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Development of WBS (Work Breakdown Structure) Standards on Risk-Based Urban Drainage Projects to Improve Implementation Time Performance

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Abstract

This study aims to develop a standard WBS (Work Breakdown Structure) for urban drainage projects and identify risk factors that affect project schedule performance. This study uses a quantitative descriptive approach involving a literature review, expert validation, a preliminary survey, a respondent survey, a risk analysis, and the Delphi method. Data collection was conducted through six stages: initial WBS expert validation, final WBS expert validation, initial risk expert validation, a preliminary survey, a respondent survey, and final risk expert validation. Respondents consisted of construction practitioners involved in urban drainage projects, while expert validation was conducted by experienced professionals in the fields of construction and project management. The results show that a standard WBS for urban drainage projects consists of six levels: project level, work group, work type, work package, work activity, and resources, including materials, equipment, and labor. Furthermore, of the 71 risk variables identified from the literature and previous studies, 61 risk variables were validated by experts as variables that impact project schedule performance. These validated risks were then integrated into the relevant WBS elements. This study is used as a guideline for project planning and control to improve schedule performance and support more effective project implementation.

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1 Introduction

The construction of urban drainage channels plays a significant role in regulating rainwater flow and minimizing the potential for flooding in urban areas. With rapid population growth and urbanization, the need for effective and efficient drainage infrastructure is increasingly pressing. However, the implementation of these projects often faces various challenges, including delays caused by inadequate planning, poor coordination, and inadequate risk identification (Siregar, 2020). Delays in construction projects can lead to various negative impacts, such as increased project costs, penalties for contractors, and environmental and social impacts on local communities due to waterlogging and flooding (Kerzner, 2017; PMI, 2021).

In managing construction projects, delays are a common issue and can impact project success. When a project experiences delays, several important steps need to be taken, such as evaluating and revising the project schedule, as well as increasing resources in the form of labor, equipment, and raw materials to expedite the construction process. Technology can also be leveraged to improve efficiency and effectiveness in project management, such as using project management software to monitor progress and quickly identify problems (PMI, 2021). One approach that can be used to improve the efficiency and effectiveness of project management is to implement a standardized Work Breakdown Structure (WBS).

The WBS is an essential tool in project management used to define and organize the total scope of a project in a structured manner (Kerzner, 2017). The WBS facilitates the breakdown of a project into smaller work units for easier control, monitoring, and the WBS also enables more efficient and effective resource allocation, improves communication between the project team and other stakeholders, and assists in the identification and assessment of risks earlier in the project. Based on guidelines from the Project Management Institute (PMI), the WBS enables project managers to monitor and control every aspect of the project more effectively, so that project risks can be better identified and managed (Hillson & Simon, 2020; Meredith & Mantel, 2011).

Urban drainage development plays a crucial role in controlling stormwater runoff and reducing the risk of flooding in densely populated areas. However, delays in urban drainage project implementation remain a common problem in various regions across Indonesia, including almost all major islands, such as Sumatra, Kalimantan, Java, Sulawesi, and Papua. Based on a construction project evaluation by Soviana et al. (2023), approximately 38% of construction projects in Indonesia experience delays due to inadequate planning, ineffective coordination between parties, and the inability to identify risks promptly. This situation indicates that most drainage projects have not implemented a comprehensive, structured project management system. Therefore, implementing a standardized WBS is crucial to minimize potential delays, optimize resource utilization, and improve overall project success.

In this study, the regional boundaries taken are the provinces of DKI Jakarta, West Java, and Banten because these regions have very dense populations (Figure 1.) and faces significant challenges in infrastructure management, particularly urban drainage systems. Urban expansion and high rates of urbanization have led to an increase in impervious areas (surfaces that cannot absorb water), such as roads and buildings, which hinder rainwater infiltration into the ground. Consequently, inadequate drainage capacity can lead to pooling and flooding, particularly in the low-lying downtown area of Jakarta, which receives runoff from upstream areas in West Java and Banten.

In addition to impacting the implementation schedule, delays in drainage projects also have economic, social, and environmental implications. Economically, delays result in project cost overruns and penalties for contractors. Socially, surrounding communities are impacted by waterlogging and traffic congestion due to construction work not being completed on time. Environmentally, suboptimal drainage conditions can worsen surface water quality and increase the risk of local flooding in densely populated areas, particularly in Jakarta, West Java, and Banten, which have high urbanization rates and limited infrastructure capacity.

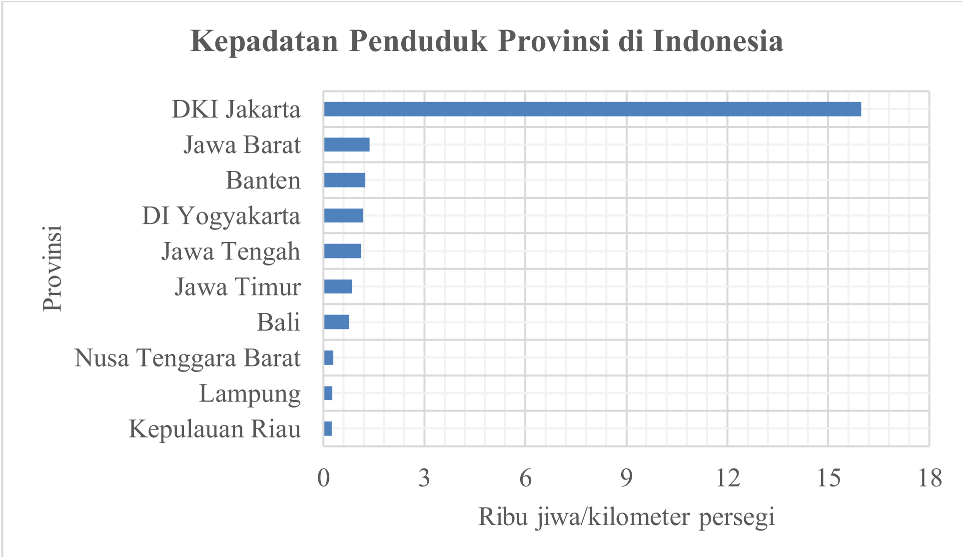

Figure 1. Population Density of Provinces in Indonesia
Source: Central Statistics Agency, 2024

This phenomenon indicates a weak planning and control structure for urban drainage projects, particularly in terms of work scope allocation and risk management. Many projects proceed without a standardized Work Breakdown Structure (WBS) as an implementation guideline, resulting in poorly documented project activities, inefficient resource allocation, and difficult comprehensive field supervision (De Bakker et al., 2010; Kerzner, 2017).

In this context, implementing a risk-based WBS is crucial for establishing a more structured, measurable, and risk-responsive project management system. This approach allows for analysis of each work element in terms of resources, activities, and work packages that could potentially impact time performance. Therefore, developing a risk-based WBS standard is expected to be a solution to address delays in urban drainage projects and improve the effectiveness of project time management.

Furthermore, no research has developed a risk-based WBS standardization for urban drainage projects. By developing a risk-based WBS standardization, it is hoped that a more efficient and effective project management system can be created, which can reduce the risk of delays and improve project implementation time performance. This WBS standardization can also serve as a guideline for practitioners and project managers in better planning and implementing urban drainage projects.

A risk-based WBS can also improve project time performance by ensuring that each work element has been thoroughly considered in the planning. With a clear and well-planned structure, each work component can be monitored and controlled more effectively, thereby reducing the possibility of errors and discrepancies in project implementation. In the long term, the implementation of risk-based WBS standardization is expected to improve the overall time performance of urban drainage projects, reduce the risk of delays, and increase the effectiveness of project management. Therefore, this study aims to develop a risk-based WBS standardization in urban drainage projects as an effort to improve the time performance of construction projects, which directly addresses the phenomenon of delays and irregularities in project management that still frequently occur in the field.

Literature Review

Understanding Drainage and Urban Drainage

The word drainage comes from the English term "drainage," which means to drain, dry, drain, dispose of, and divert water. In the context of civil engineering, drainage is generally defined as a technical measure taken to reduce excess water, whether from rainwater, seepage, or irrigation water, so that the functional condition of the land is maintained. The drainage system itself consists of a series of water constructions or structures that play a role in the flow and control of excess water, so that land use can take place optimally (Suripin, 2004). The drainage system includes a mechanism for water flow through tertiary channels that collect rainwater on the ground surface, then channel it to secondary and primary channels, which ultimately flow into rivers or the sea (Kodoatie, 2005). Based on the Regulation of the Minister of Public Works Number 12 of 2014 concerning urban drainage, an urban drainage system is a network of channels that aims to drain rainwater and prevent pooling or flooding in urban areas by channeling excess surface water to water bodies. The construction of urban drainage channels plays a significant role in regulating rainwater flow and minimizing the potential for flooding in urban areas.

Work Breakdown Structure (WBS)

The WBS is an essential tool in project management used to define and organize the total scope of a project in a structured manner (Kerzner, 2017). The WBS facilitates the breakdown of a project into smaller work units for easier control and monitoring. Furthermore, the WBS also enables more efficient and effective resource allocation, improves communication between the project team and other stakeholders, and assists in the identification and assessment of risks earlier in the project. Based on guidelines from the Project Management Institute (PMI), the WBS enables project managers to monitor and control every aspect of the project more effectively, so that project risks can be better identified and managed (Hillson & Simon, 2020; Meredith & Mantel, 2011).

Development of WBS Standards for Urban Drainage Works

The WBS development process begins with identifying the lowest-level product, the work package. The work package is then broken down into smaller components, known as activities, that represent the work effort required to complete the work package (PMI, 2017). According to Biffi (2010), a uniform master schedule can provide a consistent understanding of the project implementation strategy to all stakeholders. Meanwhile, Suanda et al. (2016) state that the WBS is a division of the work scope that breaks down work and project outcomes into smaller parts so that they become more manageable components, especially regarding cost and time. The WBS also serves as the basis for preparing the Bill of Quantities (BoQ) and the project master schedule, which serves to keep the project scope, cost, and schedule on track. In the project scheduling process (master schedule), one of the main inputs is the activity list, which is the smallest detail of the scope baseline contained in the WBS.

The Relationship between WBS and Risk Management

With rapid population growth and urbanization, the need for effective and efficient drainage infrastructure is increasingly pressing. However, the implementation of these projects often faces various challenges, including delays caused by inadequate planning, poor coordination, and inadequate risk identification (Siregar, 2020). Delays in construction projects can lead to various negative impacts, such as increased project costs, penalties for contractors, and environmental and social impacts on local communities due to waterlogging and flooding (Kerzner, 2017; PMI, 2021). Theoretically, the Work Breakdown Structure (WBS) and risk management are closely related within the project management framework. According to the Project Management Institute (PMI, 2021), the WBS is a key tool in the scope management process, defining all project work hierarchically so that it can be planned, executed, and controlled effectively. Meanwhile, according to Hillson & Simon (2020), project risk management is a systematic process for identifying, analyzing, and responding to risks that can impact project objectives, including time, cost, and quality.

Relationship of Risk-Based WBS Development to Project Time Performance

Time performance is a key indicator of construction project success, demonstrating the extent to which the project can be completed within the established schedule. According to the Project Management Institute (PMI, 2021), project time performance is measured by the accuracy of activity completion against the baseline schedule, the frequency of delays, and the effectiveness of resource utilization relative to project duration. In the context of urban drainage projects, implementation delays are often caused by irregular work scope planning and uncertain project risks that are not identified early on. Therefore, developing a risk-based Work Breakdown Structure (WBS) is a strategic approach to improving project time performance through a measurable planning structure, integrated risk management, and a systematic evaluation mechanism (Jeong & Jeong, 2021).

2 Materials and Methods

This study uses a quantitative descriptive approach involving a literature review, expert validation, a preliminary survey, a respondent survey, a risk analysis, and the Delphi method. Data collection was conducted through six stages: initial WBS expert validation, final WBS expert validation, initial risk expert validation, a preliminary survey, a respondent survey, and final risk expert validation. Respondents consisted of construction practitioners involved in urban drainage projects, while expert validation was conducted by experienced professionals in the fields of construction and project management.

The types of research data are primary data and secondary data. In this study, primary data was obtained through interviews with experts and experts to obtain responses related to research variables and through filling out questionnaires. Secondary data used include books, journals, theses, and dissertations. Both primary and secondary data used were collected through three stages, namely: data collection stage 1 - validation of the initial expert WBS, data collection stage 2 - validation of the final expert WBS, and data collection stage 3 - validation of the initial expert risk such as expert practitioners who have experience in handling urban drainage projects for at least 10 years with a bachelor's degree and a minimum of 5 years with a master's and doctoral degree and experts from the academic field with a minimum of a master's degree with teaching experience in the field of project management for at least ten years and a good reputation. Data collection stage 4 - pilot survey, and data collection stage 5 - respondent survey, namely prospective respondents have a background of knowledge and education relevant to the research, a minimum of a bachelor's degree (S1), and prospective respondents have a minimum of 3 years of work experience in the field of urban drainage projects. Data collection stage 6 – final expert risk validation, such as prospective respondents having knowledge and educational background relevant to the research topic, a minimum Bachelor's degree (S1), and prospective respondents working or having at least 3 years of work experience in the field of urban drainage projects. Quantitative risk assessment is also carried out through a series of systematically structured analysis stages, such as Homogeneity Test, Validity and Reliability Test, and data adequacy test (Kaiser-Meyer-Olkin, KMO)

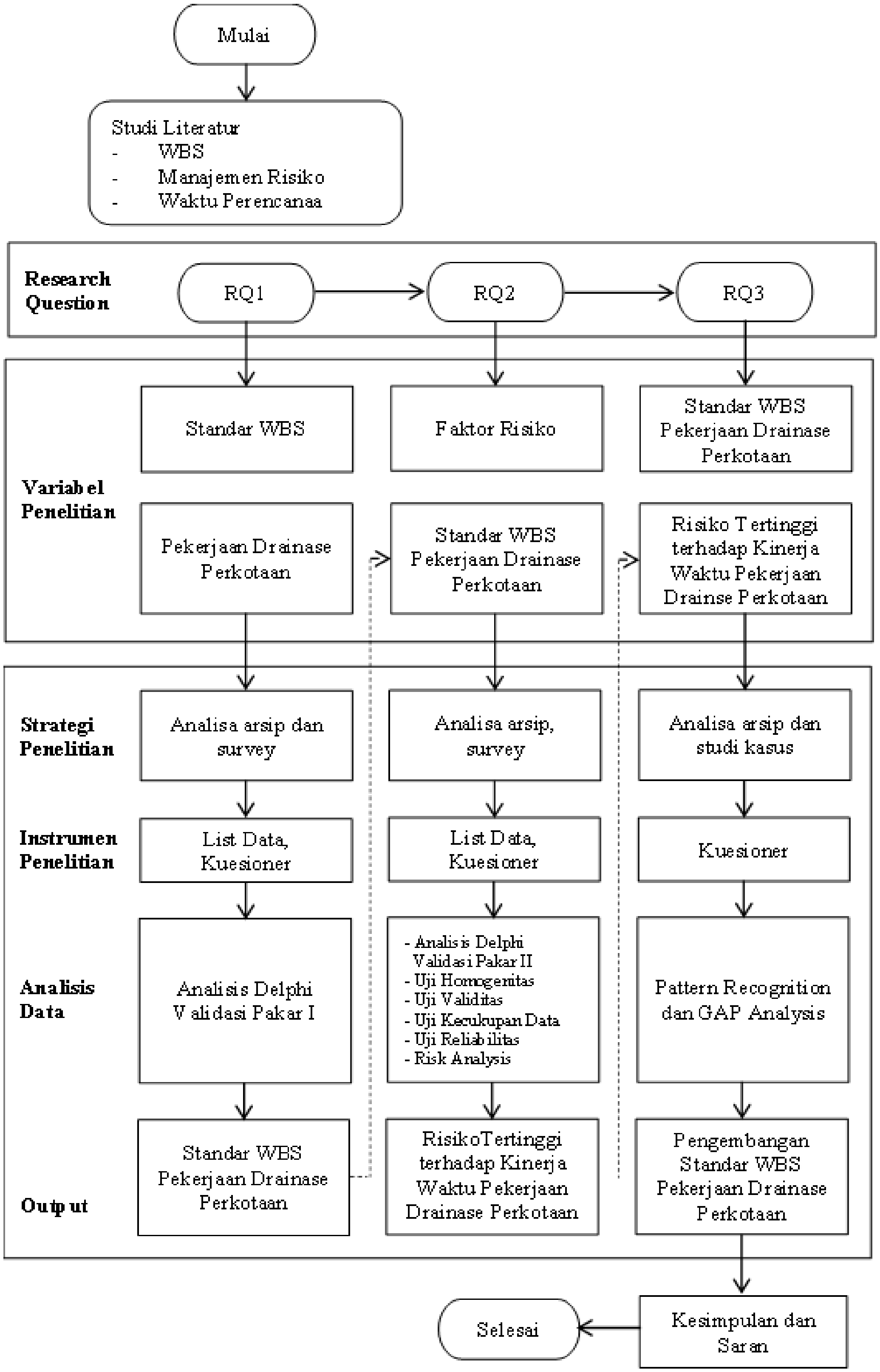

Figure 2. Research Flowchart

3 Results and Discussions

Data collection was conducted in stages in accordance with the research objectives. The first stage focused on validating the WBS structure that had been prepared based on the results of literature studies and benchmarking. The next stage was the identification and validation of risks that could potentially affect the implementation of work in each WBS element. Furthermore, an assessment of the level of risk frequency and impact was conducted to determine the dominant risks used as the basis for developing a risk-based WBS. This series of processes aimed to produce a WBS standard that not only systematically describes the work structure but also is able to accommodate risks that could potentially affect the performance of the urban drainage channel project implementation time.

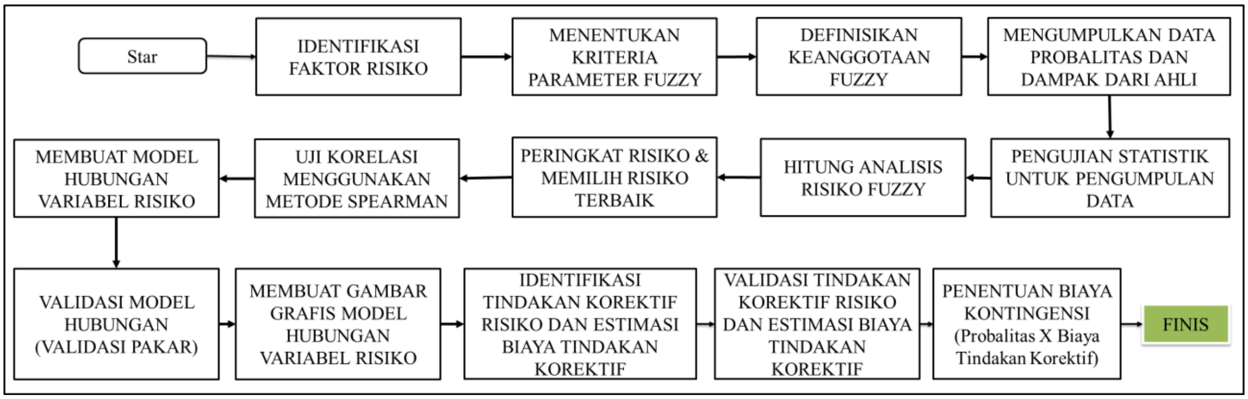

Figure 3. Flowchart for Fuzzy Analysis Application

Data Collection Stage 1 – Initial Expert WBS Validation
The first stage of data collection involved initial validation of the WBS structure, which was developed based on literature reviews, project documents, and benchmarking from relevant research and standards. This validation aimed to ensure that the developed WBS structure aligns with the work characteristics of urban drainage projects and applies to drainage infrastructure maintenance and care activities.

Table 1
Expert Profile for Data Collection Stage 1 – Initial Expert WBS Validation

No	Code	Title/Position	Last education	Length of Work Experience
1	Expert 1	Team Leader	S2	30 years
2	Expert 2	Manager	S2	18 years
3	Expert 3	Head of Drainage Development and Improvement Section, Water Resources Sub-Department	S2	16 years
4	Expert 4	Head of the PRKP Sub-Department	S2	17 years
5	Expert 5	Manager	S1	18 years

Data Collection Stage 2 – Final Expert WBS Validation
After improvements and refinements were made to the WBS structure based on the results of the first stage of validation, the second stage of data collection was carried out in the form of final expert WBS validation. This stage aims to ensure that all elements of the revised WBS are in accordance with the characteristics of the work on the urban drainage channel project and can be used as a representative WBS standard. The second stage of data collection involved the same five experts as the previous validation stage to maintain consistency of assessment and obtain agreement on the developed WBS structure. The profiles of experts involved in the final validation stage are presented in Table 2.

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Table 1
Expert Profile for Data Collection Phase 2 – Final Expert WBS Validation

No	Code	Title/Position	Last education	Length of Work Experience
1	Expert 1	Team Leader	S2	30 years
2	Expert 2	Manager	S2	18 years
3	Expert 3	Head of Drainage Development and Improvement Section, Water Resources Sub-Department	S2	16 years
4	Expert 4	Head of the PRKP Sub-Department	S2	17 years
5	Expert 5	Manager	S1	18 years

Data Collection Stage 3 - Initial Expert Risk Validation

After obtaining a validated WBS structure, the next stage was to conduct initial validation of the risk variables that could potentially affect the implementation of work on the urban drainage channel project. The risk variables in this study were obtained through literature studies, previous research results, and various references related to construction risk management, drainage work, project resources, and infrastructure work implementation. The third stage of data collection involved five experts with experience and competence in the fields of construction, project management, water resources infrastructure, and drainage operations and maintenance. The profiles of the experts involved are presented in Table 3.

Table 3
Expert Profile for Data Collection Stage 3 – Initial Expert Risk Validation

No	Code	Title/Position	Last education	Length of Work Experience
1	Expert 1	Team Leader	S2	30 years
2	Expert 2	Manager	S2	18 years
3	Expert 3	Head of Drainage Development and Improvement Section, Water Resources Sub-Department	S2	16 years
4	Expert 4	Head of the PRKP Sub-Department	S2	17 years
5	Expert 5	Manager	S1	18 years

The discussion in this chapter begins with the preparation and validation of the WBS Standard for urban drainage channel projects (RQ1), followed by the identification, analysis, and validation of dominant risks that affect project time performance (RQ2), and ends with the integration of risks into the WBS structure to produce a Risk-Based WBS Standard as a recommendation for improving project time performance (RQ3). Thus, the results of this study not only produce a standardized WBS structure but also produce the development of a WBS that is able to accommodate risk aspects from the planning stage to project implementation.

Findings and Discussion to Answer Research Question RQ1

The solution to RQ1 is carried out by identifying, compiling, and validating the Standard Work Breakdown Structure (WBS) for urban drainage projects. The WBS was compiled through a literature review of various drainage work guidelines, construction contract documents, technical specifications, and urban drainage project implementation practices commonly applied in Indonesia. WBS standardization is necessary to provide a systematic work structure, facilitate the project planning and control process, and serve as a basis for identifying risks that may affect project implementation time performance (Leony et al., 2024).

The developed WBS was then validated by experts with experience in drainage construction, project management, and infrastructure project implementation control. Based on the expert validation results, it was found that the WBS structure for urban drainage projects needs to be structured hierarchically, starting from the system level to the activity and resource levels, so that the entire scope of work can be clearly identified and measured. The structure is also considered capable of describing the relationships between tasks in more detail, so it can be used as a basis for developing a risk-based WBS (Tansar et al., 2023).

In this study, the WBS decomposition was carried out in stages starting from the project level, sub-system, work phase, work discipline, sub-work, work package, implementation method, activity, and resources. This approach was used because urban drainage channel projects have work characteristics that involve various types of construction activities, ranging from preparatory work, earthwork, channel installation, ancillary buildings, to maintenance and quality control work. Therefore, a sufficiently detailed level of decomposition is required so that each work element can be managed effectively.

In addition to serving as a project planning and control tool, the developed WBS also serves as the basis for the risk identification process in this study. Project risks are identified based on each work element contained in the WBS, allowing for more specific analysis of the relationship between the risks and the affected work. Thus, the use of a WBS allows for a systematic and comprehensive risk identification process.

Based on the results of the preparation and validation conducted, a WBS Standard for Urban Drainage Channel Projects was obtained, consisting of several levels of work decomposition. This WBS structure was then used as a basis for answering the second research question regarding the identification of risks that affect project time performance and the third research question regarding the development of a risk-based WBS.

Based on the results of expert validation, the WBS Standard for the Urban Drainage Channel Project was obtained as follows: WBS Level 1: Urban Drainage Channel Project, WBS Level 2: Sub-System, WBS Level 3: Work Phase, WBS Level 4: Work Discipline, WBS Level 5: Sub-Work, and WBS Level 6: Work Package (Implementation Method, Activities, Resources).

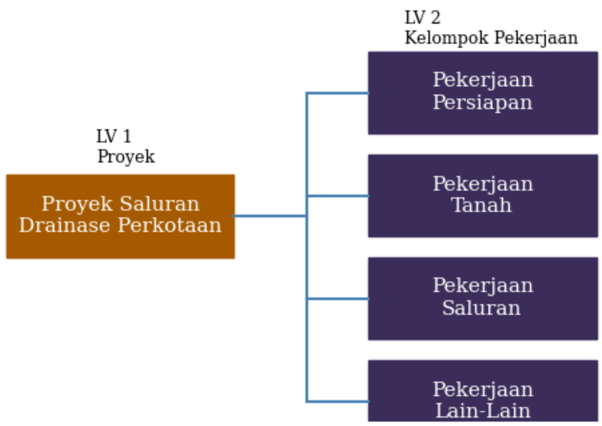

Figure 4. WBS Level 0 – 1

Based on Figure 4, the Work Breakdown Structure (WBS) of the urban drainage channel project at level 1 consists of the urban drainage channel project, while at level 2 it consists of four main work groups, namely preparatory work, earthwork, channel work, and other work. The four work groups are then decomposed into several more detailed work elements down to the activity, resource, and resource detail levels.

Considering that the WBS structure developed in this study has a fairly detailed level of decomposition up to Level 6 (resources) and Level 7 (resource details), the presentation of the entire WBS structure in Chapter V is considered less effective and has the potential to reduce the readability of the document. Therefore, the complete structure of the WBS Level 2 to Level 6 is presented in Appendix 6. The WBS structure has been validated by five experts and is used as a basis for the risk identification process and the development of a risk-based WBS in the next stage.

Findings and Discussion to Answer Research Question RQ2

The second research question (RQ2) aims to identify risk factors originating from work packages, alternative methods/designs, activities, material resources, equipment resources, labor resources, and the environment that can affect the performance of urban drainage channel project implementation time. To answer this research question, a

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risk identification process was carried out through literature studies, expert validation, questionnaire distribution to respondents, validity and reliability testing, risk level calculation, and final validation using the Delphi method. The risk identification process began with a literature review of various previous studies, construction risk management standards, and urban drainage project documents. The results of the initial identification produced a number of risk variables that were then validated by five experts with experience in the fields of drainage construction, project management, and risk management. The results of expert validation showed that all risk categories used in this study were relevant to the characteristics of urban drainage channel projects.

4 Conclusion

Data collection is the initial stage carried out to obtain information and data needed in developing a risk-based Work Breakdown Structure (WBS) standard for urban drainage channel projects. The conclusions drawn from this study aim to answer the research questions listed in Chapter 1, namely: Creating a Work Breakdown Structure (WBS) standard for urban drainage channel projects, Identifying risk factors originating from work packages, alternative methods/designs, activities, material resources, tool resources, labor resources, and the environment that can affect the performance of urban drainage channel project implementation time and Develop risk-based urban drainage project Work Breakdown Structure (WBS) standards to improve project implementation time performance. So from this study, it can be concluded that the WBS Standard for urban drainage channel projects (Appendix 6) consists of WBS Level 1: Urban Drainage Channel Project, WBS Level 2: Work groups consisting of Preparatory Work, Earthwork, Channel Work, and Miscellaneous Work, WBS Level 3: Types of work which are decompositions of each work group. In this study, there are 8 types of work in Preparatory Work, 4 types of work in Earthwork, 2 types of work in Channel Work, and 1 type of work in Miscellaneous Work. WBS Level 4: Sub-work, which is a breakdown of each type of work, WBS Level 5: Work packages, which are work units whose performance can be controlled and measured,

Future Study
As a development, further research is suggested to analyze other variables that can be integrated with field conditions, external, and technical variables as the cause of risk factors in the construction of submarine pipelines. Variables include financial risk factors and management risk factors, which influence each other and can cause cost overruns and delays in project completion.

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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