

Development of A Behavior-Based Safety Model Using EFA, CFA, and Structural Equation Modeling at PT XYZ

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ABSTRACT: Behavior-Based Safety (BBS) is an important approach to reducing unsafe actions and strengthening occupational safety performance. However, the factors shaping safety behavior may vary across organizational contexts, requiring an empirically validated model to identify the most influential determinants. This study aims to develop a Behavior-Based Safety model at PT XYZ by integrating Exploratory Factor Analysis (EFA), Confirmatory Factor Analysis (CFA), and Structural Equation Modeling (SEM). Data were collected from 200 workers using a structured questionnaire covering individual, organizational, and safety management factors. EFA was applied to explore the underlying factor structure, followed by CFA to validate the measurement model and SEM to examine the relationships between the identified factors and safety behavior. The EFA results confirmed the adequacy of the data and established 11 factor groups after eliminating indicators with cross-loading or insufficient factor loading. The final model demonstrated a satisfactory goodness of fit ($\chi^2 = 219.888$, $p = 0.126$, GFI = 0.922, TLI = 0.990, CFI = 0.993, and RMSEA = 0.024). SEM results revealed that worker attitude ($p = 0.004$) and company occupational safety and health regulations ($p = 0.003$) had significant positive effects on safety behavior, whereas knowledge, safety equipment, work relationships, personal protective equipment availability and monitoring, safety training, rewards, and punishment showed no significant direct effects. These findings indicate that effective BBS implementation should prioritize the development of positive safety attitudes and the consistent implementation of safety regulations. The proposed EFA–CFA–SEM model provides an empirically validated framework for identifying key determinants of safety behavior and supports the development of targeted safety interventions, including safety briefings, workplace safety audits, and structured safety reporting systems at PT XYZ.

KEYWORDS: Behavior-Based Safety; Safety Behavior; Exploratory Factor Analysis; Confirmatory Factor Analysis; Structural Equation Modeling

I. INTRODUCTION

Occupational accidents can cause injuries, property losses, and reduced organizational productivity. Unsafe actions are among the main factors contributing to workplace accidents. Larasatie *et al.* [1] reported that unsafe behavior remains a major cause of occupational incidents, highlighting the importance of behavioral factors in accident prevention. Therefore, safety management should address not only hazardous workplace conditions but also worker behavior.

Behavior-Based Safety (BBS) is a behavioral approach designed to identify unsafe actions and strengthen safe work practices. Cooper [2] defined BBS as a systematic process involving management and workers in continuously improving safety behavior. Geller [3] further emphasized that active worker involvement and behavioral intervention are essential for developing sustainable safety practices. Agnew and Ashworth [4] also highlighted that effective BBS should focus on understanding and improving the factors that shape employee behavior rather than merely assigning responsibility for unsafe actions.

Previous studies have demonstrated the practical value of behavioral safety approaches. Aini [5] examined BBS maturity and its relationship with occupational accidents caused by unsafe behavior. Kurniawan *et al.* [6], Monalisa *et al.* [7], and Niaz *et al.* [8] identified several individual and workplace factors associated with safety and unsafe behavior. Furthermore, Emmanuel and Widiawan [9] reported that the implementation of BBS increased safe actions in industrial operations. These findings confirm that worker behavior is influenced by multiple individual and organizational factors.

PT XYZ operates a coal-fired power plant with continuous production and maintenance activities. Its operations involve high-risk work, including hot work, high-voltage activities, confined-space work, working at height, lifting operations, chemical handling,

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radiation exposure, and work near or underwater. Despite the implementation of occupational safety and health programs, unsafe actions are still observed, including incomplete work permits, improper use of personal protective equipment, non-compliance with work procedures, and unsafe behavior during high-risk activities. These conditions indicate the need for a more systematic behavioral safety approach.

Although previous studies have examined factors associated with unsafe behavior and the effectiveness of BBS programs [5]–[9], most studies have focused on individual relationships or direct behavioral interventions. Limited research has developed an empirical BBS model by sequentially exploring latent factors, validating the measurement structure, and testing structural relationships. This gap indicates the need for an integrated statistical approach to identify the dominant factors shaping safety behavior in high-risk industrial operations.

Exploratory Factor Analysis (EFA) can identify latent structures among safety indicators, while Confirmatory Factor Analysis (CFA) validates the resulting measurement model. Structural Equation Modeling (SEM) subsequently examines relationships among latent variables and safety behavior. Hair *et al.* [10] emphasized the importance of factor analysis in identifying and validating multidimensional constructs. SEM also enables simultaneous analysis of complex relationships among variables [11], [12].

Therefore, this study aims to develop a Behavior-Based Safety model using EFA, CFA, and Structural Equation Modeling at PT XYZ. The proposed approach identifies the underlying behavioral factors, validates their measurement structure, and evaluates their effects on safety behavior. The resulting model is expected to provide an empirical basis for prioritizing behavioral safety programs and strengthening occupational safety management at PT XYZ.

II. METHODS

This study employed a quantitative approach to develop a Behavior-Based Safety (BBS) model at PT XYZ using a sequential EFA–CFA–SEM framework. Data were collected from 200 production and maintenance workers using a structured questionnaire developed from BBS concepts and previous safety behavior studies [1]–[9]. The evaluated factors included knowledge, attitude, safety equipment, work relationships, PPE availability and monitoring, OSH training, company safety regulations, rewards, punishment, and safety behavior.

Exploratory Factor Analysis (EFA) was first applied to identify the latent structure of the safety indicators. Data adequacy was evaluated using the Kaiser–Meyer–Olkin (KMO) measure and Bartlett's Test of Sphericity. Indicators with inadequate factor loadings or cross-loadings were removed to obtain a clear factor structure [10].

Confirmatory Factor Analysis (CFA) was subsequently used to validate the measurement model. Model fit was evaluated using Chi-square probability, GFI, TLI, CFI, and RMSEA. Structural Equation Modeling (SEM) was then applied to examine the effects of the validated factors on safety behavior. Relationships were considered significant at $p < 0.05$ [10]–[12]. The sequential approach enabled the study to explore the empirical factor structure through EFA, validate the measurement model through CFA, and test structural relationships through SEM. The resulting model was used to identify the dominant determinants of safety behavior and formulate priority BBS improvement programs at PT XYZ.

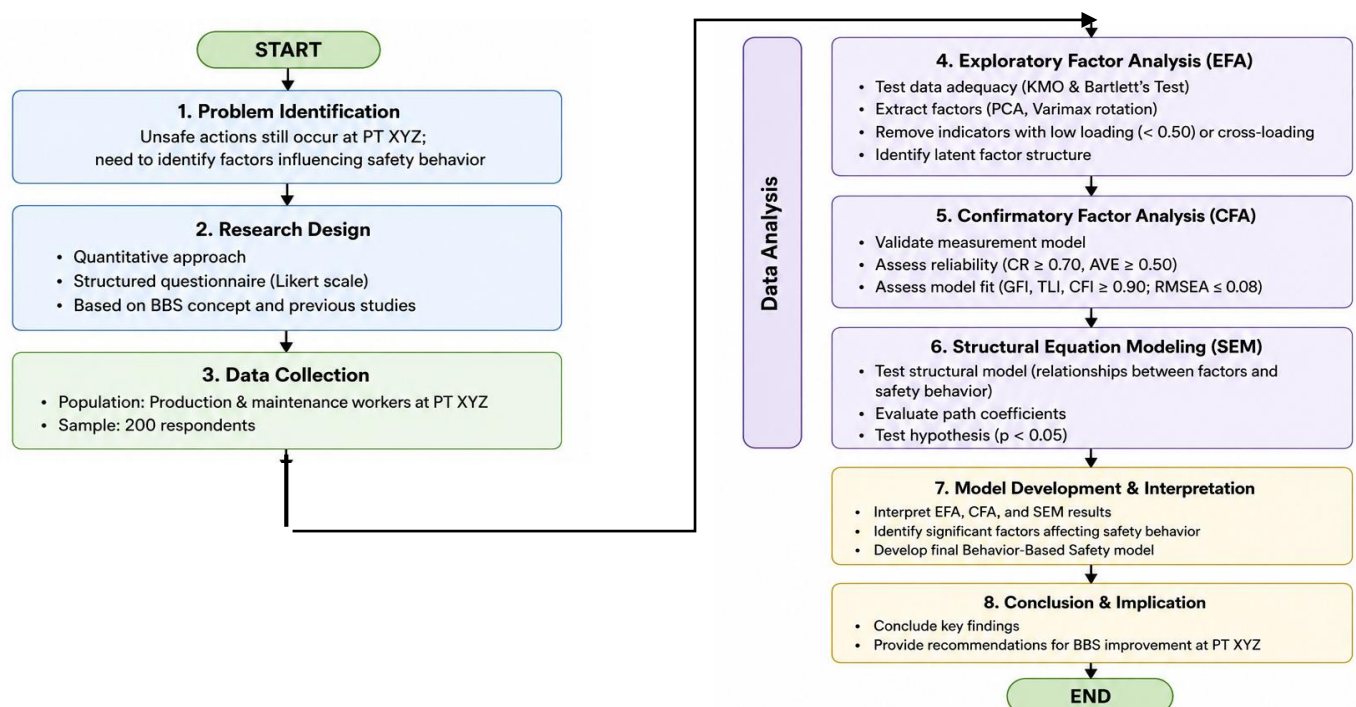


Figure 1. Research Flow Diagram

III. RESULT AND DISCUSSION

A. Exploratory Factor Analysis (EFA)

Exploratory Factor Analysis (EFA) was conducted to identify the underlying factor structure of Behavior-Based Safety (BBS) at PT XYZ. The analysis used data from 200 respondents involved in production and maintenance activities. Data adequacy was evaluated using the Kaiser–Meyer–Olkin (KMO) measure and Bartlett's Test of Sphericity.

The final EFA analysis produced a KMO value of 0.773, indicating that the data were adequate for factor analysis. Indicators with low factor loadings or cross-loadings were removed to obtain a clearer factor structure. The analysis identified 11 factor groups representing individual, workplace, and organizational dimensions related to safety behavior.

The extracted factors included knowledge, attitude, safety equipment, work relationships, PPE availability and monitoring, occupational safety and health (OSH) training, company OSH regulations, rewards, punishment, and safety behavior. The EFA results indicate that BBS is a multidimensional construct influenced by both individual and organizational factors. This is consistent with Cooper [2] and Geller [3], who emphasized that safety behavior develops through the interaction between individual behavior and the organizational safety environment.

The EFA stage provides an empirical factor structure rather than relying solely on predetermined theoretical constructs. This finding is important because the factors identified represent the actual perceptions and safety conditions of workers at PT XYZ. The resulting factor structure was subsequently evaluated through CFA.

B. Confirmatory Factor Analysis (CFA)

Confirmatory Factor Analysis (CFA) was performed to validate the measurement structure obtained from EFA. The analysis examined whether the observed indicators adequately represented their respective latent constructs. The measurement model demonstrated satisfactory goodness of fit. The Chi-square value was 219.888 with a probability value of 0.126, indicating no significant difference between the observed and estimated covariance matrices. The GFI value of 0.922, TLI of 0.990, and CFI of 0.993 exceeded the recommended threshold of 0.90. In addition, the RMSEA value was 0.024, indicating a close model fit.

Table I. Goodness-of-Fit of the BBS Model

Goodness-of-Fit Index	Result	Recommended Criteria	Evaluation
Chi-square	219.888	Expected to be low	Acceptable
Probability	0.126	≥ 0.05	Good Fit
GFI	0.922	≥ 0.90	Good Fit
TLI	0.99	≥ 0.90	Good Fit
CFI	0.993	≥ 0.90	Good Fit
RMSEA	0.024	≤ 0.08	Good Fit

These results confirm that the measurement model adequately represents the empirical data. The high TLI and CFI values indicate strong agreement between the proposed model and the observed covariance structure. Meanwhile, the low RMSEA value indicates a small approximation error. According to Hair *et al.* [10], model fit should be evaluated using multiple goodness-of-fit indices rather than a single criterion. Therefore, the overall CFA results support the validity of the measurement model and allow further structural analysis using SEM.

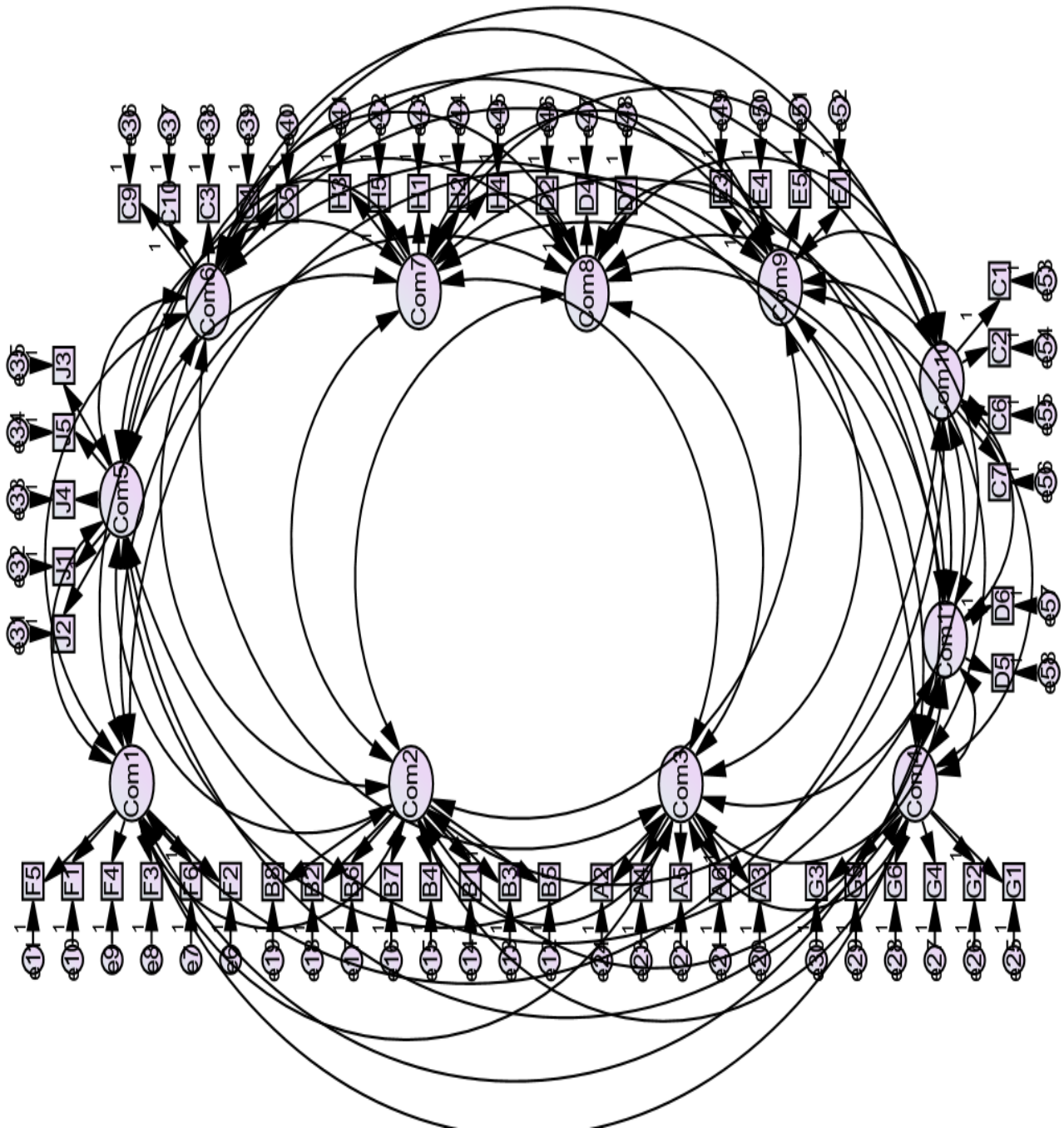


Figure 2. Initial CFA model resulting from EFA Factor Analysis

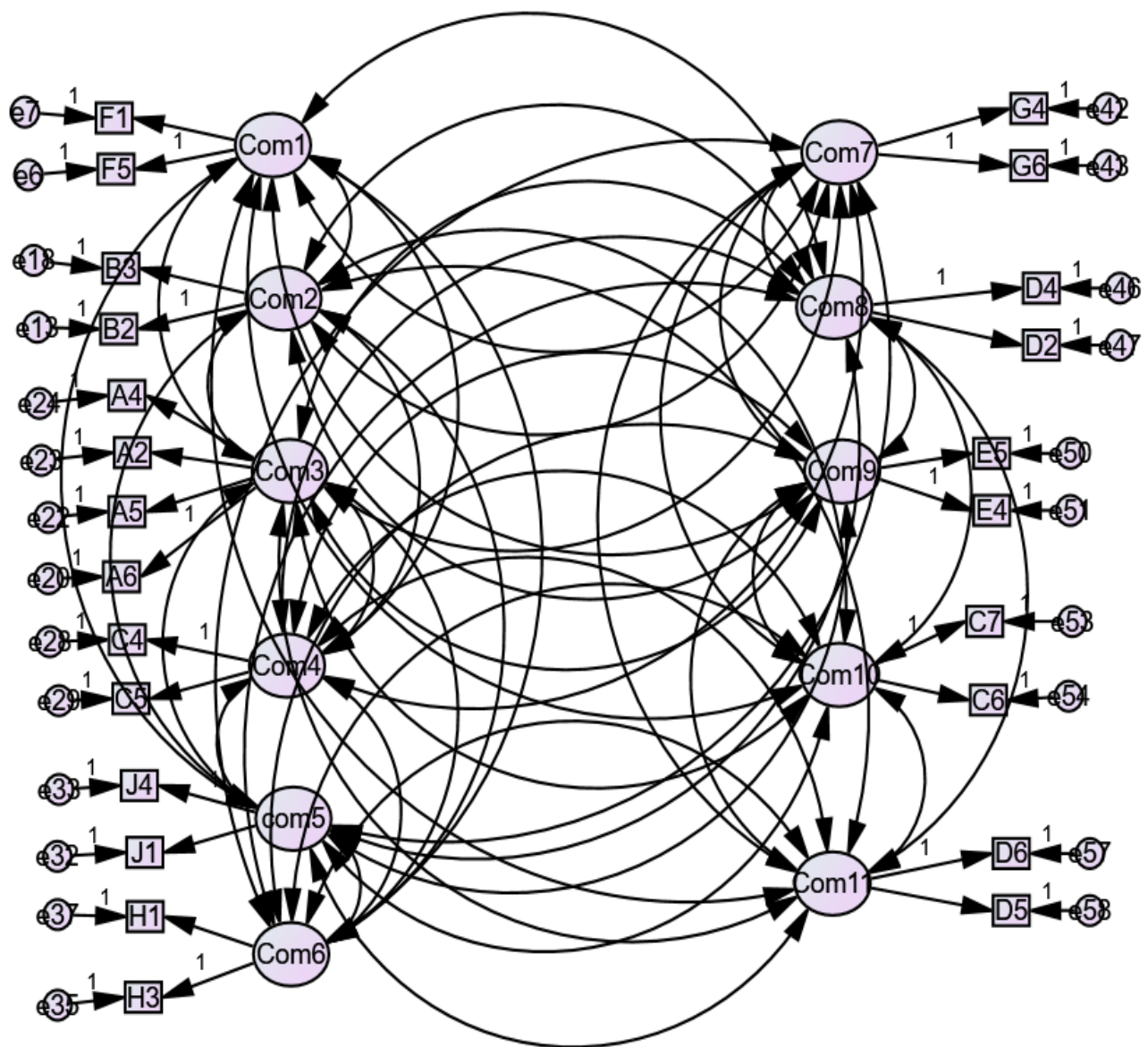


Figure 3. Model Fit Results of CFA Analysis Calculations

C. Structural Equation Modeling (SEM)

Structural Equation Modeling (SEM) was applied to examine the relationships between the validated BBS factors and safety behavior. The analysis evaluated the direct effects of knowledge, attitude, safety equipment, work relationships, PPE availability and monitoring, OSH training, company OSH regulations, rewards, and punishment on safety behavior.

The SEM results indicate that attitude and company OSH regulations have significant effects on safety behavior. Attitude showed a significance value of $p = 0.004$, while company OSH regulations showed $p = 0.003$. Both values were below the significance threshold of 0.05. In contrast, knowledge, safety equipment, work relationships, PPE availability and monitoring, OSH training, rewards, and punishment did not demonstrate significant direct effects on safety behavior. These results suggest that the availability of safety programs and resources alone does not automatically lead to safe behavior. Their effectiveness may depend on workers' attitudes and the consistent implementation of company safety regulations.

The dominance of attitude indicates that worker perceptions, awareness, and willingness to perform tasks safely are central to BBS implementation. This finding supports Geller [3], who emphasized that sustainable safety performance requires active worker involvement and personal responsibility for safe behavior. Cooper [2] also argued that behavioral safety should focus on factors that encourage workers to consistently perform safe actions.

Table II. Summary of SEM Results

Factor	Effect on Safety Behavior	Result
Knowledge	Not significant	Rejected
Attitude	Significant ($p = 0.004$)	Accepted
Safety Equipment	Not significant	Rejected
Work Relationship	Not significant	Rejected
PPE Availability and Monitoring	Not significant	Rejected
OSH Training	Not significant	Rejected
Company OSH Regulations	Significant ($p = 0.003$)	Accepted
Rewards	Not significant	Rejected
Punishment	Not significant	Rejected

The dominance of attitude indicates that worker perceptions, awareness, and willingness to perform tasks safely are central to BBS implementation. This finding supports Geller [3], who emphasized that sustainable safety performance requires active worker involvement and personal responsibility for safe behavior. Cooper [2] also argued that behavioral safety should focus on factors that encourage workers to consistently perform safe actions.

Company OSH regulations also significantly influenced safety behavior. Clear and consistently implemented safety regulations provide behavioral standards for workers during operational activities. In high-risk power generation operations, compliance with work permits, PPE requirements, and standard operating procedures is essential to prevent unsafe actions. The result is consistent with Agnew and Ashworth [4], who emphasized that organizational systems and workplace conditions influence employee safety behavior. Further analysis was conducted using the SEM method using variables and indicators that had undergone EFA and CFA analyses. The results using the AMOS application are as follows:

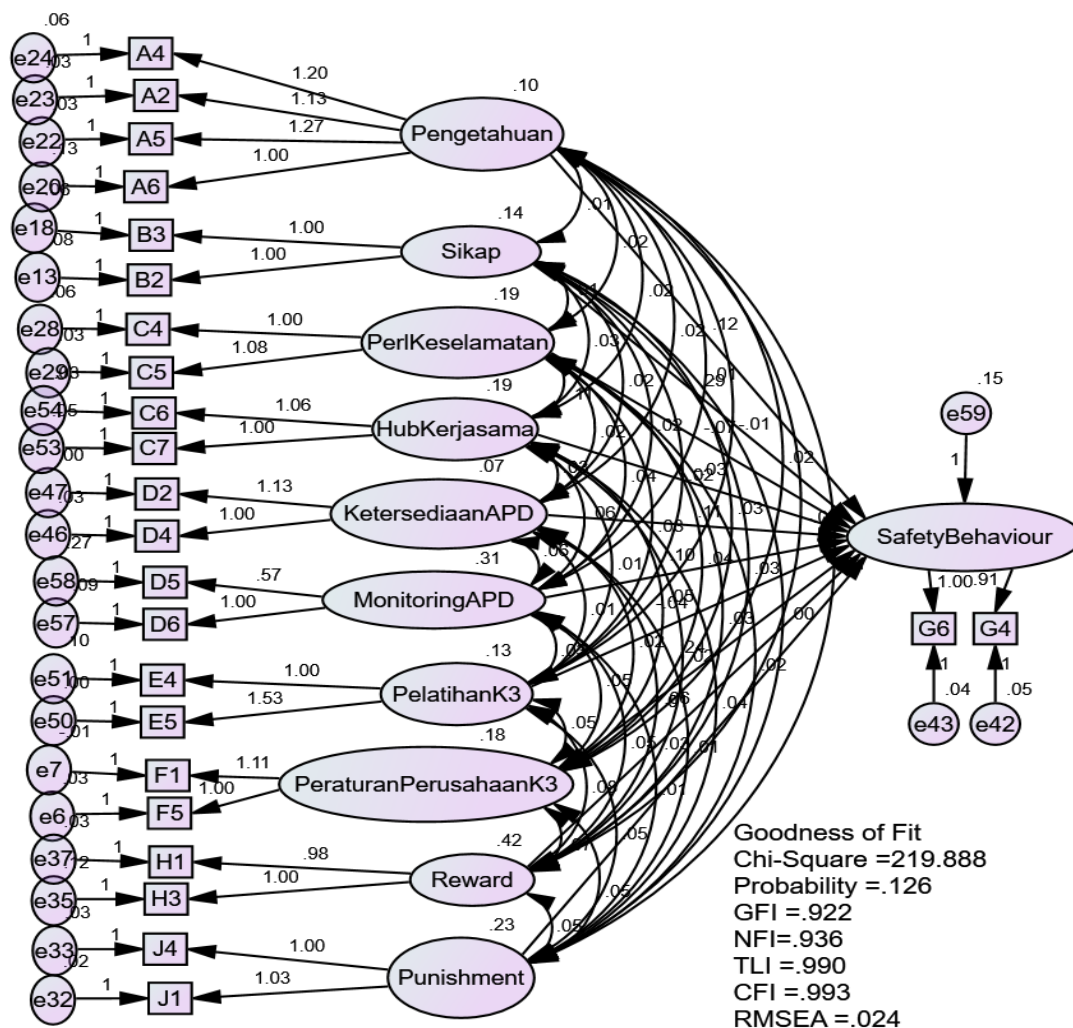


Figure 4. SEM Model according to Hypothesis

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D. Development of the Behavior-Based Safety Model

Based on the sequential EFA–CFA–SEM analysis, the final BBS model identified attitude and company OSH regulations as the dominant determinants of safety behavior at PT XYZ. EFA initially explored the empirical factor structure, CFA validated the measurement model, and SEM identified the statistically significant relationships. The model development process can be summarized as follows:

Safety Attitude → Safety Behavior

Company OSH Regulations → Safety Behavior

The findings demonstrate that the development of safe behavior at PT XYZ should not focus solely on increasing safety knowledge or providing additional safety equipment. Although these factors remain important components of the OSH system, the SEM results indicate that their direct statistical effects on safety behavior were not significant in the developed model.

Instead, BBS improvement should prioritize the formation of positive safety attitudes and consistent implementation of company OSH regulations. Safety programs should encourage workers to recognize hazards, actively care about safety, and consistently choose safe actions during high-risk activities. At the organizational level, safety regulations should be clearly communicated, monitored, and consistently applied.

The developed model differs from previous studies that primarily examined individual factors associated with unsafe actions [6]–[8]. This study integrates EFA, CFA, and SEM in a sequential framework to empirically explore the factor structure, validate the measurement model, and identify significant determinants of safety behavior. Therefore, the main contribution of this study is an empirically validated and data-driven BBS model for high-risk power generation operations.

E. Practical Implications for BBS Improvement

The developed model provides a basis for prioritizing BBS improvement programs at PT XYZ. Since attitude significantly affects safety behavior, behavioral interventions should focus on strengthening worker awareness and active participation in safety activities. Safety briefings, behavioral observation, peer feedback, and structured safety reporting can be directed toward improving workers' safety attitudes.

The significant effect of company OSH regulations also indicates the need for consistent implementation of safety requirements. Work permits, PPE compliance, and standard operating procedures should be regularly monitored through workplace safety audits and supervisory observations. The objective is not only to ensure administrative compliance but also to strengthen safe behavior during daily operations. Overall, the results demonstrate that attitude and company OSH regulations are the key factors in the developed BBS model at PT XYZ. The integration of EFA, CFA, and SEM provides a systematic framework for identifying and validating these determinants. The model can therefore support more focused BBS interventions and improve safety management in high-risk power generation activities.

F. Main Finding

The main finding of this study is that attitude and company OSH regulations are the key determinants of safety behavior at PT XYZ. The sequential EFA–CFA–SEM analysis confirmed that the developed BBS model achieved a satisfactory model fit. SEM results showed that attitude ($p = 0.004$) and company OSH regulations ($p = 0.003$) significantly influenced safety behavior, while the other evaluated factors showed no significant direct effects. These findings indicate that improving safety behavior requires greater emphasis on strengthening workers' safety attitudes and ensuring consistent implementation of OSH regulations. Therefore, the developed model provides a focused basis for prioritizing Behavior-Based Safety programs in high-risk power generation operations.

IV. CONCLUSIONS

This study developed a Behavior-Based Safety (BBS) model at PT XYZ using a sequential EFA–CFA–SEM approach. EFA identified the underlying structure of safety-related factors, while CFA confirmed that the measurement model achieved a satisfactory fit. The SEM results showed that attitude and company OSH regulations significantly influenced safety behavior, whereas the other factors had no significant direct effects.

The findings indicate that improving safety behavior should focus on strengthening positive safety attitudes and ensuring consistent implementation of company OSH regulations. Therefore, PT XYZ should prioritize behavioral interventions, safety awareness, and consistent compliance with work procedures and safety requirements. The developed BBS model provides an empirical and practical basis for prioritizing safety programs and improving occupational safety performance in high-risk power generation operations.

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