A SYSTEMATIC LITERATURE REVIEW ON THE EFFICIENCY OF HEAT REFLECTIVE ASPHALT PAVEMENTS TO REDUCE URBAN HEAT ISLANDS

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SCHOOL OF CIVIL ENGINEERING
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by

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ABSTRAK

Turapan asfalt menyerap dan menyimpan lebih banyak haba berbanding bahan semulajadi. Oleh itu, haba yang dibebaskan daripada turapan asfalt konvensional, ke atmosfera menyumbang kepada fenomena pulau haba bandar (UHI). Peningkatan suhu bandar memberi kesan buruk kepada kebolehdiaman bandar. Kajian terdahulu telah membuktikan bahawa suhu turapan mempunyai pengaruh yang kuat terhadap suhu udara sekeliling. Memandangkan permukaan turapan meliputi sebahagian besar fabrik bandar, kadar penyimpanan haba dalam bahan turapan yang rendah akan menyumbang kepada usaha mitigasi UHI. Oleh itu, teknologi turapan sejuk seperti turapan reflektif haba, termasuk penyediaan bahan tambah dan pengubahsuai, salutan permukaan dan reka bentuk lapisan, telah diperkenalkan untuk mengurangkan kesan UHI. Kajian literatur sistematik (SLR) ini tertumpu kepada kecekapan turapan asfalt reflektif haba untuk mengurangkan UHI. Selain itu, SLR ini juga mengkaji pelbagai bahan dan teknik yang digunakan untuk mencapai keupayaan pemantul haba yang lebih baik. Sementara itu, kajian terperinci terhadap mekanisme, faedah dan kelemahan turapan reflektif haba telah dijalankan. Kajian ini penting untuk memberikan pemahaman yang lebih baik dan bertindak sebagai asas yang kukuh untuk penambahbaikan dalam bidang ini. SLR ini dirancang mengikut kaedah pelaporan pilihan untuk semakan sistematik dan meta-analisis (PRISMA) bagi mengelakkan keputusan berat sebelah dan meningkatkan kesahihan data yang diekstrak dan disintesis. Tambahan pula, terdapat sejumlah 35 kertas kerja yang dirujuk dalam SLR ini dikaitkan dengan bahan tambahan lain melalui rujukan silang. Strategi carian sistematik telah digunakan untuk menyaring artikel yang tidak berkaitan, dan penilaian kualiti artikel juga digunakan untuk mengelakkan penerbitan kualiti metodologi yang lemah. Semakan ini berasaskan tempoh 10 tahun penyelidikan terakhir (2012–2022) dalam bidang kejuruteraan turapan dan boleh memberi panduan kepada penyelidik di masa hadapan untuk memaksimumkan potensi turapan asfalt pantulan haba dalam mengurangkan kesan UHI.

ABSTRACT

More heat is absorbed and stored by asphalt pavements than by natural surfaces. As a result, conventional asphalt pavements emit high temperatures that release heat into the atmosphere and contribute to the phenomenon of urban heat islands (UHI). The livability of the cities is negatively impacted by the rising urban temperature. The temperature of the pavement has a significant impact on the temperature of the air around it, according to earlier studies. A lower pavement temperature will aid in the UHI mitigation efforts because the pavement surfaces make up a sizable portion of the urban fabric. In order to lessen the effects of UHI, cool pavement technologies like heat reflective pavements, which also include the provision of additives and materials, surface coating, and layer design, have been introduced. This systematic literature review (SLR) is primarily concerned with the effectiveness of heat-reflective asphalt pavements in lowering UHI. The various materials and methods used to improve heat reflective ability are also discussed in this SLR. In the meantime, a review of the mechanisms, advantages, and disadvantages of heat reflective pavement was carried out. For a deeper understanding and to serve as a solid foundation for further research in this area, these studies are crucial. To avoid bias and improve the reliability of the data extracted and synthesised, this SLR is planned in accordance with the preferred reporting items for systematic review and meta-analysis (PRISMA). A total of 35 papers are included in this SLR, and cross-referencing links connect them to additional supporting information. The article quality assessment is also being used to avoid publications with poor methodological quality. Systematic searching techniques have been used to weed out irrelevant articles. This review examined the last ten years of pavement engineering research (2012–2022) and may offer suggestions for future researchers looking to maximise the ability of heat-reflective asphalt pavement to reduce UHI effect.

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LIST OF ABBREVIATIONS

BIPG	Blue Impala Polished Granite
CASMAs	Coarse Ceramic Waste Aggregate
HGM	Hollow Glass Micro-Sphere
LMF	Limestone Mineral Filler
PED	Primary Energy Demand
PICOS	Participants, Interventions, Comparisons, Outcomes, and Study Design
PRISMA	Preferred Reporting Items for Systematic Review and Meta-Analysis
RTPG	Rosa Tanggo Polished Granite
SHRCL	Solar Heating Reflective Coating Layer
SLR	Systematic Literature Review
SR	Solar Reflectance
TAP	Tourmaline Anion Powder
TRL	Technology Readiness Level
UHI	Urban Heat Island
UV	Ultraviolet

CHAPTER 1

INTRODUCTION

1.1 Background

The heat island, also known as the urban heat island (UHI), is a phenomenon in which the urbanised environment experiences higher temperatures and heat waves than the surrounding suburban and rural areas (Synnefa et al., 2011). The UHI effect is a localised warming effect caused by a combination of radiative trapping, increased heat storage, wind obstruction, reduced vegetation, low surface permeability, and high concentrations of human activity in urban areas. UHI is one of the most serious problems that humans are currently facing as a result of industrial urbanisation. It is caused by both man-made and natural factors (Maria et al., 2013). Solar radiation raises ambient temperatures, and residual heat passes through surfaces, affecting the environment indirectly (Naserikia et al., 2019). Severity of UHI directly proportional to the population of metropolitan areas, particularly in large cities. Over 400 major cities around the world have been affected by the UHI effect, causing growing concern among scientists around the world (Santamouris, 2015). Figure 1.1 shows the UHI effect in different areas.

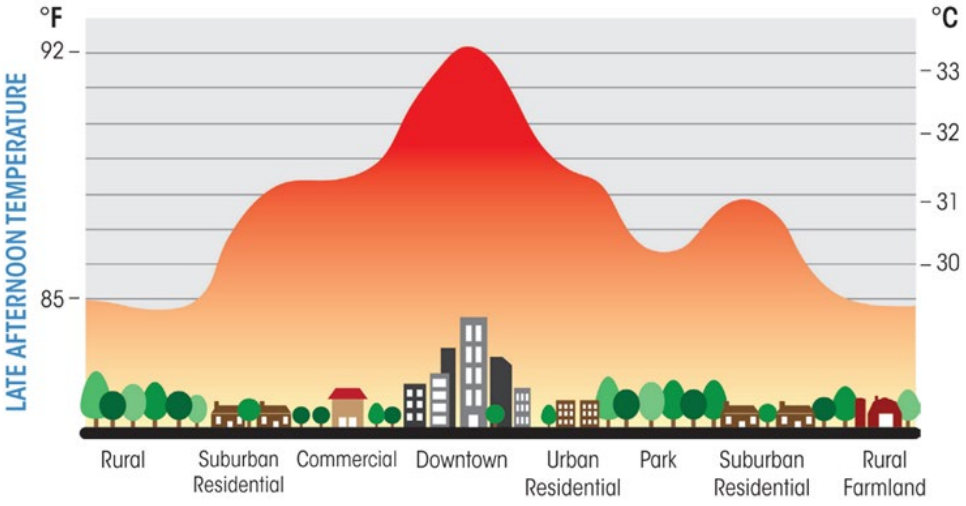

Figure 1.1: UHI effect [Source: Eco-intelligent™, 2022].

Pavements, according to much literature, played a critical role in urban thermal balance (Akbari and Kolokotsa, 2016) and significantly contributed to the UHI effect, as evidenced by satellite infrared and thermal mesoscale imagery. This was due to the large percentage of our sprawling cities' geographical area that pavements covered for solar absorption. Roof and pavement now account for 50% to 60% of urban areas as a result of urbanisation and population density (Li et al., 2020). Takebayashi and Moriyama (2012) compared the temperatures of asphalt pavement surfaces and grass, finding that the average temperature of asphalt pavement surfaces was 20°C higher than grass. Other studies have confirmed that pavements have a negative UHI effect (Zhu et al., 2021). As a consistent theme in recent studies, considering the implementation of appropriate measures to reduce pavement surface temperatures has been proven to be an effective heat land impact mitigation technology. Aside from UHI mitigation, pavement cooling can reduce waste from road maintenance, works due to rutting, ageing, and thermal cracking, thereby improving pavement durability (Santamouris, 2013). Figure 1.2 shows the heat transfer in pavements according to Aletba et al. (2021).

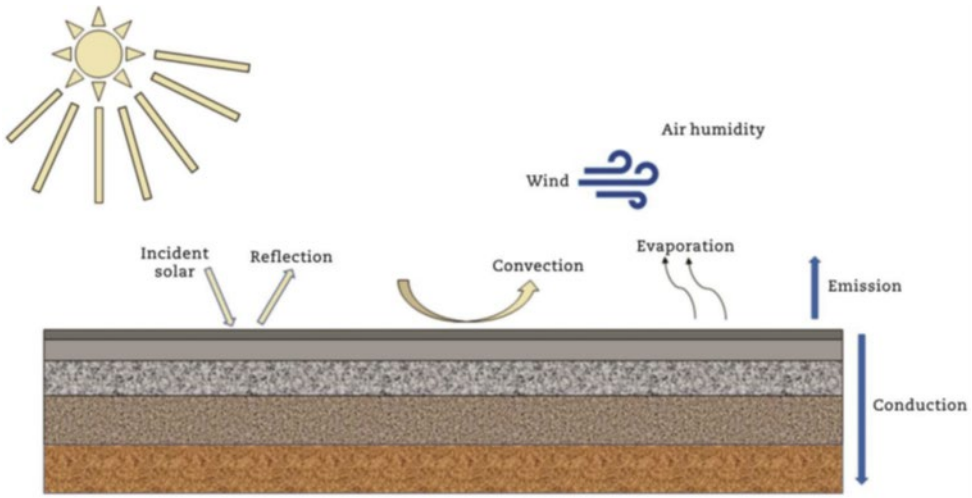

Figure 1.2: Heat transfer in pavements (Aletba et al., 2021).

Cool pavements have been studied as a strategy for mitigating the heat island effect, improving outdoor thermal comfort, and possibly reducing energy use. Any new

paving material or design technology that reduces heat transfer is referred to as cool pavements (Phelan et al., 2015; Santamouris, 2015). According to the Environmental Protection Agency, cool pavement refers to any technology that reduces heat absorption and storage in pavements, resulting in lower surface temperatures than the conventional pavement. The temperature of asphalt pavements is determined by the thermal properties of the material. As a result, the heat impact of conventional asphalt pavement materials can be reduced by using cool paving materials. Aside from material selection, another widely used strategy for reducing the impact of heat on pavements is to coat the pavement surface with various colours (Haselbach et al., 2011). Other factors that influence thermal performance include permeability and layer thickness. As shown in Figure 1.3, cool pavements can be divided into reflective pavements, evaporative pavements, and heat storage modification (Anupam et al., 2021).

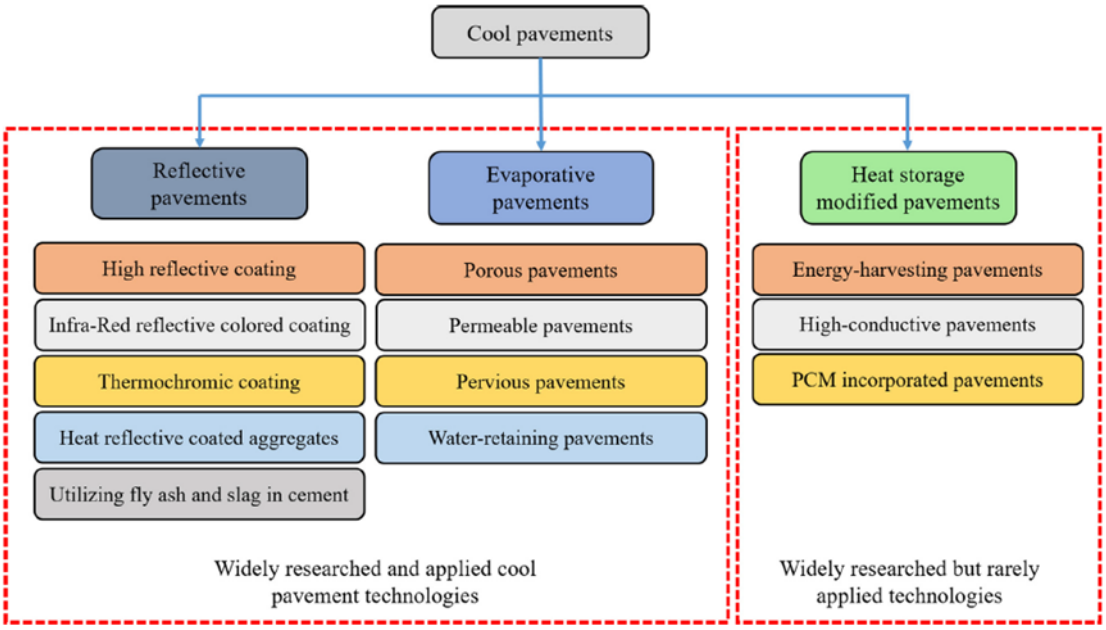

Figure 1.3: Types of cool pavement technologies (Anupam et al., 2021).

Heat reflective pavements are typically lighter in colour and have a high solar reflectance rating. Due to its light-coloured surfaces, the pavement surface has a higher solar reflectance (Anupam et al., 2022). Hence, it can reflect a large portion of incident

solar radiation. This made a significant contribution to the reduction of absorbed radiation energy, sensible heat release, and mitigation of the UHI phenomenon. Hot materials with rough and dark-coloured surfaces tended to absorb more solar radiation than cold materials with smooth and light-coloured surfaces (Santamouris and Kolokotsa, 2016). According to Xu et al. (2021), the reflective materials used on the pavement can be classified as natural material, artificial white coating, cool colour material and dynamic reflective material which including retro-reflective material and thermochromic material.

In hot summer day, the presence of alternative road surfacing with cool materials reduces ground surface temperatures by up to 14.0°C, resulting in a drop in air temperature of between 0.6°C and 1.2°C (Croce et al., 2021). However, glaring issue is a major disadvantage of reflective pavements (Cheela et al., 2021). Whereby, reflected radiations in the visible region has visually affected human eye's corona and negatively affect drivers' perception. Furthermore, reflective coatings' low durability is another shortcoming in their application that could be due to the weathering issue. Reflective pavement's thermal performance and cooling effect would be significantly harmed by the continuous exposure to sunlight, weathering, and pavement ageing (Rossi et al., 2016).

As a result, this systematic synthesis will not only review the efficiency of reflective asphalt pavement to reduce UHI effects, but it also reviews various materials and techniques used to achieve better heat reflective ability. Meanwhile, a review on the mechanism, pros, and cons of the heat reflective pavement also have been carried out. These studies are essential to provide a better understanding and act as a firm foundation for future developments in this field.

1.2 Scope of Systematic Review

The use of reflective pavements to reduce absorbed solar energy is a cost-effective way to lower pavement surface temperatures. The application of sealing, resurfacing, coating, and coloured pigments to improve the albedo and thermal performance of the pavement surface is at the forefront of reflective pavement advancements. The use of white or light-colored coatings, as well as the reduction of surface roughness, is thought to be the most effective way to reduce solar radiation absorption through surface reflectance (Santamouris, 2013). For example, a reflective coating with functional gradient multilayer structure showed an internal temperature reduction by 11.5°C to 13°C (Jiang et al., 2019). However, the reflectance of coatings reduces over time due to exposure and weathering actions (Yinfei et al., 2018). Furthermore, the reflectance of ultraviolet (UV), visible, near-infrared, and total reflectance could have negative health consequences. UV radiation, for example, has the potential to harm human skin, and visible region radiation has the potential to cause visual effects on the corona of human eyes (Santamouris, 2015). Application of fillers and pigments in the near-infrared region compared to the visible region can enhance reflectance and reduce the glare problem (Rosso et al., 2017). Despite this, there is a scarcity of scientific literature on the coatings' thermal and durability properties (Cheela et al., 2021).

Therefore, a systematic literature review is essential to review the potential materials and techniques that applied in heat reflective pavements to mitigate UHI. The mechanism, benefits, and drawbacks of different heat reflective pavements technology have been investigated to understand the characteristic of the heat reflective pavements. Lastly, the performance and cost-effectiveness of heat reflective asphalt pavements on the UHI mitigation will be evaluated thoroughly.

1.3 Review Questions

The review questions were developed in response to heat reflective pavement technology, such as the use of coating and coloured pigments, aids in lowering the pavement's surface temperature. Heat reflective technology has been given top priority in order to lower the UHI effect and improve pavement durability. The main focus of this systematic study will be on the materials and techniques that will be used, the mechanisms, advantages, and disadvantages, as well as the cooling performance and cost-effectiveness of heat reflective asphalt pavement. The following review questions are created from the related issues mentioned above:

1) What are the potential materials and techniques that applied in heat reflective asphalt pavements?
2) What are the mechanisms, benefits and drawbacks of heat reflective asphalt pavements in the reduction of UHI?
3) How is the cooling performance and cost-effectiveness of the heat reflective asphalt pavements on the UHI mitigation?

1.4 Objectives of the Systematic Review

1) To investigate the potential materials and techniques that applied in heat reflective asphalt pavements.
2) To differentiate the mechanisms, benefits, and drawbacks of different heat reflective asphalt pavements technology to reduce the effect of UHI.
3) To evaluate the cooling performance and cost-effectiveness of the heat reflective asphalt pavements on the UHI mitigation.

1.5 Significance of the Systematic Review

This study initiates to understand the efficiency of heat reflective pavement as a technology to mitigate UHI effects based on the literature review. This research provides researchers and professionals working with pavements and UHIs a valuable document that will be analysed, in-depth, the overall characteristics of heat reflective pavement.

The impact of the UHI phenomenon is due not only to the materials used in the construction of buildings, pavements, and city planning, but also to the climatic zone. This is due to the fact that different base weather conditions will have an impact on the internal city conditions. Currently, there are few state-building and urban-planning regulations that consider the effects of UHIs (Wang et al., 2021). As previously stated, the effect of the UHI is highly dependent on the climate zone, so state rules should be tailored to local regulations. These local regulations allow for the adaptation of current and future urban development conditions in the city while taking into account the local climate and the use of local materials for surface construction.

The possible advantage is achieving the sustainable development goals targets, SDG 9 (Industry, Innovation and Infrastructure), SDG 11 (Sustainable Cities and Communities) and SDG 13 (Climate Action). While efforts to address climate change, both through adaptation and mitigation, will similarly inform and shape the global development agenda. A warming climate system is expected to have an impact on many people's accesses to basic necessities like freshwater, food security, and energy. There are strong connections between climate change and sustainable development. The least developed and underdeveloped nations, in particular, will be among those most negatively impacted and least equipped to deal with the expected shocks to their social, economic, and environmental systems.

As a result, this study can be used as a foundation for the development of public policies in various decision-making organisations. To legislate certain aspects of UHIs, more forceful policy measures are required.

CHAPTER 2

SYSTEMATIC LITERATURE REVIEW (SLR): A METHODOLOGY

2.1 Introduction

A literature review is an important part of a research project. Knowledge advancement at its core should be based on previous work. It is essential to know where the knowledge frontier is in order to push it forward. It can gain a better understanding of the breadth and depth of the existing body of work by reviewing relevant literature and identifying gaps that need to be filled. It can test a specific hypothesis and/or develop new theories by summarising, analysing, and synthesising a group of related literature. It can also use a criterion to assess the validity and quality of existing work, revealing flaws, inconsistencies, and contradictions (Paré et al., 2015).

The literature review can be literally grouped into two categories which are conventional and systematic review. Generally, a conventional review is aimed at describing and discussing the topic where the author wants to. The author who has strong confidence in his view will select the paper which supports his point, left out all the one that doesn't support his point. Besides, the authors who are expert in his field, they usually present the overview in his thesis or paper with no clear methodological approach. Failure to apply the scientific principles in the review also will not produce an unbiased and reliable reviewing evidence, thus having an inaccurate conclusion (Petticrew and Roberts, 2008).

The systematic literature review (SLR) is a contrast with the traditional review. In the medical field, systematic approaches for conducting reviews of the undiscovered public knowledge have been developed with the goal of improving the quality and transparency of literature reviews by reducing biases and omissions. This type of review employs a repeatable, scientific, and transparent process. In other words, a detailed

technology that aims to minimise bias through exhaustive literature searches by providing an audit trail of the reviewers' decisions, procedures, and conclusions. The term “systematic” specifically refers to a research protocol that helps protect objectivity by providing explicit descriptions of the steps taken, such as the specific questions, the study's focus, the research strategy, and the review's inclusion and exclusion criteria (Templier and Paré, 2015).

In this chapter, the process of producing this paper were discussed in detail from the planning, conducting, and reporting stages (Figure 2.1). The review questions were formulated and pursued with a review protocol that fits the review question during the planning stage. After assessing and finalising the planning stage, the SLR was conducted by planning a search strategy, performing a quality assessment on each of the papers to be included, extracting the data needed based on the review question, and synthesizing the data carefully and systematically. At the end of the process, the results of the SLR were presented.

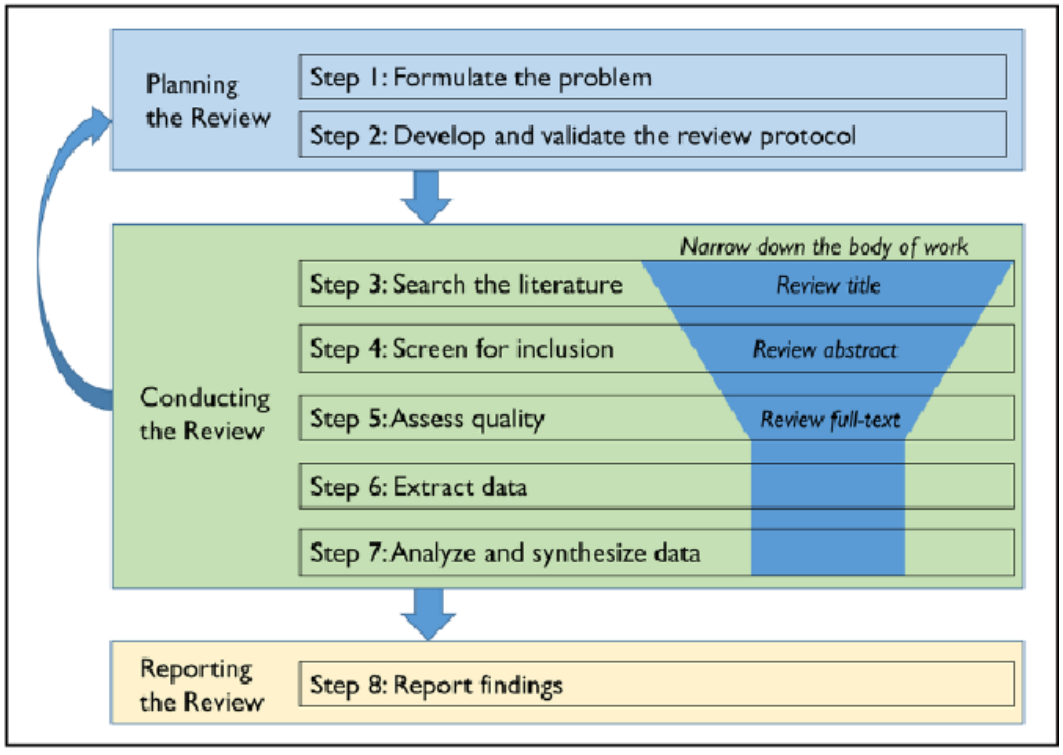

Figure 2.1: Process of systematic literature review (Xiao and Watson, 2019).

2.2 Planning of SLR

The main components in this stage are the development of a review protocol and the formulation of review questions. In a SLR, the term "plan" is frequently used to refer to the review protocol, which describes the various types of studies that will be located, evaluated, and synthesised. The goal of the planning is to reduce bias by developing a standard procedure for dealing with any conflicts that arise during the search, extraction, and analysis of the data (Brereton et al., 2007). The goal of this SLR is to evaluate heat reflective asphalt pavement as a UHI mitigation technology. Some background or understanding of the title is required because it can aid in the formation of a brief overview on how to develop sections such as the objective, review question, protocol, and methodologies (Baylissa and Beyer, 2015). A SLR, on the other hand, has a strict method for conducting the review, and a clear review protocol must be developed before the review can begin.

2.2.1 Review Protocol

A clear protocol is required before conducting a SLR because it will serve as a guide for the review. It is a pre-determined plan that outlines the methods to be used during the review. For thorough systematic reviews, the review protocol is critical (Brereton et al., 2007; Okoli, 2015). It is required for improving review quality because it eliminates the possibility of researcher bias in data selection and analysis (Kitchenham and Brereton, 2013). It also improves the review's reliability by allowing others to repeat the study for cross-checking and verification using the same protocol. The protocol of "Preferred Reporting Items for Systematic Review and Meta-analysis Statement" (PRISMA checklist 2009) was used in this study, which is widely accepted (PRISMA,

2015a). However, there is some modification on the PRISMA checklist 2009 for fitting the purpose of this engineering SLR.

The review protocol for this SLR should include all aspects of the review, such as the objective of the study, research questions, inclusion criteria, search strategies, quality assessment criteria and screening procedures, data extraction, synthesis, and reporting strategies (Gates, 2002; Gomersall et al., 2015). The review protocol is one of the main aspects that differentiate SLRs from conventional literature reviews. The protocol starts by defining the review questions, followed by a definition of the searching strategy process to be performed. The inclusion and exclusion criteria are set to provide a systematic way of selecting among identified primary studies in the searching strategy. Then, the quality of the identified studies is assessed. Subsequently, the data elements extracted from the primary studies are identified to help answer the review questions. Once the data have been extracted, the analysis/synthesis of data is performed to draw conclusions based on review questions.

Figure 2.2 shows the order in which the protocol's components are to be used. In addition, each of these elements will be discussed in depth in each of the subchapters as follows:

a) Identify review question
b) Define searching strategy
c) Define quality criteria
d) Define data extraction
e) Define data synthesis

2.2.2 Formulation of Review Questions

Literature reviews are research inquiries, and all research inquiries should be guided by research questions, as previously stated. As a result, the entire literature review

process is driven by research questions (Kitchenham and Brereton, 2013). The review's inclusion of studies, data extraction and synthesis methodology, and reporting should all be geared toward answering the research questions.

A beginner's mistake is to choose a research question that is too broad (Cronin et al., 2008). A broad research question can lead to an overwhelming amount of data being identified for the review, making it unmanageable. If this occurs, the researchers should narrow their research topic, perhaps by selecting a subtopic within the original review area. The explicit statement of the question is developed from the four major components, which are participants, interventions, comparisons, outcomes, and study design (PICOS), according to the PRISMA checklist 2009 item number 4. (PRISMA, 2015a). The above-mentioned element, however, may not be appropriate for an engineering research systematic review, as the PRISMA initiative was designed to aid in the development of healthcare interventions (Lim et al., 2014). As a result, some changes to the PRISMA checklist have been made in the development of the review question.

In this SLR, the research questions are developed from the gaps in knowledge. The timeline is narrowed to the latest 5 years (2017–2022) for studying the trend regarding cool pavement to reduce UHI effect. Scopus will be used as the database for searching for related papers to review the trend and the gap in knowledge. To identify the relevant publications, a string was developed ("cool pavement" AND "heat islands") to search (access on February 18th, 2022) within article title, abstract, and keyword in Scopus. Additionally, some inclusion criteria are imposed as follows:

1) Published between 2017 and 2022
2) Document type: article, review, book chapter
3) Source type: journal, technical reports, book

All the results in Scopus are extracted in the form of references to Microsoft Excel so as to ease the topic summarisation. There are about 96 publications throughout the

five years with the abovementioned criteria. All the papers are arranged according to the year of publication so that the development of cool pavements is easier to trace. The abstract, objectives, and conclusion of each paper have been read through in order to understand the topic well. After that, all this information in every paper is summarised according to years, as shown in Table 2.1, whereas Figure 2.2 shows the number of articles throughout 2017–2022 with a search string for topic review purposes.

Table 2.1: Review topic summary from year 2017 to 2022.

Year	Summary
2017	1. Technologies of heat reflective pavement – Infrared-reflective (IR) pigments, Cool coating layer, Waste tiles. 2. Technologies of other cool pavement – Evaporative technologies. 3. Effectiveness of various urban heat mitigation strategies.
2018	1. Technologies of heat reflective pavement – Increase albedo, Natural coating, Waste tiles. 2. Technologies of other cool pavement – Water retaining pavement, Permeable pavement, Photocatalytic pavement. 3. Effectiveness of various urban heat mitigation strategies 4. Ageing of reflective cool materials.
2019	1. Technologies of heat reflective pavement – Reflective coating, Cool pigment material. 2. Technologies of other cool pavement – Water retaining pavement. 3. Effectiveness of various urban heat mitigation strategies
2020	1. Technologies of heat reflective pavement – Reflective coating, Phosphorescent materials, Retro-reflective materials. 2. Technologies of other cool pavement – Pavement watering, Phase-changing pavement, Permeable pavement. 3. Effectiveness of various urban heat mitigation strategies 4. Compare among technologies of cool pavement 5. Weathering of coating materials
2021	1. Technologies of heat reflective pavement – Increase albedo, Cool coating layer. 2. Technologies of other cool pavement – Permeable pavement, Evaporative pavements, Reflective pavement, Water retaining pavement, Phase-changing pavement, Pavement solar collector. 3. Effectiveness of various urban heat mitigation strategies
2022	1. Technologies of heat reflective pavement – Cool coating layer. 2. Technologies of other cool pavement – Permeable pavement.

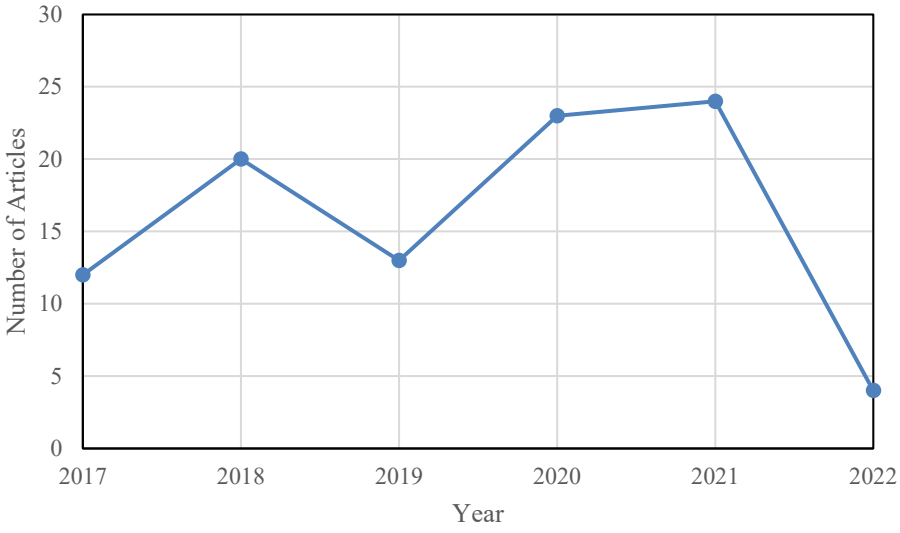

Figure 2.2: Number of articles throughout 2017-2022 with search string for topic review purpose.

Each year, the subtopic and description are almost identical, with different types of technologies being used on pavement to mitigate the UHI effect. Besides heat reflective pavement, some research has also been done on other technologies such as permeable pavement, evaporative pavement, water-retaining pavement, etc., which are excluded from this SLR. Research has been done on different cooling materials to improve the solar reflectance of pavement, particularly on heat reflective pavement. For example, infrared-reflective pigments, cool coating layers, waste tiles, phosphorescent materials, retro-reflective materials are intensively studied. There are a lot of studies about the performance of heat reduction as well as the cost-efficiency of heat reflective pavement. However, there are limited papers studied about the durability and performance of the heat reflective pavement against the weathering issues caused by the pollution from the environment. Besides, the reflectance of ultraviolet (UV), visible, near-infrared, and total reflectance could have negative health consequences. The UV radiation, for example, has the potential to harm human skin, and visible region radiation has the potential to cause visual effects on the corona of human eyes (Georgakis et al.,

2014). It is important to take into account the criteria mentioned to have a strong foundation for future development, particularly in heat-reflective asphalt pavement. Hence, this review answers the following primary research questions:

1) What are the potential materials and techniques that applied in heat reflective asphalt pavements?
2) What are the mechanisms, benefits and drawbacks of heat reflective asphalt pavements in the reduction of heat islands?
3) How is the performance and cost-effectiveness of the heat reflective asphalt pavements on the heat island mitigation?

2.3 Conducting of SLR

It is more focused on the searching and processing of the research article during the conducting stage. By using the main term from the topic and objective, systematic searching strategies are used to find the related article from the database. The articles are then filtered to eliminate irrelevant and duplicated content, leaving only the most important content. A quality assessment for the selected article was carried out after the article has been found in the database. One of the article appraisals is quality assessment, which shows how well an article's sensitivity and accuracy can be met with the review question or objective (Carroll et al., 2013). As a result, the review is less biased and more reliable. The procedure for extracting data from each article, such as the author, the objective, and the result, are referred to as data extraction. Meanwhile, the data synthesis section is in charge of synchronizing all of the articles in order to arrive at a solution to the review question. The combined result of this SLR was categorised under major themes or subthemes because it is qualitative (Brereton et al., 2007). As a result, the information extracted from each article will be presented in a table, allowing for easy comparison and display of the articles' contradictions and similarities.

2.3.1 Systematic Searching Strategies

As shown in Figure 2.3, the search framework follows the PRISMA flow diagram, which consists of four steps such as identification, screening, eligibility, and inclusion (PRISMA, 2015b). The initial search, according to the PRISMA flow diagram, is made up of several databases; however, in this SLR, Scopus will be the only database searched. Although the final included article comes from a single database, it has no bearing on the search results, and thus meets the criteria in the PRISMA checklist 2009 (item no 8) (PRISMA, 2015a).

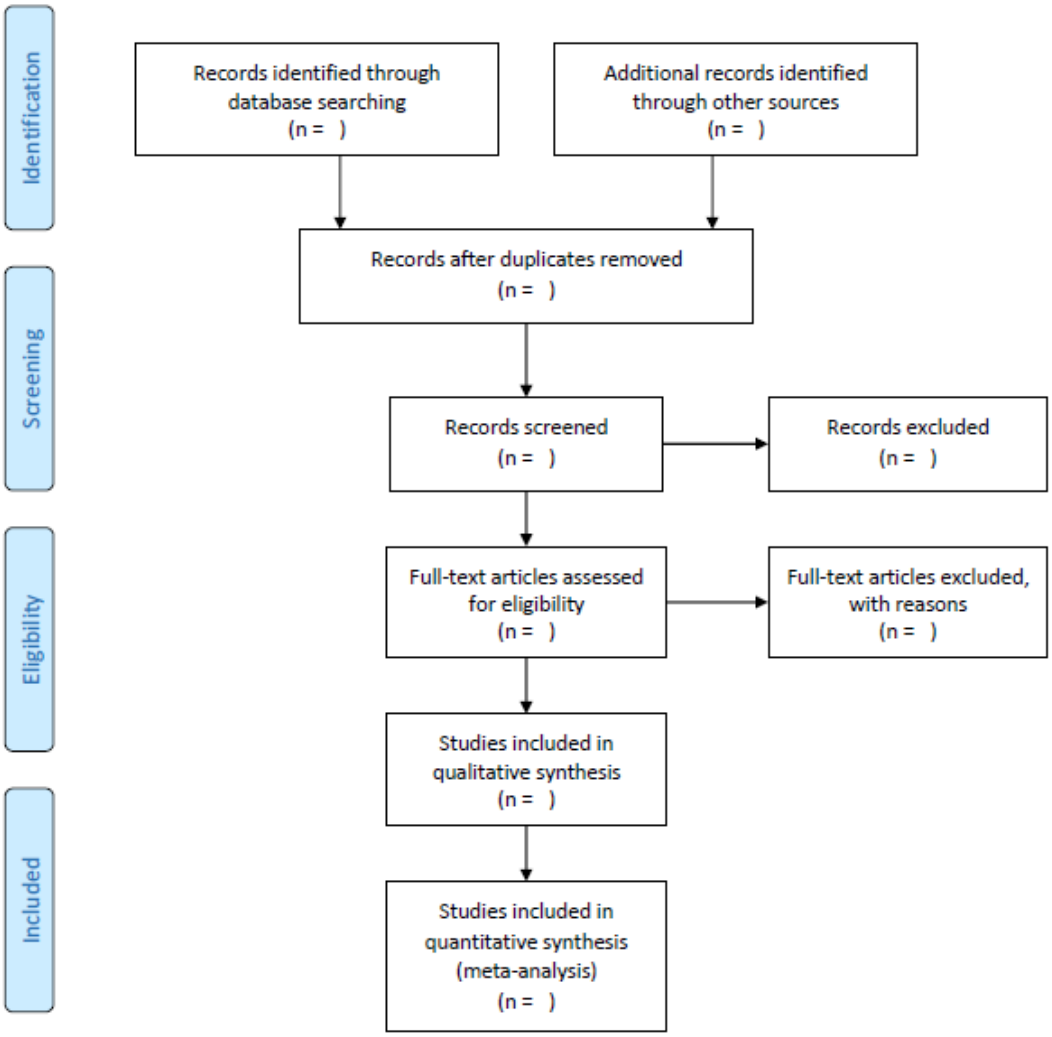

Figure 2.3: PRISMA 2009 Flow Diagram

2.3.1(a) Identification

In order to develop a comprehensive search strategy, the first phase of search strategy is identification. It is subdivided into several steps as follows:

a) Identify the keyword from the objective (related to the review question).
b) Enrich the terms
c) Create a search string

There are three objectives in this SLR that are related to the review questions. The concept domain and other important elements are used to identify a keyword (Kitchenham and Brereton, 2013). Table 2.2 showed the main terms derived from the three objectives as stated in Section 1.4.

Table 2.2: Main terms derived from the 3 objectives.

Main terms (from Objective 1)	Main terms (from Objective 2)	Main terms (from Objective 3)
1. Potential 2. Materials 3. Techniques 4. Heat reflective asphalt pavements	1. Mechanisms 2. Benefits 3. Drawbacks 4. Heat reflective asphalt pavements 5. Reduction 6. Heat islands	1. Performance 2. Cost-effectiveness 3. Heat reflective asphalt pavements 4. Heat island 5. Mitigation

Synonyms, abbreviations, alternative spellings, and other related terms, according to an article (Rowley and Slack, 2004), can spread the search statement listed. For example, the synonyms of “business” can be “enterprise” and “firm.” The terms related to “continuity” are “impact,” “recovery,” and “resilience”/ “resiliency.” “Natural disaster” can be further broken down into “flood,” “hurricane,” “earthquake,” “drought,” “hail,” and “tornado” (Xiao and Watson, 2019). There are also additional guidelines for enriching the keyword through free-text searching (also known as "natural language" or "daily language use") (Levy and Ellis, 2006). Both of these methods are used to generate comprehensive keywords for a search string using Boolean operators. Many search

engines allow to search using Boolean operators. It's critical to understand how to build search strings with Boolean "AND" and "OR" operators (Flemming, 2010). "AND" is frequently used to join main terms and "OR" to include synonyms (Brereton et al., 2007). To further narrow down the topic, the Boolean operators are used as a link to combine the main terms and their respective synonyms (Kitchenham and Brereton, 2013). The search string and its main terms are listed in Tables 2.3, 2.4, and 2.5, respectively.

Table 2.3: Enrich the term and search string from Objective 1

Main term	Potential	Materials	Techniques	Heat reflective asphalt pavements
Enrich term	1. Possible 2. Likely 3. Prospective 4. Probable 5. Latent 6. Developing	1. Matter 2. Substance 3. Stuff 4. Medium	1. Method 2. Approach 3. Procedure 4. Process 5. System 6. Way 7. Manner 8. Mode 9. Style 10. Strategy 11. Practice 12. Tactic	1. Solar reflective asphalt pavement 2. Cool asphalt pavement
Search string: ("potential" OR "possible" OR "likely" OR "prospective" OR "probable" OR "latent" OR "developing") AND ("material*" OR "matter*" OR "substance*" OR "stuff*" OR "medium*") AND ((heat reflective asphalt pavement*) OR (solar reflective asphalt pavement*) OR (cool asphalt pavement*)) ("potential" OR "possible" OR "likely" OR "prospective" OR "probable" OR "latent" OR "developing") AND ("technique*" OR "method*" OR "approach*" OR "procedure*" OR "process*" OR "system*" OR "way*" OR "manner*" OR "mode*" OR "style*" OR "strateg*" OR "practice*" OR "tactic*") AND ((heat reflective asphalt pavement*) OR (solar reflective asphalt pavement*) OR (cool asphalt pavement*))				

Table 2.4: Enrich the term and search string from Objective 2

Main term	Mechanisms	Benefits	Drawbacks	Heat reflective asphalt pavements	Reduction	Heat islands
Enrich term	1.Procedure 2.Process 3.System	1. Good 2. Satisfaction 3. Advantage	1. Disadvantage 2. Downside 3. Weakness	1. Solar reflective	1. Depletion 2. Mitigation 3. Limiting	1. Urban heat-

	4. Operation 5. Method 6. Technique	4. Comfort 5. Merit 6. Strength 7. Strong point 8. Usefulness 9. Helpfulness 10. Value	4. Defect 5. Imperfection 6. Fault 7. Limitation 8. Issue 9. Hindrance	asphalt pavement 2. Cool asphalt pavement	4. Easing 5. Alleviation 6. Lowering	island effect 2. Urban heat island 3. Heat island effect
Search string: ("mechanism*" OR "procedure*" OR "process*" OR "system*" OR "operation*" OR "method*" OR "technique*") AND ((heat reflective asphalt pavement*) OR (solar reflective asphalt pavement*) OR (cool asphalt pavement*)) AND ("reduction" OR "depletion" OR "mitigation" OR "limiting" OR "easing" OR "alleviation" OR "lowering") AND ((heat island*) OR (urban heat-island* effect*) OR (urban heat island*) OR (heat island* effect*)) (“benefit*” OR “good” OR “satisfaction” OR “advantage*” OR “comfort*” OR “merit*” OR “strength*” OR “strong point*” OR “usefulness” OR “helpfulness” OR “value*”) AND ((heat reflective asphalt pavement*) OR (solar reflective asphalt pavement*) OR (cool asphalt pavement*)) AND ("reduction" OR "depletion" OR "mitigation" OR "limiting" OR "easing" OR "alleviation" OR "lowering") AND ((heat island*) OR (urban heat-island* effect*) OR (urban heat island*) OR (heat island* effect*)) ("drawback*" OR "disadvantage*" OR "downside*" OR "weakness" OR "defect*" OR "imperfection*" OR "fault*" OR "limitation*" OR "issue*" OR "hindrance*") AND ((heat reflective asphalt pavement*) OR (solar reflective asphalt pavement*) OR (cool asphalt pavement*))						

Table 2.5: Enrich the term and search string from Objective 3

Main term	Performance	Cost-effectiveness	Heat reflective asphalt pavement	Heat island	Mitigation
Enrich term	1. Accomplishment 2. Achievement 3. Fulfilment	1. cost-effective 2. cost-benefit 3. cost-efficient 4. cost-based 5. cost-cutting 6. cost-effectively 7. low-cost 8. economical 9. customer-friendly	1. Solar reflective asphalt pavement 2. Cool asphalt pavement	1. Urban heat-island effect 2. Urban heat island 3. Heat island effect	1. Alleviation 2. Reduction 3. Diminution 4. Easing 5. Weakening 6. Relief
Search string: ("performance*" OR "accomplishment*" OR "achievement*" OR "fulfilment*") AND ((heat reflective asphalt pavement*) OR (solar reflective asphalt pavement*) OR (cool asphalt pavement*)) ("cost-effectiveness" OR "cost-effective" OR "cost-benefit" OR "cost-efficient" OR "cost-based" OR "cost-cutting" OR "cost-effectively" OR "low-cost" OR "economical" OR "customer-friendly") AND ((heat reflective asphalt pavement*) OR (solar reflective asphalt pavement*) OR (cool asphalt pavement*))					

The above strings were used in the database (Scopus) to search only within the title, abstract and keyword of articles. In this SLR, there are only three review questions formulated in order to answer the objectives of this study.

However, the search string that develops from each of the review questions will limit the search results as there are more than two components involved in each of the review questions. For example, the review question (1) requires two basic pieces of information, which are potential materials and potential techniques to perform heat reflective asphalt pavements. If the search string involved both requirements ("materials" and "techniques"), there is a high possibility to limit the paper searching as there are a lot of papers that cover only the topic of "materials" but not the "techniques". On the other hand, there are also a lot of papers that cover the topic of "techniques" but not the "materials". As a result, in order to obtain as many papers as possible to perform the data extraction, the review questions as mentioned earlier were further divided into more specific review questions for searching purpose as shown below:

1) What are the potential materials that applied in heat reflective asphalt pavements?
2) What are the potential techniques that applied in heat reflective asphalt pavements?
3) What are the mechanisms of different heat reflective asphalt pavements technology in the reduction of heat islands?
4) What are the benefits of heat reflective asphalt pavements in the reduction of heat islands?
5) What are the drawbacks of heat reflective asphalt pavements in the reduction of heat islands?
6) How is the cooling performance of heat reflective asphalt pavements on heat island mitigation?
7) How is the cost-effectiveness of heat reflective asphalt pavements on heat island mitigation?

Figure 2.4 shows the results for the search string based on objective 1 yields 82 articles, the search string based on objective 2 yields 62 articles, and the Objective 3 search strings obtained 88 articles. Table 2.6 shows how all of the information from these searches is recorded and computed. This allows to go back and retrace the literature search, as well as repeat the search on the database and source on a regular basis, in the hopes of finding new material that has surfaced since the initial search (Okoli, 2015).

Table 2.6: Search string information

Related statement	Search string applied in Scopus	Number of the article (identification stage)
Objective 1	TITLE-ABS-KEY(("potential" OR "possible" OR "likely" OR "prospective" OR "probable" OR "latent" OR "developing") AND ("material*" OR "matter*" OR "substance*" OR "stuff*" OR "medium*") AND ((heat reflective asphalt pavement*) OR (solar reflective asphalt pavement*) OR (cool asphalt pavement*)))	41
	TITLE-ABS-KEY(("potential" OR "possible" OR "likely" OR "prospective" OR "probable" OR "latent" OR "developing") AND ("technique*" OR "method*" OR "approach*" OR "procedure*" OR "process*" OR "system*" OR "way*" OR "manner*" OR "mode*" OR "style*" OR "strateg*" OR "practice*" OR "tactic*") AND ((heat reflective asphalt pavement*) OR (solar reflective asphalt pavement*) OR (cool asphalt pavement*)))	41
Objective 2	TITLE-ABS-KEY(("mechanism*" OR "procedure*" OR "process*" OR "system*" OR "operation*" OR "method*" OR "technique*") AND ((heat reflective asphalt pavement*) OR (solar reflective asphalt pavement*) OR (cool asphalt pavement*)) AND ("reduction" OR "depletion" OR "mitigation" OR "limiting" OR "easing" OR "alleviation" OR "lowering") AND ((heat island*) OR (urban heat-island* effect*) OR (urban heat island*) OR (heat island* effect*)))	22
	TITLE-ABS-KEY((“benefit*” OR “good” OR “satisfaction” OR “advantage*” OR “comfort*” OR “merit*” OR “strength*” OR “strong point*” OR “usefulness” OR “helpfulness” OR “value*”) AND ((heat reflective asphalt pavement*) OR (solar reflective asphalt pavement*) OR (cool asphalt pavement*)) AND ("reduction" OR "depletion" OR "mitigation" OR "limiting" OR "easing" OR "alleviation" OR "lowering")	31

	AND ((heat island*) OR (urban heat-island* effect*) OR (urban heat island*) OR (heat island* effect*)))	
	TITLE-ABS-KEY(("drawback*" OR "disadvantage*" OR "downside*" OR "weakness" OR "defect*" OR "imperfection*" OR "fault*" OR "limitation*" OR "issue*" OR "hindrance*") AND ((heat reflective asphalt pavement*) OR (solar reflective asphalt pavement*) OR (cool asphalt pavement*)))	9
Objective 3	TITLE-ABS-KEY(("performance*" OR "accomplishment*" OR "achievement*" OR "fulfilment*") AND ((heat reflective asphalt pavement*) OR (solar reflective asphalt pavement*) OR (cool asphalt pavement*)))	78
	TITLE-ABS-KEY(("cost-effectiveness" OR "cost-effective" OR "cost-benefit" OR "cost-efficient" OR "cost-based" OR "cost-cutting" OR "cost-effectively" OR "low-cost" OR "economical" OR "customer-friendly") AND ((heat reflective asphalt pavement*) OR (solar reflective asphalt pavement*) OR (cool asphalt pavement*)))	10

2.3.1(b) Screening

The screening stage is used to filter out irrelevant articles from the identification stage based on inclusion and exclusion criteria as shown in Table 2.7. The articles in screening stage is limited to the most recent five years of publication (2017-2022) to observe the current trend and avoid the scope of the review from becoming too broad. However, the results obtained from the database are too less to be included in the discussion. As a result, the date range in the strings is limited to the last 10 years (2012-2022). Aside from that, the document types are limited to article, conference paper, review, and all papers from journals with only English versions. After filtering the string using the aforementioned criteria, only 70, 47, and 66 papers remain, all of which are related to Objective 1, Objective 2, and Objective 3, respectively.

Table 2.7: Review criteria of the article in the screening stage.

Criteria	Inclusion	Exclusion
Timeline	2012-2022	Before 2012
Document type	Article, review, book chapter	Conference paper
Publication stage	Final	Article in press
Language	English	Non-English

2.3.1(c) Eligibility

After a filter, all of the searching articles based on each searching statement are checked for duplication. The duplicated articles will be removed, leaving only the articles that need to be reviewed. To make the process easier, all of the articles are entered and organised in Microsoft Excel, which makes it simple to find duplicates. With the help of the Excel, 30 duplicate papers were found, and the remaining ones will go through a final screening to determine which ones will be reviewed in this study. Any studies that aren't relevant will be eliminated (Xiao and Watson, 2019). Moola et al. (2015) recommends two key steps to perform the final screening. In the first step, a researcher will read the article's title, abstract, and possibly the introduction and conclusion to rule out any potentially misleading papers found through a search engine. Following that, a researcher will determine whether any key information is required for data extraction. All irrelevant papers including those that cannot be accessed in their entirety, will be excluded. There are about 35 papers left to review, but each one must go through a quality assurance process before being extracted and synthesised.