ALERT SYSTEM FOR FORGOTTEN BABY SYNDROME WITH BLUETOOTH LOW ENERGY (BLE) TAGS

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Article Info	Abstract
	Forgotten Baby Syndrome (FBS) is a tragic situation in which parents unintentionally leave their infants or young children alone in parked cars, leading to severe outcomes like heatstroke or even fatality. Cases related to this syndrome are commonly reported across the globe including Malaysia. With the aim of improving child safety, this project proposed a mobile application with an alert system to prevent FBS that works through Bluetooth Low Energy (BLE) tag. The BLE tag is attached to the child. Each BLE tag is capable of sustaining a connection up to 30 until 50 meters indoors and 100 until 240 meters in open areas. When the connection is lost, the application sounds an alarm, sends a notification to the parent's phone, and sends an SMS to the emergency contact. The project development follows the Mobile Application Development Life Cycle (MADLC) which consists of five phases: identification, design, development, prototyping, and testing. The system was designed and developed based on the information gathered. RSSI data filtered by Kalman Filtering is used to estimate the distance signal between the child tag and the parent's phone. The Haversine formula calculate the approximate distance between the parent's mobile device and the child's last recorded position. Functionality testing was conducted and all test cases passed successfully, confirming that the mobile application functions as intended. The results of this project indicated that it is capable of monitoring the BLE tag connection status continuously and notifying if the BLE signal is not detected by triggering an alert, sends push notification, and sends SMS to the emergency contact to indicate potential risks.

INTRODUCTION

Forgotten Baby Syndrome (FBS) represents a heartbreaking occurrence where parents inadvertently leave infants or young children unattended in parked vehicles, resulting in dire consequences such as heatstroke and even death. From a computer science perspective, FBS poses both challenges and opportunities for developing technological solutions to mitigate this issue. Unfortunately, cases of children being left alone in hot cars persist, and sometimes leading to tragic outcomes. The Malaysia's Ministry of Women, Family and Community Development (KPWKM) reported an average of two cases per year of children dying after being left in vehicles between 2018 and 2020, totaling six devastating losses during that period (Bernama, 2020). These incidents often stem from parents rushing to work, inadvertently forgetting to drop off their children at nurseries or daycare centers. The oversight of a child's presence in the back seat can lead to perilous situations, with documented cases of over 400 incidents of heatstroke in the past two decades alone (Diamond, 2019). Numerous heartbreaking occurrences have occurred where children were inadvertently left inside closed parked vehicles after their drivers had arrived at their destinations (Ismail et al., 2021). As shown in Figure 1 most of these events result in deaths usually because parents unintentionally leave children unattended. Data indicates that 55% of these instances involve parents leaving their children behind. Figure 2 presents a situation where a parent meant to take the child to daycare but forgot to constitute 43% of these incidents.
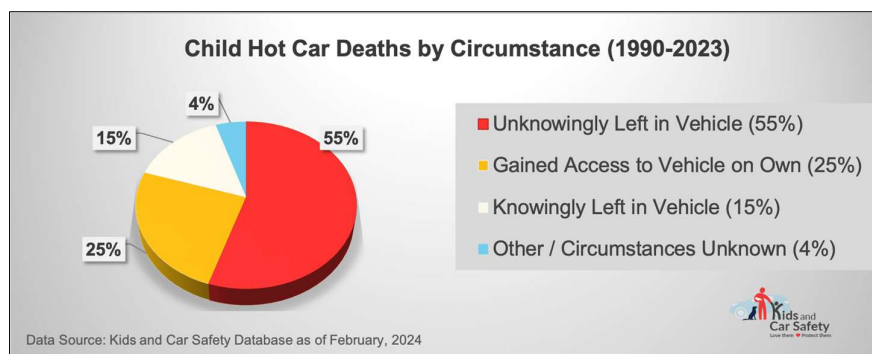

Figure 1 Child Hot Car Deaths by Circumstance (1990-2023)
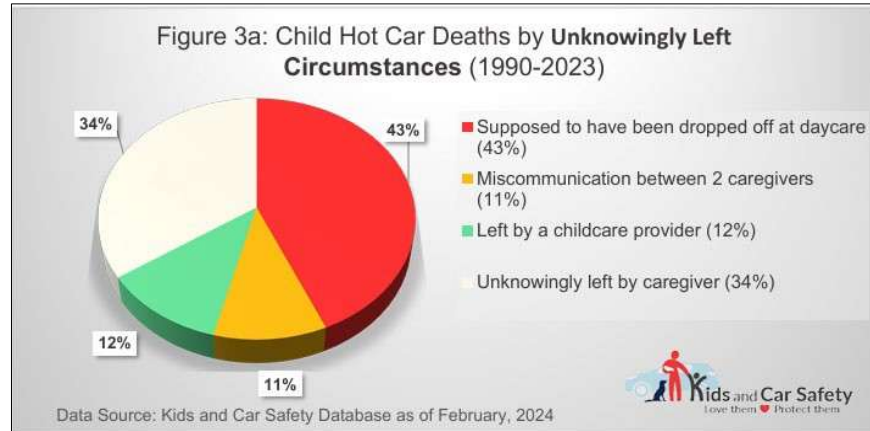(Source: KidsAndCars.org, 2024)

Figure 2 Child Hot Car Deaths by Unknowingly Left Circumstances (1990-2023)
(Source: KidsAndCars.org, 2024)

Looking at the statistics and the impact caused by this incident, it is very paramount to have a system that is capable of alerting and reminding the parents to prevent such an unfortunate incident. An alert system functions as a tool that notifies individuals when certain conditions are met, prompting immediate action. These systems monitor factors such as temperature, motion, or connectivity, and trigger alerts when something unusual or potentially dangerous occurs. Whether through timely reminders, real-time notifications, or ongoing alarms, the system effectively captures the attention of parents when it is most needed. The primary goal is to deliver early warnings that prevent accidents or life-threatening situations, ensuring that the necessary action is taken swiftly. In critical moments, such as when a child is left unattended in a vehicle, these systems provide peace of mind by ensuring that vital information reaches the right person in time.

This project proposed the use of alert alarms using Android applications and Bluetooth Low Energy (BLE) tags. BLE tags are affordable, with a long-lasting battery life that can span several years. These tags actively promote their advantages to nearby readers. Furthermore, it is noteworthy that nearly all the most recent iterations of mobile platforms are dedicated to offering built-in BLE support, making them readily accessible in the market. There are also previous experiences using smartphones to detect crowd movement using Bluetooth Low Energy (BLE), and the detection rate was as high as 90% (Gutiérrez & Ruíz, 2021). As emphasized by the National Highway Traffic Safety Administration (NHTSA) in 2022, the growing availability of affordable and user-friendly technologies presents an opportunity to develop innovative solutions to address this preventable tragedy.

Problem Statement

Forgetfulness and Distraction

According to data from KidsAndCars.org (2024), an average of 38 children dies annually in the United States from pediatric vehicular heatstroke, with over 1,000 fatalities recorded from 1990 to 2023. Forgetfulness and distraction stand as significant contributors to these heart-wrenching incidents. Camoens (2023) highlighted that busy schedules and routines often lead parents to forget a child in the car inadvertently.

Limitations of Existing Preventive Measures

Current preventive measures rely on manual checks and human vigilance which are prone to error (KidsAndCars.org, 2024). Current solutions, such as reminders or manual checks, are susceptible to human error and may fail to provide timely alerts, putting children at risk. Busy schedules and routines further exacerbate the issue, causing parents to overlook a child's presence in the backseat, leading to devastating consequences (Razali, 2023).

Existing Alert Systems Are Not Fully Integrated with Mobile Platforms

Previous studies by Rao & Prasad (2018) have indeed highlighted the importance of detecting the presence of children in vehicles but the full potential of mobile applications to enhance vehicle safety through personalized alerts, real-time location tracking, and user-friendly interaction has not been completely explored.

Project Objective

This project aims to achieve several objectives:

1. To design a mobile application capable of notifying when a child is in a vehicle alone or unprotected and detected using BLE tags.
2. To develop a mobile application capable of notifying when a child is in a vehicle alone or unprotected and detected using BLE tags.
3. To evaluate the functionality and accuracy of the mobile application.

Project Scope

This system is designed for parents or guardians who travel with children in vehicles. It consists of a mobile application and Bluetooth Low Energy (BLE) tags. The mobile application is available in English and will only be developed for Android devices. The child uses a BLE tag that the mobile application constantly searches for the signal. Due to each Tag being capable of sustaining a connection up to 30 until 50 meters indoors and 100 until 240 meters in open areas, a connection will be lost when this limit is exceeded. When this occurs, the application sounds an alarm, sends a notification to the parent's phone and sends an SMS to the emergency contact. The application will keep alarming until a parent turns the alarm off. This means that parents can be immediately informed in cases where there is a possible risk of the child being unattended.

Project Significances

The importance of this project is in its attempt to set an alert on a mobile application with BLE tags to mitigate FBS. The concern that this project seeks to resolve is the danger posed to children left unattended in vehicles, which is made possible by using BLE technology and mobile application. The BLE used in this particular system requires very little power to function and it can be used for a long period of time without frequent recharging. In addition, the communication range is short, which makes it is suitable for close distances monitoring such as inside a vehicle. The proposed application is capable of detecting and alerting parents when a child is left unattended which could significantly reduce the risk of FBS-related tragedies. Additionally, considering the mobile application increases the accessibility of parents to receive timely notifications, it has potential of preventing devastating accidents. This helps protect children and makes parents feel less worried about their safety.

LITERATURE REVIEW

Forgotten Baby Syndrome (FBS)

Forgotten Baby Syndrome (FBS) has become alarmingly common, with over a quarter of parents of children under three years old having experienced forgetting their child in the car (Ho et al., 2020). According to Diamond (2019), the basal ganglia, which governs routine actions, can override the hippocampus, which processes new information, causing parents to

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forget non-routine activities like dropping off their child at daycare. This lapse in memory can occur for various reasons, including stress, fatigue, distraction, or a change in routine (Ho et al., 2020). Stress is known to affect one's memory and focus, meaning that a parent may forget their child in a car. Stress-induced deficits in memory and concentration can lead to these types of mistakes. The body releases glucocorticoids, a stress hormone, which alters cognitive functions even further during stress (Ho et al., 2020). Cheng & Haley (2020) argue that parents suffering from cognitive overload due to excess responsibilities are more likely to forget important details. In the midst of too much stress, tasks that are less important, like remembering that their child is in the backseat, may be overlooked.

Alert System

Alert and warning systems are critical tools that state and local authorities rely on for the prompt broadcasting of a message in regard to natural disasters or emergency events like child abduction (Metych, 2024). These systems play a vital role in safeguarding public safety by notifying citizens of emergencies and prompting immediate action (Tabor & Holland, 2021). Similarly, alert systems designed to prevent Forgotten Baby Syndrome (FBS) are crucial in minimizing the dangers of leaving children unattended in vehicles (FindLaw, 2023). Several types of alert systems have been developed, including rear seat reminder systems, smartphone applications, and aftermarket devices, all of which aim to remind parents to check the backseat before exiting their vehicles. A study by the National Highway Traffic Safety Administration (NHTSA) in 2022 indicated that these technologies have significantly increased the likelihood of drivers conducting rear seat checks. Smartphone apps, another example, use GPS to detect when a vehicle has stopped and then send timely alerts to the parent's phone (Caliston & Tabia, 2021).

Bluetooth Low Energy Tags

Modern tags leverage Bluetooth technology and community tracking to determine their location whenever they come into the range of a compatible smartphone. BLE tags offer an alternative tracking solution that does not require specific configuration for smartphone interaction (Chaparro-Peláez et al., 2022). Combining BLE with smartphone localization features adds the benefit of using other smartphones to detect and share the location of lost tags with their owners. The primary advantages of BLE is its ability to extend smartphone battery

life, potentially lasting an entire workday, and the satisfactory accuracy of a BLE tag-smartphone system.

Kalman Filter for Signal Filtering

The Kalman filter (KF) is an algorithm designed to minimize measurement errors and reduce signal fluctuations to ensure more reliable data. It works by making predictions and adjusting them whenever new data comes in. The Kalman filter helps minimize RSSI signals random noise and environmental interference. Inconsistent RSSI readings, especially when measured at the same time under varying conditions can cause errors in estimating distance and position. Hence, this method is applied at regular time intervals and is widely used in tracking, navigation, and signal processing due to its ability to enhance measurement reliability (Franklin, 2020).

Haversine Formula

The Haversine formula is a mathematical method by which the distance between two locations is calculated (Hrusna et al., 2022). This formula calculates the distance between two points by measuring the straight-line distance between their latitude and longitude coordinates on the Earth's surface (Soe & Thein, 2020). This formula accounts for the Earth's curvature, making it highly accurate for navigation, logistics, and location-based (Product, 2024).

Push Notification

A push notification is a messaging service between an application and a user's device in which a server sends a message to a user. Notifications in real time are an essential part of mobile and desktop applications. It serves as an important emerging channel for direct communication with a user (Lotarev, 2023). The delivery of real-time notifications is more efficient with the use of these notifications as they pop up immediately on the device without the user having to check any emails or applications. Wheatley & Ferrer-Conill (2021) state that existing research indicates that push notifications possess greater prominence, visibility, and invite faster responses than other methods of notifications.

Short Message Service (SMS) Notification

SMS notifications are considered to be one of the most dependable and convenient means of communication for emergencies. Weil (2023) states that these notifications can be sent to

numerous users at once, ensuring swift and effective distribution of critical information. Weil further highlights the practicality of SMS in emergency scenarios, noting its success in delivery speed and the independence from internet connectivity, which ensures compatibility with all mobile devices. In addition, Sudhir (2023) states that SMS notifications are opened so often, that they practically guarantee a prompt response. This feature enables recipients to perform the appropriate response and in some situations, this can prevent loss of life.

METHODOLOGY

The alert system proposed for FBS utilizes the Mobile Application Development Lifecycle (MADLC), as recommended by Kumar & Vithani (2014) for mobile application development. The MADLC model typically consists of seven phases. However, this project concentrate on five phases which are identification, design, development, prototyping, and testing. Figure 3 illustrates the phases of the MADLC model.
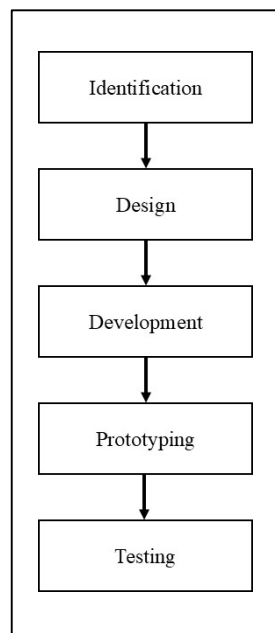

Figure 3 MADLC Model

In the identification stage, the project idea is explained, and the problem statements are set, then the project title and objectives, scope, significance of the project are defined. The system architecture, system flowchart, use case diagram, navigational diagram and user interface are created during the design phase. In the development phase, the mobile application

is programmed based on the design specifications. The prototypes are evaluated in the prototyping phase to check if the functional requirements of each prototype are met. The testing phase focuses on identifying errors and ensuring the system functions as expected. Each stage in this process clearly plays an important role in building a meaningful and well-made project.

System Architecture

System architecture serves as the structural framework that outlines the overall design of the project. Figure 4 illustrates the system architecture using Bluetooth Low Energy (BLE) tag and mobile technology for child safety monitoring. The BLE tag is worn or attached to the child and continuously sends signal strength data to an Android application on the parent's or guardian's device. The system triggers an alert if the BLE tag is disconnected or moves out of range. This alert includes sound and a pop-up notification, and it sends an SMS to an emergency contact. The application also maps the child's last known location on Google Maps and calculates the distance using the Haversine formula. Thus, parents or guardians are immediately informed and can take action to ensure the child's safety.
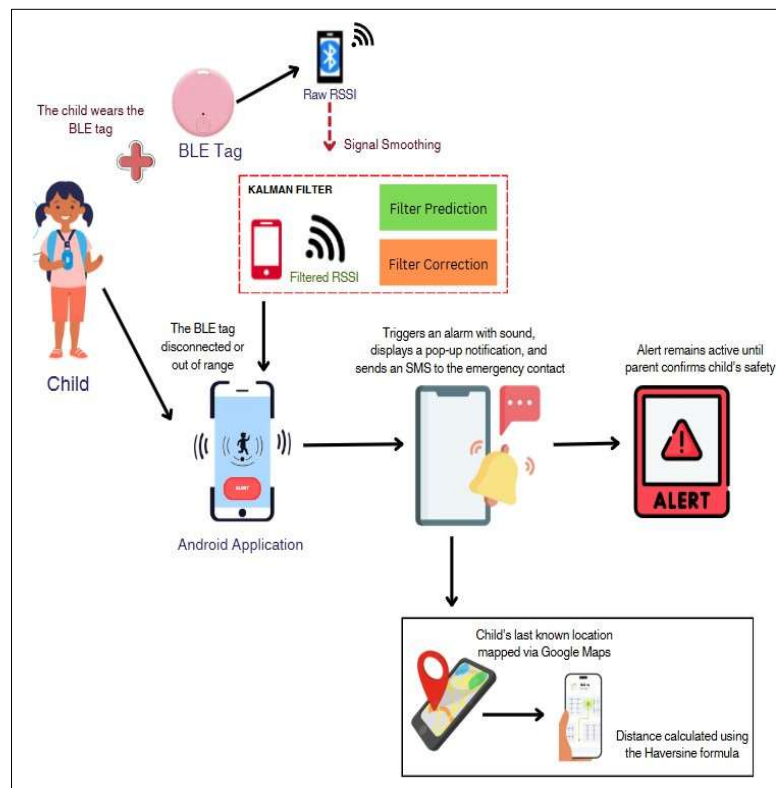

Figure 4 System Architecture

RESULT AND DISCUSSION

Testing is an essential part of system development quality control as it ensures that system operates as intended. Testing is done to validate how the system works and to develop suitable solutions when the outcome doesn't meet as expected. Functionality testing is crucial at this stage as it checks whether system functionalities are executed as per specifications. Table 1 highlights the results of functionality testing that was conducted. The results show that the application meets the requirements and works as expected.

Table 1 Overall System Functional Testing Results

Test ID	Test Case	Expected Result	(Pass/Fail)
TC-01	Scan for BLE tag	BLE tag appears in scan results	Pass
TC-02	Pair with BLE tag	Successful connection	Pass
TC-03	Rename BLE Tag	Successfully rename a connected BLE tag	Pass
TC-04	Change Color BLE Tag	The BLE tag color was changed successfully	Pass
TC-05	Disconnect and reconnect	Reconnection should be automatic or manual	Pass
TC-06	Receive tag data in-app	RSSI signal strength, MAC address, and connectivity status displayed correctly	Pass
TC-07	Alarm on BLE tag out of range	The app triggers an alarm with sound when a BLE tag goes out of range	Pass
TC-08	Push notification for alerts	The application should generate and send a push notification as soon as the alarm is triggered	Pass
TC-09	Persistent alert until confirmation	The alarm will continue to ring until the parent clicks "YES" on the alert dialog to confirm the child's safety	Pass
TC-10	Connect Multiple BLE tags	All connected tags work independently	Pass
TC-11	Remove BLE Tags	BLE tag is successfully removed upon selecting option "YES"	Pass
TC-12	Add Emergency Contact	Add a new emergency contact successfully	Pass
TC-13	Delete Emergency Contact	Delete emergency contact successfully	Pass
TC-14	Send Emergency SMS	Successfully send an emergency SMS to the specified contact when triggered	Pass

CONCLUSION

This project has successfully implemented an Alert System for FBS using a BLE tag to notify parents if they unintentionally leave their child unattended in a car. The system continuously tracks the Bluetooth connection between the child's BLE tag and the parent's mobile phone. A notification is immediately sent to the parent if the child moves beyond a predefined distance which indicates that the parent has left the vehicle without the child. This feature helps mitigate the risk of children being left in parked cars which can have severe or fatal consequences. Bluetooth Low Energy (BLE) technology, RSSI-based distance measurement, and immediate alerts provide a reliable and efficient safety solution to prevent FBS. The use of Kalman filtering enhances signal stability and tracking under environmental disturbances. In short, all primary objectives of this project were achieved. Even though there are some limitations, further improvement of the system is possible.

REFERENCES

Bernama. (2020). Dewan Rakyat addresses issue of children who died after accidentally being left in cars. *Malay Mail*. https://www.malaymail.com/news/malaysia/2020/08/03/dewan-rakyat-addresses-issue-of-children-who-died-after-accidentally-being/1890558

Caliston, N. P., & Tabia, G. C. (2021). "HELP ME": AN EMERGENCY RESPONSE MOBILE APPLICATION. In *Journal of Engineering Science and Technology Special Issue on ICITE2021*.

Camoens, A. (2023). Infant Dies After Being Left in Parked Car All Day. *The Star*. https://www.thestar.com.my/news/nation/2023/10/06/infant-dies-after-being-left-in-parked-car-all-day

Chaparro-Peláez, J., Hernández-García, Á., & Lorente-Páramo, Á.-J. (2022). May I have your attention, please? An investigation on opening effectiveness in e-mail marketing. *Review of Managerial Science*, *16*(7), 2261–2284. https://doi.org/10.1007/s11846-022-00517-9

Cheng, S.-T., & Haley, W. E. (2020). Coping with cognitive impairment and family caregiving: Introduction to the special section. *Psychology and Aging*, *35*(1), 1–7. https://doi.org/10.1037/pag0000436

Diamond, D. M. (2019). When a child dies of heatstroke after a parent or caretaker unknowingly leaves the child in a car: How does it happen and is it a crime? *Medicine, Science and the Law*, *59*(2), 115–126. https://doi.org/10.1177/0025802419831529

FindLaw. (2023). *California Code, Vehicle Code - VEH § 28160*. https://codes.findlaw.com/ca/vehicle-code/veh-sect-28160/

Franklin, W. (2020). *Kalman Filter Explained Simply*. The Kalman Filter. https://thekalmanfilter.com/kalman-filter-explained-simply/

Gutiérrez, E. D. M., & Ruíz, C. A. G. (2021). Detección De Aglomeraciones Basada En Tecnologías Ble (Crowd Detection Based on Ble Technologies). *Tecnológico Nacional de México En Celaya Pistas Educativas*, *43*(139).

Ho, K., Minhas, R., Young, E., Sgro, M., & Huber, J. F. (2020). Paediatric hyperthermia-related deaths while entrapped and unattended inside vehicles: The Canadian experience and anticipatory guidance for prevention. *Paediatrics & Child Health*, *25*(3), 143–148. https://doi.org/10.1093/pch/pxz087

Hrusna, C. S. V, Veena, M. B., & Keshihaa, R. G. D. V. (2022). OpenCV Implementation of Grid-based Vertical Safe Landing for UAV using YOLOv5. *International Journal of Advanced Computer Science and Applications*, *13*(9). https://doi.org/10.14569/IJACSA.2022.0130957

Ismail, N. H. F., Abu Husain, N., Mansor, M. S. F., Baharuddin, M. M., Mohd Zaki, N. I., Abu Husain, M. K., Ma'aram, A., Wiyono, A. S., Chaiyakul, T., & Ahmad, Y. (2021). Child Presence Detection System and Technologies. *Journal of the Society of Automotive Engineers Malaysia*, *3*(3), 290–297. https://doi.org/10.56381/jsaem.v3i3.123

KidsAndCars.org. (2024). *U.S. Child Hot Car Death Data Analysis from the Kids and Car Safety National Database (1990-2023)*. https://www.kidsandcars.org/document_center/download/hot-cars/Child-Hot-Car-Deaths-Data-Analysis.pdf

Kumar, A., & Vithani, T. (2014). A comprehensive mobile application development and testing lifecycle. *2014 IT Professional Conference*, 1–27. https://doi.org/10.1109/ITPRO.2014.7029289

Lotarev, I. (2023). *10 best practices for your push marketing strategy*. Adapty Tech Inc. https://adapty.io/blog/push-notification-best-practices/

Metych, M. (2024). *emergency alert systems*. Encyclopedia Britannica. https://www.britannica.com/topic/emergency-alert-systems

NHTSA. (2022). *Child Safety*. https://www.nhtsa.gov/road-safety/child-safety

Product, T. (2024). *The Haversine Formula for Geospatial Distances*. Product Teacher. https://www.productteacher.com/quick-product-tips/haversine-formula-for-product-teams

Rao, S. K., & Prasad, R. (2018). Impact of 5G Technologies on Smart City Implementation. *Wireless Personal Communications*, *100*(1), 161–176. https://doi.org/10.1007/s11277-018-5618-4

Razali, S. A. (2023). Baby dies after doctor mum leaves her in hospital car park for 10 hours. *NST Online*. https://www.nst.com.my/news/nation/2023/10/853589/baby-dies-after-being-left-car-over-10-hours

Soe, N. C., & Thein, T. L. L. (2020). Haversine Formula and RPA Algorithm for Navigation System. *International Journal of Data Science and Analysis*, *6*(1), 32. https://doi.org/10.11648/j.ijdsa.20200601.14

Sudhir, K. (2023). *SMS Alerts-The Modern Solution to Emergency Notifications*. Kathir Sudhir Automation India Pvt Ltd. https://www.kathirsudhirautomation.com/sms-alerts-the-modern-solution-to-emergency-notifications

Tabor, K. M., & Holland, M. B. (2021). Opportunities for improving conservation early warning and alert systems. *Remote Sensing in Ecology and Conservation*, *7*(1), 7–17. https://doi.org/10.1002/rse2.163

Weil, M. (2023, April 5). *SMS Notifications for Emergencies*. VoiceSage. https://www.voicesage.com/blog/sms-notifications-for-emergencies/

Wheatley, D., & Ferrer-Conill, R. (2021). The Temporal Nature of Mobile Push Notification Alerts: A Study of European News Outlets' Dissemination Patterns. *Digital Journalism*, *9*(6), 694–714. https://doi.org/10.1080/21670811.2020.1799425