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Identifying Key Parameters for School Bus Monitoring System Using a Triangulation Method: A Study in Zanzibar

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***Abstract*—The design and development of school bus monitoring systems require a clear understanding of the key parameters that ensure student safety, reliable communication and parental satisfaction. While various studies have proposed technological solutions to improve school bus transportation safety, they often do not clearly identify the key parameters required for school bus monitoring systems. This study aimed to identify the critical parameters for such systems by first conducting the literature review which revealed three frequently referenced parameters which are student identification, bus location tracking, and SMS notification alerts. To validate the importance of these parameters in real world context, a triangulation method was applied, involving interviews with 2 school authorities, focus group discussion with 4 school bus drivers and questionnaire survey completed by 60 parents. Data was collected from the stakeholders in Zanzibar Urban West Region. The findings across all three methods confirmed that student identification, bus location tracking and SMS notification alerts are essential parameters for school bus monitoring systems. These validated parameters provide a strong foundation for designing and developing technological solutions for school bus monitoring.**

Keywords—school bus, monitoring system, parameters, triangulation method, Zanzibar

I. INTRODUCTION

In today's busy life, physical safety has been a paramount concern in the reliability of the school bus transportation among parents and school administrators [1]. Over the years, there are number of cases that have been reported where the students were left alone in the bus without the knowledge of bus drivers and bus attendants, causing children to face more severe circumstances by losing their lives due to suffocation [2]. In countries such as United States of America, United Kingdom and Germany are reported to have the massive number of child missing cases every year followed by India [1][3]. This signals the weakness when it comes to identifying important parameters for safety of children during school bus transportation. Several school bus accidents in Kenya and Tanzania, had also been reported taking the front line due to high speed [4]. Children sometime board in the wrong buses or dropped off at the wrong locations by mistake without the driver being aware [4]. All of these incidents have made it more difficult for parents to have confidence in their children's safety while traveling to and from school [1]. But in today's modern world, various technologies such as mobile computing, application development and Internet of Things have changed people lives and provided the solution to every sector such as transportation, education, health and social life [1]. While various studies have proposed various technological solutions to ensure the safety, still they do not clearly identify the essential parameters required for school bus monitoring system.

Therefore, this study aims to identify the key parameters required for real-time school bus monitoring system. The focus is on the parameters mentioned in the existing literature reviews covering the technological solutions for school bus monitoring systems.

II. RELATED WORK

The literature review comprises numerous studies related to technological solutions for school bus monitoring systems. The common parameters identified across these related studies are as follows.

Since the system requires a unique notification for each student at their pick up and drop off points, the students need to be identified by the system so that the parents can receive the notification regarding entry and exit of their wards [6]. Moreover this parameter ensures that the right student boards at the right bus and gets dropped off at the correct stop [6][20] [7][8][9][10][13][15] emphasizes the importance of verifying students presence during boarding and drop off processes. Additionally, [11][12][14] emphasized the importance of implementing this parameter in a highly secured manner. Their studies recommended incorporating biometric features such as fingerprints and face recognition to ensure accurate verification of the student entry and exit from the school bus.

Another most common parameter that has been mentioned in various studies is bus location tracking as it enable to track the exact location of the bus when student boarded and deboarded from the bus as well as to monitor the bus throughout its journey [6]. This enhances transparency and trust especially

when parents are notified of the bus's location during key moments such as pick up and drop off [7][8]. Bus location tracking has been recognized as a fundamental parameter in several studies, including [1][6][11][13][15] due to its role in improving in timely response to transit related issues.

Additionally, as the system requires a unique notification for each student at their pick up and drop off as well as their locations so that his or her parent can be notified, [2][6][13][14] proposed Short Message Service (SMS) notification alerts for school authorities and parents so that once the child has been authenticated on boarding or deboarding the bus, a notification is sent to the concerned authorities and parents.

Furthermore, apart from these most mentioned parameters in various studies, other parameters were also proposed to school bus monitoring systems to provide added layers of security.

[2][7] introduced alcohol detection parameter to determine the alcoholic state of the driver and send notification to the required authority. Other parameters implemented were accident detection [8][11][12] to immediately inform the intended stakeholders when accident happens, emergency notification [10][20] to alert any emergency situation that might happen during the transit, bus speed status [7][12] to monitor the speed of the bus.

A thorough review of 25 existing studies was conducted to identify key parameters used in school bus monitoring systems. Fig.1 highlights that student identification, SMS notification alerts and bus location tracking are the most frequently referenced parameters across the literature.

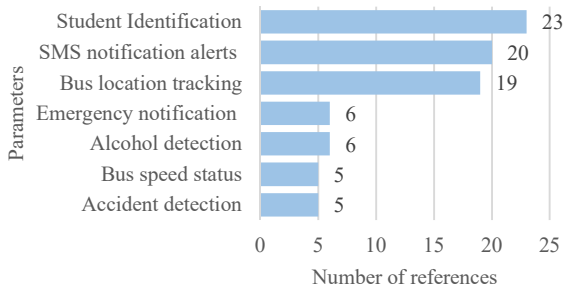

Fig. 1. *Key parameters commonly used in school bus monitoring system*

III. METHODOLOGY USED

To ensure the relevance of the key parameters identified from the literature, this study further employs the triangulation method to validate the most frequently mentioned parameters. Validation is conducted through interviews with school authorities, a focus group discussion with school bus drivers and a close-ended questionnaire with parents. Triangulation method is often used to validate and confirm qualitative results with the results of quantitative studies as it helps to overcome biases with the use of single method [5].

The literature review findings served as an input to develop the interview questions, focus discussion topics and close-ended questionnaire to confirm whether the parameters that are most frequently mentioned in the literature review are relevant as claimed to be or not.

The study was conducted in Zanzibar urban west region of Unguja, as according to Road Transport Authority of Zanzibar, the percentage of schools operating school buses in Unguja Urban West is 70%. Additionally, Zanzibar represents a relevant study due to its challenges with traditional school transportation monitoring.

A. Interview

1) Data Collection: An administered through face-to-face semi-structured interview was conducted [16]. Convenience sampling was used to ensure that participants met the following eligibility criteria.

- Minimum number of service years is 3.
- Working in schools that operate school buses for more than 5 years
- The school location is in the Urban West region of Zanzibar.

Interviews were conducted with the 2 selected schools authorities at their individual offices. [17] suggested that, the minimum informants suitable for qualitative studies would range from 2 to 10 as sufficient number to reach saturation levels that occurred during the study. The interview was further guided by 3 semi-structured questions and each interview lasted for 20 minutes. Interviews were recorded and transcribed in addition to the notes that were taken by the researcher.

TABLE I. DEMOGRAPHIC INFORMATION OF THE PARTICIPANTS

Participant	***Gender***	***Post***	***Number of service years***	***Education***
A1 (School A)	M	Headmaster	12	Master
A2 (School B)	F	Managing Director	8	Master

2) Data analysis: Following the collection of data through interview, data was analyzed to utilize thematic analysis strategy. The thematic analysis allowed the researcher to extract relevant themes and patterns from the data collection. To improve conformability, Braun and Clarks's six phases of thematic [18] were used to generate themes from the collected data. NVivo software was utilized to assist with analyzing the data.

B. Focus Group

1) Data Collection: Focus group typically can range in size from as few as 4 to as many as 12 [12]. For this study, a focus group discussion was conducted with 4 school bus drivers from the same 2 schools, school A and B where the school authority interviews had also taken place. The 4 participants were selected through convenience sampling. Each driver had a minimum of three years of service experience. The discussion

lasted approximately 45 minutes and was guided by three topics. Notes were taken during the session and the discussion was also recorded.

TABLE II. DEMOGRAPHIC INFORMATION OF THE PARTICIPANTS

Participant	*Gender*	*Post*	*Number of service years*
D1 (School A)	M	Driver	7
D2 (School A)	M	Driver	5
D3 (School B)	M	Driver	4
D4 (School B)	M	Driver	8

2) Data analysis: After collecting data from a focus group discussion, thematic analysis was employed as the primary method to interpret and organize the data. To ensure the trustworthiness of the analysis, six phases thematic analysis by [18] were used. This analysis helped to ensure transparent and credible interpretation of the focus group insight. Additionally, NVivo software was used to support analyzing the data [17][19].

C. Questionnaire

1) Data Collection: A greater number of samples is required when there is a higher degree of variations in the population group, therefore if the study population is homogeneous then a small size of sampling is enough for the study[16]. Thus the sample size of this study was 60 parents selected from school A and B. Convenience sampling technique was used to select sample size of parents. Data were obtained by using survey questionnaire contained closed-ended questions. The questionnaire used a Likert scale with 5 levels including 1=Strongly Disagree (SD), 2=Disagree (D), 3=Neutral (N), 4=Agree (A) and 5=Strongly Agree (SA) to measure the relevance of those three parameters. The demographic characteristics are as follows.

- School Representation:
  School A: 32 parents (53.3%)
  School B: 28 parents (46.7%)
- Gender Distribution:
  Female: 38 parents (63.3%)
  Male: 22 parents (36.7%)

2) Data analysis: The questionnaire data collected from 60 parents was analyzed using descriptive statistical method, specifically focusing on frequency distribution [16]. The responses were selected digitally using Google form, which also can generate automatic summaries of the data which included frequency count for each response option under every question. The results served as a basis for identifying key parameters for the proposed school bus monitoring system. Furthermore, mean and standard deviation (S.D) was calculated using an online Python-based notebook called google colab. The analysis was conducted using the Pandas and NumPy libraries.

IV. RESULTS

A. Interview

Three themes were identified from the responses of the 2 participants. The themes are Student Identification, Bus location tracking and SMS notification alerts.

1) Theme 1: Student Identification

Both participants acknowledge the usage of school bus identity cards to identify the students before entering the bus, and agreed that student identification is strongly regarded as a critical parameter that should not overlooked. Participant A2 stated;

" *Each student is given a special school bus card. The bus attendant checks the card visually when the student gets on the bus to confirm they are in the correct place. However, since the bus often has a large number of students, it becomes difficult for the attendant to identify every student properly. Sometimes a student may board the wrong bus or be left behind without being noticed*."

2) Theme 2: Bus Location Tracking

Phone calls are currently relied upon, but real-time location tracking was strongly agreed for responding quickly to unexpected issues. As participant A1 stated;

"*We usually rely on phone calls and if we need to know where the bus is, we call the driver or the bus attendant. I think it would be very helpful to know the bus location in real-time, especially when there are delays or unexpected issues."*

3) Theme 3: SMS Notification alerts

Communication is done via phone calls and not in real-time bases, regular alerts to parents were strongly supported as stated by participant A1;

"regular updates would help build trust with parents and reduce the number of phone calls we receive every day asking where is the bus".

B. Focus Group

Themes were identified from the responses of school bus drivers participated in the focus group discussion as presented in TABLE III.

The focus group discussion highlighted the critical need for three key parameters in a school bus monitoring system, as drivers find current manual methods unreliable and believed these features would reduce communication stress and improve trust especially with parents.

C. Questionnaire

From a total of 6 questions asked, findings are summarized in the following TABLE IV and Fig. 2 which are presented as follows.

TABLE III. THEMATIC ANALYSIS OF FOCUS GROUP DISCUSSION WITH SCHOOL BUS DRIVERS

Parameters	*Theme identified*	*Description*	*Supporting Quotes*
Student Identification	Unreliable manual student Identificati on	Drivers depend on memory and face recognition, which can lead to oversights.	"I rely on memory, but sometimes when kids are quiet or not in their usual spot, I might think they already got off…" – D2 "mostly using our eyes and memory. But with many students, especially in the morning rush, it's hard to be sure…" – D3
Bus location tracking	Positive perception of Real-time tracking	Good support for real-time bus location tracking, seeing it as a helpful tool that reduces parent anxiety, minimizes calls.	"It actually helps everyone… avoids unnecessary panic."- D1 "They don't have to keep calling." – Driver D3
SMS notification alerts	Support for automated SMS alerts	It was agreed that automated SMS alerts would greatly improve communication with parents, reduce unnecessary calls and confusion, and provide reassurance	"If parents get a message… they might feel more relaxed." – Driver – D1 "It should be automatic; we don't have time to send messages." – D4

TABLE IV. SURVEY RESULTS SUMMARY

Question	*SD*	*D*	*N*	*A*	*SA*	*Mean*	*S.D*
Q1. I am usually informed when my child gets on or off the school bus.	28	27	3	2	0	1.65	0.73
Q2. I would prefer a mobile application that notifies me when my child gets on or off the bus	0	0	2	26	32	4.50	0.56
Q3. I usually have to call the driver or school to know the bus status.	1	4	3	20	32	4.30	0.95
Q4. Having access to real-time bus tracking would reduce my stress.	0	2	1	26	31	4.43	0.69
Q5. . I often call driver for my child's status.	1	0	2	24	33	4.47	0.72
Q6 I would like to receive SMS alerts every time my child gets on/off the bus	1	1	2	26	30	4.38	0.78

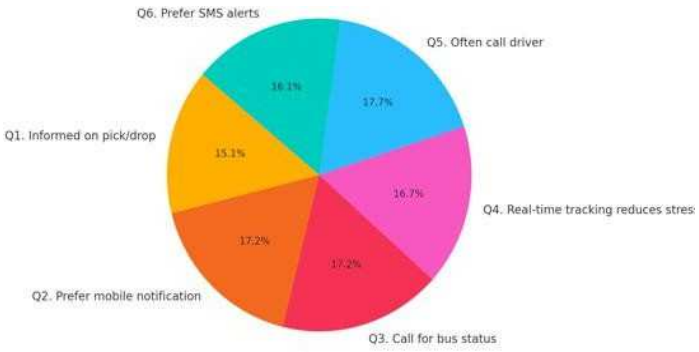

Fig. 2. *Highest Response Frequency per Question*

The pie chart illustrates the highest response frequencies recorded for each question in a parent survey related to school bus monitoring key parameters.

Q1 (Informed on pick/drop) had the lowest share at 15.1%, where most parents strongly disagreed, suggesting dissatisfaction with current communication methods about their child's bus activity.

Q2 (Prefer mobile notification) and Q3 (Call for bus status) both showed 17.2%, with most parents strongly agreeing, highlighting their strong preference for mobile-based notifications and their current need to manually check bus status.

Q4 (Real-time tracking reduces stress) followed with 16.7% strongly agreeing, indicates the value parents place on live bus tracking.

Q5 (Often call driver) received the highest share at 17.7%, where most parents strongly agreed, indicating they often find themselves having to call the driver for updates.

Q6 (Prefer SMS alerts) accounted for 16.1%, showing support for receiving SMS updates for boarding and drop-off.

V. DISCUSSION: VALIDATION OF KEY PARAMETERS THROUGH TRIANGULATION METHOD

This section presents an integrated analysis of findings from interviews with school authorities, focus group discussion with school bus drivers and questionnaire with parents. The convergence of findings across these groups confirms the relevance and importance of each parameter as shown in the Fig. 3.

A. Student Identification

School authorities had emphasized the need for a proper student identification, they also acknowledged the current use of school bus identity cards and strongly supported student identification as an important parameter that should not be avoided.

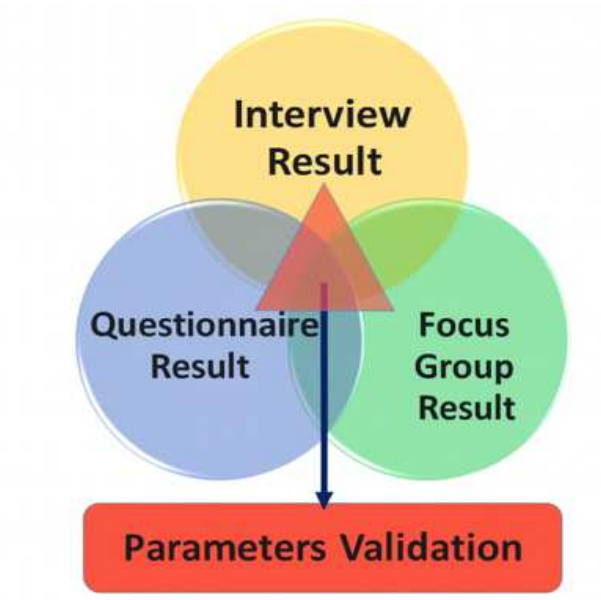

Fig. 3. *Triangulation iMethod for Parameters Validation*

This was confirmed by school bus drivers by highlighting the limitations of current manual practices that was depending on memory and facial recognition which was seen as unreliable and prone to human error. The parents supported these concerned with over 91% as they felt uninformed about their children's daily bus activity. They also expressed strong support for a mobile application that provides real-time updates on student boarding and drop off. This shows that. based on these results, there was a strong alignment across all three methods as all three stakeholder groups recognized student identification as a vital parameter. The need to shift from manual to digital identification methods was also emphasized.

B. Bus Location Tracking

School authorities pointed out current reliance on phone calls to manage delays but strongly agreed on the importance of real-time tracking for reducing uncertainty and enhancing response to unexpected events. Similarly, bus drivers viewed real-time tracking positively, describing it as useful feature that reduces parental anxiety and minimizes frequent inquiries from parents. This was further validated by parents with around 95% indicating they currently rely on phone calls but would prefer a system that allow them to view the bus location live. Based on the results, there was a high level of agreement across all stakeholders on bus location tracking highlighting it as a key parameter.

C. SMS Notification Alerts

School authorities acknowledges a gap in timely communication with parents as most updates are given via phone calls which are not timely. They supported the introduction of automatic SMS alerts to keep parents informed. Bus drivers voiced this need by agreeing that automated alerts would reduce confusion and lower the number of call from parents. Parents further emphasized strong need for such alerts with approximately 95% reporting that they frequently call the driver for updates and nearly 93% had expressed interest in receiving SMS notifications for their child's boarding and drop off. Based on the results, all three groups confirmed the importance of SMS notification alerts to improve communication and ensure timely updates to parents especially.

VI. Conclusion and Future Work

The results from interviews with school authorities, a focus group discussion with bus drivers, and questionnaires from parents show strong convergence across the three parameters. The triangulation process not only confirmed the relevance of the parameters identified in the literature but also provided practical validation within the local context of Zanzibar. This comprehensive agreement highlights the importance of implementing student identification, real-time bus location tracking, and SMS notification alerts in any proposed school bus monitoring system.

For future research, the validated key parameters can serve as core parameters by deploying them in any school bus monitoring system to enhance safety, traceability, and communication.

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