REVIEW ARTICLE

UNCOVERING KEY DRIVERS OF RISING DENGUE CASES IN MALAYSIA: A SYSTEMATIC REVIEW

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ABSTRACT

Dengue fever, a viral disease transmitted by Aedes mosquitoes, continues to escalate as a significant public health threat in Malaysia, leading to a growing burden on the healthcare system and the economy. Despite the increasing incidence, the factors contributing to the rise in dengue infections remain multifaceted and under-explored within the Malaysian context. Addressing these factors is crucial for devising more effective preventive strategies and interventions. This study provides a comprehensive examination of the complex factors driving the surge in dengue cases in Malaysia. By systematically analysing human behaviours, environmental conditions, vector dynamics, and the viral characteristics, the study aims to uncover the underlying determinants and inform targeted public health responses. A systematic review was conducted, incorporating studies published between 2011 and 2024, selected through a rigorous screening process from databases including ScienceDirect and EBSCOhost. The review adhered to the PRISMA guidelines, with quality assessments performed using the Mixed Method Appraisal Tool (MMAT) for the included 20 studies. These studies were analyzed to synthesize evidence on the key drivers for rise of dengue transmission in Malaysia. A total of 20 studies were included in this systematic review and the results were categorized into four core domains: human factors, environmental influences, vector dynamics, and virus characteristics. Human factors such as age, occupation, and socioeconomic conditions were identified as significant determinants, with older adults and those in high-risk occupations exhibiting increased vulnerability to severe dengue. Environmental conditions, particularly rapid urbanization, poor waste management, and dense population clusters, emerged as critical factors fostering mosquito breeding and transmission. The coexistence of Aedes aegypti and Aedes albopictus in both urban and rural settings exacerbated the risk. Virus-related findings revealed that DENV-3 was the dominant serotype linked to higher disease severity, while mixed serotype infections significantly heightened the risk of severe outcomes, underlining the role of viral factors in the progression of the disease. Overall, urbanisation, population density, and socioeconomic disparities were consistently identified as key drivers across the included studies. The rising incidence of dengue infections in Malaysia can no longer be attributed to a single cause but rather to an intricate interaction of human, environmental, vector, and viral factors. This study provides compelling evidence that addressing these determinants through integrated public health strategies, spanning urban planning, vector control, socioeconomic reforms, and education is essential to combat the dengue crisis. By focusing on high-risk groups, urban infrastructure, and timely medical interventions, Malaysia can better mitigate future outbreaks and safeguard its population. These findings highlight important implications for public health policy, particularly the need for integrated, multi-sectoral strategies involving urban planning, vector control, socioeconomic interventions, and community engagement. More specific actions, including strengthening surveillance systems and improving urban waste management, are essential to effectively mitigate future outbreaks.

Keywords: *Risk factor; dengue infection; dengue fever; Malaysia*

INTRODUCTION

As noted by the World Health Organisation, the emergence of dengue is associated with four distinct but closely related dengue virus (DENV) serotypes[1]. Since the first reported major outbreak in Malaysia in 1902, dengue endemic has remained prevalent and affected public health, resulting in significant societal and economic burdens[2]. The classification of dengue into dengue fever, dengue haemorrhagic fever, and dengue shock syndrome has remained widely used for reporting dengue cases in Malaysia[4-6]. Clinically, there are mild cases of dengue to more critical cases that are likely to be observed among those with secondary infection caused by a different DENV serotype[7]. Similar to the symptoms of other febrile illnesses, the initial symptoms and incidence of dengue are often misdiagnosed or underestimated[8,9]. The estimated total annual cost of USD 175.7 million for dengue prevention and illnesses in Malaysia back in 2009/2010[10]. However, the true cost incurred remains uncertain due to the lack of up-to-date comprehensive costing analyses of dengue prevention and control measures, limiting accurate estimation of the overall economic burden[11,12].

Dengue infection in Malaysia has been widely studied, with systematic reviews and meta-analyses examining multiple contributing factors. Climatic variables such as temperature, rainfall, and broader climate variability have been shown to influence dengue transmission dynamics[13,14]. Socioeconomic conditions, particularly income inequality, are also associated with rising dengue incidence[15]. In addition, vector control measures have been evaluated for their effectiveness in reducing transmission, while human behaviour, including knowledge, attitudes, and practices related to dengue prevention, has been identified as an important determinant of transmission risk[16,17].

This systematic review is necessary to address gaps in existing literature by providing a Malaysia-specific, holistic synthesis of dengue transmission factors. Unlike previous reviews that focused on isolated determinants, this study integrates human, environmental, vector, and viral factors within a unified framework. By focusing on Malaysia as a complex endemic setting, the review aims to identify key drivers and interactions shaping dengue transmission, ultimately generating actionable, context-specific evidence to inform more effective public health policies and intervention strategies.

METHODS

This systematic review was drawn up based on the updated guide lines known as PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses). The selection of databases was guided by the aim to capture region-specific and multidisciplinary studies relevant to the Malaysian context, particularly those not widely indexed in global databases. The components of mnemonic PEO (population, exposure, outcome) were identified as the following:

- Population: Malaysians.
- Exposure: associated factors for rising of dengue incidence.
- Outcome: dengue infection or dengue fever.

Search Strategy

Systematic search was conducted in the ScienceDirect and EBSCOhost databases between 1 January 2025 and 28 February 2025 using the following search terms: “Risk Factor*” AND “Dengue Infection*” OR “Dengue Fever” AND “Malaysia*”. All searches were conducted using predefined Boolean operators and consistent search strings across databases to improve reproducibility and transparency. All identified articles were exported into a Google Sheets library, and duplicate records were subsequently removed using Microsoft Excel. The selection of ScienceDirect and EBSCOhost was guided by their broad indexing of multidisciplinary research, particularly from Southeast Asia, which includes a substantial number of public health studies published in regional journals. While internationally recognized databases such as MEDLINE and PubMed which has limited coverage of region-specific literature and non-indexed local journals made them less suitable for this review, which aimed to capture studies relevant to the Malaysian context. This decision was made to increase the systematic review’s credibility

Eligibility Criteria

The inclusion and exclusion criteria were applied consistently to ensure transparency and reproducibility of the study selection process. The inclusion criteria applied were: freely accessible, full-text, English-language publications from 2011 to 2024, focusing on original article including observational study designs such as cohort, case-control, ecological, and cross-sectional studies that examined factors associated with rise of dengue infection in Malaysia. The exclusion of Malay language articles from this systematic review was primarily due to the limitations of the databases used (ScienceDirect and EBSCOhost), which predominantly index English-language publications. These databases provide access to internationally recognized studies, making it easier to synthesize findings from a global perspective. English-language articles are also more widely accessible to public health professionals and researchers, which helps ensure that the review’s insights are relevant internationally. Furthermore, including Malay language articles would require translation, potentially introducing bias, and the lack of widespread indexing of such studies presents practical challenges. While the authors acknowledge the value of local research, this review focuses on the most accessible and peer-reviewed studies.

Qualitative studies and non-original works, including conference proceedings, commentaries, reports, systematic reviews, meta-analyses, and studies employing qualitative or mixed-methods approaches, were excluded. The search, conducted up to February 2025, captured the most recent studies, ensuring a comprehensive timeline of evidence. While interventional studies are typically prioritized for establishing causality, observational studies were chosen for their ability to provide real-world data on dengue transmission dynamics. Given the scarcity of large-scale interventional studies in Malaysia, these observational studies are crucial in understanding the impact of environmental, socio-economic, and behavioural factors, especially in endemic settings where ethical and logistical challenges limit randomized controlled trials. This approach provides a robust evidence base for guiding public health interventions and policy development.

The search strategy yielded 331 unique records, with 110 articles sourced from EBSCOhost and 221 from ScienceDirect. After the removal of duplicates, the remaining 327 articles underwent an initial screening of titles and abstracts. This process led to the exclusion of 266 articles that were deemed irrelevant to the PEO components of this study. This left 61 articles for further assessment, but one could not be retrieved, reducing the total to 60 full-text publications. Following a thorough evaluation, 40 articles were excluded based on the predefined inclusion and exclusion criteria. Non-original works, such as conference proceedings, commentaries, reports, systematic reviews, and meta-analyses, were excluded for not meeting the standard of original research. Studies that utilized qualitative or mixed-methods approaches were also excluded to maintain consistency with the focus on observational study designs, including cohort, case-control, ecological, and cross-sectional studies. Additionally, any articles not specifically examining factors associated with dengue infection in Malaysia were excluded to ensure relevance to the study context. Some articles were excluded due to language barriers, as only full-text English-language publications were considered. Furthermore, articles that did not meet the rigorous quality appraisal standards set by the Mixed Methods Appraisal Tool (MMAT), particularly in terms of sampling relevance, measurement appropriateness, and statistical analysis were also excluded. After applying these carefully considered criteria, 20 original articles were selected for inclusion in this systematic review. All the above information is illustrated in Figure 1, which is referenced in the text to ensure clarity and transparency of the study selection process.

Study Selection

Two independent reviewers screened the titles and abstracts of the gathered publications based on the established criteria. Eligible articles were identified and stored for the subsequent screening and review. The third independent reviewer thoroughly reviewed potentially eligible full-text publications based on the established criteria, while the fourth reviewer dealt with any disagreements in the study selection made by the reviewers.

Critical Appraisal and Data Extraction

The quality of the selected articles was assessed using the Mixed Methods Appraisal Tool (MMAT), which evaluates methodological rigor across five core quality criteria. Data extraction was carried out by one independent reviewer, with a second reviewer verifying the extracted data. A content analysis approach, without statistical testing, was employed to synthesize the findings. Despite excluding mixed-methods studies and reviews, we selected the MMAT because its framework is applicable to a range of study designs, including observational studies. The MMAT evaluates key aspects such as relevance, representativeness, measurement appropriateness, and statistical analysis, essential for assessing the included quantitative studies. Although originally designed for mixed-methods reviews, the MMAT's structured approach ensured consistency and thoroughness in evaluating all selected studies. Although all studies met the MMAT criteria, the possibility of overestimation of study quality due to uniform scoring is acknowledged.

Data synthesis was conducted using thematic analysis within the PEO framework, categorizing factors into four domains: human, environmental, vector (Aedes mosquitoes) and pathogen (virus). While the synthesis was primarily narrative due to heterogeneity, efforts were made to compare findings across studies to identify consistent patterns and variations. This approach was chosen to accommodate the diverse study designs and the lack of statistical testing, ensuring a comprehensive understanding of the factors influencing rise of dengue in Malaysia. The data were synthesized narratively, as most of the studies included were observational, and a quantitative meta-analysis was deemed inappropriate due to the heterogeneity of study designs, populations, and outcomes. This narrative synthesis allowed the authors to identify and summarize key themes across the studies, providing a comprehensive understanding of the multifaceted drivers of dengue in Malaysia.

Ethics approval, trial registration, and consent to participate

The Universiti Putra Malaysia Ethics Committee for Research Involving Human Subjects approved this study (JKEUPM-2023-347, dated 19 June 2023). This study has also been approved for National Medical Research Registration of Malaysia (NMRR) registration on 25 September 2023 (NMRR ID-23-02823-PKM).

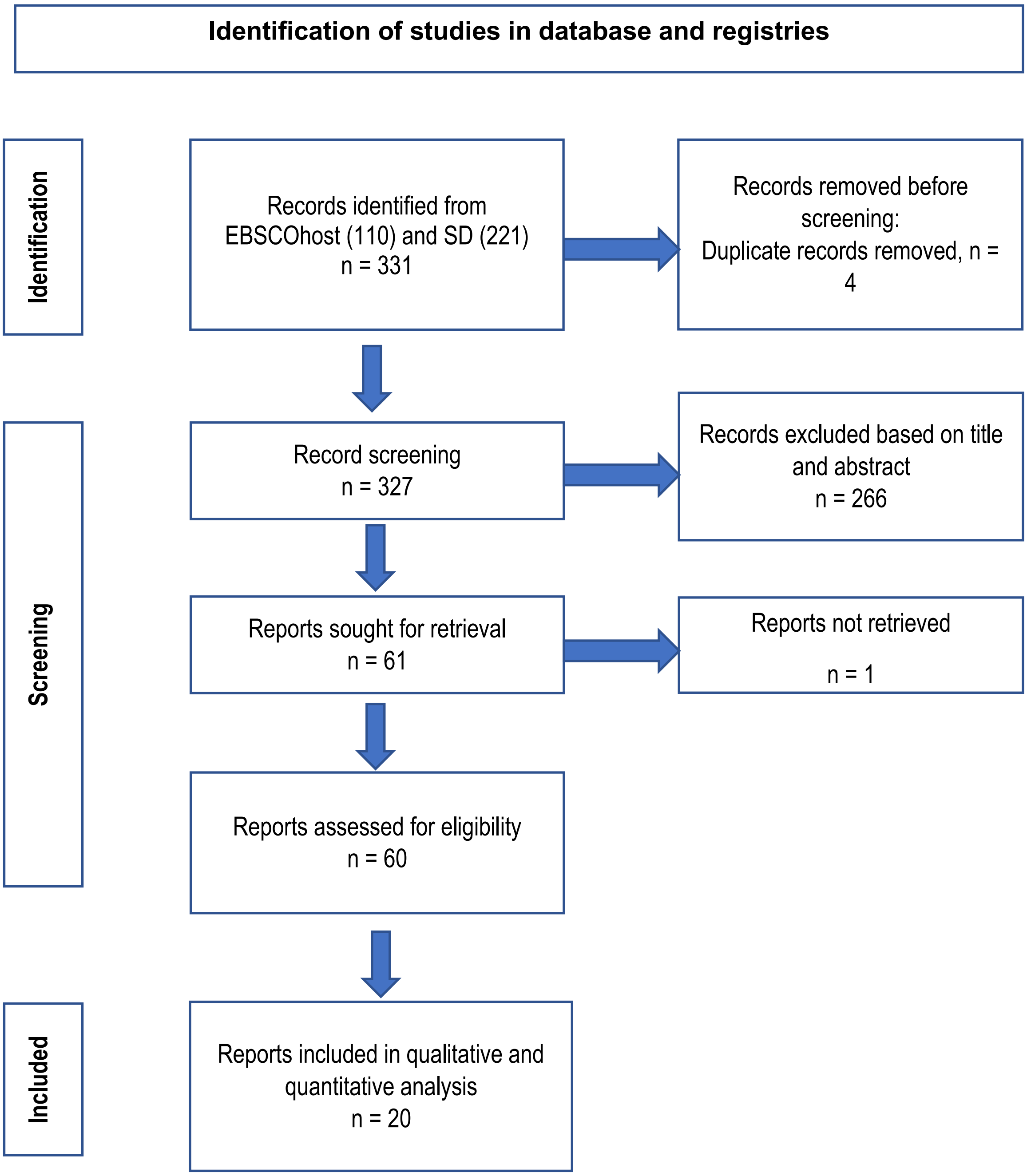

Fig 1. PRISMA flow diagram for the systematic review

RESULTS

The results of the included studies were synthesized into four key domains: (1) human factors, (2) environmental factors, (3) vector factors, and (4) virus factors. A total of 331 records were initially identified, with 110 from EBSCOhost and 221 from ScienceDirect. After removing duplicates, 327 articles underwent screening, resulting in 60 full-text articles assessed for eligibility. Following the application of inclusion and exclusion criteria, 20 studies were included in the final analysis. All the above information is illustrated in Figure 1, which is referenced in the text to ensure clarity and Transparency of the study selection process. The PRISMA flow diagram has been to improve clarity and readability. Table 1 is consistently referenced in the main text to support the synthesis of findings across the included studies.

1. Human factors: Human behavioural, sociodemographic and socioeconomic influences and their contribution to rising dengue cases in Malaysia.

Human factors, including age, socioeconomic status, occupation, housing conditions, and community behaviour, were consistently identified as significant contributors to dengue transmission in Malaysia. Age is clearly a significant factor when considering dengue susceptibility in Malaysia. The data shows a clear increase in dengue IgG seroprevalence with age, with individuals aged 45-54, 55-64, and 65-74 years being significantly more likely to test positive for the virus compared to the 35-44 age group, with the odds being 3.08, 3.89, and 3.59 times higher respectively ($p < 0.001$)[34]. This suggests that older individuals, especially those with greater cumulative exposure to the virus over time, face an increased risk of contracting dengue. Interestingly, younger populations, specifically those aged 15-29, experience the highest incidence rates, which is in line with previous findings[32]. These age-specific variations point to the need for tailored prevention and intervention measures across different age groups. Furthermore, the notion of Antibody-Dependent Enhancement (ADE) is evident in studies that show older adults, having been exposed to the virus over time, are at greater risk of severe secondary infections due to ADE, increasing the severity of the disease[35]. This variation across age groups highlights differences in exposure versus disease manifestation, indicating that risk is not uniform across populations.

Socioeconomic Factors and Public Awareness also play pivotal roles in the transmission of dengue. The higher dengue incidence among men (56.8%) compared to women (43.2%) could be attributed to their increased outdoor exposure, a key factor in vector contact[32]. Although these findings are consistent across studies, the magnitude of association varied depending on study design and population characteristics. Race also appears to influence susceptibility, with Chinese individuals having the highest number of cases, possibly reflecting differences in exposure due to urban versus rural living patterns[32]. Furthermore, occupation plays a significant role, as employed individuals, especially those in outdoor professions (construction, plantation work, and delivery services), were found to be at double the risk of contracting dengue[24,25]. Socioeconomic factors like education level and income further affect risk levels, with those from low-income communities and those with poorer education being less likely to practice preventive measures[18]. It's clear that high-density living conditions contribute significantly to mosquito-human contact, making densely populated urban areas particularly vulnerable to dengue outbreaks[25]. These findings point to the need for addressing social determinants in public health strategies, as they are critical to controlling the spread of dengue.

Housing conditions are another critical factor, with those residing in high-rise apartments being at higher risk of dengue due to crowded conditions, shared water storage, and poor drainage systems. The Ovitrap Index (OI), which measures mosquito infestation, was notably higher in these areas (OI = 16.7%) compared to apartments (OI = 6.06%), suggesting that densely populated urban areas with poor waste management are key breeding grounds for mosquitoes[17,24]. This points to the necessity of improving urban infrastructure, particularly in high-density areas, to reduce mosquito breeding sites and prevent further outbreaks. The relationship between housing type and dengue risk particularly the heightened risk in terraced houses and apartments, emphasizes how urban planning and housing design can directly impact public health[27]. While most studies emphasized urban risk, some reported comparable or higher seroprevalence in rural areas, suggesting a shift in transmission dynamics.

Community engagement and preventive measures are also crucial to reducing dengue transmission. While 91.5% of respondents indicated a desire to reduce dengue cases, 64% admitted that they did not regularly check dengue hotspot updates, suggesting gaps in community engagement and awareness[27]. This highlights the importance of effective communication and public participation in controlling the spread of the disease. Furthermore, early warning systems were well-received, with 80.6% of people believing they could help prevent infections, yet only 64.9% would contact authorities for mosquito control, pointing to a disconnect between knowledge and action[27]. Similarly, inconsistent use of repellents and delayed medical attention contribute to more severe dengue outcomes, underscoring the need for more consistent, proactive measures from both the public and authorities[36]. Although awareness of dengue was generally high, gaps between knowledge and practice were observed, with inconsistent preventive behaviours and delayed healthcare-seeking contributing to disease severity[27,36]. This also indicates that knowledge alone is insufficient without effective behavioural change strategies.

2. Environmental factors: Environmental and Urbanisation; Meteorological and Climatic Conditions; Regional and Geographic Variations and their contribution to rising dengue cases in Malaysia.

a) Environmental and Urbanisation Impacts:

Environmental factors, particularly urbanisation and population density, were identified as major drivers of dengue transmission. Urban areas with high population density were consistently associated with increased dengue risk, as they provide favourable conditions for mosquito breeding and human-vector interaction[24]. From our review of the literature, it is evident that environmental factors, particularly those linked to urbanisation, play a critical role in the transmission dynamics of dengue. While findings across studies were generally consistent, variations were observed in the magnitude of associations, particularly between urban and rural settings, indicating potential contextual influences on dengue transmission. A number of studies highlight that population density in urban areas significantly increases dengue vulnerability, as higher concentrations of humans and mosquitoes create more opportunities for virus transmission[24]. Similarly, human density in urban environments directly contributes to the breeding of *Aedes aegypti*, which is the primary vector responsible for transmitting dengue. This underscores the role of human population clusters in facilitating the spread of the disease[32]. We found that urban reservoir contact zones, particularly in densely populated settlements with inadequate drainage systems and waste accumulation, are identified as primary hotspots for dengue transmission. These findings point to the crucial role of urban infrastructure in the disease's spread[25]. Poor waste management and inadequate drainage systems were also key contributors, creating artificial breeding sites such as stagnant water in containers and construction sites[36]. While urbanisation was a dominant theme, several studies highlighted that rural areas are increasingly affected due to infrastructure development, migration, and environmental changes, indicating an expansion of dengue transmission beyond traditional urban settings.

Housing type was another important determinant. Residents in apartments and terraced houses faced higher risks compared to those in bungalows, largely due to higher density and environmental conditions conducive to mosquito breeding[27]. In urban settings, high-density housing such as apartments and terraced houses was associated with a greater dengue risk compared to bungalows, largely due to factors like shared water storage and poor drainage. The proximity to construction sites, which is common in urbanized regions, further amplifies this risk, linking urban development with increased mosquito breeding opportunities[36]. Moreover, urbanisation coupled with poor waste management practices significantly contributes to the creation of breeding sites, thus escalating the risk of dengue outbreaks. Similarly, abandoned houses, which collect stagnant water, were shown to be a significant factor in increasing dengue transmission risk, as these sites are ideal for mosquito breeding[32].

It also noted that rural vs urban differences in dengue exposure have been examined, revealing that rural areas, despite having fewer infrastructure resources, show a higher dengue IgG seropositivity rate (76.5%) compared to urban areas (55.4%), indicating that rural populations are similarly at risk of dengue transmission[31]. This contrasts with traditional beliefs that dengue is confined primarily to urban areas, highlighting the need to focus on rural regions as well. Environmental factors such as dense vegetation around homes were found to increase mosquito populations, while poor sanitation and improper waste disposal further contribute to the problem. The situation is worsened in urban areas, where house crowding exacerbates the spread of the virus within families[34]. A significant difference in mosquito larvae counts was observed between urban and rural areas, with urban areas having a higher population of both *Aedes aegypti* and *Aedes albopictus* larvae, reinforcing the notion that urban areas are at greater risk of dengue transmission[32].

The type of housing plays a pivotal role in determining dengue risk. Studies show that residents in terraced houses and apartments are at a higher risk compared to those in bungalows, likely due to factors like population density, shared water storage, and poor drainage[27]. Furthermore, shaded houses, particularly those surrounded by trees and plants, have been found to have double the dengue risk compared to houses without such surroundings[27]. Additionally, homes located near playgrounds and parks tend to have higher dengue incidences, likely due to these areas providing favourable breeding grounds for mosquitoes[27]. In addition to housing and waste management factors, poor waste management has been identified as a major risk factor, with households lacking proper garbage disposal systems facing a 3.2-fold increased risk of dengue transmission[36]. The combination of population density and urbanisation remains a dominant contributor to increased dengue rates, particularly when coupled with rainfall, which provides ample opportunities for mosquito breeding. In this regard, urban areas with poor drainage systems and the presence of construction sites further increase the risk. Rapid urban growth, leading to increased human mobility, is also significant in facilitating the spread of dengue across different regions[29]. These findings suggest that urban planning and housing design are critical components in dengue prevention strategies.

b) Meteorological and Climatic Conditions:

Climatic factors such as temperature, rainfall, and humidity significantly influenced dengue transmission dynamics. Optimal temperature ranges (22–32°C) and moderate rainfall were associated with increased mosquito breeding and dengue incidence[31]. Rainfall demonstrated a dual effect, initially reducing larvae through flushing, but subsequently creating stagnant water that supports mosquito proliferation. Although most studies reported positive associations between climatic factors and dengue incidence, variations were observed depending on geographic location and seasonal patterns. Seasonal trends were also evident, with dengue cases peaking during monsoon periods due to increased availability of breeding sites[34]. These findings highlight the importance of incorporating climatic data into predictive models and early warning systems.

Meteorological and climatic conditions are fundamental in shaping dengue transmission dynamics, with specific factors such as temperature, rainfall, and humidity playing significant roles in influencing mosquito populations and the occurrence of outbreaks. Studies have shown that dengue vulnerability increases with temperatures ranging between 20-34°C, along with moderate rainfall, which creates ideal conditions for mosquito breeding[24]. High humidity has been found to contribute to an increase in larval distribution, while high temperature and rainfall can reduce it, revealing the complex interaction between climatic variables and mosquito proliferation[32]. Urban areas, characterized by high rainfall and temperature, support year-round mosquito breeding, while in rural settings, environmental changes such as deforestation and construction have resulted in the creation of new breeding sites, further exacerbating dengue transmission[35].

The relationship between seasonal factors and dengue outbreaks is particularly evident during the monsoon season, which peaks from October to February. During this period, monsoon rains create temporary breeding sites in pools, clogged drains, and containers, thereby increasing mosquito populations and driving up dengue cases[34]. In terms of climatic influences, temperature, rainfall, and wind speed were found to be strongly correlated with dengue incidence. Notably, both temperature and rainfall have a positive correlation with increased dengue cases, while higher wind speeds appear to reduce the risk of transmission. The optimal temperature range of 22–32°C facilitates mosquito development, leading to increased biting rates and shorter viral incubation times, whereas extreme heat conditions can limit mosquito survival. Moreover, rainfall plays a dual role: while it initially washes away mosquito larvae, the accumulation of stagnant water in the weeks following heavy rainfall creates ideal conditions for mosquito breeding, with peak mosquito activity occurring 2-6 weeks after rainfall[31]. Additionally, wind speeds above 9.7 m/s disrupt mosquito flight and feeding behaviours, which significantly decreases the likelihood of dengue transmission. The effect of monsoon winds in reducing dengue transmission further emphasizes the importance of understanding climatic dynamics in managing outbreaks[31].

The concept of “wet-dry steps” in rainfall patterns, as identified by recent studies, has emerged as a key trigger for dengue outbreaks. With an $R^2 > 0.99$, this rainfall pattern is particularly useful in predicting the timing and intensity of dengue incidence[25]. Moreover, the impact of warm-wet conditions on dengue risk has been clearly demonstrated, with risk ratios (RR) of 1.32, 1.37, and 1.39 for warm-wet conditions compared to non-warm, non-wet, moderate temperature-humidity, and moderate temperature-rainfall conditions, respectively. Cold-dry weather was associated with a reduced dengue risk (RR: 0.70), while hot weather combined with higher humidity had a stronger effect on elevating dengue risk, highlighting the interactive impact of temperature and humidity on disease transmission. Furthermore, the effect of rainfall intensified in warmer temperatures, further contributing to the creation of more breeding sites for Aedes mosquitoes and facilitating disease transmission[32]. Finally, GIS-based maps have underscored that areas with heavy rainfall and dense populations are at the highest risk for dengue outbreaks, emphasizing the importance of monitoring these environmental conditions for predicting and mitigating the disease burden[32].

c) Regional and Geographic Variations:

Regional differences in dengue transmission were observed across Malaysia. Studies reported no significant differences in seroprevalence between urban and rural areas in some cases, suggesting widespread transmission[34]. However, certain regions, particularly the east coast, showed higher severity and incidence rates[34]. These inconsistencies indicate that regional factors, including healthcare access, environmental conditions, and human mobility, may influence dengue patterns. The expansion of Aedes habitats due to migration, infrastructure development, and environmental changes has contributed to the spread of dengue into previously low-risk areas[35]. This highlights the need for geographically tailored intervention strategies.

Upon reviewing the available literature on dengue transmission across Malaysia, it becomes evident that regional and geographic factors are central to understanding the rise in dengue cases. The studies indicate no significant difference in dengue IgG seroprevalence between urban (92.03%, 554/602) and rural areas (90.95%, 362/398), with a p-value of 0.550. This finding challenges the traditional assumption that dengue is an issue confined to urban settings, suggesting that the disease is now widespread and increasingly affecting rural populations as well[34]. This trend highlights how urbanisation alone cannot explain the increase in dengue cases, and there is a pressing need to address the broader distribution of dengue transmission. Moreover, the role of water bodies, such as drains, lakes, and rivers, in facilitating mosquito breeding is particularly concerning. Although these water bodies contribute to breeding sites, their impact on dengue transmission is not as strong as other factors, with a slightly decreasing non-linear association (16.1%) observed in some regions[33]. However, the expansion of Aedes habitats, particularly in rural areas, has intensified due to migration, increased travel, and infrastructure development, all of which have been key factors in the rising dengue cases. The observation that rural areas have seen a substantial increase in dengue prevalence, matching urban areas by 2008 ($P < 0.0001$, OR: 1.73, CI: 1.55–1.91), suggests that these areas are now facing challenges previously associated with urban centers. The spread of dengue to rural regions further underscores the need for targeted public health interventions across all areas, not just cities[35].

In addition to these regional differences, dengue cases in Malaysia have seen an alarming increase, rising by 580% from 2013 (724 cases) to 2018 (3,423 cases). The findings reveal significant geographic variability, with patients from the east coast of Malaysia, including Tawau, Semporna, Lahad Datu, and Sandakan, being 5.2 times more likely to develop severe dengue compared to those from the west coast (95% CI 2.74–9.79, $p = 0.00$)[34]. This stark regional difference highlights how local environmental factors, such as population density, mosquito breeding sites, and possibly healthcare access, play a major role in the severity of dengue outbreaks. Therefore, focusing on high-risk areas, particularly in the east coast, is essential for reducing the impact of dengue and improving overall disease management.

3) Vector factors: Aedes mosquito and their contribution to rising dengue cases in Malaysia.

Vector-related factors, particularly the distribution and breeding behaviour of Aedes mosquitoes, were central to dengue transmission. Both Aedes aegypti and Aedes albopictus were found to coexist across urban and rural environments, increasing transmission potential[34]. Urban areas were predominantly associated with Aedes aegypti, while Aedes albopictus was more common in rural settings[28]. The coexistence of both species complicates vector control efforts, as they occupy different ecological niches. High mosquito density was strongly associated with areas of poor waste management and high population density. The Breeding Index (BI) was significantly higher in urban areas, indicating increased vector proliferation[32]. While these findings are consistent, differences in measurement methods across studies may affect comparability. Adaptation of Aedes mosquitoes to urban environments, including multi-storey buildings, further exacerbates transmission risk[35]. This reflects the evolving ecology of dengue vectors in response to urbanisation.

Vector factors play a pivotal role in dengue transmission, with both *Aedes aegypti* and *Aedes albopictus* being major contributors to the spread of the disease. The coexistence of these two mosquito species in various habitats, both artificial and natural, significantly amplifies the transmission potential. Both species breed in environments ranging from discarded containers to water tanks and coconut shells, which highlights the importance of effective waste management in reducing breeding opportunities for these mosquitoes. Studies have shown that *Aedes aegypti* is more commonly found in urban areas, whereas *Aedes albopictus* tends to dominate in rural settings[28,34]. The presence of mixed breeding sites, such as water tanks and discarded containers, in high-risk areas results in higher mosquito densities, leading to more frequent outbreaks of dengue[34].

The Breeding Index (BI), which measures mosquito populations, was significantly higher in high-density urban areas, with values ranging from 60.0 to 94.9. This suggests that Aedes mosquitoes thrive particularly well in densely populated environments, especially where discarded containers serve as breeding grounds. This observation underscores the critical need for waste management strategies to control mosquito populations and mitigate the risk of dengue transmission[32]. Additionally, urbanisation and population density contribute significantly to the rising dengue cases[34]. High-density areas, especially in urban environments, provide ample breeding opportunities for mosquitoes, exacerbating the risk of disease spread.

In terms of seasonal and climatic conditions, the Northeast monsoon rains between December and March have been identified as a key factor in the seasonal peaks of dengue outbreaks. During this period, monsoon rains create temporary breeding sites in pools, clogged drains, and containers, further supporting the proliferation of mosquitoes and increasing the likelihood of dengue transmission during these months[34]. The role of waste management is also evident, as urban areas are more prone to artificial breeding sites such as blocked drains and discarded containers, which present higher risks of dengue compared to rural areas, where more natural breeding sites, such as water storage containers and abandoned wells, are prevalent[35].

Moreover, the Ovitrap Index (OI), a measure of mosquito infestation, was significantly higher in flats (OI = 16.7%) compared to apartments (OI = 6.06%), with poor waste management practices being a major contributor to this discrepancy[35]. *Aedes albopictus* was observed to dominate in flats (IP = 60%), while Aedes aegypti was predominantly found outdoors in flats (IP = 20%), further highlighting the role of waste management in determining mosquito densities. Additionally, Aedes mosquitoes have adapted to multi-storey buildings, breeding in plastic containers, buckets, and discarded items, which further exacerbates mosquito populations in urban, high-density locations. These findings highlight the increasing complexity of dengue control in urban, high-density areas and underscore the need for targeted measures to address mosquito breeding in such environments[35].

4) Virus factors: Dengue virus and their contribution to rising dengue cases in Malaysia.

Viral factors, particularly dengue virus serotypes and infection patterns, were identified as key contributors to disease severity. DENV-3 was frequently reported as the predominant serotype associated with higher severity and mortality[34]. Mixed serotype infections significantly increased the risk of severe dengue, highlighting the role of viral diversity in disease progression[34]. Although these associations are well documented, the extent of their impact varies across studies. Secondary infections with different serotypes were strongly linked to severe outcomes due to antibody-dependent enhancement (ADE). These findings underscore the complexity of dengue pathogenesis and the challenges in disease management.

The role of the virus in dengue transmission is pivotal, particularly regarding how each serotype, DENV-1 to DENV-4 contributes to the severity of the disease. The serotype of the virus plays a crucial role in determining the clinical outcome of an infection, influencing both the severity and the mortality rate associated with the disease. Between 2016 and 2018, DENV-3 was identified as the predominant serotype, and its presence was strongly linked to higher disease severity and increased mortality rates, underscoring the significant role of specific serotypes in the progression of dengue[34]. The observation that mixed infections, where multiple serotypes are present in a single patient, increase the likelihood of severe dengue by a factor of 13 (95% CI 3.67–46.01, p = 0.00) further emphasizes how the diversity of serotypes can exacerbate disease outcomes[34]. In addition, DENV-1 infections were found to be 1.8 times more likely to lead to severe dengue compared to other serotypes, including DENV-2, DENV-3, and DENV-4 (95% CI 1.21–2.88, p = 0.00). This finding highlights the critical role of specific serotypes in determining the clinical severity of the disease and suggests that particular strains may pose greater risks to public health[34]. Importantly, secondary infections with a serotype different from the initial infection have been identified as a significant risk factor for the development of severe complications, such as dengue haemorrhagic fever (DHF) and dengue shock syndrome (DSS). This phenomenon occurs primarily due to antibody-dependent enhancement (ADE), wherein the immune system's response to the virus inadvertently facilitates greater viral replication, thus exacerbating the severity of the disease.

Moreover, the level of exposure to the dengue virus plays a significant role in determining the severity of the disease. Increased exposure, especially in older adults, heightens the risk of severe secondary infections due to ADE. This emphasizes the need for targeted prevention efforts, particularly in populations with a higher risk of repeated exposure to the virus. As older individuals are more likely to encounter multiple serotypes over time, the risk of developing severe complications increases, thus contributing to the growing burden of dengue cases in Malaysia[35]. These findings suggest that viral factors, including the serotype and exposure levels, are crucial elements that need to be considered when analysing the rising dengue cases and planning effective public health interventions.

The analysis of these 20 selected articles were summarized into four key factors contributing to the increase of dengue infections in Malaysia: (1) human factors; (2) environmental factors; (3) vectors factors; (4) virus factors as shown in Figure 2.

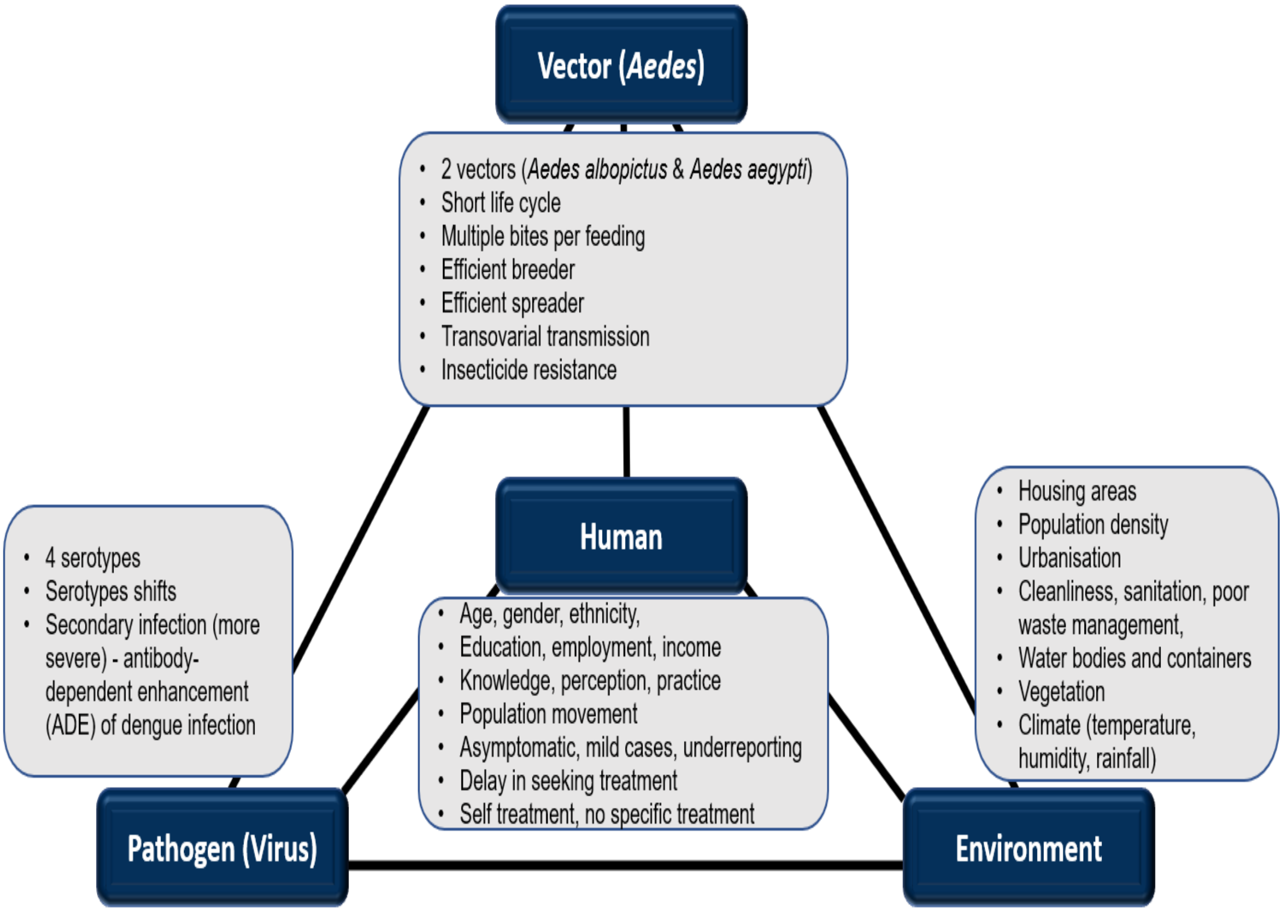

Fig.2: Dengue transmission is the result of interaction between four components

Table 1. Summary of selected articles for systematic review.

No.	Author(s) and Year of Publication	Article Title	Research Design	Findings
1	Muhammad Azami et al. (2011)[18]	Dengue Epidemic in Malaysia: Not a Predominantly Urban Disease Anymore	Cross-sectional study	**A. Human Factors**: ● Dengue IgG seroprevalence increased with age ($p < 0.001$). ● Odds of seropositivity (compared to 35-44 years): 45-54 years: 3.08 (95% CI: 1.79-5.31); 55-64 years: 3.89 (95% CI: 2.07-7.30) ($p < 0.001$); 65-74 years: 3.59 (95% CI: 1.03-12.46) ($p = 0.045$). **B. Environmental Factors**: ● No significant difference in dengue IgG seroprevalence between urban (92.03%, 554/602) and rural areas (90.95%, 362/398) ($p = 0.550$), indicating dengue is no longer confined to urban areas.
2	Dickin et al. (2013)[24]	Developing a Vulnerability Mapping Methodology: Applying the Water-Associated Disease Index to Dengue in Malaysia	Ecological study	**Weighting Scheme**: ● A weighting of 1 for susceptibility and 3 for exposure yielded the highest correlation ($r = 0.71$, $p < 0.0001$). ● Linear regression analysis showed an R^2 of 0.50 with a coefficient of 0.63 (95% CI: 0.53-0.74). **A. Human Factors**: ● **Socioeconomic Factors**: Poor housing, low education for women, and limited healthcare increase dengue vulnerability. ● **Water Storage Practices**: Pour-flush toilets and water containers promote mosquito breeding. **B. Environmental Factors**: ● **Climate**: Dengue vulnerability increases with temperatures (20-34°C) and moderate rainfall. ● **Population Density**: Higher population density in urban areas raises dengue vulnerability. ● **Land Use**: Urbanization and poor waste management create more breeding sites.
3	Dom et al. (2013)[19]	Assessing the Risk of Dengue Fever based on Epidemiological, Environmental, and Entomological Variables	Ecological study (Subang jaya)	**A. Human Factors**: ● **Gender**: Men (56.8%, n=2952) had a higher dengue incidence than women (43.2%, n=2248). ● **Age**: Highest risk was in 15-29 years (37.4%, n=1944), followed by 30-44 years (30.4%, n=1579). ● **Race**: Chinese (47.2%, n=2454) had the highest number of cases, followed by Malays (34.9%, n=1813). ● **Occupation**: Most affected were employed (52.2%, n=815) or students (27.1%, n=422). **B. Environmental Factors**: ● **Abandoned Houses**: Increased dengue risk due to stagnant water (frequency: 2.2%, duration: 7.0%, intensity: 0.1%).

No.	Author(s) and Year of Publication	Article Title	Research Design	Findings
				C. Entomological Factors: ● **Breeding Index (BI)**: High BI (60.0-94.9) found in high-density areas. Aedes mosquitoes bred in discarded containers, emphasizing waste management.
4	Cheong et al. (2014)[33]	Assessment of Land Use Factors Associated with Dengue Cases in Malaysia Using Boosted Regression Trees	Ecological study	**Boosted Regression Trees Model:** ● Learning Rate: 0.05, Tree Count: 9, Total Decision Trees: 2150 ● Cross-validated ROC AUC: 0.81 ● Ensemble Prediction ROC AUC: 0.81 (±0.001 S.D.) **A. Environmental Factors:** ● **Urbanisation and Human Settlements (39.2%)**: Strong linear increase with dengue cases. ● **Water Bodies (16.1%)**: Slightly decreasing non-linear association (e.g., drains, lakes, rivers). ● **Mixed Horticulture (8.7%)**: Increasing non-linear association, often in suburban orchards and gardens. ● **Open Land (7.5%)**: Increasing non-linear association with dengue. ● **Neglected Grassland (6.7%)**: Decreasing linear association with dengue.
5	Wong et al. (2014)[26]	Community Knowledge, Health Beliefs, Practices, and Experiences Related to Dengue Fever and its Association with IgG Seropositivity	Cross-sectional study	**A. Human Factors:** ● **Perceived Severity and Susceptibility (HBM)**: Belief in dengue severity and susceptibility increased IgG seropositivity (OR: 1.84, CI: 1.25–2.87) (P<0.001). ● **Cues to Action**: Knowing a neighbour had dengue increased preventive actions (OR: 1.45, CI: 1.28–2.53) (P<0.05). ● **Socioeconomic**: Higher household incomes (> MYR 4,000) were linked to increased IgG seropositivity (80%, P<0.05). ● **Housing Factors**: High-rise apartment dwellers (85.1%) had higher IgG seropositivity (OR: 2.67, CI: 1.10–5.65) than those in single/village houses (67.9%) or terraced houses (61.1%). ● **Community and Preventive Measures**: Frequent fogging after outbreaks was linked to higher IgG seropositivity (OR: 0.09, CI: 0.07-0.50) (P<0.001). Lack of community preventive measures increased the risk (OR: 3.1, CI: 1.58–3.85) (P<0.001). **B. Environmental Factors:** ● **Rural vs Urban**: Rural areas (76.5%) had higher IgG seropositivity than urban areas (55.4%) (OR: 0.40, CI: 0.30–0.74) (p<0.01).
6	Chandren et al. (2015)[23]	Practices of Dengue Fever Prevention and the Associated Factors Among the Orang Asli in Peninsular Malaysia	Cross-sectional survey study	**A. Human Factors:** ● **Dengue Knowledge and Awareness:** ○ Lower knowledge (score 0-18) linked to less prevention (OR = 0.63, P = 0.015). ○ Fewer barriers (score 1-5) increased prevention (OR = 2.06, P = 0.008). ○ Villages not or rarely fogged had lower prevention (OR = 0.49, P = 0.045; OR = 0.40, P = 0.004).

No.	Author(s) and Year of Publication	Article Title	Research Design	Findings
				○ Lower perceived susceptibility (score 1-5) reduced prevention (OR = 0.54, P = 0.018). ○ Higher knowledge linked to better prevention. ● **Sociodemographic Factors**: ○ Lower education level linked to poorer prevention knowledge. ○ Unemployed had poorer knowledge than skilled workers. ○ Forest-fringe villagers had better knowledge than deep jungle residents. ○ Higher household income linked to better prevention practices. ● **Perceived Barriers to Prevention**: ○ Fewer barriers (e.g., access to repellents) increased prevention (OR = 2.0). ○ Barriers included lack of education, difficulty accessing repellents, and limited healthcare. ● **Perceived Susceptibility to Dengue**: ○ Low-risk perception led to less preventive action. ○ Experience with dengue or knowing someone who had it increased prevention. **B. Environmental Factors**: ● **Fogging Frequency and Effectiveness**: ○ Villages not or rarely fogged had lower prevention (OR = 0.49, P = 0.99). ○ Frequent fogging increased awareness and prevention. ○ Fogging wasn't always effective as mosquitoes rest indoors. ● **Environmental Factors and Housing Conditions**: ○ Dense vegetation around homes linked to more mosquitoes. ○ Poor sanitation and waste disposal created more breeding sites. ○ House crowding increased dengue spread within families.
7	Basari et al. (2016)[28]	Larval Distributions and Breeding Habitats of Aedes aegypti and Ae. albopictus in Kuala Terengganu	Ecological study	**A. Environmental Factors**: ● **Urban vs Rural Differences**: Significant difference in the number of Ae. aegypti and Ae. albopictus larvae between urban and rural areas (x2 (1, N=274) = 27.93, p < 0.01). ● **Humidity and Temperature**: High humidity increased larval distribution; high temperature and rainfall reduced it. ● **Human Density**: Higher human populations in urban areas contributed to more Ae. aegypti breeding. **B. Vector Factors**: ● **Larval Species**: Ae. aegypti dominated in urban areas, while Ae. albopictus was more frequent in rural areas. ● **Breeding Sites**: Most larvae were found in glass containers, plastic bottles, water tanks, and coconut shells.
8	Chew et al. (2016)[20]	Rural-Urban Comparisons of Dengue	Seroprevalence study	**A. Human Factors**: ● **Age and Seroprevalence**: ○ Prevalence > 90% in those ≥ 70 years in both urban and rural areas.

No.	Author(s) and Year of Publication	Article Title	Research Design	Findings
		Seroprevalence in Malaysia		○ Urban areas: Younger groups (≤ 40 years) had higher seroprevalence. Rural areas: Older groups had similar prevalence. ○ Over 50% of adults 30-39 years were infected; nearly all adults ≥ 70 had prior exposure. ○ **ADE Risk**: Higher lifetime exposure increases severe secondary infections (P < 0.0008, OR: -600.91, CI: -1042, -160). **B. Environmental Factors**: ● **Time Trends in Rural Areas**: ○ Rural prevalence matched urban levels by 2008 (P < 0.0001, OR: 1.73, CI: 1.55, 1.91). ○ Expansion of Aedes habitats, migration, travel, and infrastructure contributed to rising rural cases. ● **Climatic Factors**: ○ High rainfall and temperature in urban areas support year-round mosquito breeding. ○ Deforestation and construction in rural areas created new breeding sites. **C. Vector Factors**: ● **Waste Management**: ○ Urban areas: More artificial breeding sites (e.g., blocked drains, discarded containers). ○ Rural areas: More natural breeding sites (e.g., water storage containers, abandoned wells). **D. Virus Factors**: ● **Dengue Exposure**: Increased exposure in older adults raises the risk of severe secondary infections due to ADE.
9	Nealon et al. (2016)[4]	Symptomatic Dengue Disease in Five Southeast Asian Countries: Epidemiological Evidence from a Dengue Vaccine Trial	Prospective cohort study	**A. Human Factors**: ● **Under-reporting of Dengue Cases**: ○ National passive surveillance systems underestimated cases by 5.5 to 31.7 times. ○ Only 28.8% of virologically confirmed cases met hospital clinical definitions (OR: 31.7, CI: 17.0, 57.5). ○ Mild cases were often misclassified as other febrile illnesses. ● **Age-dependent Dengue Incidence**: ○ Highest incidence (4.6% per year) in children aged 5–14. ○ Younger children were less likely to be diagnosed despite lab confirmation. ○ Older children had more severe symptoms and higher hospitalisation rates. ● **Disease Severity and Hospitalisation**: ○ Only 7.8% of confirmed cases were diagnosed as dengue haemorrhagic fever (DHF). ○ Severe cases were correctly diagnosed, while mild cases were underreported.

No.	Author(s) and Year of Publication	Article Title	Research Design	Findings
				○ Malaysia had the lowest incidence (2.2% per year), differences in clinical diagnosis and reporting affected case numbers. ● **Influence of Case Definitions on Disease Burden**: ○ Stricter clinical criteria underestimated dengue burden. ○ Broader case definitions captured more cases but increased false positives. ○ Virological confirmation (NS1 antigen, RT-PCR) provided the most accurate estimates.
10	Sairi et al. (2016)[35]	Infestation Profile of Aedes Mosquitoes in Multi-Storey Buildings in Selangor, Malaysia	Entomological surveillance study	**A. Vector Factors**: ● **Dominance of Ae. albopictus**: Found in both apartments and flats (IP = 60%). ● **Ae. aegypti**: Found outdoors in flats (IP = 20%). ● **Ovitrap Index**: Higher in flats (OI = 16.7%) than apartments (OI = 6.06%). ● **Mosquito Infestation**: Higher in flats (OI = 16.7%) due to poor waste management. ● **Adaptation to Multi-storey Buildings**: Aedes mosquitoes breed in plastic containers, buckets, and discarded items.
11	Zaki et al. (2017)[27]	Public Perception and Attitude Towards Dengue Prevention Activity and Response to Dengue Early Warning in Malaysia	Cross-sectional study	**A. Human Factors**: ● Marital status (P = 0.039), occupation (P = 0.005), knowing someone infected with dengue (P = 0.003), and monthly income (P = 0.004) were significantly associated with perception of early warning. ● **Awareness and Understanding**: ○ 97.1% knew about dengue and its severity. ○ 90.6% understood the link between climate and dengue outbreaks. ○ 45% were unsure how climate data could predict outbreaks. ● **Community Engagement and Attitude**: ○ 91.5% wanted to reduce dengue cases. ○ 64.0% didn't regularly check dengue hotspot updates, indicating gaps in participation. ○ Few were unwilling to engage in community control activities. ● **Response to Early Warning Systems**: ○ 80.6% believed early warnings would help prevent infections. ○ 83.6% would avoid outdoor activities at risk times. ○ 79.4% would request fogging after a warning. ○ 64.9% would contact authorities for mosquito control. ● **Preferred Communication Channels**: ○ 66.4% preferred television for warnings. ○ 48.7% preferred radio, 49.5% preferred Facebook. ○ 42.3% were open to mobile apps as an early warning tool.
12	Nealon et al. (2019)[36]	Feasibility of Case-Control and Test-Negative Designs to	Hospital-based case-control and	**A. Human Factors**: ● **Recent Household Dengue Contact**: Significantly increased dengue risk (OR: 54, 95% CI: 7.3–397).

No.	Author(s) and Year of Publication	Article Title	Research Design	Findings
		Evaluate Dengue Vaccine Effectiveness in Malaysia	test-negative study	**B. Environmental Factors**: 1. **Recent Neighbourhood Insecticidal Fogging**: Associated with higher dengue risk (OR: 2.1, 95% CI: 1.3-3.6).
13	Kaur et al. (2020)[30]	The East Coast Districts are the Possible Epicentre of Severe Dengue in Sabah	Retrospective epidemiological study	**A. Human Factors**: ● **Age**: Children (0-9 years old) were 6.5 times more likely to develop severe dengue than adults (95% CI 3.45-12.27, p = 0.00). ● **Movement**: Increased human movement during school holidays (December–January) contributed to the spread of dengue. ● **B. Environmental Factors**: ● **Geographic and Regional Factors**: ○ Dengue cases increased by 580% from 2013 (724 cases) to 2018 (3,423 cases), with higher mortality on the east coast of Sabah. ○ Patients from the east coast (Tawau, Semporna, Lahad Datu, Sandakan) were 5.2 times more likely to develop severe dengue than those from the west coast (95% CI 2.74–9.79, p = 0.00). ● **Seasonal and Climatic Factors**: ○ Dengue cases peaked during the late monsoon season (October–February). ○ Monsoon rains increased mosquito populations by creating temporary breeding sites (pools, clogged drains, containers). **C. Virus Factors**: ● **Dengue Serotype & Disease Severity**: ○ **DENV-3** was the predominant serotype (2016–2018) and was linked to higher severity and mortality. ○ **Mixed infections** (multiple serotypes in one patient) were 13 times more likely to cause severe dengue (95% CI 3.67-46.01, p = 0.00). ○ **DENV-1** infections had a 1.8 times higher risk of severe dengue compared to DENV-2, DENV-3, and DENV-4 (95% CI 1.21–2.88, p = 0.00).
14	Adnan et al. (2021)[21]	The Impact of Sociological and Environmental Factors for Dengue Infection in Kuala Lumpur, Malaysia	Cross-sectional survey	**A. Human Factors**: ● **Age**: Older individuals had higher dengue risk (p = 0.012, OR: 1.428, CI: 1.088-1.874). ● **Household Size**: Smaller households (fewer than 4 people) had higher risk (p = 0.008, OR: 0.626, CI: 0.432-0.908), likely due to reduced herd immunity and control efforts. ● **Employment Status**: Employed individuals had double the dengue risk (p = 0.004, OR: 0.660, CI: 0.495–0.880), likely from commuting and workplace exposure. **B. Environmental Factors**: ● **Housing Type**: Terraced houses and apartments had higher risk than bungalows (95% CI = 1.079-1.997, p = 0.023) due to density, shared water storage, and poor drainage. ● **Shaded Houses**: Houses surrounded by trees and plants had double the dengue risk (95% CI = 0.263-0.836, p = 0.012).

No.	Author(s) and Year of Publication	Article Title	Research Design	Findings
				• **Proximity to Playgrounds**: Houses near playgrounds and parks had higher dengue cases (95% CI = 0.304-0.859, p = 0.011).
15	Maluda et al. (2021)[22]	Factors Associated with Dengue Fever Patients Attending Primary Health Clinics in Kota Kinabalu	Cross-sectional study	**A. Human Factors**: • Age group (<0.01) • Household size (0.01) • Living in dengue outbreak areas (<0.01) • Indoor and outdoor water container storage (<0.01) • Installed house window screen (0.04) • Recent mosquito bites (<0.01) • Knowledge of dengue fever (0.05) • Wearing protective outdoor clothing (0.02) • Use of mosquito repellent (0.01) • Gender: Men had higher dengue risk due to more time spent outdoors. • Employment Status: Outdoor workers (construction, plantation, delivery) had higher risk from daily mosquito exposure. • **Delay in Medical Attention**: Patients delayed visits (3-5 days post-symptom onset), increasing severe dengue risk. • **Self-treatment**: 34% used home remedies or over-the-counter meds before professional care, delaying diagnosis. • **Inconsistent Prevention**: Many households only used repellents during outbreaks, not consistently. **B. Environmental Factors**: • **High-density Areas**: Apartments and terraced houses had higher dengue risk than bungalows. • **Proximity to Construction Sites**: Living within 500 meters of construction sites increased dengue risk. • **Poor Waste Management**: Households with improper garbage disposal had 3.2 times higher dengue risk.
16	Singh et al. (2022)[31]	The Effects of Meteorological Factors on Dengue Cases in Malaysia	Time-series analysis	**A. Environmental Factors**: • Temperature (mean = 0.779), rainfall (mean = 0.687), and wind speed (mean = 0.639) were correlated with dengue cases. • Rainfall and temperature were positively correlated with dengue, while wind speed had a negative correlation. • Temperature optimal range: 22–32°C enhanced mosquito development, increasing biting rates and shortening viral incubation. Extreme heat limiting mosquito survival. • Rainfall Impact: Rain washes away breeding sites initially, but later creates stagnant water pools, increasing mosquito breeding (2-6 weeks after rainfall). • Higher wind speed decreased dengue cases. Wind speed above 9.7 m/s: disrupted mosquito flight and feeding, reducing transmission.

No.	Author(s) and Year of Publication	Article Title	Research Design	Findings
				• Monsoon winds significantly reduced dengue cases.
17	Keat-Chuan Ng et al. (2023)[25]	Application of Medical Information System to Identify Dengue Outbreak Factors: Insights from a Hyperendemic City in Malaysia	Retrospective epidemiological study	**A. Environmental Factors**: • **Meteorological Factors**: The "wet-dry steps" rainfall pattern (R^2 > 0.99) triggered dengue outbreaks. • **Urban Reservoir Contact Zones**: Dense settlements (> 6.5 households/hectare) with poor drainage and waste accumulation were dengue hotspots. **B. Human Factors**: • **Socioeconomic and Behavioural Factors**: ○ High-density living increased mosquito-human contact, driving outbreaks. ○ Low-income communities had higher risk due to poor housing and lack of prevention. ○ Guerrilla gardening created microhabitats for Aedes mosquitoes. • **Age-group Vulnerability**: ○ The 30-60 age group had the highest dengue prevalence due to outdoor exposure and occupational risks. ○ Prevalence order: 30-60 > 18-29 > 5-17 > 60 > under 5 years. ○ **Platelet and White Blood Cell Count**: Higher in the under-5 group (F = 34.32, df = 4, P = 0.000; F = 15.45, df = 4, P = 0.000).
18	Wang et al. (2024)[32]	Impact of Compound Warm and Wet Events on Dengue Fever Infection in South and Southeast Asian Countries	Ecological study	**A. Environmental Factors**: • **Warm-Wet Conditions**: Increased dengue risk (RR: 1.32, 95% CI: 1.21–1.44 compared to non-warm, non-wet; RR: 1.37, 95% CI: 1.22-1.55 compared to moderate temperature-humidity; RR: 1.39, 95% CI: 1.27-1.52 compared to moderate temperature-rainfall). • **Cold-Dry Weather**: Reduced dengue risk (RR: 0.70, 95% CI: 0.62–0.80). • **Modification Effects**: Hot weather has a stronger effect on dengue risk with higher humidity, and rainfall impact increases with warmer temperatures. • **Humidity and Temperature**: High humidity and warm temperatures amplified mosquito survival. • **Rainfall**: Increased rainfall created more breeding sites for Aedes mosquitoes.
19	Hassan et al. (n.d.)[29]	Risk mapping of dengue in Selangor and Kuala Lumpur, Malaysia	Geospatial analysis	**A. Human Factors:** • **Transportation and Human Mobility**: ○ Major transport hubs had the highest dengue cases, highlighting human mobility's role in spreading the virus. ○ Highways and airports facilitated dengue transmission. **B. Environmental Factors**: • **Population Density and Urbanisation**: ○ High population density and rainfall were linked to higher dengue rates. ○ Urban areas with poor drainage and construction sites increased mosquito breeding sites. ○ Rapid urban growth raised transmission risk due to high human movement.

No.	Author(s) and Year of Publication	Article Title	Research Design	Findings
				• **Rainfall and Climate Factors**: ○ High rainfall correlated with more dengue cases, especially during the Northeast monsoon. ○ Excess rainfall creates stagnant water, ideal for breeding. ○ GIS maps showed areas with heavy rainfall and dense populations had the highest dengue burden.
20	Ling et al. (n.d.)[34]	Spatio-Temporal Patterns of Dengue in Malaysia: Combining Address and Sub-District Level	Spatio-temporal epidemiological study	**A. Human Factors**: • **Human Mobility and Transmission Clusters**: Interconnected sub-districts experienced simultaneous outbreaks, indicating human mobility's role in dengue spread. **B. Environmental Factors**: • **Urbanisation and Population Density**: 67% of dengue cases occurred in high-density urban areas (> 2,000 people per km²). • **Seasonal and Climatic Factors**: Dengue outbreaks peaked between December and March, during the Northeast monsoon rains. **C. Vector Factors**: • **Vector Ecology and Mixed Breeding**: Coexistence of *Aedes aegypti* and *Aedes albopictus* increased transmission risk, as both species breed in artificial and natural habitats. • Mixed breeding sites in high-risk zones led to higher mosquito densities and more frequent outbreaks.

Risk of Bias

The quality and relevance of selected studies were evaluated based on five key aspects in regard to MMAT, which are presented in Table 2.

Table 2. Details of the MMAT assessment.

Author	Type of Study	1.1	1.2	1.3	1.4	1.5
		The relevance of the sampling strategy with respect to the research question	The representativeness of the sample of the target population	The appropriateness of the measurements	Low risk of non-response bias	The appropriateness of the statistical analysis to answer the research question
Muhammad Azami et al. (2011)[18]	Quantitative descriptive	Yes	Yes	Yes	Yes	Yes
Dickin et al. (2013)[24]	Quantitative descriptive	Yes	Yes	Yes	Yes	Yes
Dom et al. (2013)[19]	Quantitative descriptive	Yes	Yes	Yes	Yes	Yes
Cheong et al. (2014)[33]	Quantitative descriptive	Yes	Yes	Yes	Yes	Yes
Wong et al. (2014)[26]	Quantitative descriptive	Yes	Yes	Yes	Yes	Yes
Chandren et al. (2015)[23]	Quantitative descriptive	Yes	Yes	Yes	Yes	Yes
Basari et al. (2016)[28]	Quantitative descriptive	Yes	Yes	Yes	Yes	Yes
Chew et al. (2016)[20]	Quantitative descriptive	Yes	Yes	Yes	Yes	Yes
Nealon et al. (2016)[4]	Quantitative descriptive	Yes	Yes	Yes	Yes	Yes
Sairi et al. (2016)[35]	Quantitative descriptive	Yes	Yes	Yes	Yes	Yes
Zaki et al. (2017)[27]	Quantitative descriptive	Yes	Yes	Yes	Yes	Yes
Nealon et al. (2019)[36]	Quantitative descriptive	Yes	Yes	Yes	Yes	Yes
Kaur et al. (2020)[30]	Quantitative descriptive	Yes	Yes	Yes	Yes	Yes
Adnan et al. (2021)[21]	Quantitative descriptive	Yes	Yes	Yes	Yes	Yes
Maluda et al. (2021)[22]	Quantitative descriptive	Yes	Yes	Yes	Yes	Yes

Author	Type of Study	1.1 The relevance of the sampling strategy with respect to the research question	1.2 The representativeness of the sample of the target population	1.3 The appropriateness of the measurements	1.4 Low risk of non-response bias	1.5 The appropriateness of the statistical analysis to answer the research question
Singh et al. (2022)[31]	Quantitative descriptive	Yes	Yes	Yes	Yes	Yes
Keat-Chuan Ng et al. (2023)[25]	Quantitative descriptive	Yes	Yes	Yes	Yes	Yes
Wang et al. (2024)[32]	Quantitative descriptive	Yes	Yes	Yes	Yes	Yes
Hassan et al. (n.d.)[29]	Quantitative descriptive	Yes	Yes	Yes	Yes	Yes
Ling et al. (n.d.)[34]	Quantitative descriptive	Yes	Yes	Yes	Yes	Yes

DISCUSSION

Human Factors

Human factors such as age, occupation, and socioeconomic status shape dengue transmission across multiple levels. At the individual level, older adults aged 45 years and above show higher dengue IgG seroprevalence, reflecting cumulative exposure and increased susceptibility to severe secondary infections due to antibody dependent enhancement. This highlights the importance of targeted screening and preventive measures for high-risk groups, although it also increases the burden on healthcare services managing more complex cases. In contrast, younger populations experience higher incidence rates, likely driven by greater mobility and exposure, indicating distinct age-related risk profiles that require tailored interventions. At the community level, low-income populations in high density urban areas face elevated risks due to poor housing, inadequate sanitation, and limited access to mosquito control. While this emphasizes the need for improvements in infrastructure and healthcare access, structural barriers may limit implementation and sustain health inequities.

At broader levels, systemic challenges further complicate dengue control. Inconsistencies in reporting, passive surveillance, and diagnostic practices contribute to underreporting and potential bias, affecting the interpretation of findings. These limitations constrain stakeholders such as healthcare providers and public health authorities in designing effective interventions, especially when resources are limited. Despite this, the findings support the need for integrated and multisectoral strategies targeting vulnerable populations and high-risk environments. At the national level, the increasing dengue burden places pressure on Malaysia’s healthcare system but also creates opportunities for comprehensive policy responses addressing environmental, human, and vector related factors. Strengthening infrastructure, surveillance, and healthcare access could reduce transmission, although continued increases in cases may strain resources and impact economic stability.

Environmental Factors

Environmental factors such as urbanisation, population density, and poor waste management play a central role in dengue transmission. Urban settings create favourable conditions for mosquito breeding due to dense populations and abundant artificial breeding sites, although increasing transmission in rural areas suggests a shift beyond the traditional urban focus. Climatic factors, including temperature and rainfall, are consistently associated with dengue incidence, but their interactions are complex and vary across regions and time. These findings highlight the need for context specific environmental interventions integrated with urban planning and climate adaptation strategies. At the individual level, residents in densely populated areas face higher exposure risks due to closer human and mosquito contact. While this awareness can encourage preventive behaviours such as eliminating breeding sites, individuals may be constrained by limited resources and financial barriers.

At the community level, inadequate waste management increases mosquito breeding opportunities, highlighting the importance of community driven initiatives such as clean up campaigns and vector control programmes. However, these efforts require sustained engagement and resources, which may be difficult in low awareness settings. Rapid urbanisation has further strained infrastructure, reducing the effectiveness of local control measures. At the stakeholder level, local authorities and public health organisations can implement large scale improvements in waste management and urban planning, although funding limitations, policy constraints, and logistical challenges often hinder progress. At the national level, coordinated strategies are essential to address environmental drivers of dengue through improved infrastructure and regulatory policies. Despite this, rapid development frequently outpaces public health capacity, creating ongoing challenges in balancing economic growth with effective dengue prevention.

Vector Factors

Vector related findings highlight the critical role of Aedes mosquito ecology in dengue transmission. The coexistence of Aedes aegypti and Aedes albopictus across urban and rural settings increases transmission potential, as each species has distinct breeding behaviours and ecological preferences. Urbanisation and poor waste management further elevate mosquito density, creating favourable conditions for sustained transmission. Although vector indices such as the Breeding Index are consistently associated with dengue risk, variations in measurement methods across studies limit comparability. These findings underscore the importance of integrated vector management rather than relying on single approaches. At the individual level, those living in high density areas with poor waste management face increased exposure due to abundant breeding sites around homes. While individuals can adopt preventive practices such as eliminating stagnant water and using repellents, constraints related to space and resources may limit their ability to act effectively.

At the community level, the ability of Aedes mosquitoes to breed in both artificial and natural habitats make control efforts challenging without coordinated action. Community wide programmes, including clean up campaigns and biological control, can be effective, but inconsistent or reactive measures such as sporadic fogging often fail to achieve long term impact. The coexistence of multiple vector species further complicates control strategies and requires comprehensive approaches. At the stakeholder level, public health authorities and local governments can implement targeted interventions and coordinate control programmes, although resource limitations and operational challenges may hinder sustainability. At the national level, large scale vector control, public awareness, and infrastructure improvements are essential for reducing dengue transmission. However, rapid urbanisation and the spread of dengue into rural areas place increasing pressure on national systems, making it difficult to sustain effective and coordinated vector control efforts.

Virus Factors

Viral factors, particularly serotype diversity and secondary infections, play an important role in shaping dengue severity at the population level. The co circulation of multiple serotypes over time increases transmission complexity and highlights the need for continuous surveillance. Secondary infections are strongly associated with more severe disease through antibody dependent enhancement, reinforcing the importance of integrating epidemiological and immunological perspectives in dengue control strategies. These patterns indicate that viral dynamics are not static and require sustained monitoring to inform timely public health responses and improve preparedness.

At the community level, widespread exposure to different serotypes increases the risk of secondary infections, which are a key driver of severe dengue outcomes. This underscores the importance of prevention strategies that reduce repeated exposure, such as sustained vector control, environmental management, and community awareness programmes. Strengthening early detection and timely clinical management can also help reduce complications associated with secondary infections. However, variations in serotype distribution across locations and time complicate these efforts and require adaptive, context specific approaches. Overall, the findings highlight the need for coordinated community level interventions that prioritise prevention of secondary infections to reduce disease severity and improve dengue control.

FUTURE RECOMMENDATIONS

Effective dengue prevention must be driven by strong public health action centred on community engagement. Public health professionals play a critical role in implementing community-based interventions that improve knowledge, attitudes, and practices (KAP) on dengue prevention while addressing environmental risk factors and reducing mosquito density[37,38]. Emphasis should be placed on behavioural change strategies, including safe water storage, early health-seeking behaviour, and sustained prevention practices, particularly among high-risk groups such as outdoor workers and low-income communities.

Public health efforts should also strengthen community participation in eliminating dengue hotspots through environmental modification programmes supported by policy enforcement. In addition, the use of digital health platforms, such as real-time dengue alerts and mobile applications, can enhance risk communication, public awareness, and community involvement. Ultimately, sustainable dengue control in Malaysia depends on coordinated public health leadership that integrates community-based interventions, environmental management, and evidence-based policies, ensuring a proactive and participatory approach to reducing dengue transmission.

REVIEW LIMITATIONS

This systematic review had several limitations. Firstly, there may be publication bias and language bias due to the exclusion of grey literature and non-English publications by researchers from countries where English is not their primary language especially Malaysia. Despite these limitations, this systematic review yielded pertinent insights on the factors contributing to increase of dengue infections in Malaysia, presenting key guidelines on the design and implementation of dengue prevention and control programmes. Future updates of the review could consider incorporating Malay language articles as resources and indexing mechanisms expand.

The choice to focus on only two databases, ScienceDirect and EBSCOhost, was driven by the need to capture studies most relevant to the Malaysian context, which are often published in region-specific journals that may not be indexed in widely recognized international databases such as PubMed or MEDLINE. However, the authors acknowledge the potential limitations of this approach and the possibility that relevant studies may exist in other databases not included in the current search. Future iterations of this review could include other databases, such as PubMed or Google Scholar, to capture a broader range of literature, particularly from international studies that may offer comparative insights or global trends.

CONCLUSION

The rising incidence of dengue cases in Malaysia can be attributed to a complex interplay of human, environmental, vector, and virus factors. These findings have important implications for public health policy, particularly the need for integrated, multi-sectoral strategies involving urban planning, vector control, socioeconomic interventions, and community engagement. Future strategies should prioritize evidence-based interventions, including enhanced surveillance systems, improved urban infrastructure, and targeted community-based prevention programmes to address context-specific risk factors.

Availability of data and material

All data generated or analyzed during this study are available within the published article. For any specific data requests, please contact the corresponding author directly.

Competing interests

The authors affirm that they have no known financial or interpersonal conflict that would have an impact on the research work presented in this study.

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Author Contributions Statement

K.M., R.D., A.A.A.A., R.Y., S.S. wrote the main manuscript text, tables and figures. All authors reviewed the manuscript.

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