

**BLOCKCHAIN SOFTWARE SELECTION AND RISK ASSESSMENT IN  
LOGISTICS SECTOR**

(LOJİSTİK SEKTÖRÜNDE BLOCKCHAIN YAZILIM SEÇİMİ VE RİSK ANALİZİ)

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## **LIST OF SYMBOLS**

<b>AHP</b>	: Analytical Hierachy Process
<b>ANP</b>	: Analytical Network Process
<b>RFID</b>	: Radio Frequency Identification
<b>TOPSIS</b>	: The Order of Preference By Similarity to The Ideal Solution
<b>DEMATEL</b>	: Decision Making Trial and Evaluation Laboratory
<b>IP</b>	: Internet Protocol
<b>NVOCC</b>	: Non Vessel Operating Common Carrier
<b>MCDM</b>	: Multi Criteria Decision Making
<b>IoT</b>	: Internet of Things

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## **ABSTRACT**

Supply chains have a complex structure in terms of business activities due to they contain a great number of attendees in their networks. They intrinsically tend to make increased relations between joint owners to provide satisfying service quality for them. At this point, network partners may be in search of the different purpose of utilization of information flows in the supply chain network. Blockchain technology provides to access immediately to all information goes between nodes without any party's confirmation per transaction, which build confidence between parties by rising business efficiency.

Blockchain technology provides to monitor transparent data throughout the network from the initial source point of a product or information. With its immutable data saving model in its cryptographically secured chain of blocks, it gives confidence businesses to realize their operations in front of the countless eyes on the network. Blockchain technology enables traceability and trackability for the informations flowing between nodes in the network by promising its users for security and privacy. This distributed e-ledger, creates a platform where transactions are viewable, realized fast, and not required to be verified by a mediary in the network.

In this study, an international logistics company's blockchain software selection process is examined. Even though blockchain technologies have many advantages in the utilization, they also include many risks. For instance, blockchain technology may cause difficulty in software updates and not work-in harmony with IoT and difficulty in adaptability to the logistics business process. High electricity consumption and the heat dissipated from high computational power owned processors are detrimental to the environment. Used blockchain technology may remain incapable of creating an anonymous and secure platform, and providing a strong infrastructure for hacking

attacks. Above and the other risks given in this study are identified. This process followed by the calculation of risks' importance degrees by using DEMATEL method. Our results demonstrate that continuity risks (16.910%), privacy risks (16.305%), and financial risks (16.298%) compromise almost half of the whole risks for using blockchain software technology in the logistics sector.

We decided to select the best software for the logistics company by aiming to minimize and dissipate the risks factors obtained from the risk assessment. Cost and speed of the software, privacy concerns, logistics issues related to using a blockchain software in logistics business activities, the functionality of the software, and developer availability are taken into consideration during identifying selection criteria. These are weighted with Buckley's FAHP. Outcomes of the weighting process present that purchase cost, maintenance cost, and additional cost are the main concerns for selection decision with the 42% weight. These are followed by encryption speed, speed of transactions, and latency in the results of queries with the 28% weight.

The logistics company has 4 alternative blockchain softwares which are Tradelens, Cargosmart, Shipchain, and Origintrail. The selection procedure is completed using Fuzzy TOPSIS method. Selection results give the best blockchain with the following rank from best to the worst: Tradelens, Cargosmart, Origintrail, Shipchain. In this study, purchase cost is the biggest criterion having 32% weight overall of selection criteria. Even though two of decision-makers graded the Origintrail as a medium level at the purchase cost, it is not selected as the best software at the end. This means blockchain software technology selection is required to think beyond financial concerns. Results are satisfying for the decision makers. Tradelens is the well-known blockchain software technology in the logistics sectors and used by MAERSK and IBM who are movers and shakers at their own sectors. The logistics company has planned to start to negotiate with the Tradelens about the software' adaptability to company's own logistics processes.

The major contribution of this project to the literature is that providing a new methodology on blockchain software selection by integrating risk assessment to this process. In this study, risks of using blockchain technology in the logistics sector are

explained in detail by presenting importance degrees of them. This study is the first in the literature in terms of determining blockchain software selection criteria and realizing blockchain software selection.



## ÖZET

Tedarik zincirleri, ağlarında çok sayıda katılımcı bulundurmaları sebebiyle iş aktiviteleri bakımında karmaşık bir yapıya sahiptirler. Memnun edici kalite düzeyi sağlamak amacıyla, paydaşları ile aralarındaki ilişkileri doğası gereği artırma eğilimindedirler. Bu noktada, ağ ortakları tedarik zinciri ağı içerisinde düğümler arasında akmakta olan bilgilerin farklı kullanım amaçlarını araştırıyor olabilir. Blockchain teknolojisi herhangi bir tarafın işlem başına onayı olmadan düğümler arasındaki akan tüm bilgilere anında erişmeyi sağlar ve bu da iş verimliliğini artırarak taraflar arasında güven oluşturur.

Blockchain teknolojisi bir ürün veya bilginin ilk kaynak noktasından itibaren ağ boyunca şeffaf verilerin izlenmesini sağlamaktadır. Kriptografik olarak güvenli blok zincirlerindeki değişmeyen veri saklama modeli ile, ağdaki sayısız göz önünde işlemlerin gerçekleştirilmesi işletmelere güven vermektedir. Blockchain teknolojisi, kullanıcılarına güven ve gizlilik vaat ederek ağdaki düğümler arasında akan bilgiler için takip edebilirlik ve izlenebilirlik sağlamaktadır. Bu dağıtık elektronik büyük defter, işlemlerin görüntülenebilir, hızlı gerçekleştirildiği, ve ağdaki bir aracı tarafından doğrulama gerektirmeyen bir platform oluşturmaktadır.

Bu çalışmada, uluslararası bir lojistik şirketinin blockchain yazılım seçimi süreci incelenmiştir. Blockchain teknolojileri kullanımda birçok avantaj içermelerine rağmen, birçok riskte içermektedirler. Örneğin, blockchain teknolojileri yazılım güncellemelerinde zorluğa sebep olabilir, nesnelerin interneti ile uyumlu çalışmayabilir ve lojistik iş sürecine adaptasyonda zorluğa sebep olabilirler. Yüksek elektrik tüketimi ve yüksek hesaplama gücüne sahip işlemcilerden yayılan ısı çevreye zararlıdır. Kullanılan blockchain teknolojisi anonim ve güvenli bir platform oluşturma ve bilgisayar korsanlığı saldırıları için güçlü bir altyapı sağlama konusunda yetersiz kalabilir. Yukarıdaki ve bu çalışmada verilen diğer riskler tanımlanmıştır. Bu süreci,

DEMATEL methodu kullanılarak risklerin önem derecelerinin hesaplanması takip etmiştir. Sonuçlarımız devamlılık risklerinin (16.910%), gizlilik risklerinin (16.305%) ve finansal risklerin (16.298%) lojistik sektöründe blockchain yazılım teknolojisi kullanımı için tüm risklerin hemen hemen yarısını oluşturmaktadır.

Risk değerlendirmesinden elde edilen risk faktörlerini azaltmayı ve yaymayı amaçlayarak, lojistik şirketi için en iyi yazılımı seçmeye karar verdik. Yazılım maliyeti ve hızı, gizlilik endişeleri, lojistik iş aktivitelerinde bir blockchain yazılımı kullanımına ilişkin lojistik konuları, yazılımın fonksiyonelliği, ve geliştirici mevcudiyeti seçim kriterleri tanımlanması esnasında dikkate alınmıştır. Bunlar Buckley'in FAHP metodu ile ağırlıklandırılmıştır. Ağırlıklandırma sürecinin çıktıları, satın alma maliyeti, bakım maliyeti ve ek maliyetin 42% ağırlıkla seçim kararı için ana endişeler olduğunu göstermektedir. Bunları 20% ağırlıkla şifreleme hızı, işlem hızı ve sorgu sonuçlarının gecikmesi takip etmektedir.

Lojistik şirketi Tradelens, Cargosmart, Shipchain, and Origintrail olmak üzere 4 alternatif blockchain yazılımına sahiptir. Seçim prosedürü Buckley'in Bulanık TOPSIS metodu kullanılarak tamamlanmıştır. Seçim sonuçları en iyi blockchain yazılımını en iyiden en kötüye doğru şu sırayla vermektedir: Tradelens, Cargosmart, Origintrail, Shipchain. Bu çalışmada, satın alma maliyeti tüm seçim kriterleri üzerinden 32% ağırlığa sahip en büyük kriterdir. Karar vericilerden ikisinin Origintrail'i orta düzey maliyetli olarak puanlamasına rağmen, sonunda en iyi yazılım olarak seçilmemiştir. Bu da blockchain teknoloji seçiminin finansal kaygıların ötesinde düşünmeyi gerektirdiğini göstermektedir. Sonuçlar karar vericiler için tatmin edicidirler. Tradelens lojistik sektöründen iyi bilinen bir blockchain yazılım teknolojisidir ve sektörlerinde öncü MAERSK ve IBM tarafından kullanılmaktadır. Lojistik şirketi Tradelens ile yazılımın şirketin kendi lojistik iş süreçlerine adaptasyonu hakkında görüşme hakkında plan yapmaya başlamıştır.

Projenin literatüre en büyük katkısı, risk değerlendirmesini sürece entegre ederek blockchain yazılım seçiminde yeni bir metodoloji sağlamasıdır. Bu çalışmada, lojistik sektöründe blockchain teknolojisi kullanım riskleri önem dereceleri sunularak detaylıca

incelenmiştir. Bu çalışma blockchain yazılımı seçim kriterlerini tanımlama ve blockchain yazılım seçimini gerçekleştirme açısından literatürdeki ilk çalışmadır.



## 1. INTRODUCTION

Supply chain has an intrinsically complex structure with its permanently growing supplier relationships (Stavrulaki and Davis, 2010), ever-increasing milestones, complexified inventory across multiple parties (Nakano and Lau, 2019), and complicated customer orders. In this network that is difficult to monitor information and material flows peer-to-peer, do business with paper-based manual business processes and aiming to have an optimum cost by using limited resources is a big deal in itself (Prause, 2019).

By virtue of the fact that supply chain management necessitates to work with multi-parties across the supply chain and carry on business based upon trust between counterparties, it creates a permanent dependency between parties which is affected severely from supplier volatility, privacy concerns, and interoperability issues (Mishra et al., 2016). Supplier relationship is based on trust and mutual interests. This togetherness is dependent to not shaking confidence between parties. At this point, since blockchain provides full transparency with immutable data from the initial source point of a product or information through its lifecycle, trust relationship-related concerns are diminished (Bertino et al., 2019).

Blockchain enables supply chain shareholders to track order changes, buy orders, and shipment notifications immediately without any party's confirmation per transaction (Guo and Lu, 2018).

A global scale supply chain formed by suppliers located on-shore or off-shore, which might create a great potential of the being vulnerable to information disruptions for companies (Li and Nagurney, 2015). Blockchain enables continuous information flows with its distributed databases consisting of blocks that are all authorized in data storage even though a hacking attack happens in its network or a large-scaled power cut occurs

(Chang et al., 2019). Furthermore, despite multinational firms have already noticed that having an individual based product backstory through supply chains assist them in rising business efficiency, they generally do not have it by reason of the tracing and tracking challenge, however, blockchain integrated supply chain networks bring traceability (Azzi et al., 2019) to touch points, transactions and locations.

In supply chain networks, parties generally do not take action until an event occurs such as receiving product orders, taking shipment details, obtaining information about the manufacturing process, etc. Blockchain provides an autonomous pattern of behavior with its principle of smart contract to trigger an event in its e-ledger (Christidis, 2016). Blockchain assists supply chains on real-time tracking of information or a product without waiting a third party's approval. Blockchain system brings reliability, integrity and full transparency into supply chain with its distributed, secured and immutable structure (Perboli et al., 2018). This structure assists a supply chain network in diminishing its involvement with multiple intermediaries (Tapscott D., and Tapscott A., 2017).

Partners need to sign lots of contracts, documents and transaction-related papers during their supply chain activities. With its digital signature principle, blockchain ensures companies to spend less time and decrease paper works (Hackius and Petersen, 2017). Current supply chain networks are not able to integrate data exchange in an instant across every partner because of the abundance of participants in the network. Blockchain provides an accessibility to the needed information through its nodes to make businesses possible to be informed about what is broadcasting by other attendees (Baker, 2015).

For these reasons above, an international logistics firm in Turkey has made a decision on performing logistics activities more transparent, traceable and trustworthy by benefitting a blockchain software in the logistics processes. The logistics company works with one of Turkey's biggest shoe manufacturers. The shoe manufacturer's products are picked up with generally 30 deci-sized packages from its production sites so as to distribute them to stores and shopping malls. In case products are received as not located in packages, the logistics company assigns imperatively a standard deci

value to keep record them in its database. The contract between the logistics company and the manufacturer company is based on charging per deci. However, the logistics company does not measure the decis of packages taken from the production site since assigning deci value totally belongs to itself. The manufacturer tracks daily how many shoes are located into parcel from its manufacturing site, however, since each parcel are separated both on the basis of destination and order in the logistics company's distribution centre, the manufacturer is unaware of how many shoes are grouped in a parcel package by the logistics company. By the way, logistics company delivers products in only parcel package which causes that even one product is carried in parcel whose volume is bigger than product's own. It is explicit that the logistics company does not make a loss, however, if this situation is learned by its opponents or the manufacturer, it is inevitable that the logistics company would lose its brand value, market share and customer portfolio.

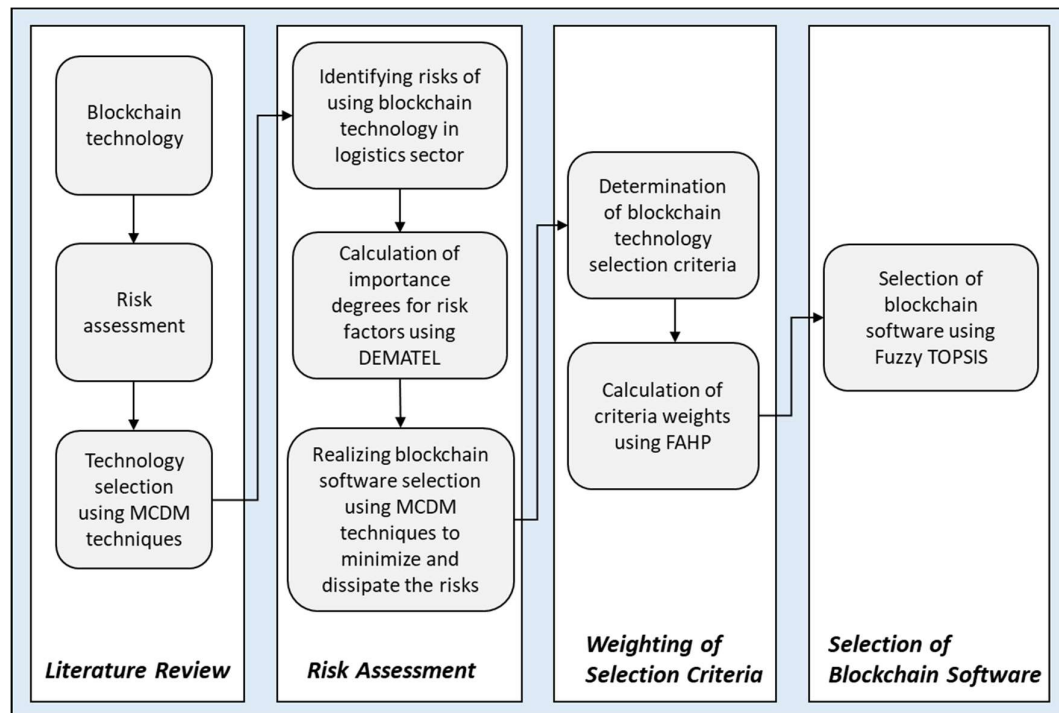
With this thesis, we aimed to present risks of using a blockchain system in the logistics sector. Furthermore, by purposing to minimize risks of the using a blockchain software, we developed a methodology to select blockchain software among alternatives to minimized risks. The proposed methodology is given in Figure 1.1.

In this study, blockchain technology is introduced with its history, characteristics and advantages. Then, usage of a blockchain system's potential risks are identified. To reveal their importance degree for the logistcics company, they are weighted in company with the preferences of decision makers who work in IT department in the logistics company. Calculation of the importance degrees of risks are computed with DEMATEL method since it provides convenience in evaluation of criteria' potential dependencies compared to ANP method. Moreover, DEMATEL method is both requiring less computational steps compared to other risk analyzing methods and it is common in the literature for risk assessment.

After obtaining the importance degree of risk factors for using a blockchain system in the international logistics company's business process, it is targeted to spreading and minimizing risks by selecting blockchain software that the company would use. Firstly, criteria are determined for the selection procedure. AHP method was selected to realize

this operation. Few of our selection criteria are not appropriate to be described with crisp values. Moreover, using fuzzy numbers would be assistive to our study in overcoming the vagueness of decision-makers' verbal judgments in the evaluation of criteria. Therefore, it was decided to use the Fuzzy AHP. Fuzzy AHP has been adopted widely and a great number of approaches have been developed. At first, Chang's Extent Analysis method was performed for criteria weighting. However, this study resulted with criteria having zero weight because of Chang's Extent Analysis's mathematical model. We put all criteria in the method to assign them a non zero weight but results were not satisfying and unacceptable. Therefore, criteria weighting is realized with Buckley's Fuzzy AHP method because of its well recognition and resulting with the acceptable weights. Since we didn't continue to selection procedure with Chang's Extent Analysis, it is not incorporated into this project. The reason of mentioning the unsuccessful attempt is giving information to potential applicators about the possible risk of using Extent Analysis method in criteria weighting.

Figure 1.1: Framework of The Proposed Methodology.



Logistics company's candidate list consists four blockchain softwares which are Tradelens, Cargosmart, Enhelix, and Shipchain. Following criteria weighting, a selection procedure is applied to alternatives. By virtue of its extensive usage, TOPSIS method is performed in the computational procedure for the selection process.

In the logistics sector, a vast number of businesses require to collaborate in their networks. Blockchain technology provides trustworthy information stored as an unalterable way. Smart contracts prevent firms to wait for any party's verifications, which causes unproductive operation time. So, this improves the speed of the actions that are taken in the sector. In the logistics sector, there are many shipments documents required to be shared with stakeholders and to be signed by them. Conventional logistics business processes are solely dependent on documents, which is a time-consuming activity in global trade. For logistics companies using blockchain technology, there would be less necessity to proceed with documents manually since blockchain technology provides electronic signature and immediate data sharing with joiners in the network. Blockchain technology provides an effective job tracking since it monitors continuously all data activities, which enables companies to spare more time on their operations instead of making calls or sending e-mails to ask for information. Blockchain technology ensures to realize transactions very fast between sides in the logistics network.

The original contribution of this project to the literature is to provide a new methodology on blockchain technology selection by integrating risk assessment to this process. This project explains the risks of using blockchain technology in the logistics industry comprehensively and presents their importance degrees. According to our findings from literature review, this study is the first one that determines blockchain software selection criteria and realizes blockchain software selection.

## **2. BLOCKCHAN TECHNOLOGY**

### **2.1. Background of Blockchain Technology**

Today's blockchain purpose is to digitalize peer-to-peer business processes by basing upon the ground of Stuart and W. Scott Stornetta' studies in 1991. They contributed to the literature by providing a computational solution to the time-stamping digital documents by using a cryptographically secured chain of blocks which would not permit to change a document's date or tamper. Such a contribution assisted 3rd parties in smoothing challenge on validation of time stamps on documents. (Haber and Stornetta, 1991).

In 1992, the scope was expanded more by using Merkle Tree which is a process that verifies data that would let computers work faster compared to before and makes time-stamping digital document system more efficient by ensuring to make a record of many documents into one block. Merkle Tree enables its user systems to secure, to verify and to scale large data sets by supporting them in its background hash-based cryptographic functions (Tijan et al., 2019).

In 1998, Nick Szabo came up with an idea of bit gold. Nick believed that money's dependency on a third party and inflationary or hyperinflationary fluctuations were not ideal for the 20th century. He indicated that repeatedly transactions of precious metals are quite costly. Therefore, he suggested securely storable and transferable "bit gold" which is eligible to be generated online by requiring minimum dependency on third parties (Szabo, 2005).

In 2000, Stefan Konst came up with a general cryptographic theory of secured chains. In 2008, an anonymous person who introduced itself with a fake identity as Satoshi

Nakamoto wrote a white paper. That paper proposes a peer-to-peer network utilizing proof-of-work to save a public transaction history. However, it would become less advantageous in the event of a cyber-attacking by comparison with the general framework of coins generated from digital signatures lacking preventing double-spending. (Szabo, 2005).

In 2009, initial Bitcoin source code, which would become an open-source for future software, put on the market following the Nakamoto's manifesto. (Swan, 2015). Since then, blockchain's practicability beyond Bitcoin has been understood that blockchain is not limited to transactions and has many brand new economic opportunities such as internet of things, smart car, smart security system, tracking and monitoring systems and etc.

## **2.2.Characteristics of Blockchain Technology**

Data transparency can be described as an ability to access effectively subjects' information related to data utilized in the business processes no matter where they are or what application created them (Bertino et al., 2019). With its time stamped-data, the blockchain system ensures data integrity in records, which makes the system transparent. There are countless eyes on the network following any change in the system, for this reason, in case a change or corruption occurs it is noticed immediately( Saberi et al., 2019).

In a blockchain system, every record is secured by a unique cryptographic key, and each unhackable key is required to access the previous contents and keys. In case a new record is written in blocks, keys are put into a cryptology algorithm in order to generate the key of an upcoming block. Usage of keys to chain blocks with each other creates a compulsory dependency between blocks, provides data consistency and data reliability through blockchain network, and makes network impossible to be altered previous records. Any user of an open network can monitor the past transactions of a record and verify the history's correctness by examining previous records in detail (Manupati et al., 2019).

All participants in a blockchain system have an access to the same records in the network and are authorized to validate transactions and verify identities. As a result, the system provides a transparent platform to its participants (Sanka and Cheung, 2018).

The blockchain immutability is blockchain's e-ledger's remaining unchanged. In a blockchain system, every node has a digital signature procured from an irrecoverable hash-based algorithm yielding embedded information with timestamps, however, blocks also have previous blocks' signatures, which means that blocks are retroactively chained and it is impossible a foreigner can intrude to the network (Chang,2019). Tampering any node's history or hash-based algorithm based yield takes overwhelming effort, thus this distributed e-ledger system seems having permanent irreversible records(Sas and Khairuddin, 2017), which is the reason why it gains trust.

E-ledger used in blockchain system is not dependent on a single organization or a person and updated when every new transaction happens. Queries realized by users/nodes reflects the real-time changes in the network (Yli-Huumo et al., 2016; Gupta, 2017; Iansiti et al., 2017).

Blockchain network gives users security and privacy, and proceeds them by using cryptographic techniques to service its users a selective visibility (Do and Ng, 2017). In case required data is acquired by the user and procedure of the new block creation is finished, transactions never can be reversed, which makes the system confidential.

Dependent on protocols, a blockchain system enables users having anonymity (Liang et al.,2019). A user can decide on permissions about details concerning his/her transactions would be viewed by other participants, thus blockchain creates both anonymity and trusted digital identity. In a transaction, rendering possible to view entire details by all participants would cause unfair advantages for opponent businesses.

Malicious entities and hacking attacks do not affect severely the entire blockchain network just because it utilizes a distributed e-ledger. In case a cyber-attack happens, since the system is not managed or controlled by a central hub, the network behaves robustly to overcome a presumptive loss in data. With its distributed structure, the

system makes risk diversification in the network and jeopardizes only a small portion of data.

### **2.3. Advantages of Blockchain Technology**

Blockchain enables data to be stored in different distributed databases which enable system and data to be resistant to cyber-attacks and technical troubles (Liang et al., 2019). Each node in the network are authorized to copy the database and keep it. Thus, blockchain network becomes more robust by not having any node to be affected severely from technical troubles or having an off-line node.

With its dispersed structure, blockchain's network nodes can interact directly with each other, and this is also the answer to why blockchain does not require to work with a third party (Barenji et al, 2019). This manner of work results in not managing and controlling and storing data from a single-center. Thus, the network cannot be cracked entirely from a single node.

Once a data is verified in blockchain network, deleting, changing or taking it out of from the network is almost impossible which gives confidence, transparency and evenness to people whom it may be affected from or use it (Gong et al., 2019). Because of aforementioned characteristics of blockchain, blockchain would be essential for the sectors which requires irrevocableness in financial data and require frequent audit in business process that are inevitable to be integrated with different parties.

Most of the traditional payments systems require dependency between two parties and an additional intermediary such as bank or payment provider, however, blockchain manages this process with the transactions between nodes on the its network, which is known as mining, that does not require a mediary or a third party (Olleros and Zhegu, 2016). In this manner, the blockchain system manages transactions cost-effectively by not obligate any mediary. Data is one of the most powerful assets in this digital era and it is created easily by any person, gadget, system or a network. Some defenders believe that blockchain forms the digital twin of the real world which would be much-needed in

the immediate future (Rejeb et al., 2019). This might also present an effective solution to firms who have concerns about how they can preserve their brands from counterfeits.

Transactions in blockchain systems are realized quicker and costs are less than banks. Any user of the network can view retroactive transactions, and monitor instantly transactions without a time or location constraint (Tijan et al., 2019). Since all transactions are viewable and blockchain stores data in multiple nodes, information spreads across a large network and makes the network transparent and confidential.

Digital signatures are cost and time saving novelty, secured by cryptography algorithms that prevents signature forgery and abusing personal informations by third parties, environment-friendly by diminishing waste of paper, and makes workflow efficient by reducing turn-around time of documents in the business world. Blockchain provides easy sharing access to documents with digital signature to its users (Jackson, 2017).

By reason of not requiring mediaries or a third parties through blockchain network, complexity of business processes are diminished and actions are taken quicker. Similarly, both transaction times are not like in the traditional methods and transaction times are not dependent on situations, blockchain systems provide time-saving in a large scale network that is not limited by a location.

With working cryptography algorithms in its background, blockchain systems guarantee securing personal information and business information having any potential to affect competitive advantage and enable data integrity with time-stamping historic e-ledger (Treiblmaier, 2019). In consequence, blockchain system gain trust and dispels doubt concerning data reliability and data protection issues.

### **3. LITERATURE REVIEW**

Technology assessment problems were introduced in the middle of the 1960s with the study based on the identification of the outcomes obtained from the latest technologies' developments (van den Ende et al., 1998, Carlsen et al., 2010). This concept used eventually for the evaluation of using new technologies (Goulet, 1994). With the technology assessment, it is aimed to estimate the future effect of alternatives to the system. Technology assessment studies also assist businesses in determining opportunities and risk factors before implementation is realized (Halicka, 2020).

In this section, firstly blockchain technology related search is shared. Secondly, literature review for risk assessment using DEMATEL method in technology selection is given. Then, FAHP methods are introduced, and recent studies about technology selection problems realized with FAHP is shared. Finally, recent studies about technology selection using TOPSIS method is listed.

#### **3.1. Literature Review for Blockchain Technology**

Blockchain technology has been adopted as a remarkable solution in several supply chain-related improvements as given in the following examples. Other blockchain related latest studies in the literature are listed in Table 3.1.

MAERSK, which is a Danish international container shipping company, accounting for approximately 20% of the market has been using blockchain technology to track shipping containers to be informed about their GPS location, temperature, moisture, etc., to reduce mountains of paperwork concerning to containers' shipments, and to utilize blockchain technology's principle of digital signature accelerating paper works (Jackson, 2017).

Provenance, which is a digital platform empowering brands to enhance transparency and gathering information related to products and supply chains' stories, has been benefiting from the opportunities of blockchain by using mobile phones and smart tagging in fishing for problems like overfishing and undeclared hunting (Hannam, 2017).

China's biggest online commerce company Alibaba, a government-owned corporation post service Australia Post, an Australian health supplements company Blackmores, and tax and consulting services PwC gathered to fight with food fraud comprising selling off-grade foods and counterfeit ingredients by use of blockchain technology, and have been aiming to compose a food trust framework to enhance integrity and traceability through global supply chains (Bindi, 2017).

Lockheed Martin, which is a USA originated aerospace and defense firm, is the first American defense contractor to incorporate blockchain as a data integrity technology to detect the threat of data manipulation in the network as a supply chain risk management mean (Higgins, 2017).

A USA based technology company Chronicled and a consulting group Linklab are an example of a joint venture focused on exploring and developing blockchain solutions for the pharmaceutical industry by aiming to track and trace prescription medicines. The compliance protocol launched as "track and trace pilot" by this joint venture is a blockchain-based protocol to meet the Drug Supply Chain Security Act (Prnewswire, 2017).

Modum, which is a Zurich based company, generating IoT sensing technology has been using blockchain technology to reveal the exact value of humidity, temperature and light conditions with timestamps for transported products through their transportation process (Allen, 2017).

Everledger, which is a digital transparency company, uses blockchain-based solutions to share history of precious assets such as a diamond or a coloured any gemstone with customers (Allen, 2017). It works with a blockchain-based system to track bottles of

wine by attaching to each bottle's cork a tamper-evident RFID tag, however, for the older bottles of wine, a label indicating a production date is utilized instead of RFID tag (Mathieson, 2017).

Walmart, which is a USA based retail company, involved in a project aiming to overcome food contamination by digitally track individual pork products' transportation from farms to stores in China by means of RFID tags, sensors, and barcodes. This blockchain-based project resulted with easy accessibility to the track data of individual pork products and a cost-saving business process since it enables to not recall the entire product line (Popper and Lohr, 2017).

Gemalto, which is a Netherland based digital security firm, got involved in a project of temperature-sensitive medicines' transportation by utilizing digital thermometers from manufacturing sites to hospitals located in hot climates. This blockchain-based project enabled participants of the supply chain network to oversee their own dataset (Mathieson, 2017).

Sawtooth, which is Intel's public demo blockchain software for the seafood supply chain, is developed as an open-source codebase to assist in seafood traceability. This work labelled as "the ocean to table movement" aiming to enhance the record keeping righteousness from the fishmonger to the seafood restaurant (Del Castillo, 2017).

Bext360, a Colorado based start-up, is connecting coffee farmers to global markets with blockchain technology, uses image recognition technology evaluating beans according to weight and quality, and creates a real time-basis e-ledger with record time-stamps and value of transactions in order to make coffee supply chains full transparent and traceable between parties (Kolodny, 2017).

Manupati et al., proposed a model describe vendors' workloads related to their capabilities and calculated their total optimal cost by using blockchain approach to optimize operational demands and carbon emissions that are denoted by carbon assets as transaction source from the sender's account to the receiver's account (Manupati et al, 2019).

Ambrosus is an integrated solution consisting hardware, software, and a protocol layer and created to demonstrate its protocol ability's to collect data from IoT devices and record it to distributed databases to compose a platform focusing on quality-focused network to track products across supply chains by using QR code, tracer and biosensor (Kirejczyk et al., 2017).

A web based solution Ascribe was created to procure a consumer friendly and effective solution for creators, which are not compensated fairly for their work, of digital contents to make registry with easy, to bring visibility into usage through SPOOL protocol and timestamps (McConaghy, Holtzman,2015).

Blockverify, a global solution for valuable articles, assists users in identifying counterfeit goods, making impossible to duplicate products without requiring rely on trust of a third party, and enable businesses to register own products and monitor them across supply chains by using block verify tag (Blockchain Based Anti-Counterfeit Solution).

OwlThing is a blockchain service enabling process control, cost control, immutable data, and customer engagement for the industrial consumer in the field of agriculture, healthcare, logistics, food processing, aviation, travel & hospitality, global trade, manufacturing, livestock farming by using transparent information (Owlchain, 2017).

Verisart is a blockchain service armed with an image identification algorithm and offers a permanent record of an art piece's history from initial authentication to present ownership, which will increases the number of people in the future who buy and sell artworks in digital trading platforms because of the great art fraud in nowadays. It is believed to be at least half of the works are either fake or dedicated to the wrong artist, so with its certifying, documenting, verifying and tracking system, Verisart develops trust between its customers (Verisart, 2015).

Trustchain is a project to be used in global diamond and jewelry supply chains and provides a blockchain assurance to consumers related to traceability by taking high-

resolution photos at every touchpoint across supply chain, recording, and certifying product details (Trustchain, 2018).

Table 3.1.a: Literature Review for Blockchain Technology Related Selection Problems

Year	Author	Objective of Study
2020	Feng et al.	Evaluating the trustworthiness of miners that gives opportunity to select random-honest miners for block creation.
2020	Farshidi et al.	Making a decision support model for blockchain platform selection.
2020	Mba and Mwambi	A Markov-switching model for cryptocurrency portfolio selection.
2020	Yizhong et al.	A fair selection protocol consisting of the mining process and confirmation of the new nodes in a permissionless blockchain.
2019	An et al.	Node selection based on twice verifications and consensuses of blockchain
2019	Wu et al.	Scheduling algorithm to realize node selection for Sapiens Chain.
2019	Wang et al.	Game-theoretic analysis of mining pool strategy selection in proof-of-work-based blockchain networks.
2019	Gorczyca and Decker	Developing an approach by using Directed Acyclic Graphs for witness selection.
2018	Luong et al.	Developing an algorithm for joint transaction transmission and channel selection in the cognitive radio based blockchain network.
2018	Bae and Lim	Decreasing the probability of double spending attacks by creating a random mining group selection method.

Table 3.1.b: Literature Review for Blockchain Technology Related Selection Problems

Year	Author	Objective of Study
2018	Sudhan and Nene	Simulating the effects of selection of outgoing connections based on randomness and proximity on transaction propagation delay.
2018	Liu et al.	Transcoder selection for blockchain-enabled video streaming platforms.
2016	Pustisek et al.	Developing blockchain based model to select the proper electric vehicle charging station.

### 3.2. Literature Review for Risk Assessment

Supply chain risk management's significance grows day by day, and many methods and approaches are developed to answer rising needs for the stages of identification, assessment, analysis and monitoring of the risk factors (Neiger et al., 2009). In the most general sense, the risk is determined as "the probability that a particular adverse event occurs during a stated period of time, or results from a particular challenge" by Royal Society. Rather than its negative sounds, it can be observed as an opportunity to enhance profit in case it is assessed properly to be minimized or eliminated (Kawamoto, 2001).

In the literature, risk management is conducted generally in 4 steps. In the *first step*, risk factors are determined and examined in-detail to understand their potential effects, which is useful for managing real-like scenarios. In the *second step*, risk assessment is carried out via associating probabilities with risk factors. This assessment is actualized according to assessor's own experience, performance results, forecasting analysis or MCDM methods. In the *third step*, to manage specified risk factors, planned risk mitigation actions are implemented to minimize the effects of risk or reduce the occurrence of them. In the *fourth step*, risk monitoring is realized to detect the risks and interfere with the system with planned actions to prevent risk effects on it (Hallikas et al., 2004). Aforementioned risk assessment steps are general accepted procedure of the risk evaluation methodology. There are many other techniques and approaches to assess risk in the industrial environment (Tixier et al., 2002).

Table 3.2 : Literature Review for Risk Assessment/Analysis in Supply Chain.

Year	Author	Objective of Study
2020	Liu and Huang	Solving risk assessment for financial fields in supply chain by suggesting a vector machine model.
2020	Dias et al.	Identifying risks of a car manufacturer and ranking them by using AHP method.
2019	Aleksic et al.	Determining risk level and priority in reverse logistics by using TOPSIS method.
2019	Salamai et al.	Designing a Fuzzy Inferenced Decision Support System by measuring levels of operational risks using an organization's big data collection.
2019	Gangulgy and Kumar	Developing a methodology for risk assessment in supply chain by using Fuzzy AHP method.
2018	Shankar et al.	Identifying and assessing the sustainability risks for freight transportation system.
2018	Schaefer et al.	Analyzing dimensions of water risk for supply chain management decisions using Monte Carlo AHP.
2018	Kara and Firat	Mitigating supplier risk by clustering suppliers into groups according to their profiles.
2017	Kolotzek et al.	Developing company-oriented risk assessment model for raw material risks using AHP
2017	Torres-Ruiz and Ravidran	Sustainable risk assessment for a supplier portfolio using rating and AHP methods.
2017	Dehdasht	Evaluating risk factors of oil and gas construction projects by creating DEMATEL-ANP risk assessment model.

### 3.3. Literature Review for Fuzzy Analytical Hierarchy Method

AHP is a well-developed MCDM method which has been used to derive ratio scales of measurement taking its multi-level hierarchical representation of criteria into consideration by using a fundamental scale reflecting the relative importance degree of preferences (Saaty, 1980).

To overcome the decision-makers' uncertainty on verbal judgments while evaluating both criteria and alternatives, Fuzzy AHP, which has been adopted widely and a great number of approaches have been developed. Van Laarhoven and Pedrycz used fuzzy numbers with triangle membership functions in expression of decision makers' opinions, and logarithmic regression to estimate weights of criteria in its priority theory (Laarhoven and Pedrycz, 1983). Buckley developed an extension method by obtaining a fuzzy positive reciprocal matrix to conduct pairwise comparisons and benefited geometric mean formula to determine weights of decisions makers based on a consensus analysis (Buckley, 1985). Chang proposed an extent analysis method, which requires to use only triangular fuzzy numbers, for the synthetic extent values of criteria in pairwise comparison. (Chang, 1996). Cheng built membership function, which was based on grade values called performance score) of judgment criteria, and used entropy concepts in calculation of aggregate weights (Cheng, 1996).

Demirag Turan et al. used Buckley's extension to identify efficient sensitive levels for some indicators in their landslide susceptibility mapping study (Demirag et al., 2020). Aydın and Kahraman used Buckley's approach for comparative analysis of firms applying to Malcolm Baldrige National Quality Award which assesses organizations in terms of performance excellence (Aydın and Kahraman, 2019). Dayanandan and Kalimuthu evaluated the influence maintainability and its attributes in software quality assessment at architectural level with Buckley's Fuzzy AHP (Dayanandan and Kalimuthu, 2018). Gul et al. used Fuzzy AHP to weigh risk parameters derived from a risk assessment method (Gul et al., 2018). Kumar et al. selected the best method of biodiesel production using Buckley's method (Kumar et al., 2017).

Table 3.3 : Literature Review for FAHP Related Selection Problems.

Year	Author	Objective of Study
2020	Demirag et al.,	Determining efficient sensitive levels of importance for indicators in a landslide susceptibility mapping study.
2019	Aydin and Kahraman	Comparative analysis of firms applying to Malcolm Baldrige National Quality Award which assesses organizations in terms of performance excellence.
2018	Dayanandan and Kalimuthu,	Evaluating the influence maintainability and its sub-attributes in software quality assessment at architectural level.
2018	Gul et al.	Weighting risk parameters derived from a risk assessment method
2017	Kumar et al.	Selecting the best method of biodiesel production.

### 3.4. Literature Review for TOPSIS

The technique for order preference by similarity to an ideal solution (TOPSIS), which is among the most utilized MCDM method, was developed by Yoon and Hwang. This method asserts that the best alternative is the one having shortest distance from the ideal solution and longest distance from the negative ideal solution (Yoong and Hwang, 1981).

Gupta and Naqvi noticed that studies about significant success factors for risk aversion in ERP implementations have not suggested a handy selection procedure. They used Fuzzy-TOPSIS for ERP system selection to propose a direct utilization in their model which used the critical success factors by prioritizing (Gupta and Naqvi, 2017). Nouri et al. set forth a methodology consisting Fuzzy-TOPSIS for technology selection problem in a manufacturing company (Nouri et al., 2015). Hanine utilized AHP and TOPSIS methods select an ETL (Extract, Transform and Load) software that has importance for Business Intelligence projects (Hanine et al., 2016). Lu et al. realized healthcare waste treatment technology selection by applying interval 2-tuple induced TOPSIS method (Lu et al., 2016). Habbal studied context-aware radio access technology selection in 5G

ultra dense networks using Fuzzy TOPSIS (Habbal et al., 2017). Vivekh benefited Fuzzy TOPSIS on a desalination technology selection problem at a campus in India (Vivekh et al., 2017). Halicka used TOPSIS for selection of road pavement technologies (Halicka, 2020).

Table 3.4 : Literature Review for Fuzzy TOPSIS Related Selection Problems.

Year	Author	Objective of Study
2020	Halicka	Selecting road pavement technologies.
2017	Vivekh et al.	Selecting desalination technology at a campus.
2017	Habbal et al.	Context-aware radio access technology selection in 5G ultra dense networks
2017	Gupta and Naqvi	Proposing a handy selection procedure about critical success factors for risk aversion in ERP implementation.
2016	Hanine et al.	Selecting a ETL (Extract, Transform and Load) software
2015	Nouri et al.	Technology selection problem in a manufacturing company.

Those concerned can reach more technology selection related studies in the literature from Halicka's study where studies are listed according to the type of technology (Halicka, 2020).

## **4. PROPOSED METHODOLOGY**

In this study, the risk assessment method is introduced and the computational procedure for calculating the importance degree of risk criteria is explained. Its results will provide a basis for blockchain software selection in dissipating and minimizing the violence of risk criteria having high importance degrees.

Following the risk assessment, Fuzzy AHP method's calculation steps are studied. This method will be supportive in the blockchain software selection procedure by providing the weights of selection criteria.

Finally, TOPSIS method that will be used in the blockchain software selection process is examined.

### **4.1. DEMATEL Method For Risk Assessment**

Decision making trial and evaluation laboratory (DEMATEL) method is developed by the Geneva Research Centre of Battelle Memorial Institute in 1972 to research and solve complicated and intertwined problem groups (Gabus & Fantela, 1972). DEMATEL enables its user to visualize the complicated structure of problems via matrixes or diagrams. DEMATEL method analyzes the cause and effect relationships of systems by using a mathematical model in its background. DEMATEL technique is utilised to reveal the interrelations between criteria in multi-criteria decision-making field (Chung & Gwo, 2009). This technique also demonstrates the strength of influence between criteria (Yang and Tzeng, 2011).

Application steps of the DEMATEL method based on Wu et al. and Shieh et al.’ study are as follows:

**Step 1.** Criteria which will be used throughout the computational procedure is determined.

**Step 2.** After determination of the criteria, each criterion is compared according to their influence level on each other. If criteria do not affect each other, the level of the influence gets 0 which refers to “no influence” between criteria. According to the degree of influence, criteria gets the integer number of 1, 2, 3, 4 which refers to “very low influence”, “low influence”, “high influence”, and “very high influence”, respectively as given in the Table 4.1.

Table 4.1: Influence scores for expert views

Influence score	Linguistic term
0	No influence
1	Very low influence
2	Low Influence
3	High Influence
4	Very high influence

**Step 3.** In the event that there is more than one decision maker in the system, influence matrix is constructed for all decision makers. As a rule, diagonal values ( $i=j$ ) gets zero in the matrix.

$$X^k = [x_{ij}^k], \quad (1)$$

where where  $k$  is the number of decision makers,  $1 \leq k \leq H$ .

$$X^k = \begin{bmatrix} 0 & X_{12} & \cdots & X_{1j} \\ X_{21} & X_{22} & \cdots & X_{2j} \\ \vdots & \vdots & \ddots & \vdots \\ X_{i1} & X_{i2} & \cdots & 0 \end{bmatrix}, \quad (2)$$

where  $x_{ij}$  refers to the degree that decision maker evaluates factor  $i$  to factor  $j$ .

Then, average mean method is used for aggregation of the scores from  $H$  decision makers. The average matrix  $A=[a_{ij}]$  is constructed as follows:

$$a_{ij} = \frac{1}{H} \sum_{k=1}^H x_{ij}^k \quad (3)$$

**Step 4.** After getting the direct influence matrix in Step 3, sums of the rows and columns are calculated. Sum of the rows connotes the direct effects of each criterion on others. The value obtained from the following formula results with the max direct influence value.

$$\max_{1 \leq i \leq n} \sum_{j=1}^n |a_{ij}| \quad (4)$$

In a similar approach, max value of the columns represents the direct effects on criterion  $I$ . The value obtained from the following formula results with the the most influenced criterion by other criteria.

$$\max_{1 \leq i \leq n} \sum_{i=1}^n |a_{ij}| \quad (5)$$

**Step 5.** After getting direct influence matrix in Step 3, average matrix is normalized by the following formula:

$$D = s.A \quad (6)$$

$$d_{ij} = s.a_{ij} \quad (7)$$

$$s > 0, i, j \in \{1, 2, \dots, n\}$$

$0 < s < \sup$ , where

$$\sup = \min \left[ \frac{1}{\max_{1 \leq i \leq n} \sum_{j=1}^n |a_{ij}|}, \frac{1}{\max_{1 \leq j \leq n} \sum_{i=1}^n |a_{ij}|} \right] \quad (8)$$

$$\lim_{m \rightarrow \infty} D^m = [0], \text{ where} \quad (9)$$

$$D = [d_{ij}]_{n \times n}, 0 \leq d_{ij} \leq 1 \quad (10)$$

The positive scalar  $s$  is equal to the larger value of the above two value (Formula 8).

**Step 6.** Matrix  $F$  is the infinite series of direct and indirect effects of each element that is obtained from the matrix  $D$  with matrix operations. Assume that  $W_i(f)$  represents the normalized  $i^{\text{th}}$  row sum of matrix  $F$ . Thereby,  $W_i(f)$  value expresses the sum of influence dispatching from element  $i$  to the other elements both directly and indirectly. By normalizing  $i^{\text{th}}$  column sum of matrix  $F$  and getting  $V_i(f)$  at the end, the sum of influence that criterion  $i$  receives from other criteria is obtained (Tzeng et al., 2007).

$$F = \sum_{i=1}^{\infty} D^i = D(I - D)^{-1} \quad (11)$$

where  $D$  is  $n \times n$  identity matrix.

**Step 7.** Let define two vectors which will assist in interpretation of direct/indirect influence between criteria. Vector  $R$  is  $n \times 1$  matrix and demonstrates the sum of the rows

in the matrix  $F$ . Vector  $R$  demonstrates both direct and indirect effects given by criterion  $i$  to the other criteria. Vector  $C$  is  $1 \times n$  matrix and represent the sum of the column  $j$  in the matrix  $F$ . Vector  $C$  shows both direct and indirect effects given by criterion  $j$  to the other criteria.

In case where  $j$  is equal to  $i$ , the sum of  $R_i$  and  $C_j$  indicates the total effects given and received from criterion  $i$ . Thereby,  $R_i + C_j$  shows the degree of importance for a criterion in the entire system. In contrast to this, the difference of  $R_i$  and  $C_j$  demonstrates the net effect that a criterion contributes to the system. When  $(R_i - C_j)$  is positive, related criterion is called as “net cause”. In case  $(R_i - C_j)$  is negative, related criterion is called as “net receiver” (Lee, et al., 2008).

In order to visualize direct or indirect influence between elements in the system after completing computational procedure until this step, threshold value is set to pick out some neglectable impacts. Thanks to this filtration, only filtered criteria that have a greater value than the threshold value will be shown in the graph. The graph is drawn according to the dataset of  $((R_i + C_j), (R_i - C_j))$  (Wu & Tsai, 2011).

#### 4.2. Fuzzy AHP Method For Criteria Weighting

Steps of Buckley’s Fuzzy AHP as it follows (Saaty 1980; Buckley,1985; Ayhan, 2013):

**Step 1.** Form hierarchical structure.

**Step 2.** Make pairwise comparison using linguistics variables in Table 4.2.

Table 4.2: Linguistics variables for pairwise comparison

Abbreviation	Linguistics Variable	Triangular Fuzzy Number
VL	Very Low	(1,1,3)
L	Low	(1,3,5)
M	Medium	(3,5,7)
H	High	(5,7,9)
VH	Very High	(7,9,9)

**Step 3.** Construct pairwise comparison matrix.

$$\tilde{A}^k = \begin{bmatrix} \tilde{a}_{11}^k & \tilde{a}_{12}^k & \dots & \tilde{a}_{1n}^k \\ \tilde{a}_{21}^k & \tilde{a}_{22}^k & \dots & \tilde{a}_{2n}^k \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{a}_{n1}^k & \tilde{a}_{n2}^k & \dots & \tilde{a}_{nn}^k \end{bmatrix} \quad (12)$$

where  $\tilde{a}_{ij}^k$  is  $k^{\text{th}}$  decision maker's preference of  $i^{\text{th}}$  criterion over  $j$  criterion.

**Step 4.** Construct aggregated decision matrix using weighted average method in case there is more than one decision maker.

$$\tilde{a}_{ij} = \frac{\sum_{k=1}^K \tilde{a}_{ij}^k}{K} \quad (13)$$

**Step 5.** Update pairwise comparison matrix.  $\tilde{A}$  is  $n \times n$  matrix.

$$\tilde{A} = \begin{bmatrix} \tilde{a}_{11} & \tilde{a}_{12} & \dots & \tilde{a}_{1n} \\ \tilde{a}_{21} & \tilde{a}_{22} & \dots & \tilde{a}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{a}_{n1} & \tilde{a}_{n2} & \dots & \tilde{a}_{nn} \end{bmatrix} \quad (14)$$

**Step 6.** Calculate the geometric mean of each parameter of  $\tilde{a}_{ij}^k$ .

$$\tilde{r}_i = \left( \prod_{j=1}^n \tilde{a}_{ij} \right)^{1/n}, \text{ where } i, j = 1, 2, \dots, n \quad (15)$$

**Step 7.** Find the vector summation of each  $\tilde{r}_i$ . Then find the -1 power of vector summation and replace them with triangular fuzzy numbers. Find the weight of each criterion.

$$\tilde{w}_i = \tilde{r}_i \otimes (\tilde{r}_1 \otimes \tilde{r}_2 \otimes \dots \otimes \tilde{r}_n)^{-1} \quad (16)$$

$$\tilde{w}_i = (lw_i, mw_i, uw_i) \quad (17)$$

,where  $i=1,2,\dots,n$ , and  $(l,m,v)$  refers to a triangular fuzzy number

**Step 8.** Fuzzy weight of  $\tilde{w}_i$  is defuzzified with Chou and Chang's Centre of Area Method (Chou and Chang, 2008).

$$M_i = \frac{lw_i + mw_i + uw_i}{3} \quad (18)$$

**Step 9.**  $M_i$  is a non-fuzzy number and requires to be normalized so that sum of weights of criteria is equal to 1. An obtained normalized value denotes  $N_i$ .

#### 4.3. Fuzzy TOPSIS Method For Blockchain Software Selection

The followed computational procedure is as follows (Dursun, 2007; Karsak, 2002; Zeleny, 1982):

**Step 1.** Construct a decision matrix including fuzzy assessment values that each alternative gets per criterion. In case multiple decision-makers are accompanying the

decision process, the decision matrix is constructed for each decision-maker and then these matrixes are aggregated.

**Step 2.** Decision matrix is normalized in order to obtain values which are unit-free and enabling comparison with other criteria. This normalization operation is realized with linear scale transformations, however, it is managed differently based on a criterion's type that is benefit type or cost type.

$$y'_{ijk} = \left\{ \begin{array}{l} \frac{y_{ijk} - y_{jk}^-}{y_{jk}^* - y_{jk}^-}, \quad k \in B_j, \quad i = 1, 2, 3, \dots, m; \quad j = 1, 2, 3, \dots, n \\ \frac{y_{jk}^* - y_{ijk}}{y_{jk}^* - y_{jk}^-}, \quad k \in C_j, \quad i = 1, 2, 3, \dots, m; \quad j = 1, 2, 3, \dots, n \end{array} \right\} \quad (19)$$

$$y_{jk}^* = \max_i y_{ijk} \quad (20)$$

$$y_{jk}^- = \min_i y_{ijk} \quad (21)$$

$B_j$  is a set of the benefit type criteria while  $C_j$  is the set of cost type criteria.  $y_{ijk}$  denotes the fuzzy values in the decision matrix.  $k$  is the subcriterion of  $j$  criterion for the alternative  $i$ . Thus,  $y_{ijk}$  represent the crisp value assigned to  $i^{\text{th}}$  alternative's  $k^{\text{th}}$  sub-criterion of  $j^{\text{th}}$  criterion.  $y'_{ijk}$  denotes the normalized value of  $y_{ijk}$ .

**Step 3.** Performance ratings of alternatives based on sub-attributes level are aggregated.

$$\tilde{x}_{ij} = (x_{aj}, x_{bj}, x_{cj}) \quad (22)$$

$\tilde{x}_{ij}$  denotes the  $i^{\text{th}}$  alternative's aggregated performance rating with regard to  $j^{\text{th}}$  criterion.

$$(x_{aj}, x_{bij}, x_{cij}) = \frac{\sum_k \tilde{w}_{jk}^1 \otimes \tilde{y}_{ijk}}{\sum_k \tilde{w}_{jk}^1}, \quad \text{for } \forall i, j \quad (23)$$

$\tilde{w}_{jk}^1$  is the average weight assigned to  $j^{\text{th}}$  criterion's  $k^{\text{th}}$  sub-criterion.  $\otimes$  denotes the fuzzy multiplication operation.

**Step 4.** Normalize the aggregated performance ratings based on criteria level. Obtained values from this operation are between 0 and 1. 1 is the best value whereas 0 is the worst.  $\tilde{r}_{ij}$  is a normalized aggregated performance rating for  $i^{\text{th}}$  alternative's  $j^{\text{th}}$  criterion.

$$\tilde{r}_{ij} = (r_{aj}, r_{bij}, r_{cij}) = \left( \frac{x_{aj} - x_{aj}^-}{x_{cj}^* - x_{aj}^-}, \frac{x_{bij} - x_{aj}^-}{x_{cj}^* - x_{aj}^-}, \frac{x_{cij} - x_{aj}^-}{x_{cj}^* - x_{aj}^-} \right), \quad \text{for } \forall i, j \quad (24)$$

$$x_{cj}^* = \max_i x_{cij} \quad (25)$$

$$x_{aj}^- = \min_i x_{aj} \quad (26)$$

**Step 5.** Find out the ideal solution and non-ideal solution.

$$A^+ = (r_1^*, r_2^*, r_3^*, \dots, r_n^*), \quad \text{where } A^+ \text{ is the set of ideal solutions} \quad (27)$$

$$r_j^* = (1, 1, 1) \quad (28)$$

$$A^- = (r_1^-, r_2^-, r_3^-, \dots, r_n^-), \quad \text{where } A^- \text{ is the set of ideal solutions} \quad (29)$$

$$r_j^- = (0, 0, 0) \quad (30)$$

**Step 6.** Compute the weighted distances from ideal and non-ideal solutions.

For ideal solutions,

$$D_i^+ = \sum_j 1/2 \left\{ \max(w_{aj}^1 |r_{aj} - 1|, w_{cj}^1 |r_{cj} - 1| + w_{bj}^1 |r_{bj} - 1|) \right\}, \text{ for } i = 1, 2, 3, \dots, m \quad (31)$$

For non-ideal solutions,

$$D_i^- = \sum_j 1/2 \left\{ \max(w_{aj}^1 |r_{aj} - 0|, w_{cj}^1 |r_{cj} - 0| + w_{bj}^1 |r_{bj} - 0|) \right\}, \text{ for } i = 1, 2, 3, \dots, m \quad (32)$$

**Step 7.** Calculate the proximity values of alternatives to the ideal solution by using values obtained in Step 6.

$$P_i^* = \frac{D_i^-}{D_i^- + D_i^+} \quad (33)$$

**Step 8.** Rank the alternatives according to proximity values obtained in Step 7 by taking non-ideal solution as a reference point. An alternative having the biggest proximity value is accepted as the best alternative.

## 5. APPLICATION

Logistics sector requires to work jointly with a great number of industries and be coherent with the business processes brought by them. Differently from other sectors, it develops a flexible and dynamic business manner to address the needs of parties integrated into its network. This sector necessitates to direct, to organize, to manage, to take action and to modernize every touch points that it comes across. The logistics sector reflects the conditions from economy to technology of the place where it takes position. Even in the same country, while a logistics firm keeps its vision busy with up-to-date trends such as cloud logistics, IoT and big data, the other logistics company may still be in the need of entering data manually for the estimations of weight or volume of shipments. These are the main reasons that the logistics sector draws our attentions.

It is known that CEOs of the logistics sector nowadays tend to have growth prospects in the short term, however, it is also widely accepted that there are limited opportunities in the sector to realize these growth targets compared to before. Hence, companies have resorted to improving their own businesses to generate their own opportunities. In this respect, we think that data management is one of today's great opportunities for firms. Not only data management but the management of utilizable data means much more for the logistics sector. Therefore, we decided to lead our research on topics that affect logistics sectors on data management. Finally, because of its innovative properties and advantages for the logistics sector, blockchain technology becomes our research field. Logistics sector feels the deficiency of immediate accurate information due to many existing mediaries inside it. Blockchain technology provides trustworthy between partners, enables to access to the transparent and secure data without waiting for a verification from a mediary, ensure to see the big picture behind the realized logistics operations.

## 5.1. Risk Assessment with DEMATEL Method

**Step 1.** Risks of using blockchain software are determined as criteria of DEMATEL method as in Table 5.1. Risk factors are explained in the following paragraphs.

- **Technology Risks** : In traditional application software systems, installation of extensive software upgrades is relatively easier than systems using blockchain technology. Blockchain systems consist of many mining computers through its network. In this structure, protocol updates get more compelling for blockchain technology since software debug happens many times with a considerable amounts. Having many nodes may make blockchain technology experience difficulty in software protocol updates (Zohar, 2015). Internet of things (IoT) such as temperature, humidity, vibration, position, etc. have significant roles in supply chain solutions. In case, potential blockchain software do not work-in-harmony with internet of things, expected benefits from the software cannot be obtained. Logistics companies such as third-party and fourth-party work with many suppliers through supply chains. With its distributed network structure, blockchain technology work with many nodes in its network, however, using wrong blockchain software may result with low performance in interoperability with other supply chains. In logistics business process reveals many different and unique type data related to product weight, package deci, invoice details, shipping charge, delivery plan and etc. At this point, used software have to process all data consistently without data loss that may put whole system in jeopardy.

Table 5.1: Risks of using a blockchain software

		Difficulty in software protocol updates
1	Technological Risks	Not work-in-harmony with Internet of Things Low performance in interoperability with other supply chains Difficulty in adaptability to logistics business process
2	Environmental Risks	Using high computational power owned processors dissipates heat High electricity consumption Permanently connected devices emit radiation
3	Privacy Risks	Anonymity Security Losing competitive advantage
4	Risks of cyber-attacks	Network-based attacks Infiltration into network via used nodes
5	Legal Uncertainties	No universal regulatory binding each country Unclear sanctions for hackers in countries in case hacking issues happen
6	Transactional Risks	Irreversibility of transactions Duplication of stored informations through nodes
7	Financial Risks	Capital Risk High maintenance cost Additional cost
8	Continuity Risks	Low adoption by future participant Failure in satisfying the needs in long run

- **Environmental Risks** : Blockchain systems' mining processes require to work with high computational power owned processors. This causes both consumption massive amount of electricity and dissipation heat into environment (Fairley, 2017; Zohar, 2015). Besides, blockchain's permanently connected nodes or devices cause emitting radiation too. These factors create environmental risk in case using blockchain software.

- **Privacy Risks** : In blockchain protocols, most users are not aware of privacy designs of the software and its backups as well (Krombholz et. al., 2016). In addition to that, blockchain's major transactions are realized via internet, which may cause many authentication details to be published in internet platform. In the network, following logs of transactions realized in the nodes give users opportunity to reveal the parties who were involved identity (Androulaki et. al; Meiklejohn et al., 2013), which is in contradiction with the characteristic of blockchain technology. From another perspective, in case a malicious user of blockchain software involved in a criminal activity, blockchain technology obstruct to be reaching real identity information of guilty since it has anonymity-supportive background. This background inherently creates a togetherness between users who are not aware of the identity of the other participaters (Bohr & Bashir, 2014; Ron & Shamir, 2013). In a blockchain software it is important to know which identity details are shared throughout the network since this may cause to lose network users' competitive advantage.
- **Risks of cyber attacks** : Network-based attacks causes to delays and blockage in the blockchain network. They also change the information received from the node users in the network, which may cause to distort comments and views on e-ledger (Gervais, Ritzdorf et. al., 2015; Karame, 2016). In case computationally powerful nodes in the network want to increase its payoffs, these nodes may cause to deviations from the existing Proof-of-Work protocols Eyal & Sirer, 2014), which is an example of infiltration into network via used nodes.
- **Legal Uncertainties** : Using blockchain systems have brought various unclear situations in regulations such as unclear taxation and not compulsion of complying with data privacy laws (Abramova & Böhme, 2016). Furthermore, there are unclear sanctions for hackers in case hacking issues. Since there is not a universal regulatory binding each country, there is not specified policy related to hacking issues, which creates a potential factor to decrease trust on blockchain system.

- **Transactional Risks** : After getting an approval related to a realized transaction, it is not possible to modify or change it (Beer & Weber, 2014; Böhme et al., 2015; Meiklejohn et al., 2013). This irreversibility principle makes impossible to revert mistakenly send information (Beer & Weber, 2014). Therefore, there is also a possibility for blockchain systems to lose its own values since there is not a centralized consensus mechanism to blacklist the realized transactions (Möser et al., 2013; Möser et al., 2014; Nofer et. al., 2017; Cohen and Zohar, 2018). Nodes increased in block size, realizes a high number of transactions in blockchain network. Moreover, proof-of-work data processing causes to store same data in different nodes. This causes to duplications of stored informations through nodes (Fairley, 2017; Zohar, 2015).
- **Financial Risks** : Softwares having blockchain technology are not budget-friendly. Moreover, they require investing a substantial amount of money only for the software itself. This may create a risk on the balance of income and expenditures of business since this spending will not yield more in a short time. All nodes and computers are connected permanently with each other. Frequent system upgrades or periodic maintenance works may cause high maintenance costs for the network. Even though the blockchain system comes with the idea of not working with a third party throughout its business process, there may be a necessity to work with them. For instance, in case a blockchain system is not enough to comprise a highly-secure user password, using a third party business would be inevitable.
- **Continuity Risks** : Blockchain technology has many advantages, however, it may lose its values on business with unforeseen reasons. Therefore, being used blockchain technology software may result in a failure in satisfying the needs in the long run or be adopted less by the future participants. These may generate risks for continuity of business processes and usage of the blockchain software.

**Step 2.** Three experts who are IT Project Group Manager, R&D Group Manager and Business Analyst respectively from the logistics company expressed opinions on the influences level of each criteria using influence level. (Table 5.2, 5.3, and 5.4).

Table 5.2: 1<sup>st</sup> decision maker's initial influence matrix

	C <sub>1</sub>	C <sub>2</sub>	C <sub>3</sub>	C <sub>4</sub>	C <sub>5</sub>	C <sub>6</sub>	C <sub>7</sub>	C <sub>8</sub>
C <sub>1</sub>	0	1	2	2	0	4	3	3
C <sub>2</sub>	0	0	0	0	0	0	1	0
C <sub>3</sub>	1	0	0	4	4	1	4	4
C <sub>4</sub>	3	0	3	0	4	1	3	4
C <sub>5</sub>	0	0	3	1	0	0	1	2
C <sub>6</sub>	3	2	1	0	0	0	1	3
C <sub>7</sub>	3	0	2	2	1	0	0	4
C <sub>8</sub>	2	1	3	0	0	0	4	0

Table 5.3: 2<sup>nd</sup> decision maker's initial influence matrix

	C <sub>1</sub>	C <sub>2</sub>	C <sub>3</sub>	C <sub>4</sub>	C <sub>5</sub>	C <sub>6</sub>	C <sub>7</sub>	C <sub>8</sub>
C <sub>1</sub>	0	2	1	1	0	3	4	4
C <sub>2</sub>	0	0	0	0	0	0	2	3
C <sub>3</sub>	1	0	0	4	4	1	2	2
C <sub>4</sub>	2	0	4	0	4	2	3	4
C <sub>5</sub>	0	0	3	1	0	0	1	2
C <sub>6</sub>	1	2	1	0	0	0	2	2
C <sub>7</sub>	2	0	3	3	0	0	0	4
C <sub>8</sub>	1	2	4	0	0	0	4	0

Table 5.4: 3<sup>rd</sup> decision maker's initial influence matrix

	C <sub>1</sub>	C <sub>2</sub>	C <sub>3</sub>	C <sub>4</sub>	C <sub>5</sub>	C <sub>6</sub>	C <sub>7</sub>	C <sub>8</sub>
C <sub>1</sub>	0	2	1	1	1	4	4	4
C <sub>2</sub>	1	0	0	0	2	0	2	2
C <sub>3</sub>	3	0	0	4	3	0	3	3
C <sub>4</sub>	2	0	3	0	3	0	3	3
C <sub>5</sub>	0	0	2	3	0	0	2	3
C <sub>6</sub>	2	1	0	1	0	0	1	3
C <sub>7</sub>	3	1	2	2	1	0	0	4
C <sub>8</sub>	2	1	3	4	0	0	3	0

**Step 3.** Aggregated matrix is calculated using average mean method (Table 5.5).

Table 5.5: Aggregated initial direct influence matrix

	C <sub>1</sub>	C <sub>2</sub>	C <sub>3</sub>	C <sub>4</sub>	C <sub>5</sub>	C <sub>6</sub>	C <sub>7</sub>	C <sub>8</sub>
C <sub>1</sub>	0	1.667	1.333	1.333	0.333	3.667	3.667	3.667
C <sub>2</sub>	0.333	0	0.000	0.000	0.667	0.000	1.667	1.667
C <sub>3</sub>	1.667	0.000	0	4.000	3.667	0.667	3.000	3.000
C <sub>4</sub>	2.333	0.000	3.333	0	3.667	1.000	3.000	3.667
C <sub>5</sub>	0.000	0.000	2.667	1.667	0	0.000	1.333	2.333
C <sub>6</sub>	2.000	1.667	0.667	0.333	0.000	0	1.333	2.667
C <sub>7</sub>	2.667	0.333	2.333	2.333	0.667	0.000	0	4.000
C <sub>8</sub>	1.667	1.333	3.333	1.333	0.000	0.000	3.667	0

**Step 4.** To demonstrate the direct effects of each criterion on others and the direct effects on criterion I, sums of the rows and columns are computed as in Table 5.6.

Table 5.6: Aggregated matrix

	C <sub>1</sub>	C <sub>2</sub>	C <sub>3</sub>	C <sub>4</sub>	C <sub>5</sub>	C <sub>6</sub>	C <sub>7</sub>	C <sub>8</sub>	Sum
C <sub>1</sub>	0	1.667	1.333	1.333	0.333	3.667	3.667	3.667	15.67
C <sub>2</sub>	0.333	0	0.000	0.000	0.667	0.000	1.667	1.667	4.33
C <sub>3</sub>	1.667	0.000	0	4.000	3.667	0.667	3.000	3.000	16
C <sub>4</sub>	2.333	0.000	3.333	0	3.667	1.000	3.000	3.667	17
C <sub>5</sub>	0.000	0.000	2.667	1.667	0	0.000	1.333	2.333	8
C <sub>6</sub>	2.000	1.667	0.667	0.333	0.000	0	1.333	2.667	8.67
C <sub>7</sub>	2.667	0.333	2.333	2.333	0.667	0.000	0	4.000	12.33
C <sub>8</sub>	1.667	1.333	3.333	1.333	0.000	0.000	3.667	0	11.33
Sum	10.67	5	13.67	11	9	5.33	17.67	21	

Then average matrix is normalized using formula (6) to get normalized aggregated matrix in Table 5.7.

Table 5.7: Normalized aggregated matrix

	C <sub>1</sub>	C <sub>2</sub>	C <sub>3</sub>	C <sub>4</sub>	C <sub>5</sub>	C <sub>6</sub>	C <sub>7</sub>	C <sub>8</sub>
C <sub>1</sub>	0.00	0.08	0.06	0.06	0.02	0.17	0.17	0.17
C <sub>2</sub>	0.02	0.00	0.00	0.00	0.03	0.00	0.08	0.08
C <sub>3</sub>	0.08	0.00	0.00	0.19	0.17	0.03	0.14	0.14
C <sub>4</sub>	0.11	0.00	0.16	0.00	0.17	0.05	0.14	0.17
C <sub>5</sub>	0.00	0.00	0.13	0.08	0.00	0.00	0.06	0.11
C <sub>6</sub>	0.10	0.08	0.03	0.02	0.00	0.00	0.06	0.13
C <sub>7</sub>	0.13	0.02	0.11	0.11	0.03	0.00	0.00	0.19
C <sub>8</sub>	0.08	0.06	0.16	0.06	0.00	0.00	0.17	0.00

**Step 5.** To obtain the sum of influence that criterion  $i$  receives from other criteria, formula (11) is applied in Table 5.9, 5.10, 5.11 using unit matrix in Table 5.8.

Table 5.8: Unit matrix  $I_{8 \times 8}$ 

	C <sub>1</sub>	C <sub>2</sub>	C <sub>3</sub>	C <sub>4</sub>	C <sub>5</sub>	C <sub>6</sub>	C <sub>7</sub>	C <sub>8</sub>
C <sub>1</sub>	1	0	0	0	0	0	0	0
C <sub>2</sub>	0	1	0	0	0	0	0	0
C <sub>3</sub>	0	0	1	0	0	0	0	0
C <sub>4</sub>	0	0	0	1	0	0	0	0
C <sub>5</sub>	0	0	0	0	1	0	0	0
C <sub>6</sub>	0	0	0	0	0	1	0	0
C <sub>7</sub>	0	0	0	0	0	0	1	0
C <sub>8</sub>	0	0	0	0	0	0	0	1

Table 5.9: (1- D)

	C <sub>1</sub>	C <sub>2</sub>	C <sub>3</sub>	C <sub>4</sub>	C <sub>5</sub>	C <sub>6</sub>	C <sub>7</sub>	C <sub>8</sub>
C <sub>1</sub>	1.00	-0.08	-0.06	-0.06	-0.02	-0.17	-0.17	-0.17
C <sub>2</sub>	-0.02	1.00	0.00	0.00	-0.03	0.00	-0.08	-0.08
C <sub>3</sub>	-0.08	0.00	1.00	-0.19	-0.17	-0.03	-0.14	-0.14
C <sub>4</sub>	-0.11	0.00	-0.16	1.00	-0.17	-0.05	-0.14	-0.17
C <sub>5</sub>	0.00	0.00	-0.13	-0.08	1.00	0.00	-0.06	-0.11
C <sub>6</sub>	-0.10	-0.08	-0.03	-0.02	0.00	1.00	-0.06	-0.13
C <sub>7</sub>	-0.13	-0.02	-0.11	-0.11	-0.03	0.00	1.00	-0.19
C <sub>8</sub>	-0.08	-0.06	-0.16	-0.06	0.00	0.00	-0.17	1.00

Table 5.10:  $(1-D)^{-1}$ 

	C <sub>1</sub>	C <sub>2</sub>	C <sub>3</sub>	C <sub>4</sub>	C <sub>5</sub>	C <sub>6</sub>	C <sub>7</sub>	C <sub>8</sub>
C <sub>1</sub>	1.137	0.137	0.222	0.190	0.106	0.215	0.355	0.381
C <sub>2</sub>	0.054	1.016	0.054	0.042	0.054	0.013	0.132	0.138
C <sub>3</sub>	0.217	0.054	1.205	0.331	0.285	0.092	0.352	0.383
C <sub>4</sub>	0.249	0.061	0.348	1.173	0.283	0.110	0.363	0.418
C <sub>5</sub>	0.083	0.027	0.228	0.170	1.078	0.030	0.185	0.238
C <sub>6</sub>	0.162	0.113	0.122	0.089	0.049	1.036	0.178	0.241
C <sub>7</sub>	0.235	0.066	0.262	0.233	0.130	0.060	1.194	0.374
C <sub>8</sub>	0.185	0.099	0.280	0.185	0.098	0.050	0.324	1.192

Table 5.11:  $D(1-D)^{-1}$ 

	C <sub>1</sub>	C <sub>2</sub>	C <sub>3</sub>	C <sub>4</sub>	C <sub>5</sub>	C <sub>6</sub>	C <sub>7</sub>	C <sub>8</sub>
C <sub>1</sub>	0.137	0.137	0.222	0.190	0.106	0.215	0.355	0.381
C <sub>2</sub>	0.054	0.016	0.054	0.042	0.054	0.013	0.132	0.138
C <sub>3</sub>	0.217	0.054	0.205	0.331	0.285	0.092	0.352	0.383
C <sub>4</sub>	0.249	0.061	0.348	0.173	0.283	0.110	0.363	0.418
C <sub>5</sub>	0.083	0.027	0.228	0.170	0.078	0.030	0.185	0.238
C <sub>6</sub>	0.162	0.113	0.122	0.089	0.049	0.036	0.178	0.241
C <sub>7</sub>	0.235	0.066	0.262	0.233	0.130	0.060	0.194	0.374
C <sub>8</sub>	0.185	0.099	0.280	0.185	0.098	0.050	0.324	0.192

**Step 6.** As indicated in detail in previous Step 5, vector R and Vector C are calculated as it follows:

Table 5.12: Aggregated matrix

	C <sub>1</sub>	C <sub>2</sub>	C <sub>3</sub>	C <sub>4</sub>	C <sub>5</sub>	C <sub>6</sub>	C <sub>7</sub>	C <sub>8</sub>	R
C <sub>1</sub>	0.137	0.137	0.222	0.190	0.106	0.215	0.355	0.381	1.74
C <sub>2</sub>	0.054	0.016	0.054	0.042	0.054	0.013	0.132	0.138	0.50
C <sub>3</sub>	0.217	0.054	0.205	0.331	0.285	0.092	0.352	0.383	1.92
C <sub>4</sub>	0.249	0.061	0.348	0.173	0.283	0.110	0.363	0.418	2.01
C <sub>5</sub>	0.083	0.027	0.228	0.170	0.078	0.030	0.185	0.238	1.04
C <sub>6</sub>	0.162	0.113	0.122	0.089	0.049	0.036	0.178	0.241	0.99
C <sub>7</sub>	0.235	0.066	0.262	0.233	0.130	0.060	0.194	0.374	1.55
C <sub>8</sub>	0.185	0.099	0.280	0.185	0.098	0.050	0.324	0.192	1.41
C	1.3208	0.57421	1.72231	1.4129	1.0814	0.6066	2.0852	2.363	

R+C and R-C values are demonstrated in the Table 5.13. Following explained rules in the previous Step 6, Technological Risks, Privacy Risks, Risks of cyber-attacks and Transactional Risks are net cause and affect other criteria (R-C value is positive). Environmental Risks, Legal Uncertainties, Financial Risks and Continuity Risks are net receiver (R-C value is negative).

Table 5.13: Normalized risk weights

Criteria	R	C	R+C	R+C	R-C	W <sub>i</sub>	Normalized Value
C <sub>1</sub>	1.743	1.321	3.063	0.137	0.422	3.067	13.717%
C <sub>2</sub>	0.503	0.574	1.077	0.048	-0.072	1.078	4.821%
C <sub>3</sub>	1.919	1.722	3.641	0.163	0.197	3.645	16.305%
C <sub>4</sub>	2.005	1.413	3.418	0.153	0.592	3.422	15.305%
C <sub>5</sub>	1.040	1.081	2.121	0.095	-0.042	2.123	9.497%
C <sub>6</sub>	0.989	0.607	1.596	0.071	0.383	1.598	7.146%
C <sub>7</sub>	1.555	2.085	3.640	0.163	-0.530	3.644	16.298%
C <sub>8</sub>	1.413	2.363	3.777	0.169	-0.950	3.780	16.910%
<b>sum</b>			22.33	1		22.36	1

**Step 7:** Threshold value is set to average value of R+C. At this point, criteria that are bigger than this mean value are accepted as highly important on the risk assessment of the usage of blockchain software. Technological Risks, Privacy Risks, Risks of cyber-attacks, Financial Risks and Continuity Risks must be take into consideration on the blockchain software selection.

### **5.1.1. Results for Risk Assessment**

DEMATEL method has presented that risks of low adoption by future participant and failure in satisfying the needs in long run are constituting the biggest concern with 16.910 % weight. The importance degrees of privacy risks and financial risks are slightly less than continuity risks with the weights of 16.305% and 16.298% respectively. Those three risk factors generates half of overall weights. Risks of network-based attacks and infiltration into network via used nodes comes with 15.305% as fourth important risk of using blockchain technology and followed by technological risks. Environmental risks' importance degree fall behind all other risk factors by getting the lowest risk criterion with 4.821% weight.

After determining and obtaining influence level of risk criteria by using DEMATEL technique, it is aimed to decrease the risks of using a blockchain system. Therefore, it is decided to follow a procedure to reach the best alternative by believing that achieving the best result would be assistive to prevent the occurrence of mentioned risk criteria and to decrease the frequency of them. In order to realize this, MCDM methods are applied to this selection problem to reach the best blockchain technology software.

## 5.2. Criteria Weighting for Blockchain Software Selection using AHP Method

**Step 1.** Criteria' hierarchy is structured as given in Table 5.14:

Table 5.14: Hierarchical Structure

Main Criteria	Sub-Criteria
	C <sub>11</sub> : Purchase Cost
C <sub>1</sub> : Cost	C <sub>12</sub> : Maintenance Cost
	C <sub>13</sub> : Additional Cost
	C <sub>21</sub> : Encryption Speed
C <sub>2</sub> : Speed	C <sub>22</sub> : Speed Of Transactions
	C <sub>23</sub> : Latency In Results Of Queries
	C <sub>31</sub> : Security
C <sub>3</sub> : Privacy Concerns	C <sub>32</sub> : Anonymity
	C <sub>33</sub> : IP Tracking
	C <sub>41</sub> : Work-in-harmony With Internet Of Things
C <sub>4</sub> : Logistics Issues	C <sub>42</sub> : Interoperability With Other Supply Chains
	C <sub>43</sub> : Range Of Services Provided
	C <sub>44</sub> : Adaptability To Logistics Business Process
C <sub>5</sub> : Functionality	-
C <sub>6</sub> : Developer Availability	-

- **Cost** : Purchase cost is the price that logistics company is willing to pay to get the usufruct of the blockchain software package. Maintenance cost refers to the expenditures to be done to keep software and software technical infrastructure including equipment in good conditions. Even though blockchain technology promises to reduce using third parties through its data traffic in the network, there are occasions that using a third party is inevitable. For instance, in case blockchain software users attach a lot importance to receive super strong usernames and passwords, a third party is utilized to generate them.

- ***Speed*** : Encryption speed implies the speed of the process of encoding data flows through in the network. Because of blockchain technology's data verification structure, transactions speed through nodes is significant in software's working fast. Users demand to see any data's realized transactions in its history, which is highly acceptable supported by blockchain technology with its transparency feature. Therefore, software that has less latency in intended queries is more beneficial.
- ***Privacy Concerns*** : All data activities is open to view by users via internet. Therefore blockchain software's security system must be strong to protect users' identical informations as well as their transactions. The software should meet all the anonymity related requirements in its structure to guarantee it to users. In case IP tracked datas are shared with participator of the network, estimating the real identitiy of the users would not be difficult. This does more harm than good. For instance, if company A and B are competitors and do not know that they are integrated into the same blockchain software, they would be able to know each other using IP tracking with hacking tricks. Then, being able to follow their transactional operations may cause to reveal their competitive advantage in their business fields.
- ***Logistics Issues*** : Internet of things enhance the asset utilization, provide efficient process controlling increase productivity with a cost saving manner. Hence, blockchain software that would be used as a supply chain solution should work-in-harmony with the internet of things sensors. Despite the company plans to solve the transparency problem for the sole company at the first stage, it is significant to be sure that software would be flexible to work with many complex supply chain networks. Alternative blockchain software may have a brand new component that will put forward it during comparison with other softwares. Therefore, blockchain software's range of services provided is take into consideration in the decision process. Despite blockchain software seems to perform well in the earlier stages, there may have problems in adaptability to logistics business process. Thence, software should be criticized and assessed with its all component by considering the logistics business process.

- **Functionality** : Promising advantages should be achievable at every possible conditions. Components should be user-friendly and able to be utilised as it is promised. Tracking and tracing should not be a time-spending activity instead of being supportive.
- **Developer Availability** : Using blockchain technology in the supply chain network is relatively a brand new solution. There may situations to interfere with the software's code blocks to prevent something's not right before it happens and causing to more damage in the future. At times like these, finding an experienced and well-informed developer for the software in use would be vital importance for the network.

**Step 2.** After determining selection criteria, pairwise comparisons are realized using linguistics variable given in Table 4.1. Three decision maker accompanied to the decision process as indicated in the Step 2 of DEMATEL method's application.

**Step 3.** Decision matrixes are constructed. Decision-makers' criteria comparisons for main criteria are given in the following tables.

Table 5.15 : DM<sub>1</sub>'s pairwise comparison for main criteria

DM <sub>1</sub>	C <sub>1</sub>	C <sub>2</sub>	C <sub>3</sub>	C <sub>4</sub>	C <sub>5</sub>	C <sub>6</sub>
C <sub>1</sub>	1	M	H	L	VH	VH
C <sub>2</sub>		1	H	M	VH	VH
C <sub>3</sub>			1	H	H	VH
C <sub>4</sub>				1	H	VH
C <sub>5</sub>					1	M
C <sub>6</sub>						1

Table 5.16 : DM<sub>2</sub>'s pairwise comparison for main criteria

DM <sub>2</sub>	C <sub>1</sub>	C <sub>2</sub>	C <sub>3</sub>	C <sub>4</sub>	C <sub>5</sub>	C <sub>6</sub>
C <sub>1</sub>	1	L	L	M	H	VH
C <sub>2</sub>		1	M	L	H	VH
C <sub>3</sub>			1	M	L	VH
C <sub>4</sub>				1	VH	VH
C <sub>5</sub>					1	H
C <sub>6</sub>						1

Table 5.17 : DM<sub>3</sub>'s pairwise comparison for main criteria

DM <sub>3</sub>	C <sub>1</sub>	C <sub>2</sub>	C <sub>3</sub>	C <sub>4</sub>	C <sub>5</sub>	C <sub>6</sub>
C <sub>1</sub>	1	H	M	M	H	VH
C <sub>2</sub>		1	L	H	VH	VH
C <sub>3</sub>			1	M	H	H
C <sub>4</sub>				1	H	H
C <sub>5</sub>					1	VH
C <sub>6</sub>						1

**Step 4-5.** Decision makers' judgments on pairwise comparisons are aggregated using formula 13. Obtained aggregated decision matrix for main criteria is in given in Table 5.18a and 5.18b.

Table 5.18a. Aggregated matrix for decision makers' preferences on main criteria.

	C <sub>1</sub>	C <sub>2</sub>	C <sub>3</sub>
C <sub>1</sub>	(1,1,1)	(3, 5, 7)	(3, 5, 7)
C <sub>2</sub>	(1/7, 2/9, 1/2)	(1, 1, 1)	(11/3, 17/3,23/3)
C <sub>3</sub>	(1/7, 2/9, 1/2)	(1/8, 1/6, 2/7)	(1, 1, 1)
C <sub>4</sub>	(1/8, 1/6, 2/7)	(1/7, 2/9, 1/2)	(1/8, 1/6, 2/7)
C <sub>5</sub>	(1/8, 1/8, 1/6)	(1/9, 1/8, 1/6)	(1/7 1/5, 1/2)
C <sub>6</sub>	(1/9, 1/9, 1/7)	(1/9, 1/9, 1/7)	(1/9, 1/8, 1/6)

Table 5.18b. Aggregated matrix for decision makers' preferences on main criteria.

	C <sub>4</sub>	C <sub>5</sub>	C <sub>6</sub>
C <sub>1</sub>	(7/3, 13/3, 19/3)	(17/3, 23/3, 9)	(7, 9, 9)
C <sub>2</sub>	3, 7, 7)	(19/3, 25/3, 9)	(7, 9, 9)
C <sub>3</sub>	(11/3, 17/3, 23/3)	(11/3, 17/3, 23/3)	(19/3, 25/3, 9)
C <sub>4</sub>	(1, 1, 1)	(17/3, 23/3, 9)	(19/3, 25/3, 9)
C <sub>5</sub>	(1/9, 1/8, 1/6)	(1, 1, 1)	(5, 7, 25/3)
C <sub>6</sub>	(1/9, 1/8, 1/6)	(1/8, 1/7, 2/9)	(1, 1, 1)

**Step 6.** Geometric mean for each parameter  $\tilde{a}_{ij}^k$  is calculated using formula 15.

Table 5.19. Geometric mean of each main criterion

Geometric mean of	Fuzzy number of geometric mean
$\tilde{r}_1$	(3.07, 4.42, 5.41)
$\tilde{r}_2$	(2.05, 2.8, 3.61)
$\tilde{r}_3$	(1.09, 1.49, 2.07)
$\tilde{r}_4$	(0.68, 0.88, 1.23)
$\tilde{r}_5$	(0.32, 0.28, 0.52)
$\tilde{r}_6$	(0.16, 0.17, 0.02)

**Step 7.** Vector summation is realized for fuzzy number of geometric means.

Table 5.20. Vector Summation for fuzzy number of geometric means

Name of the value	Fuzzy number of the value
Vector Summation	(7.37, 10.1, 13.1)
Reverse (power of -1)	(0.14, 0.1, 0.08)
Increasing order	(0.08, 0.1, 0.14)

Reverse power of vector summation values are calculated. Then, they are ranked in increasing order. These increasing ordered values in the Table 5.20 are multiplied with fuzzy number of geometric mean given in Table 5.19. Thus, Table 5.21 is obtained.

Table 5.21. Weighted fuzzy number of geometric mean

Geometric mean of criteria	Weighted fuzzy number of geometric mean
$\tilde{r}_1$	(0.23, 0.44, 0.73)
$\tilde{r}_2$	(0.16, 0.28, 0.49)
$\tilde{r}_3$	(0.08, 0.15, 0.28)
$\tilde{r}_4$	(0.05, 0.09, 0.17)
$\tilde{r}_5$	(0.02, 0.04, 0.07)
$\tilde{r}_6$	(0.01, 0.02, 0.03)

**Step 8.** Fuzzy weights calculated in Table 5.21 is defuzzified using Chou and Chang's Centre of Area Method using formula 18 (Table 5.22).

Table 5.22.  $M_i$  weights

Geometric mean of criteria	$M_i$
$\tilde{r}_1$	0.47
$\tilde{r}_2$	0.31
$\tilde{r}_3$	0.17
$\tilde{r}_4$	0.1
$\tilde{r}_5$	0.04
$\tilde{r}_6$	0.02
Sum	1,11

**Step 9.** Even though  $M_i$  is a non-fuzzy number it requires to be normalized to make sum of the weights equal to 1.

Table 5.23. Weights of main criteria

Geometric mean of criteria	$M_i$	$N_i$
$\tilde{r}_1$	0.47	0.42
$\tilde{r}_2$	0.31	0.28
$\tilde{r}_3$	0.17	0.15
$\tilde{r}_4$	0.1	0.09
$\tilde{r}_5$	0.04	0.04
$\tilde{r}_6$	0.02	0.02
Sum	1,11	1

Using the same steps given in methodology, sub-criteria weights are calculated and overall weights of them computed as it is in Table 5.24.

Table 5.24. Weights of main criteria and sub-criteria

Main Criteria	Sub-Criteria	Weights	Overall
C <sub>1</sub> : Cost	C <sub>11</sub> : Purchase Cost	0.760	0.32
	C <sub>12</sub> : Maintenance Cost	0.182	0.08
	C <sub>13</sub> : Additional Cost	0.058	0.02
C <sub>2</sub> : Speed	C <sub>21</sub> : Encryption Speed	0.656	0.18
	C <sub>22</sub> : Speed Of Transactions	0.274	0.08
	C <sub>23</sub> : Latency In Results Of Queries	0.070	0.02
C <sub>3</sub> : Privacy Concerns	C <sub>31</sub> : Security	0.703	0.11
	C <sub>32</sub> : Anonymity	0.242	0.04
	C <sub>33</sub> : IP Tracking	0.055	0.01
C <sub>4</sub> :Logistics Issues	C <sub>41</sub> :Work-in-harmony With Internet Of	0.608	0.06
	C <sub>42</sub> : Interoperability With Other Supply	0.218	0.02
	C <sub>43</sub> : Range Of Services Provided	0.078	0.01
	C <sub>44</sub> :Adaptability To Logistics Business	0.096	0.01
C <sub>5</sub> : Functionality	-	-	0.04
C <sub>6</sub> : Developer Availability	-	-	0.02

### 5.2.1. Results

Cost criterion is the dominant weight with 0.42, and Speed follows it with 0.28. With Privacy Concerns having third biggest weight, these three weights account for 0.85, which purports they will take a big role in blockchain software selection problem. Logistics Issues has relatively bigger weight than Functionality and Developer Availability, however, their effects will be less with 0.15 weight selection procedure. This result shows us that software cost, software speed, and privacy concerns are main determinants of the selection.

### 5.3. Blockchain Software Selection using Fuzzy TOPSIS Method

The logistics company has 4 alternative blockchain softwares (Tradelens, Cargosmart, Shipchain, and Origintrail) that are suitable to be operated in its logistics business processes.

- *TradeLens* is a platform gathering supply chain partners such as cargo owners, ocean and inland carriers, freight forwarders and logistics providers, ports and terminals, and customs authorities ([tradelens.com](http://tradelens.com)).
- *Cargosmart* involves with shippers, consignees, logistics service providers, and NVOCCs. It enables transferring data in the network into the participants' internal systems. Cargosmart promises potential users to serve as a solution on decreasing transportation management costs, improving management efficiency and collaboration between supply chain partners ([cargosmart.com](http://cargosmart.com)).
- *Shipchain* ensures end-to-end track and trace in supply chains from the moment that a shipment leaves the production facility, to the final delivery on the customer's doorstep. Shipchain also consists of a mobile application called Geofencing to make shipments fully visible and trackable by providing an online map. Shipchain promises an untroubled utilization for companies without stipulating to a specific programming language for integrated working with current systems of potential users ([shipchain.com](http://shipchain.com)).

- *Origintrail* is a protocol for supply chains that work in a blockchain technology. The logistics company is intended to evaluate this alternative for the probability of generating its own distributed database.

**Step 1:** As aforementioned in section 5.1 and 5.2, three decision makers accompanied to the evaluation of alternatives and they used triangular fuzzy numbers given in Table 4.2 for evaluation of alternatives.

Table 5.25: First decision maker's judgments on alternatives

		S1	S2	S3	S4
C <sub>1</sub>	C <sub>11</sub>	VH	H	H	M
	C <sub>12</sub>	VL	VL	VL	L
	C <sub>13</sub>	VL	M	L	L
C <sub>2</sub>	C <sub>21</sub>	VH	VH	H	VH
	C <sub>22</sub>	H	VH	H	VH
	C <sub>23</sub>	L	VL	M	VL
C <sub>3</sub>	C <sub>31</sub>	VH	H	H	H
	C <sub>32</sub>	VH	H	H	H
	C <sub>33</sub>	VL	VL	VL	M
C <sub>4</sub>	C <sub>41</sub>	VH	VH	VL	VL
	C <sub>42</sub>	VH	L	L	H
	C <sub>43</sub>	VL	VH	M	H
C <sub>5</sub>	C <sub>44</sub>	VH	VH	VH	VH
	C <sub>5</sub>	VH	H	H	VH
C <sub>6</sub>	C <sub>6</sub>	VH	M	L	M

Table 5.26: Second decision maker's judgments on alternatives

		S1	S2	S3	S4
C <sub>1</sub>	C <sub>11</sub>	VH	VH	H	H
	C <sub>12</sub>	M	L	L	M
	C <sub>13</sub>	L	M	L	L
C <sub>2</sub>	C <sub>21</sub>	H	VH	H	VH
	C <sub>22</sub>	H	VH	H	H
	C <sub>23</sub>	L	VL	M	L
C <sub>3</sub>	C <sub>31</sub>	VH	H	M	M
	C <sub>32</sub>	VH	H	M	H
	C <sub>33</sub>	VL	L	M	M
C <sub>4</sub>	C <sub>41</sub>	VH	H	VL	VL
	C <sub>42</sub>	VH	L	M	M
	C <sub>43</sub>	VL	H	VL	M
	C <sub>44</sub>	VH	VH	L	M
C <sub>5</sub>	C <sub>5</sub>	VH	H	M	H
C <sub>6</sub>	C <sub>6</sub>	H	M	VL	L

Table 5.27: Third decision maker's judgments on alternatives

		S1	S2	S3	S4
C <sub>1</sub>	C <sub>11</sub>	VH	VH	H	M
	C <sub>12</sub>	M	L	L	VL
	C <sub>13</sub>	VL	L	L	L
C <sub>2</sub>	C <sub>21</sub>	VH	H	H	VH
	C <sub>22</sub>	VH	VH	VH	H
	C <sub>23</sub>	VL	VL	VL	M
C <sub>3</sub>	C <sub>31</sub>	VH	H	H	M
	C <sub>32</sub>	VH	VH	M	H
	C <sub>33</sub>	VL	VL	VL	M
C <sub>4</sub>	C <sub>41</sub>	VH	VH	L	L
	C <sub>42</sub>	VH	M	H	M
	C <sub>43</sub>	VL	H	H	L
	C <sub>44</sub>	VH	VH	H	VH
C <sub>5</sub>	C <sub>5</sub>	VH	VH	H	H
C <sub>6</sub>	C <sub>6</sub>	VH	M	L	VL

Then, decision makers's preferences are aggregated via weighted average method (formula 13) as given in Table 5.28.

Table 5.28: Aggregated decision matrix

	S1	S2	S3	S4
C <sub>11</sub>	(7,9,9)	(6.33,8.33,9)	(5,7,9)	(3.67,5.67,7.67)
C <sub>1</sub> C <sub>12</sub>	(2.33,3.67,5.67)	(1,2.33,4.33)	(1,2.33,4.33)	(1.67,3,5)
C <sub>13</sub>	(1,1.67,3.67)	(2.33,4.33,6.33)	(1,3,5)	(1,3,5)
C <sub>21</sub>	(6.33,8.33,9)	(6.33,8.33,9)	(5,7,9)	(7,9,9)
C <sub>2</sub> C <sub>22</sub>	(5.67,7.67,9)	(7,9,9)	(5.67,7.67,9)	(5.67,7.67,9)
C <sub>23</sub>	(1,2.33,4.33)	(1,1,3)	(2.33,3.67,5.67)	(1.67,3,5)
C <sub>31</sub>	(7,9,9)	(5,7,9)	(4.33,6.33,8.33)	(3.67,5.67,7.67)
C <sub>3</sub> C <sub>32</sub>	(7,9,9)	(5.67,7.67,9)	(3.67,5.67,7.67)	(5,7,9)
C <sub>33</sub>	(1,1,3)	(1,1.67,3.67)	(1.67,2.33,4.33)	(3,5,7)
C <sub>41</sub>	(7,9,9)	(6.33,8.33,9)	(1,1.67,3.67)	(1,1.67,3.67)
C <sub>4</sub> C <sub>42</sub>	(7,9,9)	(1.67,3.67,5.67)	(3,5,7)	(3.67,5.67,7.67)
C <sub>43</sub>	(1,1,3)	(5.67,7.67,9)	(3,4.33,6.33)	(3,5,7)
C <sub>44</sub>	(7,9,9)	(7,9,9)	(4.33,6.33,7.67)	(5.67,7.67,8.33)
C <sub>5</sub>	(7,9,9)	(5.67,7.67,9)	(4.33,6.33,8.33)	(5.67,7.67,9)
C <sub>6</sub>	(6.33,8.33,9)	(3,5,7)	(1,2.33,4.33)	(1.67,3,5)

**Step 2.** Purchase cost, maintenance cost, additional cost, latency in results of queries and IP tracking are cost type criteria whereas rest of the criteria are benefit type. To obtain unit free values for alternatives with regard to criteria, decision matrix is normalized using formula 19, 20 and 21 as in Table 5.29.

Table 5.29: Normalized aggregated decision matrix

	S1	S2	S3	S4
C <sub>11</sub>	(0.375,0,0)	(0.5,0.125,0)	(0.75,0.38,0)	(1,0.625,0.25)
C <sub>1</sub> C <sub>12</sub>	(0.71,0.43,0)	(1,0.71,0.29)	(1,0.71,0.29)	(0.86,0.57,0.14)
C <sub>13</sub>	(1,0.875,0.5)	(0.75,0.375,0)	(1,0.63,0.25)	(1,0.63,0.25)
C <sub>21</sub>	(0.33,0.83,1)	(0.33,0.83,1)	(0,0.5,1)	(0.5,1,1)
C <sub>2</sub> C <sub>22</sub>	(0,0.6,1)	(0.4,1,1)	(0,0.6,1)	(0,0.6,1)
C <sub>23</sub>	(1,0.71,0.29)	(1,1,0.57)	(0.71,0.43,0)	(0.86,0.57,0.14)
C <sub>31</sub>	(0.625,1,1)	(0.25,0.625,1)	(0.13,0.5,0.88)	(0,0.375,0.75)
C <sub>3</sub> C <sub>32</sub>	(0.625,1,1)	(0.375,0.75,1)	(0,0.38,0.75)	(0.25,0.625,1)
C <sub>33</sub>	(1,1,0.67)	(1,0.89,0.56)	(0.89,0.78,0.44)	(0.67,0.33,0)
C <sub>41</sub>	(0.75,1,1)	(0.67,0.92,1)	(0,0.08,0.33)	(0,0.08,0.33)
C <sub>4</sub> C <sub>42</sub>	(0.73,1,1)	(0,0.27,0.55)	(0.18,0.45,0.73)	(0.27,0.55,0.82)
C <sub>43</sub>	(0,0,0.25)	(0.58,0.83,1)	(0.25,0.42,0.67)	(0.25,0.5,0.75)
C <sub>44</sub>	(0.57,1,1)	(0.57,1,1)	(0,0.43,0.71)	(0.29,0.71,0.86)
C <sub>5</sub>	(0.57,1,1)	(0.29,0.71,1)	(0,0.43,0.86)	(0.29,0.71,1)
C <sub>6</sub>	(0.67,0.92,1)	(0.25,0.5,0.75)	(0,0.17,0.42)	(0.08,0.25,0.5)

**Step 3.** Alternatives' performance rating are aggregated at sub-criteria level as in Table 5.30 using formula 23. With this step, fuzzy values are converted to  $\tilde{x}_{ij} = (x_{aij}, x_{bij}, x_{cij})$  type. Weights are obtained in Section 5.2 via Buckley's AHP Method.

Table 5.30: Weighted normalized aggregated decision matrix at sub-criteria level.

	S1	S2	S3	S4
C <sub>11</sub>	(0,0,0.38)	(0,0.1,0.5)	(0,0.29,0.76)	(0.14,0.48,1.01)
C <sub>1</sub> C <sub>12</sub>	(0,0.33,0.72)	(0.16,0.55,1.01)	(0.16,0.55,1.01)	(0.08,0.44,0.87)
C <sub>13</sub>	(0.28,0.67,1.01)	(0,0.29,0.76)	(0.14,0.48,1.01)	(0.14,0.48,1.01)
C <sub>21</sub>	(0.19,0.64,1.01)	(0.19,0.64,1.01)	(0,0.39,1.01)	(0.28,0.77,1.01)
C <sub>2</sub> C <sub>22</sub>	(0,0.46,1.01)	(0.23,0.77,1.01)	(0,0.46,1.01)	(0,0.46,1.01)
C <sub>23</sub>	(0.16,0.55,1.01)	(0.32,0.77,1.01)	(0,0.33,0.72)	(0.08,0.44,0.87)
C <sub>31</sub>	(0.36,0.77,1.01)	(0.14,0.48,1.01)	(0.07,0.39,0.88)	(0,0.29,0.76)
C <sub>3</sub> C <sub>32</sub>	(0.36,0.77,1.01)	(0.21,0.58,1.01)	(0,0.29,0.76)	(0.14,0.48,1.01)
C <sub>33</sub>	(0.38,0.77,1.01)	(0.32,0.69,1.01)	(0.25,0.6,0.9)	(0,0.26,0.67)
C <sub>41</sub>	(0.43,0.77,1.01)	(0.38,0.71,1.01)	(0,0.06,0.34)	(0,0.06,0.34)
C <sub>4</sub> C <sub>42</sub>	(0.41,0.77,1.01)	(0,0.21,0.55)	(0.1,0.35,0.73)	(0.16,0.42,0.83)
C <sub>43</sub>	(0,0,0.25)	(0.33,0.64,1.01)	(0.14,0.32,0.67)	(0.14,0.39,0.76)
C <sub>44</sub>	(0.32,0.77,1.01)	(0.33,0.77,1.01)	(0,0.33,0.72)	(0.16,0.55,0.87)
C <sub>5</sub>	(0.32,0.77,1.01)	(0.16,0.55,1.01)	(0,0.33,0.87)	(0.16,0.55,1.01)
C <sub>6</sub>	(0.38,0.71,1.01)	(0.14,0.39,0.76)	(0,0.13,0.42)	(0.05,0.19,0.50)

**Step 4.** Following weighted normalization at sub-criteria level, normalization operation is conducted at criteria using formula 24, 25 and 26 as given in Table 5.31.

Table 5.31: Weighted normalized aggregated decision matrix at criteria level.

	S1	S2	S3	S4
C <sub>1</sub>	(0.02,0.23,0.72)	(0,0.22,0.78)	(0.03,0.32,0.96)	(0.04,0.34,1)
C <sub>2</sub>	(0.03,0.3,1)	(0.07,0.39,1)	(0,0.21,0.90)	(0.036,0.3,0.95)
C <sub>3</sub>	(0.15,0.51,1)	(0.08,0.38,1)	(0.03,0.27,0.83)	(0,0.22,0.80)
C <sub>4</sub>	(0.08,0.35,0.91)	(0.07,0.35,1)	(0,0.15,0.68)	(0.02,0.20,0.77)
C <sub>5</sub>	(0.11,0.5,1)	(0.06,0.35,1)	(0,0.21,0.86)	(0.06,0.35,1)
C <sub>6</sub>	(0.15,0.51,1)	(0.06,0.28,0.75)	(0,0.09,0.42)	(0.02,0.14,0.5)

**Step 5.** Using formula 27, 28, 29 and 30, following ideal and non-ideal solution sets are defined.

Table 5.32: Ideal solution set

	S1	S2	S3	S4
$r_1^*$	1	1	1	1
$r_2^*$	1	1	1	1
$r_3^*$	1	1	1	1
$r_4^*$	1	1	1	1
$r_5^*$	1	1	1	1
$r_6^*$	1	1	1	1

Table 5.33: Non-ideal solution set

	S1	S2	S3	S4
$r_1^-$	0	0	0	0
$r_2^-$	0	0	0	0
$r_3^-$	0	0	0	0
$r_4^-$	0	0	0	0
$r_5^-$	0	0	0	0
$r_6^-$	0	0	0	0

**Step 6.** Weighted distances from the ideal and non-ideal solutions are calculated using formula 31 and 32.

$$D_1^+ = 1.37, D_2^+ = 1.35, D_3^+ = 1.57, D_4^+ = 1.51$$

$$D_1^- = 0.10, D_2^- = 0.07, D_3^- = 0.02, D_4^- = 0.03$$

**Step 7-8.** Alternatives' proximity to the non-ideal solutions are calculated using formula 33 and ranked in descending order.

$$P_1 = 0.066, P_2 = 0.049, P_4 = 0.020, P_3 = 0.013$$

### 5.3.1. Results

By applying Fuzzy TOPSIS method in the selection procedure, we obtained the best blockchain software among alternatives with the following rank from best to the worst: Tradelens, Cargosmart, Origintrail, Shipchain. With the weight of 32% overall, purchase cost is ended up as the most important criterion in the the process of criteria weighting. Two of decision-makers express their views on Origintrail as medium level for its purchase cost while they determine other alternatives as high level. However, it is

not selected as the best software for the logistics company. This leads us to think that blockchain software technology selection necessitates thinking beyond financial concerns as well. Therefore, taking criteria such as security, anonymity, encryption speed, and work-in harmony with IoT into consideration becomes inevitable.

Decision makers's aggregated preferences in Table 5.28 demonstrates that Tradelens and Cargosmart have gotten similar judgments. Similarly, Origintrail and Shipchain have been graded so close by the decision-makers. This situation is also viewed in the rank that is obtained from Fuzzy TOPSIS. Tradelens, Cargosmart, Origintrail and Shipchain get the value of the proximity to the ideal solution as 0.066, 0.049, 0.020, 0.013, respectively.

Tradelens is one of the well-known logistics blockchain software and it is used by the firms, which are the leaders of their own sectors, such as MAERSK and IBM. Moreover, Tradelens is used by the logistics company's some of the foreign branches. Because of that cause and the proposed methodology's result, decision-makers decided to proceed with the Tradelens.

## 6. CONCLUSION

The purpose of this project is analyzing the risks of using blockchain technology in the logistics sector and realizing blockchain software selection. At first, risk assessment for using blockchain technology in an international logistic company is realized. Then, blockchain technology selection is actualized by aiming to minimize and dissipate the risk factors obtained from the risk assessment.

As far as we concerned from our recent literature reviews, the proposed methodology in this research is new by combining risk assessment for blockchain technology with a blockchain software selection problem. In the literature, there are limited studies about selection topics related blockchain technology, however, our research is the first study with its blockchain software selection part.

With this study, we present the potential risks of using blockchain technology in the logistics sector by discussing an international logistics company's blockchain software selection problem. We presented potential benefits of using blockchain technology in the logistics sector. We introduced blockchain technology from its history to advantages and risks.

Our study demonstrates that blockchain technology selection problem can not be limited with financial concerns. This selection problem requires to think many other criteria which might become more important than capital risk, the risk of high maintenance cost and the risk of additional costs.

In this study, three MCDM methods (DEMATEL, Fuzzy AHP and Fuzzy TOPSIS) are accompanied to the selection procedure. This research yields Tradelens software as the best alternative for the logistics firm.

For further researchers, this project can be extended by utilizing different MCDM techniques and fuzzy numbers in the phase of criteria weighting and alternative selection. We plan to apply our model in other extensions of Fuzzy AHP methods to observe how these methods can affect the criteria weights. We also think about developing smart contracts for daily routines in the logistics sector to analyze how it can be possible to increase blockchain technology's self-coordinating business processes in the logistics sector.



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## **BIOGRAPHICAL SKETCH**

Ferhat Karayazı was born in Istanbul on February 25, 1994. He graduated from Suleyman Demirel University with the degree of Bachelor of Industrial Engineering in 2017. Currently, he has been studying M.Sc. in Logistics and Financial Management under the supervision of Assist. Prof. İlke Bereketli Zafeirakopoulos in the Graduate School of Science and Engineering of Galatasaray University. He has been working as an IT Project Engineer at CEVA Logistics since 2019.

## **PUBLICATIONS**

Ferhat Karayazı, İlke Bereketli Zafeirakopoulos, (2020). Criteria Weighting for Blockchain Software Selection Using Fuzzy AHP, Intelligent and Fuzzy Techniques: Smart and Innovative Solutions, pp. 608-615, *Proceedings of the INFUS 2020 Conference*, Istanbul, Turkey, July 21-23, 2020.