Work Type (WBS)	Risk Category	Risk	Risk Factor
1. Excavation (NATM tunnel)	1.1. Construction	1.1.1. Increased vertical (horizontal) strain	1.1.1.1. Heaven (Tunnel Ceiling) Deformation
			1.1.1.2. Adjacent to the crusher
			1.1.1.3. Sidewall deformation
			1.1.1.4. Excessive displacement
			1.1.1.5. Tunnel subsidence
			1.1.1.6. Excessive internal displacement
		1.1.2. Collapse (Tunnel collapse, subsidence)	1.1.2.1.Crushing zone, progressive over burrowing
			1.1.2.2. Insufficient coping with rapid changes in membrane lipids
			1.1.2.3. Unsecured bearing capacity of existing bedrock
			1.1.2.4. Unsecured safety of support materials (shotcrete, rock bolts, steel supports)
			1.1.2.5. Non-compliance with design excavation site
			1.1.2.6. Appearance of abnormal geologic zone and occurrence of water
		1.1.3. Collapse of the posterior membrane	1.1.3.1. Insufficient rear wall lock bolt and support work
		1.1.4. Economic loss due to under-excavation and over-excavation	1.1.4.1. Excessive use of explosives
			1.1.4.2. Survey error
			1.1.4.3. Failure to comply with the proper amount of gunpowder
			1.1.4.4. Non-compliance with design excavation site
			1.1.4.5. Joint, fault zone impact
		1.1.5. Cost increase due to drilling alignment error	1.1.5.1. Move the location of the survey datum point (insufficient confirmation)
		1.1.6. Economic loss due to deterioration of blasting efficiency	1.1.6.1. Insufficient coloring work, many joints and wide gaps

Work Type (WBS)	Risk Category	Risk	Risk Factor
1. Excavation (NATM tunnel)	1.2. Management	1.2.1. Damage to surrounding structures (roads, buildings, underground pipes, utility poles, etc.)	1.2.1.1. Too much charge
			1.2.1.2. Vibration value exceeded during blasting
			1.2.1.3. Inadequate investigation of underground facilities
			1.2.1.4. Excess displacement during excavation
		1.2.2. Damage to surrounding structures (roads, buildings, underground pipes, ground poles, etc.), sinkholes	1.2.2.1. Groundwater level drop
			1.2.2.2. Groundwater runoff during excavation
			1.2.2.3. Lowering of the groundwater level in urban low-depth tunnels
			1.2.2.4. Insufficient groundwater layer reinforcement, non-treatment of water during drilling
		1.2.3. Possibility of civil complaints for damage to fixed-temperature facilities such as neighboring houses and barns, delay in construction	1.2.3.1. Blasting noise and vibration effects
			1.2.3.2. Too much charge
		1.2.4. Risk of falling after excavation and before support installation	1.2.4.1. Lack of design and judgment according to rock quality (blasting pattern, reinforcement method, etc.)
			1.2.4.2. Risk of falling until the first shotcrete is poured
			1.2.4.3. Insufficient clean-up of dead ends
		1.2.5. Delayed construction period	1.2.5.1. Calculation of appropriate time considering excavation pattern and recent blasting permission time
			1.2.5.2. (Types 4 to 6 are between 7:00 and 19:00 when two blasts are performed per day, and types 1 and 3 are finished between 7:00 and 11:00 the next day when 2 blasts are performed per day. increase permit time)
			1.2.5.3. Rocky non-uniform section
			1.2.5.4. Excavation method change and rock determination
	1.3. Safety	1.3.1. Worker electric shock	1.3.1.1. Jumbo Drill Temporary Wire Leakage Current

Work Type (WBS)	Risk Category	Risk	Risk Factor
1. Excavation (NATM tunnel)	1.3. Safety	1.3.2. Worker being trapped	1.3.2.1. Charging car malfunction: unskilled operator
			1.3.2.2. Pumice stone removal
			1.3.2.3. Close-up work
			1.3.2.4. Poor visibility due to dust after blasting
		1.3.3. Occupational accidents related to workers' diseases	1.3.3.1. Poor working conditions in the pit due to gas and dust after blasting
		1.3.4. Fire	1.3.4.1. Concern about fire due to blasting during tunnel excavation
		1.3.5. Explosion	1.3.5.1. Risk of explosion from striking residual unexploded gunpowder
		1.3.6. Charging car conduction	1.3.6.1. Ground weakening (soft ground)
		1.3.7. Car overturn accident	1.3.7.1. Steep slope of sand pit material transport route
	1.4. Technology	1.4.1. Shaft collapse	1.4.1.1. Non-compliance with construction procedures such as chain block installation during sand pit lining work
2. Support treatment	2.1. Management	2.1.1. Air delay due to earthwork flow imbalance	2.1.1.1. Disruption in the selection of adjacent fill area or sand pit.
			2.1.1.2. Additional quantity due to over-excavation
			2.1.1.3. When rock filling is used, additional work types for rock filling are generated.
		2.1.2. Damaged dump truck cover and rockfall	2.1.2.1. Overloading/Unloading
		2.1.3. Dump overturning in case of prop failure	2.1.3.1. Loading box jam due to excessive load size,
			2.1.3.2. Poor ground conditions at the landing site
			2.1.3.3. Traffic damage due to speeding and overloading
	2.2. Safety	2.2.1. Safety accident	2.2.1.1. Fall due to poor loading and overloading during propulsion transportation using buckets
			2.2.1.2. Fall due to non-execution of workplace control during bucket movement and rotation using a crane
			2.2.1.3. Fire due to overheating of dump truck and loading equipment in the tunnel

Work Type (WBS)	Risk Category	Risk	Risk Factor
2. Support treatment	2.2. Safety	2.2.1. Safety accident	2.2.1.4. Fall due to wire rope breakage during lifting with a crane
			2.2.1.5. Overturning and narrowing of running vehicles due to lack of illumination and poor zoning of movement lines
			2.2.1.6. Accidents occur when moving workers with upper supports
			2.2.1.7. Equipment narrowing during loading and unloading
			2.2.1.8. Unsecured safety due to increased driver fatigue
			2.2.1.9. In the case of a railway tunnel with a small cross-sectional width, the dump truck has to come out backward when handling the support, so there is a risk of colliding and colliding with workers.
			2.2.1.10. Collision with other equipment and workers due to speeding in tunnels and construction roads
			2.2.1.11. Risk of collision and suffocation with nearby workers due to narrow space during loading work
	2.3. Construction	2.3.1. Waste environmental issues	2.3.1.1. Difficulties in securing a site for a temporary stockyard in the complex
			2.3.1.2. Mixed with shotcrete repellent material and taken out
			2.3.1.3. Shotcrete is mixed with the blasting stone during buckling, causing environmental issues.
			2.3.1.4. Noise and dust generated due to damage caused by the support vehicle
		2.3.2. Increase in economic loss and cost (division, waste disposal)	2.3.2.1. Consideration of equipment combination considering transport distance and support size
			2.3.2.2. Addition of tent installation cost for separating shotcrete classified as waste
			2.3.2.3. Excavation rock transport required
			2.3.2.4. Cycle time increase due to unsecured stocking
			2.3.2.5. Due to the shotcrete rebound, it is mixed in the holding force when excavating the lower half
			2.3.2.6. Increase in noise, vibration, and cycle time due to breakdown

Work Type (WBS)	Risk Category	Risk	Risk Factor
2. Support treatment	2.3. Construction	2.3.3. Additional yard storage permits and increased yard storage costs	2.3.3.1. In the case of a long tunnel, a separate storage yard is required
3. Formwork	3.1. Construction	3.1.1. Formwork transformation	3.1.1.1. Stress concentration on the right leg
			3.1.1.2. Formwork transverse hook not fastened
			3.1.1.3. Delayed installation of steel girders, insufficient maintenance of the arch shape due to severe irregularities in the original ground
		3.1.2. Tunnel deformation	3.1.2.1. Occurrence of the section where steel support is not installed due to excessive excavation site
		3.1.3. Lower support effect	3.1.3.1. Construction is difficult by water
			3.1.3.2. Structural instability due to poor bolting connection between upper and lower halves
		3.1.4. Decreased support effect (separation behavior)	3.1.4.1. H-beam support member shotcrete casting creates a gap on the back side
		3.1.5. Steel support beam deformation and damage	3.1.5.1. Poor support member connection
		3.1.6. Unexploded strong beam linear mismatch	3.1.6.1. Insufficient shotcrete thickness around formwork (decreased durability)
		3.1.7. Support deflection	3.1.8.1. Too much quick-setting shotcrete
			3.1.8.2. Decreased ground support capacity
	3.2. Safety	3.2.1. Formwork Falling Accident	3.2.1.1. Material lifting rope peeling off
		3.2.2. Worker safety accident	3.2.2.1. Accident caused by a worker falling while working on support installation.
			3.2.2.2. Worker collision due to fall of support material while transporting support material
		3.2.3. Strong support conduction occurs	3.2.3.1. Insufficient support and excessive weight
		3.2.4. Strong support for overturning and subsidence	3.2.4.1. Poor support
	3.3. Technology	3.3.1. Decrease in durability	3.3.1.1. Difficulty in securing internal holes and reinforcing bar coating due to support material deformation or curvature error

Work Type (WBS)	Risk Category	Risk	Risk Factor
3. Formwork	3.3. Technology	3.3.2. Strong support movement or warping occurs	3.3.2.1. Installation error occurs when tunnel auxiliary construction method (pipe loop, pore pulling) is performed in parallel
	3.4. Design	3.4.1. Delay due to scope change	3.4.1.1. Produce new types when changing types according to cancer determination during excavation
		3.4.2. Sunk costs incurred	3.4.2.1. Pre-prepared materials are not required when changing the type due to cancer determination during excavation
		3.4.3. Suspension of construction due to the need for reinforced steel support	3.4.3.1. Discrepancy between design and actual ground condition
4. Shotcrete Work	4.1. Construction	4.1.1. Arch formation difficulty	4.1.1.1. Long pouring time
		4.1.2. Cost increase due to excessive use of shotcrete material	4.1.2.1. Occurrence of over burrow
		4.1.3. Insufficient secondary support	4.1.3.1. Over-pouring of shotcrete
		4.1.4. Defective shotcrete attachment	4.1.4.1. Increased thickness of the first layer of casted shotcrete due to the presence of foreign matter on the surface.
			4.1.4.2. Insufficient cleaning of the pouring surface before construction (failure to remove floating stones and pumice stones, etc.).
		4.1.5. Collapse	4.1.5.1. Shotcrete pouring delay
		4.1.6. Environmental problems	4.1.6.1. Insufficient rebound material treatment
			4.1.6.2. Environmental problems arise due to the inability to separate waste from shotcrete sealing
	4.2. Safety	4.2.1. Occupational accidents of workers	4.2.1.1. Dust penetration into the human body
			4.2.1.2. Overloaded connections due to clogged shotcrete nozzles
	4.3. Technology	4.3.1. Defective shotcrete attachment	4.3.1.1. Lack of steel fiber content and length
			4.3.1.2. Failure to establish appropriate drainage measures for the water-generating section
			4.3.1.3. Poor quality of quick payment

Work Type (WBS)	Risk Category	Risk	Risk Factor
4. Shotcrete Work	4.3. Technology	4.3.2. Insufficient shotcrete strength.	4.3.2.1. Poor aggregate granularity.
		4.3.3. Increased shotcrete disposal cost.	4.3.3.1. Increased rebound.
			4.3.3.2. Defective shotcrete material (sand with a lot of soil, problems with quick fixing, etc.).
			4.3.3.3. Non-compliance with shotcrete placement angle.
5. Rock bolt	5.1. Construction	5.1.1. Rock bolt installation is not possible.	5.1.1.1. Excessive outflow of groundwater.
			5.1.1.2. Collapse of the drilled holes in poor ground.
		5.1.2. Fastening loosening due to excessive stress caused by blasting vibration, etc.	5.1.2.1. Fastening with a force exceeding the yield strength.
		5.1.3. Lower support effect	5.1.3.1. Flowing down of the fixing material from the ceiling rock bolt
			5.1.3.2. Insufficient rock bolt preload due to blasting without sufficient curing time for rock bolt grouting.
		5.1.4. Increase in construction cost	5.1.4.1. Excessive injection of mortar in cracks.
		5.1.5. Lack of support	5.1.5.1. Poor construction
	5.2. Management	5.2.1. Damaged waterproof sheet	5.2.1.1. Damage to waterproofing sheets due to failure to remove wire for construction verification
	5.3. Safety	5.3.1. Worker constriction, collision, accident, damage	5.3.1.1. Falling to the rock bolt workbench with overloaded material
			5.3.1.2. Falling rock bolt lifting due to poor lifting equipment and work practices.
			5.3.1.3. Worker struck due to insufficient mounting during rock bolt withdrawal test.
			5.3.1.4 Falling of rock bolts due to self-weight when installing rock bolts and collision with workers below.
			5.3.1.5. Fall due to self-weight, fear of collision with lower workers
			5.3.1.6. Risk of falling workers by opening the charging car door when loading lock bolts in the charging car.

Work Type (WBS)	Risk Category	Risk	Risk Factor
5. Rock bolt	5.3. Safety	5.3.1. Worker constriction, collision, accident, damage	5.3.1.7. Construction of rock bolts at one time after excavating two layers to reduce construction time and risk of falling down.
		5.3.2. Safety accident	5.3.2.1. Injuries during rock bolt insertion and grouting work
			5.3.2.2. Falling when inserting and grouting rock bolts at the top end
			5.3.2.3. Safety accidents due to plastic fragments when using resin
			5.3.2.4. Safety accident risk due to selection of rock bolt filling material.
			5.3.2.5. Difficulty in constructing rock bolts due to difficulty in constructing the design length
	5.4. Technology	5.4.1. Reduced rock bolt effect	5.4.1.1. Failure to consider the joint direction and insufficient adhesion to the pressure plate shotcrete surface.
		5.4.2. Poor installation of rock bolt	5.4.2.1. Fixing material dripping
			5.4.2.2. Difficulty in verifying settlement
			5.4.2.3. Number of drilled holes.
		5.4.3. Mortar quantity increase	5.4.3.1. Excessive joints
			5.4.3.2. Fault zone emergence
			5.4.3.3. Groundwater seepage
		5.4.4. Lack of support	5.4.4.1. Insufficient rock bolt length, off-specification
6. Lining	6.1. Construction	6.1.1. Occurrence of cracks in the ceiling	6.1.1.1. Difficulty in injecting ready-mixed concrete at the top end
			6.1.1.2. Difficulty compacting concrete
			6.1.1.3. Poor mix
			6.1.1.4. Underground water occurs due to damage to the waterproofing membrane

Work Type (WBS)	Risk Category	Risk	Risk Factor
6. Lining	6.1. Construction	6.1.2. Leak	6.1.2.1. Underground water leakage due to water pressure in the lining due to damage to the waterproof membrane
			6.1.2.2. Split casting of joint wall
			6.1.2.3. Damage to the waterproof membrane when assembling rebar
			6.1.2.4. Poor construction of water stop plate.
		6.1.3. Longitudinal cracks, lining cracks, and breakage at the ceiling.	6.1.3.1. Lining back settlement.
			6.1.3.2. Long-term hydraulic load on the lining due to poor water pressure relief in the drainage tunnel.
			6.1.3.3. Cracks in mass concrete in cross-sectional tunnel section
			6.1.3.4. Reconstruction due to poor interface in subsequent processes (railway system, road disaster prevention).
			6.1.3.5. Shrinkage and non-compliance with installation spacing and depth of construction joints.
			6.1.3.6. Construction after convergence of main beam displacement.
			6.1.3.7. Insufficient vibration during casting and cold joint with insufficient spacing.
			6.1.3.8. Water pressure is generated in the lining.
		6.1.4. Additional cost incurred	6.1.4.1. Expenses incurred due to the use of vertical car lift and movement within the tunnel (mixer truck transport).
			6.1.4.2. Transportation costs cannot be applied when contracting for materials to be paid (mixer truck transportation)
			6.1.4.3. Surface replacement after construction of lead haunch section.
			6.1.4.4. Defects in the finished surface of the connection due to separate casting of the lining lead haunch area.
			6.1.4.5. Surface replacement costs due to defective lining surface and damage to lining foam.
		6.1.5. Elution water generation	6.1.5.1. Excessive water generation
			6.1.5.2. Problems with concrete adhesion, strength, and thickness.

Work Type (WBS)	Risk Category	Risk	Risk Factor
6. Lining	6.2. Safety	6.2.1. Occurrence of accidents, worker entrapment, and collision	6.2.1.1. Fall during setting work at the top of the form for lining casting work
			6.2.1.2. Risk of falling during work such as welding the top of the lining
			6.2.1.3. Falling during movement for assembling the outer foam of the opening lining
			6.2.1.4. Fall due to failure to install handrails on top of rebar between rebar sections.
			6.2.1.5. Falls while installing a workbench due to workers not wearing safety belts.
			6.2.1.6. Falls during work due to failure to install safety railings at the end of the rebar workbench
			6.2.1.7. Falling while going up and down the rebar workbench without lifting facilities
			6.2.1.8. Fall in the construction of each piece of lining foam.
			6.2.1.9. Fall material between the footplates inside the fall truck and the worker fell through the central passageway
			6.2.1.10. Rebar falling while being hoisted due to rebar hoist rope breakage.
			6.2.1.11. Collision and fall due to vibration of rebar during lifting work with 1 rope hanger
			6.2.1.12. Collision with a forklift moving backwards due to the lack of a warning light on the rear of the forklift
			6.2.1.13. During the lifting of the rebar, the rope fell off due to a release device not being installed on the hook, causing the rebar to fall.
			6.2.1.14. Electric shock while cutting and bending rebar with a rebar processor
			6.2.1.15. Neck and back pain caused by working toward the ceiling (musculoskeletal disease).
			6.2.1.16. Collapse during installation and dismantling of the rebar workbench due to unskilled work procedures.

Work Type (WBS)	Risk Category	Risk	Risk Factor
6. Lining	6.2. Safety	6.2.1. Occurrence of accidents, worker entrapment, and collision	6.2.1.17. Fall due to excessive gap between the truck work platform and the tunnel wall.
			6.2.1.18. Bronchial damage caused by flying dust during lining foam sanding work.
			6.2.1.19. Overturn/collapse due to the use of unsuitable materials in place of rebar.
			6.2.1.20.Workers fall and slip due to poor material arrangement of lining foam stairs and work scaffolding.
			6.2.1.21. Electric shock and fire during lining foam welding and fusing work.
			6.2.1.22. Danger due to fire and lack of oxygen during curing using a hot air fan in winter
			6.2.1.23. Nearby workers stabbed by rebar during rebar placement
			6.2.1.24. Optic nerve damage as rebar powder gets into the eye while assembling rebar toward the ceiling
			6.2.1.25. In an inclined shaft, a steel workbench rolls on a slope and collapses due to external collision.
			6.2.1.26. Traffic jam accident due to failure to place a signalman and failure to install a vehicle stopper while the concrete mixer truck is reversing
			6.2.1.27. Fall accident due to failure to install inspection window opening cover during lining placement
			6.2.1.28. Workers are trapped due to malfunction due to foot switch cover not being installed during cutting work for rebar assembly
			6.2.1.29. Constriction accident due to insufficient fixation of the rebar between the slope section
			6.2.1.30. Risk of damage/collapse due to non-compliance with formwork bogie structural review and arbitrary changes
			6.2.1.31. Collapse due to non-compliance with scaffolding structural review and non-compliance with assembly order

Work Type (WBS)	Risk Category	Risk	Risk Factor
6. Lining	6.2. Safety	6.2.1. Occurrence of accidents, worker entrapment, and collision	6.2.1.33. Fall due to poor handling, unloading, or transportation of reinforcing bar materials
			6.2.1.34. Fall from workbench due to movement
			6.2.1.35. Concerns about collision and narrowing when the remicon vehicle reverses
		6.2.2. Fire	6.2.2.1. Risk of electric shock and fire during lining foam welding and fusing work
			6.2.2.2.Danger due to fire and lack of oxygen during curing using a hot air fan in winter
	6.3. Technology	6.3.1. Architectural limits	6.3.1. 1. Unsecured construction limits
7. Waterproof	7.1. Construction	7.1.1. Leak	7.1.1.1. Poor welding of waterproof paper at connection part
			7.1.1.2. Bad culvert connection at the bottom
			7.1.1.3. Reinforced sagging anchor connection, not air tested
			7.1.1.4. Connection part air test not conducted
			7.1.1.5. Damage to waterproof sheet during reinforcement work
			7.1.1.6. Poor welding of waterproof sheet joints
			7.1.1.7. Torn waterproof sheet during rebar work
			7.1.1.8. Poor connection between construction joint and waterproof sheet
			7.1.1.9. Leakage due to lack of waterproofing membrane overlapping
			7.1.1.10. Leakage due to poor connection of waterproof membrane longitudinal drainpipe
			7.1.1.11. Watertight plate damage due to rebar assembly and rebar fixed anchor construction
			7.1.1.12. NATM-Cut Tunnel Joint

Work Type (WBS)	Risk Category	Risk	Risk Factor
7. Waterproof	7.1. Construction	7.1.1. Leak	7.1.1.13. Influence of the surrounding groundwater level
		7.1.2. Accidents caused by insufficient surface clearance in the tunnel	7.1.2.1. Induced cracks in the lining due to damage to the waterproofing film.
		7.1.3. Sagging of waterproof paper	7.1.3.1. Installation of shotcrete waterproofing fixing device at regular intervals
		7.1.4. Dropped after installation of tunnel waterproofing membrane	7.1.4.1. Strong wind inflow into the tunnel, insufficient quantity of fixing facilities installed at end connections
		7.1.5. Waterproof membrane damage	7.1.5.1. Shotcrete surface has severe irregularities and damage during the construction of reinforcing bars and formwork
		7.1.6. Damaged waterproof sheet	7.1.6.1. Damage when installing lining foam
			7.1.6.2. When the lining is placed, the waterproof sheet is torn due to the weight of the concrete
			7.1.6.3. Tearing caused by shotcrete protrusions
			7.1.6.4.Torn due to lack of rock bolt head trim
	7.2. Safety	7.2.1. Accidents, damages (due to high-place work, excessive movement, working environment, working conditions, welding work, material falling, collision, etc.)	7.2.1.1. Pain in the neck and back as a result of working toward the ceiling
			7.2.1.2. Lower back pain due to excessive movements, such as moving up and down the waterproof seat cart
			7.2.1.3. Falling due to self-weight of sheet members, collision, etc., while lifting the waterproof sheet to the workbench
			7.2.1.4. Falling accidents due to slipping on stairs due to insufficient lighting when getting on and off the workbench
			7.2.1.5. Collision of the truck by a moving vehicle under the truck, such as an excavator
			7.2.1.6. A worker falling through the center aisle due to material falling between the inner scaffolding of the cart.

Work Type (WBS)	Risk Category	Risk	Risk Factor
7. Waterproof	7.2. Safety	7.2.1. Accidents, damages (due to high-place work, excessive movement, working environment, working conditions, welding work, material falling, collision, etc.)	7.2.1.7. Worker collision due to falling upper material while moving work cart
			7.2.1.8. When installing and dismantling the waterproof workbench, overturning and collapsing due to unlearned work order in advance
			7.2.1.9. Burns during fusion welding of waterproof sheet
			7.2.1.10. Concerns about loosening and deformation of member connections due to damage accumulated during movement of the work cart due to irregularities in the floor, poor inclination of the upper foot of the cart
			7.2.1.11. Fall/collapse due to the use of unqualified materials for the waterproof bogie
			7.2.1.12. Fall due to excessive gap between the platform and the tunnel wall
			7.2.1.13. Electric shock accident due to use of outdated welding machine and failure to install electric shock arrestor
			7.2.1.14. Fall while working on the waterproof sheet at the top of the waterproof cart
			7.2.1.15. Falls while installing a workbench due to workers not wearing seat belts
			7.2.1.16. Fall while lifting the waterproof sheet to the top of the workbench
			7.2.1.17. Stumble and fall while forcibly working at the end of the workbench
			7.2.1.18. Electric shock accident due to use of outdated welding machine and failure to install electric shock arrestor
		7.2.2. Fire	7.2.2.1. Fire occurred during welding/cutting work around the area after installing the waterproof sheet
			7.2.2.2. Waterproof sheet fire due to overheating of bonding equipment
	7.3. Management	7.3.1. Damaged waterproof sheet	7.3.1.1. Tear due to foreign (nail, fixed iron, etc.) matter in shotcrete

Work Type (WBS)	Risk Category	Risk	Risk Factor
7. Waterproof	7.3. Management	7.3.1. Damaged waterproof sheet	7.3.1.2. Difficulty in repairing damaged parts
			7.3.1.3. Difficulty in checking the joint condition of the damaged part
			7.3.1.4. Impossible to check micro-damage.
			7.3.1.5. Damage caused by fixtures when fixing the waterproof sheet
			7.3.1.6. Carelessness when assembling the lining steel formwork
	7.4. Technology	7.4.1. Poor connection of waterproof sheet	7.4.1.1. Inadequate adapter temperature.
			7.4.1.2. Difficulty in identifying defective joints
			7.4.1.3. Improper connection speed
			7.4.1.4. Insufficient joint spacing (insufficient joint length)
			7.4.1.5. Poor connection between waterproof sheet and non-woven fabric
8. Drain	8.1. Construction	8.1.1. Linkage of groundwater back into the lining	8.1.1.1.Insufficient induced drainage before waterproofing work
		8.1.2. Leakage at construction joints	8.1.2.1. Construction joints caused by separate casting
		8.1.3. Clogged drain	8.1.3.1. Inflow of foreign substances due to carelessness during construction
		8.1.4. Roadbed uplift	8.1.4.1. Generation of drainage water pressure
		8.1.5. Possibility of uplift on the pavement surface due to uplift	8.1.5.1. Water reservoir in the lower part of the geologic zone
		8.1.6. Subgrade separation and deformation	8.1.6.1. Poor drainage
		8.1.7. Ceiling settlement due to groundwater level drop	8.1.7.1. Over drain
	8.2. Management	8.2.1. Damaged packaging	8.2.1.1. Poor drainage of the bottom outlet
	8.3. Safety	8.3.1. Safety accident	8.3.1.1. Risk of falling when working at height
	8.4. Technology	8.4.1. Culvert depth difference caused by excavation type (ex., inverted section, normal section, etc.)	8.4.1.1. Design error

Work Type (WBS)	Risk Category	Risk	Risk Factor
9. Common area	9.1. Safety	9.1.1. Collapses when used as an emergency evacuation passage	9.1.1.1. Lack of rigidity
		9.1.2. Electric shock accident due to non-use of machinery and equipment.	9.1.2.1. Leakage current, grounding, earth leakage breaker not installed
		9.1.3. Risk of falling accidents due to poor installation of worker passageways	9.1.3.1. Floor irregularities
		9.1.4. Accidental cuts from high-speed rotating equipment.	9.1.4.1. Floor irregularities
		9.1.5. Eye damage from residual concrete fragments	9.1.5.1. Insufficient safety measures during sanding of utility tunnel formwork.
	9.2. Technology	9.2.1. Separation and level difference on the mounting surface of the common hole lid	9.2.1.1. Defect in the mounting surface of the joint lid.
	9.3. Construction	9.3.1. Poor settlement of new and old joint	9.3.1.1. Excessive split pouring of utility tunnel.
		9.3.2. Crack occurrence	9.3.2.1. No cutting
10. Shaft gates and retaining walls	10.1. Safety	10.1.1. Shaft gate-slope confined space disease occurrence	10.1.1.1. Lack of oxygen during asphalt coating work
	10.2. Construction	10.2.1. Shaft slope collapse and loss.	10.2.1.1. Neglecting the back slope after installing the gate.
			10.2.1.2. Insufficient shaft length or parapet height during heavy rains.
			10.2.1.3. Continuous loss of slopes in the shaft section due to rain
			10.2.1.4. Insufficient drainage on the side of the shaft
		10.2.2. Retaining wall sliding and ground settlement.	10.2.2.1. Insufficient backfilling of the retaining wall
		10.2.3. Retaining wall collapse.	10.2.3.1. Insufficient infiltrate treatment facility in retaining wall causes an increase in back earth pressure
			10.2.3.2. Increase in active soil pressure on retaining walls due to increase in volume of frozen soil in winter
			10.2.3.3. Increase in retaining wall dynamic earth pressure due to increased frozen soil volume in winter.

Work Type (WBS)	Risk Category	Risk	Risk Factor
10. Shaft gates and retaining walls	10.2. Construction	10.2.3. Retaining wall collapse	10.2.3.4. Insufficient compaction of the ground under the retaining wall
			10.2.3.5. Cracks and damages due to poor placement management
		10.2.4. Shaft top slope failure	10.2.4.1. Inappropriate shaft type or location
			10.2.4.2. Installation of shaft doors on steep slopes or large-cut slopes
			10.2.4.3. Inadequate shaft drainage.
		10.2.5. Shaft deformation	10.2.5.1. Shaft installed on a one-sided slope, causing lateral soil pressure
11. Shaft part (Shaft slope)	11.1. Construction	11.1.1. Falling rock and stones	11.1.1.1. Horizontal cuts in tunnel shaft rock in the direction of excavation
			11.1.1.2. Absence of shaft slope reinforcement
			11.1.1.3. Insufficient pumice clearance at the top of the tunnel slope.
		11.1.2. Shaft door damage	11.1.2.1. Rockfall, avalanche
		11.1.3. Shaft slope collapse	11.1.3.1. Poor slope protection
			11.1.3.2. Topography
			11.1.3.3. Failure to select an appropriate construction method to secure slope stability
			11.1.3.4. Discrepancy between the design shaft slope and the actual shaft slope on the ground.
			11.1.3.5. Slope reinforcement not implemented after shaft part installation.
			11.1.3.6. Stability not reviewed when cutting slope, inappropriate selection of reinforcement type according to review.
			11.1.3.7. Improper shaft location (valley, piled soil layer, etc.)
			11.1.3.8. Slope collapse due to a large amount of surface water inflow from concentrated lakes
			11.1.3.9. Slope collapse due to ground weakness caused by rainfall during the rainy season.

Work Type (WBS)	Risk Category	Risk	Risk Factor
11. Shaft part (Shaft slope)	11.1. Construction	11.1.4. Deformation and collapse	11.1.4.1. Measurement management standard exceeded
			11.1.4.2. Step-by-step over excavation
			11.1.4.3. Lack of earth anchor fixing effect
			11.1.4.4. Use of defective materials (deformed oral materials, etc.)
			11.1.4.5. Background tensile crack
12. Auxiliary facilities	12.1. Construction	12.1.1. Intensification of cracks due to gaps at the top of the lining	12.1.1.1. Impact of load on facilities (signboards, jet fans) at the top of the lining
	12.2. Management	12.2.1. Poor air quality inside the tunnel	12.2.1.1. Air supply system centered on dead surface
		12.2.2. Noise complaints and air delays	12.2.2.1. Impossible to install soundproof doors until a certain section is entered.
		12.2.3. Water pollution	12.2.3.1. After tunnel opening, it is necessary to reduce PH for a certain period, but it is reflected in the design only during the excavation period, and facilities that can reduce PH for other periods are not reflected in the design.
			12.2.3.2. Wall washing water generated during wall washing in the tunnel should be separated and treated separately, but in many cases, it is not reflected in the design
	12.3. Safety	12.3.1. Electric shock	12.3.1.1. Insufficient distribution box management during electrical construction
			12.3.1.2. Inadequate management of electrical facilities in tunnels
			12.3.1.3. Inadequate installation of ventilation facilities in tunnels
		12.3.2. Suffocation accident	12.3.2.1. Insufficient ventilation during use of chemicals in confined spaces
		12.3.3. Fire	12.3.3.1. Fire caused by sparks during welding/cutting work during miscellaneous steel construction
13. Instrumentation	13.1. Construction	13.1.1. Accidents such as cracks and collapses	13.1.1.1. Lack of reliability in measured values
			13.1.1.2. Displacement error occurs due to not conducting initial measurement after installation

Work Type (WBS)	Risk Category	Risk	Risk Factor
14. Auxiliary method (steel pipe multi-stage grouting)	14.1. Construction	14.1.1. Grouting Injection Pipe Crashes Due to Pipe Vibration	14.1.1.1. Grouting injection pipe clogged
		14.1.2. Wall collapse	14.1.2.1. Steel pipe insertion and caulking work not carried out immediately after drilling
			14.1.2.2. Groundwater leakage and soil leakage after drilling is completed
		14.1.3. Inadequate ground improvement (consolidation of joint surface) due to early hardening of grouting material	14.1.3.1. Poor mixing of hardener
		14.1.4. Drilling slime flows into the steel pipe	14.1.4.1. Damaged steel pipe inlet bending part
		14.1.5. Collapse	14.1.5.1. Cave-in due to overburden
	14.2. Management	14.2.1. Material fall	14.2.1.1. Concerns about worker collision in the event of sliding or falling due to self-weight after inserting multi-stage steel pipe materials
			14.2.1.2. Unbound wire and falls during the transportation of multi-stage steel pipes
			14.2.1.3. Defective hook release device
	14.3. Safety	14.3.1. Risk of electric shock	14.3.1.1. Mixer power supply, short circuit in distribution panel
		14.3.2. Safety accident	14.3.2.1. Fall, collision, and constrictions during steel pipe insertion
			14.3.2.2. When inserting a steel pipe after drilling, the pipe is pushed back, and there is a risk of hitting workers in the rear
	14.4. Technology	14.4.1. Collapse due to lack of support	14.4.1.1. Insufficient design length due to poor ground
			14.4.1.2. Grouting pressure not secured due to cracks, etc.
			14.4.1.3. Insufficient water and reinforcement
			14.4.1.4. Lack of required support
		14.4.2. Poor grouting strength	14.4.2.1. Poor grouting mixing ratio
	14.5. Design	14.5.1. Waiting cost due to scope change	14.5.1.1. Type change in tunnel.
			14.5.1.2. Personnel and equipment input problems when changing the presence or absence of multi-stage steel pipes

Work Type (WBS)	Risk Category	Risk	Risk Factor
15. Ground investigation before construction	15.1. Technology	15.1.1. Construction cost increase and construction delay due to ground grade (pattern) change	15.1.1.1. Poor geotechnical survey results from underbidding by geotechnical survey company.
			15.1.1.2. Poor GPS reception in mountainous terrain makes it difficult to drill in the correct location.
			15.1.1.3. Estimation analysis after a geotechnical survey of adjacent sections due to inability to enter equipment in mountainous terrain.
		15.1.2. Increased construction cost and delayed construction due to additional ground investigation	15.1.2.1. Generation of additional factors reflecting physical exploration
			15.1.2.2. Failure to conduct an appropriate investigation according to tunnel type, etc.
			15.1.2.3. Inexperienced ground survey company.
			15.1.2.4. Possible existence of vulnerable ground in the survey omission section.
		15.1.2. Increased construction cost and delayed construction due to additional ground investigation	15.1.2.5. Due to poor ground investigation at the time of design, it differs from the ground investigation result before construction.
			15.1.2.6. Ground survey not conducted due to equipment inaccessibility.
		15.1.3. Increased construction cost and delayed construction due to soft ground	15.1.3.1. Impossible to reflect design when creating discontinuous soft ground.
			15.1.3.2. Different design and construction survey
		15.1.4. Groundwater level drop	15.1.4.1. Insufficient preliminary investigation of groundwater level
			15.1.4. Groundwater contamination due to insufficient treatment after boring investigation
		15.1.5. Ground disturbance	15.1.5.1. Excessive survey work due to ground volatility
			15.1.5.2. Groundwater contamination through boring holes
			15.1.5.3. Inflow of surface/groundwater in the tunnel due to poor quality of closed holes after completion of ground investigation
			15.1.5.4. Settlement due to ground disturbance by drilling water during the ground investigation of the soft layer