ISTANBUL TECHNICAL UNIVERSITY ★ GRADUATE SCHOOL

DIGITALIZATION IN CONSTRUCTION CLAIM MANAGEMENT

M.Sc. THESIS

Nil DENİZMEN

Department of Civil Engineering

Construction Management Programme

FEBRUARY 2025

ISTANBUL TECHNICAL UNIVERSITY ★ GRADUATE SCHOOL

DIGITALIZATION IN CONSTRUCTION

CLAIM MANAGEMENT

M.Sc. THESIS

Nil DENİZMEN
(501211131)

Department of Civil Engineering

Construction Management Programme

Thesis Advisor: Assoc. Prof. Deniz ARTAN

FEBRUARY 2025

ISTANBUL TEKNİK ÜNİVERSİTESİ ★ LİSANSÜSTÜ EĞİTİM ENSTİTÜSÜ

İNŞAAT HAK TALEBİ YÖNETİMİNDE DİJİTALLEŞME

YÜKSEK LİSANS TEZİ

Nil DENİZMEN
(501211131)

İnşaat Mühendisliği Anabilim Dalı

Yapı İşletmesi Programı

Tez Danışmanı: Doç. Dr. Deniz ARTAN

ŞUBAT 2025

Nil DENİZMEN, a **M.Sc.** student of **ITU Graduate School of Science Engineering and Technology** student ID 501211131, successfully defended the thesis/dissertation entitled "**DIGITALIZATION IN CONSTRUCTION CLAIM MANAGEMENT**", which she prepared after fulfilling the requirements specified in the associated legislations, before the jury whose signatures are below.

Thesis Advisor :	**Assoc. Prof. Dr. Deniz ARTAN** Istanbul Technical University	.....
Jury Members :	**Prof. Dr. Esin Ergen Pehlevan** Istanbul Technical University	.....
	Assoc. Prof. Dr. Özge Akboğa Kale Izmir Demokrasi University	.....

Date of Submission : 10 January 2025
Date of Defense : 12 February 2025

To my beloved parents,

FOREWORD

This thesis is written as a completion of a master's degree in the Construction Management Department at Istanbul Technical University. The subject of the study is to provide research guidance for researchers and practitioners in the applications of digitalization of claim management in the construction industry.

I would like to express my gratitude to my supervisor, Associate Professor Dr. Deniz ARTAN, for her great recommendation on choosing the appropriate topic and for shedding light on how I grasped it.

February 2025

Nil DENİZMEN
(Civil Engineer)

TABLE OF CONTENTS

Page

ABBREVIATIONS

AEC **:** Architecture, Engineering, and Construction

AI **:** Artificial Intelligence

API **:** Application Programming Interface

ASCII : American Standard Coding Interface Interchange - Data transfer format

BIM **:** Building Information Modeling

BCT **:** Block-chain Technologies

CMS **:** Claim Management System

DBB **:** Design-Bid-Build

EoT **:** Extension of Time

HPGL **:** Hewlett-Packard Graphic Language - graphic format

IT **:** Information Technology

ML **:** Machine Learning

NBIMS **:** National Building Information Modeling Standard

NRC **:** National Research Council

WEF **:** The World Economic Forum

3D **:** Three Dimensional

LIST OF TABLES

Page

LIST OF FIGURES

Page

DIGITALIZATION IN CONSTRUCTION CLAIM MANAGEMENT

SUMMARY

In recent years, the complexity of construction projects has been steadily increasing. This has led to a corresponding increase in the number and complexity of construction claims, which depletes project resources to a greater extent. Due to the dynamics and fragmented nature of modern construction projects, the task of managing claims within the project is more complex than it has ever been. Traditional methods for managing claims are frequently criticized for being time-consuming, costly, and prone to human error. To address these challenges, it has become inevitable to digitalize claim management throughout the project life cycle, from the tender stage to the post-delivery period, by utilizing developing technologies. Recently, the construction sector has adopted innovative tools and systems to improve claim management efficiency. However, the digitalization of claim management is a relatively recent issue and is still underexplored compared to other topics in the construction project lifecycle. The purpose of this study is to provide an overview of digitalization in construction claim management, analyze the current knowledge base to unfold the factors behind the relatively underdeveloped state of the field, and suggest future research directions.

This thesis employed a systematic literature review approach as the primary methodology, leveraging established academic databases such as Scopus, and Web of Science. A comprehensive review was conducted on studies addressing the digitalization of construction claim management published between 1992 and 2024, resulting in the inclusion of 42 studies in this research. These publications were analyzed based on various criteria, including annual publication trends, country distribution, publication types, data sources, research topics, keywords, citations, and the main outputs of the articles. Additionally, the selected studies were categorized into three distinct groups: exploratory studies, conceptual models, and experimental prototypes. The systems approach facilitated a comprehensive understanding of the available literature and identify existing gaps and possibilities in the chosen topic. As a result, four research domains have been identified in the digitalization of construction claim management as the utilization of (1) digital tools, (2) BIM, (3) blockchain, and (4) artificial intelligence and a research road map has been developed as the main contribution of the study for each of these four research domains. In such manner, this study provides a clear roadmap for ongoing research efforts on the digitalization of construction claim management practices by employing bibliometric and thematic analysis methods.

Since computers began playing an active role in our lives in the 1990s, they have become a significant tool in the management of construction projects. This transformation not only altered traditional construction practices but also directly impacted project management processes. In particular, the management of construction claims has emerged as a critical factor influencing project success. Claim management, frequently encountered in construction projects, is a process that

consumes substantial financial resources. Delays, extensions of time, design errors, breaches of contract, scope changes, and change orders are among the primary causes of claims.

As construction projects continue to grow in scale and complexity, traditional methods of managing claims have become increasingly challenging due to their costly and time-consuming nature, disruptions caused by turnover among key personnel overseeing project activities, and the prolonged duration of legal proceedings. With shrinking profit margins and increasing project complexity in the construction sector, the rising number and complexity of claims, which consume significant project resources, have made the digitalization of construction claim management an intriguing subject for researchers. Given that technology is not static but continuously evolving, the examination of how each newly developed digital tool contributes to claim management remains an ongoing process. Researchers have argued that integrating various digital technologies into claim management could mitigate these challenges. For instance, Building Information Modeling (BIM) facilitates the documentation, visualization, and analysis of claims, while blockchain technology ensures more transparent and reliable storage of project-related data. Artificial intelligence (AI) applications, through Case-Based Reasoning (CBR) and Rule-Based Reasoning (RBR) methods, aim to make claim management processes more efficient by training claim professionals, guiding them throughout the claim process, and enhancing decision-making capabilities. Particularly after 2020, researchers' interest has increasingly shifted toward machine learning (ML), a subset of artificial intelligence. In both conceptual and prototype models developed by using ML algorithms, researchers have primarily focused on predicting the occurrence or outcomes of disputes rather than directly addressing claim management. Their efforts have been dedicated to leveraging machine learning techniques for dispute resolution by anticipating potential dispute issues or their consequences.

The findings reveal that digitalization in construction claim management is predominantly explored through the application of Building Information Modeling (BIM), Artificial Intelligence (AI), Smart Contracts, Blockchain Technology, Delay Analysis Tools, and Document Control Systems. According to findings, these technologies play important roles in delay analysis, document management, change detection, and dispute resolution. These tools enable faster, more transparent, and efficient management of claims, reducing the time and costs traditionally associated with resolving disputes. However, the study also identifies significant barriers, including the lack of standardization, difficulties in incorporating digital tools into projects that have traditional project delivery types, and limited applicability across the project lifecycle. Additionally, challenges such as the high costs of implementation and resistance to change within the industry further complicate widespread adoption.

Conceptual and experimental models developed by researchers in recent years demonstrate perceptible results in efforts to improve claim management. The digitalization of construction claim management has the potential to reduce project costs, enhance time management, and increase the reliability of management processes. Proper integration of digital tools appears to reduce disruptions in claim management processes significantly. However, due to the inherently complex nature of construction projects and the widespread reliance on manual data entry and project tracking, integrating advanced technologies into claim management presents significant challenges.

For these technologies to be effectively applied in claim management, it is essential to raise sector professionals' awareness of digital tools, enhance their technical knowledge, and provide appropriate training programs. Broad testing of these models in real-world projects and comparative analyses of their effectiveness across diverse projects are critical for advancing claim management practices. Furthermore, future research should extend beyond superstructure projects to include infrastructure projects, thereby improving the adoption and efficiency of digital claim management practices.

Specialized solutions for financial claims must be developed, and the integration of blockchain and artificial intelligence technologies should be strengthened. Additionally, several research gaps remain, including the lack of sufficient case studies to validate the functionality of proposed digital claim management systems, the predominantly conceptual presentation of blockchain-based claim management solutions, the absence of prototypes, the inability to tailor proposed models to the unique conditions of each contract, and customization challenges.

Further research is also needed to address difficulties in integrating BIM-based systems into traditional project delivery methods such as Design-Bid-Build (DBB), Engineering-Procurement-Construction (EPC), and Public-Private Partnership (PPP), all of which have layered structures. Issues such as trust and intellectual property rights within BIM applications must be thoroughly examined to understand their impact on the applicability of BIM-based claim management systems.

In conclusion, this research provides a comprehensive analysis of the current state of digitalization in construction claim management, identifies key knowledge gaps, and proposes a research roadmap for future studies. By offering insights into the contributions, limitations, and potential applications of emerging technologies, this study aims to serve as a guideline for researchers and industry professionals. It emphasizes the importance of integrating digital tools into claim management processes to improve efficiency, reduce conflicts, and ultimately enhance the success of construction projects. The conclusions of this thesis emphasize actionable recommendations for advancing the field. Key steps include developing integrated frameworks that combine multiple digital technologies, addressing adoption challenges like cost and expertise gaps, and fostering collaborations between academia and industry to validate and implement innovative solutions. Furthermore, this research highlights the need for pilot projects and case studies to demonstrate the practical benefits of digital claim management tools in real-world scenarios. The digitalization of claim management is a significant tool with the potential to enhance the success rate of construction projects. Increasing the efforts of researchers and practitioners in this field and implementing more practical examples within the industry will enable the full realization of the potential offered by the digitalization of claim management.

İNŞAAT HAK TALEBİ YÖNETİMİNDE DİJİTALLEŞME

ÖZET

Günümüzde inşaat projelerinin giderek artan karmaşık yapısı, hak taleplerinin sayısında ve çeşitliliğinde de önemli bir artışa yol açmıştır. Proje boyunca yaşanan gecikmeler, maliyet artışları, sözleşmeye dayalı uyuşmazlıklar, değişiklik talepleri, projenin kaynaklarını ciddi şekilde tüketmekte olup, hak talebi yönetimini, inşaat yönetiminde kritik bir konu haline getirmiştir. Geleneksel hak talebi yönetim yöntemleri, genellikle zaman alıcı, yüksek maliyetli ve insani hatalara açık süreçlerdir. Öte yandan, dokümantasyon, kilit personel değişiklikleri, hasar yönetiminde deneyimli ve uzman personel eksikliği ve hak talebi ile ilgili hususların sistem içerisinde görselleştirilmesi ihtiyacı gibi faktörler nedeniyle hak talebi yönetimi süreçleri sıklıkla yavaşlamakta ve daha maliyetli hale gelmektedir. Bu sorunlar, sıklıkla hak taleplerinin tahkime veya mahkeme süreçlerine taşınmasına yol açmaktadır. Bu bağlamda, dijitalleşmenin hak talebi yönetimi süreçlerine entegrasyonu, kaynakların daha etkin kullanılması, süreçlerin hızlanması ve hata oranlarının azaltılması açısından büyük bir potansiyele sahiptir. Teknolojik gelişmelerin, bu zorlukları aşmak için sunduğu çözümler hak talebi yönetiminin dijitalleşmesini kaçınılmaz hale getirmiştir. Ancak hak talebi yönetiminin dijitalleştirilmesi, nispeten yeni bir konudur ve inşaat projesi yaşam döngüsündeki diğer konularla karşılaştırıldığında hala yeterince araştırılmamaktadır. Bu alanla ilgilenen araştırmacılar ve uygulayıcılar konuya her geçen gün ilgilerini artırsalar da, gerek kullanılan dijital teknolojilerin, gerek inşaat projelerinin katmanlı yapısından kaynaklı hak talebi yönetimi konularının çeşitliliği konu ile ilgili verileri dağınık bir hale getirmiştir.

Bu araştırmanın amacı, inşaat hak talebi yönetiminin dijitalleşmesi ve uygulamaları konusunda, alandaki araştırmacıların ve uygulayıcıların karşılaştığı belirsizlikleri gidermek, kafa karışıklığını azaltmak ve yeterince benimsenemeyen bu konuyla ilgili açık ve anlaşılır bir rehber sunmaktır. Bu tezde, dijitalleşmenin inşaat hak talebi yönetimine sunacağı potansiyel katkıları incelenerek, bilgisayar destekli yönetim sistemleri, BIM (Yapı Bilgi Modellemesi), blok zinciri ve yapay zeka gibi teknolojilerin kullanım potansiyelleri değerlendirilmiştir. Araştırma, inşaat sektöründe hak talebi yönetimi konusunda bu teknolojilerin benimsenmesini artırmak amacıyla, yapılan çalışmalardaki mevcut sınırlamaları, araştırmaya ve iyileştirmeye açık noktaları göz önüne sunmuştur.

Bu araştırma, 1992 ve 2024 yılları arasında, inşaat hak talebi yönetiminin dijitalleşmesi konusunda yapılan çalışmalar için sistematik bir metodoloji aracılığıyla analitik ve eleştirel bir inceleme sunarak, araştırma alanında bir referans kaynağı işlevi görmesi bakımından özgün bir katkı sağlamaktadır. Bibliyometrik ve tematik analiz yöntemleri kullanarak, inşaat hak taleplerinin yönetim uygulamalarının dijitalleşmesine yönelik devam eden araştırma çabalarına dair net bir yol haritası sunmaktadır. Bu amaçla oluşturulan sistem metodolojisinde, Scopus ve Web of Science gibi akademik veri tabanları taranmış ve toplam 42 adet araştırma kategorize

edilerek incelenmiştir. Daha sonra her araştırmanın ana çıktıları, konuya katkıları, eksiklikleri ve sınırları belirlenmiştir. Çalışmaların bibliyometrik analizini yapmak, konu hakkında yapılan araştırmaların son durumunu (state of the art) belirlemek amacıyla literatür sınıflandırılmış, yıllık yayın eğilimleri, ülke dağılımları, yayın türleri, veri kaynakları, araştırma konuları, anahtar kelimeler, alıntılar ve çalışmaların ana çıktıları analiz edilmiştir. Ek olarak, araştırma yollarını aralarındaki ilişkiyi görselleştirmek amacıyla araştırmaların ana hatları ve yapılan bütün araştırmalar kronolojik olarak düzenlenmiş ve ilişkilendirilmiştir. Son olarak inşaat hak talebi yönetiminin dijitalleşmesi konusundaki araştırma alanları ve gelecekteki araştırma yollarını gösteren bir takım sonuçlar ortaya konulmuştur.

Bilgisayarların, 1990'lı yıllardan itibaren hayatımızda aktif bir rol oynamaya başlamasıyla, inşaat projelerinin yönetiminde de önemli bir araç haline geldikleri görülmektedir. Bu değişim, yalnızca geleneksel inşaat uygulamalarını değiştirmekle kalmayıp, inşaat projelerinin yönetimini de doğrudan etkilemektedir. Özellikle inşaat hak taleplerinin yönetimi, projelerin başarısını etkileyen kritik bir faktör olarak öne çıkmaktadır. İnşaat projelerinde sıklıkla karşılaşılan hak talebi yönetimi, ciddi mali kaynakları tüketen bir süreçtir. Gecikmeler, süre uzatımları, tasarım hataları, sözleşme ihlalleri kapsam değişiklikleri ve değişiklik emirleri hak taleplerinin başlıca nedenleri arasındadır. İnşaat projelerinin boyut ve karmaşıklık açısından büyümeye devam etmesiyle birlikte, hak taleplerinin geleneksel yöntemlerle yönetim faaliyetlerinin, maliyetli ve zaman alıcı doğası, bu faaliyetleri denetleyen kilit personeldeki değişimlerin yarattığı aksaklıklar ve mahkeme süreçlerinin uzun süreli olması, hak taleplerinin yönetim sürecini giderek daha karmaşık hale getirmektedir. İnşaat sektöründe kâr marjlarının daralması ve proje karmaşıklığının artmasıyla birlikte, projelerin kaynaklarının önemli bir kısmını tüketen hak taleplerinin sayısındaki ve karmaşıklığındaki artış, inşaat hak talebi yönetiminin dijitalleşmesini araştırmacılar için ilgi çekici bir konu haline getirmiştir. Teknolojinin durağan değil, sürekli gelişen bir yapıya sahip olması nedeniyle, her yeni geliştirilen dijital aracın hak taleplerinin yönetimine katkısının incelenmesi süreci devam etmektedir. Araştırmacılar, çeşitli dijital teknolojilerin hak talebi yönetimine entegrasyonunun bu zorlukları azaltabileceğini savunmuşlardır. Örneğin, BIM hak taleplerinin belgelenmesini, görselleştirilmesini ve analiz edilmesini kolaylaştırırken; blok zinciri teknolojisi, projeye dair verilerin daha şeffaf ve güvenilir bir şekilde saklanmasını sağlamaktadır. Yapay zeka uygulamaları ise, CBR (Vaka Tabanlı Çıkarsama), RBR (Kural Tabanlı Çıkarsama) yöntemleriyle sektörde hak talebi yapacak personelleri eğiterek, onlara hak talebi sürecinde yol göstererek hak talebi yönetimi sürecini daha etkin bir hale getirmeyi amaçlamaktadır. Özellikle 2020'den sonra, araştırmacıların ilgisinin giderek yapay zekanın bir alt kümesi olan makine öğrenimine doğru kaymaya başladığı görülmüştür. Makine öğrenim algoritmalarından faydalanarak geliştirilen hem kavramsal hem de prototip modellerde, araştırmacılar öncelikle talep yönetimini doğrudan ele almak yerine anlaşmazlıkların oluşumunu veya sonuçlarını tahmin etmeye odaklanmıştır. Çabaları, potansiyel anlaşmazlık sorunlarını veya sonuçlarını öngörerek anlaşmazlık çözümü için makine öğrenme tekniklerinden yararlanmaya adanmıştır.

Bu çalışma beş bölümden oluşmaktadır. Giriş kısmında tanımlamalar, araştırmanın amaç ve hedefleri, kapsamı, katkıları, sınırlamaları ve tezin organizasyonu ile ilgili genel bilgiler verilmiştir. Bu araştırmanın genel olarak gerçekleştirdiği ana hedefler şunlardır: (1) Her araştırmanın inşaat hak talebi yönetiminin dijitalleşmesi ile ilgili iyileştirme ve geliştirme yaklaşımları, veri kaynakları, yöntemleri, kullanılan dijital

araçları, katkıları, boşlukları ve sınırlamaları analiz edilmiştir. (2) Araştırmanın ana hattı tespit edilmiştir. (3) Bu alandaki araştırmaların aralarındaki ilişkilerin görselleştirmek amacıyla bibliyometrik araştırma haritaları oluşturulmuş ve kronolojik sırayla listelenmiştir. (4) İnşaat hak talebi yönetiminin dijitalleşmesi konusundaki araştırmaların durumları, eksiklikleri belirlenmiş ve gelecekteki olası araştırmalara ışık tutulmaya çalışılmıştır. (5) Sonuç olarak, inşaat hak talebi yönetiminin dijitalleşmesinde (1) dijital araçlar, (2) BIM, (3) blokzinciri ve (4) yapay zeka kullanımı olarak dört ana araştırma alanı belirlenmiş ve bu dört araştırma alanı için geliştirilen araştırma yol haritası bu çalışmanın ana katkısı olmuştur.

Giriş bölümünün ardından ikinci bölümde yapılan literatür araştırması yer almaktadır. İnşaat projelerinde hak talebi yönetimi, bilgisayar destekli hak talebi yönetimi konularına yer verilmiş ve yapılan araştırmaların katkılarından bahsedilmiştir. Ayrıca literatürdeki boşluk tespit edilerek tezin amacı ortaya konmuştur.

Üçüncü bölüm olan metodoloji bölümünde, kullanılan metodoloji ve seçilen makalelerin nasıl ve neden seçildiklerine dair açıklamalara yer verilmiştir.

Çalışmanın dördüncü bölümü analiz ve sonuçlar kısmıdır. Bu bölümün ilk alt bölümünde konu adına yapılmış çalışmalar, kullanılan ortak anahtar kelimeler, yıllık yayın trendi, yayınlanan dergi dağılımı, ortak yazarlık ve demografik dağılım, atıf sayıları, araştırmaların bilgi kaynağı ve ana çıktıları başlıkları altında analiz edilerek değerlendirilmiştir. Gelişme seviyesi alt başlığı altında çalışmalar, ana araştırma çıktılarına göre (1) öncül çalışmalar ve genel görüşler, (2) kavramsal/teorik modeller, (2) deneysel/prototip modeller olmak üzere, üç ana gruba ayrılmış ve kullanılan dijital araca göre kategorize edilip değerlendirilmiştir. Üçüncü alt başlıkta yapılan çalışmalar konu edindikleri dijital teknolojiye göre sınıflandırılmış ve aralarındaki ilişkileri ortaya koyacak şekilde araştırma yol haritaları oluşturulmuştur.

Bilgisayar tabanlı yönetim sistemleri ve diğer dijital araçları konu edinen araştırmacılar, başta gecikmeler, verimlilik ve değişiklik emirleri gibi hak taleplerine ilişkin sorunlara çözümler arayarak, bu araçların söz konusu zorlukların üstesinden nasıl gelebileceğine dair teorik çerçeveler geliştirmişlerdir. Araştırmacılar tarafından sunulan modellerde ağırlıklı olarak BIM ve eklentilerine odaklandığı görülmüştür. Bu ilgi, BIM'in proje ile ilgili neredeyse tüm verilerin farklı seviyelerde girişine olanak tanıması ve özellikleri ile eklentilerinin doküman kontrol sistemleriyle sorunsuz bir şekilde entegre edilebilmesi yeteneğinden kaynaklanmaktadır. Bu bağlamda, araştırmacıların süre uzatımları, gecikme analizleri ve değişiklik emirleri gibi hak taleplerine yönelik sorunları çözmek amacıyla BIM tabanlı hak talep yönetim modelleri ve BIM eklentileri geliştirmeye odaklanmış olmaları şaşırtıcı değildir. BIM, inşaat projesinde multidisipliner çalışmaya olanak sağlamasının yanı sıra tüm proje verilerini tek bir platformda toplar ve bunları belgeleme, analiz etme ve raporlama için kullanılabilir hale getirir. BIM tabanlı hak talebi yönetim sistemlerinin geleneksel proje teslim yöntemlerine entegrasyonu bazı zorluklar barındırmaktadır. Herhangi bir spesifik yönetim modeli önerilmemiş olsa da, araştırmacılar çalışmalarında blokzincir ve akıllı sözleşme teknolojilerine yer vermiştir. İncelenen çalışmalar, bu araçların özellikle finansal hak taleplerinin yönetimine potansiyel katkılarını ve projelere adaptasyonlarıyla ilgili zorlukları vurgulamaktadır. Bu teknolojiler, özellikle finansal hak taleplerinin, belge yönetiminin daha güvenilir ve şeffaf bir şekilde gerçekleşmesini sağlarken, bu teknolojilerin uygulanabilirliğini ispatlar nitelikte örnek bir hak talebi yönetim sistemiyle karşılaşılmamıştır. Günümüzde hayatın birçok alanında giderek yaygınlaşan kablosuz iletişim ve yapay zeka teknolojilerine odaklanan çalışmaların da

mevcut olduğu belirlenmiştir. Özellikle değişiklik emirlerine ilişkin hak taleplerinin yönetim sürecine yardımcı olmak amacıyla çeşitli modeller önerilmiştir.

Son bölüm olan beşinci bölümde, gelecekteki araştırmalar için sonuç ve öneriler tartışmalı olarak değerlendirilmiştir. İnşaat sektöründeki hızlı dijitalleşme ile birlikte, proje yaşam döngüsü boyunca inşaat hak taleplerinin yönetiminde dijital araçların kullanımı giderek daha önemli hale gelmekte olup, sektör uzmanları ve akademisyenler tarafından araştırma ilgisi her teknolojik yenilikle artmaktadır. Yapılmış araştırmaların ağırlıklı olarak amacı, güçlü ve dijital hak talebi yönetim sistemleri oluşturmaktır. Bununla birlikte, inşaat sektöründeki araştırmacılar ve uygulayıcılar için yapılan çalışmaların ve sonuçlarının son derece dağınık olması, bir karışıklığa neden olmaktadır. Bu tezde, tüm bu karışıklıklar yapılan analiz ve değerlendirilmelerle düzeltilmeye çalışılmıştır. Bunun yanında, bu tezin bir diğer yazım amacı, hak talebi yönetimi konusundaki yeni yaklaşım ve teknolojileri inşaat sektörüne tanıtmak ve adapte edebilmektir. Bu araştırma, bu alandaki beklentileri genişletmeyi, sektörün bu teknolojileri benimseyebilmesini sağlamayı ve özellikle kompleks inşaat projelerindeki hak talebi yönetimi sürecinde karşılaşılan birçok karmaşıklığı çözmeyi amaçlamıştır.

Araştırmacılar tarafından son yıllarda geliştirilen kavramsal ve deneysel modeller, hak taleplerinin yönetimini iyileştirmeye yönelik araştırmaların somut sonuçlar verdiğini göstermektedir. İnşaat hak talebi yönetiminin dijitalleşmesi, inşaat projelerinin maliyetlerini azaltma, zaman yönetimini iyileştirme ve yönetim süreçlerinin güvenilirliğini artırma potansiyeline sahiptir. Dijital araçların doğru entegrasyonu sayesinde hak talebi yönetimi süreçlerinde yaşanan aksaklıkların büyük ölçüde azaltılabileceği görülmektedir. Ancak, inşaat projelerinin karmaşık doğası ve manuel veri girişi ile proje takibinin yaygın kullanımı nedeniyle, ileri teknolojilerin inşaat hak taleplerinin yönetimine entegre edilmesi önemli zorluklar barındırmaktadır. Bu teknolojilerin etkin bir şekilde hak talebi yönetiminde uygulanabilmesi için sektör profesyonellerinin dijital araçlara yönelik farkındalığının artırılması, teknik bilgi düzeylerinin yükseltilmesi ve uygun eğitim programlarının sağlanması gerekmektedir. Bu modellerin gerçek projelerde yaygın olarak test edilmesi, bu modellerin farklı projelerdeki etkinliğinin karşılaştırılmalı analizlerle değerlendirilmesi, hak talebi yönetimi uygulamalarının gelişimi açısından kritik bir öneme sahiptir. Ayrıca, gelecekteki araştırmaların yalnızca üstyapı projelerini değil, altyapı projelerini de kapsayacak şekilde genişletilmesi, hak talep yönetiminin dijitalleşmesinin benimsenmesini ve uygulamaların verimliliğini artıracaktır. Finansal hak taleplerine yönelik özel çözümler geliştirilerek, blok zinciri ve yapay zeka teknolojilerinin entegrasyonu güçlendirilmelidir. Bunlara ek olarak, belirlenen sonuçlar ve dikkat çeken boşluklar doğrultusunda, önerilen dijital hak talep yönetim sistemlerinin işlevselliğini doğrulamak için yeterli sayıda vaka çalışmasının yapılmaması, blok zinciri tabanlı hak talep yönetiminin yalnızca kavramsal düzeyde sunulması ve prototiplerin eksikliği, her sözleşmenin özel koşullarının önerilen modellere uygulanamaması ve özelleştirme sorunları halen araştırılmaya açık konulardır. Katmanlı bir yapıya sahip olan geleneksel DBB (Tasarım-İhale-Yapım), EPC (Mühendislik-Satın Alma-İnşa Etme), PPP (Kamu-Özel İşbirliği) gibi farklı proje teslim yöntemlerine BIM tabanlı sistemlerin entegrasyonunda yaşanan zorluklar üzerinde çalışması gerekmektedir. BIM uygulamalarında güven ve fikri mülkiyet hakları gibi zorlukların BIM tabanlı hak talep yönetim sistemlerinin uygulanabilirliğine etkisi gibi tespit edilmiş eksikliklerin araştırılması gerekli görülmektedir.

Sonuç olarak, hak talebi yönetiminin dijitalleştirilmesi, inşaat projelerinin başarı oranını artırma potansiyeline sahip önemli bir araçtır. Araştırmacıların ve uygulayıcıların bu alandaki çalışmalarını artırmaları ve sektörde daha fazla örnek uygulamaların gerçekleştirilmesi, hak talebi yönetiminde dijitalleşmenin tam olarak potansiyeline ulaşmasını sağlayacaktır.

1. INTRODUCTION

1.1 Background

The construction industry is rapidly evolving due to technological advancements while profit margins are decreasing. This transformation not only alters traditional construction practices but also impacts the management of construction projects. Particularly, the management of construction claims is a critical factor affecting the success of projects. Managing these claims through traditional methods can be time-consuming, costly, and susceptible to mistakes. Therefore, with the rapid digitalization in the construction sector, using digital tools to manage construction claim management throughout the project lifecycle is becoming increasingly important.

1.2 Research Goal and Objectives

In 2023, average dispute values in North America increased to US$42.8 million, while the average dispute resolution process decreased to 13.6 months also, one dispute registered in 2021 reached a record value of US$2 billion (Arcadis, 2023). The report indicates that disputes are most prevalent in transportation projects such as highways, bridges, mass transit, airports, and ports, which are currently heavily undertaken in developing regions such as South America, Africa, Australia, and Asia, where these values could deteriorate further. This highlights the necessity for the digitalization of claim management to evolve alongside the complexity of construction projects, emphasizing the need for a more optimized approach. Furthermore, the future is expected to see a further increase in the digitalization trend.

The digitalization of claim management in construction projects has only recently begun to develop compared to other areas and has been increasingly researched by scholars and practitioners in recent years. Upon review of the literature, it is evident that there is no roadmap for researchers to follow to enhance the efficiency of future studies.

This study aims to provide a roadmap for future research in digitalization in the construction claim management research domain by outlining the limitations of previous research.

1.3 Research Scope

This study provides a comprehensive systematic literature review by analyzing the existing knowledge base to offer a general overview of digitalization in construction claim management, uncover factors behind the relatively underdeveloped state of the field, and propose future research directions. This objective is achieved by classifying and mapping the literature and analyzing annual publication trends, country distribution, publication types, data sources, research topics, keywords, citations, and the main outputs of the studies.

The literature review reveals that researchers predominantly (James E. Diekmann, Moonja P. Kim 1992, Vidogah W.; Ndekugri I. 1998, El-Ghrory A. et al. 2019, Seo W, Kim J, Kang Y 2022, M. Asem U. Abdul-Malak et al. 2002), Building Information Modeling (BIM) or visualization tools (Brown, JD; Fruchtman, E 2000, Shahhosseini, Hajarolasvadi 2021, Jalal et al. 2021, Ali et al. 2020, Ali et al. 2022, Handayani et al. 2019, Askari et al. 2013, Wang et al. 2023, Abougamil et al. 2023, Mijwel Aljumaily H.S et al. 2022, Guévremont, M; Hammad, A, 2021), electronic document management systems (Baram G.E.,1994), delay analysis software (Tsai MK et al. 2013, Fan SL 2022, Ali, B et al. 2022), artificial intelligence (AI) (Wang W. 2010, El-Adaway I.H. and Kandil A.A. 2010, Li Y. 2022) and Smart Concrats / Blockchain (Mahmudnia, D et al. 2022, Nalioğlu et al. 2023, Msawil M. et al. 2022) platforms concerning the digitalization of claim management in construction. The contributions of these studies to construction projects are thoroughly examined under these headings.

This study seeks to answer the following questions:

1. What studies have been conducted on the digitalization of claim management in construction from 1992 to 2024, and what are their contributions?

2. What are the limitations and future research subjects identified in these studies?

1.4 Research Contributions

This research distinctively contributes by offering an analytical and critical review through a systematic methodology, serving as a research reference. It provides clear guidance on the ongoing research efforts towards the digitalization of construction claim management practices. In this study, the research conducted to date on claim management, a relatively newer and developing topic in the digitalization process compared to other construction project management areas, has been analyzed. The digital technologies explored in these studies, the models developed, the claim-related issues these models aim to address, and the limitations of the studies have been thoroughly examined and summarized. These analyses will serve roadmap for future research in the field. The purpose of this study is summarized as follows:

1) To present the current state of research on the digitalization of construction claim management.

2) To establish a roadmap for future studies.

1.5 Review Limitations

Since the digitalization of claim management is a relatively new topic within construction project management, no limitations were imposed during the research to ensure a comprehensive evaluation of all available data. As the number of search engines used in the research increased, it was observed that the number of duplicate records rose while the number of new records decreased significantly. Therefore, to access the most relevant papers, data from the search engines Scopus, and Web of Science were utilized during the research.

1.6 Thesis Organization

This study comprises four main sections. Following the “Introduction” section, the "Literature Review" section presents theoretical knowledge on claim management in construction that will support the methodology, results, discussions, and conclusions of the study. The "Methodology" section describes the rigorous examination methodology conducted to address the aforementioned questions. The “Analysis and Results” section presents the analyses and outlines the findings derived from the analysis. In the "Research road map" section, the digital technologies that are the

subject of the thesis are grouped, the studies on them are listed chronologically, and the relationships between the studies are explained. The final section, "Conclusion and Recommendations," evaluates the study's findings and provides recommendations for future research.

2. LITERATURE REVIEW

2.1 Claim Management in Construction

In the construction sector, conflicts or disagreements may emerge concerning the contractual responsibilities or anticipations among various participants of a project. When one participant believes that the contractual responsibilities or anticipations have not been fulfilled as stipulated in the agreement, and they are entitled to financial and/or time-related recompense, they submit a claim (Semple, Hartman, et al. 1994). Shah et. al (2014), defined a construction claim as a "request by either party to the contract, usually the contractor, for compensation for damages caused by failure of the other party to fulfill his part of obligations as specified in the contract." It could develop into a dispute or disagreement that isn't settled amicably. (Jervis and Levin 1988; Mishmish and El-Sayegh 2018), as depicted in Fig. 3.1.

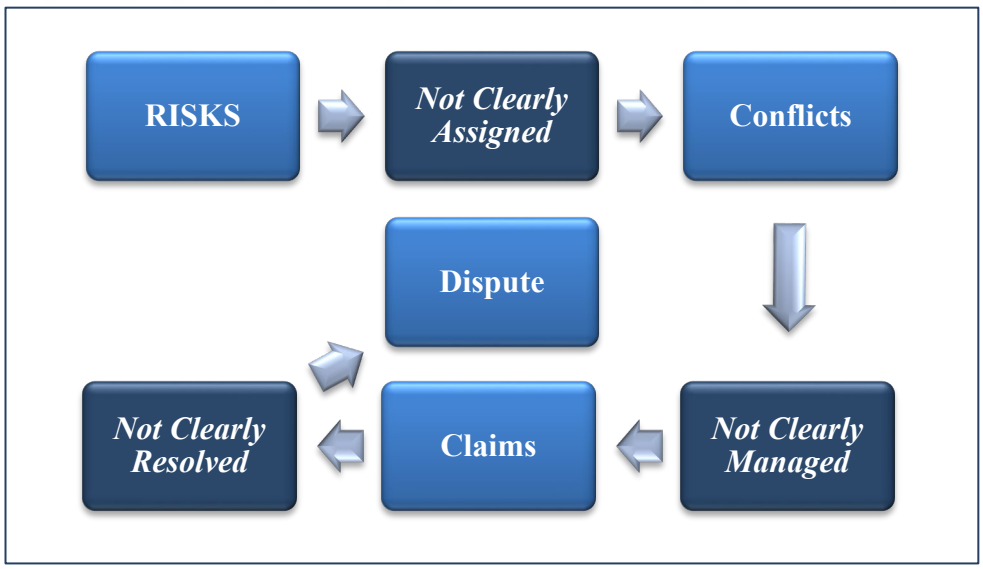

Figure 2.1: "Risks, Conflict, Claims, and Dispute Continuum Model"
(Dhanke and Futane, 2020)

Claims prodigally drain project assets and are viewed as a significant contributor to budget excess. Conflicts in construction projects redirect resources away from

achieving project goals, thus escalating expenses (Riad et al. 1991). The management of claims is essential for the effective delivery of construction projects.

As stated in reports from the National Research Council (NRC), the transactional expenditures involved in settling conflicts related to construction projects can vary between $4 billion and $12 billion annually. Additionally, there are indirect costs that encompass reduced quality and strained relationships among parties who could have otherwise benefitted from sustained long-term collaborations (National Research Council 2009). These findings have highlighted the increasing significance of claim management in growing and complex construction projects, thereby encouraging both researchers and industry practitioners to research this topic. (e.g. Kauffmann et al. (2002), Enshassi AA et al. (2008), Enshassi A et al. (2009), Sibanyama et al. (2012), Le-Hoai et al. (2018), Stamatiou et al. (2018), Matseke et al. (2022)).

2.2 Computer-aided Claim Management

Claims are significantly evaluated upon the completion of construction projects. The lengthy nature of these projects, coupled with frequent changes in essential team members from all involved parties, has rendered the process of retrieving supporting documentation and thereby justifying claims both challenging and labor-intensive. Issues surrounding claims management are particularly severe in the realms of claims substantiation and quantification, as well as notably regarding the recovery of supporting details and the sufficiency of the information provided (Vidogah and Ndekugri 1998). Insufficient site personnel awareness to actively identify claims, the inaccessibility or absence of pertinent documents, and disputes that emerge during negotiations between the owner and contractor represent significant challenges linked to the claim management process. (Bakhary et al. 2015).

The World Economic Forum (WEF) recognizes the significant eventuality of the AEC's assiduity in enhancing its productivity and effectiveness by enforcing digitalization, innovative technologies, and new construction approaches. Embracing and using leading-edge digital technologies can significantly ameliorate construction companies' productivity, project management, working procedures, work quality, and safety (WEF 2016).

The studies conducted on this subject have contributed valuable insights into the digitalization of claims management.

The data indicating a decreasing trend in claim processes, as disclosed by research organizations, and the survey results following the use of technological tools in some studies, serve as evidence of this. However, some challenges and limitations still exist. Efforts are needed to address these limitations in future research endeavors.

2.2.1 Computer-based systems, and digital tools

Employing computers and information technology is a necessity to enhance construction efficiency. Over the past thirty years, various research efforts have been conducted on utilizing computers in managing claims in the construction sector. (Arditi and Patel 1989; Riad et al. 1991; Diekmann and Kim 1992; Vidogah and Ndekugri 1998; Abdul-Malak et al. 2002; Gibbs et al. 2013; El Hawary and Nassar 2015; Yousefi et al. 2016; Marzouk et al. 2018, El-Ghory et al. 2019).

In primary studies, researchers argued that expert systems commonly utilized in sectors such as medicine, organic chemistry, space applications, and molecular genetics during that period, could serve as an alternative to time-consuming and costly construction project management. They discussed the potential benefits of employing such systems. (Arditi and Patel, 1989), Cobb and Diekmann (1986), defined expert systems "as programs capable of handling complex real-world problems requiring expert interpretation. These systems resolve such problems by employing a computer model of expert human reasoning, arriving at the same conclusions as a human expert would when confronted with a similar problem."

Literature indicates that computer-aided claim management systems have emerged as a viable option within the construction sector. The primary benefit of employing a digital claim management system is the ability to settle construction claims more economically and at an accelerated pace.

2.2.2 BIM

Frequently mentioned by scholars as a possibly powerful tool for the digital transformation of claim management, the Building Information Model (BIM), can be considered as the rearmost technological development related to construction information and it's anticipated to give new conception of designing, planning,

executing, and managing the construction projects. (Shahhosseini, Hajarolasvadi 2021, Jalal et al. 2021, Ali et al. 2020, Ali et al. 2022, Handayani et al. 2019, Askari et al. 2013, Wang et al. 2023, Abougamil et al. 2023, Mijwel Aljumaily H.S et al. 2022, Guévremont, M; Hammad, A, 2021). BIM, is described by the National Building Information Modeling Standard (NBIMS) as "an improved planning, design, construction, operation, and maintenance process using a standardized machine-readable information model for each facility, new or old, which contains all appropriate information created or gathered about that facility in a format usable by throughout its lifecycle" (NBIMS, 2008). "BIM advances the construction industry from current task automation of project and paper-centric processes toward an integrated and interoperable workflow where tasks are integrated into a collaborative and coordinative process that maximizes the computing capabilities." (Eastman, Teicholz et al. 2011).

BIM illustrates tangible elements such as doors, walls, and windows as three-dimensional (3D) objects. Besides geometric details, additional information can be linked to these entities such as manufacturers, fire ratings, schedules, and cost projections. Another benefit of BIM is the simplicity of inserting, extracting, updating, or altering digital information by all project participants such as owners, clients, engineers, architects, contractors, suppliers, and building officials. (Goedert and Meadati 2008). The BIM model for each facility contains all information related to the facilities, such as different types of activities, accurate quantities of work for each activity, required resources, cost, and activity duration in addition to geometric information that can be used in 3D (Three-Dimensional), 4D and 5D visualization of the facility. (Askari et al. 2013) BIM levels are utilized for different purposes for different types of projects. Different level of BIM represents a particular level of "maturity" starting from level 0 to 6. The purpose of BIM levels is to incorporate relevant and exact information along with the BIM model throughout the design-build process. (ASC Technology Solutions LLC, 2022) Different levels of BIM are described below in Figure 3.2 to be utilized effectively. According to the literature, researchers have utilized BIM in various conceptual and experimental models aimed at the digitalization of claim management by developing different tools. Depending on the specific claim issues they aim to address, they have leveraged relevant features of BIM at different levels.

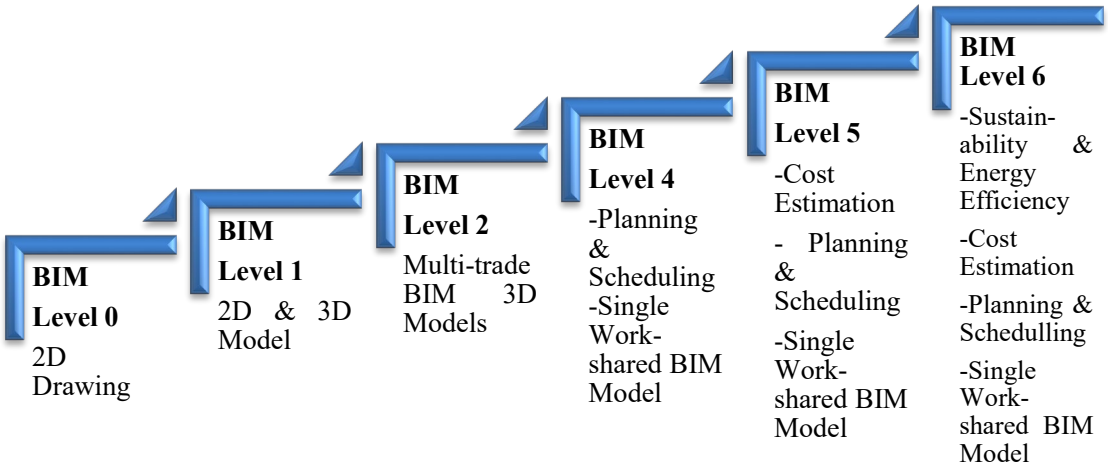

Figure 2.2: BIM Levels 0-6 (ASC Technology Solutions, 2022)

The most cited studies on BIM in the past five years are those conducted by Shahhosseini and Hajarolasvadi (2021), Jalal et al. (2021), and Ali et al. (2020). Shahhosseini and Hajarolasvadi stated that the main problem with existing claim management practices according to the literature, is providing data and proving claims. To handle this problem, they suggested a framework for creating a BIM-based claim management system. To enhance BIM's efficiency in rule-checking applications, they introduced a Communication Management Subsystem (CMS) to collect project documents' valuable data (e.g. change orders, daily progress reports, financial statements, or submittals). Like Shahhosseini and Hajarolasvadi (2021), Jalal et al. proposed a model to solve claim documentation issues. They stated that their model must be capable of collecting, storing, and retrieving extensive building data. They expected that this framework would deliver greater precision in the claimed cost or time, more rational clash detection, risk assessments, and early recognition and after that settlement of errors and omissions. Ali et al. (2020), highlighted that in traditional claim management systems, Extension of Time (EOT) claims often lead to disputes among stakeholders, emphasizing the need to transition these traditional systems into a digital environment. To manage EOT claims more effectively, they developed a plug-in for Autodesk Revit using an application programming interface (API) to create a BIM-Based Claims Management System (BIM-CMS). Lack of BIM knowledge, cost, and resistance to embracing new methods in traditional construction techniques,

contracts' limitations, and models not applicable throughout the construction project's entire life cycle are some of these studies' common limitations.

2.2.3 Blockchain and smart contracts

Advancements in technology, including building information modeling (BIM), cloud computing, and the Internet of Things (IoT), have transformed the methods used for data storage, sharing, and analysis (Tang et al., 2019). Numerous project management tools and contracts within the construction sector are influenced and digitally updated by incorporating the latest technological innovations (Li and Kassem, 2021). Recently, the construction industry has adopted smart contracts to digitally streamline the transfer of funds, shares, assets, contents, and additional digital resources. Scholars have thoroughly examined multiple facets of the application of BCT (Blockchain technologies) (Stallone et al., 2021). Recent studies have demonstrated that blockchain technology can alleviate hacking and security risks in Internet of Things systems and Building Information Modeling systems. (Das et al., 2022) The distinctive attributes of blockchain encompass unchangeability, immediate traceability, decentralized management of digital records, and autonomous operation combined with the unchangeable results produced by blockchain-powered smart contracts (i.e., programmed coded protocols) (Hamledari et al., 2021). Consequently, the attainments of audit capability, clarity, responsibility, and distinctly outlined roles and duties of the participants are accomplished (Greenwood et al., 2019). The features of blockchain present promising remedies for the previously mentioned issues related to ineffective Construction Contract Administration (CCA). Few articles have reviewed the potential of 'Blockchain' to resolve conflicts in the construction sector.

The investigation by Msawil et al. (2022) explored the inquiry regarding the potential contributions of blockchain toward enhancing CCA and identified the distinct obstacles to its integration into CCA. They observed that the majority of applications were predominantly focused on two functionalities of CCA: management of projects' finance and management of documents and records. Furthermore, they highlighted that aspects of CCA involving intricate contractual mechanisms, such as claims and dispute resolution management, have been largely overlooked. To promote the application of blockchain in CCA, they proposed a framework outlining significant challenges associated with technology, processes, policies, and societal aspects for subsequent

study. Mahmudina et al. (2022) concentrated on assessing the characteristics of BCT to determine its effects on alleviating disputes. They concluded that for the successful application of blockchain technology (BCT) in diminishing construction disputes, several unresolved issues must be tackled: cultivating a comprehensive understanding of blockchain to prevent encountering larger risks and conflicts and addressing uncertainties to bolster the effectiveness of BCT in reducing construction disputes. Nalioglu et al. (2023) investigated the possible impacts of smart contracts and their findings indicate that smart contracts could offer significant advantages in the management of the claim process, such as maintaining record authenticity, removing extraneous red tape, ensuring document dependability, increasing transparency, and decreasing transaction expenses. In all the reviewed studies, while the positive impacts of blockchain technology (BCT) and smart contracts on digital construction claim management were highlighted, it was observed that, unfortunately, no theoretical or experimental management model was proposed.

2.2.4 Artificial intelligence

With the advancement of technology, two relatively new topics that have begun to appear in the literature are wireless communication and artificial intelligence. In the evolution of these fields, leveraging contemporary information technology for overseeing construction projects has become a prominent trend within the construction sector (Dastyar et al., 2018, Al-Zwaniy et al. 2018). The integration of wireless communication and artificial intelligence can equip managers with a clearer and more scientific understanding of engineering systems, providing robust support for claims processing. Consequently, to enhance the efficiency of claims management, it is essential to create a construction engineering claims operation framework (Petherbridge, 2019).

Few models have been presented using wireless technology and artificial intelligence. In his 2022 study, Li introduced a claim management system developed by utilizing wireless communication and artificial intelligence technologies. This system is designed comprehensively, incorporating modules for claim process tracking, analyzing relevant issues to determine the responsible party, managing claim documents, calculating the cost of the claims, and storing situations subject to claims. Wang's presented construction claim decision support system in 2010 is designed

based on rule-based reasoning (RBR) and case-based reasoning (CBR) in artificial intelligence—which is considered a relatively newer application for construction claim management compared to other digital technologies—. The model is designed to assist users in hydraulic engineering to accomplish intricate claims by leveraging the expertise and insights of claims specialists. According to El-Adaway and Kandil (2010), who, like Wang (2010), worked on improving the management of change order claims with artificial intelligence, the time and associated costs spent by lawyers, contract administrators, and claims consultants in reviewing precedent cases to identify similarities and differences is a significant problem. To solve this problem, they created a multiagent system for construction dispute resolution (MAS-COR), which generates legal arguments based on precedent cases.

2.3 Literature Gap

Industry experts and researchers have aimed to adopt digital technologies to improve existing practices and achieve more effective and yielding claim management processes in various applications within the sector. Despite the novelty of the subject, it has been observed that researchers have developed several promising models and plug-ins as a result of nearly three decades of work. Although research in this area has become more widespread, it has been observed that efforts have branched out where research is fragmented and disorganized. This issue can be attributed both to the fact that the digitalization of claim management is relatively new compared to other fields of project management, and the absence of a clear roadmap for future research endeavors. It is aimed that, with this thesis, the gap in the literature regarding a roadmap will be addressed and the areas where current studies require further development will be highlighted.

3. METHODOLOGY

3.1 The Review Process

In this thesis, to determine the present level of understanding regarding digital transformation in construction claim management, the available literature was examined, investigated, and analyzed. A systematic review of a field via the evaluation of scholarly works is a recognized approach within the field of construction management (Betts and Lansley, 1993; Dickinson et al., 2006; Lu et al., Pietroforte and Stefani, 2004; 2015 Wolfe, 1994; Volk et al., 2014).

Scholarly publications introduce innovative concepts grounded in previous research, which shape currents within a particular discipline. Examining these currents reveals trends of development that encompass origins, results, impact, constraints, partnerships, as well as emerging and overlooked topics. This activity plays a vital role in enhancing an ever-expanding knowledge framework by providing a comprehensive overview of the domain, prompting fresh investigative inquiries, and cultivating novel viewpoints and future research agendas (Ilter D., Ergen E. 2015)

For this purpose, to address the questions mentioned in the introduction section, the literature on "Digitalization in Construction Claim Management" was reviewed, and selected publications were analyzed for measurable characteristics such as annual publication trend, country distribution, publisher, citations, data sources, and keywords. Subsequently, the main topic headings, outputs, contributions, and limitations of these publications were identified.

3.2 Keyword Searching and Selection of Articles

In this study, no specific journal criteria were applied to reach the maximum number of potential publications. To access the most relevant papers, search engines such as Scopus and Web of Science were utilized. Due to the relatively new and open nature of the topic, no time limit was imposed. The same set of keywords (“construction”

AND ("claim" OR "dispute")) AND ("digital" OR "technology" OR "digital technologies" OR "BIM" OR "building information modeling" OR "automated" OR "artificial intelligence" OR "machine learning" OR "NLP" OR "AI" OR "blockchain" OR "agent"), were used to identify all English-language sources in each search engine. A search was conducted in the search engine using this keyword set, specifically targeting titles, abstracts, and keywords. These settings ensured that all relevant studies were identified, including journal papers, books and conference papers.

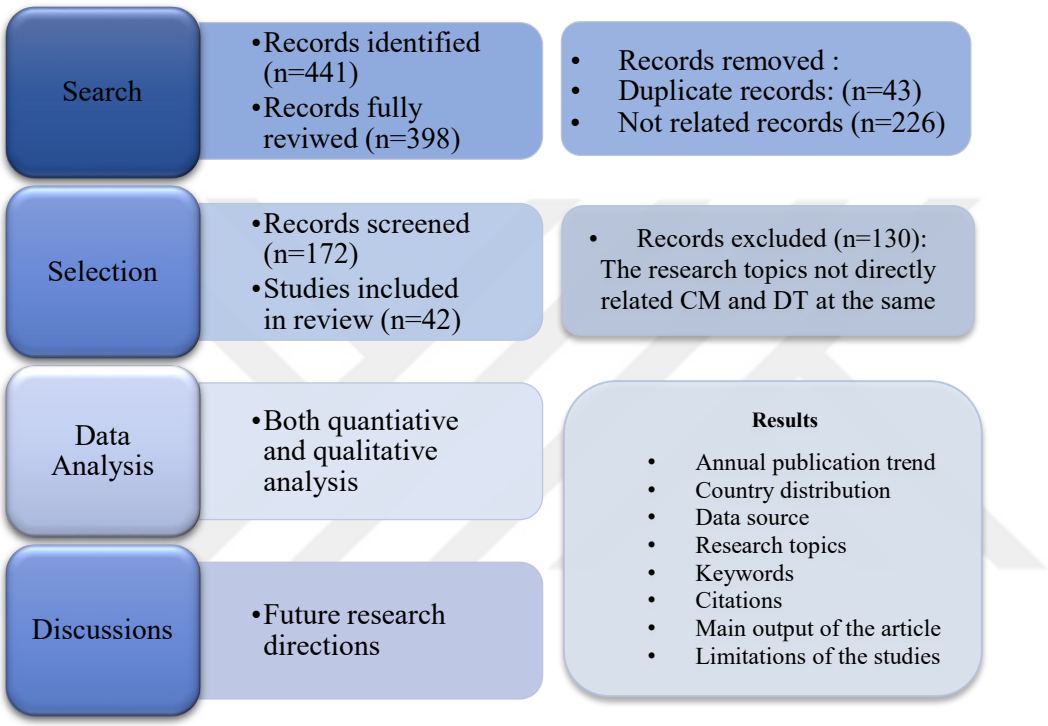

Figure 3.3: Research Methodology Overview

As a result of the search, 1154 records were identified. During the preliminary screening, records that were not accessible online and irrelevant records were excluded, resulting in 441 records being scanned. After removing the duplicate (=43) records, the remaining 398 articles were fully reviewed and not related articles (=226) were removed. After the screening, 130 articles were excluded from the study as they were not simultaneously relevant to claim management and digital technologies. A total of 42 relevant publications were selected and examined in terms of annual publication trend, country distribution, publication type, data source, research topics, keywords, citations, and the main output of the article. In Figure 2.1, a general overview of the research methodology of the study is presented.

4. ANALYSIS AND RESULTS

In this section, an analysis of selected articles for this study is demonstrated. Latterly, the analysis of former reviews and the originality of the review are illustrated. Eventually, the review of the research efforts on Digitalization in Construction Claim Management will be discussed in the following subsections.

Content analysis is a thorough observational approach that goes beyond simply tallying words; it scrutinizes materials deeply to identify key aspects and sound conclusions. (Ragap and Marzouk 2021)

At this stage of the study, the selected articles were analyzed by dividing them into seven groups with specific aspects: their journals, keywords, publication years, demographics, data sources, main output types, and citation statuses. Subsequently, they were classified based on the digital tools under study, and their contributions and limitations to the subject were evaluated.

4.1 Co-occurring Keywords

Keywords are considerable words that serve as a point of reference and aid the description of contents and understanding of concepts in research studies (Su and Lee 2010).

In the past thirty years, limited subjects and themes have progressed in studies focused on the digitalization construction claim management. Information sourced from the Web of Science database was uploaded to VOSviewer to create a visualization diagram illustrating co-occurring keywords and an overlaid network of research areas on the digital transformation of construction claim management.

The closeness of keywords to each other and their resemblance dictates the extent of co-occurrence (Van Eck and Waltman 2014; Liang et al. 2018).

A co-occurrence network was constructed from 217 keywords utilizing VOSviewer software. With a threshold of at least two co-occurrences per keyword, 51 keywords were identified to co-occur, forming five prominent keyword clusters. Figure 4.1 illustrates a visual representation of these five co-occurring keyword clusters, showcasing 450 links and an overall link strength of 661.

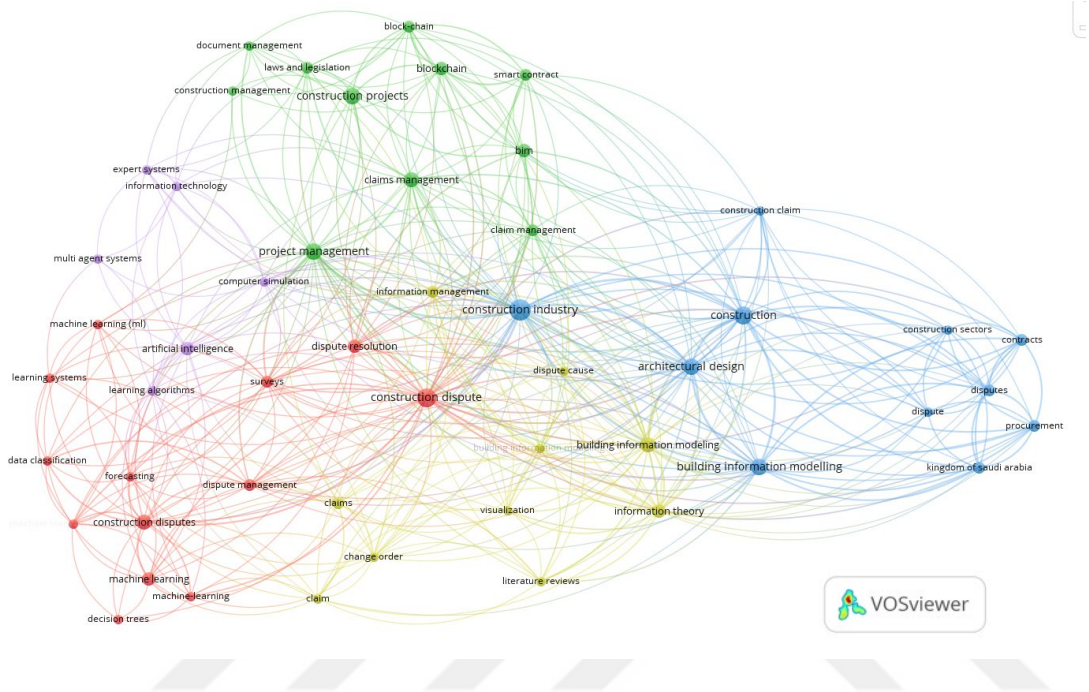

Figure 4.1: Cluster Visualization Map for co-occurring keywords

Table 4.1 shows the most active keywords in the 42 analyzed documents. The top five keywords were Dispute Resolution, BIM, Construction Industry, Claims, and Claim Management.

Apart from BIM, claim management, and construction dispute, which are search keywords of this study, delay analysis, extension of time, smart contracts, change order, and visualization sharing most occurred keywords, reflecting on the other digital technologies or claim issues for construction claim management.

Table 4.1: Keyword co-occurrence

Keywords	No. of Published Articles	Frequency of Occurrence%
Dispute Resolution / Contractual Dispute / Construction Dispute / Dispute Support / Dispute Avoidance	19	**45%**
BIM / BIM Benefits	15	**36%**
Construction industry/project/management	14	**33%**
Claim* / Hard Claim / Construction Claim / Claim Impact	13	**31%**
Claim Management	11	**26%**
Contract management/model	10	**24%**
Delay/Delay analysis/claims	9	**21%**
Artificial intelligence (AI) / Machine Learning (ML) / Hybrid Intelligence	8	**19%**
EoT	6	**14%**
Smart Contracts	4	**10%**
Information / Information Technology	3	**7%**
Document* / Control - Management-Tracking	4	**10%**
Change Order / Change Detection Application	4	**10%**
Blockchain	4	**10%**
Visualization / Visual Analytics / Color-Coded Visualization	3	**7%**
API (Application Programming Interface)	3	**7%**
Productivity / Productivity Claims	2	**5%**
Project Management	2	**5%**

4.2 Annual Publication Trend

The number of articles published on Digitalization in Construction Claim Management each year is depicted in Figure 4.2. As stated in the methodology section, no time constraints were imposed in this study due to the novelty and openness of the subject to research.

The total number of articles is relatively small, as expected. The timeline of published articles indicates that research on this topic began in the 1990s with the increasing use of computers. 37 publications, constituting 88% of the total count, with 15 focusing on BIM and with 9 focusing on artificial intelligence, were published after 2010. This suggests that digitalization in claim management remains a relatively new research topic compared to other areas in construction management. The rise in publications since 2010 can also be attributed to the widespread adoption of BIM in construction

projects and the initiation of research on integrating claim management with BIM. The trend in published articles indicates a steady increase in interest in the digitalization of construction claim management.

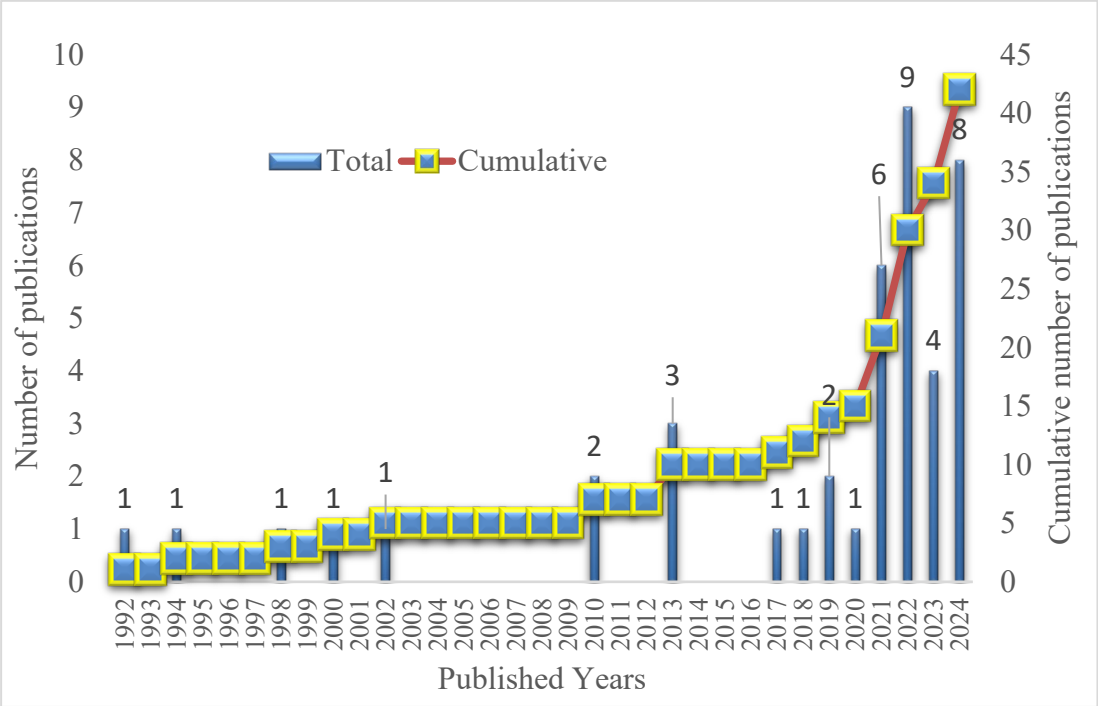

Figure 4.2: Annual publication trend

4.3 Journal Distribution

The distribution of articles among journals in each year and journal shares are given in Table 4.2. Automation in Construction published the most articles (six articles), followed by the Journal of Legal Affairs And Dispute Resolution in Engineering andnd Construction (five articles), followed by the Journal of Construction Engineering and Management (four articles), Buildings and total conference papers (three articles each), and Engineering Journal-Thailand and, International Journal of Construction Management (two articles each), The remaining 17 journals, namely Asian Journal of Civil Engineering, Computers in Industry, Construction Innovation-England, Cost Engineering, Engineering, Construction and Architectural Management, Expert Systems Wıth Applications, International Journal of Recent Technology and Engineering, Journal of Applied Engineering Science, Journal of Civil Engineering and Management, Journal of Engineering Research (Kuwait), Journal of Information Technology in Construction, Journal of Management in Engineering, KSCE Journal

of Civil Engineering, Lecture Notes in Civil Engineering, Pertanika Journal of Social Science and Humanities, Smart and Sustainable Built Environment, Wireless Communications & Mobile Computing published one article each. The three conference papers were published respectively in the Construction Congress VI, Building Together for a Better Tomorrow in an increasingly Complex World; the 5th International Conference on Computer Sciences and Convergence Information Technology (ICCIT 2010); and the Annual Conference of the Canadian Society for Civil Engineering.

The distribution shows that the Digitalization of Construction claim management attracted attention from a wide spectrum of AEC Journals, Legal Affairs and Dispute Resolution, and IT related journals.

4.4 Co-authorship and Demographic Distribution

The corresponding author's institutional address or association was utilized to assess how publications were distributed among different countries. The countries were recognized along with their respective publication counts. As depicted on the world map in Figure 4.3, among the countries contributing most significantly to this topic are Australia, Turkey, Malaysia, the USA, the UK, Canada, China, Iran and Taiwan. The intensity of research conducted on this topic seems to correlate with the intensity of construction projects carried out in the regions.

Figure 4.3: Public country/region distribution

The blue lines on the map, indicate the co-authorship network of the countries. These publications have been co-authored by researchers from the countries/regions of Thailand-Japan *(Handayani, TN; Likhitruangsilp, V; Yabuki, N 2019),* Australia-Iran *(Mahmudnia, D; Arashpour, M; Yang, RBC 2022),* Australia-Pakistan *(Ali B.; Zahoor H.; Aibinu A.; Nasir A.R.; Tariq A.; Imran U.; Khan R.M. 2021),* Iraq-Malaysia *(Mijwel Aljumaily H.S.; Al-Zwainy F.M.S.; Chiad Alharishawi S.S.; Ali R.H.; Hayder G. 2022), and* China-Netherlands-UK *(Wang, JP; Zhang, S; Fenn, P; Luo, XW; Liu, Y; Zhao, LL 2023),* respectively.

Table 4.2: Chronological distribution of articles within journals

Journal	Number of Articles															
	1992	1994	1998	2000	2002	2010	2013	2017	2018	2019	2020	2021	2022	2023	2024	TOTAL
Asian Journal of Civil Engineering															**1**	**1**
Automation in Construction										1		5				**6**
Buildings														1	2	**3**
Computers in industry			1													**1**
Construction Innovation-England												1				**1**
Cost Engineering (Morgantown, West Virginia)		1														**1**
Engineering Journal-Thailand									1		1					**2**
Engineering, Construction and Architectural Management															1	**1**
Expert Systems With Applications							1									**1**
International Journal of Construction Management											1				1	**2**
International Journal of Recent Technology And Engineering									1							**1**
Journal of Applied Engineering Science												1				**1**
Journal of Civil Engineering and Management							1									**1**
Journal of Construction Engineering and Management	1					1				1			1			**4**
Journal of Engineering Research (Kuwait)													1			**1**
Journal of Information Technology in Construction										1						**1**
Journal of Legal Affairs And Dispute Resolution in Engineering And Construction								1			1				3	**5**
Journal of Management in Engineering					1											**1**
KSCE Journal Of Civil Engineering												1				**1**
Lecture Notes in Civil Engineering													1			**1**
Pertanika Journal of Social Science and Humanities								1								**1**
Smart And Sustainable Built Environment											1					**1**
Wireless Communications & Mobile Computing												1				**1**
Conference Papers				1		1	1									**3**
TOTAL	**1**	**1**	**1**	**1**	**1**	**2**	**3**	**1**	**1**	**2**	**3**	**4**	**9**	**4**	**8**	**42**

4.5 Citations

As noted by Lu et al. (2015), rankings based on citations offer a historical view that reflects the significance and popularity of the current body of knowledge. The five publications with the highest citation counts presented in Table 4.3 provide intriguing insights into the impact of the research.

Table 4.3: Top five most cited publications

No	Publication Name	Author(s)	Publishing Year	Journal Name	No. of Citations
1	Blockchain in construction management: Applications, advantages and limitations	Mahmudnia, D. et al.	2022	Automation in Construction	74
2	A decentralized structure to reduce and resolve construction disputes in a hybrid blockchain network	Saygili M. et al.	2022	Automation in Construction	52
3	BIM-based claims management system: A centralized information repository for extension of time claims	Ali, B. et al.	2020	Automation in Construction	48
4	Multiagent system for construction dispute resolution (MAS-COR)	El-Adaway I.H.and Kandil A.A.	2010	Journal of Construction Engineering and Management	47
5	Improving classification accuracy of project dispute resolution using hybrid artificial intelligence and support vector machine models	Chou, JS. et al.	2013	Expert Systems with Applications	46

These publications were cited 267 times in total and 53 times per article on average. In the article with the highest number of citations on the table, with 74 citations, Mahmudnia et al.2022, presented their literature review about blockchain technology to evaluate impacts on mitigating construction disputes. Two out of these articles, with total 93 citations, deal with experimental / prototype and general insights for artificial intelligence respectively. (El-Adaway I.H.and Kandil A.A. 2010; Chou et al., 2013). In the paper published in 2020 and cited 48 times, Ali B. et al. introduced their BIM based claim management system to manage EOT claims. Lastly, the article prepared by Saygılı et al. in 2022, which ranks second on the list with 52 citations, presented a

conceptual/theoretical model to illustrate the integration of blockchain, and smart contracts as an alternative to legal procedures in construction.

4.6 Sources of Information and Main Output of the Articles

Different sources of information used in the reviewed articles were divided into four main categories: case study (ten articles), system analysis (nine articles), reviews (21 articles), and survey/interview (22 articles). The reason for the total number of articles in each category being greater than the total number of reviewed articles is that 18 of the articles utilized multiple sources of information.

As depicted in Figure 4.4, among these information sources, reviews and surveys/interviews are the leading sources. Since 2018, reviews, and surveys/interviews have shown an increasing trend. The underlying reason for this could be the ongoing openness of the subject to further research, the necessity to introduce and testing digital tools to the industry through various surveys, and the author's awareness of the importance of obtaining feedback from industry professionals for the integration of developed or to-be-developed models into construction claim management.

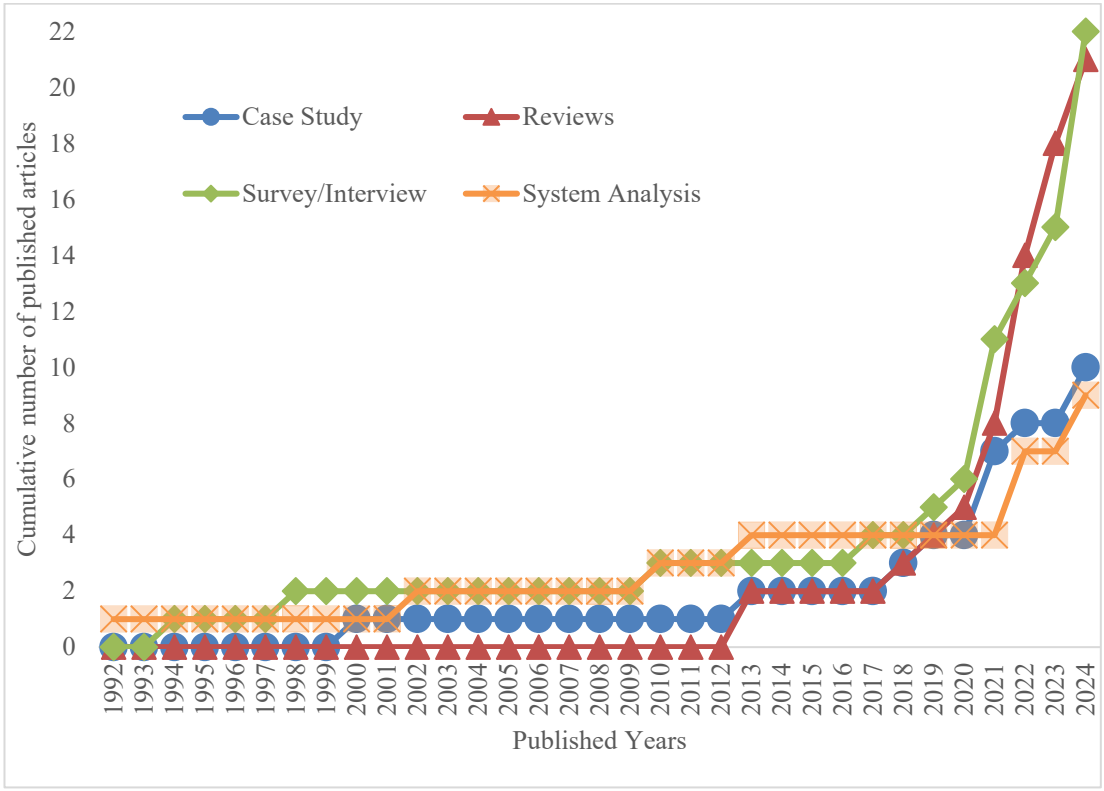

Figure 4.4: Cumulative number of articles by source of information

The main output of the reviewed articles was categorized into four groups: conceptual/theoretical model (11 articles), experimental / prototype model (17 articles), general insights (ten articles) and statistical results (four articles). As seen in Figure 4.5, the experimental prototype models predominate as research outputs. This indicates that approximately three decades of research on the subject have laid the groundwork for the development of these prototypes.

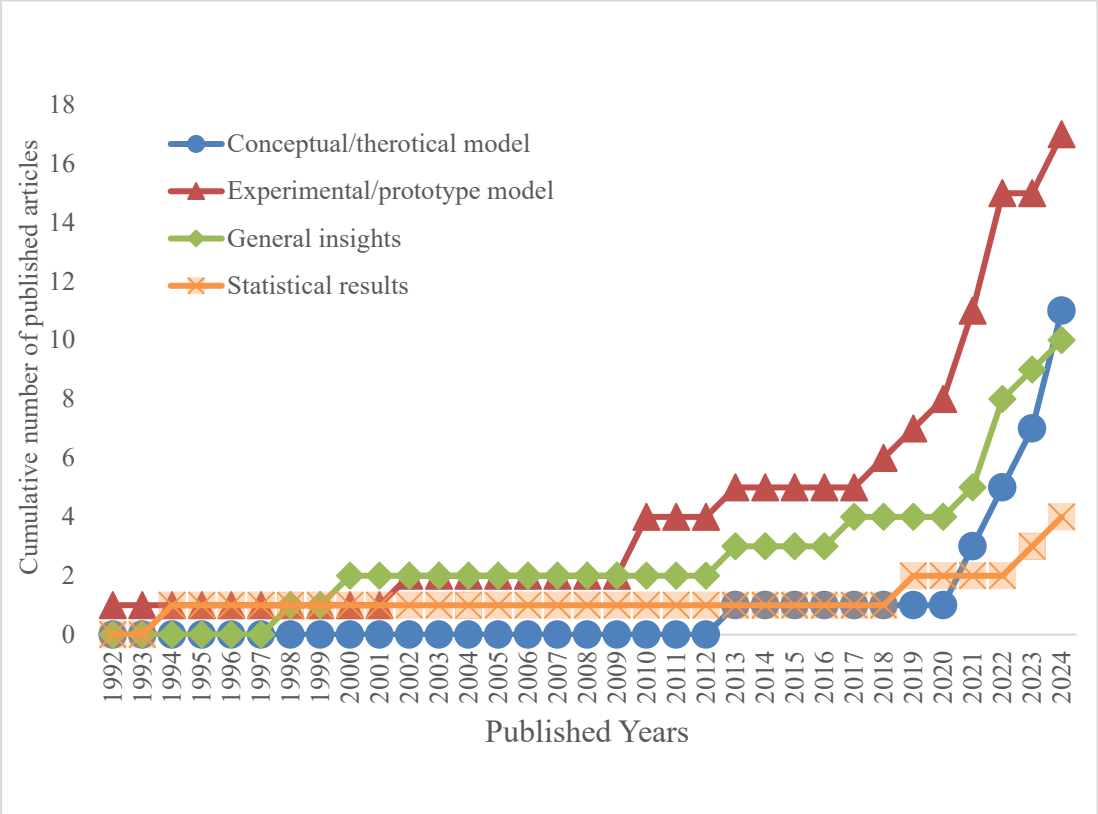

Figure 4.5: Cumulative number of articles by research output

A relationship can be observed between the source of information and the output of the article. Most of the experimental/prototype models, are based on surveys/interviews, reviews and case studies (79 percent) rather than system analysis. Also, statistical results are primarily based on survey/interviews (80 percent), while reviews and surveys/interviews (80 percent) tend to provide general insights on the subject.

4.7 State of the Art

In this section, the studies have been categorized according to the research outputs as mentioned in the previous section, and closely examined under these headings. By

highlighting the purpose and shortcomings of the studies, attention is drawn to the areas that need improvement to shed light on the current state and future research in the digitalization of construction claim management with classifying the contribution of an article into (1) Exploratory studies on current practice, (2) conceptual/theoretical models, (3) experimental/prototype models.

4.7.1 Exploratory studies & general insights

Since computers began playing an active role in our lives in the 1990s, they have become an important tool in managing construction projects too. Particularly in the construction industry, as profit margins are decreasing and project complexity is increasing. The rising number and complexity of claims, which consume a significant portion of project resources, have made the digitalization of construction claims management a subject of interest for researchers.

Since technology is not static but constantly evolving, the investigation of the contribution of each newly developed digital tool to claims management has continued.

In this section, exploratory studies and general insights on this topic have been examined in four main groups according to the enabling technology, as seen in the tables below. These groups are computer-based claim/project management systems (Table 4.4), computer and digital tools (Table 4.5), BIM (Table 4.6), blockchain/smart contracts (Table 4.7), and Artificial Intelligence (Table 4.8).

In the realm of computer-based claim management systems, Vidogah and Ndekugri (1998) explored the inherent application of Information Technology (IT) tools in handling construction claims as an aspect of systems analysis aimed at creating an effective expert system. Their research revealed that, although claims are presented in the currency of significant projects, there is a lack of thorough systems designed specifically for such claims. Nevertheless, various systems have been devised to address certain facets of the claim management procedure. Their findings indicated that the primary challenge in quantifying claims often occurs in the domain of supporting evidence.

El-Ghory et al. (2019) conducted a study by receiving feedback from 43 experts in Malaysia and United Arab Emirated (UAE) to investigate the necessary features of a claim management system (CMS). In a study focused on the development of systems

for managing claims encountered in the construction sector, the inclusion of data from interviews with industry experts—86% of whom have previously dealt with an average of 30 claim cases—adds significant value to the research. Their findings confirmed the most important feature for CMS was Tracking Claim Status (99.5%), followed by Supporting All Types of Documents (96.3%), Categorizing Claim Documentation (93.0%), and Centralized Database (91.4%), with the lowest being Providing Templates for Letters and Reports (64.3%).

Finally, the expert programs facilitate dispute resolution by using alternative dispute resolution methods instead of going directly to arbitration or litigation.

Table 4.4: Summary of exploratory studies (Computer-based claim/project management systems)

Enabling Technology	Article Name	Author(s)	Publication Year	Research Focus	Limitations of Technological Systems
Computer-based claim/project management systems	A review of the Role of information technology in construction claims management	Vidogah, W Ndekugri, I	1998	Examination of current use of and the potential use of Information Technology IT tools in claims management	- Cost - Inexperience on IT - Retrieving documents
	Construction claims management system features and requirements	El-Ghrory A et al.	2019	Proposing of features required to establish construction claim management by collecting expertises' and opinion	-

In their study, *Brown and Fruchtman (2000)* and *Baram, (1994)* provided information on how digital tools such as computers, digital cameras, and digital projectors, as well as document control digital supports like ASCII (American Standard Code for Information Interchange) and HPGL (Hewlett-Packard Graphic Language), AutoCAD drawings, and outputs from Primavera software schedules, could contribute to construction claim management. *Yusuwan et al*., in their studies conducted in 2017 and 2024, aimed to improve extension of time (EOT) claims in Malaysia, while *Abdela et al. (2021)* evaluated the impact of scheduling practices on delay claims.

Table 4.5: Summary of exploratory studies (Computer and digital tools)

Enabling Technology	Article Name	Author(s)	Publication Year	Research Focus	Limitations of Technological Systems
Computer and digital tools	Integrity and credibility in construction dispute resolution: Documenting and presenting the facts	Baram, GE	1994	Demonstrate the power of technology in presenting technical material in claim management with a real-world claim case	- Interest value - Credibility - Cost
	Construction dispute solved with computer graphics	Brown, JD Fruchtman, E	2000	Provide information on how the available technologies could be used in the name of claim management under the conditions of that day	- Lack of data collection procedures requiring manual data entry to the platforms
	Reasons for the Unsuccessful Extension of Time (EoT) Claim in the Malaysian Construction Industry	Yusuwan, NM. Et al.	2017	Identifying the reasons for the unsuccessful extension of time (EoT) claims in the Malaysian construction industry	-
	Towards a Successful Extension of Time (EoT) Claim: A Consensus View of Construction Professionals via a Modified Delphi Method	Yusuwan, NM. Et al.	2021	Identifying the reasons for the unsuccessful extension of time (EoT) claims in the Malaysian construction industry	-
	Impact of Construction Scheduling Practice on Delay Claim Analysis	Abdela, SA. Et al.	2024	To evaluate the impact of construction scheduling practice on delay claim analysis	-

Table 4.6: Summary of exploratory studies (BIM)

Enabling Technology	Article Name	Author(s)	Publication Year	Research Focus	Limitations of Technological Systems
BIM	Closing the information gaps: a systematic review of research on delay and disruption claims	Ali B. et al	2022	Review and synthesize the contributions of previous research undertaken in delay and disruption claims and propose future directions for improving the process of this area.	-Collection, storage and access of information - Transparency and uniformity in required information for delay and disruption claims
	Investigating the Source of Claims with the Importance of BIM Application on Reducing Construction Disputable Claims in KSA	Abougamil, RA. et al.	2023	Investigate the origins of construction disputes in Kingdom of Saudi Arabia (KSA) and emphasize the significance of employing Building Information Modeling (BIM) applications to diminish the factors causing claims in both commercial and residential construction projects	-No evidence of applications or case studies in infrastructure projects

Ali et al. (2022) have stated that delays and disruptions in construction projects lead to significant cost overruns. Based on the results of past statistical research, it has been noted that 90% of construction projects worldwide encounter delays and disruptions (Flyvbjerg, 2009), and construction contracts can be used to compensate for these overruns using delay and disruption claims. Authors, conducted a bibliographic study to thoroughly examine delay and disruption claims and pinpoint areas requiring further research. They found that there has been a lack of action-oriented research and active involvement of end-users in formulating solutions for these claims. In their study, for the digitalization of delay and disruptions claim management, necessary technologies

were categorized into two groups for the collection, storage, and access of information. The first group includes BIM, radio frequency identifiers (RFIDs), drone technology and cameras, and blockchain, while the second group comprises big data analytics and machine learning (ML). Their findings suggest that establishing a system integrating these suggested technologies would alleviate the challenges in managing pertinent information for delay and disruption claims. Furthermore, it would enhance transparency and consensus regarding the information utilized for these claims. This system would assist in avoiding, mitigating, and resolving disputes, along with their unnecessary related expenses due to such claims. The authors have offered valuable insights that can facilitate the development of experimental models and plugins aimed at addressing delay and disruption claims moving forward.

Abougamil et al. (2023), in their study, investigated the importance of using Building Information Modeling (BIM) to reduce the factors leading to claims in the construction sector of the Kingdom of Saudi Arabia. They observed that, although it constitutes a major sector in the Middle East with yearly expenditures surpassing $120 billion, this industry encounters multiple obstacles, such as a lack of skilled workforce, increasing expenses, conflicts, and shortages of materials. Their research examines 50 factors contributing to the reasons behind claims, alongside conducting a field survey interview session with 35 participants from the KSA construction sector. The results uncover seven key origins that lead to construction claims in the KSA, affecting 75 projects. Among these primary seven causes, variation orders and delay-related claims lead with importance indices of 36% and 35%, respectively. The other causes, in order, include payment delays (29%), coordination issues and design error claims (27%), lack of decisions from the owner and consultant, and contract ambiguities (23%). The authors emphasize that the implementation of BIM can help reduce claims in construction projects by facilitating the design process, lowering costs, improving allocation and communication among stakeholders, easily identifying changes to reduce variation orders, and offering better project visualization. A limiting factor of the research is that it only examined the causes of claims in commercial and residential construction projects. This does not provide insights into the applicability of BIM in infrastructure or industrial construction projects, leaving this area as a topic for further research.

Regarding blockchain technologies and smart contracts, Msawil et al. (2022) found that BCT can be centered on two functions in construction contract administration: financial management and document/record management. In their study focusing on blockchain technologies to mitigate disputes in construction projects, Mahmudina et al. (2022), explored the three primary issues that conflicts are rooted in: payment, documentation, and interaction. By implementing blockchain solutions, the study likely proposed ways to improve transparency, traceability, and automation around payments, document management, and information sharing among project stakeholders. This could help prevent or more effectively resolve disputes stemming from these three key areas. Nalioglu et al. (2023) investigated possible impacts of smart contracts and their findings show that smart contracts may have considerable benefits in the claim management process including, record integrity, elimination of unnecessary bureaucracy, reliability of documents, reduction of transaction costs, and enhancing transparency.

Table 4.7: Summary of exploratory studies (Blockchain / Smart Contracts)

Enabling Technology	Article Name	Author(s)	Publication Year	Research Focus	Limitations of Technological Systems
Blockchain / Smart Contracts	A Systematic evaluation of blockchain-enabled contract administration in construction projects	Msawil M et al.	2022	Addressing the possible contributions of blockchain to improving CCA (Construction Contract Administration) and specific challenges to its adoption in CCA.	- Lack of prototypes
	Blockchain in construction management: Applications, advantages and limitations	Mahmudnia, D	2022	Reviewing BCT characteristics to evaluate impacts on mitigating disputes.	-Lack of professional training - Lack of regulatory clarity - Lack of trust
	Possible Impacts of Smart Contracts on Construction Claim Management	Nalioglu V et al.	2023	Analyze the possible effects of smart contracts on construction claim management	- Security risks

Chou et al. (2013)'s study showcases that a suitable integration of AI for projects dispute resolutions can notably enhance classification testing efficiency, despite the hybrid model being potentially more complex and time-intensive than alternative systems. In relation to the cross-fold accuracy with test data, the top hybrid model emerged from merging an fmGA, FL, and SVMs.

In 2024, *Hasan et al.*'s analysis via machine learning techniques shows that delay claims significantly influence construction project performance efficiency. According to Hasan et al., construction companies should focus on creating thorough change management strategies, including precise documentation, communication with stakeholders, impact assessments, and organized approval procedures.

Table 4.8: Summary of exploratory studies (Artficial Intelligence)

Enabling Technology	Article Name	Author(s)	Publication Year	Research Focus
Artificial Intelligence	Improving classification accuracy of project dispute resolution using hybrid artificial intelligence and support vector machine models	Chou, JS. Et al.	2013	Assessing the efficacy of hybrid AI techniques in classifying project dispute resolutions
	Assessing the impact of claims on construction project performance using machine learning techniques	Hasan H.M. et al.	2024	Assessing via machine learning techniques the impact of claims on construction project performance and evaluate the effectiveness of change management strategies

4.7.2 Conceptual/theoretical models

In this section, the conceptual/theoretical models proposed by researchers are examined, considering how digital technologies can be utilized in claim management as discussed in exploratory studies. These models are summarized in three grups. These groups are BIM (Table 4.9), Blockchain (Table 4.10), and Artificial Intelligence (Table 4.11).

BIM's widespread adoption in construction projects since the 2010s, particularly for its capabilities in visualization (e.g. for variation order claims), its ability to integrate project schedule and budget data (e.g. for financial or delay claims), and its emergence as a highly relevant topic for the digitalization of claim management.

Askari et al. (2013), noted that the time-consuming and requires effort nature of construction delay claims may lead to disputes among project stakeholders. Their study aims to investigate various methods used in construction delay analysis and propose a methodological approach to integrate them with the Building Information Model (BIM).

The study proposes a methodological approach for integrating the delay analysis methods with the Building Information Model (BIM) by designing an artifact to address these limitations, particularly the associated time and cost of delay analysis, and facilitates accurate delay analysis using state-of-the-art technology in the construction industry. Authors, to solve delay analysis problems using state-of-the-art technology, use design-science research methodology in combination with multi-case study. After conducting a literature review and evaluating the performance of all existing delay analysis methods, they developed the conceptual framework presented in Figure 4.6.

According to Figure 4.6, the proposed framework integrates the BIM with the scheduling software that can access the project database and perform the analysis using the project database. The delay analysis utilizes different methods taking into consideration related assumptions. (Askari et al., 2013)

Table 4.9: Summary of conceptual/theoretical studies (BIM)

Enabling Technology	Article Name	Author(s)	Publication Year	Limitations of Technological Systems	Type of Conflict	The use of 4D/ 5D Visualization
BIM	Improving construction claim management using building information model (BIM)	Askari A.S. et al.	2013	-limitations associated with CPM	Delays	4D
	A conceptual framework for developing a BIM-enabled claim management system	Shahhosseini, V. and Hajarolasvadi, H.	2021	- Difficulty in integrating BIM-based systems in traditional project delivery methods with a fragmented nature - Customization issues	No specific claim	-
	Adopting BIM to Facilitate Dispute Management in the Construction Industry: A Conceptual Framework Development	Wang, JP et al.	2023	-The absence of a real-world-related source of information (e.g., case study, questionnaire survey, and interview) to verify the proposed model.	-Design errors -Delays -Change orders	-5D
	BIM-Enabled Claims Management Concept: Implications for Dispute Avoidance and Management	Giwa F. et al.	2024	- The sector's resistance to change, - Lack of standardization, - The need for continuous upskilling	No specific claim	-
	An Investigation of BIM Advantages in Analysing Claims Procedures Related to the Extension of Time and Money in the KSA Construction Industry	Abougamil R.A et al.	2024	- The model only for projects in KSA. -Real-world testing	No specific claim	-5D

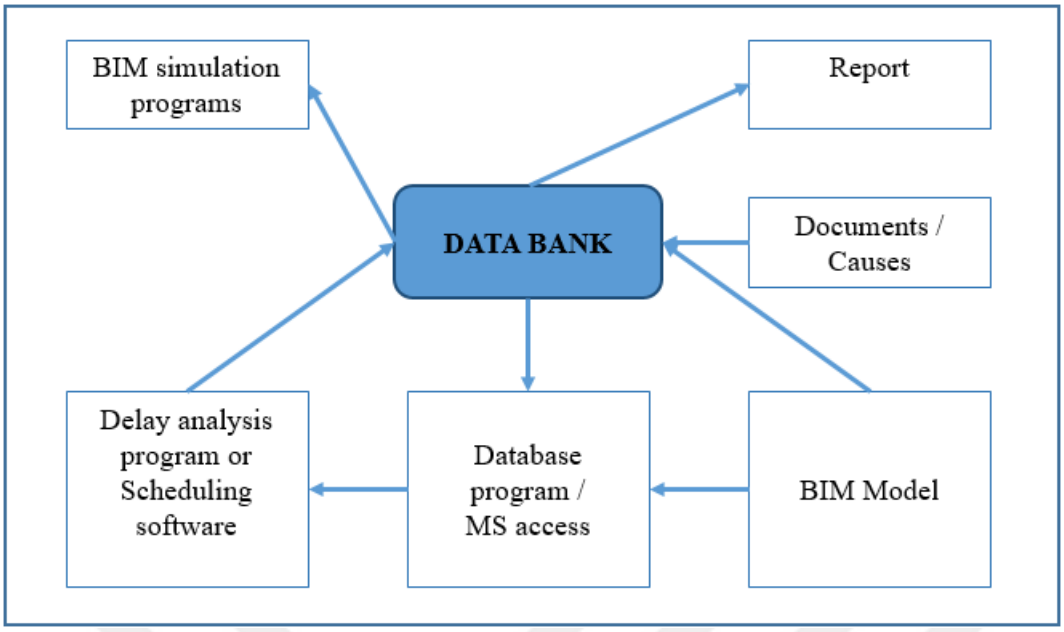

Figure 4.6: Conceptual framework (Askari et al., 2013)

In this model, the data bank synchronized with every design modification or project update in the BIM model meticulously reports whether there is a delay in the current state of the project. This output serves as a document for the project team preparing a claim, clearly indicating the cause of the delay and identifying the responsible party (liability). By taking the necessary precautions depending on the outputs of this model, delays and resulting compensation claims may be prevented or reduced.

Shahhosseini et al. (2021), in their literature review part of the study, concluded that nearly all reported knowledge-based expert systems are either not comprehensive or struggle to provide the necessary information by system effectively. They indicated that, as per the available literature, the primary challenge with current claims management practices lies in delivering data and substantiating claims. To tackle this concern, they suggested a framework for creating a BIM-based claims management system. They outlined a structure for generating computable rules and implementing them over BIM. To enhance BIM's performance in rule-verification applications, they introduced a Communication Management Subsystem (CMS) to gather valuable data from project documents such as change orders, daily project progress reports, financial statements, or submittals. They defined resulting BIM as a new dimension of BIM (nD BIM), a “contract model”. In summary, in the first stage, the user, entering a claim into the system, provides inputs related to time, cost, performance, and technical data. The core of the system, referred to as the system’s heart, is pre-loaded with project-related

documents such as the contract, addendum, general and private conditions, and other governing documents. The system's rules (e.g. "The project should be finished within the planned budget. The contractor will be liable to earn/pay 30% of cost deviations.") are generated using MATLAB. Ultimately, the system checks the user's input data against these computable rules and generates reports in Excel format. This article stands out among other conceptual model studies proposed by researchers due to its detailed information provided about system features through a well-presented case study with a simplified approach. With its holistic features, the system can be used as a tool to monitor a project's planned and actual data, which may help to prevent critical situations related to the project by notifying the responsible party. By doing so, it can aid in resolving potential claims before they arise, thereby helping to avoid unwanted disputes.

The most significant feature of *Wang et al. (2023)'s* study is that it highlights how other researchers have demonstrated the benefits of BIM in addressing specific claim issues (such as change orders or delays) and presents a framework that aligns the major claim causes encountered throughout the project lifecycle with the key benefits of adopting BIM in construction projects. The proposed framework underscores the importance of BIM integration in claim management, potentially encouraging both the industry and researchers to focus on and contribute to this area through further studies and developments.

Following their initial exploratory study in 2023, Abougamil et al. presented a conceptual model in 2024 as a continuation of their research. This research sought to examine claim management processes within conventional methods and contrast them with a suggested BIM solution as a potential remedy to alleviate construction conflicts. The study's aim centers on minimizing the duration spent analyzing claims concerning the precision of claims amounts.

Kim et al. (2022) developed a model capable of producing, transmitting, and aligning blocks triggered by email exchanges whenever an event arises. It offers features such as document acquisition, historical tracking, automatic extraction of relevant documents, and authenticity verification for document management in the preparation of claims or disputes. Saygılı et al.'s framework developed in 2022, DCENTR (Decentralized Construction Enabling Transparent Resolution) promotes punctual and direct transactions, while JUS-DCENTR's justice-focused voting system allows for

clear, rapid, and cost-effective conflict resolution. The construction-oriented hybrid blockchain network stands out as the key feature of the tool, as it enables the evaluation of dispute scenarios by individuals knowledgeable in construction processes. Gupta et al. in 2024, a comprehensive blockchain-oriented conceptual model suggested based on their literature review results.

Table 4.10: Summary conceptual/theoretical (Blockchain / Smart Contracts)

Enabling Technology	Article Name	Author(s)	Publication Year	Limitations of Technological Systems
Blockchain / Smart Contracts	Blockchain-Based Automatic Tracking and Extracting Construction Document for Claim and Dispute Support	Kim, EW. Et al.	2022	-Long term-Data storage and management of past projects to reuse the records -The system needs a control manager -The chaincode has only been developed and utilized for PDF format attachment that extracts text data, not for CAD filer or BIM models.
	A decentralized structure to reduce and resolve construction disputes in a hybrid blockchain network	Saygılı M. et al.	2022	-Every user in the network can keep track of payments, transparency issues. - Sybil attacks, - Lack of legal validation, and – -Construction industry culture.
	Integration of blockchain in contract management for prevention of construction disputes: a systematic literature review and conceptual framework	Gupta P. and Jha K.N.	2024	-The model requires validation through exposure to a real-life project or a proof-of-concept.

All three models developed using artificial intelligence aimed to make predictions by employing machine learning techniques. Ayhan et al. (2021) focused on predicting the occurrence of disputes by utilizing machine learning (ML) techniques on empirical data, while in 2023, their study aimed to predict the associated compensations in construction disputes. The study of Un 2024's findings emphasizes the model's strength and real-world relevance in predicting the results of construction disputes.The majority of the used variables effective in predicting the outcome of the disputes are also significant for this model.

Table 4.11: Summary of conceptual/theoretical studies (Artificial Intelligence)

Enabling Technology	Article Name	Author(s)	Publication Year	Limitations of Technological Systems	Type of Conflict
Artificial Intelligence	Predicting the Occurrence of Construction Disputes Using Machine Learning Techniques	Ayhan M. et al.	2021	-	contract related issues
	Disputes Using Machine Learning Techniques Classifying Compensations in Construction	Ayhan M. et al.	2023	-The extent of experimented ML techniques was limited.	changes - delays - financial
	Forecasting the outcomes of construction contract disputes using machine learning techniques	Un B. et al.	2024	-Use of limited sample size and hybrid classification techniques	no specific issue

4.7.3 Experimental/prototype models

In this section, the prototype models proposed by researchers to improve the efficiency of claim management through the use of digital tools will be examined. Tables, which summarize the studies, categorize these prototypes based on the digital technologies utilized. These are computer and other digital tools, systems (Table 4.12), BIM (Table 4.13), and Artificial Intelligence (Table 4.14).

The prototype introduced by *Diekmann and Kim in 1992*, *SuperChange*, is one of the pioneering tools in the digitalization of construction claim management. This expert system is designed to assess the legitimacy of a claim, inform the user about the legal concepts at play, and record the details and rationale concerning the claim. The system, in addition to generating extensive documentation related to the facts of the claim case and the analyzing engineer's thoughts and judgments, serves as an alternative dispute resolution tool by highlighting the key issues in disagreement after both stakeholders upload their answers to posed questions by the system.

Tsai et al. (2013), introduced a method, information flow analysis, to illustrate the essential efforts required when scheduling analysts create computer-assisted schedule delay analysis techniques. They asserted that, after the introduction of the proposed method, a validated case study revealed that the delay responsibility for project owners and contractors was determined promptly and distinctly. This may assist industry professionals in managing delay-related claims. *Fan (2022)*, like Tsai et al. (2013), has worked towards facilitating delay analysis and proposed an algorithm aimed at streamlining the submission of Extension of Time (EOT) claims. The author noted that, due to the existence of the soft logic delay analysis technique, which allows for activities to be executed in various orders, and the contractor's obligation to mitigate delays, the logic must be updated to accurately calculate the Extension of Time (EoT). The presence of soft logic in a schedule makes manual updates time-consuming and prone to errors. The algorithm proposed addresses this issue by automatically updating the schedule based on delay events project-wise.

Seo et al. (2022), identified productivity loss as a significant claim in construction projects and introduced an add-on they developed for *Primavera P6* that automatically calculates the cost impact of productivity loss. They declared that this tool assists professionals in systematically arranging information from the field instantaneously, ultimately aiding them in efficiently handling claims. The study stands out for presenting a tool specifically for cost-related claim management, a topic that has been relatively less emphasized in other proposed models. Moreover, the applicability of the tool being validated through a case study and interviews with industry experts makes the study more compelling.

M. Asem U. Abdul-Malak et al. introduced CLAIMS MANAGER 2000, a computer-based claim management system, in their 2002 publication. The process model aims to guide the party claiming the process by providing relevant information, explanations, and sample court decisions, while also offering constructive criticism. The model stands out by assisting both project owners, who need to track and manage claims submitted by contractors comprehensively, and contractors, who must prepare documentation under contract conditions to successfully support their claims.

Table 4.12: Summary of experimental / prototype models (Computer based systems and digital tools)

Enabling Technology	Article Name	Author(s)	Publication Year	Limitations of Technological Systems	Type of Claim
Computer based systems and digital tools	SuperChange: Expert system for analysis of change claims	Diekmann J.E. and Kim M.P.	1992	-Lack of sufficient trials	-No specific claim
	Developing Computer-Based Schedule Delay Analysis Methods Based on Information Flow Analysis: A Case Study	Tsai M.K. et al.	2013	-	-Delays
	Soft logic delay analysis technique	Fan S.L.	2022	-BIM integration	-Delays
	Calculating the cost impact in loss of productivity claims	Seo W. et al.	2022	-Necessity of real-time data entry	-Productivity issues
	Process Model for Administrating Construction Claims	M. Asem U. Abdul-Malak et al.	2002		-Differing site conditions -Variation orders -Defective specifications

When the prototypes were examined, it was found that eight out of the seventeen models used BIM as their digital technology. In the previous section, considering that the group with the highest number of conceptual models is BIM theme, it is not surprising that BIM emerged as the most studied digital category (47%) among the prototype models as well. A noteworthy point is that 63% of these studies focus on managing delay claims. The predominant presentation of models aimed at utilizing the 4D level of BIM in construction claim management may reflect that integrating other claim issues such as finance or contracts into BIM is more challenging compared to integration of issues about projects' schedules or delays.

The proposed *BIM-Integrated System for Evaluating the Impacts of Construction Change Orders (BIM-ISICO)* by *Handayani et al. (2019)*, aimed at creating a full

package that provides complete evidence to support change order claims, was developed through the integration of various BIM-enabled tools, including *Autodesk Revit, Dynamo, Microsoft Excel, and Visual Basic for Applications (VBA)*. The system assesses three key effects of change orders in construction projects: budget, physical conditions, and timeline. For a specific construction change order, the system automatically identifies the modified building components, including material, location, and quantity. While the system conducts delay analyses and cost assessments to evaluate the implications of the change order, BIM showcases the findings through color-coded 3D representations. They also applied their system to demonstrate its efficiency and practicality to an actual 18-story building project to analyze the impact of a construction change order. They stated that the results can mitigate the conflicts between the project owner and the contractor about the construction claims resulting from change orders. Another noteworthy feature of this study is the performance of the system is not only illustrated through its application to an actual building project but it was also evaluated by a group of experts.

Ali et al. (2020), highlighted that in traditional claim management systems, Extension of Time (EOT) claims often lead to disputes among stakeholders, emphasizing the need to transition these traditional systems into a digital environment. To manage EOT claims more effectively, they designed a plug-in for Autodesk Revit utilizing an application programming interface (API) to establish a BIM-Based Claims Management System (BIM-CMS). The evaluation of the developed plug-in, conducted through questionnaires and semi-structured interviews with sector experts, makes the model more realistic. In 2021, Ali B. et al. presented their BIM plug-in name of *BIM-CDR (BIM Based Construction Delays Recorder).* BIM-CDR serves as a consolidated repository, capturing comprehensive details associated with delays, which can be accessed and visualized to evaluate their influence on delay claims. To gauge the effectiveness of BIM-CDR, a feasibility study is undertaken with the review panel of experts. The findings indicated that BIM-CDR can document extensive information related to all the critical issues leading to delays on construction sites, facilitating the efficient management of their respective claims.

Based on their previous research, *Guévremont and Hammad (2021),* noted that evaluating the specifics of delay claims and visualizing, including their impacts and causes, as well as assigning liability, is a challenging task for lawyers, legal experts,

and judges. They suggested that 4D simulation could be a valuable tool in managing and preventing delayed claims. Unlike other models proposed for managing delay claims their model, *Claim4D-Onto*, integrates BIM, 4D simulation, and the analysis of delay effects and causes. Furthermore, the authors have included a case study to demonstrate the benefits of the proposed model, showcasing its potential to facilitate faster and more equitable resolution of construction delay claims.

Jalal et al. (2021), based on their literature review, summarized the reasons for the inefficiency of current claim management practices in construction projects into three main points. Initially, a substantial volume of data storage and processing needs (Zhang and Hu, 2011), followed by the analysis and presentation of data collection (Chou and Yang, 2017); (Abdul-Malak and Abdulhai, 2017), and finally, the absence of an effective document management system, a team to supervise the entire process, along with the departure of essential personnel.

In addition, they pointed out that the existing claim and dispute management methods are outdated, fail to meet the industry's needs, and are time-consuming and exhausting. To address these gaps, they proposed a model that integrates design and construction and program coordination. They stated that their model must be capable of collecting, storing, and retrieving extensive building data. They also anticipated that this system would yield more precise estimates of the claimed expense or time, more rational risk evaluations, detection of clash, and the prompt identification and rectification of omissions and errors. Jalal et al. explained a claim as a "hard claim" if it can be linked to one or more components within the 3D model and can be visualized, for example, claims arising from errors or omissions in the design or specifications.

In 2022, *Mijwel Aljumaily et al.* reviewed the model proposed by *Ali et al. in 2020* and concluded that it could offer solutions to problems encountered in construction projects conducted in the Republic of Iraq. They suggested that the model could become more accurate and comprehensive if gaps related to insufficient BIM knowledge, cost, safety concerns, and contract limitations were addressed.

Following their conceptual model study in 2023, Abougamil et al. presented an experimental model in 2024 as a continuation of their research. The model presents the BIM Package as a viable approach for minimizing construction claims within the KSA construction sector. This package encompasses the application of Revit

Architectural in 3D perspectives to develop detailed 3D models. Moreover, it integrates MS Project in 4D dimensions for effective project scheduling and employs Cost-X in 5D dimensions to generate accurate cost assessments.

Table 4.13: Summary of experimental / prototype models (BIM)

Enabling Technology	Article Name	Author(s)	Publication Year	Limitations of Technological Systems	Type of Claim
BIM	Using BIM to Identify Claims Early in the Construction Industry: Case Study	Marzouk M. et al.	2018	-	Delays
	A Building Information Modeling (BIM)-Integrated System for Evaluating the Impact of Change Orders	Handayani, T.N. et al.	2019	-Necessity of costly powerful computer hardware and software -Challenging using for projects that are not on 4D or 5D BIM platforms	Change orders
	BIM-based claims management system: A centralized information repository for EOT claims	Ali, B. et al.	2020	- Lack of BIM knowledge - Cost - Reluctance for innovation in traditional construction practices - Contract limitation	-Delays
	A BIM-based construction claim management model for early identification and visualization of claims	Jalal, MP et al.	2021	-The limited range of claim issues that can be resolved with the model. -The model is valid only for the construction phase	-Hard claims
	Ontology for Linking Delay Claims with 4D Simulation to Analyze Effects-Causes and Responsibilities	Guévremont, M. and Hammad, A.	2021	-	-Delays

Table 4.13 (continued): Summary of experimental / prototype models (BIM)

Enabling Technology	Article Name	Author(s)	Publication Year	Limitations of Technological Systems	Type of Claim
	BIM Aided Information and Visualization Repository for Managing Construction Delay Claims	Ali, B. et al.	2021	-Lack of experimental exercise with employees in sector -Lack of BIM education of construction practitioners, -Cost and training involved in its implementation, -limitation of contract clauses.	-Delays
	Adopting Building Information Modeling in Claims Management in Construction Industry	Mijwel Aljumaily H.S et al.	2022	- Lack of BIM knowledge -Fragmented nature of the construction industry -Security -The imitation of contracts	-Delays
	A BIM Package with a NEC4 Contract Option to Mitigate Construction Disputes in the Kingdom of Saudi Arabia	Abougamil R.A et al.	2024	- The model only for projects in KSA.	-EoT

The model presented by *Wang in 2010*, specifically designed for hydraulic construction projects, is distinguished as the only study among all the reviewed articles that focuses on a specific project type. This construction claim decision support system is designed based on rule-based reasoning (RBR) and case-based reasoning (CBR) in artificial intelligence—which is considered a relatively newer application for construction claim management compared to other digital technologies—. The model is designed to assist users in hydraulic engineering to accomplish intricate claims by leveraging the expertise and insights of claims specialists.

According to *El-Adaway and Kandil (2010)*, who, like Wang (2010), worked on improving the management of change order claims with artificial intelligence, the time and associated costs spent by lawyers, contract administrators, and claims consultants in reviewing precedent cases to identify similarities and differences is a significant

problem. To solve this problem, they created a multiagent system for construction dispute resolution (MAS-COR), which generates legal arguments based on precedent cases. The authors found that, when they tested their developed system with 30 previously concluded arbitration cases, it demonstrated a satisfactory alignment with the reported actual decisions. This system may assist stakeholders in gaining insights into a claim based on a change order in a construction project, potentially helping them avoid the need for arbitration.

Table 4.14: Summary of experimental / prototype models (Artificial Intelligence)

Enabling Technology	Article Name	Author(s)	Publication Year	Limitations of Technological Systems	Type of Claim
Artificial Intelligence	Study of claim support system for hydraulic engineering based on CBR and RBR	Wang W.	2010	-	-Change orders
	Multiagent system for construction dispute resolution (MAS-COR)	El-Adaway I.H. and Kandil A.A.	2010	-	-Change orders
	Construction Project Claim Management under the Background of Wireless Communication and Artificial Intelligence	Li Y.	2022	-Lack of case study	-No specific claim
	Predicting the Outcome of Construction Change Disputes Using Machine-Learning Algorithms	Alqaisi A.S. et al.	2024	-	-Change orders

In her 2022 study, *Li* introduced a claim management system developed by utilizing wireless communication and artificial intelligence technologies. This system is designed comprehensively, incorporating modules for claim process tracking, analyzing relevant issues to determine the responsible party, managing claim

documents, calculating the cost of the claims, and storing situations subject to claims. Additionally, based on the 476 valid survey responses he obtained, Li ranked the key success factors according to their importance, the most rated factor was complete project data preservation, which could lead to claims and demonstrated that his system works positively and efficiently in addressing these factors. This evaluation may serve as significant proof of the system's applicability in the industry, demonstrating its potential for practical use.

Alqaisi et al. 2024 explored disputes arising from change orders by compiling a list of legal elements that influenced court decisions in previously related cases, aiming to assess the probability of a potential outcome for an upcoming claim and they developed a model for change order-related disputes by examining the legal grounds utilized by jurists in earlier legal proceedings. In this study, various machine learning algorithms were implemented and assessed to identify the most effective conforming model. These algorithms were: *decision tree (DT); random forest (RF); neural network (NN), and support vector machine (SVM)*. These algorithms were reviewed using a confusion matrix based on their accuracy, precision, recall, and sensitivity. The research concluded that the *random forest algorithm* provided the best overall results, achieving a prediction accuracy of 95.0%. Alqaisi et al. in this study, examined a total of 90 construction-related cases, sourced from online platforms Westlaw and Lexis Nexis. These cases were lodged in Illinois, Indiana, and Wisconsin between 2002 and 2022. Out of these cases, 40 pertained to disputes regarding change orders, leading to 60 distinct judgments on change orders. *Python programming language* is utilized to create machine learning models. The model formulated in this analysis could be useful for disputing stakeholders to assess and determine whether to pursue a claim or settle privately, thereby enabling more effective resolution of disputes in construction negotiations.

4.8 Research Road Map

The investigation of applications and plug-ins developed so far, along with studies exploring the integration of each new technological tool into claim management, serves as concrete evidence that claim management in the construction industry is actively keeping pace with technological advancements. In conclusion, industry experts and researchers have aimed to adopt these technologies to improve existing

practices and achieve more effective and yielding claim management processes in various applications within the sector. Despite the novelty of the subject, it has been observed that researchers have developed several promising models and plug-ins as a result of nearly three decades of work. Although research in this area has become more widespread, it has been observed that efforts have branched out where research is fragmented and disorganized. While valuable theoretical solutions have been proposed to address the challenges in claim management, researchers have often introduced new and open-ended ideas rather than building on previous work with solution-focused approaches. Consequently, the models developed remain behind in terms of market introduction, gathering feedback from industry experts for improvement, testing, application in real projects, and solving identified limitations. This lag can be attributed both to the fact that the digitalization of claim management is relatively new compared to other fields of project management, and the absence of a clear roadmap for future research endeavours. It is hoped that, with this thesis, the gap in the literature regarding a roadmap will be addressed.

Upon reviewing all studies, another striking and common finding is that, except for only one model, all proposed models have been developed for superstructure projects. Given that a significant portion of projects undertaken worldwide, particularly in developing countries, focuses on infrastructure, there is a pressing need for research on the digitalization of claim management in these types of projects. This need can be addressed either by improving existing models or by developing new models tailored to the specific types of projects. Thus, the digitalization of claim management will be positioned to appeal to the industry at large, facilitating the adoption of these technologies across the sector.

The digital technologies examined throughout this study have been categorized and evaluated under subheadings below.

4.8.1 Computer-based systems, and digital tools

From the initial studies to the present, researchers have aimed to demonstrate the power of computers and other digital tools in construction claim management and have advocated for moving away from traditional claim management methods. These studies are shown in the research domain map in Figure 4.7. Researchers, primarily

seeking solutions to claim issues such as delays, productivity, and changes, have theorized how these tools could be used to address such challenges.

As exploratory studies, Brown and Fruchtman (2000) and Baram, (1994), with similar research interest, provided information on how digital tools such as computers, digital cameras, and digital projectors, could contribute to construction claim management. They stated that document control digital supports like ASCII (American Standard Code for Information Interchange) and HPGL (Hewlett-Packard Graphic Language), AutoCAD drawings, and outputs from Primavera software schedules, also could contribute to construction claim management. Vidogah and Ndekugri (1998), focusing on a related area of study, investigated the unspoken application of Information Technology (IT) tools within the realm of construction claim management as part of a system analysis aimed at developing a suitable expert system. Their findings revealed that while claims are documented in the financing of major projects, there are no all-encompassing systems created specifically for these claims. Nevertheless, various systems have been established to manage certain facets of the claim management process. They discovered that the primary challenge concerning claim quantification typically arises in the realm of substantiating evidence.

Yusuwan et al., in their studies conducted in 2017 and 2024, aimed to improve extension of time (EOT) claims by determining the causes behind ineffective claim management in the Malaysian construction sector. According to them, the inadequacy of the claim documentation, weak presentation of claims, and insufficient evidence to substantiate the claims have been identified as key factors leading to their rejection. Their found results indicate that proficiency in managing claims, efficient record maintenance, and stringent compliance with the contract are essential components for a successful Extension of Time (EoT) claim.

Although there are no conceptual/theoretical model examples related to the use of computer-based expert systems or digital tools in construction claim management, there are a few experimental/prototype model studies proposed.

Diekmann & Kim and Abdul-Malak et al. sought to address a similar problem while developing their prototypes: to educate and guide the claiming party throughout the process by providing relevant information, explanations, and sample court decisions. The prototype introduced by Diekmann and Kim in 1992, SuperChange, is one of the

pioneering tools in the digitalization of construction claim management. SuperChange is, designed to assess the legitimacy of a claim, inform the user regarding the legal principles at play, and record the facts and rationale surrounding the claim. Afterwards, M. Asem U. Abdul-Malak et al. in 2002, introduced CLAIMS MANAGER 2000, a computer-based claim management system. The process model aims to guide the party claiming the process by providing relevant information, explanations, and sample court decisions; while offering constructive criticism. The model stands out by assisting both project owners, who need to track and manage claims submitted by contractors comprehensively, and contractors, who must prepare documentation under contract conditions to successfully support their claims.

Tsai et al. (2013) and Fan (2022) focused on developing prototypes aimed at the digitalization of time-related claims in construction projects. Tsai et al., in 2013, proposed a method, information flow analysis, to show the necessary work when schedule analysts develop computer-based schedule delay analysis methods. They said that, when the proposed method was provided, a validated case study demonstrated that the delay responsibility for the project contractors and owners was classified quickly and distinctly. This may assist industry professionals in managing delay-related claims. Fan, in 2022, like Tsai et al. (2013), has worked towards facilitating delay analysis and proposed an algorithm aimed at streamlining the submission of Extension of Time (EOT) claims. The author noted that, due to the existence of the soft logic delay analysis technique, which allows for activities to be executed in various orders, and the contractor's obligation to mitigate delays, the logic must be updated to accurately calculate the Extension of Time (EoT).

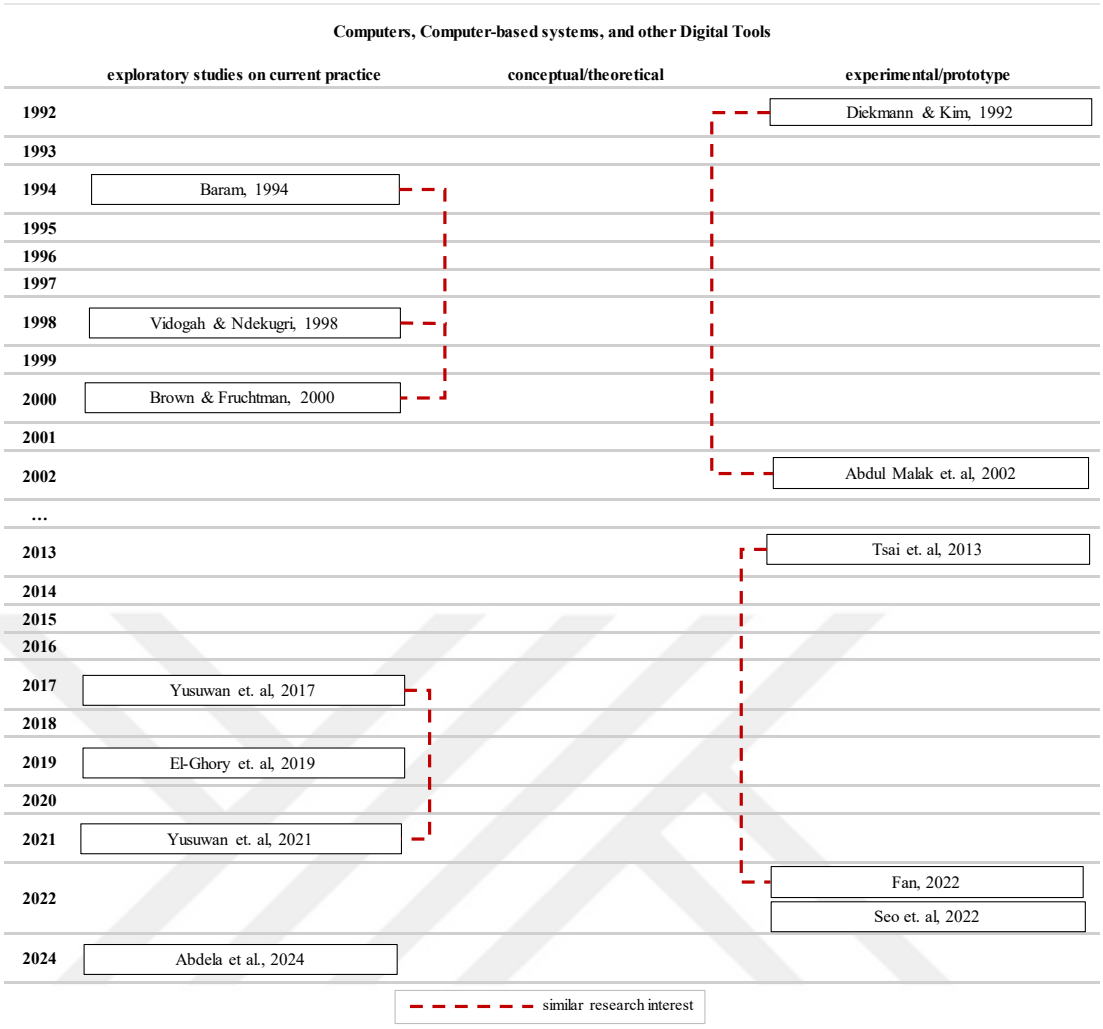

Figure 4.7: Research domain map (Computer-based systems, and digital tools)

While these studies have yielded promising results, the necessity of real-time data entry into the platforms and the lack of established data collection procedures, as well as the absence of satisfactory trial tests, remain significant limitations.

4.8.2 BIM

The models presented by researchers have predominantly focused on BIM and its plug-ins. Since the introduction of Level 3 BIM in construction projects starting in the 2010s, there has been intense interest from researchers in this topic. This attention is driven by BIM's ability to allow the entry of nearly all project-related data across various levels and the seamless integration of its features and extensions with document control systems. Such capabilities enhance project control and make the management process more streamlined and efficient. On the other hand, claim management processes are often slowed down and become more costly due to factors

such as documentation challenges, key personnel changes, a lack of experienced and specialized personnel in claim management, and the need to visualize claim-related aspects within the project. These issues frequently lead to claims being escalated to arbitration or court proceedings. Given this context, it is unsurprising that researchers have focused on developing BIM-based claim management models and BIM plug-ins to address claim issues such as extensions of time (EOT), delay analysis, and change orders. However, the lack of BIM knowledge, the difficulty in integrating BIM-based systems into traditional project delivery methods like Engineering-Procurement-Construction (EPC), and Public-Private Partnership (PPP), or Design-Bid-Build (DBB), which are inherently fragmented, the challenge of incorporating the special conditions of each contract into proposed frameworks, customization issues, as well as concerns over security and intellectual property, IP rights remain significant barriers to the adopting BIM in claim management. The research domain map related to BIM is presented in Figure 4.8.

In the context of digitalization in construction claim management, Askari et al. (2013) proposed a theoretical model aimed at resolving delay-related claims through BIM, while Ali et al. (2020) and Guévremont and Hammad (2021) developed prototypes with similar objectives.

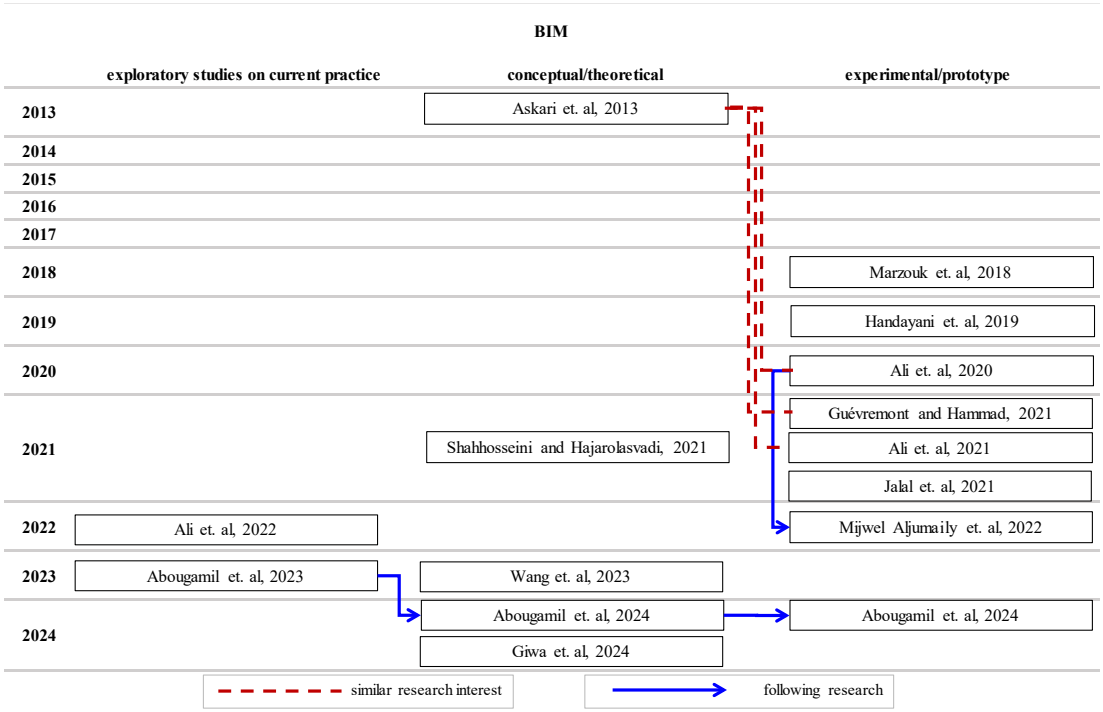

Figure 4.8: Research domain map (BIM)

Askari et al. (2013), noted that the time-consuming and requires effort nature of construction delay claims may lead to disputes among project stakeholders. Their study aims to investigate various methods used in construction delay analysis and propose a methodological approach to integrate them with the Building Information Model (BIM). The study proposes a methodological approach for integrating the delay analysis methods with the BIM by designing an artifact to address these limitations, particularly the associated time and cost of delay analysis, and facilitates accurate delay analysis using state-of-the-art technology in the construction industry. Authors, to solve delay analysis problems using state-of-the-art technology, use design-science research methodology in combination with multi-case study. After conducting a literature review and evaluating the performance of all existing delay analysis methods, they developed the conceptual framework. The proposed framework integrates the BIM with the scheduling software that can access the project database and perform the analysis using the project database. The delay analysis utilizes different methods taking into consideration related assumptions. (Askari et al., 2013) In this model, the data bank synchronized with every design modification or project update in the BIM model meticulously reports whether there is a delay in the current state of the project. This output serves as a document for the project team preparing a claim, clearly indicating the cause of the delay and identifying the responsible party (liability). By taking the necessary precautions depending on the outputs of this model, delays and resulting compensation claims may be prevented or reduced. Like Askari et al (2013), based on their previous research, *Guévremont and Hammad (2021),* noted that analyzing and visualizing the specifics of delay claims, including their impacts and causes, as well as assigning liability, is a challenging task for lawyers, legal experts, and judges. They suggested that 4D simulation could be a valuable tool in managing and preventing delayed claims. Unlike other models proposed for managing delay claims their model, *Claim4D-Onto*, integrates BIM, 4D simulation, and the analysis of delay effects and causes. Furthermore, the authors have included a case study to demonstrate the benefits of the proposed model, showcasing its potential to facilitate faster and more equitable resolution of construction delay claims. *Ali et al. (2020),* like in other two similar studies, pointed out that traditional claim management applications frequently result in disagreements among participants, underscoring the necessity to shift these traditional applications into a digital setting. To manage EOT claims more effectively, they developed a plug-in for Autodesk Revit utilizing an

application programming interface (API) to develop a BIM-Based Claims Management System (BIM-CMS). The evaluation of the developed plug-in, conducted through questionnaires and semi-structured interviews with industry experts, makes the model more realistic. In 2021, *Ali et al.,* presented their BIM plug-in: *BIM CDR (BIM-Based Construction Delay Recorder)*. BIM-CDR serves as a centralized database, containing comprehensive details about delays that can be accessed and visualized to evaluate their effects on delay claims. They performed a review panel to experts to determine the efficacy of BIM-CDR. The findings indicated that BIM-CDR can log extensive information regarding all major factors contributing to delays on construction projects, and can aid in proficiently managing their associated claims. In 2022, *Mijwel Aljumaily et al.* reviewed the model proposed by *Ali et al. in 2020* and concluded that it could offer solutions to problems encountered in construction projects conducted in the Republic of Iraq. They suggested that the model could become more accurate and comprehensive if gaps related to insufficient BIM knowledge, cost, safety concerns, and contract limitations were addressed.

Abougamil et al. (2023), in their study, investigated the importance of using Building Information Modeling (BIM) to reduce the factors leading to claims in the construction sector of the Kingdom of Saudi Arabia. Following their initial exploratory study, Abougamil et al. presented a conceptual model in 2024 as a continuation of their research. This research sought to examine claim management processes within conventional methods and contrast them with a suggested BIM solution as a potential remedy to alleviate construction conflicts. The study's aim centers on minimizing the duration spent analyzing claims concerning the precision of claims amounts. Afterward, following their conceptual model study in 2023, they presented an experimental model in 2024 as a continuation of their research. The model presents the BIM Package as a viable approach for minimizing construction claims within the KSA construction sector. This package encompasses the application of Revit Architectural in 3D perspectives to develop detailed 3D models. Moreover, it integrates MS Project in 4D dimensions for effective project scheduling and employs Cost-X in 5D dimensions to generate accurate cost assessments.

4.8.3 Blockchain and smart contracts

Although no specific experimental / prototype model has been proposed, researchers have included blockchain and smart contract technologies in their studies. Reviewed studies highlighted the potential contributions of these tools to the management of specifically financial claims and the challenges related to their adaptation in projects. Fundamental limitations such as the lack of prototypes, insufficient professional training, and security-related risks continue to be relevant for the models that underpin these digital tools. Figure 4.9 shows the research domain map for blockchain and smart contracts.

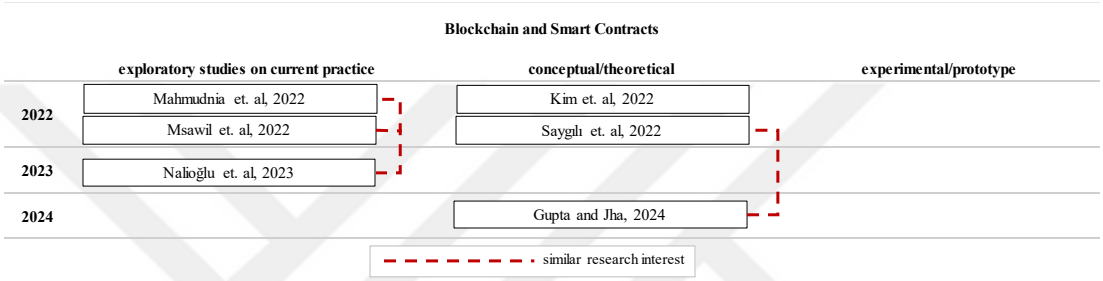

Figure 4.9: Research domain map (Blockchain and smart contracts)

Few articles have reviewed the potential of 'Blockchain' to resolve conflicts in the construction sector. The investigation by Msawil et al. (2022) explored the inquiry regarding the potential contributions of blockchain toward enhancing CCA and identified the distinct obstacles to its integration in CCA. They observed that the majority of applications were predominantly focused on two functionalities of CCA: management of projects' finance and management of documents and records. Furthermore, they highlighted that aspects of CCA involving intricate contractual mechanisms, such as claims and dispute resolution management, have been largely overlooked. To promote the application of blockchain in CCA, they proposed a framework outlining significant challenges associated with technology, processes, policies, and societal aspects for subsequent study. Mahmudina et al. (2022) concentrated on assessing the characteristics of BCT to determine its effects on alleviating disputes. They concluded that for the successful application of blockchain technology (BCT) in diminishing construction disputes, several unresolved issues must be tackled: cultivating a comprehensive understanding of blockchain to prevent encountering larger risks and conflicts and addressing uncertainties to bolster the

effectiveness of BCT in reducing construction disputes. Nalioglu et al. (2023) investigated the possible impacts of smart contracts and their findings indicate that smart contracts could offer significant advantages in the management of the claim process, such as maintaining record authenticity, removing extraneous red tape, ensuring document dependability, increasing transparency, and decreasing transaction expenses. With a similar research focus, Saygılı et al. (2022) and Gupta & Jha (2024) proposed theoretical models that leverage blockchain technology to enhance claim management. Saygılı et al. introduced the DCENTR (Decentralized Construction Enabling Transparent Resolution) model, which aims to improve the management of financial claims, while Gupta & Jha suggested that their model could be beneficial in preventing contractual disputes. Saygılı et al.'s study was showcasing a different method to diminish and settle construction conflicts. According to them, by utilizing blockchain technology, conflicts can be addressed in significantly less time, with considerably lower expenses and labor. In accordance with Gubta&Jha's literature review results, block-chain based model should include a contracting proceeding and this proceeding should be (1) productive and clear-cut; (2) digitally unified; and (3) reliable and safe in execution.

In all the reviewed studies, while the positive impacts of blockchain technology (BCT) and smart contracts on digital construction claim management were highlighted, it was observed that, unfortunately, no experimental management model was proposed.

4.8.4 Artificial intelligence

It has been identified that there are also studies focusing on artificial intelligence, which is increasingly prevalent in many areas of life today. Specifically, various models have been proposed to assist in the claim management process related to change orders. Wang and El-Adaway&Kandil utilized artificial intelligence in their studies, while Li additionally incorporated wireless technology into the model she proposed. Particularly after 2020, researchers' interest has increasingly shifted toward machine learning, a subset of artificial intelligence. In both preliminary studies and conceptual or prototype models, researchers have primarily focused on predicting the occurrence or outcomes of disputes rather than directly addressing claim management. Their efforts have been dedicated to leveraging machine learning techniques for

dispute resolution by anticipating potential dispute issues or their consequences. The research domain map related to artificial intelligence is provided in Figure 4.10.

The model presented by Wang in 2010, specifically designed for hydraulic construction projects, is distinguished as the only study among all the reviewed articles that focuses on a specific project type. This construction claim decision support system is designed based on rule-based reasoning (RBR) and case-based reasoning (CBR) in artificial intelligence—which is considered a relatively newer application for construction claim management compared to other digital technologies—. The model aims to help users (in hydraulic engineering) accomplish complicated claims by sharing the knowledge and experience of claim experts. According to El-Adaway and Kandil (2010), who, like Wang (2010), worked on improving the management of change order claims with artificial intelligence, the time and associated expenses spent by lawyers, contract administrators, and claims consultants in reviewing precedent cases to identify similarities and differences is a significant problem. To solve this problem, they created a multiagent system for construction dispute resolution (MAS-COR), which generates legal arguments based on precedent cases. The authors found that, when they tested their developed system with 30 previously concluded arbitration cases, it demonstrated a satisfactory alignment with the reported actual decisions. This system may assist stakeholders in gaining insights into a claim based on a change order in a construction project, potentially helping them avoid the need for arbitration.

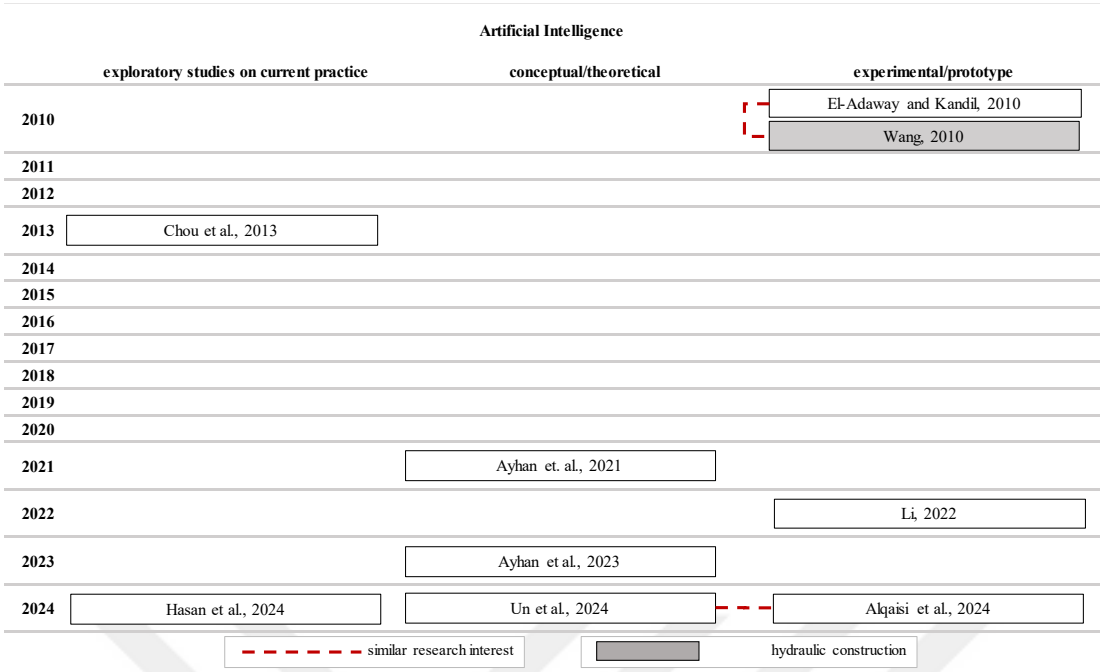

Figure 4.10: Research domain map (Artificial intelligence)

These models aim to similar claims and legal cases from past claims and legal cases, guiding them on how to proceed in resolving disputes effectively. However, the lack of case studies demonstrating the usability of the proposed models unfortunately distances these studies from practical application. Testing these decision support systems with a variety of real-life cases could be beneficial in further developing the models and making them more viable for implementation in the industry. Alqaisi et al. (2024) and Un et al. (2024) have focused on predicting dispute outcomes using machine learning techniques in their experimental and conceptual models, respectively, with a similar research interest. Alqaisi et al.'s study investigates the prediction of dispute outcomes related to change orders in construction projects, while Un et al. aims to predict the outcomes of disputes arising from contractual issues. In Alqaisi et al.'s study, various machine learning algorithms were implemented and assessed to identify the most effective conforming model. These algorithms were: decision tree (DT); random forest (RF); neural network (NN), and support vector machine (SVM). These algorithms were reviewed using a confusion matrix based on their accuracy, precision, recall, and sensitivity. The research concluded that the random forest algorithm provided the best overall results, achieving a prediction accuracy of 95.0%.

5. CONCLUSIONS AND RECOMMENDATIONS

As construction projects continue to grow in scale and complexity, traditional methods of managing claims have become increasingly challenging due to their costly and time-consuming nature, disruptions caused by turnover among key personnel overseeing project activities, and the prolonged duration of legal proceedings. With shrinking profit margins and increasing project complexity in the construction sector, the rising number and complexity of claims, which consume significant project resources, have made the digitalization of construction claim management an intriguing subject for researchers. Given that technology is not static but continuously evolving, the examination of how each newly developed digital tool contributes to claim management remains an ongoing process.

This research distinctively contributes by offering an analytical and critical review through a systematic methodology, serving as a research reference. It provides clear guidance on the ongoing research efforts towards the digitalization of construction claim management practices using scientometric and thematic analysis.

Since the digitalization of claim management is a relatively new topic within construction project management, no limitations were imposed during the research to ensure a comprehensive evaluation of all available data. The methodology of the review is systematically synthesized to compile, organize and analyze a total of 42 research articles, published between 1992 and 2024. Each study was examined in terms of the digital technology it focused on, the claim issue it aimed to address, the model, plug-in, or insight it proposed, its contribution to solving the problem, as well as its limitations and gaps. Based on the analysis of selected research, summarizing research maps are created to visualize and detect the trails of the research and identify the research category.

The scientometric analysis unanimously revealed the following results:

- The leading publication on digitalization in construction claim management, regarding released articles and citations, is Automation in Construction (Elsevier)
- The study conducted by Mahmudnia et al. (2022), has the highest number of citations;
- Keyword linkage analysis has identified and acquired fields linking digitalization in claim management with BIM, delay analysis/claims, EoT, information technology, artificial intelligence (AI), smart contracts, visualization, change orders, API (Application Programming Interface), and blockchain
- The leading countries active in this field of research are Australia, Turkey, the United Kingdom, the United States and Malaysia.

The thematic exploration uncovered possible areas of significance for the scientific community within this research domain, categorized into four themes according to the digital technologies employed in the studies: 1. Computer-based systems, and digital tools, 2. BIM, 3. Blockchain and smart contracts, 4. Artificial intelligence. Also, in the state-of-the-art section, potential themes are grouped into three themes based on the outputs of the studies: 1. exploratory studies & general insights, 2. Conceptual/theoretical models, and 3. Experimental/prototype models.

Researchers have argued that integrating various digital technologies into claim management could mitigate these challenges. The findings reveal that digitalization in construction claim management is predominantly explored through the application of Building Information Modeling (BIM), Artificial Intelligence (AI), Smart Contracts, Blockchain Technology, Delay Analysis Tools, and Document Control Systems. According to findings, these technologies play important roles in delay analysis, document management, change detection, and dispute resolution. These tools enable faster, more transparent, and efficient management of claims, reducing the time and costs traditionally associated with resolving disputes. For instance, Building Information Modeling (BIM) facilitates the documentation, visualization, and analysis of claims, while blockchain technology ensures more transparent and reliable storage of project-related data. Artificial intelligence (AI) applications, through Rule-Based

Reasoning (RBR) and Case-Based Reasoning (CBR) methods, aim to make claim management processes more efficient by training claim professionals, guiding them throughout the claim process, and enhancing decision-making capabilities. Particularly after 2020, researchers' interest has increasingly shifted toward machine learning, a subset of artificial intelligence. In both preliminary studies and conceptual or prototype models, researchers have primarily focused on predicting the occurrence or outcomes of disputes rather than directly addressing claim management. Their efforts have been dedicated to leveraging machine learning techniques for dispute resolution by anticipating potential dispute issues or their consequences. However, this study also identifies significant barriers, including the lack of standardization, difficulties in incorporating digital tools into projects that have traditional project delivery types, and limited applicability across the project lifecycle. Additionally, challenges such as the high costs of implementation and resistance to change within the industry further complicate widespread adoption.

Conceptual and experimental prototypes developed by researchers in recent years demonstrate that research aimed at improving claim management is yielding results. However, due to the complex nature of construction projects and the prevalent use of manual data entry and tracking, integrating cutting-edge technologies into construction claim management poses significant challenges. The widespread testing of these models in real projects is crucial for the advancement of claim management practices. Also, expanding future research to include not only superstructure projects but also infrastructure projects will enhance the adoption of digitalization of claim management and the efficiency of applications. Based on the identified results and notable gaps, further studies are recommended in the following summarized fields:

- Limited number of case studies to verify the functionality of proposed digital claim management systems,
- Absence of widespread real-world applications on all topics covered,
- Blockchain-based claim management is only presented on a conceptual level and lack prototypes,
- Lack of data collection procedures requiring manual data entry to the platforms,
- Lack of applicability of the proposed systems on financial claims,

- Implementation of special conditions of each contract into proposed frameworks, customization issues,
- Difficulty in integrating BIM-based systems in traditional project delivery methods such as DBB, which have a fragmented nature,
- Studies only in superstructures, but no evidence of applications or case studies in infrastructure projects,
- Impact of the challenges in BIM implementations (such as trust, and IP rights) on the applicability of BIM-based claim management systems.

The digitalization of construction claim management has the potential to reduce project costs, enhance time management, and increase the reliability of management processes. Proper integration of digital tools appears to reduce disruptions in claim management processes significantly. However, due to the inherently complex nature of construction projects and the widespread reliance on manual data entry and project tracking, integrating advanced technologies into claim management presents significant challenges. For these technologies to be effectively applied in claim management, it is essential to raise sector professionals' awareness of digital tools, enhance their technical knowledge, and provide appropriate training programs. Broad testing of these models in real-world projects and comparative analyses of their effectiveness across diverse projects are critical for advancing claim management practices. Furthermore, future research should extend beyond superstructure projects to include infrastructure projects, thereby improving the adoption and efficiency of digital claim management practices.

Specialized solutions for financial claims must be developed, and the integration of blockchain and artificial intelligence technologies should be strengthened. Additionally, several research gaps remain, including the lack of sufficient case studies to validate the functionality of proposed digital claim management systems, the predominantly conceptual presentation of blockchain-based claim management solutions, the absence of prototypes, the inability to tailor proposed models to the unique conditions of each contract, and customization challenges.

Upon examining the limitations of BIM-based prototypes developed in the last five years, it has been observed that these studies share common limitations. Further research is needed to address difficulties in integrating BIM-based systems into traditional project delivery methods such as Design-Bid-Build (DBB), Engineering-Procurement-Construction (EPC), and Public-Private Partnership (PPP), all of which have layered structures. Issues such as trust and intellectual property rights within BIM applications must be thoroughly examined to understand their impact on the applicability of BIM-based claim management systems. First and foremost, if industry professionals are not provided with the necessary knowledge on the subject and if experimental studies on the applicability of these prototypes are not conducted with them, it will, unfortunately, be unlikely for the industry to adopt such applications.

As someone who has been working exclusively in project management teams for metro and industrial facility projects since 2019, i can confidently say that BIM applications in metro projects in Turkey, unfortunately, remain limited to being mere "visualization tools." The primary reasons for this are not only the sector's reluctance to embrace innovation but also the fact that effectively utilizing BIM requires a continuous and up-to-date flow of information. Managing projects solely through BIM is hindered by the lack of field personnel capable of supplying the necessary data to the model and the insufficient training of these personnel. Moreover, in the reviewed studies, no case study applications of models developed for construction claim management have been observed in infrastructure projects, except for one study. Particularly in Turkey, for BIM-based claim management to be practically adopted by the industry in infrastructure projects, researchers need to conduct case studies specifically focused on such projects.

In the past five years, when examining theoretical or prototype models developed by researchers, it is evident that, after BIM (50%), the most attention has been given to AI-based studies (25%). Particularly in recent years, researchers have shown significant interest in artificial intelligence, especially for construction dispute resolution. In both conceptual and prototype models, researchers have primarily focused on predicting the occurrence or outcomes of disputes rather than directly addressing claim management. Their efforts have been dedicated to leveraging machine learning techniques for dispute resolution by anticipating potential dispute issues or their consequences.When the limitations of these studies are examined, it has

become evident that the narrowness of the datasets used is a common limitation across the studies. In order to improve the accuracy of the prediction results, researchers would benefit from providing more data input on the subject of prediction.

In Turkey, construction projects carried out for public entities, such as the Ministry of Infrastructure or municipalities, are governed by the Public Procurement Authority's standard contract unless financed by the World Bank, hence, bound by international contracts such as FIDIC. In the absence of a specific clause, contractors are only entitled to claim extensions of time and cannot seek additional financial compensation from the employer. Any monetary claims must be pursued through arbitration or litigation. The prolonged court proceedings in Turkey and contractors' reluctance to jeopardize their commercial relationships with employers have particularly driven them to seek experts specializing in claim management and dispute resolution. The interest in dispute outcome or dispute causes prediction models created using machine learning algorithms by researchers may stem from the lack of experienced experts in this specific area within the industry and the lengthy court processes. It is not surprising that 43% of the developed models have emerged from studies conducted in Turkey. Therefore, at least within the context of the Turkish construction sector, it can be said that the use of AI in claim management and dispute resolution is currently the most attractive digitalization method. Further studies on this topic should be deepened and diversified for the prediction of the occurrence or outcomes of construction disputes. Additionally, models should be evaluated by industry experts to validate their applicability. Such industry-focused research could enhance the adoption of AI-based applications within the sector.

The findings, along with the identified state-of-the-art, addressed the first research question: "What studies have been conducted on the digitalization of claim management in construction from 1992 to 2024, and what are their contributions?" Subsequently, the studies were critically examined in detail, and their limitations and areas in need of development were identified, with recommendations provided in the research roadmaps. Thus, the second question, "What are the limitations and future research subjects identified in these studies?" has also been answered through this thesis.

In conclusion, the digitalization of claim management is a significant tool with the potential to enhance the success rate of construction projects. Increasing the efforts of

researchers and practitioners in this field, along with implementing more practical examples within the industry, will enable the full realization of the potential offered by digital claim management.

REFERENCES

Abdela SA., Mengistu DG. and Asfaw DA. (2024) *Impact of Construction Scheduling Practice on Delay Claim Analysis* Journal of Legal Affairs and Dispute Resolution in Engineering and Construction 16 (4)

Abdul-Malak, M.A.U., El-Saadi M.M., and Abou-Zeid M.G. (2002) *Process model for administrating construction claims*, J. Manag. Eng. 18 (2)84–94

Abdul-Malak, M.A.U. and Abdulhai, T.A. (2017) *Conceptualization of the contractor's project management group dynamics in claims initiation and documentation evolution*, Journal of Legal Affairs and Dispute Resolution in Engineering and Construction, Vol. 9 No. 3.

Abougamil, RA., Thorpe, D. and Heravi, A (2023) *Investigating the Source of Claims with the Importance of BIM Application on Reducing Construction Disputable Claims in KSA.* Buildings, 13(9)

Abougamil, R. A., Thorpe, D., and Heravi, A. (2024). *A BIM Package with a NEC4 Contract Option to Mitigate Construction Disputes in the Kingdom of Saudi Arabia.* Buildings, 14(7).

Abougamil, R. A., Thorpe, D., and Heravi, A. (2024). *An investigation of BIM advantages in analysing claims procedures related to the extension of time and money in the KSA construction industry.* Buildings, 14(2), 426.

Ali, B., Aibinu, AA. and Paton-Cole, V. (2022) *Closing the information gaps: a systematic review of research on delay and disruption claims*. Construction Innovation-England. 23(3): 790-810

Ali, B., Zahoor, H., Nasir, AR., Maqsoom, A., Khan, RWA. And Mazher, KM (2020) *BIM-based claims management system: A centralized information repository for extension of time claims.* Aut. in Con.

Ali, B., Zahoor, H., Aibinu, A., Nasir, A. R., Tariq, A., Imran, U., and Khan, R. M. (2021). *BIM aided information and visualization repository for managing construction delay claims.* J. Inf. Technol. Constr., 26(Dec), 1023-1040.

Alqaisi, A. S., Ataei, H., Seyrfar, A., and Al Omari, M. (2024). *Predicting the outcome of construction change disputes using machine-learning algorithms.* Journal of Legal Affairs and Dispute Resolution in Engineering and Construction, 16(1), 04523051.

Al-Zwainy F. M. S., Jaber F. K., and Hachem S. W., (2018) *Diagnostic of the claims and disputes between the contractor and owner in construction project using narrative analysis approach,* International Journal of Civil Engineering and Technology, vol. 9, no. 12, pp. 619–626.

Arcadis, (2023). 13th Annual Construction Disputes Report. https://www.arcadis.com/en-us/knowledge-hub/perspectives/north-america/united-states/2023/construction-disputes-report-2023

Arditi D. and Patel BK. (1989) *Expert system for claim management in construction projects*. Int J Project Manag. 7(3): 141–146.

ASC Technology Solutions LLC (2022) https://www.linkedin.com/pulse/bim-levels-level-development-lod-ascbimservices/

Askari A.S.., Forgues D. and Francis A. (2013*) Improving construction claim management using building information model (BIM).* Proceedings, Annual Conference – CSCE 1347-1406

Ayhan, M., Dikmen, I., and Talat Birgonul, M. (2021). *Predicting the occurrence of construction disputes using machine learning techniques.* Journal of construction engineering and management, 147(4), 04021022.

Ayhan, M., Dikmen, I., and Birgonul, M. (2023). *Disputes using machine learning techniques classifying compensations in construction.* Journal of Engineering Research (Kuwait), 11(1).

Bakhary NA, Adnan H., and Ibrahim A. (2015) *A study of construction claim management problems in Malaysia*. Proc Econom Fin. 23:63–70.

Baram G.E. (1994) *Integrity and credibility in construction dispute resolution. Documenting and presenting the facts.* Cost Engineering (Morgantown, West Virginia) 36(4): 27-33.

Betts, M. and Lansley, P. (1993), *Construction management and economics: a review of the first ten years*, Const. Manag. and Economics, 11(4), 221-245.

Brown, JD. and Fruchtman, E. (2000) *Construction dispute solved with computer graphics*. Construction Congress VI, Proceeding: Building Together For A Better Tomorrow in an Increasingly Complex World*,* 214-223.

Cobb, J and Diekmann, J. (1986) *Claims Analysis Expert System,* Project Management Journal, Vol.17 39-48.

Chou, H.-Y. and Yang, J.B. (2017) *Preliminary evaluation of BIM-based approaches for schedule delay analysis*, IOP Conference Series: Materials Science and Engineering, IOP Publishing, Vol. 245 No. 6.

Chou, JS., Cheng, MY., and Wu, YW. (2013) *Improving classification accuracy of project dispute resolution using hybrid artificial intelligence and support vector machine models,* Expert Systems with Applications, Volume 40, Issue 6, Pages 2263-2274, ISSN 0957-4174**.**

Das M., Tao X., Liu Y., and Cheng J.C.P. (2022), *A blockchain-based integrated document management framework for construction applications*, Automat. Constr. 133 (2022) 104001,

Dastyar B., Esfahani A. F., Askarifard M., and Abbasi A.M., (2018*)* Identification, prioritization, and management of construction project claims, Journal of Engineering Project and Production Management, vol. 8, no. 2, pp. 90–96.

Dhanke S. and Futane N. (2021) *Introduction of conflict and dispute in the construction industry*. Int J. Sci. Res. (IJSR), 10(6):44–47

Dickinson, M., Cooper, R., McDermott, P. and Eaton, D. (2006), *An analysis of construction innovation literature*, Proceedings of the 3rd Int. Built and Human Environment Research Week, Delft University of Technology, Delft, 3-4 April.

Diekmann JE. and Kim MP. (1992) *SuperChange: an expert system for analysis of changes claims*. J Construct Eng. Manag. 118(2):399–411.

Eastman, C., Teicholz, P., Sacks, R. and Liston K. (2011). "Bim handbook: a guide to building information modeling for owners, managers, designers, engineers and contractors."

El-Adaway I.H. and Kandil A.A. (2010) *Multiagent system for construction dispute resolution (MAS-COR)*. J. of Const. Eng. and Manag. 136(3): 303-315

El-Ghrory A., Bin Tahir N.H. and Binti Ismail N. (2019) *Construction claims management system features and requirements.* Int. Journal of Recent Tech. and Eng. 871-874

El Hawary A. and Nassar A. (2015). *The effect of building information modeling (BIM) on construction claims*. Int. J Sci Technol Res. 5(12):25–33.

Enshassi AA, Choudhry RM and El-Ghandour SM. (2008) *Owners' perception towards causes of claims on construction projects in Palestine*. Arab Gulf J Sci Res. 26(3): 133–144.

Enshassi A, Choudhry RM. and El-Ghandour S. (2009) Contractors' perception towards causes of claims in construction projects. Int J Constr Manage. 9(1):79–92.

Fan SL. (2022) *Soft logic delay analysis technique*. Aut. in Const. Vol. 133

Flyvbjerg, B. (2009), *Survival of the unfittest: why the worst infrastructure gets built – and what we can do about it,* Oxford Review of Economic Policy, Vol. 25 No. 3, pp. 344-367.

Gibbs D-J, Emmitt S, Ruikar K and Lord W. (2013). *An investigation into whether building information modeling (BIM) can assist with construction delay claims*. Int J 3D Inform Model. 2(1):45–52.

Giwa F., Omotayo T., Tzortzopoulos P., and Malalgoda, C. (2024) *BIM-Enabled Claims Management Concept: Implications for Dispute Avoidance and Management.* Journal of Legal Affairs and Dispute Resolution in Engineering and Construction 16(3):1-12

Goedert JD. and Meadati P. 2008. *Integrating construction process documentation into building information modeling*. J. Constr. Eng. Manage. 134(7):509–516.

Göbel, H. and Cronholm S. (2012). "*Design science research in action-experiences from a process perspective.*"

Greenwood J. Li, D., and Kassem M. 2019, *Blockchain in the built environment and construction industry: a systematic review, conceptual models and practical use cases*, Autom. Constr. 102 (2019) 288–307.

Gupta P. and Jha K.N. (2024)*, Integration of blockchain in contract management for prevention of construction disputes: a systematic literature review and conceptual framework, Integration of blockchain in contract management for prevention of construction disputes: a systematic literature review and conceptual framework.* International Journal of Construction Management, 24(10), 1054–1065.

Hamledari H., Asce S.M., Fischer M., and Asce A.M. (2021), *Role of blockchain-enabled smart contracts in automating construction progress payments*, J. Legal Affair Dispute. Re-Sol. Eng. Construct. 13 (2021).

Handayani, TN., Likhitruangsilp, V. and Yabuki, N. (2019) *A Building Information Modeling (BIM)-Integrated System for Evaluating the Impact of Change Orders*. Engineering Journal-Thailand 23(4):67-90

Hasan, H.M., Khodeir, L. and Yassa, N. (2024), *Assessing the impact of claims on construction project performance using machine learning techniques.* Asian J Civ Eng 25, 5765–5779 (2024).

Jalal, MP., Roushan, TY., Noorzai, E. and Alizadeh, M. (2021) *A BIM-based construction claim management model for early identification and visualization of claims*. Smart and Sustainable Built Environment 227-257.

Jervis BM. and Levin P. (1988) Construction law, principles and practice. New York: McGraw-Hill College.

Kauffmann P, Keating C, and Considine C. (2002). *Using earned value methods to substantiate change-of-scope claims*. Eng. Manage. J. 14(1):13–20.

Kim, E.W., Park, M.S., Kim, K. et al. (2022) *Blockchain-Based Automatic Tracking and Extracting Construction Document for Claim and Dispute Support*. KSCE J Civ Eng 26, 3707–3724.

Le-Hoai L, Dang CN, Lee SB. and Lee YD. (2018) *Benchmarking claim causes against contractors in emerging markets: an empirical case study*. Int. J. Constr. Manage.

Li J. and Kassem M. (2021) *Applications of distributed ledger technology (DLT) and Blockchain-enabled smart contracts in construction*. Autom. Constr. 132:103955

Li Y. (2022) *Construction Project Claim Management under the Background of Wireless Communication and Artificial Intelligence*. Wireless Communication & Mobile Computing (12):1-6

Liang H, Zhang S, and Su Y. (2018) *The structure and emerging trends of construction safety management research: a bibliometric review.* Int. J. Occupant Safety Ergonomic. 1:20–29.

Lu, Y., Li, Y., Skibniewski, M., Wu, Z., Wang, R. and Le, Y. (2015), *Information and communication technology applications in architecture, engineering, and construction organizations: a 15-year review*, J. Manage. Eng., Vol. 31(1):1-19.

Mahmudnia, D., Arashpour, M. and Yang, RBC. (2022) *Blockchain in construction management: Applications, advantages and limitations.* Aut. in Const.

Marzouk M, Othman A, Enaba M. and Zaher M. (2018). *Using BIM to identify claims early in the construction industry: a case study*. J. Leg. Aff. Dispute Res. Eng. Constr. 10(3).

Matseke, D.A., Khatleli, N. and Root, D. (2022) *An Overview of Multi-Criteria Decision Making Techniques in Construction Projects Claim Management.* Proceedings of International Structural Engineering and Construction 9(1)

Mijwel Aljumaily H.S., Al-Zwainy F.M.S., Chiad Alharishawi S.S., Ali R.H. and Hayder G. (2022) *Adopting Building Information Modeling in Claims Management in Construction Industry*. Journal of Applied Eng. Sci. 20(4):1152-1164

Msawil M., Greenwood D. and Kassem M. (2022) *A Systematic evaluation of blockchain-enabled contract administration in construction projects*. Aut. in Const.

Nalioğlu V., Tokdemir H. and Artan D. (2023) *Possible Impacts of Smart Contracts on Construction Claim Management*. Lecture Notes in Civil Eng.

NBIMS (2008) *United States National Building Information Modeling Standard*, version 1-Part 1: Overview, principles, and methodologies.

Petherbridge L., (2019) *Teva and the process of claim construction*, Florida Law Review, vol. 70, no. 2, pp. 1–1.

Pietroforte, R. and Stefani, T.P. (2004), *ASCE Journal of Construction Engineering and Management: review of the years 1983-2000*, Journal of Const. Eng. and Manage, 130(3):440-448.

Ragab, M. A., and M. Marzouk. (2021) *BIM adoption in construction contracts: Content analysis approach.* J. Constr. Eng. Manage. 147 (8):04021094.

Riad N., Arditi D. and Mohammadi J. (1991). *A conceptual model for claim management in construction: an AI approach*. Comput. Struct. 40(1):67–74

Saygili, M., Mert, I. E., & Tokdemir, O. B. (2022). *A decentralized structure to reduce and resolve construction disputes in a hybrid blockchain network.* Automation in construction, 134, 104056.

Semple C., Hartman F.T. and Jergeas G. (1994). *Construction claims and disputes: causes and cost/time Overruns*. J of Const. Eng. and Manag. 120(4): 785-795.

Shah A., Bhatt R. and Bhavsar J. (2014) *Types and causes of construction claims*, Int. J. Eng. Res. Tech.. 3(12):732–735.

Shahhosseini V. and Hajarolasvadi H. (2021) *A conceptual framework for developing a BIM-enabled claim management system*. International Journal of Const. Manag. 21(2):208-222

Sibanyama G, Muya M. and Kaliba C. (2012) *An overview of construction claims: a case study of the Zambian construction industry*. Int. J. Constr. Manage. 12(1):65–81.

Stallone V., Wetzels M., and Klaas M. (2021), *Applications of blockchain technology in marketing systematic review of marketing technology companies*, Blockchain Res. Appl. 2 (2021), 100023

Stamatiou DRI, Kirytopoulos KA, Ponis ST, Gayialis S. and Tatsiopoulos I. (2018) *A process reference model for claims management in construction supply chains: the contractors' perspective*. Int. J. Constr. Manage. 1–19.

Su HN. and Lee PC. (2010) *Mapping knowledge structure by keyword co-occurrence: A first look at journal papers in Technology Foresight* Scientometrics 85(1):65-79 85(1):65-79

Tan, H. and Anumba, C. (2013), *Web-based Construction Claims Management System: Operation of the Prototype*, Beijing, China

Tang S., Shelden D.R., Eastman C.M., Pishdad-Bozorgi P., and Gao X. (2019), *A review of building information modeling (BIM) and the Internet of things (IoT) devices integration: present status and future trends*, Autom. Constr. 101 (2019) 127–139

Tsai, MK., Yang, JB. and Yau, NJ. (2013) *Developing Computer-Based Schedule Delay Analysis Methods Based on Information Flow Analysis: A Case Study*. J of Civil Eng. and Manag. 19(6):823-835

Van Eck NJ. and Waltman L. (**2014)** V*isualizing bibliometric networks. In Ding Y, Rousseau R, & Wolfram D, editors. Measuring scholarly impact: Methods and practice*, Cham: Springer; p. 285–320.

Un, B., Erdis, E., Aydınlı, S., Genc, O., and Alboga, O. (2024). *Forecasting the outcomes of construction contract disputes using machine learning techniques.* Engineering, Construction and Architectural Management.

Vidogah W. and Ndekugri I. (1998). *A review of the role of information technology in construction claims management*. Com. Indust. 35(1):77–85.

Volk, R., Stengel, J. and Schultmann, F. (2014), *Building information modeling (BIM) for existing buildings: literature review and future needs*, Aut. in Const., 38: 109-127.

Wang, JP., Zhang, S., Fenn, P., Luo, XW., Liu, Y. and Zhao, LL (2023) *Adopting BIM to Facilitate Dispute Management in the Construction Industry: A Conceptual Framework Development.* J. of Const. Eng. and Manag. 149(1)

Wang W. (2010) *Study of claim support system for hydraulic engineering based on CBR and RBR.* Proceeding – 5th Int. Conf. on CS and Convergence information Technology, iccit 763-765

WEF (World Economic Forum) (2016) *Shaping the future of construction: A breakthrough in mindset and technology.* https://www.weforum.org/publications/shaping-the-future-of-construction-a-breakthrough-in-mindset-and-technology/

Wolfe, R.A. (1994), *Organizational innovation: review, critique and suggested research directions*, Journal of Management Studies, 31(3):405-431.

Yousefi V., Yakhchali SH., Khanzadi M., Mehrabanfar E. and Saparauskas J. (2016). *Proposing a neural network model to predict time and cost claims in construction projects* J Civil Eng. Manag.. 22(7):967–978.

Yusuwan NM., Adnan H., Rashid ZZA. and Hashim. N, (2017) *Reasons for the Unsuccessful Extension of Time (EoT) Claim in the Malaysian Construction Industry,* Pertanika J. Soc. Sci. & Hum. 25 (S): 281 – 290.

Yusuwan NM., Adnan H., Rashid ZZA., Ismail WNW., and Mahat NAA. (2021) *Towards a Successful Extension of Time (EoT) Claim: A Consensus View of Construction Professionals via a Modified Delphi Method,* Engineering Journal 25(1):263-274.

Zhang, J.P. and Hu, Z.Z. (2011), *BIM-and 4D-based integrated solution of analysis and management for conflicts and structural safety problems during construction: 1. Principles and methodologies*, Automation in Construction, Vol. 20 No. 2, pp. 155-166.

APPENDICES

APPENDIX A: Dataset of Reviewed Articles

APPENDIX A.1: Article Title-Publication Year-Author(s)

APPENDIX A.2: Document Type-Research Country-Number of Citations

APPENDIX A.3: Sources of Information/Research Methods-Main Output of the Article-Enabling techs-Type of Conflict-Tools/Models Developed

APPENDIX A

APPENDIX A.1

Table A.1.1: Dataset (Article Title-Publication Year-Author(s))

Article Code	Article Title	Publication Year	Author(s)
1	A Conceptual Framework for Developing a BIM-Enabled Claim Management System	2021	Shahhosseini, V; Hajarolasvadi, H
2	A BIM-Based Construction Claim Management Model for Early Identification and Visualization of Claims	2021	Jalal, MP; Roushan, TY; Noorzai, E; Alizadeh, M
3	Adopting BIM to Facilitate Dispute Management in The Construction Industry: A Conceptual Framework Development	2023	Wang, JP; Zhang, S; Fenn, P; Luo, XW; Liu, Y; Zhao, LL
4	Investigating The Source of Claims with the Importance of BIM Application on Reducing Construction Disputable Claims	2023	Abougamil, RA; Thorpe, D; Heravi, A
5	BIM-Based Claims Management System: A Centralized Information Repository for Extension of Time Claims	2020	Ali, B; Zahoor, H; Nasir, AR; Maqsoom, A; Khan, RWA;
6	Construction Dispute Solved with Computer Graphics	2000	Brown, JD; Fruchtman, E
7	Blockchain in Construction Management: Applications, Advantages and Limitations	2022	Mahmudnia, D; Arashpour, M; Yang, RBC
8	A Building Information Modeling (BIM)-Integrated System for Evaluating the Impact of Change Orders	2019	Handayani, TN; Likhitruangsilp, V; Yabuki, N
9	Construction Project Claim Management under the Background of Wireless Communication and Artificial Intelligence	2022	Li, Y
10	Developing Computer-Based Schedule Delay Analysis Methods Based on Information Flow Analysis: A Case Study	2013	Tsai, MK; Yang, JB; Yau, NJ
11	Ontology for Linking Delay Claims with 4D Simulation to Analyze Effects-Causes and Responsibilities	2021	Guévremont, M; Hammad, A
12	Closing the Information Gaps: A Systematic Review of Research on Delay and Disruption Claims	2022	Ali, B; Aibinu, AA; Paton-Cole, V

Table A.1.1 (continued): Dataset (Article Title-Publication Year-Author(s))

Article Code	Article Title	Publication Year	Author(s)
13	Improving Construction Claim Management Using Building Information Model (BIM)	2013	Askari A.S.; Porgues D.; Francis A.
14	Adoptıng Buildıng Information Modelıng In Claıms Management In Constructıon Industry	2022	Mijwel Aljumaily H.S.; Al-Zwainy F.M.S.; Chiad Alharishawi S.S.; Ali R.H.; Hayder G.
15	A Review of The Role of Information Technology in Construction Claims Management	1998	Vidogah W.; Ndekugri I.
16	Integrity and Credibility in Construction Dispute Resolution. Documenting and Presenting The Facts	1994	Baram G.E.
17	Construction Claims Management System Features and Requirements	2019	El-Ghrory A.; Bin Tahir N.H.; Binti Ismail N.
18	Study of Claim Support System for Hydraulic Engineering Based on CBR and RBR	2010	Wang W.
19	Multiagent System for Construction Dispute Resolution (MAS-COR)	2010	El-Adaway I.H.; Kandil A.A.
20	Possible Impacts of Smart Contracts on Construction Claim Management	2023	Nalioğlu V.; Tokdemir H.; Artan D.
21	A Systematic Evaluation of Blockchain-Enabled Contract Administration in Construction Projects	2022	Msawil M, Greenwood D, Kassem M
22	Soft Logic Delay Analysis Technique	2022	Fan SL
23	Calculating The Cost İmpact in Loss of Productivity Claims	2022	Seo W, Kim J, Kang Y
24	Superchange: Expert System for Analysis of Changes Claims	1992	James E. Diekmann, Moonja P. Kim
25	Process Model for Administrating Construction Claims	2002	M. Asem U. Abdul-Malak, A.M.ASCE; Mustafa M. H. El-Saadi; and Marwan G. Abou-Zeid

Table A.1.1 (continued): Dataset (Article Title-Publication Year-Author(s))

Article Code	Article Title	Publication Year	Author(s)
26	Blockchain-Based Automatic Tracking and Extracting Construction Document for Claim and Dispute Support	2022	Kim, EW; Park, MS; Kim, K; Kim, KJ
27	Improving classification accuracy of project dispute resolution using hybrid artificial intelligence and support vector machine models	2013	Chou, JS; Cheng, MY; Wu, YW
28	BIM-Enabled Claims Management Concept: Implications for Dispute Avoidance and Management	2024	Giwa, F; Omotayo, T; Tzortzopoulos, P; Malalgoda, C
29	Impact of Construction Scheduling Practice on Delay Claim Analysis	2024	Abdela, SA; Mengistu, DG; Asfaw, DA
30	Reasons for the Unsuccessful Extension of Time (EoT) Claim in the Malaysian Construction Industry	2017	Yusuwan, NM; Adnan, H; Rashid, ZZA; Hashim, N
31	Towards a Successful Extension of Time (EoT) Claim: A Consensus View of Construction Professionals via a Modified Delphi Method	2021	Yusuwan, NM; Adnan, H; Rashid, ZZA; Ismail, WNW; Mahat, NAA
32	Integration of blockchain in contract management for prevention of construction disputes: a systematic literature review and conceptual framework	2024	Gupta P.; Jha K.N.
33	Assessing the impact of claims on construction project performance using machine learning techniques	2024	Hasan H.M.; Khodeir L.; Yassa N.
34	Forecasting the outcomes of construction contract disputes using machine learning techniques	2024	Un B.; Erdis E.; Aydınlı S.; Genc O.; Alboga O.
35	BIM Aided Information And Visualization Repository for Managing Construction Delay Claims	2021	Ali B.; Zahoor H.; Aibinu A.; Nasir A.R.; Tariq A.; Imran U.; Khan R.M.
36	Predicting the Outcome of Construction Change Disputes Using Machine-Learning Algorithms	2024	Alqaisi A.S.; Ataei H.; Seyrfar A.; Al Omari M.
37	Using BIM to Identify Claims Early in the Construction Industry: Case Study	2018	Marzouk M.; Othman A.; Enaba M.; Zaher M.
38	A BIM Package with a NEC4 Contract Option to Mitigate Construction Disputes in the Kingdom of Saudi Arabia	2024	Abougamil R.A.; Thorpe D.; Heravi A.
39	A decentralized structure to reduce and resolve construction disputes in a hybrid blockchain network	2022	Saygili M.; Mert I.E.; Tokdemir O.B.

Table A.1.1 (continued): Dataset (Article Title-Publication Year-Author(s))

Article Code	Article Title	Publication Year	Author(s)
40	Disputes Using Machine Learning Techniques Classifying Compensations in Construction	2023	Ayhan M.; Dikmen I.; Birgonul M.T.
41	An Investigation of BIM Advantages in Analysing Claims Procedures Related to the Extension of Time and Money in the KSA Construction Industry	2024	Abougamil R.A.; Thorpe D.; Heravi A.
42	Predicting the Occurrence of Construction Disputes Using Machine Learning Techniques	2021	Ayhan M.; Dikmen I.; Talat Birgonul M.

APPENDIX A.2

Table A.2.1: Dataset (Document Type-Research Country-Number of Citations)

Article Code	Document Type	Searching From	Number of Citations
1	Article	Iran	18
2	Article	Iran	26
3	Review	China + Netherlands + UK	15
4	Article	Australia	8
5	Article	Pakistan	48
6	Proceedings Paper	USA	2
7	Review	Australia +Iran	74
8	Article	Thailand + Japan	11
9	Article	China	4
10	Article	Taiwan	7
11	Article	Canada	10
12	Review; Early Access	Australia	3
13	Conference paper	Canada	9
14	Article	Iraq + Malaysia	6
15	Article	UK	12
16	Article	Canada	1
17	Article	Malaysia	1
18	Conference paper	China	1
19	Article	USA	47
20	Conference paper	Turkey	2
21	Journal Article	UK	21
22	Journal Article	Taiwan	1
23	Journal Article	South Korea	1
24	Article	USA	10
25	Article	Lebanon	43
26	Article	South Korea	10
27	Article	Taiwan	46
28	Article	UK	0
29	Article	Ethiopia	0
30	Article	Malaysia	1
31	Article	Malaysia	3
32	Article	India	2
33	Article	Egypt	1
34	Article	Turkey	0
35	Article	Australia + Pakistan	7

Table A.2.1 (continued): Dataset **(**Document Type-Research Country-Number of Citations)

Article Code	Document Type	Searching From	Number of Citations
36	Article	USA	3
37	Article	Egypt	31
38	Article	Australia	0
39	Article	Turkey	52
40	Article	Turkey	4
41	Article	Australia	1
42	Article	Turkey	41

APPENDIX A.3

Table A.3.1: Dataset (Sources of Information/Research Methods-Main Output of the Article-Enabling techs-Type of Conflict-Tools/Models Developed)

Article Code	Sources of Information/Research Methods	Main Output of the Article	Enabling techs	Type of Conflict	Tools/models developed
1	reviews + case study	conceptual/theoretical model	BIM	No specific claim	Conceptual framework for developing a BIM-enabled claim management system
2	questionnaire + case study	experimental / prototype model	BIM	hard claims	Claim management model with the aid of BIM
3	critical literature review	conceptual/theoretical model	BIM	No specific claim	Conceptual framework for developing a BIM-enabled claim management system
4	compheransive literature review + interview	general insights and statistical results	BIM	No specific claim	-
5	literature review + semi-structured interview	experimental / prototype model	BIM, Information and Communications Technology (ICT)	Delays	Plugin in Autodesk Revit for managing EOT claims

Table A.3.1 (continued): Dataset (Sources of Information/Research Methods-Main Output of the Article-Enabling techs-Type of Conflict-Tools/Models Developed)

Article Code	Sources of Information/Research Methods	Main Output of the Article	Enabling techs	Type of Conflict	Tools/models developed
6	case study	general insights	Computer, digital camera, and digital projector	No specific claim	-
7	literature review	general insights	Blockchain	No specific claim	-
8	reviews + case study	experimental / prototype model	BIM	change orders	BIM-Integrated System for Evaluating the Impacts of Construction Change Orders (BIM-ISICO)
9	questionnaire	experimental / prototype model	Wireless Communication + Artificial Intelligence	No specific claim	Claim management system
10	review + case study	experimental / prototype model	Computer-based technology	Delays	Computer-based schedule delay analysis system based on information flow analysis
11	review + case study + questionnaire	experimental / prototype model	BIM	Delays	Claim4D-Onto

Table A.3.1 (continued): Dataset (Sources of Information/Research Methods-Main Output of the Article-Enabling techs-Type of Conflict-Tools/Models Developed)

Article Code	Sources of Information/Research Methods	Main Output of the Article	Enabling techs	Type of Conflict	Tools/models developed
12	critical literature review	general insights	BIM	no specific claim	-
13	review	conceptual/theoretical model	BIM	Delays	Conceptual framework for developing a BIM-enabled claim management system
14	review + system analysis	experimental / prototype model	BIM	Delays	Plug-in conceptual framework for developing a BIM-enabled delay claim management system
15	interview	general insights	expert systems, project management software and databases	no specific claim	-
16	survey	general insights and statistical results	* ASCII * HPGL * AutoCAD, Primavera	no specific claim	-

Table A.3.1 (continued): Dataset (Sources of Information/Research Methods-Main Output of the Article-Enabling techs-Type of Conflict-Tools/Models Developed)

Article Code	Sources of Information/Research Methods	Main Output of the Article	Enabling techs	Type of Conflict	Tools/models developed
17	semi-structured interview	general insights and statistical results	Computer-based claim management system	no specific claim	-
18	system analysis	experimental / prototype model	Artificial Intelligence	change orders/detection	Construction claim decision support system based on CBR (case-based reasoning) and RBR (rule-based reasoning)
19	survey	experimental / prototype model	Artificial Intelligence	change orders	Multiagent system for construction dispute resolution MAS-COR
20	literature review	general insights	Smart Contracts, Blockchain	no specific claim	-

Table A.3.1 (continued): Dataset (Sources of Information/Research Methods-Main Output of the Article-Enabling techs-Type of Conflict-Tools/Models Developed)

Article Code	Sources of Information/Research Methods	Main Output of the Article	Enabling techs	Type of Conflict	Tools/models developed
21	literature review	general insights	Blockchain	no specific claim	-
22	system analysis	experimental / prototype model	Scheduling Softwares	Delays	Algorithm for streamlining the submission of Extension of Time (EOT) claims
23	case study + interview	experimental / prototype model	Primavera	Loss of productivity	As-on tool (PLC) Productivity loss calculation
24	system analysis	experimental / prototype model	Hypertext	no specific claim	SuperChange, comprehensive, hyper-text based, context-sensitive expert system
25	system analysis	experimental / prototype model	Computer-based claim management system	no specific claim	Claims Manager 2000
26	literature review	conceptual/theoretical model	Blockchain		-

Table A.3.1 (continued): Dataset (Sources of Information/Research Methods-Main Output of the Article-Enabling techs-Type of Conflict-Tools/Models Developed)

Article Code	Sources of Information/Research Methods	Main Output of the Article	Enabling techs	Type of Conflict	Tools/models developed
27	system analysis	general insights	AI - ML		-
28	literature review + semistructured interview	conceptual / theoretical model	BIM	-	-
29	questionnaire	general insights	Computer and other digital tools	delay	-
30	questionnaire	general insights	Computer and other digital tools	-	-
31	questionnaire	general insights	Computer and other digital tools	-	-
32	literature review + semistructured interview	conceptual / theoretical model	blockchain	contract related issues	-

Table A.3.1 (continued): Dataset (Sources of Information/Research Methods-Main Output of the Article-Enabling techs-Type of Conflict-Tools/Models Developed)

Article Code	Sources of Information/Research Methods	Main Output of the Article	Enabling techs	Type of Conflict	Tools/models developed
33	questionnaire	general insights + statistical results	AI - ML	-	-
34	system analysis	Conceptual / theoretical model	AI - ML	contract related issues	-
35	literature review + semi-structure interview	experimental / prototype model	BIM	Delays	plug-in: BIM-based Construction Delays Recorder (BIM-CDR)
36	system analysis + questionaire	experimental / prototype model	AI- ML	Change orders	-
37	literature review + case study	experimental / prototype model	BIM	Delays	-
38	questionnaire + case study	experimental / prototype model	BIM	EOT	-

Table A.3.1 (continued): Dataset (Sources of Information/Research Methods-Main Output of the Article-Enabling techs-Type of Conflict-Tools/Models Developed)

Article Code	Sources of Information/Research Methods	Main Output of the Article	Enabling techs	Type of Conflict	Tools/models developed
39	literature review + system analysis	Conceptual / theoretical model	blockchain	financial claims	Decentralized Construction Enabling Transparent Resolution (DCENTR)
40	literature review + questionnaire	Conceptual / theoretical model	AI - ML	changes - delays - financial	-
41	literature review + questionnaire + case study	Conceptual / theoretical model	BIM	delays	-
42	literature review + questionnaire	Conceptual / theoretical model	AI - ML	no specific issue	-

CURRICULUM VITAE

Name Surname **:** Nil DENİZMEN

EDUCATION **:**

- **B.Sc.** **:** 2019, Yıldız Technical University, Faculty of Civil Engineering, Civil Engineering Department

PUBLICATIONS, PRESENTATIONS AND PATENTS ON THE THESIS:

- **Artan D. and Denizmen N.** 2024. Digitalization in Construction Claim Management, *International Graduate Research Symposium, May 08-10, 2024 Istanbul, Turkey.*