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APPLICATION AREAS OF E-SIGNATURE TECHNOLOGY IN SUPPLY CHAIN AND ITS EFFECTS ON SUPPLY CHAIN MANAGEMENT

Metin YILDIRIM[*]

Abstract

Considerable progress has been made in information technology and cryptology in recent decades. A outcome of these developments is the electronic signature technology. Electronic signature technology has responded to the needs of security, reliability, and legal acceptability in several application areas. E-signature technology is an essential part of legal and economic systems. Electronic signature technology's legal basis began to form at the end of the 20th century. Several countries have passed laws governing the electronic signature technology. Supply chain systems have a highly complicated structure. Supply chain operations have taken place in various locations, possibly across multiple countries. A supply chain operation structure requires high integration of legal and economic systems. The public and private sector have conducted several electronic signature technology implementations in many supply chain processes. Electronic signature technology is used in various new applications that affect supply chain operations. The research focused on the legal and technical fundamentals of electronic signatures, their use and impact on supply chain management.

Keywords: *E-Signature, Supply Chain, Electronic Signature Technology*

TEDARİK ZİNCİRİNDE E-İMZA TEKNOLOJİSİNİN UYGULAMA ALANLARI VE TEDARİK ZİNCİRİ YÖNETİMİNE ETKİLERİ

Öz

Bilişim teknolojileri ve kriptoloji alanında önemli gelişmelerin her geçen gün hızlandığı görülmektedir. Bu gelişmelerin sonuçları arasında elektronik imza teknolojisi gelmektedir. Elektronik imza teknolojisi, çeşitli uygulama alanlarında güvenlik, güvenilirlik ve yasal kabul edilebilirlik ihtiyaçlarına cevap vermektedir. Elektronik imza teknolojisi, yasal ve ekonomik sistemlerin önemli bir parçası olarak yer almaktadır. Elektronik imza teknolojisinin yasal dayanağı yirminci yüzyılın sonlarında oluşmaya başlamıştır. Elektronik imza teknolojisini ile ilgili yasal düzenlemeler farklı coğrafyalarda yer alan bir dizi ülkede başlamıştır. Önemli kısmında, gerekli ön adımların atıldığı tespit edilmiştir. Değişen şartlar, kanuni düzenlemelerde bir dizi güncellemeyi gerekli kılmıştır. İlgili düzenlemeler önemli

[*] Dr.Öğr.Üyesi, İstanbul Gelişim Üniversitesi İİSBF Lojistik Yönetimi, meyildirim@gelisim.edu.tr, https://orcid.org/0000-0003-0424-9834.

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sayıda ülke tarafından tamamlanmıştır. Tedarik zinciri sistemleri oldukça karmaşık bir yapıya sahiptir. Tedarik zinciri operasyonları farklı konumlarda, muhtemelen birden fazla ülkede yürütülmektedir. Kamu ve özel sektör, birçok tedarik zinciri sürecinde çeşitli elektronik imza teknolojisi uygulamaları gerçekleştirmiştir. Elektronik imza teknolojisi, tedarik zinciri işlemlerini etkileyen çeşitli uygulamalarda kullanılmaktadır. elektronik imzaların yasal ve teknik temelleri, kullanımları ve tedarik zinciri yönetimi üzerindeki etkileri araştırmada yer alan temel konu başlıklarıdır.

Anahtar Kelimeler: *E-İmza, Tedarik Zinciri, Elektronik İmza Teknolojisi*

Introduction

Both professionals and academics have regard the supply chain as one of a crucial business functions. Information technology and cryptology significantly impact efficient and effective communication in supply chain management. The primary interest area of cryptology science is secure communications. The history of cryptology draws back to over 2500 years. Initially considered a branch of linguistics, cryptology science later developed solid mathematical foundations. Compared to logistics and cryptology, information technology has a more recent past. Information technology (IT) manages and delivers information using voice, data, and video. Hardware, software, services, and support infrastructure are managed and deliver information. With the advancement of IT in the recent time frame, IT has tremendous impacts on communication. The foundation of digital signature technology is the information and cryptology technologies. The key benefits of a digital signature are authentication, integrity, and nonrepudiation. These topics are critical items that will resolve different vital problems in supply chain management. The rapid advancements in electronic signature technology have made the use of electronic signatures in various supply chain activities by the public and private sector. Electronic signature usage accounts for about 17% of the world's GDP (Dzhangarov and Suleymanova, 2020:6). Many supply chain operations extensively use electronic document management systems that support e-signatures. Use of e-signatures is becoming increasingly crucial in supply chain operations.

1. DIGITAL TRANSFORMATION IN SUPPLY CHAIN MANAGEMENT

The flow of materials, services, and related information begins at suppliers and ends at the point of consumption in the context of the supply chain. Although material and financial flows are primarily unidirectional, information flow is bidirectional in all supply chain processes. The flow of material, finance, and information must be optimized to increase the efficiency and effectiveness of supply chain processes. Efforts have been made to increase material, financial, and financial flows. Information flow is the critical item that significantly impacts the supply chain's effectiveness

and efficiency. The supply chain's efficiency and productivity have gradually increased. Bills of lading, in which information stated in the document would be beneficial to all related parties in planning processes, Purchase order would example for upstream information flow. It contains vital information to be used in operation and inventory planning. Authentication, integrity, and nonrepudiation are highly desired features in both downstream and upstream flows. One of the key technologies that can provide these attributes to information flow is a digital signature accompanied by a time stamp.

Allocating digitalization to most supply chain processes could result in optimal or near-optimal solutions. Efforts in information flow to increase efficiency and productivity could positively impact significant supply chain processes. Even though companies have understood the importance of digital transformation of the supply chain on a global scale, only a small fraction they are pleased with the business gain of digitization. One of the roots causes is thought to be people's negative attitude toward digital transformation (Agrawal et al., 2019). The introduction of Industry 4.0 technologies has improved the efficiency of production processes. Industry 4.0 caused a decline in the need for labor. employees are at risk of losing their jobs as a result of this situation. In contrast, even under harsh conditions, businesses can maintain their competitiveness by maintaining efficient production (Bağcı, 2018: 122-125). Inadequacies in leadership, digital skills, and top management support are significant topics that could be classified as the main barriers to digital transformation implementation (Kohnke, 2017: 87-89). Talent, urgency sense, strategic orientation, the appropriate organizational structure, aligned business objectives, flexible business processes, confidence in keeping confidential information, the existence of sector-specific guidelines, and the ability to keep up with digital business dynamism are essential topics in achieving successful digital transformation. The deficiencies in these topics may harm successful implementation (Agrawal et al., 2019). The removal of these barriers will not only need great efforts but also need a great time .

All internal and external parties in the supply chain process take an active role in information creation, usage, and sharing. The information flow causes challenges and creates opportunities to improve efficiency. Digital Transformation not only creates business values but also forces the implementation of new technological methods in all critical supply chain processes. The research on digital transformation in supply chain management focuses primarily on the level of impact of technological solutions (Büyüközkan and Göçer, 2018:174). Several sectors, especially textiles, contribute significantly to the industrialization of countries because of their dynamic structure and ability to adjust to technological changes(Şişmanand Bağcı,2014:31). Implementing new technologies in supply chain operations could increase efficiency and the relative

competitive advantage. Decreased process time and operating cost are the following advantages. The stated possible outcomes are crucial for the private and public sectors (Calatayud et al., 2018). Classical supply chain logistics operations consist of paper-based documentation and digital-based processes. Digital transformation of supply chain processes will have a positive impact on value, affordability, and accessibility. Digital transformation in the supply chain is based on three main pillars. They are digitalization, technology implementation, and supply chain (Patrucco et al., 2020: 1094). Digitalization could be defined as the digital technology usage leading to business model revision, creation of new income, and value-generating opportunities (Schreckling and Steiger, 2017). Project management, technology-human interaction, technology infrastructure establishment, and technology enablers are the four categories of technologies implementation. The supply chain is the final pillar and is divided into six categories: process, analytics, automation, reconfiguration, and integration (Büyüközkan and Göçer, 2018:170). The supply chain of the high technology production and services sector would not only have a major impact on economic growth, but also on gross fixed capital formation and employment. (Erkişi and Boğa,2019:669). Due to the changes in the global market, not only corporations but also governments have been forced to adopt a digital transformation in the supply chain. Many governments have made and implemented several important legal and administrative regulations to eliminate administrative and legal barriers that prevent the digital transformation in the supply chain processes. In many countries, governments have implemented digital transformation projects within the scope of increasing efficiency and productivity in all supply chain-related processes and many successful examples have been seen.

2. LEGAL FRAMEWORK OF ELECTRONIC SIGNATURE

An electronic signature is the output of the transformation process of a handwritten signature into digital format. Biometric authentication methods have been used in this process. The foundation of a digitalized signature, a branch of electronic signature, is information and cryptography technology. In many countries, the authorities make significant efforts during the transformation process to the digital society. User authentication, message integrity, and nonrepudiation are the key features of an electronic signature. These features are the critical elements in the digital transformation of supply chain processes.

Authentication, message integrity, and nonrepudiation in transactions and communication are essential processes. Electronic signature authentication is a reliable and effective technique. The use of electronic signatures could end disputes resulting from these causes. The compatibility of legal regulations is an essential prerequisite for the implementation of electronic signatures. Lawmakers in many countries are working on new laws and regulations to expand the use of electronic signatures.

Traditional signatures are used in most of the transactions and communication in supply chain processes. Even though a globally accepted definition of a traditional signature does not exist, a traditional signature is the written form of the person's name in an elegant and stylized manner. Advances in technology have led to the emergence of the electronic signature concept. The electronic signature definition of varies with different laws and regulations. In the Florida electronic commerce act electronic signature is defined as "any letters, characters, or symbols, manifested by electronic or similar means, executed or adopted a party with an intent to authenticate a writing"(Florida Electronic Signature Act, 1996). In Turkish Electronic Signature Law No:5070, an electronic signature is defined as the "Electronic data attached to other electronic data or logically linked to electronic data and used for authentication purposes" (Turkish Electronic Signature Act, 2004). UN approved Model Law on Electronic Signatures (MILES) defined electronic signatures as "data in electronic form in, affixed to or logically associated with, a data message, which may be used to identify the signatory about the data message and to indicate the signatory's approval of the information contained in the data message"(Model Law on Electronic Signatures Adopted by the United Nations Commission on International Trade Law, 2001). In many countries, laws and regulations strictly regulate the technical and legal aspects of electronic signatures. Electronic signature and time stamp structure, electronic certification service providers ' missions and liabilities, and issues related to certificates given by foreign electronic certification service providers are the important subjects for which regulations are completed or work in progress stage in many countries.

The Model Law of Electronic Commerce (MLEC) is one of the initial regulations. The United Nations Commission on International Trade Law (UNCITRAL) drafted MLEC. U.N. The General Assembly approved MLEC in 1996. The law is a guide that includes required procedures and principles for modern data recording and communication techniques. The main intention of MLEC is "to serve as a model to countries for the evaluation and modernization of certain aspects of their laws and practices in the field of commercial relationships involving the use of computerized or other modern communication techniques, and for establishing relevant legislation where none presently exists" (UNCITRAL Model Law on Electronic Commerce with Guide to Enactment 1996, 1996). The technology-neutral approach has been used in MLEC(Fischer, 2001:235). Continuation of UNCITRAL studies on the related subject resulted in preparing the Model Law on Electronic Signatures (MILES) in 2001. In the law, the reliability of electronic signatures is bound to the satisfaction of a series of requirements. One of the critical requirements is the relationship between signature creation data and the signatory. The signatory should not only be the sole party who has control of signature creation data but also be

linked to signature creation data. Another stated requirement is the ability to detect any alteration in the electronic signature and related information after signature (Model Law on Electronic Signatures Adopted by the United Nations Commission on International Trade Law, 2001)

On the European side, Directive 1999/93/EC of the European Parliament has been stated as one of the early legislation. Facilitation of electronic signature usage and increasing legal recognition are the stated aims of the directive. It has been structured as an electronic signatures and specific certification-services legal framework. According to the directive, qualified certificates generated by secure signature creation devices and compliance with the stated requirements are required for advanced electronic signatures to be legally equivalent to handwritten signatures. (Directive 1999/93/EC, 2022). Most of the EU Member States and candidate countries have taken the necessary actions to implement the directive (Orthacker et al., 2010:104). Significant progress has been achieved in harmonizing their national law with the directives among EU Member States and candidate countries (Dumortier et al., 2003:141). Directive 1999/93 enabled legal usage of the e-signature in communications among administrations, citizens, and businesses in electronic applications with fiscal implications (Manea, 2014:228). A framework for cross-border and cross-sector electronic signature usage for safe, trustable, and practical electronic transactions was the missing point for the directive. To improve and extend the scope of Directive 1999/93/EC, the European Parliament approved Regulation (EU) No 910/2014 on electronic identification and trust services for domestic electronic transactions (eIDAS) in 2014. Directive 1999/93/EC was repealed in 2016(Regulation (EU) No 910/2014, 2014). Increasing the usage not only of electronic signatures but also trust services, creating a united EU digital market, and establishing a consistent legal framework for accepting electronic IDs and signatures for all EU member states are the principal aims of the eIDAS(Şimşek et al., 2019:138).

On the United Kingdom side, one of the first regulations on e-signature was put into force in the U.K. Electronic Communications Act 2000(ECA). The enaction date of ECA is May 25, 2000. Legal recognition of electronic signatures and the processes through which they are verified, created, and transmitted are listed among the main objectives of the relevant law (Electronic Communications Act 2000-UK Public General Acts, 2000). In the continuation of the legal process, The Electronic Signatures Regulations 2002 was put in force on 08.03.2002. The stated purpose of the act is to implement Directive 1999/93/EC for electronic signatures (The Electronic Signatures Regulations 2002 (Revoked)-UK, 2002).

One of the first regulations in the USA on this subject is the Uniform Electronic Transactions Act proposed by the National Conference of Commissioners on Uniform State Laws. UETA has not only played the model law role in US jurisdictions but also established the legal equivalence of electronic signatures with hand-written signatures (Uniform Electronic

Transaction Act, 2000). UETA is technologically neutral with no preferences on applicable technology such as Public Key Infrastructure (Blythe, 2005:13).

In Turkey, legal regulation efforts on E-Signature have been started in the scope of harmonization activities during the EU integration process of Turkey. Legal regulation regarding electronic signatures was made with the E-signature law numbered 5070. The law was published in the Official Gazette on January 23, 2004, and went into effect on July 23, 2004. The legal framework governs the legal structure of electronic signatures, the activities of electronic certificate service providers, and the procedures for using electronic signatures.(Turkish Electronic Signature Act, 2004).

3. ELECTRONIC SIGNATURE INFRASTRUCTURE

An electronic signature is a technology-neutral concept that includes all methods used to electronically sign data, documents, and materials. An electronic signature refers to different technical solutions, including biometric and digital signatures that enable the identification of signees. Digital signature is a cryptographic software technology based on encrypting and decrypting data asymmetrically (Yılmaz, 2016:3443)

Electronic signatures can be classified in a variety of ways. Binary classification based on whether digital signature techniques have been used or not is one of the leading classification methods (Çitli et al., 2012). Inserting the scanned version of the hand-written signatures into an electronic document is one of the most common electronic signature types created without using digital signature techniques. Signing by hand with a special pen on the computer screen is another electronic signature type classification. Using biological characteristics such as fingerprint, palm print, voice, retina, and DNA replication in the authentication process are among the methods in which digital signature techniques have not been used (Bengshir and Topcan, 2008:97).

The other widely accepted electronic signature classification is the classification specified in eIDAS, and which has divides electronic signatures into three primary headings: Simple, Advanced, and Qualified electronic signature. A simple signature is an electronic form that can be presented as evidence of a signer's acceptance or approval of the document Signed document and signature being in electronic form, signature either being attached or logically associated to electronic data are the main prerequisites of a simple electronic signature (Şimşek et al., 2019:139) Attaching the scanned copy of handwritten signature to the document, approval button clicking, any password that will enable us to identify the sender and writing name and surname at the end of the e-mail could list as the examples of simple signature.

A simple electronic signature is the base for an electronic signature. In article 25 Part 1 of eIDAS, an electronic signature being in electronic form

or not meeting the qualified electronic signature's requirements shall solely be enough to deny the legal effect of the electronic signature (Regulation (EU) No 910/2014, 2014). This stated article did not imply that a simple electronic signature is legally equivalent to a hand-written signature (Şimşek et al., 2019:138;139) The second group is called advanced electronic signatures. According to eIDAS, a connection between the signatory and the signature and access to the signatory's identity was established using e-signature creation data. The ability of the signatory to detect any subsequent change in the data is a requirement for advanced electronic signatures listed in Article 26 of eIDAS(Regulation (EU) No 910/2014, 2014). The unique link between signatory, ability to determine the signatory, creation by electronic signature creation data, and detectability of data change is the listed requirement for advanced electronic signatures, which are stated in Article 26 of eIDAS electronic signature creation data under the signatory (Erdősi, 2018:408)

A qualified electronic signature is not only the last class of electronic signature but also the single electronic signature that has an equivalent legal effect to a handwritten signature. Article 26 Clause 12 of eIDAS states that a qualified electronic signature is an advanced electronic signature with two additional requirements. Initial requirements include creating the electronic signature with a qualified device.. The other requirement is that the signature should be based on a qualified certificate. The personal information of the electronic certificate holder and the public key information of the certificate are included in the electronic certificate. Requirements for qualified certificates for electronic signatures have been submitted in Annex 1 of eIDAS. Qualified certificates and private keys are kept in qualified electronic signature creation devices. Annex 2 of eIDAS contains the requirements for qualified electronic signature creation devices. Even though a technology-neutral approach has been used in eIDAS, in Commission Implementing Decision (EU) 2015/1506 of September 8, 2015, advanced and qualified electronic signatures technical formats have been defined. Advanced and qualified electronic signatures must be in CAdES-, XAdES-, PAdESoder ASiC(Pelikánová et al., 2019). Public key infrastructure (PKI) in the cryptographic system is used to create advanced and qualified electronic signatures (Şimşek et al., 2019:139). Public key infrastructure (PKI) is mainly based on using two keys, namely, public and private keys, which are long digit numbers. the Private Key cannot be determined using the Public key. As it could be understood from the name, a private key is the key in which the owner has full control and keeps a secret. Private keys could be stored in high-security chip cards to eliminate copies and unauthorized use. PINs and biometric methods such as fingerprint and voice recognition have been used in the authentication process to prevent unauthorized use of the private key. The signee utilized a private key in the signing procedure. The public key is open data and is distributed freely. The receiver uses the public key in the signature validation procedure. Public

key cryptographic and digest algorithms have been used in the signature and validation processes. Rivest Shamir and Adleman (RSA), El Gamal, Elliptic Curve, Digital Signature Algorithm (DSA/DSS), and Lucas Sequences (LUC) are major public key algorithms used in advanced and qualified electronic signatures (İskender, 2006:19) SHA could be considered as one of the major digest algorithms used in advanced and qualified electronic signature process. The digital signature process could be separated into two major parts. In the initial part, the document subject to signing has been selected. The hash value of the document must be obtained. Any change in the documents would yield a different hash value. Any document change could be detected by comparing the original hash value with the existing hash value. The identical hash values confirm that the documents on hand are the same as the document at the time of signature. The second stage of the signing process is the encryption process. The obtained hash value obtained is encrypted using a private key. The initial document is sent to the recipient with the encrypted hash value. The signing process is completed with this step. When the signed document is received, a series of verification processes are conducted on the recipient side. The recipient wants to authenticate the signatory and confirm that the received message is the same as the signed message. The first action is to take the hash value of the incoming document. The hash value of the original message is obtained through the decryption of the digital signature using the public key. The two hash values are compared. If these values are identical, the recipient is confident that the document was signed with the sender's private key and that the retrieved document is the original signed document (Şenocak, 2001:100).

In functional terms, an electronic signature serves three essential functions: signee authentication, message integrity, and nonrepudiation. A document bearing the electronic signature allows the authentication of the signee. The first assumption is that the Electronic Certificate Service Provider created the certificate for the right person and delivers it to the related person. The relevant document is electronically signed only with the private key. The authentication of the signed document is conducted only with the related public key. These key pairs have a mathematical link. Verification cannot be performed without the relevant public key. This property of the electronic signature provides signee authentication (Bengshir and Topcan, 2008:98).

Message integrity is checked through the comparison of hash values. A change in the signed document results in a different hash value. In the verification process, the file with an electronic signature is decrypted with the public key, and the digest value is obtained. However, the hash value of the document in hand is acquired. If the two hash values are identical, message integrity could be confirmed. Otherwise, the document with an electronic signature could not be verified.

The last function of an electronic signature is nonrepudiation. This function is defined as the signee's inability to claim that the signature on the document is not his own. Two essential elements provide this feature. The first of these is that the document can only be signed only by the private key. It is impossible to sign the document with the publicly available public key. The second element is that the private key is under the signer's control over the entire period. The signing process is impossible without his/her consent and knowledge. The factor that will disrupt this feature is the situations where it is necessary to know whether the relevant certificate is valid at the date of signature. Denial possibilities can be reduced using timestamps in electronic signatures.

4. ADOPTION OF ELECTRONIC SIGNATURE IN SUPPLY CHAIN

The supply chain may be considered a line composed of several points. The delivery of commodities to the point of consumption has been set at the end of the line, while the procurement procedure has been placed at the starting point. Electronic signatures can be reliable solutions as an insurer of authentication, message integrity, and nonrepudiation. Electronic signature technology has been implemented in many services for supply chain management.

Among the business documents in the supply chain, one of the most exchanged items is an invoice. The most common types could be listed as commercial, proforma, freight, and consular invoices. Many governments worldwide are showing great efforts to digitize the invoicing process and spread the e-invoicing concept on a solid foundation. Increasing supply-chain financing efficiency, eliminating human-made errors in invoice processing, reducing invoice storage costs, and reducing payment processing delays are among the main advantages of e-invoicing (IMDA, 2022). Member states of the European Union have issued required regulations regarding the electronic invoicing of public procurement within the framework of the conditions specified in Directive 2014/55/EU. One method that could be used to ensure the authenticity of the origin and the integrity of the content of the invoice, as stated in Clause 25 of the directive, is the use of an electronic signature (Directive 2014/55/EU, 2014). Every European union member state has a different approach to dealing with an electronic invoice. B2G electronic invoice status of European union member states has been stated in the eInvoicing Country Fact sheets. Sweden, Spain, Slovenia, Romania, Portugal, Poland, Norway, Netherlands, Malta, Luxembourg, Lithuania, Latvia, Italy, Ireland, Iceland, Hungary, Greece, Germany, France, Finland, Estonia, Denmark, Czechia, Cyprus, Croatia, Bulgaria, Belgium, and Austria have completed the implementation phase of B2G electronic invoicing according to European standard. The Slovak Republic and Liechtenstein are two countries within the EU for which European standards for electronic invoice are not entirely implemented. Spanish

regulation mandates an electronic signature on all B2G electronic invoices. Hungarian legislation enabled the use of electronic signatures for the authenticity of the B2G e-invoice origin and the integrity of B2G e-invoice content. In Romania, additional legislation for regulating the usage of electronic signatures in the process of B2G electronic invoicing has been issued (EU 2021 EInvoicing Country Factsheets, 2022). Andorra, Argentina, Brasil, Canada, Colombia, Chile, Hong Kong, Israel, Japan, Mexico, Peru, Qatar, United Arab Emirates, and Uruguay are among the countries, which enable the use of electronic signature technology in their electronic invoicing process (Global E-Invoicing - Countries Containing e-Invoicing Information, 2022). Considering that there are 193 member states of the United Nations, it is seen that electronic signature technology in e-invoice processes has a deficient percentage of usage (Growth in United Nations Membership, 2022). The number of countries that have created and implemented the necessary e-invoice regulations is steadily increasing. Many e-invoicing concerns are expected to arise as more businesses use electronic invoices in B2B and B2C transactions. Regarding the problems originating from invoice origin authenticity and invoice content integrity, electronic signature technology is one of the key technologies that would help overcome such problems. It is among the major indicators of an increase in the usage of electronic signatures in the e-invoice processes

Transportation costs are a significant portion of the total costs in supply chain management. The process of transportation documents has a key impact on the efficiency of supply chain operations. Ocean Bill of Lading, Short Form Bill of Lading, Liner Bill of Lading, Container Bill of Lading, Charter Party Bill of Lading, Non-Negotiable Sea Way Bill, and Mate Receipt are among the primary transportation documents in Maritime Transportation. CMR, Rail Way Bill, Air Waybill, Multimodal Bill of Lading, Courier Receipt, FIATA FCR, FIATA FCT, and FIATA FBL are the other important transport document types. Great efforts have been made to digitize documents using electronic signature technology.

Transportation documents play a significant key role, especially in international transportation. According to the United Nations Commission on International Trade Law (UNCITRAL) report, the estimated cost of transportation documents is around $ 420 billion per year (Jović et al., 2019). Transportation sector administration costs have been estimated at 8,738 and 9,287 million euros for 2025 and 2030, respectively. The estimated figures based on transportation mode for 2025 and 2030 are submitted as follows: 6,614 and 7,026 million euros for road, 576 and 625 million euros for rail, 635 and 674 million euros for IWT, 882 and 926 million euros for maritime, 31 and 36 million euros for aviation (Proposal for a Regulation of the European Parliament and of the Council on Electronic Freight Transport Information, 2018). Cost originating from paper-based transportation documents is one of the major problems in supply

chain management. Other significant issues associated with paper-based transportation documents include delays caused by the document's unavailability at the required time and security issues caused by misplaced, stolen, or lost documents (Jović et al., 2019)

To increase the efficiency, increase speed and reduce cost, a strenuous effort has been on digitalize transportation documents by all related parties. High initial investment cost, significant business process differences between digital and printed transportation documents, not fully determined international standards, insufficient demand from the parties, and high reliance on a paper-based system are among the main obstacles to the digitalization of transportation documents (Civelek et al., 2015). Related parties could unsuccessfully find a unique method for the digitalization of transportation documents. One of the important requirements for digitalizing transportation documents is the international and national legislation unification in the exchange of transport documents.

Different solutions have been implemented on domestic and international levels under countries' current regulations. CMRs are among the first digitized transportation documents. Countries have different rules and regulations affecting the contracts of carriage in international transport. At the level of the United Nations Economic Commission for Europe, the problems have been negotiated on the Convention on the Contract for the International Carriage of Goods by Road (C M R). The protocol was signed in Geneva in May 19 1956(Convention on The Contract For The International Carriage of Goods By Road, 1956). 58 countries have ratified it (United Nations Treaty Collection, 2022). Thirty countries have accepted the Additional Protocol to the Convention on the Contract for the International Carriage of Goods by Road (CMR) Concerning the Electronic Consignment Note. Uzbekistan, United Kingdom, Ukraine, Turkey, Tajikistan, Switzerland, Sweden, Spain, Slovenia, Slovakia, Russian Federation, Romania, Republic of Moldova, Portugal, Poland, Oman, Norway, Netherlands, Luxembourg, Lithuania, Latvia, Ireland, Iran, Germany, France, Finland, Estonia, Denmark, CzechRepublic, Bulgaria, Belgium, and Belarus are the name of the countries who have signed the addendum (Additional Protocol, 2022). The committee on transport and tourism of the European Parliament approved the regulation on electronic information about the carriage of goods on May 4, 2020. The regulation enforces all member states to use e-CMR by the latest 2025(Bazhina, 2022). Article 3 of the protocol, which regulates the authentication of the electronic consignment note, allows the authentication process to be performed through either use of reliable electronic signatures or other electronic verification methods permitted by the laws of the country in which the electronic consignment note has been made out (E-CMR, 2011). One of the biggest concerns regarding using electronic signatures in transport documents is the requirement that digital certificates be valid in each country where the transport document is processed. Most of the technical and legal regulations

required for electronic signatures have been completed within the EU and member states have fulfilled their obligations. This situation has prevented the problem of losing the validity of digital certificates obtained from EU member countries in other member countries. The number of e-CMR-using countries, especially EU member states, is expected to increase significantly until 2025. Therefore, the use of electronic e-CMR is expected to increase considerably in the near future. The validity of the electronic signature in the e-CMR continues to be a major concern, not only for transport between non-EU countries but also between the EU and non-EU countries. E-CMR that was signed with an e-signature removed or significantly simplified the paperwork. Consequently, more than 66% of the transaction cost savings were achieved. Enhanced transparency resulting from data accuracy, shipment control, and receipt of the shipment is the second significant benefit of electronically signed e-CMR(Bazhina, 2022).

The Air Waybill is the contract of carriage between the shipper and the carrier in air transportation. After January 1, 2019, e-AWB has become the default contract of carriage on enabled trade lanes. The key benefits of e-AWB are the elimination of paper-based processes, increased efficiency, reliability, and delivery times, reduced processing errors, and environmental friendliness (IATA Announces E-AWB, 2022). The first step is using e-AWB as the signature of the Multilateral e-AWB Agreement. IATA recommended Usage Electronic signatures as part of signing the Multilateral Agreement on Electronic Commerce, especially for Freight Forwarders. An increase in electronic signature usage in e-AWB processing is expected especially to overcome authentication problems. IATA e-AWB legislation dealing with the use of electronic signatures needs to be detailed.

The certificate of insurance, insurance policies, and cover tickets are among the primary insurance documents commonly used in supply chain management. Electronic signature technology in several supply chain assurance processes appears feasible in countries where an electronic signature is regulated. E-signature brings the above-stated advantages and increases confidence in the digitalized insurance process. The widespread use of electronic signatures will contribute positively to confidence in digital assurance processes (Çitli et al., 2012:12).

The TIR carnet is another intensive-use digitized transport document that uses electronic signature technology. The TIR (Transports Internationaux Routiers) Convention, established in 1959 and administered by the United Nations Economic Commission for Europe (UNECE), consists of 68 members. The TIR Convention has laid down an internationally recognized procedure. The primary goal of the procedure is to facilitate the cross-border transport of goods. It was carried out using an internationally recognized customs document, the TIR carnet. It shall also provide evidence of internationally valid security (Reis, 2016:23). Members of the TIR Convention started the e-TIR project in 2003.. The project's mission is to

conduct secure data transfer between related parties, including national custom administration parties, by transferring truck contract procedures (Karabulut and Civelek, 2019). Reduced fraud, administrative load, and TIR process delay are the main advantages of e-TIR, whereas the advantages of integrated supply chain management have increased (UNECE, 2022). In clause 258 of eTIR conceptual, functional, and technical documentation version 4.3: eTIR technical specifications, it has been stated that messages exchanged with the international eTIR system must be authenticated and have the integrity to reach nonrepudiation. The use of electronic signatures has enabled nonrepudiation (ETIR Technical Specifications, 2022).

As part of the digitization of the supply chain, electronic signature technology has been used in several projects . One of the initial examples of these projects is ebXML, which was initiated in 1999 by OASIS and the UN Agency/ECE CEFACT. ebXML is a modular series of specifications that allows organizations to conduct their operations via the Internet. It allows organizations to exchange business messages standardized, build business relationships, communicate data in standard terms, and define and record business processes. It has a broad use in the management of the supply chain (Bujak et al., 2018:14). The electronic signature has been optionally configured as part of the message authentication process (EbXML Whitepapers, 2022).

Another important project of interest in this area is the Pan-European Online Public Procurement (PEPPOL) project. The start and completion dates of the project are May 2008 and August 2012, respectively. The project's main aim is to enable cross-border public procurement within the EU internal market. Peppol has defined and implemented a solution based on validation service for cross-border electronic signatures (Ølnes, 2012:282). A substantial number of European countries have implemented Peppol specifications, which have solved interoperability problems in electronic public procurement. Following the completion of the project, the OpenPeppol Association, a nonprofit organization, was founded on September 1, 2012. OpenPeppol's goal is to make it easy for European companies to deal electronically with European public sector purchasers in their procurement processes (OpenPeppol, 2022). Peppol could not be defined as an e-Procurement platform. Peppol has provided specifications for integrating existing eProcurement solutions. Many documents used on the supply chain, including e-Orders, e-Advance Shipping Notes, eInvoices, and eCatalogues can be exchanged within the relevant parties via the Peppol network (Peppol, 2022). Peppol's transport infrastructure was used to connect various eProcurement systems. In securing the message content, digital signature technology has been utilized (Transport Infrastructure, 2022).

Electronic Simple European Networked Services (e-SENS) are on the list of projects considered in this area. Turkey, The Netherlands, Sweden, Spain, Slovenia, Slovakia, Romania, Portugal, Poland, Norway,

Luxembourg, Italy, Ireland, Greece, Germany, France, Estonia, Denmark, CzechRepublic, Austria, OpenPEPPOL, and ETSI are the major participants of the project. The project lasted for 48 months and was completed on March 31, 2017. Facilitating the delivery of cross-border digital public services had been among the project's primary goal. eGovernment Basic Services Platform for the eGovernment Cross-Border Digital Infrastructure provided for the Implementation Regulation of the Connecting Europe Facility (CEF) is the primary planned outcome of the project. e-Signature with e-ID, e-Documents, and e-Delivery have been considered among the significant critical tools used in consolidated technical solutions (About the E-SENS, 2022). The Building Block e-Signature was used to build a secure authentication infrastructure in different domains, which is necessary for building interoperable cross-border parties. Electronic signature technology is a component of the Digital Service Infrastructure Building Blocks of the Connecting Europe Facility program. Electronic signature technology is a component of the Digital Service Infrastructure Building Blocks of the Connecting Europe Facility program, mainly using electronic identification and authentication processes (E-Signature Building Block, 2022).

Commercial organizations that offer electronic signature-enabled digitization services in supply chain management came during the last part of the research. Bolero has been considered one of the significant organizations offering electronic signature embedded trade and supply chain digitization services (Bolero Rulebook, 2022). The principal solution for supply chain management that Bolero offers is the electronic bills of lading (Bolero for Carriers and Logistics, 17.08.20222). Another critical organization working in this field is essDOCs in, which the company provide paperless trade solutions. Preferential and Non-Preferential Certificates of Origin, EUR1, ATR, Arab Certificates, Commercial Invoices, and bills of lading are among the significant digitized documents. A substantial amount of documentation, including bills of lading, can be signed electronically on the essDOCs' platforms (EssDOCS, 17.08.20222).

Conclusion

The focus of this research is to identify the application areas of electronic signature technology in the supply chain and examine the shaping effect of electronic signature use on supply chain management. One of the critical requirements for electronic signatures in supply chain processes is the issue of electronic signature law and the necessary legislative changes allowing electronic signatures. One of the critical requirements for electronic signatures in supply chain processes is the issue of electronic signature law and the necessary legislative changes allowing electronic signatures. Another critical issue in electronic signatures is the need to change the relevant legislation with technological development in the electronic signature infrastructure. Our research shows that many countries have completed these

steps. In international supply chain processes, it is necessary to confirm that the relevant digitally signed document follows the laws of all countries . These situations highlight the need for process and standard harmonization across international boundaries. In particular, the European Union's member states have implemented the required changes in this regard. They have substantially reduced the legal barriers to electronic signatures in the global supply chain. One of the most significant effects of an electronic signature is creating a set of generally accepted standards for various processes in supply chain management. Processes within the supply chain must be completed in several signed documents. The electronic signature has resulted in the digitalization of the associated processes. Digitization must improve lengthy and complex supply chain procedures. In supply chain management digitization projects, authenticity, integrity, and nonrepudiation are essential requirements. Electronic signature technology is critical in removing decision-makers' and practitioners' reservations and meeting the specified requirements with confidence.

The need for employees to be physically present in the same work environment will diminish as specific supply chain processes are digitalized. As a result, significant savings on various expenses, particularly employee transportation to and from the office and office rent, would be realized. The elimination of printing and shipping costs is a benefit of documents signed with an electronic signature. One of the most crucial strategies for minimizing the carbon footprint of supply chain operations is the use of electronic signatures. Within the context of the reasons stated, the significance of electronic signature technology in the supply chain is becoming increasingly vital. Electronic signatures are expected to be used in more areas of the supply chain in the near future, and the growth in the number of supply chain transactions completed using an electronic signature is expected to accelerate.

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