Development of Risk-Based Standarized Work Breakdown Structure (WBS) for Maintenance public Railways Infrastructure To Improve Safety Performance

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Abstract. Post-construction maintenance is important to maintain the reliability of buildings/infrastructure. In some cases, damage often occurs due to negligence in the post-construction maintenance process. This research discusses the maintenance system of railways and railway bridges, where currently the railway and railway bridge infrastructure often cannot be used properly due to negligence in the maintenance process. Maintenance that is not carried out properly will be very detrimental to many parties. The aim of this research is to improve safety performance in railways and railway bridges maintenance and care work on railway infrastructure. The case studies in this research are railways and railway bridges. The methods used in this research are literature review, case study, and survey conducted using questionnaires from several experts such as people involved in maintenance activities at PT Kereta Api (Persero), and several contractors who built the railway infrastructure and also take charge of the post-construction maintenance and care activities. The results of the research are the development of Risk-Based WBS Standards which are used to improve safety performance in railway and bridge maintenance and care work on railway infrastructure.

I. Introduction

In quite dense urban areas, appropriate public transportation is highly needed in order to sustain the economy, population mobility, and long-term development [1]. Public transportation that is very suitable in this quite dense urban area is railway infrastructure. In addition to the importance of railway infrastructure for the effective and efficient functioning of dense urban areas and commercial business areas, the funding related to the operation and transit maintenance systems is a common challenge for densely populated cities [2]. The funding is very dependent on the efficient operation and maintenance activities [2].

Public transportation is highly dependent on its function and maintenance [1]. The maintenance of a railway infrastructure is very important [3]. It needs to be done in order to get a well-functioning transportation system [3]. The maintenance work consists of a number of activities [3]. Currently in Indonesia, the maintenance and care of public railway infrastructure is carried out regularly [4]. This is done to ensure the safety and comfort of train travel because it involves a lot of parties [4]. The operational condition of public railway facilities and infrastructure must always be functionally maintained so that trains can pass [4]. Most incidents related to damage to railway infrastructure facilities are due to the lack of supervision of the maintenance and care activities. According to The Ministerial Regulation of Transportation Number 60 of 2012, railway infrastructure consisted of train tracks, train stations, and the facilities needed so that the railway facilities can be operated. A railway track is a path consisting of a series of rail tracks located on the surface, below and above the ground to direct the passage of trains.

II. Research Methods

From the operational model of research and research methodology that are used, there are 4 X variables (X1. Material Aspect K2 Risk, X2. Equipment Aspect K2 Risk, X3. Worker Aspect K2 Risk, X4. Environment/Public Aspect K2 Risk) and 1 Y variable which is construction safety performance where the X variable is interconnected to each other in order to achieve the Y variable

which is the Construction Safety Performance.

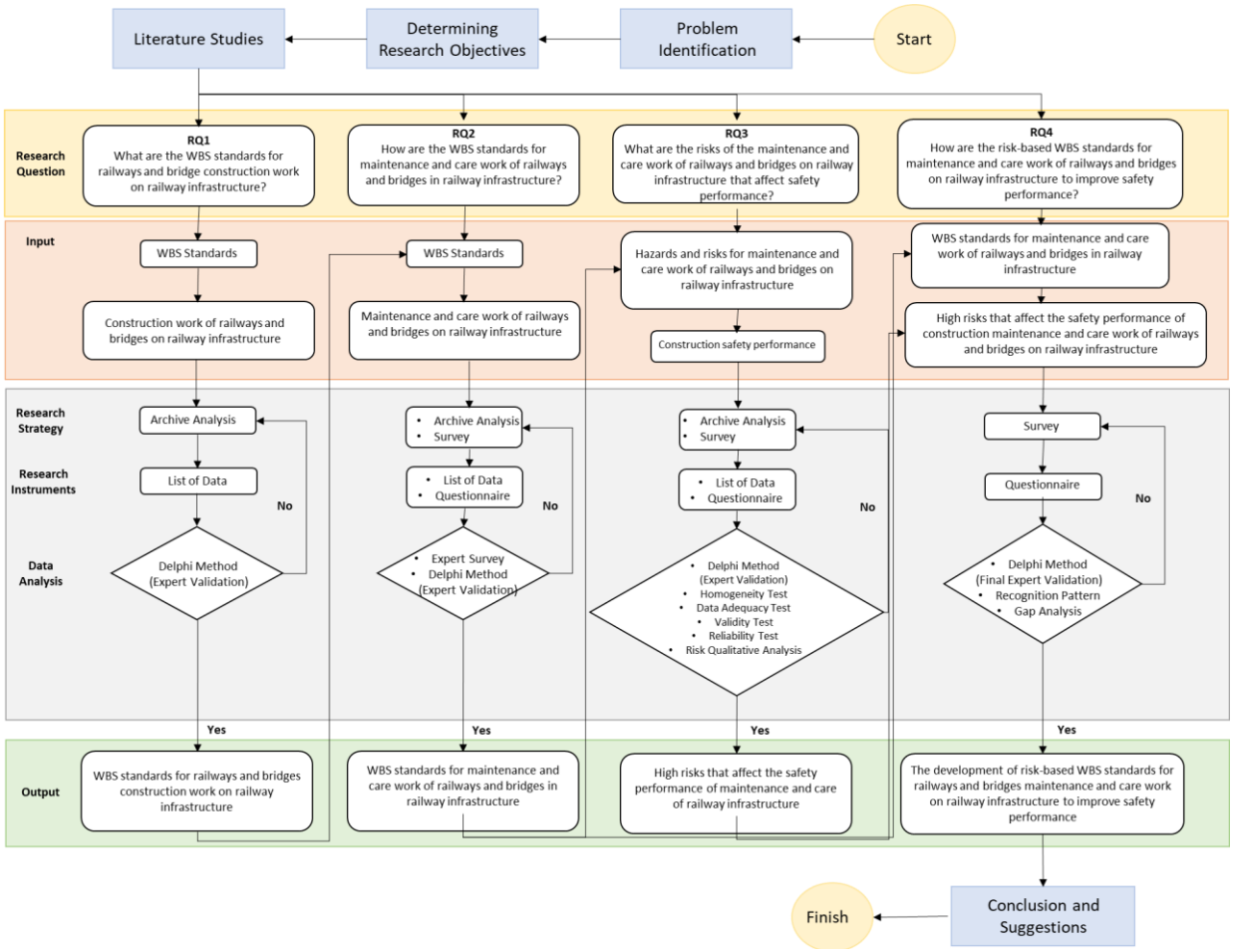
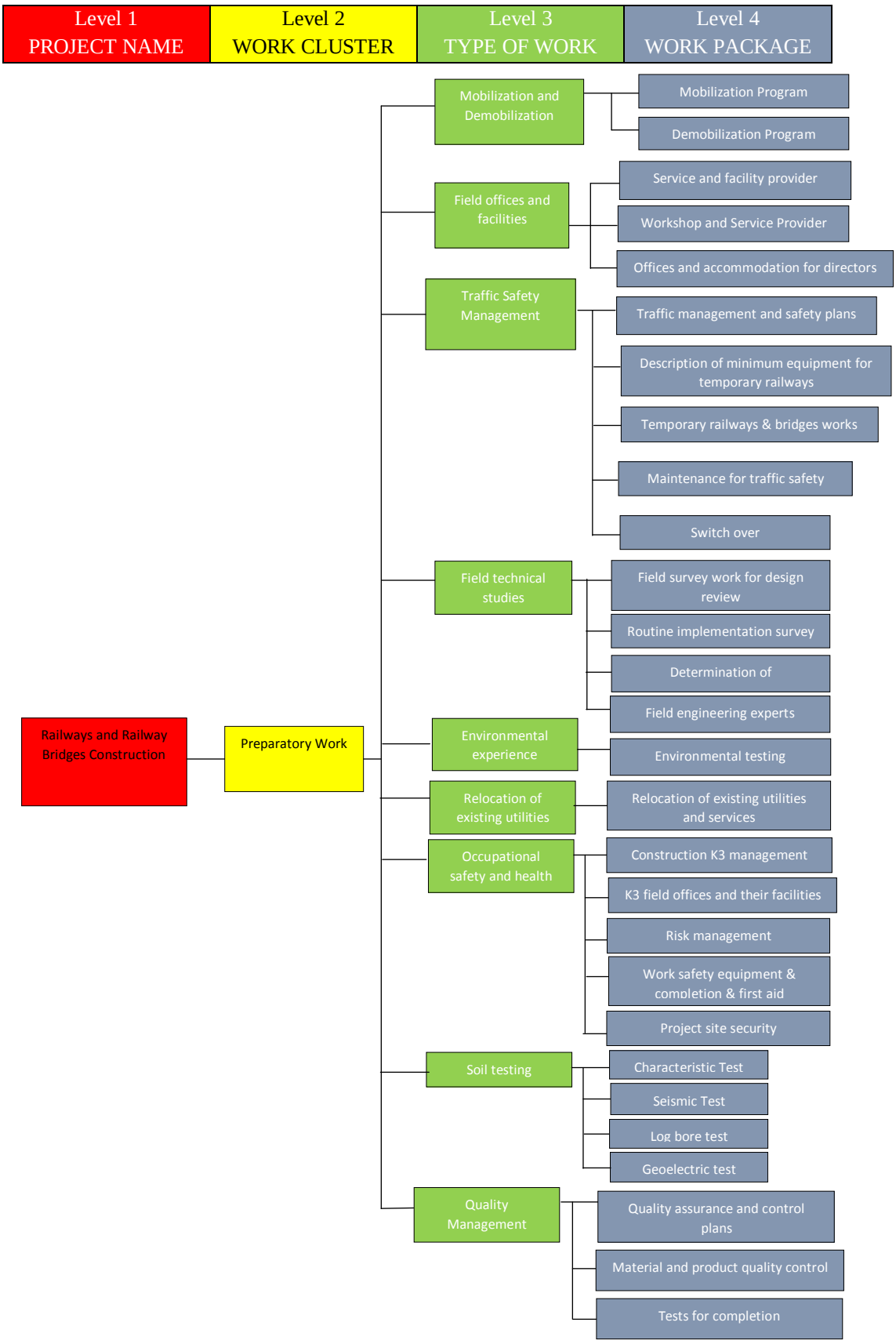


Figure 1. Research Methodology

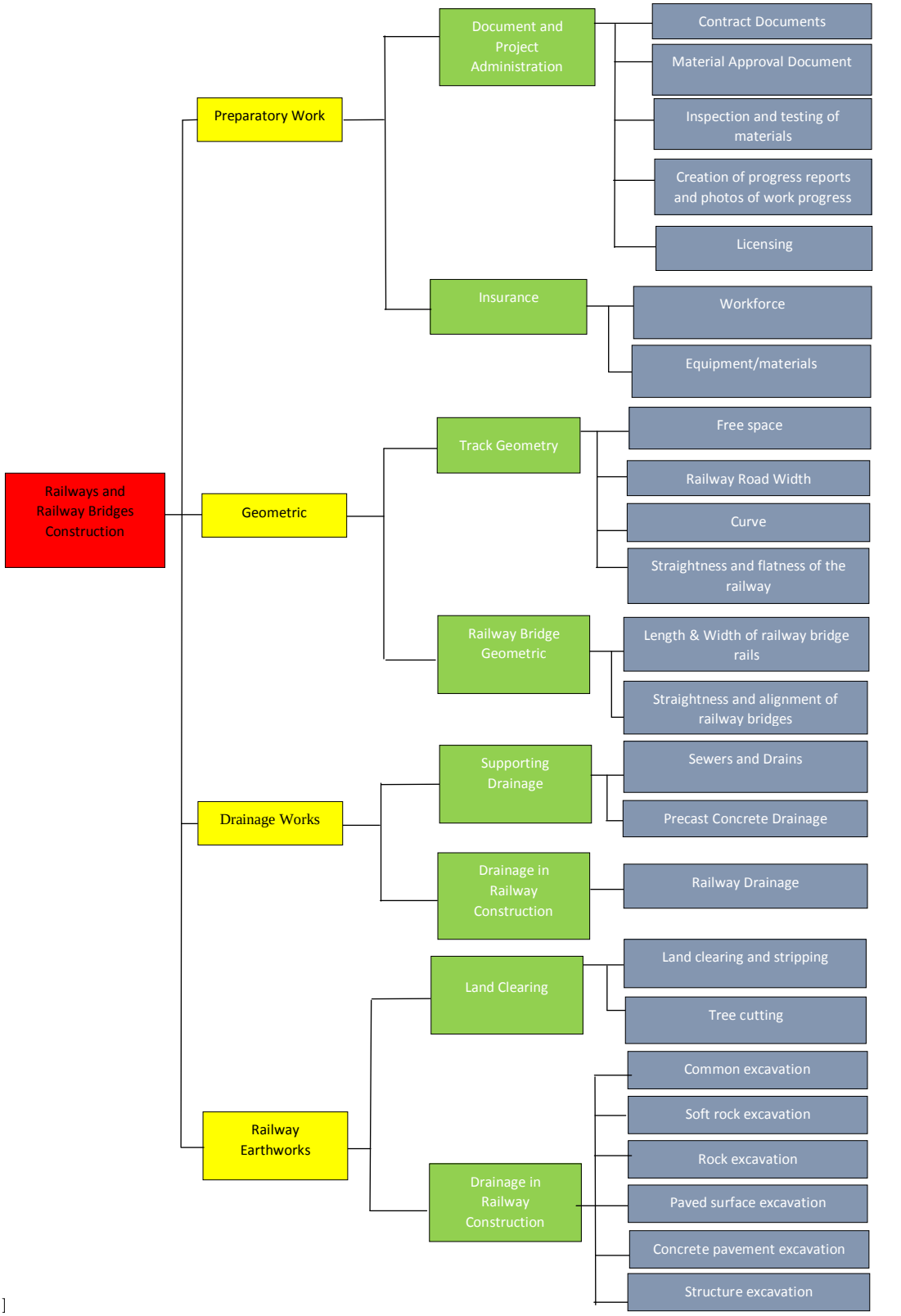
III. Research Results and Discussion

3.1 WBS Railways and Bridges Construction Works

The results of RQ1 are expert validation regarding WBS for railways and bridges construction on railway infrastructure. In the validation process for each work package, a construction category is accepted if more than 2 experts agree that this work category is required in the related work package. There were 10 work clusters, 38 types of work, and 142 work packages in the WBS for railways and railway bridges construction work.


Level 1
PROJECT NAME
Level 2
WORK CLUSTER
Level 3
TYPE OF WORK
Level 4
WORK PACKAGE
Railways and Railway Bridges Construction
Preparatory Work
Mobilization and Demobilization
Mobilization Program
Demobilization Program
Field offices and facilities
Service and facility provider
Workshop and Service Provider
Offices and accommodation for directors
Traffic Safety Management
Traffic management and safety plans
Description of minimum equipment for temporary railways
Temporary railways & bridges works
Maintenance for traffic safety
Switch over
Field technical studies
Field survey work for design review
Routine implementation survey
Determination of
Field engineering experts
Environmental experience
Environmental testing
Relocation of existing utilities
Relocation of existing utilities and services
Occupational safety and health
Construction K3 management
K3 field offices and their facilities
Risk management
Work safety equipment & completion & first aid
Project site security
Soil testing
Characteristic Test
Seismic Test
Log bore test
Geoelectric test
Quality Management
Quality assurance and control plans
Material and product quality control
Tests for completion

Level 1 PROJECT NAME	Level 2 WORK CLUSTER	Level 3 TYPE OF WORK	Level 4 WORK PACKAGE



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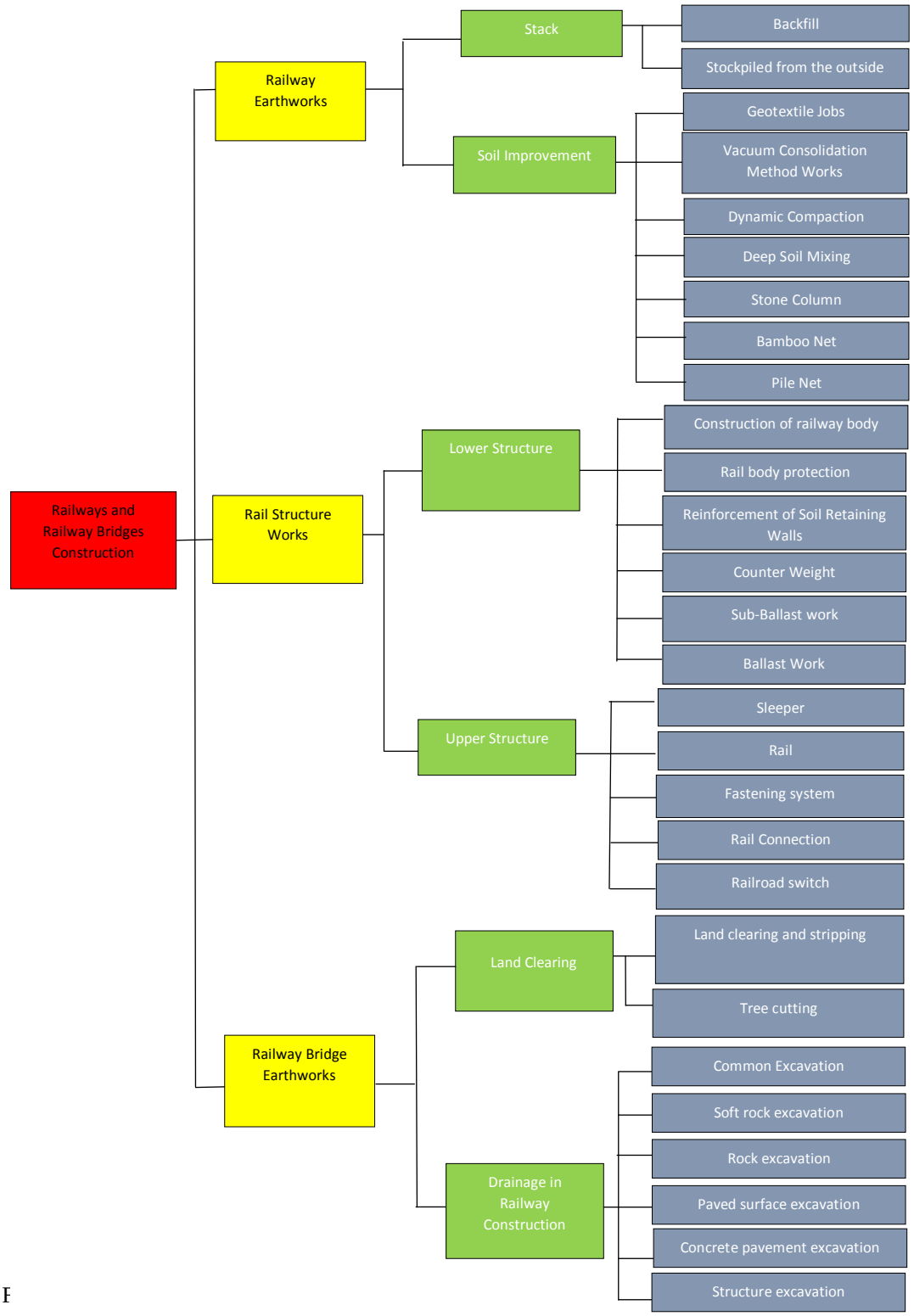
Level 1 PROJECT NAME	Level 2 WORK CLUSTER	Level 3 TYPE OF WORK	Level 4 WORK PACKAGE



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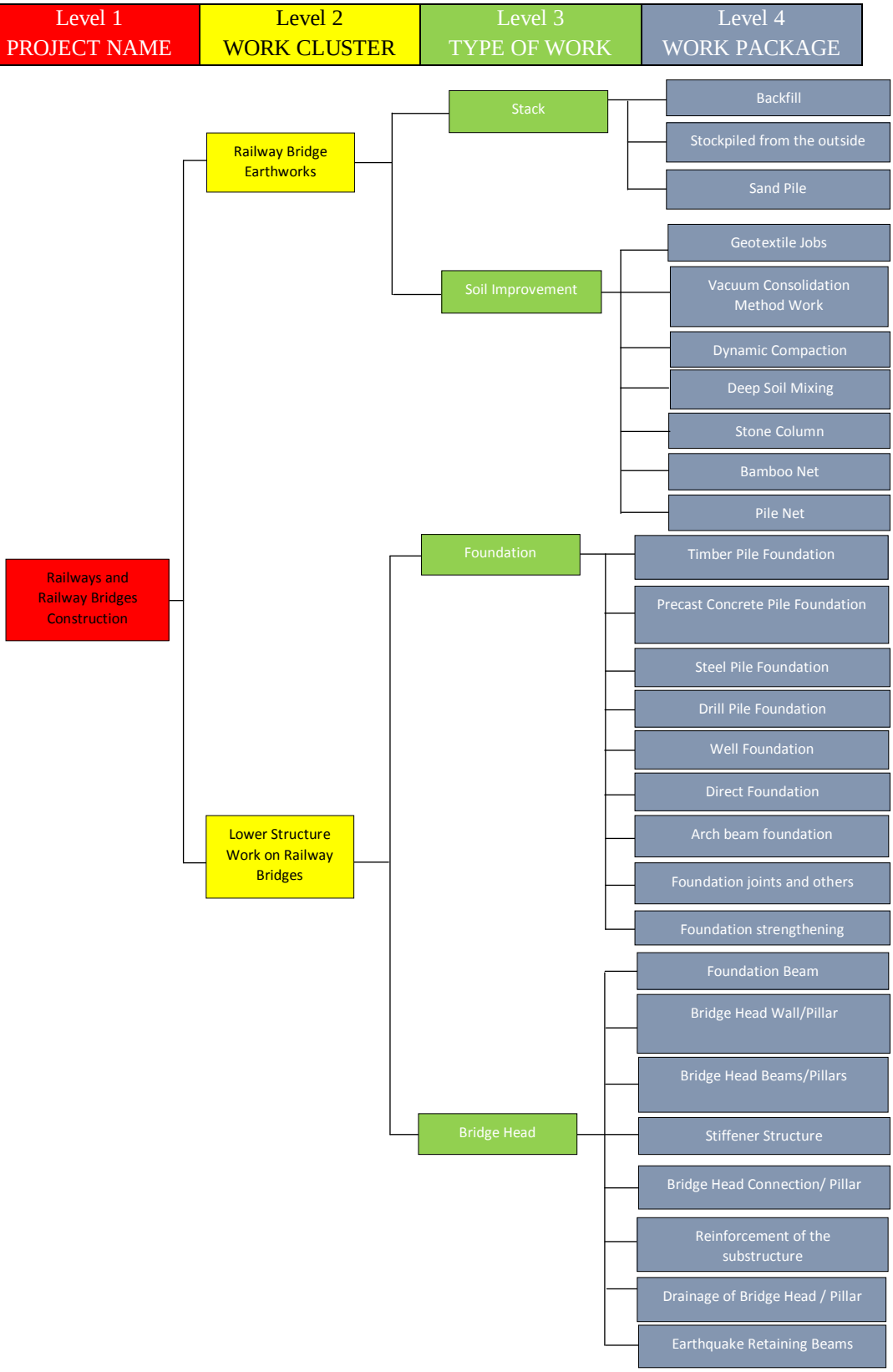

Level 1
PROJECT NAME
Level 2
WORK CLUSTER
Level 3
TYPE OF WORK
Level 4
WORK PACKAGE
Railways and Railway Bridges Construction
Railway Bridge Earthworks
Stack
Backfill
Stockpiled from the outside
Sand Pile
Soil Improvement
Geotextile Jobs
Vacuum Consolidation Method Work
Dynamic Compaction
Deep Soil Mixing
Stone Column
Bamboo Net
Pile Net
Lower Structure Work on Railway Bridges
Foundation
Timber Pile Foundation
Precast Concrete Pile Foundation
Steel Pile Foundation
Drill Pile Foundation
Well Foundation
Direct Foundation
Arch beam foundation
Foundation joints and others
Foundation strengthening
Bridge Head
Foundation Beam
Bridge Head Wall/Pillar
Bridge Head Beams/Pillars
Stiffener Structure
Bridge Head Connection/ Pillar
Reinforcement of the substructure
Drainage of Bridge Head / Pillar
Earthquake Retaining Beams

Figure4. Tree Diagram WBS for Railways & Railway Bridges Construction Works (IV)

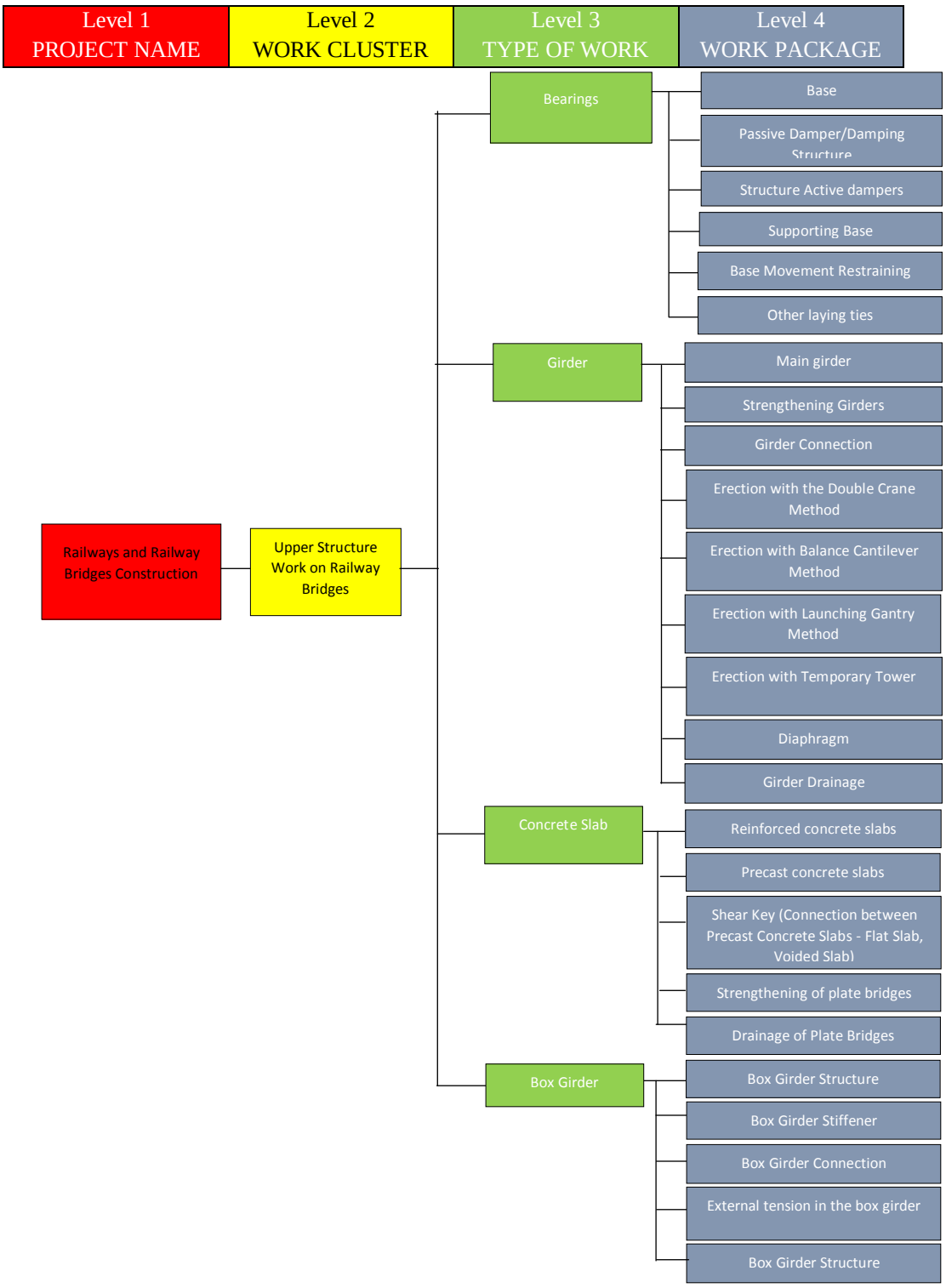


Figure 5. Tree Diagram WBS for Railways & Railway Bridges Construction Works (V)

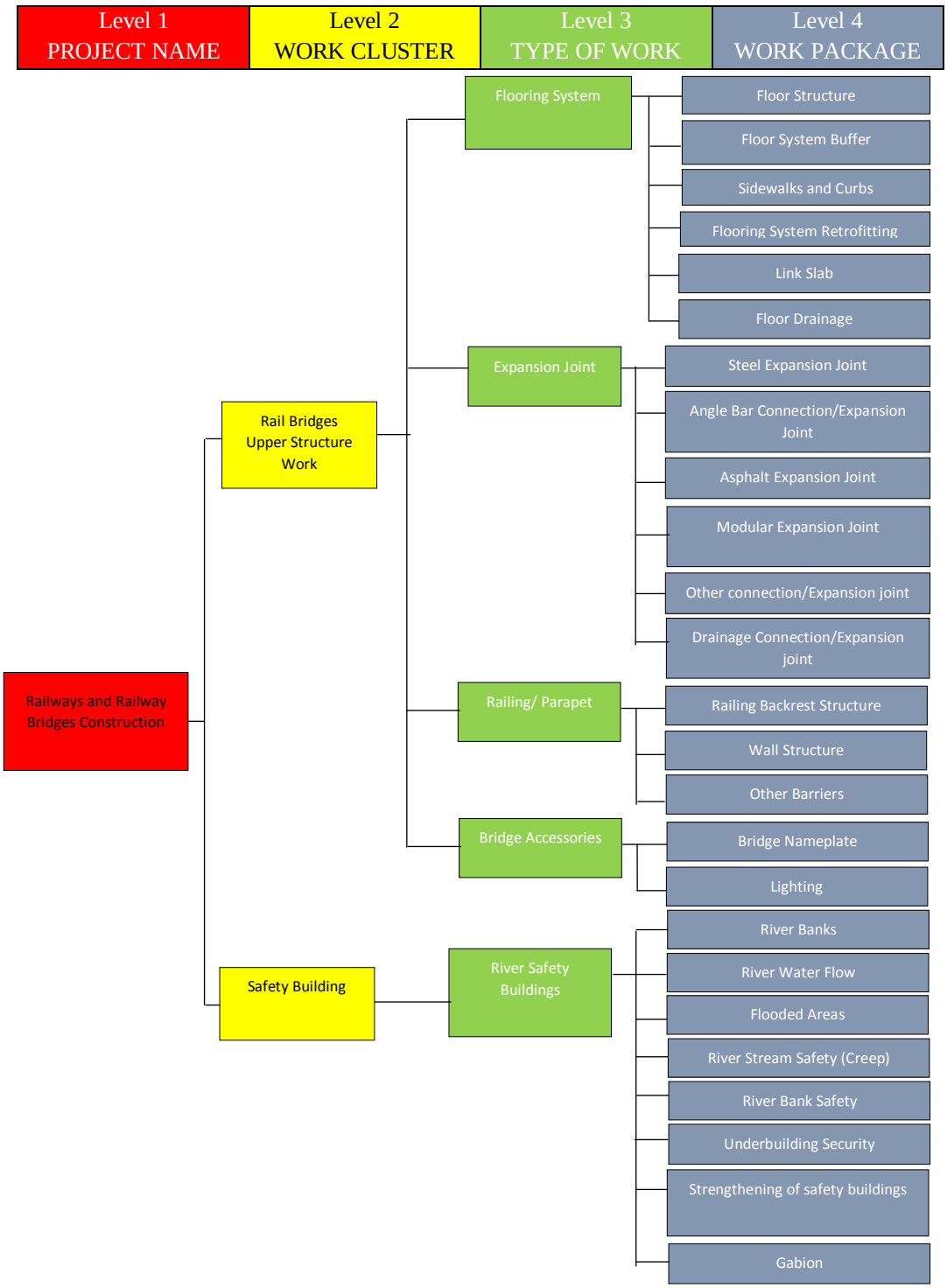

Level 1
PROJECT NAME
Level 2
WORK CLUSTER
Level 3
TYPE OF WORK
Level 4
WORK PACKAGE
Railways and Railway Bridges Construction
Rail Bridges Upper Structure Work
Safety Building
Flooring System
Expansion Joint
Railing/ Parapet
Bridge Accessories
River Safety Buildings
Floor Structure
Floor System Buffer
Sidewalks and Curbs
Flooring System Retrofitting
Link Slab
Floor Drainage
Steel Expansion Joint
Angle Bar Connection/Expansion Joint
Asphalt Expansion Joint
Modular Expansion Joint
Other connection/Expansion joint
Drainage Connection/Expansion joint
Railing Backrest Structure
Wall Structure
Other Barriers
Bridge Nameplate
Lighting
River Banks
River Water Flow
Flooded Areas
River Stream Safety (Creep)
River Bank Safety
Underbuilding Security
Strengthening of safety buildings
Gabion

Figure6. Tree Diagram WBS for Railways & Railway Bridges Construction Works (VI)

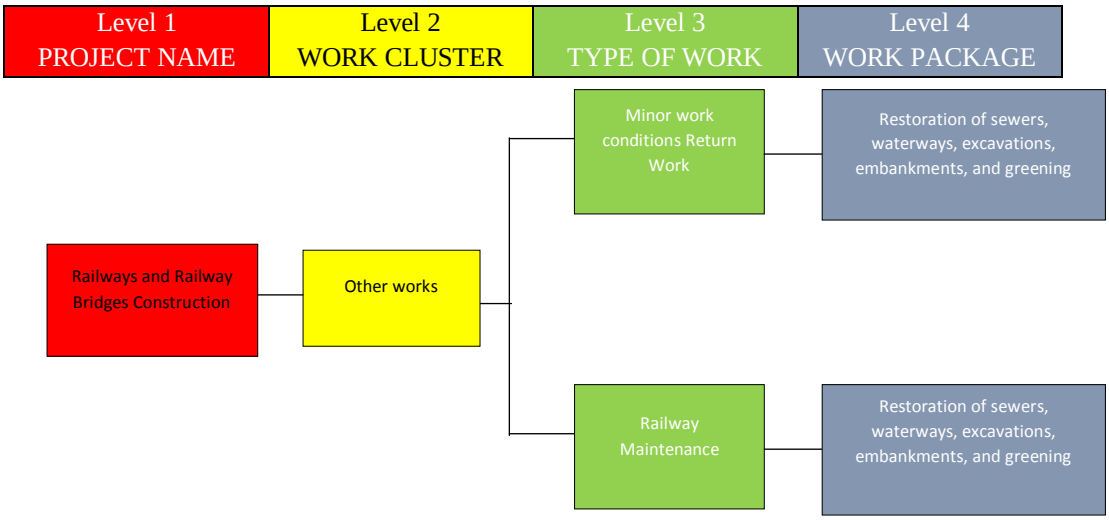
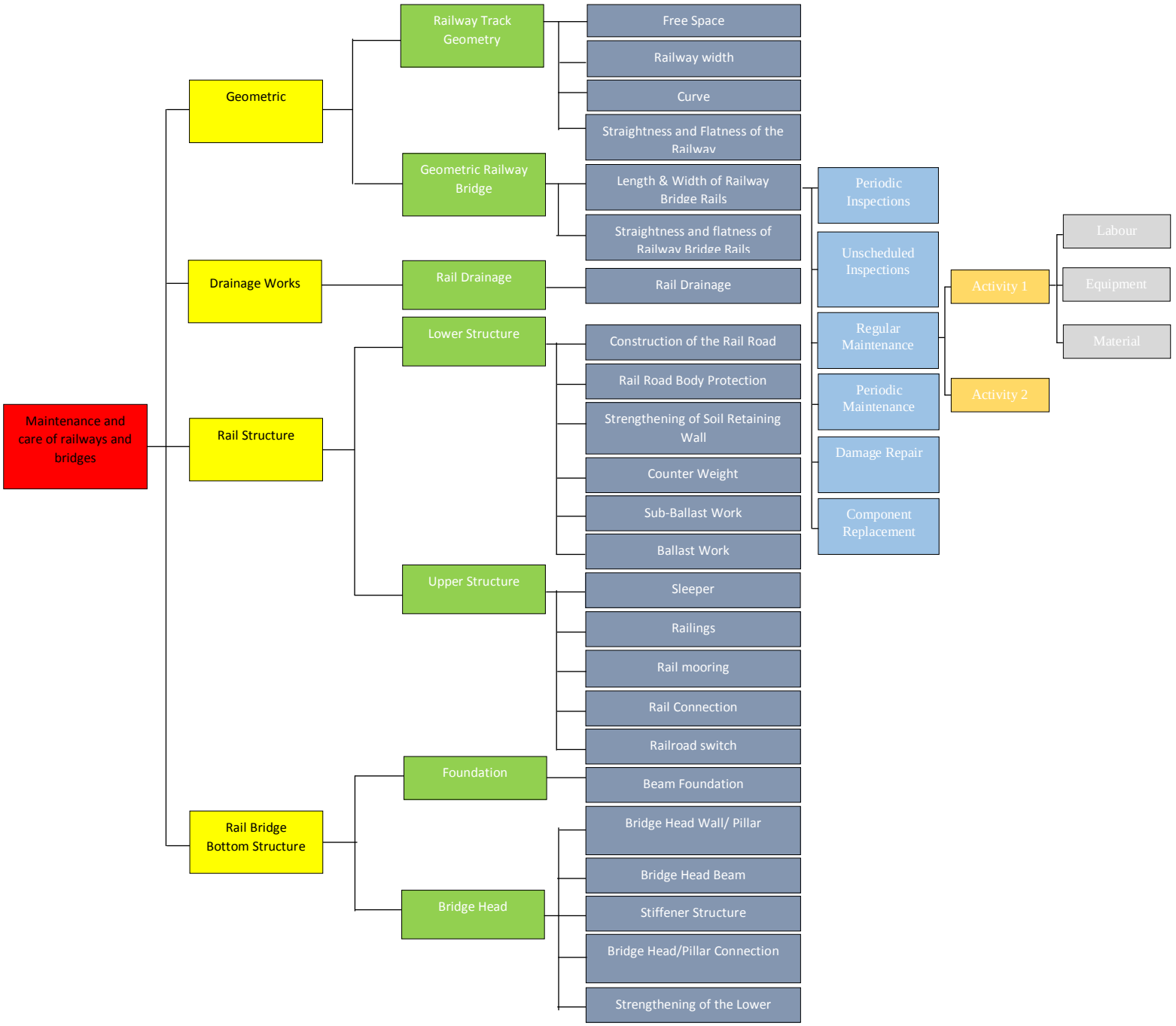


Figure 7.Tree Diagram WBS for Railways & Railway Bridges Construction Works (VII)

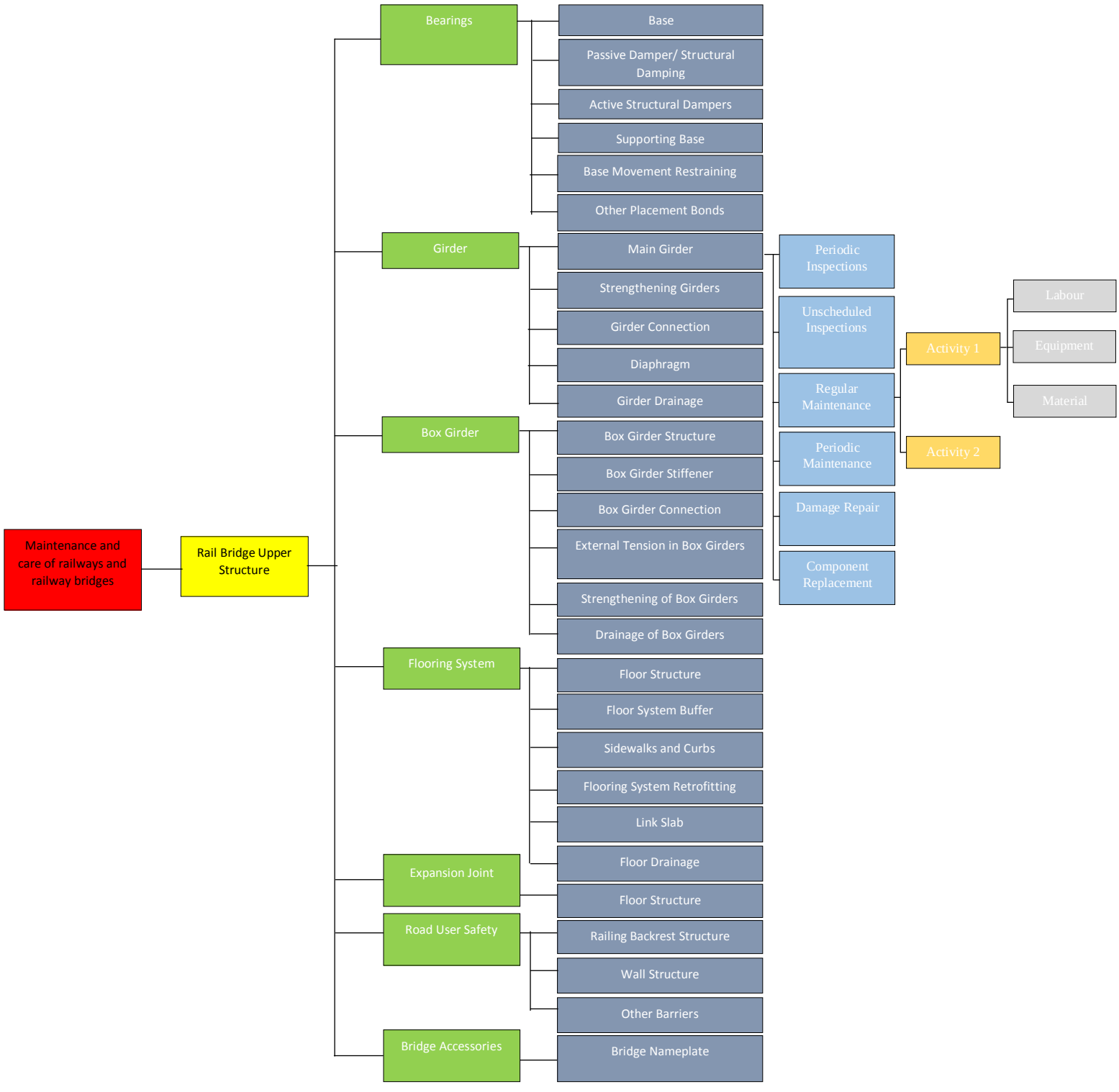
1.1. Railways and Railway Bridges Maintenance and Care Work WBS

In the RQ2 research process, the author examined maintenance and care work based on Ministerial Regulation of Transportation Number 32 of 2011 and integrating it with the WBS for Railway and Railway Bridge Construction Works. Therefore, the author carried out another expert validation of the WBS for Maintenance and Care of Railways and Railway Bridges to 5 experts to validate, and if less than 3 experts did not agree regarding the work package in the WBS, a review is conducted based on the input of the experts. Based on the results of expert validation, there are 6 work clusters, 15 types of work, 60 work packages, and 349 activities in the WBS for maintenance and care of railways and railway bridges.

Level 1 PROJECT NAME	Level 2 WORK CLUSTER	Level 3 TYPE OF WORK	Level 4 WORK PACKAGE	MAINTENANCE CATEGORY	Level 5 ACTIVITY	Level 6 RESOURCES



Level 1 PROJECT NAME	Level 2 WORK CLUSTER	Level 3 TYPE OF WORK	Level 4 WORK PACKAGE	MAINTENANCE CATEGORY	Level 5 ACTIVITY	Level 6 RESOURCES



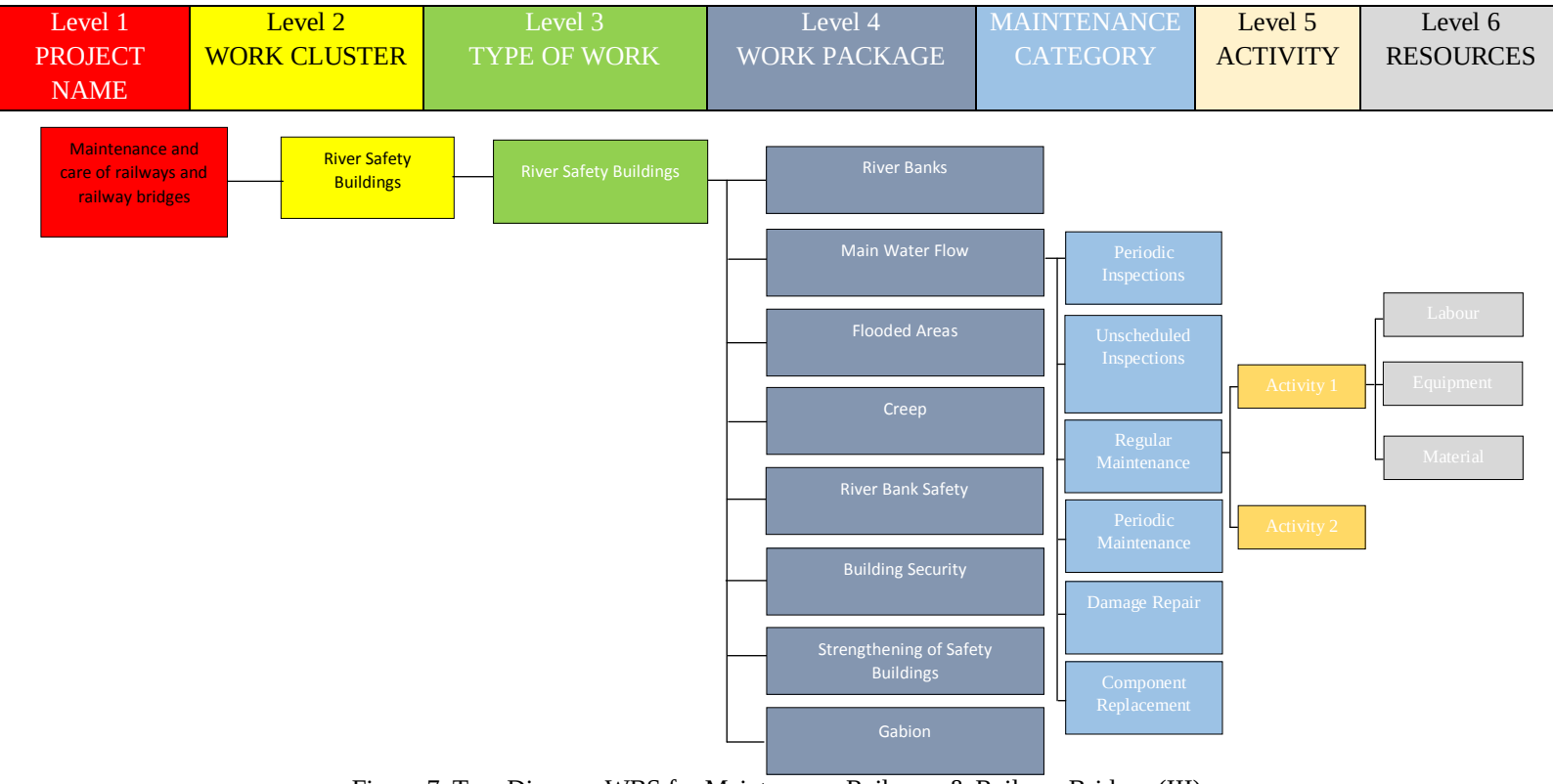


Figure 7. Tree Diagram WBS for Maintenance Railways & Railway Bridges (III)

1.2. Risks in Railways and Railway Bridges Maintenance and Care Work that Affect Performance Safety

In the RQ3 research process, the author examines the risks in maintenance and care of railways and railway bridges which affect safety performance. Therefore, the author carried out expert validation of the risks in the maintenance and care of railways and railway bridges to 5 experts to validate, and if less than 3 experts did not agree regarding the risks in the work, review is conducted based on the input of the experts. Based on the results of expert and respondent validation, 141 high risks were found in railway maintenance and care work on railways and railway bridges.

Table 1. High Risks in Railway Maintenance and Care Work on Railways and Bridges

WBS Level 4 Work Packages	Maintenance and Care Category	Hazard Types	Hazard Description	Risk Type	Risk Description
Ballast Work	Periodic Inspections & Unscheduled Inspections	Worker	Not bringing communication equipment	Worker	Get hit by a passing train

WBS Level 4 Work Packages	Maintenance and Care Category	Hazard Types	Hazard Description	Risk Type	Risk Description
	Periodic Maintenance				
	Crash Repair				
	Component Replacement				
Sleeper	Periodic Inspections & Unscheduled Inspections	Worker	Not bringing communication equipment	Worker	Get hit by a passing train
	Periodic Maintenance				
	Crash Repair				
	Component Replacement				
Rail	Periodic Inspections & Unscheduled Inspections	Worker	Not bringing communication equipment	Worker	Get hit by a passing train
	Crash Repair				
	Component Replacement				
Rail Connection	Periodic Inspections & Unscheduled Inspections	Worker	Not bringing communication equipment	Worker	Get hit by a passing train
	Crash Repair				
	Component Replacement				
Railroad Switch	Periodic Inspections & Unscheduled Inspections	Worker	Not bringing communication equipment	Worker	Get hit by a passing train
	Crash Repair				
	Component Replacement	Environment/Public	Closing of railway lines	Environment/Public	Disruption of train travel and train accidents

Based on the table above, high risks in railway maintenance and care work include a hazard description of not carrying communication equipment with the risk of being hit by a passing train, as well as a hazard description of closing railway lines with the risk of disruption to train travel and train accidents in the free space work package, railway track width, curve, straightness & flatness of railway track, length & width of rail bridge rails, straightness and flatness of the rail bridge track, rail track drainage, rail track body construction, rail track body protection, soil retaining walls, counter weight, sub-ballast work, ballast work, sleeper, rails, fastening system, rail connection, railroad switch, arch beam foundations, bridge head walls/pillars, bridge head beams/pillars, stiffening structures, bridge head/pillar connections, substructure strengthening, foundations , passivedamping/structural damping, structural active damping, base support, support for base movement, other laying ties, main girder, girder strengthening, girder connection, diaphragm, girder drainage, box girder structure, box girder stiffener, box girder connection, external prestressing in box girders, box girder reinforcement, box girder drainage, floor structures, floor system supports, sidewalks and curbs, floor system reinforcement, slab links, floor drainage, steel expansion joints, railing support structures, wall structures, other barriers, bridge nameplates, river banks, river water flows, flood inundation areas, river flow protection (creep), river bank protection, substructure protection, safety building reinforcement, and gabions.

1.3. Risk-Based WBS Standards for Maintenance and Care Work of Railways and Railway Bridges to Improve Performance Safety

In the RQ4 research process, the author examines the causes, impacts, preventive actions and corrective actions for high risks in railways and bridges maintenance and care work which affect the safety performance. Therefore, the author carried out expert validation of the causes, impacts, preventive actions and corrective actions for high risks in the maintenance and care work of railways and railway bridges to 5 experts to validate, and if less than 3 experts does not agree regarding the risks in the work, review is conducted based on the input of the experts. Based on the results of the experts validation, 5 causes, 8 impacts, 5 preventive actions and 8 corrective actions were obtained.

Table 2. Mapping of Causes, Impacts, Preventive Actions and Corrective Actions

Variable	Hazard Description	Risk Description	Reason		Preventive Action		Effect		Corrective action	
X1	Not bringing communication equipment	Get hit by a passing train	P1	*Human error* such as worker negligence	TP1	Ensure that all workers bring communication equipment before the implementation of work	D1	Workers suffered minor, moderate, & severe injuries	TK1	Rescuing and treating victims, as well recovery activity
							D2	The worker died	TK2	Replacing the workforce
			P2	Workers are not familiar/untrained in using communication equipment	TP2	Create procedures for using communication equipment	D3	Late/delayed work (reduces productivity)	TK3	Carry out an evaluation/review of the combination of the number of workers & craftsmen

Variable	Hazard Description	Risk Description	Reason		Preventive Action		Effect		Corrective action	
							D4	Supervisors have difficulty monitoring and giving instructions to workers	TK4	Provide training to workers on how to use communications equipment
			P3	Damage to communications equipment	TP3	Carry out routine maintenance of communications equipment and create maintenance and reporting procedures if damage occurs	D3	Late/delayed work (reduces productivity)	TK3	Provide extra supervision on critical work
X1	Not bringing communication equipment	Get hit by a passing train	P3	Damage to communications equipment	TP3	Carry out routine maintenance of communications equipment and create maintenance and reporting procedures if damage occurs	D4	Supervisors have difficulty monitoring and giving instructions to workers	TK4	Provide training to workers on how to use communications equipment
			P4	Limited communications equipment	TP4	Carry out inventory and procure equipment periodically according to needs	D3	Late/delayed work (reduces productivity)	TK3	Provide extra supervision on critical work
							D4	Supervisors have difficulty monitoring and giving instructions to workers	TK4	Provide training to workers on how to use communications equipment
X2	Closing of railway lines	Disruption of train travel	P5	Doing the maintenance and care work endangers train travel	TP5	Carry out maintenance &care work at night/ when the train traffic is relatively low	D5	Delay or temporary cessation of train operations	TK5	Announce the passengers quickly and clearly

Based on the preventive and corrective actions that have been analyzed previously, the risk control response will become a recommendation for developing risk-based WBS standards.

Table 3. Categories of Preventive Actions

Code	Preventive Action	Action Category	Information

		1	2	3	4	5	
TP1	Ensure that all workers bring communication equipment before the implementation of work	□			□		1. Addition to management 2. Addition to other WBS 3. Additional related to WBS elements 4. Addition to the job requirements 5. Affects the WBS coefficient
TP2	Create procedures of using the communication equipment	□	□				
TP3	Carry out routine maintenance of communications equipment and create maintenance and reporting procedures if damage occurs	□			□		
TP4	Carry out inventory and procure equipment periodically according to needs	□			□		
TP5	Carry out maintenance &care work at night/ when the train traffic is relatively low	□			□		

Table 4. The development of WBS Standards for Risk-Based Maintenance and Care of Railways and Railway Bridges

WBS Level 1		WBS Level 2		WBS Level 3		WBS Level 4		Maintenance and Care Category	WBS Level 5		WBS Level 6		Condition
Code	Project name	Code	Work Cluster	Code	Type of Work	Code	Work Packages		Code	Activity	Distribution	Resource	
	Maintenance and Care of Railways and Railway Bridges	1	Geometric	1.1	Railway Geometrics	1.1.1	Free space	Periodic Inspection	1.1.1.1	Free Space Checking	TK	Railway Infrastructure Inspection Personnel	- Ensure that all employees bring communication equipment before the implementation of work. - Carry out routine maintenance of communications equipment and create maintenance and reporting procedures if damage occurs.
											A	Meter	
												Personal protective equipment (PPE)	
												Tools for documentation	
												Communication tool	
								Routine Maintenance	1.1.1.3	General Cleaning	TK	Railway Infrastructure Inspection Personnel	- Ensure that all workers bring communication equipment before the implementation of work. - Carry out routine maintenance of communications equipment and create
												Maintenance Personnel	

Additional Activity:
Create procedures for using communication equipment

Managerials:
- Providing communication equipment based on what is needed
- Provide training to workers on how to use communications equipment
- Carry out maintenance & care work at night/ when the train traffic is relatively low
- Provide a responsive customer service team to help answer customer complaints.

											A	Cleaning Aids	maintenance and reporting procedures if damage occurs. - Carry out maintenance & care work at night/ when the train traffic is relatively low
												PPE	
												Tools for Documentation	
												Communication tool	

IV. Conclusion

The WBS for railways and railway bridges maintenance and care work consists of 6 levels, namely Level 1 (Project Name), Level 2 (Work Clusters), Level 3 (Type of Work), Level 4 (Work Package), Level 5 (Activity), and Level 6 (Material Resources, Labor, and Equipment) and Maintenance and Care Category. The maintenance and care work clusters consists of geometric, drainage work, railway structure work, lower structure work on railway bridges, upper structure work on railway bridges, and river safety buildings. High risk in railway maintenance and care work which affects performance safety includes a hazard description of not carrying communication equipment with the risk of being hit by a passing train, as well as a hazard description of closing the railway line with the risk of disrupting train travel and train accidents. The development of WBS standards is carried out through risk response analysis in the form of preventive and corrective actions. Risk responses are identified through analysis of the causes and impacts of the highest risks from the survey results of respondents. The recommendations for WBS development in terms of preventive actions can be grouped into additions to management, additions to other WBS, and additions to the job requirements.

V. Future Study

In the future, the Risk-Based WBS Development Safety is very suitable to be integrated with Building Information Modelling (BIM) as monitoring database for maintenance and care work on railway and railway bridges to facilitate railway infrastructure maintenance and care activities and reduce the risk of work accidents on maintenance and care work.

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