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# Development of Risk-Based Work Breakdown Structure (WBS) Standards for Maintenance and Care Work on LRT (Light Rail Transit) Station Building Infrastructure to Improve Safety Performance

**Grace Oktavina Marpaung** [a]
**Rully Andhika Karim** [b]

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**Abstract**

This study aims to review the current maintenance and care system, formulate WBS standards, and identify and analyze risk factors that affect safety performance in the maintenance and care of LRT station buildings. The risk factors analyzed include material, equipment, workers, and environmental/public aspects. Furthermore, this study develops a model of the relationship between risks in the WBS structure and safety performance and formulates the development of risk-based WBS standards to improve safety performance. The research method used is a quantitative approach through the distribution of questionnaires to respondents involved in the maintenance and care of Jabodebek LRT station buildings. The data obtained will be analyzed using the Statistical Product and Service Solutions (SPSS) method to test the relationship between WBS standard variables, risk factors, risk-based WBS, and safety performance. The expected results of this research are the preparation of a risk-based WBS standard that is integrated with the main risk factors in each work activity, so that it can be used as a reference in efforts to prevent, reduce, and control the risk of work accidents and improve safety performance in maintenance and care work for LRT station buildings.



***Corresponding author:***
Grace Oktavina Marpaung,
Department of Civil Engineering, Faculty of Engineering,
Universitas Indonesia, Depok, West Java 16424, Indonesia.
*Email address: graceoktavina@gmail.com*

[a] Department of Civil Engineering, Faculty of Engineering, Universitas Indonesia, Depok, West Java 16424, Indonesia
[b] Department of Civil Engineering, Faculty of Engineering, Universitas Indonesia, Depok, West Java 16424, Indonesia

## 1 Introduction

Mass transportation in urban areas is a strategic approach to addressing congestion, reducing carbon emissions, and increasing public mobility efficiently. One mode of transportation experiencing rapid development in Indonesia is the Light Rail Transit (LRT), which has operated in several cities such as Jakarta and Palembang and continues to be developed in other metropolitan areas. The presence of the LRT not only contributes to increasing the efficiency of the transportation system but also demands reliable and high-standard infrastructure management, particularly in station buildings as the main points of passenger activity.

Unlike long-standing conventional railway systems, Indonesia's LRT station infrastructure is relatively new. Most LRT stations are built with elevated structures and are supported by more modern architectural systems and building utilities, including integrated mechanical, electrical, and plumbing (MEP) systems, vertical transportation systems, and passenger safety and service facilities. This complexity results in relatively high-risk maintenance activities, particularly for work at heights, electrical systems, and station operational facilities.

From a regulatory perspective, the implementation of maintenance and care of transportation infrastructure is an obligation that must be fulfilled to ensure operational safety and reliability. Law No. 23 of 2007 concerning Railways emphasizes that railway operations must ensure the safety of train travel through continuous infrastructure maintenance. In addition, Government Regulation No. 36 of 2005 concerning Buildings, Article 16, states that every building must be maintained and cared for to ensure its continued function, including in terms of the safety of building users.

Furthermore, Minister of Transportation Regulation No. 63 of 2019 concerning the Railway Safety Management System requires every railway operator to implement risk management in all operational and maintenance activities. Article 5, paragraph (2) emphasizes that the risk management process must include the identification, analysis, evaluation, and control of risks that have the potential to cause accidents or operational disruptions.

Despite the availability of regulations, workplace accidents in the transportation and railway sectors remain a serious concern. Data from the International Labour Organization (ILO) shows that each year, more than 2.78 million workers worldwide die from workplace accidents and occupational diseases, with the construction and transportation sectors among those with the highest risk. In Indonesia, according to BPJS Ketenagakerjaan data, the number of workplace accidents continues to rise, reaching more than 265,000 in 2023. Most of these accidents occur in construction, utilities, and public infrastructure maintenance, which are high-risk activities.

In the context of rail-based transportation, several studies have shown that maintenance activities significantly contribute to potential safety risks. Research by Andrews et al. (2014) in the field of railway infrastructure maintenance explains that maintenance work on rail systems and station facilities has a high level of exposure to hazards due to the interaction between technical work, limited maintenance time, and active operational conditions. Furthermore, research by Zou et al. (2007), states that failure to control risks in transportation infrastructure maintenance work can lead to workplace accidents, facility damage, and disruption of public services.

Maintenance accidents also occur in modern urban transportation systems such as the LRT and MRT. Some of the incidents include workers being electrocuted while maintaining utility panels, falling from elevated areas while inspecting building facilities, and being struck by falling materials during repairs to station structures and utilities. These risks are heightened because most LRT station buildings are elevated structures with limited work access and involve high-voltage mechanical and electrical systems.

Workplace accidents can result in work delays, cost overruns, damage to an organization's reputation, and reduced worker and public trust in the public transportation system (Wang et al., 2006). Furthermore, according to the ILO (2003), Chen et al. (2004), and Hinze (1997), the impact of workplace accidents can be viewed from micro, meso, and macro perspectives. At the micro level, accidents disrupt work activities, cause worker injuries, and increase operational costs. At the meso level, accidents affect company performance and lead to legal consequences. Meanwhile, at the macro level, workplace accidents can impact national productivity and increase economic losses.

Research by Gambatese et al. (2008) also showed that 42% of construction accidents were related to a failure to consider safety aspects during the planning and control stages of the work. This indicates that safety management cannot be carried out only during the implementation stage but must be integrated from the planning stage, including in the development of maintenance and upkeep work structures.

In the context of project management, one approach that can be used to ensure the orderliness, traceability, and effectiveness of work is the Work Breakdown Structure (WBS). The WBS functions to break down work into more structured packages, facilitating planning, implementation, monitoring, and control. However, to date, there is no

specific WBS standard designed for LRT station building maintenance and upkeep activities in Indonesia, particularly one that integrates occupational safety risk aspects.

The novelty of this research lies in the development of a Work Breakdown Structure (WBS) specifically for LRT station building maintenance and upkeep, integrated with systematic risk analysis. Unlike previous research, which generally focused on the construction phase, this study focuses on the maintenance phase, which has different and more dynamic risk characteristics (Siami-Irdemoosa et al., 2015).

Furthermore, this study integrates risk identification and analysis into each WBS element, resulting in a Risk-Based WBS model that serves not only as a work planning tool but also as a preventive instrument in improving safety performance. Thus, this study not only provides a conceptual contribution but also produces output in the form of a risk-based WBS standard that is applicable and relevant for use in LRT station infrastructure in Indonesia.

Therefore, this research focuses on developing a risk-based Work Breakdown Structure (WBS) standard for LRT station building maintenance and upkeep. With this approach, each work package is not only identified based on its technical activities but also analyzed for its level of risk to safety performance. The research results are expected to contribute to a risk-based WBS guideline that is applicable, systematic, and supports improvements in occupational safety and operational reliability of LRT infrastructure in Indonesia (Fakrunnisa et al., 2024).

## 2 Materials and Methods

This research uses methods including archival analysis, surveys, and case studies. The independent variable (X) and the dependent variable (Y) in this study are used as research instruments in answering RQ-3. In the process of answering RQ-3, the X variable is identified in the form of risk factors at each stage of the LRT Station building maintenance and care work activities based on PUPR Ministerial Regulation No. 10 of 2021, where the risk categories that impact construction safety are risks to workers, equipment, materials, and the environment/public. While the Y variable is safety performance, where safety performance, which is included in the leading indicator category, becomes an output measurement, then the safety performance variable in the leading indicator is reduced to two indicators related to the WBS standard for LRT Station Building maintenance and care work, namely resource suitability (Y1) and form/implementation of monitoring (Y2).

The research variable to answer RQ 1 is the independent variable, namely the WBS standard based on previous research from archive analysis. The research variables in RQ 1 are as follows: WBS level 1 is the project name, WBS level 2 is the work group, WBS level 3 is the type of work, and WBS level 4 is the work package.

The research instrument used is a written guideline for interviews or observations, or a list of questions prepared to obtain information from respondents. The research instrument is used to measure the value of the variables being studied; thus, the number of instruments to be used for the study depends on the number of variables to be studied (Sugiyono, 2009). The research instrument used to answer RQ 1 is a questionnaire. The research instrument stage 1 is used to validate WBS levels 2-4 of the LRT Station Building Construction Work with experts. The questionnaire is filled in in the form of expert responses agreeing or disagreeing at each WBS level. The following is the format of the stage 1 questionnaire for RQ 1:

Data collection used primary data and secondary data. Primary data was obtained from expert interviews and questionnaires distributed to respondents to obtain responses to research variables. Secondary data came from books, journals, theses, and government regulations related to the research theme. Data Collection Stage 1 – Archive Analysis and Data Collection Stage 2 – WBS Validation. The data collected by the researcher will be analyzed to answer the research questions. Data Analysis Stage 1 – WBS Standard Validation and initial validation of WBS level 2-4 standards by experts. At this stage, consensus was made to obtain WBS level 2-4 standards that have been approved by at least 3 out of 5 experts at each level of WBS variable decomposition.

The research variables to answer RQ 2 are independent variables, namely the WBS standard based on the output of RQ 1, WBS LRT station building work, and archive analysis. The research variables in RQ 1 are as follows: WBS level 1 is the project name, WBS level 2 is the work family, WBS level 3 is the type of work, WBS level 4 is the work package, WBS level 5 is the work activity, and WBS level 6 is the resources, which consist of materials, tools, and labor. The research instrument used to answer the research question RQ 2 is in the form of a questionnaire. The questionnaire distribution was carried out in 2 (two) stages. The research instrument in stage 2 was used to validate WBS levels 2-4 LRT Station Building Maintenance and Care Work to experts. The questionnaire was filled in the form of expert responses agreeing or disagreeing at each WBS level. Next is the third stage questionnaire to continue the validation, verification, and clarification of WBS levels 4-6 LRT Station Building Maintenance and Care Work

to experts. This questionnaire was carried out after the stage 2 questionnaire had been validated. The following is the format of the stage 3 questionnaire given for RQ 4.

Data Collection Stage 3 – WBS (Output RQ 1). The third stage of data collection is the WBS of the LRT Station building construction work based on the output in RQ 1 and secondary data in the form of Guidelines for Maintenance and Care of LRT Station Buildings in PM Perhubungan No. 32 of 2011, PM PUPR No. 10 of 2022 concerning the Implementation of Bridge and Road Tunnel Safety, Annual Railroad and Bridge Maintenance Plan Book published by PT Kereta Api Indonesia Seri Perjana in 2012. Data Collection Stage 4 – WBS Validation. At this stage, it is carried out to identify and validate WBS levels 2-6 as the standard approval of the Work Breakdown Structure (WBS) for maintenance and care work obtained from the results of the third stage of data collection.

Data Analysis Phase 3 – Validation of Maintenance WBS Standards. The third stage of data collection is the validation process for WBS level 2-4 standards with experts. At this stage, consensus is achieved to obtain WBS level 2-4 standards that have been approved by at least 3 of the 5 experts at each level of the Maintenance WBS variable decomposition. Data Analysis Phase 4 – Validation of Maintenance WBS Standards. Data analysis in the fourth stage of data collection is the process of validating WBS level 4-6 standards with experts. At this stage, consensus is achieved to obtain WBS level 4-6 standards that have been approved by at least 3 of the 5 experts at each level of the Maintenance WBS variable decomposition.

The research variables to answer RQ 3 are the independent variable (X) and the dependent variable (Y), namely the independent variable (X) is a risk consisting of four, namely workers, equipment, materials, and the environment/public, and the dependent variable (Y) is safety performance. Data Collection Stage 6 - Pilot Survey, Data Collection Stage 7 - Risk Respondent Survey, questionnaires will be distributed to a minimum of 30 potential respondents with the following criteria: Respondents have a minimum education of D3 with knowledge and education relevant to the research. Respondents have a minimum of 5 years of experience in the field of building/railway maintenance and care work.

Data Analysis Methods, data analysis stage 5 – risk validation, data analysis stage 6 – pilot survey, data analysis stage 7 – risk respondent survey. In this study, the homogeneity test used is non-parametric statistics. There are two non-parametric statistical tests, namely the Kruskal-Wallis test used in more than 2 categories and the Mann-Whitney test used in 2 categories. The data sufficiency test used is the KMO (Kaiser-Mayer-Olkin) test. The sample will be considered sufficient if the KMO value is > 0.5. In this study, the validity test was conducted using the corrected item-total correlation method. Reliability testing and qualitative risk analysis are risk prioritization processes by assessing and combine the probability and impact of each risk. The method for determining the risk factor (FR) value is by multiplying the frequency value by the impact value to obtain the risk ranking. The guidelines for risk ranking based on the probability and impact matrix are as follows.

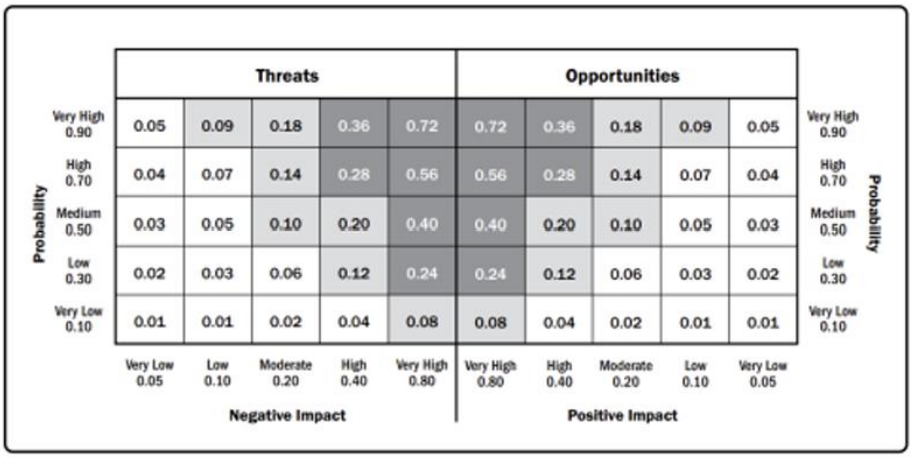


Figure 1. Probability and Impact Matrix
Source: PMBOK, 2017

Based on the matrix above, the range in risk assessment is as follows: Low risk: 0.01 – 0.05, Medium risk: 0.06 – 0.14, and High risk: 0.18 – 0.72. Data Collection Stage 9 – Validation of Causes, Impacts, Preventive Actions and Correlative Actions. At this stage, validation is carried out on the causes, impacts, preventive actions, and corrective

actions to prevent or reduce the impact of risks which are then grouped into 5 (five) categories, namely additional management, additional to other WBS elements, additional to the relevant WBS elements, additional to job requirements/RKS, and additional to the productivity coefficient, as recommendations for developing WBS standards. The expert criteria required in validation are as follows: Experts in the field of practitioners have a minimum of a Bachelor's degree with a minimum of 10 years of work experience, and professional experience in the field of planning, implementation, or maintenance and care of railway tracks and bridges for at least 5 years. Experts in the academic field have a minimum of a Master's degree and knowledge in accordance with the research theme, have a minimum of 10 years of teaching experience, and have a good reputation.

## 3 Results and Discussions

### *3.1 Data Collection Research Question 1*

*Data Collection Phase 1 – WBS Standard Archive Analysis*
The first phase of data collection was conducted through archival analysis of the Work Breakdown Structure (WBS) standard for LRT station construction. According to Yin (2018), archival analysis is a systematic data collection method for extracting information from existing documents, thus providing a deeper understanding of the research context. This method was chosen because it allows researchers to identify best practices that have been implemented in similar construction projects.

*The data sources analyzed include: Construction WBS Theory and Literature*
A literature review was conducted on theses, dissertations, and scientific journals discussing the development and implementation of WBS in building construction and transportation infrastructure projects. Primary references include the Project Management Institute (PMI) WBS standards, the Construction Industry Institute (CII) WBS development guidelines, and previous research examining WBS structures in similar large-scale projects. Through this literature analysis, researchers can understand the fundamental principles in developing a comprehensive WBS, the proper hierarchy, and the completeness of construction work elements.

*LRT Construction Project Bill of Quantities (BOQ) Document*
The BOQ data analyzed comes from Jabodebek LRT station construction projects that have been or are being executed. The BOQ is a detailed contract document containing a complete list of work along with the volume and unit price of the work. Through the analysis of the BOQ, researchers can identify: The types of work included in station construction (structural, architectural, finishing, and installation of supporting systems), Grouping of work based on work groups and types, the level of detail of the technical specifications of each work package, and Work package grouping patterns that have been applied in practice.

*Construction Project Standards and Guidelines*
The analysis was conducted on standard documents for implementing the LRT construction project, including: the project Work Plan and Conditions (RKS), the project management Standard Operating Procedures (SOP), the Execution Plan and Project Scheduling Guide, and the structural breakdown documents of similar projects that have been compiled by the relevant parties.

From the analysis of the three data sources above, an initial WBS structure can be developed consisting of four hierarchical levels: Level 1: Project Name (Jabodebek LRT Station Construction), Level 2: Work Group (large groups of work such as land preparation, structural work, architectural work, finishing work, and utility/support system installation), Level 3: Type of Work (more detailed division of each work group, for example in the structure group: foundation work, concrete structure, steel structure, etc.), and Level 4: Work Package (the most detailed work element which is the basic unit of project planning, bidding, and execution). This WBS structure is then used as a baseline for validation in the next stage to ensure completeness, accuracy, and feasibility of its implementation in the context of the Jabodebek LRT station construction project.

*Data collection stage 2 - Validation of WBS Standards Level 1 – 4*
After obtaining the initial WBS structure from the archive analysis, the next step is to validate the WBS standard that has been developed. Expert validation is a very important method in research to develop new standards or

frameworks, as explained by Goodman (1987), that expert validation ensures that research results have practical relevance, construct validity, and can be applied effectively in an industrial context.

For this validation stage, the researcher involved five (5) experts selected based on the criteria of expertise, experience, and relevance to the research topic. This expert selection follows the recommendation of Grant & Davis (1997), that a minimum of 3-10 experts is sufficient to conduct expert validation in research developing frameworks or operational standards. The five experts involved are:

Table 1
Profile of WBS Validation Experts level 1-4

| No | Expert Code | Last education | Company | Work experience | Position / Title |
|---|---|---|---|---|---|
| 1 | P1 | S2 | PT. Adhi Persada Building | 28 Years | Senior Manager Building Maintenance |
| 2 | P2 | S1 | PT. Indonesian Railways (Persero) | 17 years | Infrastructure Maintenance Manager |
| 3 | P3 | S1 | PT. Adhi Karya (Persero) Tbk | 22 years | Infrastructure Maintenance Manager |
| 4 | P4 | S1 | PT. Adhi Karya (Persero) Tbk | 15 years | LRT Project Safety Manager |
| 5 | P5 | S1 | PT. Indonesian Railways (Persero) | 15 years | LRT Facility & Asset Maintenance Manager |

Source: Author's processing, 2026

These experts were asked to provide assessments, responses, and input on the WBS structure that had been developed in stage 1, specifically regarding: Completeness of each WBS level, Accuracy of work categorization at levels 2, 3, and 4, Relevance and applicability of the WBS structure to LRT station construction practices in Indonesia, Suggestions for improvements or additions to work elements that may not have been covered, and Feasibility of the level of detail (level 4 - work packages) for use in project practice.

*Data Analysis Research Question 1*

Data Analysis Stage 1 - Expert Validation of WBS Structure Using Interview and Questionnaire Methods (Level 2 – 4)

The expert validation process in this study used a combination of semi-structured interviews and questionnaire instruments. According to Creswell (2014), the combination of qualitative (interviews) and quantitative (questionnaires) methods in the data validation process allows researchers to gain in-depth insights while also measuring the level of consensus or agreement between experts.

Table 2
Summary of Expert Input Validation for WBS Standards for LRT Station Construction Work

| WBS Level 1 | | WBS Level 2 | | WBS Level 3 | | WBS Level 4 | | Pakar | | | | | KESIMPULAN |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Kode | Nama Proyek | Kode | Rumpun Pekerjaan | Kode | Jenis Pekerjaan | Kode | Paket Pekerjaan | P1 | P2 | P3 | P4 | P5 | Ya/Tidak |
| X | Konstruksi Bangunan Stasiun LRT | 1 | Pekerjaan Persiapan | 1.1 | Mobilisasi dan Demobilisasi | 1.1.1 | Program Mobilisasi | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 1.1.2 | Program Demobilisasi | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | 1.2 | Kantor Lapangan dan Fasilitas Lainnya | 1.2.1 | Pekerjaan *Temporary Office* | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 1.2.2 | Tempat pabrikasi dan gudang penyedia jasa | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 1.2.3 | Kantor dan akomodasi untuk direksi pekerjaan | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | 1.3 | Manajemen Keselamatan Lalu Lintas | 1.3.1 | Rencana manajemen dan keselamatan lalu lintas | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 1.3.2 | Uraian perlengkapan jalan kerja sementara | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 1.3.3 | Pengalihan akses / penutupan jalur saat pekerjaan pondasi stasiun LRT | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 1.3.4 | Pemeliharaan untuk keselamatan lalu lintas | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | 1.4 | Kajian Teknis Lapangan | 1.4.1 | Pekerjaan survei lapangan untuk peninjauan rancangan | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 1.4.2 | Pekerjaan survei rutin | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 1.4.3 | Penetapan titik pengukuran / marking | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | 1.5 | Pengamanan lingkungan hidup | 1.5.1 | Pengujian lingkungan | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | 1.6 | Relokasi eksisting utilitas | 1.6.1 | Pekerjaan relokasi utilitas dan pelayanan yang ada | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| **WBS Level 1** | | **WBS Level 2** | | **WBS Level 3** | | **WBS Level 4** | | **Pakar** | | | | | **KESIMPULAN** |
| **Kode** | **Nama Proyek** | **Kode** | **Rumpun Pekerjaan** | **Kode** | **Jenis Pekerjaan** | **Kode** | **Paket Pekerjaan** | **P1** | **P2** | **P3** | **P4** | **P5** | **Ya/Tidak** |
| X | Konstruksi Bangunan Stasiun LRT | 2 | Pekerjaan Tanah | 2.1 | Land Clearing | 2.1.1 | Pembersihan dan pengupasan lahan | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 2.1.2 | Pemotongan pohon | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | 2.2 | Galian | 2.2.1 | Galian biasa | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 2.2.2 | Galian batu | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 2.2.3 | Galian perkerasan beraspal | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 2.2.4 | Galian perkerasan beton | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 2.2.5 | Galian struktur | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | 2.3 | Timbunan | 2.3.1 | Timbunan kembali | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 2.3.2 | Timbunan dari luar | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | 2.4 | Perbaikan Tanah | 2.4.1 | Pekerjaan geotekstil | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 2.4.2 | Dynamic compaction | ☒ | ☒ | ☒ | ☒ | ☒ | TIDAK |
| | | | | | | 2.4.3 | Deep soil mixing | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 2.4.4 | Bamboo Net | ☒ | ☒ | ☒ | ☒ | ☒ | TIDAK |
| | | | | | | 2.4.5 | Pile Net | ☒ | ☒ | ☒ | ☒ | ☒ | TIDAK |

| WBS Level 1 | | WBS Level 2 | | WBS Level 3 | | WBS Level 4 | | Pakar | | | | | KESIMPULAN |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Kode | Nama Proyek | Kode | Rumpun Pekerjaan | Kode | Jenis Pekerjaan | Kode | Paket Pekerjaan | P1 | P2 | P3 | P4 | P5 | Ya/Tidak |
| X | Konstruksi Bangunan Stasiun LRT | 3 | Pekerjaan Struktur | 3.1 | Struktur Bawah | 3.1.1 | Tiang Pancang beton pracetak | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 3.1.2 | Tiang Pancang baja struktur | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 3.1.3 | Tiang Bor Beton Cor | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 3.1.4 | Pondasi Sumuran | ☒ | ☒ | ☒ | ☒ | ☒ | TIDAK |
| | | | | | | 3.1.5 | Pekerjaan Pile Cap | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 3.1.6 | Pekerjaan Tie Beam | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 3.1.7 | Pekerjaan Pedestal | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | 3.2 | Struktur Atas | 3.2.1 | Pekerjaan Kolom | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 3.2.2 | Pekerjaan Balok | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 3.2.3 | Pekerjaan Pelat Lantai | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 3.2.4 | Pekerjaan Tangga Kerja | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | | Pekerjaan expansion Joint | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | | Pekerjaan parapet | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 3.2.5 | Pekerjaan Baja Atap / Crown | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 3.2.6 | Pekerjaan Shear Wall | ✓ | ✓ | ✓ | ✓ | ✓ | YA |

| WBS Level 1 | | WBS Level 2 | | WBS Level 3 | | WBS Level 4 | | Pakar | | | | | KESIMPULAN |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Kode | Nama Proyek | Kode | Rumpun Pekerjaan | Kode | Jenis Pekerjaan | Kode | Paket Pekerjaan | P1 | P2 | P3 | P4 | P5 | Ya/Tidak |
| X | Konstruksi Bangunan Stasiun LRT | 3 | Pekerjaan Struktur | 3.3 | Struktur Atap | 3.3.1 | Pekerjaan kolom atap baja | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 3.3.2 | Pekerjaan balok atap baja | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 3.3.3 | Pekerjaan rangka atap | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 3.3.4 | pekerjaan gording | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 3.3.5 | Pekerjaan bracing | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 3.3.6 | Pekerjaan pengecatan/proteksi baja | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 3.3.7 | Pekerjaan penutup atap (sandwich panel roofing) | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 3.3.8 | Pekerjaan canopy peron | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | 4 | Pekerjaan Fasilitas Penunjang Stasiun | 4.2 | Fasilitas penunjang | 4.2.1 | Loket Karcis | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | 5 | Pekerjaan Arsitektural | 5.1 | Pekerjaan plafon | 5.1.1 | Pekerjaan Plafond (finishing beton expose) | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 5.1.2 | Pekerjaan Plafond (Finishing gypsum) | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | 5.2 | Pekerjaan dinding | 5.2.1 | Pekerjaan Dinding beton ekspos | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 5.2.2 | Pekerjaan dinding bata cat interior | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 5.2.3 | Pekerjaan dinding bata keramik area basah | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | 5.3 | Pekerjaan lantai | 5.3.1 | Lantai floor hardener | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 5.3.2 | Lantai Keramik Area Kering | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 5.3.3 | Lantai Keramik Area Basah | ✓ | ✓ | ✓ | ✓ | ✓ | YA |

| WBS Level 1 | | WBS Level 2 | | WBS Level 3 | | WBS Level 4 | | Pakar | | | | | KESIMPULAN |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Kode | Nama Proyek | Kode | Rumpun Pekerjaan | Kode | Jenis Pekerjaan | Kode | Paket Pekerjaan | P1 | P2 | P3 | P4 | P5 | Ya/Tidak |
| X | Konstruksi Bangunan Stasiun LRT | 3 | Pekerjaan Struktur | 3.3 | Struktur Atap | 3.3.1 | Pekerjaan kolom atap baja | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 3.3.2 | Pekerjaan balok atap baja | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 3.3.3 | Pekerjaan rangka atap | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 3.3.4 | pekerjaan gording | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 3.3.5 | Pekerjaan bracing | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 3.3.6 | Pekerjaan pengecatan/proteksi baja | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 3.3.7 | Pekerjaan penutup atap (sandwich panel roofing) | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 3.3.8 | Pekerjaan canopy peron | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | 4 | Pekerjaan Fasilitas Penunjang Stasiun | 4.2 | Fasilitas penunjang | 4.2.1 | Loket Karcis | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | 5 | Pekerjaan Arsitektural | 5.1 | Pekerjaan plafon | 5.1.1 | Pekerjaan Plafond (finishing beton expose) | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 5.1.2 | Pekerjaan Plafond (Finishing gypsum) | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | 5.2 | Pekerjaan dinding | 5.2.1 | Pekerjaan Dinding beton ekspos | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 5.2.2 | Pekerjaan dinding bata cat interior | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 5.2.3 | Pekerjaan dinding bata keramik area basah | ✓ | ✓ | ✓ | ✓ | ✓ | YA |

| WBS Level 1 | | WBS Level 2 | | WBS Level 3 | | WBS Level 4 | | Pakar | | | | | KESIMPULAN |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Kode | Nama Proyek | Kode | Rumpun Pekerjaan | Kode | Jenis Pekerjaan | Kode | Paket Pekerjaan | P1 | P2 | P3 | P4 | P5 | Ya/Tidak |
| X | Konstruksi Bangunan Stasiun LRT | 5 | Pekerjaan Arsitektural | 5.3 | Pekerjaan lantai | 5.3.1 | Lantai floor hardener | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 5.3.2 | Lantai Keramik Area Kering | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 5.3.3 | Lantai Keramik Area Basah | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | 5.4 | Pekerjaan pintu, kusen dan jendela | 5.4.1 | Pintu Kayu | ☒ | ☒ | ☒ | ☒ | ☒ | TIDAK |
| | | | | | | 5.4.2 | Pintu Toilet | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | 5.5 | Pekerjaan Finishing Cat | 5.5.1 | Cat dinding interior | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 5.5.2 | Cat dinding exterior | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 5.5.3 | Cat Plafon | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 5.5.4 | Cat struktur baja | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 5.5.5 | Cat kolom dan balok ekspos | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 5.5.6 | Coating anti karat | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 5.5.7 | Waterproof coating | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 5.5.8 | Pengecetan railing dan handrail | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 5.5.9 | Epoxy floor coating | ✓ | ✓ | ✓ | ✓ | ✓ | YA |

| WBS Level 1 | | WBS Level 2 | | WBS Level 3 | | WBS Level 4 | | Pakar | | | | | KESIMPULAN |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Kode | Nama Proyek | Kode | Rumpun Pekerjaan | Kode | Jenis Pekerjaan | Kode | Paket Pekerjaan | P1 | P2 | P3 | P4 | P5 | Ya/Tidak |
| X | Konstruksi Bangunan Stasiun LRT | 7 | Pekerjaan Finishing dan Testing | 7.1 | Pengujian sistem struktur | 7.1.1 | Pemeriksaan visual struktur | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 7.1.2 | Uji mutu beton | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 7.1.3 | Uji sambungan baja | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 7.1.4 | Uji deformasi struktur | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 7.1.5 | Pemeriksaan alignment | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | 7.4 | Pengujian keselamatan bangunan | 7.4.1 | Simulasi evakuasi darurat | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 7.4.2 | Pengujian alarm kebakaran | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 7.4.3 | Pemeriksaan jalur evakuasi | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 7.4.4 | Pemeriksaan APAR | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 7.4.5 | Pengujian platform screen door | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | 7.5 | Pembersihan akhir bangunan | 7.5.1 | General Cleaning Area Publik | ☒ | ☒ | ☒ | ☒ | ☒ | TIDAK |
| | | | | | | 7.5.2 | Pembersihan kaca dan façade | ✓ | ✓ | ✓ | ✓ | ✓ | YA |

Source: Author's processing, 2026

*Data Analysis Phase 2 – Validation of WBS Standard Content and Construct*

After stage 1 of expert validation is completed (in the form of evaluating the general structure and providing input/recommendations for improvement), stage 2 is carried out to validate the content validity and construct validity of the revised WBS.

*Content Validity*

Content validity refers to the extent to which an instrument, or in this case, the WBS structure, can comprehensively represent the domain it is intended to measure (Polit & Beck, 2014). In the context of this study, content validity means how completely and accurately the WBS covers all elements of the LRT station construction work without missing anything.

The content validation process is carried out through:

*Systematic analysis of stage 1 results*: Researchers analyzed expert input from stage 1 to identify job elements that were suggested for addition because they were not covered, suggested for revision of categorization because they were placed incorrectly, and suggested for removal because they were irrelevant or redundant

*WBS structure improvements*: Based on the analysis above, the researcher revised the WBS structure by adding work groups, types of work, or work packages that were previously missed, revising inaccurate categorization or placement of work elements, adjusting the nomenclature/naming of work elements to be clearer and unambiguous, and ensuring there is no duplication or overlap between work elements.

*Revalidate content:* The revised WBS is returned to the experts for further verification and validation, ensuring that the revisions have accommodated their input and do not introduce new issues.

*Construct Validation*

Construct Validation refers to how well the instrument or WBS structure actually measures its intended construct (Creswell, 2014). In this context, construct Validation refers to whether the WBS hierarchy (levels 1-4) logically represents the relationships between work elements and whether this structure can be applied consistently across LRT station construction projects.

The result of the content and construct validation stage is the WBS structure that has gone through a comprehensive expert validation process, both from the content aspect and from the logic and consistency of the structure. This validated WBS is then determined to be the standard WBS for LRT station construction work that can be used as a reference in planning new LRT station construction projects, developing LRT station maintenance and care standards (as input for research question 2), and Training and capacity building for LRT station construction project teams.

Table 3
Recapitulation of Expert Input for WBS Phase 1 (RQ1)

| No. | Input | Repair |
|---|---|---|
| 1 | For the type of supporting facility work, add the railing & handrail work package and signage work. | Added railing & handrail work packages as well as signage work |
| 2 | For wall work types, ACP work packages are added. | Adding ACP work package to wall work |
| 3 | For the type of door work, an aluminum door work package is added. | Adding an aluminum door work package to the door work |
| 4 | For the architectural work group, the type of roofing work was added. | Adding roofing work types to the Architecture section |
| 5 | For the type of roofing work, the work package includes sandwich panel roof covering, roof drainage, roof maintenance access, and finishing and protection work. | Adding a work package of sandwich panel roof covering, roof drainage, roof maintenance access, and finishing and protection work on the roof work |

Source: Author's processing, 2026

The following is a more complete WBS standard table after adding input and suggestions from experts:

Table 4
Final Recapitulation of WBS Standards for LRT Station Construction Work

| WBS Level 1 | | WBS Level 2 | | WBS Level 3 | | WBS Level 4 | | Pakar | | | | | KESIMPULAN |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Kode | Nama Proyek | Kode | Rumpun Pekerjaan | Kode | Jenis Pekerjaan | Kode | Paket Pekerjaan | P1 | P2 | P3 | P4 | P5 | Ya/Tidak |
| X | Konstruksi Bangunan Stasiun LRT | 1 | Pekerjaan Persiapan | 1.1 | Mobilisasi dan Demobilisasi | 1.1.1 | Program Mobilisasi | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 1.1.2 | Program Demobilisasi | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | 1.2 | Kantor Lapangan dan Fasilitas Lainnya | 1.2.1 | Pekerjaan *Temporary Office* | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 1.2.2 | Tempat pabrikasi dan gudang penyedia jasa | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 1.2.3 | Kantor dan akomodasi untuk direksi pekerjaan | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | 1.3 | Manajemen Keselamatan Lalu Lintas | 1.3.1 | Rencana manajemen dan keselamatan lalu lintas | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 1.3.2 | Uraian perlengkapan jalan kerja sementara | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 1.3.3 | Pengalihan akses / penutupan jalur saat pekerjaan pondasi stasiun LRT | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 1.3.4 | Pemeliharaan untuk keselamatan lalu lintas | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | 1.4 | Kajian Teknis Lapangan | 1.4.1 | Pekerjaan survei lapangan untuk peninjauan rancangan | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 1.4.2 | Pekerjaan survei rutin | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 1.4.3 | Penetapan titik pengukuran / marking | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | 1.5 | Pengamanan lingkungan hidup | 1.5.1 | Pengujian lingkungan | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | 1.6 | Relokasi eksisting utilitas | 1.6.1 | Pekerjaan relokasi utilitas dan pelayanan yang ada | ✓ | ✓ | ✓ | ✓ | ✓ | YA |

| WBS Level 1 | | WBS Level 2 | | WBS Level 3 | | WBS Level 4 | | Pakar | | | | | KESIMPULAN |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Kode | Nama Proyek | Kode | Rumpun Pekerjaan | Kode | Jenis Pekerjaan | Kode | Paket Pekerjaan | P1 | P2 | P3 | P4 | P5 | Ya/Tidak |
| X | Konstruksi Bangunan Stasiun LRT | 1 | Pekerjaan Persiapan | 1.7 | Keselamatan dan Kesehatan Kerja | 1.7.1 | Sistem manajemen K3 Konstruksi | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 1.7.2 | K3 kantor lapangan dan fasilitasnya | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 1.7.3 | Manajemen Risiko | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 1.7.4 | Peralatan dan perlengkapan keselamatan kerja dan P3K | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 1.7.5 | Pengamanan lokasi proyek | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | 1.8 | Pengujian Tanah | 1.8.1 | Uji Karakteristik | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 1.8.2 | Uji Seismik | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 1.8.3 | Uji bor log | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 1.8.4 | Uji Geolistrik | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | 1.9 | Manajemen Mutu | 1.9.1 | Rencana jaminan dan pengendalian mutu proyek | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 1.9.2 | Pengendalian mutu material dan produk | ✓ | ✓ | ✓ | ✓ | ✓ | YA |

| WBS Level 1 | | WBS Level 2 | | WBS Level 3 | | WBS Level 4 | | Pakar | | | | | KESIMPULAN |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Kode | Nama Proyek | Kode | Rumpun Pekerjaan | Kode | Jenis Pekerjaan | Kode | Paket Pekerjaan | P1 | P2 | P3 | P4 | P5 | Ya/Tidak |
| X | Konstruksi Bangunan Stasiun LRT | 1 | Pekerjaan Persiapan | 1,10 | Dokumen dan Administrasi Proyek | 1.10.1 | Dokumen Kontrak | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 1.10.2 | Dokumen approval material dan bahan | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 1.10.3 | Pemeriksaan dan pengujian bahan/material | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 1.10.4 | Pembuatan laporan kemajuan dan foto-foto kemajuan pekerjaan | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 1.10.5 | Perizinan | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | 1.11 | Asuransi | 1.11.1 | Tenaga kerja | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 1.11.2 | Peralatan / material | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | 2 | Pekerjaan Tanah | 2.1 | Land Clearing | 2.1.1 | Pembersihan dan pengupasan lahan | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 2.1.2 | Pemotongan pohon | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | 2.2 | Galian | 2.2.1 | Galian biasa | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 2.2.2 | Galian batu | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 2.2.3 | Galian perkerasan beraspal | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 2.2.4 | Galian perkerasan beton | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 2.2.5 | Galian struktur | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | 2.3 | Timbunan | 2.3.1 | Timbunan kembali | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 2.3.2 | Timbunan dari luar | ✓ | ✓ | ✓ | ✓ | ✓ | YA |

| WBS Level 1 | | WBS Level 2 | | WBS Level 3 | | WBS Level 4 | | Pakar | | | | | KESIMPULAN |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Kode | Nama Proyek | Kode | Rumpun Pekerjaan | Kode | Jenis Pekerjaan | Kode | Paket Pekerjaan | P1 | P2 | P3 | P4 | P5 | Ya/Tidak |
| X | Konstruksi Bangunan Stasiun LRT | 2 | Pekerjaan Tanah | | | 2.4.1 | Pekerjaan geotekstil | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | 2.4 | Perbaikan Tanah | 2.4.2 | Dynamic compaction | ☒ | ☒ | ☒ | ☒ | ☒ | TIDAK |
| | | | | | | 2.4.3 | Deep soil mixing | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 2.4.4 | Bamboo Net | ☒ | ☒ | ☒ | ☒ | ☒ | TIDAK |
| | | | | | | 2.4.5 | Pile Net | ☒ | ☒ | ☒ | ☒ | ☒ | TIDAK |
| | | 3 | Pekerjaan Struktur | | | 3.1.1 | Tiang Pancang beton pracetak | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 3.1.2 | Tiang Pancang baja struktur | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 3.1.3 | Tiang Bor Beton Cor | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | 3.1 | Struktur Bawah | 3.1.4 | Pondasi Sumuran | ☒ | ☒ | ☒ | ☒ | ☒ | TIDAK |
| | | | | | | 3.1.5 | Pekerjaan Pile Cap | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 3.1.6 | Pekerjaan Tie Beam | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 3.1.7 | Pekerjaan Pedestal | ✓ | ✓ | ✓ | ✓ | ✓ | YA |

| WBS Level 1 | | WBS Level 2 | | WBS Level 3 | | WBS Level 4 | | Pakar | | | | | KESIMPULAN |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Kode | Nama Proyek | Kode | Rumpun Pekerjaan | Kode | Jenis Pekerjaan | Kode | Paket Pekerjaan | P1 | P2 | P3 | P4 | P5 | Ya/Tidak |
| X | Konstruksi Bangunan Stasiun LRT | 3 | Pekerjaan Struktur | | | 3.2.1 | Pekerjaan Kolom | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 3.2.2 | Pekerjaan Balok | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 3.2.3 | Pekerjaan Pelat Lantai | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | 3.2 | Struktur Atas | 3.2.4 | Pekerjaan Tangga Kerja | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 3.2.5 | **Pekerjaan expansion Joint** | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 3.2.6 | **Pekerjaan parapet** | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 3.2.5 | Pekerjaan Baja Atap / Crown | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 3.2.6 | Pekerjaan Shear Wall | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 3.3.1 | Pekerjaan kolom atap baja | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 3.3.2 | Pekerjaan balok atap baja | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 3.3.3 | Pekerjaan rangka atap | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | 3.3 | Struktur Atap | 3.3.4 | pekerjaan gording | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 3.3.5 | Pekerjaan bracing | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 3.3.6 | Pekerjaan pengecatan/proteksi baja | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 3.3.7 | Pekerjaan penutup atap (sandwich panel roofing) | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 3.3.8 | Pekerjaan canopy peron | ✓ | ✓ | ✓ | ✓ | ✓ | YA |

| WBS Level 1 | | WBS Level 2 | | WBS Level 3 | | WBS Level 4 | | Pakar | | | | | KESIMPULAN |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Kode | Nama Proyek | Kode | Rumpun Pekerjaan | Kode | Jenis Pekerjaan | Kode | Paket Pekerjaan | P1 | P2 | P3 | P4 | P5 | Ya/Tidak |
| X | Konstruksi Bangunan Stasiun LRT | 4 | Pekerjaan Fasilitas Penunjang | 4.1 | Fasilitas penunjang | 4.1.1 | Loket Karcis | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 4.1.2 | **Railing dan Handrail** | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 4.1.3 | **Signage** | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | 5 | Pekerjaan Arsitektural | 5.1 | Pekerjaan plafon | 5.1.1 | Pekerjaan Plafond (finishing beton expose) | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 5.1.2 | Pekerjaan Plafond (Finishing gypsum) | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | 5.2 | Pekerjaan dinding | 5.2.1 | Pekerjaan Dinding beton ekspos | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 5.2.2 | Pekerjaan dinding bata cat interior | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 5.2.3 | Pekerjaan dinding bata keramik area basah | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 5.2.4 | **Pekerjaan ACP** | ✓ | ✓ | ✓ | ✓ | ✓ | YA |

| WBS Level 1 | | WBS Level 2 | | WBS Level 3 | | WBS Level 4 | | Pakar | | | | | KESIMPULAN |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Kode | Nama Proyek | Kode | Rumpun Pekerjaan | Kode | Jenis Pekerjaan | Kode | Paket Pekerjaan | P1 | P2 | P3 | P4 | P5 | Ya/Tidak |
| X | Konstruksi Bangunan Stasiun LRT | 5 | Pekerjaan Arsitektural | 5.3 | Pekerjaan lantai | 5.3.1 | Lantai floor hardener | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 5.3.2 | Lantai Keramik Area Kering | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 5.3.3 | Lantai Keramik Area Basah | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | 5.4 | Pekerjaan pintu, kusen dan jendela | 5.4.1 | Pintu Kayu | ☒ | ☒ | ☒ | ☒ | ☒ | TIDAK |
| | | | | | | 5.4.2 | Pintu Toilet | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 5.4.3 | **Pintu Aluminium** | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | **5.5** | **Pekerjaan Atap** | **5.5.1** | **Penutup Atap Sandwich Panel** | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | **5.5.2** | **Drainase Atap** | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | **5.5.3** | **Akses Pemeliharaan Atap** | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | **5.5.4** | **Finishing dan Proteksi** | ✓ | ✓ | ✓ | ✓ | ✓ | YA |

| WBS Level 1 | | WBS Level 2 | | WBS Level 3 | | WBS Level 4 | | Pakar | | | | | KESIMPULAN |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Kode | Nama Proyek | Kode | Rumpun Pekerjaan | Kode | Jenis Pekerjaan | Kode | Paket Pekerjaan | P1 | P2 | P3 | P4 | P5 | Ya/Tidak |
| X | Konstruksi Bangunan Stasiun LRT | 5 | Pekerjaan Arsitektural | 5.5 | Pekerjaan Finishing Cat | 5.5.1 | Cat dinding interior | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 5.5.2 | Cat dinding exterior | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 5.5.3 | Cat Plafon | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 5.5.4 | Cat struktur baja | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 5.5.5 | Cat kolom dan balok ekspos | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 5.5.6 | Coating anti karat | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 5.5.7 | Waterproof coating | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 5.5.8 | Pengecetan railing dan handrail | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 5.5.9 | Epoxy floor coating | ✓ | ✓ | ✓ | ✓ | ✓ | YA |

| WBS Level 1 | | WBS Level 2 | | WBS Level 3 | | WBS Level 4 | | Pakar | | | | | KESIMPULAN |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Kode | Nama Proyek | Kode | Rumpun Pekerjaan | Kode | Jenis Pekerjaan | Kode | Paket Pekerjaan | P1 | P2 | P3 | P4 | P5 | Ya/Tidak |
| X | Konstruksi Bangunan Stasiun LRT | 6 | Pekerjaan Finishing dan Testing | 6.1 | Pengujian sistem struktur | 6.1.1 | Pemeriksaan visual struktur | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 6.1.2 | Uji mutu beton | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 6.1.3 | Uji sambungan baja | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 6.1.4 | Uji deformasi struktur | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 6.1.5 | Pemeriksaan alignment | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | 6.2 | Pengujian keselamatan bangunan | 6.2.1 | Simulasi evakuasi darurat | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 6.2.2 | Pengujian alarm kebakaran | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 6.2.3 | Pemeriksaan jalur evakuasi | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 6.2.4 | Pemeriksaan APAR | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | | | 6.2.5 | Pengujian platform screen door | ✓ | ✓ | ✓ | ✓ | ✓ | YA |
| | | | | 6.3 | Pembersihan akhir bangunan | 6.3.1 | General Cleaning Area Publik | ☒ | ☒ | ☒ | ☒ | ☒ | TIDAK |
| | | | | | | 6.3.2 | Pembersihan kaca dan façade | ✓ | ✓ | ✓ | ✓ | ✓ | YA |

Source: Author's processing, 2026

Based on the WBS structure validated by the five experts, the next step is to visualize the WBS structure in the form of a tree diagram. This tree diagram is a graphical representation of the Work Breakdown Structure, designed to provide a clear visual understanding of the work hierarchy from the highest to the lowest levels.

According to the PMBOK Guide (Project Management Institute, 2021), the WBS tree diagram functions to: Provide information about the overall project scope by visualizing all work elements in one integrated diagram, Facilitate communication between various project stakeholders (owner, contractor, subcontractor, consultant) by providing a mutually understood scope representation, Support planning details by showing the hierarchical relationship between high-level work and detailed-level work, Assist in the assignment of responsibilities through a clear definition of the boundaries of each work element, and The WBS tree diagram of the LRT station construction work developed in this study displays a four-level structure as follows:

LEVEL 1: JABODEBEK LRT STATION CONSTRUCTION PROJECT
└── LEVEL 2: JOB CLASSIFICATION
    ├── [Group 1: Preparation & Excavation Work]
    │   └── LEVEL 3: TYPE OF JOB
    │   ├── [Type 1.1]
    │   │   └── LEVEL 4: JOB PACKAGE
    │   │   ├── [Package 1.1.1]
    │   │   ├── [Package 1.1.2]
    │   │   └── [...]
    │   ├── [Type 1.2]
    │   │   └── [...]
    │   └── [...]
    ├── [Group 2: Structural Works]
    │   └── LEVEL 3: TYPE OF JOB
    │   ├── [Type 2.1: Foundation Work]
    │   │   └── LEVEL 4: JOB PACKAGE
    │   │   ├── [Detailed work package]
    │   │   └── [...]
    │   ├── [Type 2.2: Structural Concrete Works]
    │   │   └── [...]
    │   ├── [Type 2.3: Structural Steel Works]
    │   │   └── [...]
    │   └── [...]
    ├── [Group 3: Architectural Works]
    │   └── LEVEL 3: TYPE OF JOB
    │   ├── [Types of various architectural work]
    │   └── [...]
    ├── [Group 4: Finishing Work]
    │   └── LEVEL 3: TYPE OF JOB
    │   └── [...]
    └── [Group 5: Support System/Utility Installation]
        └── LEVEL 3: TYPE OF JOB
            └── [...]

## 4 Conclusion

The conclusions of this study were developed through a literature review and expert validation approach. The literature review was conducted to identify potential hazards and risks based on scientific references, while expert validation was carried out through interviews with professionals who have extensive experience in the maintenance and upkeep of LRT station facilities.

Risk identification was performed at WBS Level 5, namely the activity level, by categorizing risks into four aspects in accordance with the Regulation of the Minister of Public Works and Housing of the Republic of Indonesia No. 10 of 2021 concerning Guidelines for the Construction Safety Management System. These four aspects include risks related to workers, equipment, materials, and the environment/public.

Based on the results of the literature review and discussions with five experts, a total of 350 risk variables were initially identified. Subsequently, an expert validation process involving the same five experts resulted in the elimination of 73 risk variables that were considered irrelevant or insignificant to safety performance by the majority of experts. In addition, 40 new risk variables were proposed and incorporated. As a result, a final total of 317 risk variables was established and agreed upon.

A main survey was then conducted involving 35 respondents to assess the frequency and impact levels of each risk variable on safety performance. Risk analysis was carried out by measuring risk levels using frequency and impact weighting based on the PMBOK Guide, Sixth Edition.

The results of the risk assessment identified 121 high-priority risks that have the potential to significantly affect safety performance in LRT station building maintenance and upkeep activities. These risks were distributed across four major risk categories, namely worker-related risks, equipment-related risks, material-related risks, and environmental/public-related risks.

The findings indicate that worker-related risks constitute the most critical safety concerns, particularly those associated with working at heights, slips and falls during maintenance activities, and accidents occurring during the handling and installation of building components. These risks may result in severe injuries or fatalities and therefore require stringent safety controls and supervision.

Equipment-related risks were primarily associated with equipment malfunction, improper use of tools, and failures of access or lifting devices used during maintenance operations. Such incidents may lead to worker injuries, damage to facilities, and disruptions to maintenance activities. Material-related risks mainly involved the use of unsuitable materials, material deterioration, leakage recurrence, and falling objects, which may compromise both safety performance and infrastructure reliability.

In addition, environmental and public-related risks were found to have a significant impact on passenger safety and comfort. These risks include exposure to paint or welding fumes, slippery floor conditions, falling debris, operational disturbances, and other hazards that may affect station users during maintenance activities.

Overall, the results demonstrate that safety risks in LRT station maintenance activities are multidimensional and involve the interaction of human, equipment, material, and environmental factors. Therefore, effective risk mitigation strategies should be integrated into each activity within the risk-based Work Breakdown Structure (WBS) to enhance safety performance, minimize accident potential, and ensure the safe and reliable operation of LRT station infrastructure.

*Conflict of interest statement*

The authors declared that they have no competing interests.

*Statement of authorship*

The authors have a responsibility for the conception and design of the study. The authors have approved the final article.

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