the market, for example, Hyperledger Fabric blockchain from the Linux Foundation or the Ethereum blockchain by the Ethereum Foundation. These platforms were mainly acquired from documentation and literature discussing the most important contemporary Domain Alternatives. All these contemporary *Domain Alternatives* had to fulfill additional criteria, such as having their main-net deployed. It should be noted however, that some *Domain Alternatives* were be included that are strictly speaking not conform the definition of blockchains. But rather these platforms are distributed ledger technologies (DLT), which is an umbrella term for blockchains among other technologies [26].

A. DECISION MODEL

The framework from our previous work assumes different required data. This data can roughly be divided into several sets: Quality aspects, Domain Features, Domain-Alternatives and the Domain-feature requirements. The *Domain Qualities* are metrics to define the quality of software. The ISO/IEC 25010 [13] and Ext. ISO/IEC 9126 [4] are the most general applicable metrics. These quality aspects are domain independent and thus will all be utilized. The *Domain-Features* is a collection of the generic Domain-features which the *Domain-Alternatives* provide. Novel *Domain-features* will be excluded. Examples of *Domain-Features* in the blockchain domain are smart-contract support or off-chain transactions. Each *domain feature* has a data-type, which could be boolean or numeric. For example, smart-contracts are either supported or not (boolean), while the technological maturity of the platform can be either low, medium or high (numeric). These boolean *Domain-Features* were gathered through interviews with Domain Experts. The numerical features are: Technological Maturity, Popularity in the market, Innovation and Transaction speed. Compared to our previous work *Total Cost of Ownership* has been left out due to the open-source nature of many of the available *Domain Alternatives*. The numerical values were determined based on different parameters which are supported by literature and Domain expert knowledge.

To create the Decision Model the Domain-(sub)Qualities were mapped against which Domain-Features have a positive influence on those qualities. The Domain Alternatives are mapped against which Domain-Feature they provide in a similar way.

The ISO/IEC quality aspects in this model were used to indicate the relationship among the *Domain Features* in order to measure the importance of each *Domain Feature* based on the domain experts and the decision maker's perspectives. For example, the off-chain transactions feature influences the performance quality aspect or different consensus-mechanisms influence the fault tolerance quality aspect. The other mapping is between the *Domain-Alternatives* and the *Domain-Features* they provide. For example the Ethereum blockchain supports smart-contracts while the NEO blockchain offers book-keeping nodes. The lists of *Domain-Alternatives, Domain-Features, Domain-Qualities* together with the mappings (based on Domain Experts knowledge) form the Decision Model. In addition to this, there are the *Domain Feature Requirements*. The Domain Feature Requirements provide the decision-makers with the ability to prioritize each of the Domain-Features based on the MoSCoW-prioritization technique [5]. This technique categorizes the feature-requirements into either must-have, should have, could have or wont have. The Inference Engine receives these *Domain Feature Requirements* and their priorities, according to MoSCoW-technique as its input. A feasible solution must support all *Domain Feature Requirements* with Must Have priorities, and must not support all *Domain Feature Requirements* with Wont Have priorities. The Inference Engine ranks the feasible alternatives based on their calculated scores. The score calculation process is based on the well-known Weighted Sum Model. Thus, by sorting the feasible solutions in descending order of their scores, the final ranked feasible solutions will be given as the result of the DSS.

V. BLOCKCHAIN PLATFORM SELECTION

This Section will describe the parts of the Decision Model from Section 3 with respect to applying this in practice in the blockchain domain. Initially first the generic set of *Domain Features* was gathered and subsequently mapped against both the *Software Quality Aspects* and the *Domain Alternatives*. In addition to this, this section will also describe the different case studies providing the *Domain Feature Requirements* and their *Domain Alternative* choices.

Feature-Values: The generic *Domain Features* gathered were categorized as either boolean or numerical features. For the boolean features an initial set of domain features were extracted from blockchain literature. This initial list of Domain Features consists of 76 different boolean features, only informally sorted by category. These 76 features were discussed during 9 blockchain expert interviews (four researchers from Dutch research institutes, two blockchain-developers and four blockchain consultants/public-speakers). A feature was considered generic in a similar way as in our previous work. After this process 75 boolean features were identified as generic blockchain features. The final step was validating this set of features with several of the considered more knowledgeable experts.

The numerical features relevant for the BPDSS were *Technological Maturity, Popularity in the Market, Transaction Speed and Innovation*. The value for each of these numerical features for a specific platform could either be low, medium or high based on several underlying parameters. However, *Total Cost of Ownership* was left out due to many blockchain platforms being open-source. The starting point for all these parameters were based on our previous work. Adaptation to these parameters were made based on domain expert's opinion. the four parameters for maturity were: Number of employees, Yearly Revenue, consensus-mechanism used and founding year. The parameters for *Popularity in the Market* were: Number of followers on different social medias, daily executed operations and market-capitalization (if applicable). The numerical value for the *Transaction Speed* waas determined by the paremeters: confirmation time, the relative speed of consensus-mechanism and number of scalability technologies implemented. The parameters for *Innovation* were if a certain platform was supported by other organizations with respect to funding research, if platforms were working on niche features or focusing on specific industries.

Feature-Quality Aspects Relationships

To create the SF-Mapping, the relationship between the final list of Domain Features and the Software Quality Aspects from ISO/IEC 25010 Ext. ISO/IEC 9216 [4] had to be mapped. Determining these relationships would again be based on Domain Expert knowledge extracted from interviews. Four of these interviews were conducted, from which three experts also participated in the Domain Feature gathering process. These three experts were familiar with this research and the fourth expert was selected based on extensive experience with developing in the blockchain domain.

Feature-Alternatives Relationships

To create the FA-Mapping, the relationship between the final list of (boolean) Domain Features and the Domain Alternatives had to be mapped. Determining these relationships was based mainly on analyzing documents and auxiliary domain expert knowledge. These documents consist mainly of whitepapers describing each specific blockchain platform, updates in blogs by blockchain platform developers on *Medium* and other grey literature such as e.g. benchmarks from consultancy firms.

Case Studies Description

Three case studies in the context of three software producing organizations have been conducted to evaluate and signify the usefulness and efficiency of the DSS. The case study companies considered a number of feasible Blockchain Platforms for their organizations through multiple internal expert meetings and investigation into blockchain alternatives before participating in this research.

Case Study 1: ShareCompany BIQH: Following Regulation (EU) No 1286/2014 (Regulation 1286/2014), issuers of packaged retail investment and insurance-based products (PRIIPs) are by means of legislation compelled to lay

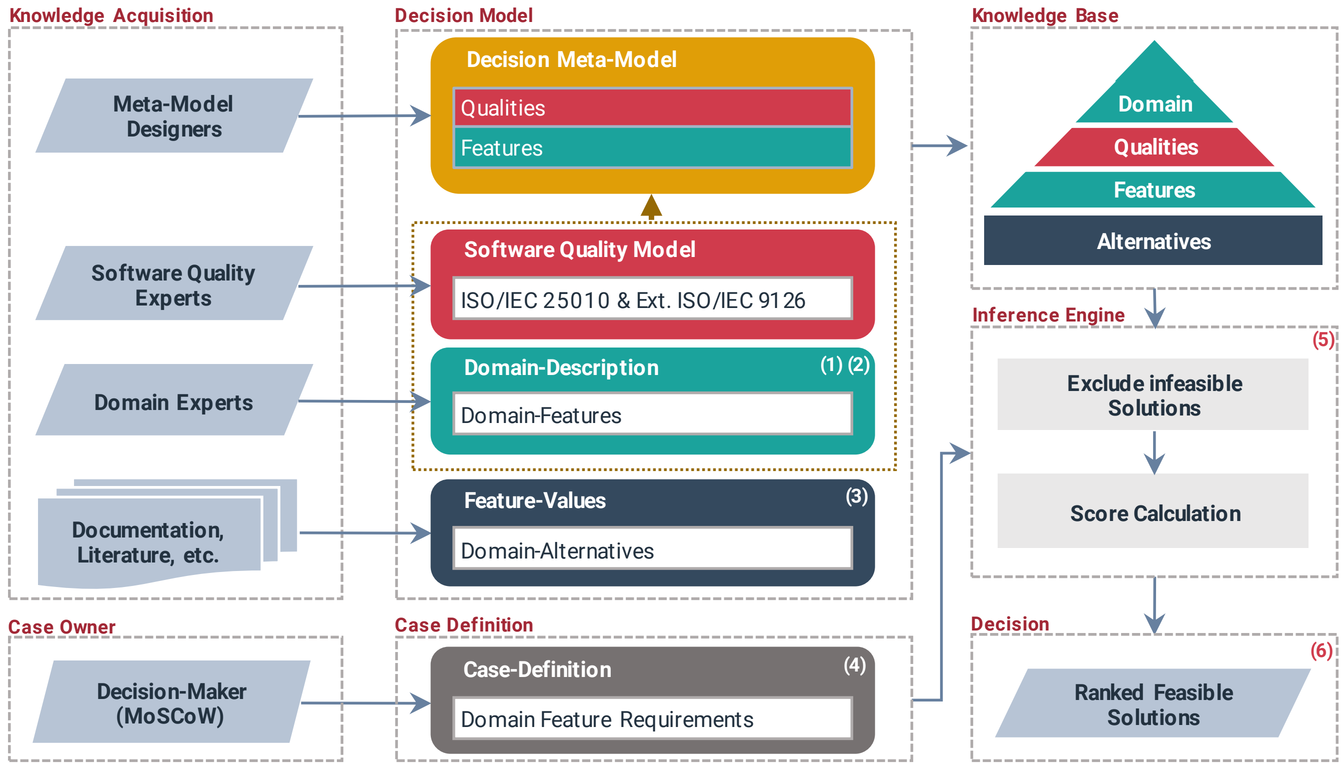

Fig. 1. A model-based decision support system for MCDM problems [1].

down uniform format on key information documents (KID), which are documents connected to PRIIPs. In wake of the legislation, at the request of one of their customers, Share-Company BIQH (A Dutch Fin-tech company) developed an information system that would help banks accommodate the requirements put forth by the European Union. Packaged retail investment and insurance-based products constitute an intentionally broad category (for sake of regulation), and encompasses all packaged and publicly marketed financial products that have exposure to underlying assets such as stocks, bonds, treasuries, etc. They have many properties, whereof the KID is but one. The purpose of the KID is to present essential information to the buyer about the product, in a way that is as unambiguous as possible. In other words, the KID is what investors are left with when information about PRIIPs has been trimmed for perplexing financial jargon. The concerning products are difficult to understand, in this way they are made more approachable to the general public, so that more people may benefit from them. The PRIIP issuing entities must ensure the correct and most recent KID has been shown to the investor at the moment of purchase of the PRIIP. After a successful deployment of a centralized solution, Sharecompany BIQH now wants to investigate distributed ledger technology (DLT), with the existing information system as the starting point and case for utilizing the blockchain technology. ShareCompany BIQH selected two potential alternatives for developing a decentralized application appropriate for this case. Their first choice as a potential alternative is the Hyperledger Fabric project. Strictly speaking, the Hyperledger project envelops several tools (Hyperledger Caliper, Cello, and Composer, Explorer and Quilt) and frameworks (Hyperledger Sawtooth, Fabric, Iroha, Indy and Burrow) from which the frameworks can be seen as independent blockchain platforms. However, for the sake of clarity, all these tools and frameworks are categorized under the term 'Hyperledger' in the BPDSS. The second choice as a potential alternative is the Quorum blockchain platform from JPMorgan. Initially Ethereum would be the second choice behind Hyperledger, however it was identified that proof-of-work feature was undesirable and there would be no need for a token. Quorum did meet these criteria, thus was chosen as the second alternative.

Case Study 2: DUO: DUO is the administrative and executive agency of the Dutch government for man- aging the educational system. DUO operates in the name of the Ministry of Education, Culture and Science and the Ministry of Social Affairs and Employment. DUO has eight different main functions with several activities as their core focus. This case study will merely focus on the process of student financing in the form of granting loans. Together with an Utrecht University student they created a Proof-Of-Concept for a decentralized application built utilizing the blockchain technology for the case of student financing by DUO. In this thesis project interviews were conducted with the relevant stakeholders, being representatives from: DUO Innovation Lab, LiteBit, Cyber Capital, Nibud and Foundation Forus. The Innovation Lab of DUO is the innovation unit from the extensively discussed DUO organization. LiteBit is a

Dutch cryptocurrency exchange, Cyber Capital is a Dutch company that specializes in cryptocurrency investments, Nubid is an independent consultancy agency in the Netherlands that researches financial matters of Dutch households and Foundation Forus is an independent foundation that develops blockchain applications. During these meetings and interviews, the *Domain Feature Requirements* and desirable *Domain Alternatives* were determined for this proof-of-concept.

The three main platforms that were considered are Ethereum, NEO and Hyperledger. Hyperledger, although deemed mature and offering a broad range of features there is no build-in cryptocurrency on this platform. Regarding development this would make things unnecessarily complicated, therefore Hyperledger was ranked third on the short-list. The other two alternatives (Ethereum and NEO) both offer this built-in cryptocurrency but differ on other aspects. Ethereum was considered to be the most developed of the two alternatives and therefore ranked as the most desirable solution on the short-list. However, NEO offers a higher scalability at the cost of less decentralization.

Case Study 3: Veris Foundation: The Veris Foundation is an organization focusing on the American healthcare system. One of the most heavily regulated and fractured markets in existence is the current healthcare market in the United States. Unnecessary expenses are added for everyone (and especially patients) due to an abundance of redundant processes between different parties such as providers, insurers, and patients. These unnecessary expenses are estimated to be above 59 billion dollars per year as mentioned by the Veris Foundation. They are under the assumption this fragmentation is a result of the different stakeholders unwillingness to assume the risk associated with designating an intermediary to handle the processing of data related to healthcare services between all stakeholders. This means that all the stakeholders duplicate processes which could be executed by a central authority as well, thus reducing redundancy. However, moving these processes based on contemporary technologies would require an overwhelming amount of trust in this central authority. This is in the current American healthcare landscape no viable solution for the reasons mentioned. A blockchain solution would allow users to interact with each other without relying on the trust of a single entity. All transactions would be completed with absolute certainty, thus allowing for a versatile system capable of replacing the numerous fragmented systems in the current situation. The main process that would be revised is processing claims.

Veris Foundation thoroughly explains their decision process when selecting the right platform for their solution [27]. They felt the three most important criteria for the creation of a success of their system would be: Technical capability, Governance, and Community. The governance and community will only briefly be discussed since the focus of this research is on technical capabilities in the form of features. The main *Domain Alternatives* considered were the Ethereum and NEO blockchains. With respect to fundamental technical differences, Veris chose NEO. The first fundamental difference is that NEO allows for the use of bookkeeping nodes. These bookkeeping nodes become the gatekeeper between those who are holding coins and those who are creating insurance contracts on the chain. Veris feels this is critical to the success of their product. The second fundamental technical difference identified by Veris between Ethereum and NEO is the split of network fees from coins. Within the Ethereum network, the execution of smart-contracts requires ETH currency. This would reduce however the stakeholder's ETH after a prolonged time of usage. NEO solves this problem by splitting having a stake in the network and paying for network fees. The NEO currency generates GAS tokens and this GAS is used to execute smart-contracts and transactions on the NEO network. Even after a prolonged time of usage, the stake in the network of a stakeholder stays the same.

VI. Results and Analysis

This section will describe the results, the means of generating these results as well as analyzing these results. As input for the BPDSS the *Domain Features Requirements* from the three case studies were used (Table 2). The BPDSS calculated the score based on these *Domain Feature Requirements* for each *Domain Alternative* in all the case studies. The results are presented in Table 3 and for each of the three case studies the Feasible Solutions, whether an alternative was on the case participants shortlist or not (if so including the rank) and the DSS score.

ShareCompany BIQH

Beforehand ShareCompany ranked Hyperledger first on their short-list and JPMorgan Quorum second. Hyperledger proved indeed to be the best scoring Feasible Solution by providing in all the must-have features and most of the should-have and could-have features. However, the alternative from JPMorgan Quorum was not second in the DSS results. R3 Corda scores slightly higher, mainly due to having a higher popularity in the market and a higher technology maturity compared to Quorum. The main difference why Hyperledger scores significantly higher than the other feasible solutions is due to it supporting the should-have features JavaScript, Zero-knowledge Proofs, and Golang.

DUO

Beforehand DUO ranked Ethereum as the most prominent platform, NEO second and Hyperledger third. When looking at the score of Ethereum this proved to be the right choice according to the DSS as well since Ethereum has the highest score. Wanchain was not on the case participant short-list, but since it is an Ethereum-based fork Wanchain scoring high is not too surprising. Despite Hyperledger scoring high, it should be noted however that the solution for DUO makes intensive use of cryptographic tokens. Hyperledger supports this feature, however Hyperledger has no native-token and token-based solutions are more troublesome on Hyperledger. Several of the should-have features are token-based, which Hyperledger doesn't support. Due to a large amount of could have features for this case study (and the should have feature High Maturity) Hyperledger does support, it scores quite high nevertheless. It was expected NEO would score slightly higher beforehand although the difference with Hyperledger's score is not too significant.

Veris Foundation

Beforehand the Veris Foundation had two main alternatives to develop their solution on, NEO as first choice and Ethereum as second. However, in the results from the DSS Cosmos Network would be the most appropriate platform. The reason Cosmos Network scores so high is due to the fact that it is rather flexible regarding different pluggable consensus-mechanisms and both allowing for any combination of permissioned/permissionless and public/private blockchains compared to both NEO and Ethereum. Hyperledger is a feasible solution once again, however the same possible difficulties as in the DUO case study could arise with a heavy reliance on different token-types which are harder to implement in practice. It is interesting to see that Chain (next to Hyperledger) is a feasible solution in all three case studies to develop their solutions on. Another interesting observation (based on these three case studies) is that it seems the main decision that has to be made is the choice between permissioned or permissionless platforms and whether cryptographic tokens are required or not.

VII. DISCUSSION

The DSS was evaluated against the evaluation-metrics efficacy, validity, and generality. The efficacy is the degree to which the artifact produces its desired effect. With respect to efficacy the BPDSS seems to perform sufficiently and might prove rather valuable in the future. This was based on the opinion of the different case participants. They acknowledge this DSS could aid other SPOs in the future as well besides being relevant for their own case. The validity metric is defined as the degree to which the artifact works correctly. The validity was measured in two ways. The results of the DSS were compared to the predefined case participant choices for alternatives and the opinion on the DSS by a blockchain expert. Based on the analysis of the results, the BPDSS scored the highest ranked case participant solutions in two of the three case studies highest as well. In the case of the ShareCompany BIQH case study, the platform ranked second Quorum from JPMorgan scored rather high. As mentioned in the analysis as well, Quorum is basically a permissioned version of Ethereum without a cryptographic token or mining-based consensus-mechanism. And R3 Corda scoring high for ShareCompany which is also an organization active in the financial domain increases the Validity of the BPDSS. So with respect to the validity of the results based on the three case studies, the DSS scores more than sufficient. The first aspect the BPDSS struggles with is partially implemented features or features which are possible but tougher to make work in practice. An example of this are the cryptographic tokens within the Hyperledger platform. Another aspect the BPDSS struggles with according to this expert, is the distinction between blockchain platforms having a focus on a specific industry (e.g. healthcare, finance, etc) or being industry agnostic.

The first theoretical limitation is the somewhat limited scope of the BPDSS. The BPDSS assumes the blockchain technology is the appropriate technology. In practice however, this is still quite an issue with organizations utilizing the blockchain while a simple DBMS would've been sufficient as well when. Thus, it is assumed the decision maker knows the advantages and disadvantages of a blockchain and is capable of selecting the right technology. Our future work will consist on creating a decision model for selecting the most appropriate *Software Architecture Patterns*, which should alleviate this problem. Another limitation of this research is having the BPDSS evaluated in only three case studies, so results are not directly generalizable. Preferably at least one additional case study evaluation was conducted. Also, the Veris Foundation case study evaluation was not the most optimal solution for a case study. It was expected to be a case study at a large bank in the Netherlands instead, unfortunately this bank withdrew halfway from this project. Their main reason was that they were still in the middle of the decision-making process and couldn't release details about their case under any circumstances. When the bank decided to resign from this research the time-factor started being a constraint so therefore the Veris Foundation was selected since they made all their information publicly available. The most important information publicly available was their thoroughly explained decision-making process between different blockchain platforms. Obviously, this is far from an ideal solution but given the time-constraints better than just two case study evaluations.

VIII. CONCLUSION

In this research we've identified the choice between different blockchain platforms can be classified as a multi-criteria decision making problem for technology selection. Based on our previous research we've created the Blockchain Platform Decision Support System (BPDSS). This BPDSS is a feature-based artifact which incorporates Software Quality Aspects from ISO/IEC 25010 Ext. ISO/IEC 9216 and feature-priorziziation based on the MoSCoW-technique. In the current version of the BPDSS 75 generic features from the blockchain domain are included as well as 29 blockchain platforms which support these features. This BPDSS has been evaluated and validated with three case-studies and an expert validation. The BPDSS was evaluated in the goal-dimension on efficacy, validity and generality. Based on the results for these metrics we've concluded that the BPDSS is capable of assisting developers sufficiently during the selection process between different blockchain platforms despite some drawbacks as struggling with partially implemented features.

IX. FUTURE WORK

Future work building on the current artifact can be done in several different ways. A limitation of the artifact is that

TABLE II

DOMAIN FEATURE REQUIREMENTS FOR EACH CASE STUDY

MoSCoW	ShareCompany BIQH		DUO		Veris Foundation	
Must Have	Permissioned, Smart Contracts, Sybil-attack resistant, etc.	10	Smart Contracts, Application Layer, Cryptographic Tokens, etc.	8	Permissioned, Cryptographic Tokens, Enterprise system integration, etc.	9
Should Have	Zero-knowledge Proof, High Maturity, High Popularity, Golang, Private, etc.	9	JavaScript, High Maturity, Solidity, Cryptocurrency (purpose), etc.	6	Delegated Proof-of-Stake, Work token, Security token, Usage token, etc.	9
Could Have	Turing-complete, Virtual Machine, SNARKS, Turing-complete, etc.	8	Permissioned, Permissionless, Java, Proof-of-Authority, C++, etc.	23	Privacy Technologies, Virtual Machine, Turing Complete	3
Won't have	Proof-of-Work, Proof-of-Stake, Directed Acyclic Graph	3	Directed Acyclic Graph	1	None	0

TABLE III

FEASIBLE SOLUTIONS DSS SCORE FOR EACH CASE STUDY

Case Study	DSS Feasible solutions	CP Shortlist	DSS Score	CP Rank
ShareCompany BIQH	Hyperledger	✓	99.39	1
	R3 Corda		68.13	-
	JPMorgan Quorum	✓	61.92	2
	Chain		40.05	-
DUO	Ethereum	✓	98.25	1
	Hyperledger	✓	73.22	3
	Wanchain		64.68	-
	NEO	✓	62.1	2
	Cosmos Network		51.1	-
	Stellar		37.91	-
	Komodo		37.65	-
	Waves Platform		37.25	-
	Chain		34.3	-
	VeChain		31.31	-
Veris Foundation	Cosmos Network		99.64	-
	NEO	✓	69.42	1
	Ethereum	✓	54.52	2
	Stellar		53.33	-
	Hyperledger		44.48	-
	Chain		44.48	-
	VeChain		30.27	-
	ICON		28.63	-
	Symbiont		28.16	-
	Neblio		21.37	-

after a while the DSS becomes outdated. Future work can be keeping the list of alternatives and features up to date so the artifact stays relevant. A possible way of doing this as opposed to done is this research is collecting these generic features could be done with natural language processing (NLP) techniques. Using NLP would save a lot of time compared to collecting all alternatives and features manually. Adding (or removing if needed) features or alternatives can be easily done due to the way the BPDSS was created.

In regards to new research there are a few possibilities when using this research as foundation and starting point. Currently the BPDSS makes barely distinction between the application domain a blockchain might focus on. Currently the only part where this is taken into consideration is the numerical feature innovation. Several application domains are parameters for the innovation feature, such as a focus on supply-chain management, finance or internet-of-things. New DSSs could be created for these domains, but also healthcare (like the Veris Foundation case-study) or social media for example. These DSSs would be more specialized versions of the BPDSS, with less domain alternatives. For example, it is not unthinkable that all blockchains focusing on the finance sector have a higher throughput compared to non-finance focused blockchains but differ on other sub-features that might be more relevant for that sector. The creation of these DSSs could be done in a similar fashion as done is this research and utilize gathered features to find generic features for certain application domains.

NOTES

- We implemented an online Decision Model Studio (http://dss.amuse-project.org) to build decision models for technology selection problems in SPOs.

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