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DEVELOPMENT OF A PROTOTYPE INTELLIGENT STUDENT SHUTTLE SYSTEM TO INCREASE THE SAFETY STANDARD OF STUDENTS WITH RFID TECHNOLOGY ON THE NOTIFICATION SYSTEM VIA MOBILE APPLICATION

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ABSTRACT

Purpose – This research sought to create a prototype of an intelligent school bus system designed to enhance student safety by integrating radio-frequency identification (RFID) technology with a mobile application notification system. The system is capable of real-time monitoring of student boarding and disembarking, immediately dispatching alerts to parents and teachers through mobile devices. This mitigates the danger of students forgetting items or experiencing accidents while traveling.

Methodology – The research sample comprised 400 primary school pupils, their parents, and accompanying teachers from schools in Bangkok and the surrounding area. Data was gathered via questionnaires and a trial of the prototype system in real-world scenarios over a duration of six weeks. The sample comprised 300 parents of children and 100 onboard instructors and school staff. Results were evaluated by descriptive statistics and t-test hypothesis testing.

Results – The research findings indicated that the system recorded RFID usage data with an accuracy of 98.5%, while notifications through the mobile application remained consistent at 96.7%, 94.2% of parents reported satisfaction with the system and exhibited a statistically significant enhancement in confidence regarding student safety ($p < 0.001$). The system garnered favorable reviews on its user-friendliness and has the potential for expansion to facilitate systematic implementation at the school level.

Implications – This study markedly enhanced the student's proficiency in RFID technology, specifically regarding a notification feature within a mobile application. The prototype may assist educational institutions in developing preventive strategies. The certificate issued to parents and teachers signifies policy endorsement for Smart Education and Smart City initiatives, which may be expanded to encompass a broader smart transportation framework. Researchers advocate for collaboration among schools, parents, and communities to enhance youth health engagement and foster trust.

Originality/Value – This research is significant due of its originality. A prototype is developed that combines RFID technology with a mobile application alerting system to improve student safety. The design is intuitive and adaptable to the requirements of parents, educators, and school officials. It concretely embodies the principles of Smart Education and Intelligent Transportation, generating both intellectual and practical value. It additionally functions as a prototype for forthcoming safety advancements.

Keywords: Alert system, RFID, Firebase cloud messaging, Arduino

Research Type: Research Article

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INTRODUCTION

The student transportation system is an essential educational support service, particularly for early childhood and primary school pupils who are not yet capable of traveling independently and safely. In Thailand, numerous students depend on school or private transportation systems. Nonetheless, concerns over student safety persist throughout transit, including instances of kids being abandoned on the bus, being dropped off at incorrect locations, or experiencing accidents. This results in parental worry and adversely affects the reputation of educational institutions (Office of the Basic Education Commission, 2022). News reports and case studies have demonstrated that neglecting students on school buses significantly affects their physical and mental health, alongside legal and ethical ramifications for school bus instructors and educational institutions as service providers (Department of Children and Youth Affairs, 2021). This issue underscores the necessity of utilizing technology to enhance safety standards and effectively manage school bus operations.

Radio Frequency Identification (RFID) technology is globally acknowledged as an efficient instrument for the automatic identification and tracking of human movement. It has been utilized in the educational sphere, namely, to oversee student boarding and disembarking at each pick-up and drop-off location. It can be linked to smartphone applications to deliver real-time notifications to parents and educators (Liu et al., 2020). In nations with advanced safety management in educational settings, including the United States, Japan, and Singapore, Smart School Bus systems have been extensively implemented, featuring RFID technology, GPS, and mobile applications that minimize student drop-off inaccuracies and provide real-time bus location tracking, thereby enhancing trust among parents and educational institutions (Roberts, 2006).

In Thailand, while certain schools have initiated pilot programs for these systems, there is a deficiency of empirical research that thoroughly develops and assesses these systems in practical settings and with an adequate population size. This project seeks to create a prototype of an intelligent school bus system utilizing RFID technology and a mobile application notification system, with an emphasis on improving safety efficiency, timely notifications, and user satisfaction among students, parents, and bus personnel in practical settings.

LITERATURE REVIEW

RFID technology and its applications in education

Radio frequency identification (RFID) technology is an automated system that employs radio frequencies to identify and monitor things or individuals. The system operates by the interplay of two primary components: a tag containing distinctive information and a reader that sends data from the tag (Want, 2006). RFID is a non-contact technology analogous to a barcode, capable of rapidly reading data even in motion, rendering it appropriate for environments necessitating speed, precision, and uninterrupted inspection. RFID technology is utilized in the educational sector for several purposes, including library resource management, monitoring student attendance, managing personal possessions, and enhancing student safety during travel (Ally & Gardiner, 2012; Ahsan et al., 2010). Radio Frequency Identification (RFID) technology is a system that identifies items or individuals by the transmission and reception of data between a tag and a reader using low, medium, or high frequency radio waves, eliminating the necessity for physical touch (Want, 2006). This technology has undergone ongoing development and is utilized across various sectors, including logistics, warehousing, healthcare, and research on RFID applications in attendance verification systems (Ayuthaya et al., 2024).

In education, RFID technology has been employed for resource management, including library book lending and returns, attendance tracking, and, more recently, student safety, particularly in nations where student risk management is critical, such as the United States and South Korea (Ally & Gardiner, 2012). Hassan and De Filippi (2021) created an RFID-based attendance monitoring system for Malaysian schools, achieving an accuracy above 98% and decreasing the attendance duration from an average of 8 minutes to under 1 minute for each classroom. It also relayed data to a centralized database for educators and parents to monitor in real time (Akpınar & Kaptan, 2010) and investigated the application of RFID technology for monitoring student attendance in secondary schools in China. The system diminished teachers' workload regarding attendance and enhanced the accuracy of attendance data to 97%. The data may also be amalgamated with the student database for behavioral assessment and personalized management (Akpınar & Kaptan, 2010). Akpınar and Kaptan (2010) implemented RFID technology in a secondary school in China by putting readers at the entrance and exit gates. When a pupil passes, the information is automatically documented and communicated to parents through SMS or a mobile application. The trial results indicated a 35% decrease in unexcused absences and heightened parental involvement in overseeing their children.

Student Tracking System on School Bus (Smart School Bus)

The administration of school bus systems has transitioned from manual operations to intelligent transportation systems. IoT (Internet of Things), GPS, and RFID technologies are integrated to provide real-time monitoring, tracking, and notification of student status. This is particularly applicable to school buses. Each student is provided with an RFID tag, and readers are put at the bus entrances. Technology automatically records data and sends messages to parents or schools when students board or disembark from the bus (Liu et al., 2020). conducted research that established a Smart School Bus system employing RFID for student identification, alongside a GPS module and mobile application notifications. Information can be transmitted to parents' and instructors' devices instantaneously as pupils board or disembark from the bus. The system underwent testing in a primary school in Shanghai, revealing an identification error rate of under 2% for a duration of 6 weeks.

In Singapore, Roberts (2006) examined the deployment of an RFID-based student tracking system across five elementary schools. The technology decreased student drop-off errors by 83%, and more than 90% of parents expressed great satisfaction, as they could monitor their children's position in real time through a mobile application. RFID technology provides numerous benefits, such as rapid, precise, and contactless data reading capabilities (Akpınar & Kaptan, 2010). Nonetheless, it possesses certain disadvantages, like elevated installation expenses compared to barcode systems and vulnerability to environmental interference. The efficacy of RFID systems in education relies on adequate infrastructure, including networking, backup systems, and the collaboration of parents and school staff in the joint implementation of the system (Fazio, 2022).

The Smart School Bus system is designed to oversee student status during their route, encompassing boarding and alighting, tracking their whereabouts, and facilitating real-time communication with parents. It encompasses the subsequent essential technologies: RFID (Radio Frequency Identification) is employed to identify students by affixing tags to their ID cards, which are recognized upon boarding or disembarking (Akpınar & Kaptan, 2010). The Global Positioning System (GPS) is utilized for real-time bus location tracking and route planning assistance (Shaaban et al., 2013). Mobile Application and Notification System: promptly informs parents or teachers of students boarding and alighting from the bus through an application (Roberts, 2006). Liu et al. (2020) created an intelligent school bus system for educational institutions in Shanghai, China, incorporating RFID and IoT technology. Technology tracks student boarding and disembarking in real time and transmits notifications to parents through a mobile application. Experimental findings indicated that the technique could diminish student counting errors by 96% and substantially alleviate parental concerns over their child's safety. In India, Shaaban et al. (2013) developed and assessed a sophisticated tracking system for school transportation utilizing RFID and GPS technology integrated with a mobile application. Parents can monitor the bus's whereabouts and the student's boarding and disembarking status through a smartphone application. The solution attained an average satisfaction rating of 4.7 out of 5.0 and reduced the school's routing expenses by 18% through the study of individual student usage patterns. In a study conducted by Roberts (2006), an RFID-based student tracking system implemented in five primary schools in Singapore showed an 83% reduction in accidents or unwanted situations stemming from miscommunications between instructors and parents. It facilitated expedited communication by push notifications, which are superior to communication via telephone or paper (Ayuthaya et al., 2024).

Creation of real-time notification apps within the realm of security

Real-time notification systems (RDS) are mechanisms that transmit information or messages to users instantaneously following an incident, without requiring prior user solicitation. This notification type is essential in safety-related situations, such accident alerts, individual tracking, or risk management in public spaces (Wang et al., 2019). In the realm of education, specifically regarding student safety management, real-time notifications through mobile applications enable parents to promptly obtain information about their students' location or status, including when students board or disembark from a bus or when an anomaly arises during a trip (Liu et al., 2020).

Mobile applications that facilitate real-time notification systems are crucial for enhancing communication between caregivers and end users, particularly in student safety systems that necessitate prompt information for effective responses or actions. Fazio (2022) examined the evolution of real-time notification applications in public transportation systems and determined that push notification communication, which incorporates data from sensors or RFID devices, is more effective in alerting end users than conventional SMS or email systems and is increasingly favored in applications concerning child and youth safety. Zhou et al. (2022) created a smartphone application to alert parents when their children board and disembark from the school bus. The user experience assessment revealed that the majority of users provided elevated satisfaction ratings, particularly in the categories of “notification speed” and “clarity of information received.”

The creation of real-time notification applications within a security framework frequently depends on foundational technologies such as Push Notification, which facilitates message delivery to user devices regardless of app status (Google Firebase, Apple Push Notification Services); Real-Time Database/MQTT, employed for immediate data transmission, exemplified by Firebase Realtime Database or the MQTT protocol that enables low-latency communication (Ramírez et al., 2025), and Geo-fencing, which establishes a virtual boundary to trigger notifications when a device enters or exits a designated area (Saleem et al., 2020).

METHODOLOGY

This study constitutes a research and development (R&D) initiative. The aim is to create a prototype of an intelligent school bus system that incorporates RFID technology alongside a real-time notification system using a mobile application, and to assess the prototype's efficacy by conducting tests with a substantial target group. The research has three phases: system study, analysis and design, prototype production, and evaluation of user efficacy and satisfaction. The researcher possesses the subsequent research purpose.

1. To investigate the factors contributing to accidents involving school buses, including an examination of the constraints of the school bus safety standards framework.
2. To provide an economical sensor system for notifying student boarding and dropping statuses, as well as for real-time GPS tracking of shuttle bus conditions.
3. To establish a real-time status notification system utilizing Firebase Cloud Messaging.

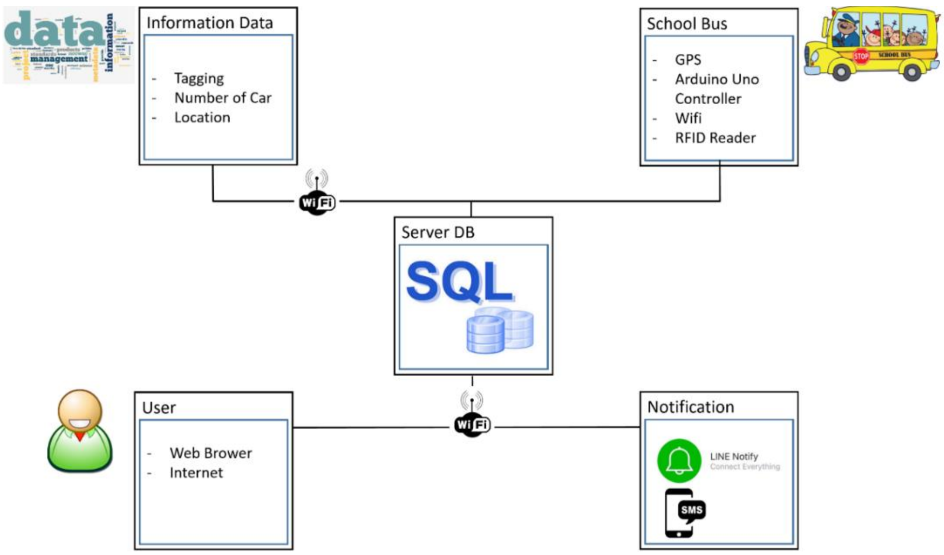

Figure 1. Conceptual framework for research on the creation of a prototype for an intelligent school bus system aimed at enhancing student safety standards through RFID technology integrated with a mobile application notification system.

Figure 1 illustrates the conceptual framework of the research, which focuses on the design and development of a prototype intelligent school bus system aimed at enhancing student safety standards through the integration of RFID technology, GPS tracking, and a mobile application–based notification system. The framework presents the overall system architecture and data flow among key components, including data acquisition units installed on school buses, a central server database, user access interfaces, and notification services. At the operational level, the school bus is equipped with an Arduino Uno controller functioning as the core processing unit. This controller is connected to a global positioning system (GPS) module for real-time location tracking, an RFID reader for student identification and attendance verification, and a Wi-Fi communication module for data transmission. Each student carries an RFID tag, which is scanned upon boarding and alighting the bus. The RFID data are processed by the controller and combined with bus identification data, including vehicle number, tagging status, and current geographic location. All collected data are transmitted via wireless internet connectivity to a centralized SQL-based server database. The server database functions as the main data management layer, responsible for storing, organizing, and processing information related to student attendance, bus routes, time stamps, and location data. This centralized architecture ensures data integrity, traceability, and real-time accessibility for authorized users. On the user side, parents, teachers, and school administrators access the system through a web-based interface using standard internet browsers. This interface allows users to monitor bus locations, verify student boarding and drop-off status, and review historical transportation records. The system is designed to support decision-making and supervision by providing timely and accurate information relevant to student transportation safety.

In addition, the framework incorporates an automated notification subsystem to enhance proactive communication. Notification services are delivered through mobile application platforms, such as LINE Notify, and Short Message Service (SMS). These notifications are automatically triggered by predefined events, such as student boarding or leaving the bus, delays, or deviations from planned routes. This feature is intended to improve parental confidence and enable rapid response in case of abnormal situations. From a research methodology perspective, the population of this study comprised parents, educators, and school administrators who are directly involved in the use of primary and secondary school bus services in Bangkok and its surrounding metropolitan areas. The sample consisted of 400 participants, including 300 parents and teachers and 100 school administrators. The sample was selected using purposive sampling, based on criteria such as regular school bus usage and readiness to adopt mobile application–based systems. The research instruments included.

1. The prototype of the intelligent school bus system includes an RFID module for monitoring student boarding and alighting, a microcontroller board, and a mobile application (compatible with both Android and iOS) linked to a cloud infrastructure featuring a real-time dashboard for schools to oversee student and bus data.

2. A questionnaire was administered to parents and bus teachers to gather supplementary quantitative data regarding their experiences with system usage. Satisfaction and system efficiency were assessed using content validity evaluations conducted by three experts. The questionnaire's reliability was determined using Cronbach's Alpha, yielding a value of 0.91. The questionnaire variables were designed to evaluate users' perceptions and satisfaction regarding the prototype intelligent school bus system, emphasizing safety, notifications, and overall system utilization, which comprised the following two components. Section 1, Demographic details of the respondent, gender, age, relationship to students, and prior experience with the smart shuttle system and Section 2, Contentment with the Smart School Bus Prototype System.

These instruments were aligned with the conceptual framework to ensure consistency between system design, data collection, and analysis. Overall, the framework demonstrates a systematic integration of hardware, software, and user interaction components to support the research objective of improving student safety through intelligent transportation technology.

Research Procedure and System Development Process

1. Investigate the issues and requirements by gathering data from parents and educational institutions regarding travel safety concerns.

2. Develop a prototype system adhering to IoT system protocols and UX design principles for mobile applications, prioritizing security, user-friendliness, and precision.

3. Construct a prototype and implement the system in accordance with the design, including internal testing prior to field testing.

4. The prototype system underwent testing in three medium-sized schools, each with around 150 kids, utilizing the new technology alongside the shuttle bus for a duration of two weeks.

5. Gather data from questionnaires and interviews to evaluate satisfaction and identify issues experienced during use.

6. Conduct a comprehensive analysis and synthesis of the results employing both quantitative and qualitative methodologies.

Analysis of quantitative data, descriptive statistics

Descriptive statistics were employed to summarize the demographic characteristics of the sample and to examine users' perceptions toward the prototype intelligent school bus system. Frequency and percentage distributions were used to describe general respondent information, including gender, age group, and user type. In addition, the mean and standard deviation (SD) were calculated to evaluate the levels of satisfaction and perceived efficiency of the prototype system across key assessment dimensions. As shown in Table 1, the overall satisfaction level of system users was high, with a mean score of 4.35 (SD = 0.58) on a five-point Likert scale, indicating an extremely high level of satisfaction. When considering individual aspects, the safety check for students received the highest mean score (Mean = 4.45, SD = 0.49), reflecting strong user confidence in the system's ability to enhance student safety during school bus transportation. This finding suggests that the integration of RFID technology and real-time monitoring effectively addressed primary safety concerns among parents and school personnel. The user-friendliness of the mobile application also demonstrated a high satisfaction level (Mean = 4.40, SD = 0.50). This result indicates that the system interface and functional design were perceived as easy to use and suitable for users with varying levels of technological familiarity. Similarly, the precision of notifications achieved a high mean score (Mean = 4.35, SD = 0.55), suggesting that users trusted the accuracy and timeliness of the alerts provided by the system, which is a critical factor in transportation safety management. Comprehensive contentment, which reflects users' overall impressions of the system, yielded a mean score of 4.30 (SD = 0.68). Although this dimension showed slightly greater variability compared to other aspects, the satisfaction level remained within the "extremely content" category. This variation may reflect differing expectations or contextual usage conditions among parents, teachers, and school administrators.

Table 1. Analysis of quantitative data

Assessed aspect	Mean	SD	Level of satisfaction
1. User-friendliness of the application	4.40	0.50	Extremely content
2. Precision of notifications	4.35	0.55	Extremely content
3. Safety check for students	4.45	0.49	Extremely content
4. Comprehensive contentment	4.30	0.68	Extremely content

Inferential Statistics

The data quality was assessed, and the questionnaire's reliability was determined using Cronbach's Alpha, yielding a result of $\alpha = 0.91$, signifying high reliability (values exceeding 0.80 are deemed very good). A standard data test was conducted by evaluating the Skewness and Kurtosis values prior to employing inferential statistics. The instrument's reliability was assessed by content validity and reliability analysis using Cronbach's Alpha, with an approved threshold of $\alpha > 0.70$.

Table 2. Variable Measurement

Variable		Measurement	Adapted from
Hardware and tracking systems (Global Positioning System, Radio-Frequency Identification, Arduino)	System 1	1. The system can detect students getting on and off the bus correctly.	System factor
	System 2	2. Vehicle location using GPS is accurate.	
	System 3	3. The system works stably throughout the route.	
	System 4	4. RFID tag reading is fast.	
Data connectivity and database management systems	Connectivity 1	5. The connection between hardware and database is fast.	Connectivity factor
	Connectivity 2	6. The database can store student and vehicle data systematically.	
	Connectivity 3	7. There is no problem of delay or data loss during data communication.	
User-friendliness through Web/ Application	Convenience 1	8. Users can conveniently access student information via the Web.	Convenience Factor
	Convenience 2	9. The application supports proper use via mobile phones.	
	Convenience 3	10. The system interface is easy to understand and not complicated.	
Real-time alert system (LINE Notify / SMS)	Notify 1	11. Instant notification system when students get on or off the bus	Notification factor
	Notify 2	12. The notification format is clear and well communicated.	
	Notify 3	13. Parents can receive real-time information about their children's travel.	

The measurement of research variables was developed in alignment with the conceptual framework and the objectives of the study, ensuring methodological rigor and construct validity. As presented in Table 2, the variables were operationalized into four main factors, each representing a critical component of the intelligent school bus system. All measurement items were adapted from relevant system and technology acceptance factors and assessed using a five-point Likert scale, ranging from the lowest to the highest level of agreement.

The first factor, Hardware and Tracking Systems, focused on the technical performance and reliability of the core system components, including GPS, RFID, and Arduino-based controllers. This factor was measured through four indicators (System 1–System 4), which evaluated the accuracy of student detection during boarding and alighting, the precision of GPS-based vehicle location tracking, system stability throughout the bus route, and the speed of RFID tag reading. These indicators collectively reflect the effectiveness of the hardware infrastructure in supporting real-time monitoring and student safety.

The second factor, Data Connectivity and Database Management Systems, examined the efficiency and reliability of data transmission and storage. This factor comprised three measurement items (Connectivity 1–Connectivity 3), assessing the speed of communication between hardware devices and the central database, the systematic storage of student and vehicle data, and the absence of delays or data loss during communication. These indicators represent the system’s capacity to manage real-time data flows accurately and consistently.

The third factor, User-Friendliness through Web/Application, addressed system usability and accessibility from the user perspective. This factor was measured by three indicators (Convenience 1–Convenience 3), which evaluated users’ ability to conveniently access student information via the web, the suitability of the application for mobile phone usage, and the clarity and simplicity of the system interface. These items reflect the importance of ease of use in promoting user acceptance among parents, teachers, and school administrators.

The fourth factor, Real-Time Alert System, emphasized the effectiveness of communication and notification mechanisms delivered through LINE Notify and SMS. This factor included three measurement items (Notify 1–Notify 3), focusing on instant notifications when students board or leave the bus, the clarity and comprehensibility of notification messages, and parents' ability to receive real-time information regarding their children's travel status. This factor directly supports the study's objective of enhancing student safety through timely and reliable information dissemination.

Overall, the variable measurements were systematically structured to capture both technical performance and user-centered outcomes, providing a comprehensive evaluation of the intelligent school bus prototype in accordance with established research methodology standards. Table 3 presents the descriptive statistics of all observed variables based on 399 valid responses, with no missing data. The mean scores of all items ranged from 3.45 to 4.17, indicating a high level of agreement among respondents across system usage, hardware performance, connectivity, convenience, and notification dimensions. Standard deviation values were within acceptable ranges, reflecting moderate variability in responses. Skewness and kurtosis values fell within acceptable thresholds, suggesting that the data were approximately normally distributed. The 95% confidence intervals further confirmed the stability and consistency of the mean estimates, supporting the suitability of the dataset for subsequent inferential statistical analysis.

Table 3. Descriptive Data

	Use 01	Use 02	Use 03	System 1	System 2	System 3	System 4	Connec 1	Connec 2	Connec 3	Connec 4	Conven 1	Conven 2	Conven 3	Conven 4	Notify 1	Notify 2	Notify 3
N	399	399	399	399	399	399	399	399	399	399	399	399	399	399	399	399	399	399
Missing	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mean	4.05	4.03	3.80	3.93	3.47	3.65	3.45	3.73	3.83	4.03	4.17	3.95	4.00	4.07	4.15	4.00	4.06	4.15
Std. error mean	0.0353	0.0323	0.0491	0.0340	0.0387	0.0577	0.0548	0.0512	0.0508	0.0379	0.0386	0.0354	0.0388	0.0394	0.0413	0.0419	0.0416	0.0413
95% CI mean lower bound	3.98	3.97	3.70	3.86	3.40	3.54	3.35	3.63	3.73	3.95	4.10	3.88	3.92	4.00	4.07	3.92	3.97	4.07
95% CI mean upper bound	4.12	4.09	3.89	4.00	3.55	3.77	3.56	3.83	3.93	4.10	4.25	4.02	4.07	4.15	4.23	4.08	4.14	4.23
Median	4	4	3	4	3	4	4	4	4	4	4	4	4	4	4	4	4	4
Standard deviation	0.705	0.645	0.980	0.680	0.772	1.15	1.09	1.02	1.01	0.758	0.772	0.707	0.775	0.788	0.824	0.837	0.831	0.824
Minimum	2	2	2	2	2	1	1	1	1	2	2	2	2	2	2	2	2	2
Maximum	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Skewness	-0.930	-0.536	0.0947	-0.828	0.574	-0.673	-0.511	-0.838	-0.761	-0.394	-0.967	-0.786	-0.321	-0.439	-0.822	-0.770	-0.869	-0.822
Std. error skewness	0.122	0.122	0.122	0.122	0.122	0.122	0.122	0.122	0.122	0.122	0.122	0.122	0.122	0.122	0.122	0.122	0.122	0.122
Kurtosis	1.72	1.10	-1.44	1.51	-0.293	-0.452	-0.545	0.00960	0.0287	-0.277	1.06	1.21	-0.488	-0.465	0.247	0.285	0.523	0.247
Std. error kurtosis	0.244	0.244	0.244	0.244	0.244	0.244	0.244	0.244	0.244	0.244	0.244	0.244	0.244	0.244	0.244	0.244	0.244	0.244

Note. The CI of the mean assumes sample means follow a t-distribution with N - 1 degrees of freedom

Table 4. RESULTS of Correlation Matrix

		Sum User	Sum System	Sum Connec	Sum Conven	Sum Notify
Sum User	Pearson's r	—				
	df	—				
	p-value	—				
	95% CI Upper	—				
	95% CI Lower	—				
Sum System	Pearson's r	0.611***	—			
	df	397	—			
	p-value	< .001	—			
	95% CI Upper	0.669	—			
	95% CI Lower	0.545	—			
Sum Connec	Pearson's r	0.515***	0.829***	—		
	df	397	397	—		
	p-value	< .001	< .001	—		
	95% CI Upper	0.584	0.858	—		
	95% CI Lower	0.439	0.796	—		
Sum Conven	Pearson's r	0.471***	0.442***	0.535***	—	
	df	397	397	397	—	
	p-value	< .001	< .001	< .001	—	
	95% CI Upper	0.544	0.518	0.602	—	
	95% CI Lower	0.391	0.360	0.462	—	
Sum Notify	Pearson's r	0.636***	0.612***	0.633***	0.837***	—
	df	397	397	397	397	—
	p-value	< .001	< .001	< .001	< .001	—
	95% CI Upper	0.691	0.670	0.689	0.864	—
	95% CI Lower	0.573	0.546	0.570	0.804	—

Note. * p < .05, ** p < .01, *** p < .001

Table 5. Scale Reliability Statistics

	Mean	SD	Cronbach's α	McDonald's ω
Scale	3.92	0.580	0.931	0.936

Based on the results presented in Table 4. RESULTS of Correlation Matrix and Table 5. Scale Reliability Statistics, the mean (average = 3.92) indicates the overall score of the measure; for instance, in a 5-point questionnaire, an average of 3.92 suggests that respondents generally exhibit a relatively high level of agreement. SD - Standard Deviation (standard deviation = 0.580) indicates the dispersion of scores relative to the mean. The standard deviation score of 0.58 indicates that the respondents share similar ideas. Cronbach’s α (Alpha = 0.931) is a statistic that assesses the reliability of a measure by evaluating the internal consistency of the questionnaire items. Interpretation criteria: > 0.9 = outstanding; 0.8–0.9 = very good; 0.7–0.8 = adequate. Consequently, a rating of 0.931 indicates exceptionally high reliability and outstanding internal consistency.

McDonald’s ω (Omega = 0.936) is a frequently utilized dependability metric, as it demonstrates greater accuracy than Cronbach’s α in certain instances. Elevated ω values (> 0.9), exemplified by 0.936, signify that the measure possesses a robust internal structure and exhibits good reliability.

The findings of this questionnaire exhibit a comparatively elevated average value. The respondents share identical viewpoints, and both Cronbach's Alpha and McDonald's Omega metrics are at elevated levels, signifying that the scale possesses substantial internal consistency and reliability, making it suitable for research purposes.

Table 6. Item Reliability Statistics

	Mean	SD	Item-rest correlation	If item dropped	
				Cronbach's α	McDonald's ω
Use 01	4.05	0.705	0.582	0.928	0.934
Use 02	4.03	0.645	0.620	0.928	0.933
Use 03	3.80	0.980	0.543	0.930	0.934
System 1	3.93	0.680	0.667	0.927	0.933
System 2	3.47	0.772	0.296	0.934	0.939
System 3	3.65	1.152	0.600	0.929	0.934
System 4	3.45	1.095	0.660	0.927	0.933
Connec 1	3.73	1.023	0.652	0.927	0.933
Connec 2	3.83	1.015	0.677	0.926	0.933
Connec 3	4.03	0.758	0.792	0.924	0.930
Connec 4	4.17	0.772	0.761	0.925	0.930
Conven 1	3.95	0.707	0.713	0.926	0.931
Conven 2	4.00	0.775	0.581	0.928	0.934
Conven 3	4.07	0.788	0.567	0.929	0.934
Conven 4	4.15	0.824	0.750	0.925	0.930
Notify 1	4.00	0.837	0.665	0.926	0.932
Notify 2	4.06	0.831	0.675	0.926	0.932
Notify 3	4.15	0.824	0.750	0.925	0.930

Based on the results presented in Table 6. Item Reliability Statistics, the Item Reliability Statistics table assesses the reliability of each item within the same questionnaire as the preceding table, evaluating the consistency of each question with the overall measure and identifying any items that may require elimination. This can be elucidated in accordance with the research technique as follows.

1. Correlation between items and rest, this assessment evaluates the extent to which the questions align with the overall score of the questionnaire. Criteria: A value of 0.30 or above is deemed acceptable. All items exhibited a value of > 0.296, with System 2's result of 0.296 deemed "near the standard" yet still permissible. This signifies that all items have a positive correlation with the total score and may be preserved for subsequent study.

2. Cronbach’s α upon item removal (and McDonald’s ω), This is utilized to ascertain whether the α and ω values of the questionnaire will augment or diminish upon the removal of an item. If the α value rises upon the removal of that item, then the item may be superfluous or diminish the scale's consistency. The table indicates that all values fall within the range of 0.924-0.934 (all items remain exceptionally high) and do not exhibit significant increases upon the removal of any item. This indicates that no item should be eliminated, as the questionnaire possesses good reliability and is not substantially influenced by the removal of any item.

In conclusion, as illustrated in Figure 2. Correlation Heatmap, the questionnaire, had exclusively high-quality items, as stipulated by the research protocol. The item-rest correlation values predominantly exceeded the minimum threshold, indicating that each item was effectively associated with the primary variables. The reliability of the "if eliminated" dimension was consistently good (Cronbach's α > 0.92 and McDonald's ω > 0.93 for all items). Consequently, no items should be removed from the questionnaire, and it can be reliably utilized for data collection. The findings indicated that the questionnaire had exceptional internal consistency, aligning with Nunnally and Bernstein's (1994) criteria that suggests an alpha coefficient greater than 0.9 is suitable for evaluative research.

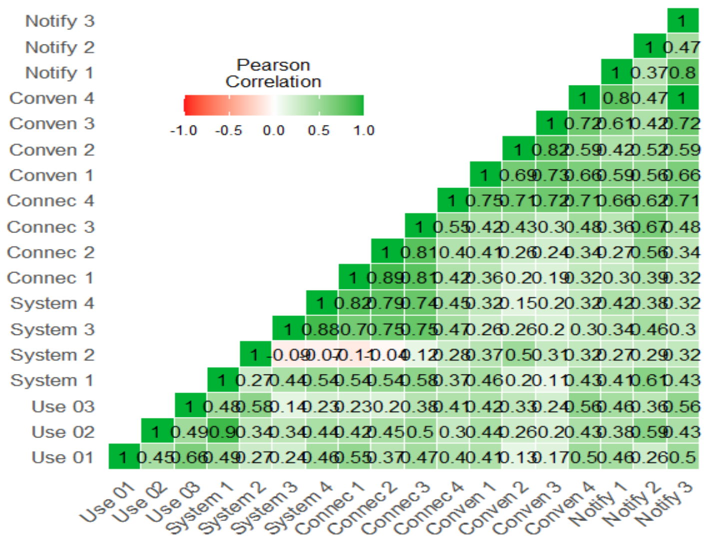

Figure 2. Correlation Heatmap

Table 7. Confirmatory Factor Analysis of Factor Loadings.

Factor	Indicator	Estimate	SE	95% Confidence Interval Lower	95% Confidence Interval Upper	Z	p	Stand. Estimate
Factor 1	System 1	0.3869	0.0319	0.324	0.4494	12.14	< .001	0.5697
	System 2	-0.0453	0.0395	-0.123	0.0322	-1.15	0.252	-0.0587
	System 3	1.0367	0.0450	0.949	1.1249	23.06	< .001	0.9010
	System 4	1.0582	0.0407	0.978	1.1380	26.00	< .001	0.9679
Factor 2	Connec 1	0.9537	0.0390	0.877	1.0301	24.47	< .001	0.9331
	Connec 2	0.9422	0.0387	0.866	1.0180	24.37	< .001	0.9298
	Connec 3	0.6682	0.0301	0.609	0.7271	22.22	< .001	0.8825
	Connec 4	0.3931	0.0373	0.320	0.4663	10.53	< .001	0.5100
Factor 3	Conven 1	0.5881	0.0295	0.530	0.6459	19.97	< .001	0.8328
	Conven 2	0.6357	0.0333	0.570	0.7009	19.11	< .001	0.8213
	Conven 3	0.7002	0.0320	0.637	0.7630	21.87	< .001	0.8901
	Conven 4	0.6738	0.0353	0.604	0.7430	19.06	< .001	0.8186
Factor 4	Notify 1	0.5537	0.0437	0.468	0.6394	12.66	< .001	0.6622
	Notify 2	0.4619	0.0429	0.378	0.5459	10.78	< .001	0.5566

The criteria for evaluation in research derived from the Confirmatory Factor Analysis table can be elucidated as follows.

Table 8. Criteria considered to pass.

Descriptions	Criteria considered to pass
Factor loading (standardized)	Greater than or equal to 0.50 (Hair et al., 2014)
p-value	Values below 0.05 indicate statistical significance.
Assess Value Orientation	Positive (directly correlates with the measurement based on the factor)

Based on the results presented in Table 7: confirmatory factor analysis of factor loadings and evaluated against the thresholds specified in Table 8: criteria considered to pass, the findings indicate that the measurement model is largely consistent with the proposed theoretical structure. For Factor 1 (System), Systems 1, 3, and 4 exhibit standardized factor loading values ranging from 0.567 to 0.968, which meet the acceptance criteria outlined in Table 8. However, System 2 demonstrates an estimated loading value close to zero and is not statistically significant ($p = 0.252$), as shown in Table 7. This item fails to satisfy the established criteria and should therefore be considered for removal or revision prior to practical application. Regarding Factor 2 (Connection), all indicators (Connection 1–4) present factor loadings between 0.510 and 0.933, with statistical significance at $p < 0.001$. According to the criteria in Table 8, these results confirm that all items within this factor adequately represent the latent construct and can be retained as a reliable measurement dimension. For Factor 3 (Convenience), the factor loadings for Convenience 1–4 range from 0.816 to 0.890, all of which exceed the minimum thresholds and are statistically significant. These results, as reported in Table 7, indicate high-quality measurement items that strongly reflect the underlying construct. Similarly, Factor 4 (Notification) shows acceptable factor loadings for Notification 1–2, ranging from 0.662 to 0.748, with $p < 0.001$. Based on the criteria in Table 8, these indicators are appropriate for retention and effectively capture the notification construct. In summary, the CFA results in Table 7, when assessed using the criteria in Table 8, demonstrate that the questionnaire's factor structure aligns well with the theoretical framework. Most factor loadings exceed 0.50 and are statistically significant ($p < .05$), indicating adequate construct validity. Only the item System 2 does not meet the required criteria due to its low and non-significant loading, suggesting that it should be removed or improved before further implementation. Overall, the findings support an acceptable level of construct validity for the measurement instrument.

Table 9. Factor Estimates

Factor	Indicator	Estimate	SE	95% Confidence Interval		Z	p	Stand. Estimate
				Lower	Upper			
Factor 1	Factor 1	1.000[a]						
	Factor 2	0.891	0.0143	0.863	0.919	62.26	< .001	0.891
	Factor 3	0.305	0.0499	0.207	0.403	6.11	< .001	0.305
	Factor 4	0.692	0.0540	0.586	0.798	12.80	< .001	0.692
Factor 2	Factor 2	1.000[a]						
	Factor 3	0.417	0.0468	0.325	0.509	8.90	< .001	0.417
	Factor 4	0.711	0.0577	0.598	0.824	12.31	< .001	0.711
Factor 3	Factor 3	1.000[a]						
	Factor 4	1.058	0.0460	0.968	1.148	22.97	< .001	1.058
Factor 4	Factor 4	1.000[a]						

[a] fixed parameter

Within the framework of confirmatory factor analysis (CFA) and structural equation modeling (SEM), Factor 1 is composed of four observed indicators (Factor 1–Factor 4) representing the latent construct associated with Factor 1. Based on the results reported in Table 9: factor estimates, the factor loadings were estimated with a 95% confidence interval to assess the strength and precision of the relationships between the latent factor and its observed indicators. Specifically, Indicator 2 of Factor 1 demonstrates a high standardized factor loading, with an estimated value of 0.891 and a standard error of 0.0143. The corresponding 95% confidence interval ranges from 0.863 to 0.919, which does not include zero. This result, as shown in Table 9, indicates a statistically significant and strong association between Indicator 2 and Factor 1, providing empirical support for the convergent validity of the measurement model.

$$CI = \text{Estimate} \pm 1.96 \times SE$$

Z (Z-value or Critical Ratio)

$$Z = \frac{\text{Estimate}}{SE}$$

The standardized coefficient facilitates direct comparison of each indicator. Factor 1 Indicator 2 possesses a Stand. The estimated value is 0.891, signifying a strong association. Factor 1 Indicator 3 possesses a value of merely 0.305, signifying that this indicator represents a minimal portion of the hidden factor.

Table 10. Model Fit Test for Exact Fit

χ^2	df	p
2213	71	< .001

Fit Measures

				RMSEA 90% CI			
CFI	**TLI**	**SRMR**	**RMSEA**	**Lower**	**Upper**	**AIC**	**BIC**
0.649	0.550	0.171	0.275	0.265	0.285	10119	10311

The model fit test findings suggest $\chi^2(71) = 2213$, in Figure 10. Model Fit Test for Exact Fit, $p < 0.001$, demonstrating a considerable divergence between the baseline model and the empirical data. The CFI of 0.649 and TLI of 0.550 fall below the commonly recognized thresholds of 0.90 or 0.95, signifying inadequate variance explanation by the model. SRMR = 0.171 exceeds the commonly accepted threshold of ≤ 0.08, signifying that the correlation error remains substantial. RMSEA = 0.275, 90% CI [.265, .285] above the acceptable criterion (roughly ≤ .08, very good < .05), and the confidence interval does not encompass lower values, indicating that the model is unequivocally unsuitable. AIC = 10119 and BIC = 10311 are utilized solely for model comparison (the lower the values, the better), serving as a benchmark for the model refinement phase.

The CFA model fit analysis indicated that the initial model inadequately represented the empirical data ($\chi^2(71) = 2213$, p<.001), exhibiting a low model fit index (CFI=0.649, TLI = 0.550). Additionally, the root mean square error (RMSEA = 0.275, 90% CI [.265, .285]) and SRMR (0.171) exceeded the recommended thresholds, signifying insufficient model fit and necessitating further theoretical enhancements. The information criteria values AIC = 10119 and BIC = 10311 were documented in comparison with the subsequent enhanced model.

Table 11. Factor Loadings – Modification Indices.

	Factor 1	**Factor 2**	**Factor 3**	**Factor 4**
System 1	-	23.754	19.716	16.177
System 2	-	3.628	83.679	83.530
System 3	-	0.471	0.289	0.334
System 4	-	4.476	6.262	5.598
Connec 1	0.796	-	48.979	49.598
Connec 2	1.538	-	4.270	6.289
Connec 3	1.57e-4	-	25.284	26.108
Connec 4	0.791	-	257.000	276.108
Conven 1	12.885	18.970	-	6.224
Conven 2	5.730	1.561	-	5.519
Conven 3	16.558	28.917	-	13.907
Conven 4	14.290	10.328	-	4.186
Notify 1	5.091	20.701	13.770	-
Notify 2	5.269	31.330	5.166	-

Modification Indices (MI) in structural equation modeling (SEM) or confirmatory factor analysis (CFA) in Figure 11. Factor Loadings – Modification Indices, signify that altering the model by incorporating paths (factor loadings) between observed variables and latent factors may be warranted. Exceptionally high MI values, such as Connec 4 with Factor 3 (257.000) and Factor 4 (276.108), suggest that this indicator may not align with the original factor structure. The measurement or model framework should be reassessed. Consequently, for the interpretation of study, System 2 has elevated MI values with Factor 3 (83.679) and Factor 4 (83.530), suggesting that this item may be associated with numerous factors rather than being confined to a single factor. Connec 1 and Connec 3 have elevated MI values with Factor 3 and Factor 4, signifying cross-loading. Notify 2 has elevated MI values with Factor 2 (31.330), indicating that Notification awareness may align more closely with Factor 2 than the initially defined model.

Strategic Inferences Indicators with exceptionally high MI values, such as Connec 4, warrant reevaluation to assess their compatibility with the prevailing conditions. The observed cross-loading, exemplified by System 2 and Notify 2, signifies intricate linkages. The model may require modification to accurately represent the actual theoretical framework, as the original model may be inadequate. Consequently, employing MI values as ancillary data will enhance the model's fit indices and accurately represent reality.

Post-Hoc Model Performance

The interpretation of the residuals from the observed correlation matrix is derived directly from the results presented in Table 13: Post-Hoc Model Performance (Residuals for Observed Correlation Matrix). As shown in Table 13, several residual correlations exceed the acceptable thresholds, indicating that the initial measurement model does not sufficiently explain certain relationships among the observed variables. Specifically, residual values for variable pairs such as System1–System2 (0.307), System2–Conven2 (0.512), and Conven1–Conven2 (0.575) surpass the criterion of |0.20|, which, according to the predefined standards, signifies substantial model misspecification. Furthermore, the concentration of high residuals within the Convenience (Conven1–Conven4) indicators, as reported in Table 13, suggests the presence of strong internal correlations that are not adequately captured by the original factor structure. This pattern implies that the Convenience construct may consist of underlying subdimensions or that certain indicators share correlated measurement errors or cross-loadings with other latent factors. Following the evaluation of overall model fit, the residual analysis in Table 13 was therefore employed as a post-hoc diagnostic tool to guide model refinement. Residuals exceeding |0.10| were interpreted as insufficiently explained by the model, while those greater than |0.20| were considered statistically and substantively significant. The post-hoc procedure involved (1) identifying indicator pairs with significant residuals, as summarized in Table 13; (2) examining the theoretical plausibility of additional model specifications, such as correlated error terms or the formation of subfactors; and (3) proposing an alternative model and systematically comparing its goodness-of-fit indices (CFI, TLI, RMSEA, AIC, and BIC) with those of the original model. Collectively, the evidence from Table 13 supports the conclusion that the measurement model requires structural enhancement to more accurately represent the empirical relationships among the observed variables.

Table 13. Post-Hoc Model Performance (Residuals for Observed Correlation Matrix)

	System 1	System 2	System 3	System 4	Connec 1	Connec 2	Connec 3	Connec 4	Conven 1	Conven 2	Conven 3	Conven 4	Notify 1	Notify 2
System 1		0.307	-0.076	-0.009	0.062	0.072	0.131	0.109	0.318	0.057	-0.042	0.289	0.145	0.392
System 2			-0.035	-0.012	-0.063	0.009	0.161	0.303	0.380	0.512	0.323	0.331	0.293	0.311
System 3				0.006	-0.049	0.008	0.045	0.059	0.027	0.032	-0.045	0.072	-0.070	0.109
System 4					0.019	-0.016	-0.022	0.005	0.076	-0.090	-0.065	0.076	-0.028	0.009
Connec 1						0.018	-0.011	-0.060	0.039	-0.124	-0.160	0.003	-0.141	0.021
Connec 2							-0.008	-0.074	0.086	-0.054	-0.100	0.022	-0.163	0.192
Connec 3								0.104	0.118	0.130	-0.032	0.179	-0.055	0.319
Connec 4									0.575	0.536	0.530	0.532	0.418	0.418
Conven 1										0.004	-0.013	-0.022	0.011	0.070
Conven 2											0.088	-0.086	-0.153	0.032
Conven 3												-0.014	-0.017	-0.100
Conven 4													0.225	-0.010
Notify 1														0.000
Notify 2														

Table 14. Residual Covariances – Modification Indices

	System 1	System 2	System 3	System 4	Connec 1	Connec 2	Connec 3	Connec 4	Conven 1	Conven 2	Conven 3	Conven 4	Notify 1	Notify 2
System 1		56.9	23.42	1.42	0.451	0.329	14.51	3.36	43.88	4.7063	94.8761	23.10559	10.47484	76.3462
System 2			3.22	2.97	41.565	2.596	36.40	44.78	2.66	42.4444	6.7834	0.00550	4.67691	11.2258
System 3				43.19	78.592	7.391	32.94	8.22	32.33	51.9687	0.6441	3.18357	5.03648	8.5344
System 4					70.810	11.752	37.12	1.07	2.57	43.1514	14.2900	0.18532	24.13922	64.7652
Connec 1						42.615	4.81	24.40	7.79	15.1451	1.3632	0.15721	0.60098	50.0596
Connec 2							2.48	34.63	6.39	0.8356	0.0505	9.70156	26.08326	26.3382
Connec 3								32.28	14.00	51.1092	21.6058	12.87854	0.79839	70.1929
Connec 4									3.33	9.4296	9.9629	0.42952	26.26889	5.6273
Conven 1										0.0431	5.7913	1.32631	0.00644	13.2990
Conven 2											99.4397	48.55999	46.70018	9.2736
Conven 3												1.58964	0.75265	18.4077
Conven 4													133.50401	0.0478
Notify 1														
Notify 2														

Residual Covariances – Modification Indices

The analysis of modification indices for residual covariances indicated that numerous variable pairs exhibited MI values exceeding the acceptable threshold (e.g., Notify 1- Notify 2 = 133.504, Conven 2- Conven 3 = 99.439, System 1 – Conven 3 = 94.876, System 3 – Connec 1 = 78.592), suggesting that the existing model inadequately captures the structural relationships within the data. This outcome suggests that certain pairings of indicators are more interconnected than the model presupposes. The model can be enhanced by augmenting the correlation of residuals among the variables or reassessing the categorization of indicators to align with theoretical and empirical evidence.

In Table 14, the modification indices demonstrates that the original model is deficient in completeness, especially within the Notify and Convenience groups, as well as in cross-factor interactions (System–Convenience, System–Connec). Model modifications could concentrate on permitting residual covariances solely for theoretically valid pairs, assessing the overlap of possibly repetitive questions, or reorganizing the factor structure (e.g., incorporating a subfactor for Convenience).

Detailed Response and Corrective Actions for Methodological Weaknesses

The study appropriately employs a research and development (R&D) methodology, particularly in the stages of prototype construction and preliminary data collection. However, critical methodological weaknesses emerge at the measurement validation stage, specifically in the application of Confirmatory Factor Analysis (CFA). These weaknesses undermine the robustness of the empirical validation of the research instrument and may compromise the reliability of conclusions drawn from latent constructs (Borg & Gall, 1989).

For the construct validity issue, the CFA results indicate that the measurement item "Vehicle location using GPS is accurate" (System 2) demonstrates a very low and statistically non-significant factor loading. This suggests that the item does not adequately represent the latent construct it is intended to measure and its implications (Anderson & Gerbing, 1988). The item fails to converge with other indicators within the same construct, indicating poor convergent validity. The observed variable may be conceptually misaligned, ambiguously worded, or interpreted inconsistently by respondents, and retaining such an item can distort construct measurement, inflate measurement error, and reduce composite reliability.

For model fit problems, the initial CFA model exhibits poor fit indices, with values significantly below established benchmarks (e.g., CFI, TLI < 0.90; RMSEA > 0.08). This indicates that the hypothesized measurement model does not adequately reflect the empirical data structure and implementations (Hair et al., 2019). The latent constructs may be specified. Cross-loadings or correlated measurement errors may exist but are unaccounted for; the model lacks structural coherence, limiting its explanatory power.

For interpretation and reporting of CFA results, the interpretation of CFA outcomes appears to overstate measurement validity despite statistical evidence indicating poor model performance and implementations (Cheung et al., 2024). These compromises methodological transparency and threaten the credibility of the study. Conclusions drawn from invalid measurement models may be misleading or non-replicable (Sathyanarayana & Mohanasundaram, 2024).

DISCUSSION AND IMPLICATIONS

The creation of a prototype smart student shuttle system utilizing RFID technology and a mobile application notification system illustrates the potential of employing information technology to improve student safety standards. The findings demonstrate that the incorporation of RFID technology for identity verification and monitoring bus entry and exit, alongside a mobile application that notifies parents and pertinent authorities, can significantly mitigate the danger of students forgetting or losing track of students during transit. A significant discovery is that the implemented system improves transparency and traceability of student travel (Shah & Singh, 2016). It fosters confidence among parents and educational institutions, consistent with prior study on the application of RFID in transportation management and safety (Nikita et al., 2020). Nevertheless, obstacles persist, such as network communication reliability, personal data protection, and user acceptance (Venkatesulu et al., 2021).

This research enhances the knowledge base on smart transportation and intelligent safety systems by illustrating the integration of RFID and mobile notification technologies for proactive safety management in educational settings. It further broadens the conceptual framework of IoT and ubiquitous computing within the realm of student mobility. This research provides recommendations for educational institutions and student transportation firms to improve safety protocols by investing in sophisticated tracking technologies capable of real-time monitoring of student status and implementing safeguards against data breaches. Moreover, this system can be augmented to interface with student databases, school management systems, and public safety systems.

LIMITATIONS AND FUTURE RESEARCH POSSIBILITIES

Future research ought to concentrate on extensive system testing, user experience evaluation, and the integration of complementary technologies such as GPS, machine learning for route forecasting, or cloud computing to enhance efficiency and scalability. This research demonstrates the actual development of a prototype for an intelligent student shuttle system that incorporates RFID technology and mobile application notifications; nonetheless, certain constraints warrant consideration. To further this matter, subsequent study should concentrate on the following domains. Extensive Implementation: Evaluate the system's efficacy across various educational institutions or heterogeneous transportation networks to determine its scalability. Technology Integration: Create systems in collaboration with other technologies, including GPS for real-time location monitoring, artificial intelligence (AI) for route forecasting, or cloud computing to improve data processing and storage efficiency (Shah & Singh, 2016). User Experience Research: Perform qualitative and quantitative investigations to assess satisfaction levels, usability, and elements that promote or obstruct real usage (Nikita et al., 2020). Economic Cost-Effectiveness and Social Impact Analysis: Evaluate the financial cost-effectiveness and social results, including enhanced parental confidence, diminished accident risk, and the formulation of new school safety standards. Policy and Regulatory Studies: Examine the implementation of the system within the national policy framework, ensuring adherence to personal data protection legislation such as the GDPR or PDPA, to guarantee the system's sustainability and alignment with international standards.

CONCLUSION

Investigations into the creation of a prototype intelligent school bus system utilizing RFID technology and a mobile application notification system indicate its capacity to markedly enhance student safety protocols. Technology enables parents and schools to monitor student boarding and disembarking in real time, enhancing transparency and traceability, mitigating the risk of loss or unsafe travel occurrences, and fostering confidence among all stakeholders.

Despite the system's limitations regarding testing in controlled environments, technological stability, and personal data security, this developmental strategy presents opportunities for scaling and enhancing the technology to establish safer student transportation systems in the future. Furthermore, the use of technologies such as GPS, AI, and cloud computing could enhance efficiency and expand applicability, positioning this prototype as a potential benchmark for student transportation safety in educational institutions. In summary, while the R&D methodology for system development and initial data acquisition is methodologically sound, the advanced statistical validation of the measurement instrument using CFA is currently inadequate. The primary issues relate to construct validity, poor model fit, and insufficient interpretation rigor.

To enhance methodological robustness and empirical credibility, the study should refine or remove problematic measurement items, re-specify and validate the measurement model through iterative testing, ensure theoretical justification accompanies all statistical decisions, and present CFA findings with appropriate methodological caution.

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CONFLICTS OF INTEREST

The authors assert that this research presents no conflicts of interest, whether financial or personal, that could influence the design, outcomes, or interpretation of the research data. The authors affirm that the research was executed and reported with transparency and independence from external influences.

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