Disruptive Technology Adoption in the Malaysian Road Infrastructure Operation and Maintenance Stage: A Systematic Literature Review

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ABSTRACT:

This study aims to determine the current adoption of disruptive technologies in road infrastructure's operation and maintenance stage as well as discover the factors influencing the adoption of disruptive technologies. Systematic Literature Review method is adopted in this study. SLR seeks to summarize the recent state-of-the-art of articles related to adoption of disruptive technologies in road infrastructure's operation and maintenance stage. A PRISMA checklist is reviewed and the PRISMA flowchart is proposed for the research methodology of this study. Study found that from 56 final retained articles, 33 articles (59 %) are from Scopus database. Only 11 articles (19.6%) and 12 articles (21.4%) are obtained from Web of Science and Taylor and Francis databases respectively. Basically, there are 2 types of study covered for the final articles, which are theoretical study and empirical study. Results showed that numbers of empirical study are prominent, which is 40 articles in total (71.4%). While there is only 16 theoretical study included in this study. Future studies could examine the specific challenges that need to be addressed and identify potential solutions. This could involve exploring new business models, developing policies and regulations that promote the adoption of these technologies, and addressing issues related to cost and infrastructure.

Keywords: Disruptive technology, road infrastructure, operation, maintenance and systematic literature review

INTRODUCTION

Development of infrastructure brings substantial impacts on the economics of a country, especially in developing countries like Malaysia. Infrastructure as the physical assets of the country, unravelling connectivity within and between cities and countries, providing facilities to link living systems of residents for example transportation, education, communication, sewage, water, and electric systems and etcetera. In the aspect of Malaysian highway infrastructure, Malaysia is well known as one of the best among developed nations. Presently, there are about 30 inter urban and intra urban highways or expressways in operation, 6 are under construction phase and another 5 are in planning stage besides several other major main roads (Sazali & Firdaus, 2018). In Malaysia, statistics from Public Work Department (PWD) in 2017 stated that the length of Malaysian highways is 2,000.880km. Economic growth of the country is greatly affected by the highway network system occasionally. Most of Malaysia's highways can be found in Peninsular Malaysia. Recent longest highway in Malaysia is the North-South Expressway, which is a 823-km road that runs from Bukit Kayu Hitam near the border with Thailand in the North, to Johor Bahru in the South of the Peninsular Malaysia. The lifecycle of the roads is greatly depending on the road maintenance works. Road maintenance process should be carried out timely in order to prevent major road deterioration and the maintenance tasks can be identified and planned with suitable maintenance tools and it requires a trained workforce with equipment to carry out the tasks. "Maintenance" is defined as work in order to keep, restore or improve every part of building or facilities, to maintain building performance and its services including the surroundings, as well as to sustain the utility and value of the building. It includes improvement, refurbishment, upgrading and repair works to the existing facilities according to a currently accepted standard (Ahmad et. al, 2016). Lack of road maintenance will lead to shorter functionable lifespan of road, high operating costs and a high incidence of accidents. Asian Development Bank (2013) stated that inadequate maintenance was associated with rapidly growing traffic, poor road maintenance standards, and design and construction deficiencies.

Disruptive technologies, on the other hand, are innovations for existing products but on attributes that differ from those that are mainly valued by mainstream customers. These innovations, which initially underperform with respect to the main attributes of sustaining technologies, become disruptive when they reach the same performance as the sustaining innovations on the attributes valued by mainstream customers. At this point, they displace existing technologies and cause, in most cases, the failure of incumbent firms. (Corsi & Minin, 2014). Augmented reality (AR), virtual reality (VR), artificial intelligent (AI), drone, robots and so on are the examples of disruptive technologies which might potentially impacted the construction industry, in recent times, the construction industry is facing massive challenges characterized by the adoption of digital technologies such as sensor systems, intelligent machines, smart materials and so on (Craveiro et al., 2019). Research gap to be filled in this study is that disruptive technologies are not so widespread in construction industry especially in infrastructure operation and maintenance. Previous study found that disruptive technology like multirotor drone is less popular and has not yet been widely adopted in the construction industry, as this industry has been a slow adopter of emerging technologies (Holton et al. 2015). The implementation of blockchain technology in the Architecture, Engineering, and Construction (AEC) industry is also limited in comparison to other industries such as finance, e-commerce, and health industries. Lately, only some researchers tackled the subject at a higher level noting the capabilities of blockchain technology drives competences in the AEC and transform industry culture and advance innovative advancements (Mathews et al., 2016; Turk & Klinc, 2017). Moreover, limited academic literature are published and discovered in technological issues linked with disruptive technology like autonomous vehicles (Cavoli et. al., 2017), the construction industry has been slow to adopt new technologies and has never undergone a major disruptive transformation and revolution (Gerbert et. al., 2016). Thus, a systematic literature review is conducted in this study in order to fill up the aforementioned gaps of research.

LITERATURE REVIEW

In the literature review section, the definition of disruptive technology is defined, at the same time few types of disruptive technology are also identified in this section. Last but not the least, technique used in this research, which is Systematic Literature Review (SLR), is also explored in this section.

2.1 Define Disruptive Technology

Disruptive technology is any completely new or enhanced technology that replaces and disrupts an existing technology by slowly obsoleted the existing technology. According to previous studies, Disruptive technology can be described as "…a technology that changes the bases of competition by changing the performance metrics along which firms compete." (Bower & Christensen, 1995; Danneels, 2004). Christensen (1995) also clarified that disruption happens when a small firm lacks many resources, for example, a start-up is able to challenge large firmly established companies or is able to capture totally new markets. This concept was later revised by Christensen (2003) to disruptive innovation (DI) to a more holistically view by including not only technological disruptions.

2.2 Types of Disruptive Technology

There are various types of disruptive technology introduced for the construction industry such as, Intelligent Transport System (ITS), autonomous vehicles (AV), Internet-of-things (IoT), Unmanned aerial vehicle (also known as drone), smart sensors (wired or wireless), blockchain and so on. In this study, we are focused on few disruptive technologies that are widely applied in the construction industry especially in the road and highway infrastructure.

2.2.1 Intelligent Transport System

Intelligent transport systems (ITS) is a set of transport infrastructure and operation systems that maximize safety, efficiency and accessibility of the road network system by using advanced information technologies while minimize costly large-scale road construction (United Nations - ESCAP, 2017). At present, there is no single universally agreed definition for ITS, it is generally understood to be the combination of technologies, most of which involve information and communications technology (ICT) as a platform, that are embedded within conventional transport infrastructure. These systems are a combination of technologies based on the new capabilities offered by modern ICT systems (United Nations - ESCAP, 2017). A wide variety of communications-related applications are comprised in ITS which intended to improve travel safety, minimize environmental impact, improve traffic management, and maximize the benefits of transportation to both commercial users and the public. Therefore, ITS has become a very effective means for traffic safety and disaster response through the rapid development of related technologies.

2.2.2 Internet-of- things

The Internet-of- things (IoT) is broadly interpreted as the most disruptive phase of the Internet revolution (Atzori et al., 2017). The IoT refers to physical objects that have network connectivity, processing abilities and sensors. These physical characteristics allow the devices to record, process and communicate the data (Lee & Lee, 2014). The IoT permitting devices to be in contact with other local devices, global Internet and mobile network infrastructures to communicate with remote devices either in wired or wireless mode (Gluhak et al., 2011). The process proficiency and human productivity can be enhanced with the ability of IoT to broadcast contextual data over space and time (Balakrishna, 2012). At the same time, new digital platforms and services can be generated (Saarikko et al., 2019), and the delivery of public services and support citizen participation can ne strengthen with the IoT (Allwinkle & Cruickshank, 2011). Studies found that IoT is a promising technology for smart public services (Atzori et al., 2010; Jin et al., 2014) as the transparent and seamless integration of different systems can be facilitated and unrivalled access to data for the development of smart city services can be provided at the same time (Zanella et al., 2014). The government can keep an eye on almost every aspect of a city by equipping a city with IoT devices. Instant action can be taken when problems arise, and relevant information and services can be provided to the residents. In short, IoT able to improve efficiency, transparency, accessibility, sustainability and efficacy for a city (Aldama-Nalda et al., 2012). Unfortunately, IoT systems can only advantageous to the public sector if it incorporates and synthesises the IoT data with public services (Tomar & Kaur, 2019), for example, the public sector can leverage IoT to enhance public services include smart and connected bus stops, real-time traffic information, thermostat regulators and sensors that control the indoor temperature of public buildings based on actual practice.

2.2.3 Autonomous Vehicles

Autonomous vehicles (AV), which are also well-known as self-driving vehicles, which are cars with a self-driving mode employing a fully automated driving system to perform the complete driving tasks without human intervention (Panagiotopoulos & Dimitrakopoulos, 2018). AVs are the crucial innovative technology in the automotive sector which changing the perspectives of the world and society in seeing the vehicles revolutions. AVs can enhance the mobility, reduce the resources consumption, lower the carbon emissions and decrease the needs for parking spaces as well as improve the traffic safety (Yuen et al., 2020; Wang et al., 2020). Recently, explorations and studies on AV topics are getting considerable attentions from scholars, governments, and professionals as an essential development in the automobile industry (Adnan et al., 2018). Previous research noticed that AV has quite a few advantages and the major being road passengers' safety (WHO, 2021). According to the recent road traffic injury data from WHO (World Health Organization), over 1.35 million people die every year on the road. The human mistake found to be the main cause for these tragedies. These mistakes can be caused by speeding, intoxication, distraction, abuse, or misuse of safety gear such as seatbelts and etcetera (WHO, 2021). Therefore, Autonomous cars or vehicles are immune to such human errors by reduces crashes, increases reliability, and enhances traffic flow. Unfortunately, Kumar et. al. (2022) discovered that developed countries face different challenges in AV implementation, such as opportunities for public space liberation and land use management in respect to projected outwardness of autonomous vehicles, the potential contribution of autonomous vehicles in places with limited route capacity and deficient roadway characteristics, possibilities for innovative urban infrastructure design to accommodate autonomous vehicles. Besides that, Bagloee et al. (2016) pointed out that lack of roads, bridges, and public transportation impedes third-world economies, but using AV rather than capital-intensive infrastructure development could save the money of these countries.

2.2.4 Blockchain Technology

Blockchain technology was first introduced in Bitcoin, which is the first cryptocurrency to accomplish widespread distribution and mainstream application. Blockchain technology is known as a technological solution for peer-to-peer infrastructure based on a network-wide allocated databases linked through smart contracts (Kang et. al., 2022). Blockchain technology can be considered as a cutting-edge technology that could possibly modernize and transform the current digital infrastructure and methodologies to support business and operational activities, for examples finance, computing, government services, and virtually every existent industry (Crosby et al., 2015). Five (5) unique characteristics of blockchain bring disruptive impacts in different industries, which are:

1. Peer-to-peer communication without a central authority.
2. Transparent transaction processing with optionally-disclosed ownership.
3. Decentralised transaction history verifiable by all applicants.
4. Immutability of records assuring chronological sequence and accessibility.
5. Logic-based processing to trigger algorithms and events.

(Hirtan, Dobre & González-Vélez, 2020)

Recently, Blockchain technology has been acknowledged as an inventive and disruptive technology that could likely transforming various industries, like the finance, logistics, manufacturing industries and etcetera (Nakamoto, 2008; Tan et al., 2020; Zhang et al., 2020). At the same time, both academia and industrial practitioners have begun applying and developing Blockchain technology in the construction industry and plenty of initiatives have been introduced in transforming the construction industry with Blockchain (Kang et. al., 2022). However, Nawari & Ravindra (2019) claimed that research studies on blockchain application in Architecture, Engineering, and Construction (AEC) industry are limited.

2.3 Systematic Literature Review

A Systematic Literature Review (SLR) is "a systematic, precise, and replicable approach for identifying, evaluating, and integrating the existing body of completed and recorded works generated by the researchers, scholars, and practitioners" (Fink, 2019). A substantial and comprehensive analysis of the research in the field can be offered to the readers by using SLR approach. At the same time, many audiences can be beneficial essentially with this integrating research study. SLRs are exceptionally vital tools as they offer a baseline for scientific progress and SLRs are gradually utilized by researchers (Brereton et al., 2007; Kitchenham et al., 2009). The SLR protocol for this research is developed in the Research Method Section. First of all, the research questions for the study are established and systematic search strategies are conducted including the queries formulation, criteria formulation, qualitative assessment and critical analysis.

RESEARCH METHOD

The protocol of SLR is developed in this section. SLR seeks to summarize the recent state-of-the-art of articles related to adoption of disruptive technologies in road infrastructure's operation and maintenance stage. An intensive search of papers since 2009 was performed and the main results and findings were reported according to the protocol suggested by Kitchenham (2004). Furthermore, the PRISMA checklist (Moher et. al., 2009) is reviewed and the PRISMA flowchart is proposed in the Figure 2.

3.1 Research Questions

The main research question in this systematic review research is: ‘‘What are the current adoption of disruptive

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technologies in road infrastructure's operation and maintenance stage?''. A few of sub-questions were asked to answer the main research question:

RQ1 - What are the current disruptive technologies in operation and maintenance of road infrastructure?

RQ2 - What is the stage of adoption of disruptive technologies in operation and maintenance of road infrastructure?

RQ3 - What are the factors influencing the adoption of disruptive technologies in operation and maintenance of road infrastructure?

3.2 Systematic Search Strategies

This search process and strategies used in this research are indicated in this section, including the search databases, search queries, inclusion and exclusion criteria, quality assessment as well as the data extraction. According to Kitchenham (2004), the steps involved in Systematic Literature Review is presented as Figure 1 below:

Figure 1: Systematic Literature Review's Steps (Kitchenham, 2004)

3.3 Search Databases/Resources

As there are plenty of search databases available online, such as Scopus, Web of Science, Taylor & Francis Online, SAGE Journals, Springer Link, Wiley Online Library and so on. As the number of searched databases increased, the more yield, precise and comprehensive results can be obtained (Tawfik et al., 2019). **Web of Science, Scopus and Taylor & Francis Online** are used as the search databases in this research.

3.4 Search Queries

The primary search keys were **"adopt, implement, disrupt technology, smart technology, road, highway, expressway, infrastructure, operation and maintenance"**. The main queries used in this research were (("adopt*" or "implement*") and ("disrupt* technology") or ("smart technology") and ("road" or "highway*" or "expressway*" or "infrastructure") and ("operation*" or "maintenance*")). The queries were then modified to comply with the search capabilities of each database in order to get best relevant results, but overall, the semantics was maintained. A total number of **1,159** articles were obtained from three (3) afore-mentioned databases. Table 1 below illustrated the number of articles obtained in each database.

Table 1: Outcomes of Online Database Search Results

Database	Number of articles
Web of Science	429
Scopus	415

Taylor and Francis Online	315
Total	1,159

3.5 Inclusion and Exclusion Criteria

The interpretation of inclusion and exclusion criteria is a crucial step for all systematic literature review (Kitchenham et al., 2009). This step is quite vital when including the related articles and papers by filtering out the irrelevant or inappropriate sources. Four (4) of criteria including language, publication timeline, document type and keywords are employed in this research. The inclusion and exclusion criteria for this study are indicated in Table 2 below:

Table 2: Inclusion and exclusion criteria for disruptive technology adoption in road infrastructure.

Criteria	Inclusion	Exclusion
Language	English	Language other than English
Publication Timeline	Papers published on or after 2005 (This year was the starting point of SLR as methods applied. Rule-based methods are found earlier than this year and their usage is nowadays deprecated)	Paper published before 2005
Document Type	Indexed journal and articles by reputable publishers (Example Scopus, ScienceDirect, Web of science, Taylor & Francis and etc.)	Conference paper, review paper, editorial and etc. (other than article)
Keywords	Involved at least two of the search queries keywords	Less than two search queries keywords are excluded

(Reference: Farina, Kostin & Succi, 2022)

3.6 Quality Assessment

Quality Assessment was conducted after the formulation of inclusion and exclusion criteria. The qualities of the selected papers were evaluated by adapting the checklist proposed by Kitchenham and Charter (2007) and Petersen et al. (2015). four (4) quality assessment (QA) questions were developed and each question can be answered by one of three scores: with 1 (Yes), 0.5 (Partly), and 0 (No). The questions are as below:

QA1: Does the study discover a main research purpose? A primary study should come up with a clear purpose for the inquiry of disruptive technologies in road infrastructure.

QA2: Does the study clearly define the concept of disruptive technologies? The definition is useful in developing the perception of disruptive technologies.

QA3: Does the study illustrate the methodology clearly? The applied methodology can embody the applicability of a paper to this research.

QA4: Does the study discuss any limitations? The discussion on current shortcomings of disruptive technologies can expose the direction of future studies on this research area.

The selected papers were ranked by calculating the total scores of four (4) QA questions. The score of each paper can be categorised into three (3) categories: Good ($3 < \text{score} \leq 4$), fair ($1 < \text{score} \leq 3$), and fail ($0 \leq \text{score} \leq 1$). The papers in good and fair groups were involved while the papers in fail group were ignored in this phase.

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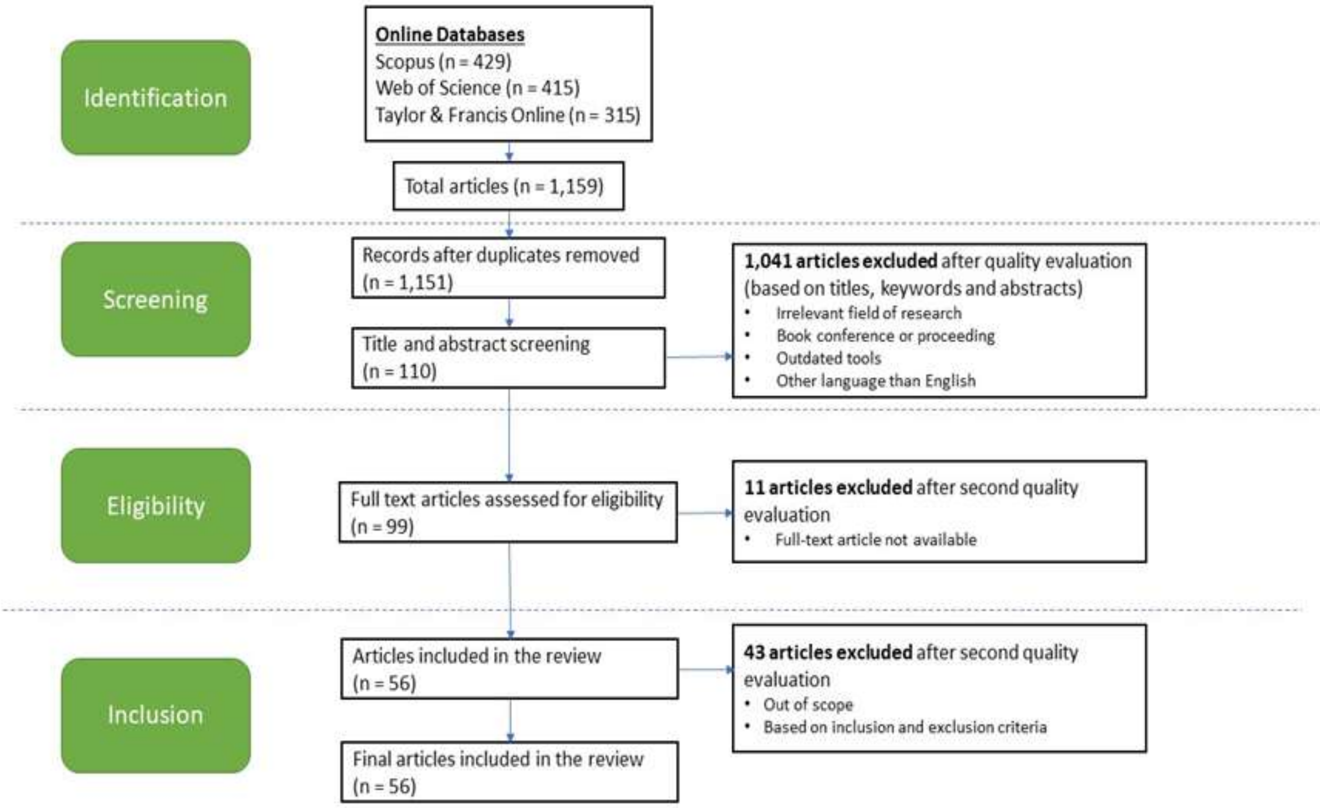

Figure 2: PRISMA Flowchart Illustration

3.7 Data Extraction

The articles from the search databases were downloaded for data extraction. In order to record the original data from the articles, a Microsoft Excel sheet was developed which including the basic information (i.e.: title, author/s, publication year, search source, type of technology, method of study, context investigated and type of study (T: Theoretical; E: Empirical)).

RESULTS

In this section, general statistics of systematic literature review are explored in the aspects of years of publication distribution, search databases distribution, types of disruptive technology distribution and lastly distribution by types of study.

4.1 General Statistics

Total fifty-six (56) articles are included in this study after conducting the systematic search strategies. Three (3) databases which are Scopus, Web of Science and Taylor and Francis. The leading position is held by Scopus (n=33) and followed by Taylor and Francis (n=12). Only 11 articles are included from the Web of Science database. The analysis of articles shows a dominant in the year 2021 (n=14) and followed by year 2022 (n=13). In short, the general statistics of distribution for the articles are reported in this section.

4.1.1 Distribution by years of publication

The final 56 articles are spreading from year 2009 to 2022. From year 2009 to year 2017, the number of articles studied are fluctuated between one (1) and two (2) articles. Five (5) articles are included in year 2018 and dropped to three (3) articles in year 2019. The number of articles increased remarkably from year 2020, which is twelve (12) articles and reached peak in year 2021 (n=14). In year 2022, a slightly dropped in final articles obtained to thirteen (13). Table and figure below showed the percentage and number of final articles by year of publication.

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4.1.2 Distribution by Search Databases

Three (3) search online databases are utilized in this study, which are Web of Science, Taylor and Francis and Scopus. From 56 final retained articles, 33 articles (59 %) are from Scopus database. Only 11 articles (19.6%) and 12 articles (21.4%) are obtained from Web of Science and Taylor and Francis databases respectively. Table, Figure 3 and 4 respectively below depicted the number of articles distribution by databases.

Table 3: Percentage Distribution by Publication Years

Year	Numbers of articles	Percentage (%)
2009	2	3.6
2010	1	1.8
2011	2	3.6
2016	2	3.6
2017	2	3.6
2018	5	8.9
2019	3	5.4
2020	12	21.4
2021	14	25.0
2022	13	23.2
Total	56	100

Figure 3: Number of Articles versus Year of Publication

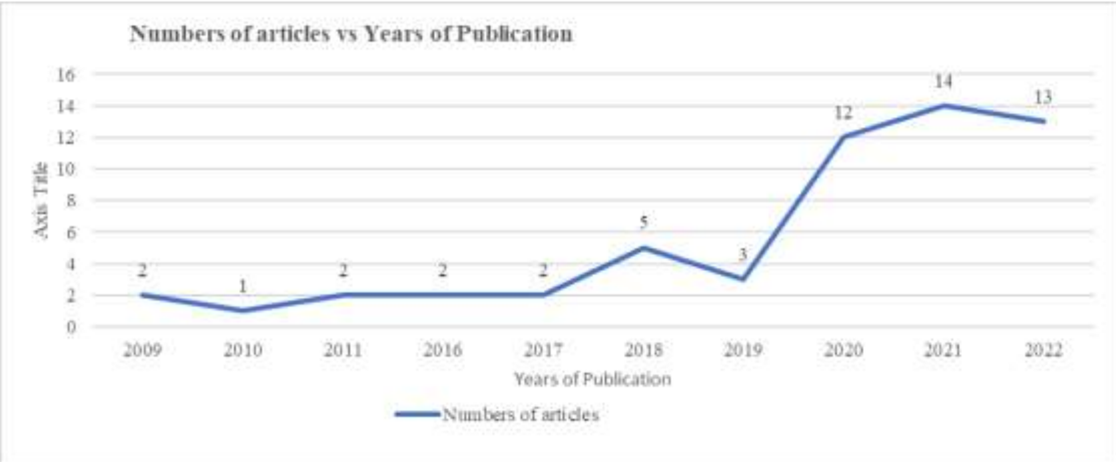

Table 4: Percentage Distribution by Databases

Database	Numbers of articles	Percentage (%)
Web of Science	11	19.6
Taylor & Francis	12	21.4
Scopus	33	59.0
Total	56	100

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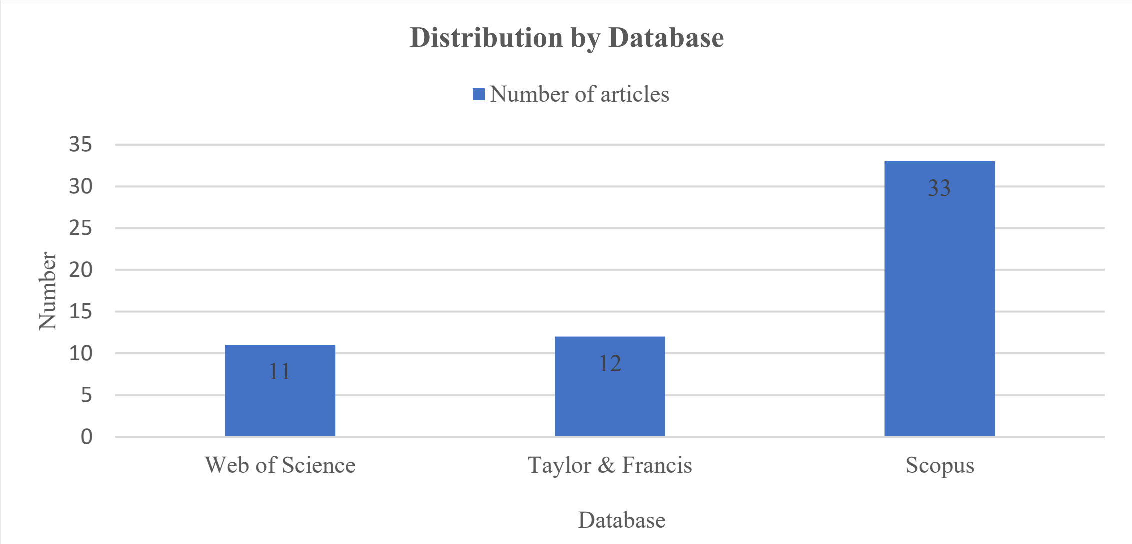

Figure 4: Number Distribution by Three (3) Databases

4.1.3 Distribution by Disruptive Technologies Application

Numerous disruptive technologies are assessed from the final retained articles, such as Radio-frequency identification (RFID), Internet of Things (IoT), Autonomous vehicle (AV), Building Information Modelling (BIM), Intelligent transportation system (ITS), sensors (wireless and wired), blockchain technology and etcetera. Additionally, some articles also discussed several types of disruptive technologies in the single paper. Table and Figure 5 respectively indicated the percentage distribution of articles by different types of disruptive technologies.

Table 5: Percentage Distribution by Disruptive Technologies

Disruptive technology/ies	**Numbers of articles**	**Percentage (%)**
Radio-frequency identification (RFID)	2	3.8
Drone	1	1.7
Autonomous vehicle (AV)	8	14.3
Internet of Things (IoT)	5	8.9
Building Information Modelling (BIM)	4	7.1
Augmented reality (AR)	1	1.7
Intelligent transportation system (ITS)	4	7.1
Sensors	5	8.9
Blockchain	8	14.3
AI & Big data	3	5.4
Big data + IoT + Machine learning + AI	2	3.8
Digital twin & BIM	1	1.7
BIM + IoT	1	1.7
Others (NEM, STAMP, robotic & etc.)	11	19.6
Total	56	100

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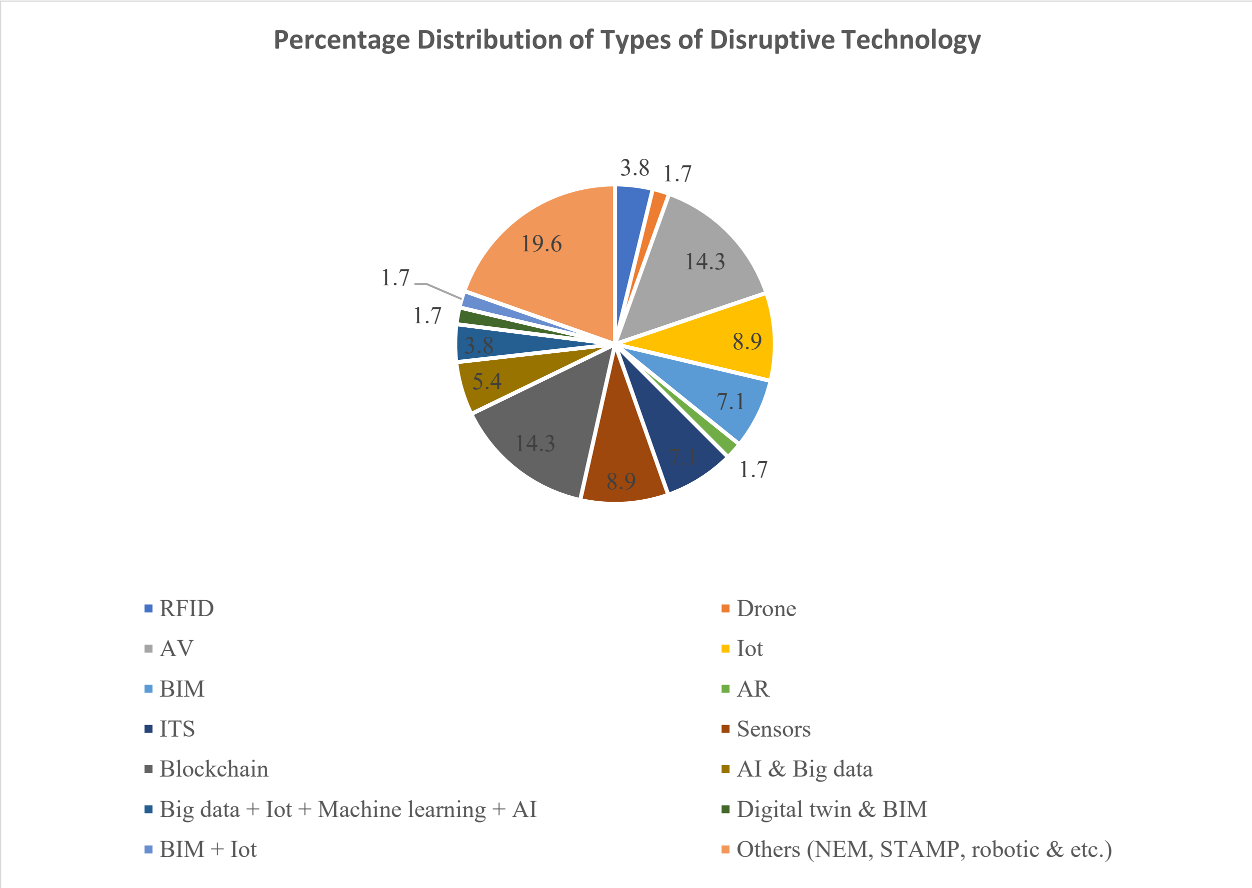

Figure 5: Percentage Distribution of Types of Disruptive Technology

4.1.4 Distribution by Types of Study

Basically, there are 2 types of study covered for the final articles, which are theoretical study and empirical study. Results showed that numbers of empirical study are prominent, which is 40 articles in total (71.4%). While there is only 16 theoretical study included in this study. Table and figure below illustrated the percentage distribution by types of study.

Table 6: Percentage Distribution by Study Types

Type of Study	Numbers of articles	Percentage (%)
Theoretical	16	28.6
Empirical	40	71.4
Total	56	100

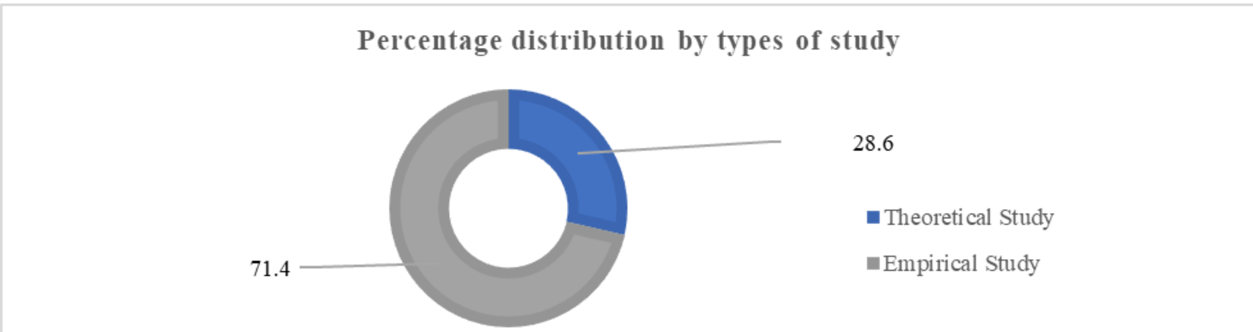

Figure 6: Percentage Distribution by Two (2) Types of Study

DISCUSSION

In this section, the research questions that have been developed in the earlier section are answered with the extracted results. The final articles from the databases are reviewed and evaluated to answer the research questions.

5.1 RQ1: What are the current disruptive technologies in operation and maintenance of road infrastructure?

According to the percentage distribution by disruptive technologies from the final articles, both Autonomous vehicle (AV) and Blockchain technologies achieved the highest numbers of article, which are 8 articles (14.3%) out of 56 articles respectively. For the articles related to AV technology, 3 articles are related to road users' experience regarding the AV, 2 articles are related to road safety and another 2 articles transportation related area and lastly 1 article concerned about automobile industry. These articles are discovered between Year 2018 to 2022. In addition, most of the Blockchain related articles are found in Architecture, Engineering, and Construction (AEC) industry, where 5 articles are discovered in this industry. While 1 article related to blockchain technology is found in each IT field, supply chain management and urban infrastructure areas. These articles are discovered between Year 2019 to 2022.

In road infrastructure, Bosurgi et al., (2021) proposed an effective and reliable solution on pavement maintenance management in I-BIM environment which combining traditional and modern processes. The solution was entirely tested on a real scenario in Southern Italy, and found to be stable and helpful in identifying the road conditions and needs. Furthermore, Trubia et. al. (2020) claimed that Smart Roads Environment (SRE) comprises real time monitoring, analysis and accounting of users behaviours, journey planners, intelligent road lights and signals, parking and loading areas, sensors and ITS (Intelligent Transport Systems). The authors stated that SRE can assure optimal effective cooperation between infrastructure, users and vehicles by sharing data information.

Singh et. al. (2021) discussed the significance of the digitalization of highways that supporting band realizing a sustainable environment on the highways. Five (5) subcomponents of digitalization are categorised in their paper, namely smart highway lighting system, smart traffic and emergency management system, renewable energy sources in highways, smart display and AI in highways. The authors addressed a hybrid architecture for highways digitalization and declared that digitalization of highways is the prominent answer for achieving the goals of the UN 2030 agenda.

In short, limited journal articles were found in this SLR study especially in road infrastructure operation and maintenance stage as disruptive technologies like blockchain, IoT, big data, AI and etcetera. Although these technologies are getting plenty of interests and attentions but not much on-field adoptions are discovered.

5.2 RQ2: What is the stage of adoption of disruptive technologies in operation and maintenance of road infrastructure?

Smart Road Environment (SRE) is the combination of several systems, such as real time monitoring, journey planner, sensors, intelligent road lights and signals, analysis and accounting of users behavior and ITS (Intelligent Transport Systems). Trubia et. al. (2020) explored the SRE in the transport sector and mainly focus on the ITS system. The authors found that ITS devices are still expanding worldwide with positive expectations on the market for future years. Results show that the ITS market in North America and Europe increased steadily from Year 2017 to 2022. In overall, The ITS market in North America is less than in Europe.

Furthermore, Oke et al., (2022) studied on the benefits of augmented reality technology (ART) in the Nigerian construction sector and they noted that 51.8% of the respondent were aware of the ART, while 30.1% were not aware of ART and the rest of 18.1% of respondents were not sure whether they aware or not. This implies that more than half of the population were aware and have relative knowledge of ART. Additionally, the authors also discovered the awareness level of respondents on ART collaboration with numerous ICT tools. More than half of the respondents (50.6%) were aware of ART collaboration with various ICT tools while 37.3% of them were not aware of ART association with various ICT tools. Only 18.1% of the respondent were not sure if they are aware of ART collaboration with various ICT tools.

Blockchain technology is an emerging technology which provides a ground-breaking way to solve current system ineffectiveness. Recently, many countries like the United Arab Emirates, United States, Australia, Singapore, China, Georgia, and so on have started adopting blockchain technology either experimentally or at the level of production services (Alketbi, et al., 2018; Jun, 2018; Kshetri, 2021). The UAE have taken the initiatives to implement blockchain with a plan to switch 50% of the government's trades to blockchain platforms by 2025 (Altaei et. al., 2019) but it is noted that the adoption process of the blockchain technology facing many challenges and the UAE is in its early stages of blockchain adoption. Salimet. al. (2022) studied the mediation and moderation roles of the perceived cost on the relationship between organization readiness and the intention to adopt blockchain. The authors found that blockchain technology has not yet been fully implemented in the UAE and the actual users of blockchain technology are hard to be found.

5.3 RQ3: What are the factors influencing the adoption of disruptive technologies in operation and maintenance of road infrastructure?

As the disruptive technologies are quite fresh and recent in the construction industry especially in road infrastructure operation and maintenance stage, factors that affecting the adoption of disruptive technologies can be discovered in final SLR articles. First of all, Bukhsh and Stipanovic (2020) determined the factors affecting the predictive maintenance (PdM) adoption for infrastructure asset management. They concluded that long term digitalisation strategies from top management is crucial for PdM implementation and adoption for asset management. Additionally, there are few factors that affecting the PdM from the business viewpoint, like lack of understanding about role of PdM in decision making process, lack of straightforward measurement to estimate the return on investment (ROI) of PdM projects, and lastly extensive investments in technologies are needed for PdM adoption and it could possibly change the legacy practices and systems of the organisations.

Study also carried out by Velsberg, et al., (2020) about the role of IoT in public sector innovation in creating and delivering smart winter road maintenance services. The authors concluded that efficiency is a critical factor for public organisation when considering the IoT investment. Efficiency can be recognized from internal and external perspectives. Internal efficiency ensures the public official constantly has a thorough overview of road status and how the service contractors are performing, while external efficiency means the trustworthy information to citizens can be provided by the public officials by using the IoT solution whenever they inquired or had comments about the road maintenance. Lekan, et al., (2021) carried out research on identifying the adaptable areas of Construction 4.0 in design, planning, construction and maintenance as well as studying the industrial application drivers of Industry (I4.0) and Construction (C4.0) hindrances in achieving C4.0. The authors investigated the issues and challenges involved in achieving sustainable innovation in infrastructural development and found that "People psychological attachment to old ways of doing things" issue ranked first and "Educational underdevelopment" issue ranked second among the challenges. Besides that, "Unwillingness to transfer the skill to learners on projects" issue is the third important challenge when moving toward C4.0.

A study about the driving forces of smart road transformation and adoption in the UK was carried out by Suresh et. al. (2020). Results illustrated that 63% of the interviewees noted maintenance as a big challenge in the current road network due to the old road infrastructure of the UK and the implementation of smart road transport elements is in infancy stage. Furthermore, the critical factor that affecting the adoption of smart infrastructure in the UK road system is the investment issue, where overwhelmingly 94% of the interviewees acknowledged this barrier factor. Besides that, around 88% of the interviewees also claimed that the state of readiness is another barrier of smart road transport adoption. Generally, the adoption and implementation of the smart technologies are still in the infancy stage in many countries and both government and private stakeholders play important roles in driving and encouraging the smart technology solutions in the infrastructure operations and maintenance.

CONCLUSION AND RESEARCH LIMITATIONS

As a conclusion remarks, based on the results of the study, it can be concluded that the adoption of disruptive technologies in the operation and maintenance of road infrastructure is still in its infancy stage. Although stakeholders acknowledge the benefits of these technologies, there are several factors and barriers preventing their widespread adoption. The findings of the study indicate the need for further research to explore ways of overcoming these barriers to adoption. Future studies could examine the specific challenges that need to be addressed and identify potential solutions. This could involve exploring new business models, developing policies and regulations that promote the adoption of these technologies, and addressing issues related to cost and infrastructure.

Overall, the study highlights the importance of understanding the current state of adoption of disruptive technologies in the operation and maintenance of road infrastructure. It provides a starting point for further research in this area and underscores the need for continued exploration of this topic.

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