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Investigating the Dynamic Interactions Between Safety Knowledge, Attitudes, Behaviors, and Workplace Accidents Among Solid Waste Management Personnel

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ABSTRACT

Ensuring workplace safety in solid waste management companies is critical due to the daily hazards' employees face. This study examines the relationships between safety knowledge, attitude, behavior, and accident occurrences among solid waste management (SWM) workers using structural equation modeling (SEM). Data were collected via self-administered questionnaires from general employees within a SWM company in a northern state in Malaysia. The findings revealed significant positive correlations between safety attitude and behavior, showing that workers with more positive safety attitudes demonstrate safer behaviors. Additionally, safety behavior was negatively associated with accident occurrences, highlighting the crucial role of safe practices in preventing accidents. Safety knowledge positively influenced safety attitudes and behaviors, emphasizing the importance of comprehensive safety training programs. Effect size measures, R-squared values, and beta coefficients provided insights into the model's practical significance and predictive power. Indirect effects were also explored, indicating that safety knowledge indirectly impacted accident occurrences through its influence on safety behavior and attitudes. The study's limitations include its cross-sectional design and reliance on self-reported data, suggesting the need for longitudinal studies and objective measures in future research. Despite these limitations, the study contributes to understanding safety dynamics within the solid waste management industry. Practical implications include developing targeted safety interventions to enhance safety knowledge, attitudes, and behaviors to foster a safety culture and reduce workplace accidents. Specifically, the finding of this study helps the solid waste management industry be more alert in responding to workplace accident prevention by focusing on the employees' safety knowledge and attitude toward enforcing better safety behavior among the employees.

1. INTRODUCTION

Solid waste management companies play a crucial role in maintaining public health and environmental sustainability by managing waste materials' collection, transportation, and disposal. However, the nature of work in this industry poses significant safety challenges for employees exposed to various hazards, including heavy machinery, hazardous chemicals, and potential ergonomic injuries. For example, Municipal waste handlers in Thulamela Municipality, South Africa, face many occupational health and safety challenges, ranging from physical, psychological, and biological to chemical risks [1]. These hazards include inadequate personal protective equipment, exposure to harsh weather conditions, noise pollution, and musculoskeletal injuries. Additionally, waste handlers endure community harassment, discrimination, and insufficient training, contributing to psychological strain [1]. Biological risks stem from exposure to infectious diseases from contaminated waste, while chemical hazards pose respiratory health issues due to harmful substance exposure [1]. Similarly, workers in informal waste management enterprises encounter diverse and significant occupational hazards, such as muscular-skeletal disorders from heavy lifting, disease transmission risks from insects and rodents, and chemical exposures from hazardous waste materials [2]. They also face mechanical hazards like cuts, needle pricks, and electrocution, as well as ergonomic strains from repetitive tasks [2]. Psychosocial challenges, including societal stigma and job devaluation, compound the occupational health concerns experienced by waste workers in Brazil [3]. Mitigating these risks requires the implementation of proper Personal Protective Equipment (PPE), comprehensive training, and

public education on responsible waste disposal practices [3]. Addressing these multifaceted hazards is essential to ensuring waste workers' health, safety, and well-being in formal and informal waste management settings.

Despite efforts to implement safety protocols and training programs, accidents continue to occur, highlighting the need for a deeper understanding of safety dynamics within the solid waste management sector. One of the key challenges faced by solid waste management companies is the complex interplay of safety knowledge, attitude, and behavior among employees. While safety training programs aim to equip workers with the necessary knowledge and skills to identify and mitigate risks, the effectiveness of these programs in influencing safety attitudes and behaviors remains unclear. For example, the safety training program had a modest impact on the safety attitudes of Australian construction workers, primarily affecting their cognitive and behavioral aspects of safety behavior, with minimal change observed in the affective component. Workers demonstrated a better understanding of safety risks and increased intention to behave safely. However, their emotional engagement or concern for safety did not notably shift. In essence, the training significantly improved knowledge and behavioral intentions but did not significantly enhance workers' emotional commitment to safety issues [4].

Safety-related work behaviors are considered predictive of accidents, with individual factors influencing behaviors such as adherence to safety rules, participation in safety activities, and reporting of hazards, ultimately reducing accidents and injuries.

Basahel [5] emphasizes the substantial impact of effective safety leadership and positive attitudes on safety motivation and knowledge within electrical construction projects, highlighting the necessity of clear policies and supportive environments to enhance safety compliance and active participation. Despite previous research demonstrating the positive correlation between safety attitudes, motivation, performance, accident rates [6], and safety knowledge [7], the linkage between safety attitudes, knowledge, behavior, and accidents remains underexplored. This gap persists even though [8] has proposed an integrated safety management framework illustrating how safety knowledge and attitudes influence safety behavior and, consequently, predict safety outcomes (accidents).

Previous research, such as Zhao et al. [9], has explored the influence of safety attitude, safety knowledge, and safety leadership on risk perception among chemical industry workers, yielding significant findings. However, the study does not delve into the relationship between safety knowledge and safety attitude nor extend its investigation to encompass safety behavior and accidents. While existing studies have shown a significant positive correlation between safety attitude and safety behavior in construction projects, they often overlook the comprehensive exploration of how safety knowledge and attitude interrelate and influence subsequent safety behaviors and accident rates [10]. Therefore, our research aims to bridge this gap by investigating the intricate relationships between safety knowledge, attitude, behavior, and accident occurrences within the context of solid waste management workers, offering a more comprehensive understanding of safety dynamics in this specific industry.

Additionally, there is a lack of research examining the relationship between safety knowledge, attitude, behavior, and accident occurrences specifically within solid waste management companies [11]. The escalating trend of workplace accidents and fatalities in Malaysia, particularly within the public cleansing services sector encompassing utilities and cleaning activities, demands urgent attention. Recent data from 2018 onwards, including statistics from 2022, reveal a significant increase in accidents and fatalities within this sector [12, 13]. These figures highlight persistent safety challenges that underscore the critical need for effective safety management strategies and robust leadership to mitigate risks and ensure the well-being of workers in this high-risk industry. The reported figures for 2022 alone indicate a troubling trend that necessitates immediate action to address safety concerns and prevent further incidents.

By conducting research focused on safety knowledge, attitudes, and behaviors among workers in the public cleansing services sector, this study aims to identify key factors influencing safety outcomes and develop evidence-based strategies to mitigate risks and improve overall safety performance. This research is essential for informing policy and practice initiatives to reduce accidents and fatalities, ultimately safeguarding the health and well-being of workers in this high-risk industry.

Furthermore, existing research on workplace safety often focuses on individual constructs in isolation, overlooking the interconnectedness of safety knowledge, attitude, and behavior. Understanding the complex interactions among these factors is essential for developing targeted interventions to promote a safety culture and reduce accident rates in the solid waste management industry. By identifying the factors influencing safety outcomes and exploring potential pathways for intervention, this study seeks to contribute to developing evidence-based strategies for enhancing workplace safety practices and protecting the well-being of employees in solid waste management companies.

Based on the literature review, it can be summarized that safety knowledge and attitude are among the predictors that can influence the employees' safety behavior, which further helps to overcome workplace accident issues. Thus, in this study, the researchers aim to bridge this gap by investigating the intricate relationships between safety knowledge, attitude, behavior, and accident occurrences within the context of solid waste management workers, offering a more comprehensive understanding of safety dynamics in this specific industry where most of the literature is conducted in the construction industry [7, 11].

2. RESEARCH FRAMEWORK AND HYPOTHESES DEVELOPMENT

Safety attitudes reflect employees' perceptions and sentiments toward safety protocols, guidelines, and practices [14], while safety behaviors encompass individuals' actions to uphold workplace safety standards [15]. The Knowledge-Attitude-Behavior (KAB) model posits that positive safety attitudes correlate with corresponding behaviors [16], as observed in studies on miners' safety practices [16] and construction workers' mental processes [17]. Research also highlights a significant relationship between safety attitude and behavior [18], particularly in food safety studies [18].

Despite the separate emphasis on safety knowledge and attitude in many studies, their interconnectedness remains understudied [19-21]. According to the Theory of Reasoned Action, attitudes precede behavior, mediated by intention, with knowledge serving as a key predictor of behavioral change [22, 23]. Attitudes are shaped by experiences and

acquired knowledge [24]. In manufacturing, understanding how safety knowledge and attitudes influence behaviors is crucial, given their impact on individual actions and organizational safety (KAB approach). Heinrich's safety theory, proposed by Heinrich in 1931, has significantly influenced safety management practices by emphasizing the sequence of events leading to accidents, starting with unsafe behaviors [25]. While Heinrich's theory remains foundational in safety research, contemporary approaches incorporate broader perspectives, considering organizational factors, safety culture, and human behaviors [26]. In the context of public cleansing and utility services, integrating Heinrich's theory with contemporary frameworks like the Theory of Planned Behavior [27], Social Cognitive Theory [28], and Health Belief Model [29] offers a comprehensive understanding of safety attitudes, behaviors, and accident prevention strategies tailored to specific industry challenges.

Safety behavior, reflecting actions to maintain a safe working environment, plays a pivotal role in accident prevention [8, 30]. Proactive safety measures reduce accidents, while deviations from safe practices increase risks [31]. This understanding fosters a proactive safety culture [32]. In summary, the role of safety behavior in accident prevention underscores the importance of exploring how safety knowledge and attitudes influence behaviors, ultimately impacting accident rates among manufacturing workers in Malaysia. The proposed framework is illustrated in Figure 1.

Hypothesis 1 (H_1): Safety knowledge positively influences safety attitude.

- Explanation: Individuals who possess greater safety knowledge are more likely to develop positive attitudes toward safety policies, procedures, and practices, as they understand the importance and rationale behind them.

Hypothesis 2 (H_2): Safety attitude positively influences safety behavior.

- Explanation: Employees with positive safety attitudes are more inclined to engage in safety-promoting behaviors, as they perceive safety as a priority and are motivated to uphold it in their actions.

Hypothesis 3 (H_3): Safety behavior negatively influences accident occurrences.

- Explanation: Proactive safety behaviors, such as adherence to safety protocols and hazard identification, are associated with lower accident rates, as they reduce the likelihood of unsafe incidents and mitigate potential risks.

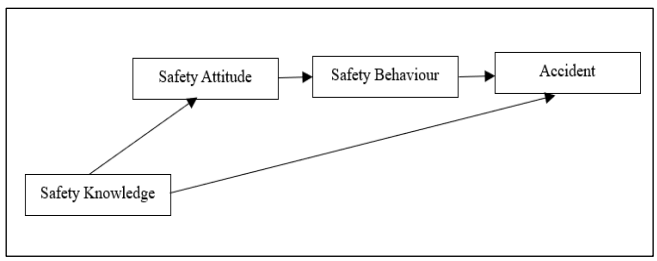


Figure 1. Research framework

Hypothesis 4 (H_4): Safety attitude mediates the relationship between safety knowledge and behavior.

- Explanation: Safety attitude serves as a mediator between safety knowledge and behavior. Individuals with greater safety knowledge are more likely to develop positive safety attitudes, which, in turn, influence their safety behaviors.

Hypothesis 5 (H_5): Safety behavior mediates the relationship between safety attitude and accident occurrences.

- Explanation: Safety behavior acts as a mediator between safety attitudes and accidents, whereby individuals with positive safety attitudes are more likely to engage in safety-promoting behaviors, consequently reducing the likelihood of accidents.

In addition, the theoretical foundation of this study is grounded in well-established behavioral and safety theories, such as the Theory of Planned Behavior (TPB) and Heinrich's Safety Theory, which provide insights into the relationship between knowledge, attitude, and behavior in workplace safety contexts. The TPB posits that individual attitudes towards behaviors, combined with subjective norms and perceived behavioral control, influence behavioral intentions and actual behaviors [27]. This aligns with the study's hypothesis that safety attitudes positively influence safety behaviors (H_2). Heinrich's Safety Theory emphasizes the critical role of unsafe acts in the sequence of events leading to accidents, underscoring the importance of proactive safety behaviors in mitigating risks [25]. These theories collectively support the conceptual framework, which explores how safety knowledge and attitudes shape safety behaviors and, ultimately, accident occurrences.

Furthermore, building on prior research, such as Zhao et al. [9], which identified safety knowledge and attitudes as pivotal factors in risk perception, this study extends the scope by integrating these constructs into a comprehensive model for solid waste management workers. Moreover, the KAB model-Knowledge-Attitude-Behavior-provides additional theoretical grounding by emphasizing the sequential influence of knowledge on attitudes and subsequently on behaviors [16]. Previous studies in diverse contexts, such as food safety [18] and construction safety [10], have validated these relationships, reinforcing the hypotheses proposed in this study.

3. METHODOLOGY

The present research is a hypothesis-testing study employing a cross-sectional approach. This study undertakes a quantitative exploration of proposed hypotheses. A self-administered questionnaire was devised to gather data, adapted from existing research to formulate items encapsulating both predictor and outcome variables [33, 34]. The questionnaire sets were distributed randomly and answered by 220 general workers of a solid waste management company located in the northern state of the Malaysian Peninsula.

3.1 Selection and size of the sample

The questionnaire was administered to general workers employed by a solid waste management company in the northern Malaysian Peninsula. The sample size was determined using G*Power software, which indicated a minimum sample size of 89. G*Power is a widely used and validated software tool for conducting power analyses across various statistical methods, including t-tests, ANOVA, regression analysis, and more. It allows researchers to input parameters such as effect size, desired power level (typically set at 0.80 or higher), significance level (usually set at 0.05),

and number of predictors to estimate the required sample size [35]. In this case, the minimum sample size of 89 determined by G*Power ensures that the study has sufficient statistical power to detect meaningful relationships between variables within the specified context of general workers in a solid waste management company.

3.2 Study instrument

A collection of self-administered questionnaires containing items for assessing independent and dependent variables was developed and employed as the research instrument. All questionnaire items were crafted using a Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree), adapted from earlier research endeavors [33, 34]. To establish face validity, subject matter experts, researchers, and practitioners familiar with workplace safety and solid waste management carefully crafted and reviewed the questionnaire items. Their input and feedback helped ensure the questionnaire items were relevant, clear, and representative of the measured constructs, enhancing the instrument's face validity [36]. The content validity and construct validity of the questionnaire items were ensured through a rigorous process of item selection and adaptation based on previous research conducted by reputable scholars in the field [34]. Leveraging validated measures from reputable studies enhances the credibility and robustness of the research instrument used in this investigation. Additionally, the measurement model was assessed for construct validity, including both convergent and discriminant validity, to verify the rigor of the instrument. Furthermore, the pilot test results, which demonstrated high Cronbach's alpha values for each construct (e.g., Safety Knowledge =0.81, Safety Attitude =0.89), confirmed the internal consistency and reliability of the measurement instruments [37].

3.3 Pilot test

A pilot test involving 30 workers from a solid waste management firm was conducted to assess the reliability of the questionnaire's items, which is essential for ensuring the stability and coherence of the measurement tools used to evaluate each variable. The Cronbach's alpha coefficients for Safety Knowledge (5 items), Safety Attitude (4 items), Safety Behavior (7 items), and Accidents (4 items) were 0.81, 0.89, 0.81, and 0.78, respectively. These high alpha values indicate strong internal consistency among the items within each variable. Overall, these findings demonstrate that the measurement tools employed in the pilot phase are reliable. These results justify a solid foundation for subsequent data collection and analysis in the main study [37].

3.4 Technique of data analysis

This study comprehensively evaluated the measurement model, meticulously scrutinizing its elements. Moreover, it rigorously investigated the structural model to evaluate the proposed hypotheses. The analysis was performed using Smart PLS version 3 software, offering strong statistical backing for the results outlined in this paper. The utilization of SmartPLS version 3 software in this analysis is academically justified, given its specialized capabilities for structural equation modeling (SEM) and its widespread acceptance in academic research. SmartPLS is recognized for its effectiveness in handling complex statistical analyses, including path analysis, mediation testing, and bootstrapping, particularly in studies with small or non-normal data sets. Its user-friendly interface and flexibility in model specification make it a preferred choice for researchers across disciplines, offering robust statistical backing for testing theoretical models and deriving meaningful insights from empirical data [38]. Additionally, SmartPLS can accommodate non-normal data distributions, making it suitable for analyses where the assumption of normality may not hold, further enhancing its applicability in diverse research contexts.

4. RESULTS AND DISCUSSIONS

The measurement model for this study was rigorously evaluated for reliability and convergent validity. Cronbach's alpha coefficients demonstrated strong internal consistency for Accident occurrences (α=0.826), Safety Attitude (α=0.930), Safety Behavior (α=0.974), and Safety Knowledge (α=0.974). Additionally, composite reliability values (Accident=0.881, Safety Attitude=0.950, Safety Behavior=0.978, Safety Knowledge=0.980) and average variance extracted (AVE) values (Accident=0.650, Safety Attitude=0.826, Safety Behavior=0.864, Safety Knowledge=0.906) further supported robust convergent validity. These findings affirm the reliability and validity of the measurement instruments, providing a solid foundation for robust data analysis and accurate interpretation of results [38]. Figure 2 depicts the measurement model results.

Discriminant validity evaluates whether the constructs under investigation are distinct from one another. The HTMT ratio compares the correlations between different constructs (heterotraits) to those within the same construct (monotraits). A lower HTMT ratio suggests more substantial discriminant validity, indicating that the constructs are distinct.

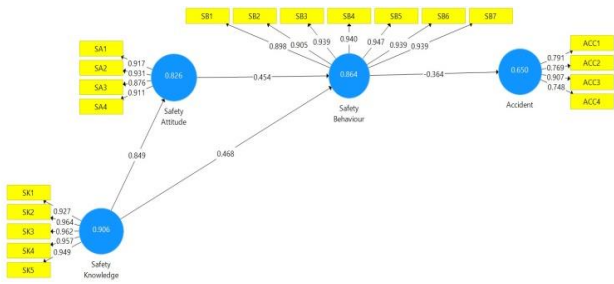


Figure 2. The measurement model

Table 1. Heterotrait-Monotrait (HTMT) bootstrapping

	Original Sample (O)
Safety Attitude -> Accident	0.374
Safety Behaviour -> Accident	0.373
Safety Behaviour -> Safety Attitude	0.894
Safety Knowledge -> Accident	0.376
Safety Knowledge -> Safety Attitude	0.892
Safety Knowledge -> Safety Behaviour	0.876

Table 1 presents the Heterotrait-Monotrait (HTMT) bootstrapping analysis results, which are crucial for evaluating the discriminant validity between the constructs examined in this study. The HTMT ratios provide insights into the extent to which the constructs are distinct. This analysis shows the HTMT ratios for each construct pair based on the original sample. For instance, the HTMT ratio for Safety Attitude ->

Accident is 0.374, while for Safety Behavior -> Safety Attitude, it is notably higher at 0.894. These values indicate the degree of overlap between different constructs, with lower ratios suggesting greater distinctiveness. Overall, the results indicate satisfactory discriminant validity between most construct pairs, although the relatively higher HTMT ratio for Safety Behavior -> Safety Attitude, which is still lower than the threshold value of 0.90 [39]. Hence, the HTMT ratios in Table 1 confirm the distinctiveness of the constructs, validating the measurement instruments used and enabling accurate interpretation of their relationships in subsequent analyses [40].

4.1 Effect size and R^2

Table 2 presents the R-squared (R^2) values, which denote the proportion of variance in each construct explained by the predictors in the model. The R^2 values shed light on the predictive power of Safety Attitude and Safety Behavior about Accident occurrences. Specifically, the R^2 value for accidents is 0.132, indicating that approximately 13.2% of the variance in accidents can be accounted for by combined safety attitude and safety behavior. Similarly, Safety Attitude demonstrates a substantial explanatory capability, with an R^2 value of 0.721, suggesting that about 72.1% of the variance in Safety Attitude is elucidated by Safety Knowledge. Likewise, Safety Behavior exhibits a notable predictive ability, evidenced by an R^2 value of 0.786, signifying that approximately 78.6% of the variability in Safety Behavior is clarified by the Safety Attitude and Safety Knowledge. These findings underscore the significance of Safety Attitude and Safety Behavior in elucidating accident occurrences, albeit with varying degrees of explanatory power.

Cohen's guidelines offer a commonly used framework in interpreting effect sizes, where f^2 values of 0.02, 0.15, and 0.35 represent small, moderate, and large effect sizes, respectively [41]. The findings from Table 2 indicate a moderate effect size for Safety Behavior on Accidents (f^2=0.15). Likewise, the effect sizes for Safety Knowledge and Safety Attitude on Safety Behavior are moderate (f^2=0.27 and f^2=0.29, respectively). In contrast, the effect size for Safety Knowledge on Safety Attitude is substantial (f^2=2.58). These effect sizes suggest varying degrees of impact of predictor variables on the dependent variable and intermediary constructs, providing insights into their practical significance within the research framework.

Table 2. R^2 and effect size (f^2)

	R^2	1	2	3	4
Accident	0.132				
Safety Attitude	0.721			0.268	
Safety Behaviour	0.786	0.153			
Safety Knowledge			2.582	0.286	

4.2 Hypotheses testing

Table 3 presents the path coefficients, respective β values, and T statistics, offering valuable insights into the strength and significance of the relationships among predictor and outcome variables within the structural model. The positive path coefficient (β=0.454, T=3.727, p<0.05) from Safety Attitude to Safety Behavior signifies a direct and statistically significant association, indicating that higher Safety Attitude levels correspond to increased Safety Behavior engagement. Conversely, the negative path coefficient (β=-0.364, T=4.811, p<0.05) from Safety Behavior to Accident underscores a significant inverse relationship, suggesting that enhanced Safety Behavior is linked to reduced Accident occurrences [42].

Furthermore, the strong positive path coefficient (β=0.849, T=16.249, p<0.05) from Safety Knowledge to Safety Attitude highlights a robust association, indicating that greater Safety Knowledge is conducive to more positive Safety Attitudes. Similarly, the positive path coefficient (β=0.468, T=3.706, p<0.05) from Safety Knowledge to Safety Behavior elucidates a significant relationship, suggesting that increased Safety Knowledge correlates with higher levels of Safety Behavior. These findings underscore the interplay among safety-related constructs and emphasize the importance of fostering positive attitudes and behaviors through enhanced safety knowledge, thereby contributing to promoting a safer work environment and mitigating accidents within the studied context.

Table 4 presents the indirect effects of Safety Attitude and Safety Knowledge on Accident occurrences, mediated through Safety Behavior. The negative β values for all pathways indicate that higher levels of Safety Attitude and Safety Knowledge are indirectly associated with reduced Accident occurrences through their influence on Safety Behavior. Specifically, the indirect effect of Safety Attitude on Accidents through Safety Behavior (β=-0.165, T=2.696, p<0.05) and the indirect effect of Safety Knowledge on Accidents via Safety Attitude and Safety Behavior (β=-0.140, T=2.496, p<0.05) are statistically significant. Additionally, the indirect effect of Safety Knowledge on Accidents through direct influence on Safety Behavior (β=-0.170, T=2.911, p<0.05) is significant. Notably, the positive indirect effect of Safety Knowledge on Safety Behavior through Safety Attitude (β=0.385, T=3.413, p<0.05) indicates that higher Safety Knowledge fosters positive Safety Attitudes, leading to increased engagement in Safety Behavior [43, 44], ultimately contributing to Accident prevention. These results underscore the intricate pathways through which Safety Attitude and Safety Knowledge influence Accident occurrences, emphasizing the pivotal role of Safety Behavior as a mediator in promoting a safer work environment among solid waste management workers [8]. A nuanced understanding of the indirect effects was also achieved through mediation analysis. For instance, safety attitude was found to mediate the relationship between safety knowledge and safety behavior (H_4: β=0.385, T=3.413, p<0.05), while safety behavior mediated the relationship between safety attitudes and accident occurrences (H_5: β=-0.165, T=2.696, p<0.05). These findings highlight the interconnected pathways through which knowledge and attitudes influence behaviors and, subsequently, accident outcomes.

In summary, the positive indirect effect of Safety Knowledge on Safety Behavior through Safety Attitude underscores the importance of instilling comprehensive safety knowledge, which fosters positive attitudes and subsequently influences behavior toward accident prevention. These findings emphasize the multifaceted nature of safety interventions, suggesting that interventions targeting safety attitudes and knowledge can effectively enhance safety behavior and contribute to Accident prevention among solid waste management workers. This is supported by Hie and Hien's study [45], which states that safety compliance behavior is crucial in preventing workplace accidents. Figure 3 depicts the Structural Model, illustrating the complex

relationships among safety-related constructs-Safety Attitude, Safety Behavior, and Safety Knowledge influencing Accident occurrences among solid waste management workers.

Table 3. Path coefficient

	β Value	T Statistics
Safety Attitude -> Safety Behaviour	0.454	3.727*
Safety Behaviour -> Accident	-0.364	4.811*
Safety Knowledge -> Safety Attitude	0.849	16.249*
Safety Knowledge -> Safety Behaviour	0.468	3.706*

* Sig. @ P<0.05.

Table 4. Indirect effect

	β Value	T Statistics	Lower LL	Upper LL
Safety Attitude -> Safety Behaviour -> Accident	-0.165	2.696*	-0.294	-0.090
Safety Knowledge -> Safety Attitude -> Safety Behaviour -> Accident	-0.140	2.496*	-0.259	-0.071
Safety Knowledge -> Safety Behaviour -> Accident	-0.170	2.911*	-0.275	-0.084
Safety Knowledge -> Safety Attitude -> Safety Behaviour	0.385	3.413*	0.225	0.597

* Sig. @ P<0.05.

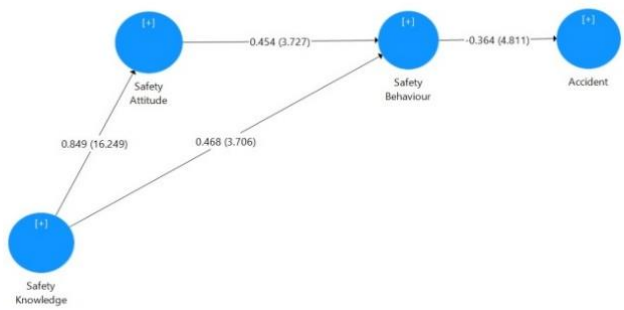


Figure 3. The structural model

5. CONCLUSIONS

In closing, this study transcends traditional paradigms by amalgamating statistical rigor with a profound understanding of the intricate dynamics of workplace safety. Through a judicious synthesis of effect size measures, R-squared values, and beta coefficients, this research offers a nuanced exploration of the multifaceted relationships among safety knowledge, attitude, behavior, and accident occurrences. By peering beyond the conventional boundaries of linear regression models, this research unveils a kaleidoscope of interrelated factors shaping safety outcomes, shedding light on previously uncharted pathways and mechanisms within solid waste management companies. In doing so, it propels the discourse on workplace safety into uncharted territory, offering a transformative perspective that transcends mere statistical significance to reveal the practical implications of safety interventions in safeguarding employee well-being and organizational sustainability.

Furthermore, this research sets a pioneering precedent for future investigations by championing a holistic approach to safety management that acknowledges the interconnectedness of individual, organizational, and environmental factors. By embracing the complexities inherent in workplace safety, future researchers can build upon this foundation to explore novel methodologies and conceptual frameworks that capture the intricacies of safety dynamics in diverse organizational contexts. This study beckons researchers to embark on a journey of discovery, transcending disciplinary boundaries and methodological constraints to unlock the full potential of safety interventions in fostering a culture of safety excellence. In doing so, it catalyzes a paradigm shift in how researchers and practitioners conceptualize, measure, and promote workplace safety, ushering in a new era of research that embraces complexity and diversity as catalysts for innovation and progress.

This research contributes to future studies by exemplifying the integration of advanced statistical techniques, such as structural equation modeling (SEM), and utilizing effect size measures, R^2 values, and beta coefficients to examine complex relationships within workplace safety contexts. By showcasing the application of SEM, researchers gain insights into the interplay among multiple variables and their direct and indirect effects on safety outcomes, offering a robust framework for analyzing complex phenomena. Furthermore, incorporating effect size measures enhances the interpretability of findings by providing a quantitative assessment of the practical significance of predictor variables, facilitating more informed decision-making in practice. Additionally, the use of R-squared values elucidates the proportion of variance in outcome variables explained by the proposed model, aiding researchers in evaluating the model's predictive power and identifying areas for further investigation.

Moreover, this research sets a methodological precedent for future studies by emphasizing the importance of considering both direct and indirect pathways in examining the relationships among safety-related constructs. By exploring indirect effects, researchers can uncover nuanced mechanisms through which predictor variables influence outcome variables, offering a more comprehensive understanding of the underlying processes driving safety outcomes. Furthermore, the integration of moderator and mediator analyses within the SEM framework can provide deeper insights into the contextual factors influencing safety behaviour and accident occurrences, offering avenues for future research to explore the moderating effects of organizational culture, leadership styles, and individual characteristics on safety outcomes.

Overall, this research methodologically advances the field of workplace safety research by demonstrating the application of sophisticated statistical techniques and highlighting the importance of considering indirect pathways and contextual factors in analyzing safety-related phenomena.

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