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Improving the management of tunneling operations in urban areas of Vietnam

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ABSTRACT

Nowadays, in Vietnam's major cities, making use of underground space (tunnels) in road traffic is necessary, especially at river crossings or at complex intersections with high traffic density. However, there have been many problems in the operation, exploitation and maintenance of traffic tunnels due to damages such as cracks in the tunnel shell, water infiltration, flooding, fire and explosion, causing traffic insecurity, which needs to be further considered and perfected, especially the safety of people and vehicles traveling through the tunnels. The drafting of management procedures for tunnel works has some limitations in the operation process, because the tunnel operation process contains many potential risks that can lead to risks affecting the function, the existence of the work and the damage to human life and property, the cost and time for the maintenance. This article focuses on perfecting the management process of tunneling operations in order to contribute to ensuring stability, longevity, workability and efficiency when operating tunnels in general and urban traffic tunnels in particular.

Keywords : Underground works, traffic tunnels, operation management, traffic safety in tunnels.

I. INTRODUCTION

Nowadays tunnels are used quite commonly in different sectors of the national economy, especially in developed countries. Most underground works are used more and more, especially large tunnels used for traffic purposes such as car tunnels, railway tunnels and diversion tunnels in waterway works. Some underground facilities are jointly used for railway and automobile. Tunnel works are also common, sometimes unavoidable items in the construction of metro works, hydroelectric power stations, hydroelectricity, hydro treatment works, land reclamation, etc. In construction and development of industrial parks, cities with large population, especially modern cities, tunnels are widely used to arrange traffic networks to make warehouses and storage tanks, garages, parking lots and a host of other special

purposes. Therefore, the management, protection, maintenance and organization of tunnel exploitation becomes more and more necessary and urgent. On the basis of theory and practice of tunneling in Vietnam, the concept of tunneling operation can be proposed as follows:

Operation of tunneling works and organizing traffic in tunnels is a collection of actions on management, monitoring, inspection, maintenance, to maintain the quality and life of the works, to ensure smooth operation to meet the requirements of construction quality, safety for people and vehicles traveling through the tunnels [1]. For tunnel works, the objectives of maintenance work include 1) Maintaining the tunnel in a safe condition when in use; 2) Minimizing tunnel traffic stops and tunnel environmental impacts through careful and detailed planning for each job of tunnel operation and maintenance.

Tunnel maintenance is carried out by the tunnel management unit or the construction contractor, depending on the signed contract. The most important thing is to carry out maintenance at the right time, in the right process and to minimize traffic disruptions inside the tunnel and the tunnel access. The Tunnel management and operation unit must establish a maintenance plan for the tunnel, which outlines the necessary level and required quality of work for the types of maintenance to be carried out. This strategy should reflect the requirements or recommendations of the Tunnel operation and maintenance manual and previous maintenance records.

The management of the traffic tunnel is to ensure that the traffic through the tunnel is safe and stable with the volume and distance between vehicles in accordance with regulations. In addition, the management of traffic in the tunnel to ensure smooth traffic, the safety of vehicles as well as people and equipment for maintenance and repair of the tunnel, or incidents occurring in the tunnel is very necessary.

This article focuses on studying the current situation of management, exploitation and maintenance of the road traffic tunnel system in Vietnam in order to provide safe solutions when participating in traffic in tunnels and ensure stability, service life, working capacity and efficiency of the process of exploiting traffic tunnels in general and urban tunnels in particular.

II. SITUATION OF TRAFFIC MANAGEMENT OPERATION CONSTRUCTION IN VIETNAM

2.1. Current status of road tunnel management and operation in Vietnam

The operation of the whole system of management, protection and exploitation of the road traffic tunnel system in general and urban tunnels in particular in recent years has basically contributed to the provision of traffic infrastructure to meet the requirements of the traffic conditions, socio-economic development in terms of goods circulation and people's travel.

However, due to objective as well as subjective limitations, the management, protection and maintenance of the road tunnel system in Vietnam still has some shortcomings that threaten human life and property losses.

The shortcomings are as follows:

- The road transport infrastructure system is insufficient, low in quality, not synchronous, not meeting the increasing transport requirements. The reason is that the investment in transport infrastructure has not kept up with the demand for transport, the maintenance is not good, leading to the rapid deterioration of the road traffic tunnel infrastructure after being put into operation.
- On the other hand, the organization of the maintenance management apparatus is still unprofessional. Although most management units hire professional companies to directly perform maintenance and repair work, they have not yet met

the requirements of expertise in both technical and managerial aspects.

- The level of science and technology, equipment and technology used in the field is low and out of date.
- The system of legal regulations on road management and maintenance is inadequate and inappropriate; standards and norms are out of date compared to reality.
- Funds for maintenance management are still limited, not commensurate with the length of the tunnel network and the pressure on transport on the current road network.
- Management and protection of road traffic infrastructure, especially management and protection of tunnels, still have many shortcomings.
- Although the government has issued Decree 06/2021/ND-CP on quality management and maintenance of construction works, in reality the implementation is still inadequate due to many reasons.

In order to accurately identify the shortcomings and inadequacies to provide appropriate solutions, the article cites a number of incidents in the process of tunnel management and exploitation in Vietnam over the past two decades in section 2.2.

2.2. Current status of road tunnel management and operation in Vietnam

Road tunnels in Vietnam have contributed to improving and enhancing the capacity of key traffic routes, but the process of exploitation and use is facing problems with the environment, fire and explosion prevention, and excessive vibration and noise, cracks in the tunnel shell, water seepage, etc.. Therefore, there have been many doubts about the quality and longevity of the works. Currently, depending on the scale and nature of the work, the organization of exploitation and maintenance management needs appropriate solutions.

For small-scale underground tunnel works at intersections, the operation management is usually assigned to the unit in charge of managing and exploiting the road traffic infrastructure of that area. However, for large-scale traffic tunnels such as Ca pass tunnel, Hai Van tunnel and tunnel crossing the Saigon River, there is a separate management unit; using the tunnel operation manual. In Vietnam, there is currently no main process in traffic management and operation.

In order to clarify the current situation in the process of operating and exploiting tunnel works in Vietnam, the author delves into some shortcomings as well as issues that need to be adjusted through the management and exploitation of a number of construction of traffic tunnels, tunnels leading to urban areas and tunnels in urban areas, in order to determine the causes and find suitable solutions and solutions in Vietnamese conditions.

For road tunnels leading to urban areas, Hai Van tunnels can be mentioned (Figure 1). During the operation and exploitation of Hai Van road tunnel from 2005 up to now, there have been many traffic accidents [2]. According to Hamadeco's statistics, since the day Hai Van road tunnel was put into operation and used, dozens of cars spontaneously caught fire, causing accidents in the tunnel; in which there were 9 cases of vehicles in traffic that spontaneously ignited due to various reasons... Besides the cars caught fire in the tunnel, there were also many accidents with many different causes occurring inside the tunnel. In particular, the serious accident on August 20, 2015, a truck carrying frozen shrimp with plate No. 94L... was running in the tunnel at Km 4+012 in the South - North direction at a speed of 73 Km/h, lost control and crashed into the tunnel wall, causing gasoline to leak, and the battery also exploded and caught fire (Figs. 1-2). The accident caused the passenger to die at the site, the driver was taken to the emergency room. This is the first fatal accident in the Hai Van tunnel since it came into operation. However, this is a very serious problem that requires timely handling and preventive measures to avoid unfortunate accidents later.

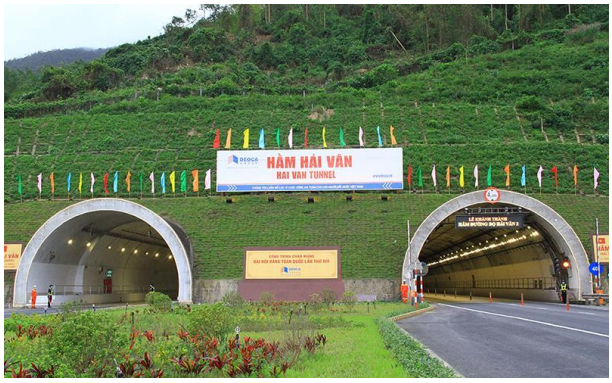

Fig. 1. Hai Van tunnel

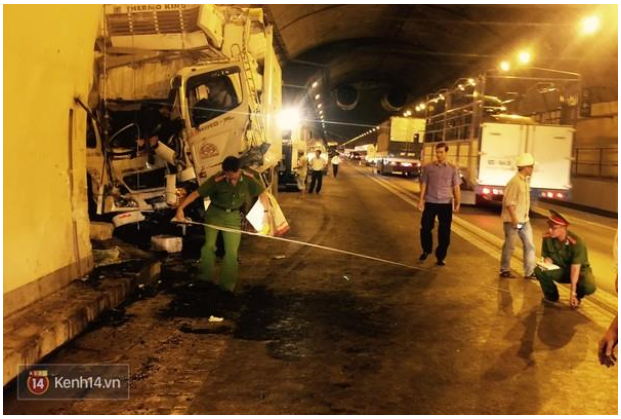

Fig. 2. The accident at the Hai Van tunnel (2015)

Recently, the problem of cracking the concrete shell of the Hai Van tunnel has received more attention from the media and experts. Although currently the cracks have not been recorded abnormally, most of the cracks with a width of 0.2mm do not need to have measures to monitor the development of cracks and for cracks with a larger width of 0.2mm, they have been handled. In general, the entire main tunnel structure does not have any abnormal phenomenon, there is no phenomenon of displacement and deformation at the main tunnel segments; the strength and quality of the tunnel shell concrete is at a stable level, the tunnel shell concrete is uniform. There is no water seepage in the tunnel shell, and the main tunnel has no height difference.

The Saigon River Tunnel is the largest river crossing tunnel in Southeast Asia (Fig. 3). The tunnel is 1,490m long. The submerged tunnel consists of 4 segments; each segment is 92.17m long; weighing 27,000 tons; thickness is approximately 1.2m; 6m deep in the river bed [3]. The tunnel has been put into use since November 20, 2011. Since it was put into operation until now, there are still many outstanding problems that need to be promptly prevented, specifically during the tunnel's operation.

Fig. 3. Tunnel crossing the Saigon River

Figure 4. The accident at the tunnel crossing the Saigon River (2016)

There have been many accidents inside the tunnels causing human life losses as well as material losses. The Saigon River Tunnel Management Center (under the Department of Transport of Ho Chi Minh City) was forced to close the tunnel door to deal with the accident and handle the scene (Fig. 4). With the average number of vehicles so far (only cars) 1 million vehicles per month, so the frequency of traffic is quite large, an average increase of 10% per year, the number of accidents due to collisions, due to tire explosion, self-overturning, burning, etc., there are still many occurrences. Although the warning systems in operation have been put into operation well, contributing to reducing incidents in the tunnel, in order to comprehensively evaluate and determine the

cause, there are still many problems to be solved in order to protect the safety of the tunnel, especially the phenomenon of fire and explosion, major accidents, in addition to causing death and traffic jams, also damage the tunnel shell structure system.

Through the accidents caused by vehicles traveling through the tunnel, there are still many violations such as: not keeping a safe distance, exceeding the prescribed speed, using the horn in the tunnel, not turning on the lights. … These violations are also potential causes of accidents and unfortunate incidents in the tunnel.

In addition to the problems caused by the vehicles participating in traffic, the maintenance and repair work also has many backlogs that need to be promptly resolved such as: the organization of traffic flow during cleaning and maintenance, tunnel maintenance, the arrangement of notification and warning devices also needs to be reviewed and supplemented accordingly.

In particular, the situation of flooding in the tunnel is a matter of special concern, as recently, the historic heavy rain on the evening of September 26, 2016, caused the tunnel crossing the Saigon River to be heavily flooded, forcing the management unit to stop motorbike traffic for nearly 1 hour to pump water. For the first time since it was put into operation (in 2011), Thu Thiem tunnel was flooded, due to heavy rain, water from the two tunnels could not be drained in time, overflowing into the tunnel. At the deepest part of the tunnel was flooded more than 20cm.

Underground works in urban areas also face many problems in terms of exploitation management, specifically [3]:

Tan Tao underground tunnel in Binh Tan District, Ho Chi Minh City was officially put into use at the end of 2007 with a length of 38m, the height from the ground to the surface of the tunnel is 2.6m, with a total investment cost of up to 27,4 billion dong. The tunnel is invested so that more than 90,000 workers in Tan Tao and Pouyuen industrial parks do not have to cross National Highway 1A, causing danger every time they come to work in the industrial park. But now this underground tunnel is being encroached on by small traders. In addition, when it rains heavily, there is often flooding in the tunnel, which makes it difficult to pump and drain water because the surrounding roads are often flooded with no place to escape. In a lot of garbage dumps, the pump is constantly clogged, causing dangerous flooding for people passing through at night.

Linh Xuan underground tunnel - Thu Duc district, Ho Chi Minh City is 38m long, nearly 30m wide with two directions for motorbikes and small cars. The project is invested more than 60 billion VND to solve traffic jams and accidents. However, during the exploitation process, there were almost no passers-by and there are issues of garbage, flooded water, even young people playing football right in the tunnel.

Ben Cat underground tunnel project - District 12, Ho Chi Minh City was put into use before 2013. Although the tunnel is fully invested with a drainage pump system, lighting etc., during the exploitation process, there is flooding during heavy rains and high tides. In addition, there have been many accidents caused by motorbikes going in the opposite direction.

The Trung Hoa - Hanoi underground project has been put into use since early January 2016. However, after more than 3 months of operation, this project is overflown with garbage, there is no regular cleaning unit.

Kim Lien - Hanoi underground tunnel was built and put into use in 2009, with a length of 644m, of which 140m underground, 405m open, tunnel width of 18.5m. Since put into use, there have been many accidents in the tunnel, most recently on October 17, 2016, a series of motorbikes slipped and fell in the tunnel due to the oil spill on the road surface in the tunnel causing slippery.

Through the above situations, it can be seen that the protection, maintenance, traffic safety of road tunnels in urban areas still have many shortcomings and the main causes can be briefly summarized as follows:

- Management units have not properly implemented regulations on management and regular maintenance of tunnels.
- The awareness of road users is still low, the propaganda, warnings and instructions from the authorities have not been paid due attention and implemented.
- The patrol and inspection work is not effective. it is formal, not aware of the danger when there is an incident in the tunnel.
- Reacting to incidents is slow, awkward in handling situations.
- Also ignore the regular maintenance, until the work has been damaged or breakdown, the maintenance and repair is performed.
- Not taking seriously the longevity of the works.
- Staff is weak in terms of capacity, experience and sense of responsibility.
- Most of the management units have not yet completed the responsibility mechanism when assigning the contract to the maintenance management unit.

In addition, the financial constraints that do not allow the management unit to use appropriate materials or technology in maintenance and repair work also contribute to affecting the quality and service life of the tunnels as well as risks that easily cause traffic safety accidents.

2.3. Evaluation of tunnel operation management in road traffic and urban tunnels in Vietnam

In general, at present, traffic tunnel works in Vietnam are being exploited relatively smoothly because there are not many tunnels and they have been invested and put into use only in the past 15 years. However, the occurrence of incidents in the tunnel works such as accidents, fire and explosion, leakage of basement water, flooding, etc., pose a potential risk of damage to the works. Besides, the maintenance work does not have an official process, the maintenance is only compliance with the tunnel operation manual and the instructions of the design, the circulars, decisions, instructions of the tunnel operator, specialized ministries or separate processes applied to Hai Van Tunnel, Ca Pass tunnel on National Highway 1 or Thu Thiem underground tunnel in Ho Chi Minh City.

About construction maintenance manual: Currently, for small-scale projects such as tunnels at intersections, maintenance work is carried out for basic equipment mainly for electromechanical equipment, lighting, drainage pump, etc. As for large-scale tunnel works such as Hai Van tunnel, Ca pass tunnel and tunnel crossing the Saigon River, the tunnel maintenance and repair manual is basically drafted and completed, especially for the maintenance manual of the tunnel crossing the Saigon River, which can be said to be quite specific and complete with details of inspection, maintenance, recording, etc., but there are still problems including quality and unfortunate traffic accidents.

Up to now, the state management has not had a thorough study to draft the official exploitation management process for tunnel works, the implementation of exploitation management is still mainly done according to experience. The proactive drafting of processes such as: fire and explosion incident handling procedures, accident handling procedures, flood handling procedures, power failure handling, etc. have not yet been considered by the state management and officially drafted, even for large tunnel works such as Hai Van tunnel, tunnel crossing the Saigon River, and Ca pass tunnel, the management and exploitation process has not yet been drafted. In addition, measures to organize traffic in the process of exploitation management, or as safety control methods such as patrolling, inspecting, and dredging riverbeds for submerged tunnels have not yet been considered and controlled, especially the height of sand fill and solid waste stranded on the roof of the tunnel.

Regarding incident handling drills, in the past time, the preparation and drills to handle accidents, fire, explosion, etc. in the tunnels have been focused on by

the management units for large-scale tunnel works such as Hai Van, Thu Thiem, and Ca pass. It is still lacking regularity, while tunnel works at urban intersections have not yet been focused and rehearsed. That can lead to confusion and delay in handling unfortunate incidents occurring at tunnel works.

Regarding the maintenance and repair work, for small-scale underground tunnels [4], maintenance and repair work has not yet been paid due attention by the management unit, through reality it can be seen that many underground tunnels were flooded due to inadequate pumping capacity, or unclean sewer cleaning, causing flooding when it rains. The lighting system in the tunnels is damaged and cannot be repaired and replaced in time, the tunnels do not have enough light to operate, causing unsafety, this is partly due to the fact that the operation manual has not been completely drafted and the lack of experience as well as responsibility and experience of the technical staff of the mining management unit.

For large-scale tunnel works such as the tunnel crossing the Saigon River and the Hai Van tunnel, the maintenance and repair work has been well organized, but due to limited experience in inspection and maintenance work [5], [6]. Due to the lack of maintenance or poor capacity, the tunnels still have many problems for the structure such as cracking of the tunnel wall, water infiltration of the basement shell, lack of warning equipment, etc.

The safety situation when participating in traffic in tunnels, especially in urban tunnels, still has problems, and there are many unfortunate accidents.

- Regarding the regulation and distribution of traffic through the tunnel works, although it has been paid attention by the parties, it is still necessary to pay attention to some more issues such as: before the tunnel works, it is necessary to place additional racks (limiting height pillars) to prevent oversized vehicles to intentionally enter the tunnel, causing damage to the tunnel; for tunnels with a small radius of curvature it is necessary to arrange suitable lanes, especially the conditions on super-elevation arrangement with appropriate speed limiter and spherical mirrors for two-way tunnels [7], [8], [9].

General assessment: construction of traffic tunnels is a new industry of Vietnamese engineers, especially in the period of tunnel exploitation and operation. But with the support of foreign experts, Vietnam has made significant development. But during the exploitation phase, Vietnam still has many shortcomings as mentioned above, it needs to be adjusted in time by the official process applied to the operation and exploitation of traffic tunnels on the basis of additional and perfecting the theoretical basis system suitable to Vietnam's conditions.

Through the research process on the basis of practice, the authors propose the content and process of managing and exploiting traffic tunnels as the next part.

III. PROPOSED SYSTEM SOLUTIONS FOR MANAGEMENT OF ROAD TRAFFIC EXPLOITATION

3.1 Contents of traffic tunnel operation management

On the basis of research works and relevant current legal documents of Vietnam, especially with reference to Circular No. 37/2018/TT-BGTVT of the Ministry of Transport dated June 7, 2018 , regulations on management, operation, exploitation and maintenance of road works, the article defines the content of technical management of traffic tunnels (Fig. 4), including 03 contents: Technical management of tunnel works traffic; Manage the protection and maintenance of traffic tunnels; Managing costs and socio-economic benefits [10].

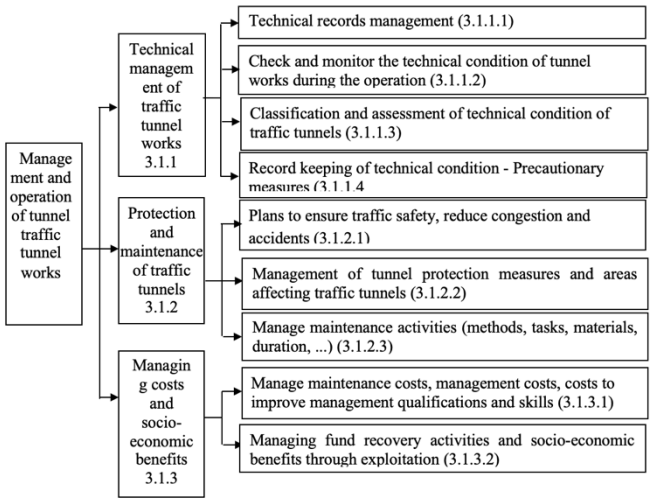

Fig. 4. Management and exploitation of urban road traffic works

3.1.1 Technical management of traffic tunnel works

3.1.1.1. Technical records management

Store original documents (design documents, explanations, construction contracts, construction methods, as-built documents, etc.), documents related to changes in the technical status of works, records of preliminary maintenance of tunnel cover, tunnel traffic, equipment in tunnel, etc., as a database for management and exploitation.

- Technical documents: design, completion, registration for tunnel inspection, BDSC file, work incident file (if any), relevant legal documents.

- Decentralized management of technical documents: the investor is the person who is responsible and makes the decisions assigned to the lower-level specialized units for management. Specifically:

+ Centrally managed road traffic tunnels: Directorate for Roads of Vietnam is responsible for managing or authorizing subordinate units (counties, sections, local Departments of Transport) to manage: list of documents completion, records of inspection, traffic safety inspection, renovation, repair, maintenance etc, depending on the size and grade of the project.

+ If the traffic tunnel is managed by the locality, the provinces and cities assign the local Departments of Transport to manage and store the initial completion records, the completion records of the repair and inspection times, the handling records and other relevant documents. For cities directly under the Central Government, the Department of Transport assigns subordinate units in the process of exploitation to manage and control the implementation.

3.1.1.2. Check and monitor the technical condition of tunnel works during the operation

Objects of inspection and monitoring of tunnel technical condition include: all tunnel works; the system of the inner surface of the tunnel; tunnel traffic; ventilation and drainage systems; notice board; lighting, warning equipment system... ancillary works related to traffic safety assurance activities. Management entities must develop a plan:

- Develop a plan for regular, periodical and unexpected inspection.

- Develop inspection process, testing resources, reporting regime.

- Develop plans to coordinate with specialized agencies.

Inspection activities are conducted in the following forms: regular inspection, periodical inspection, unexpected inspection, and special inspection.

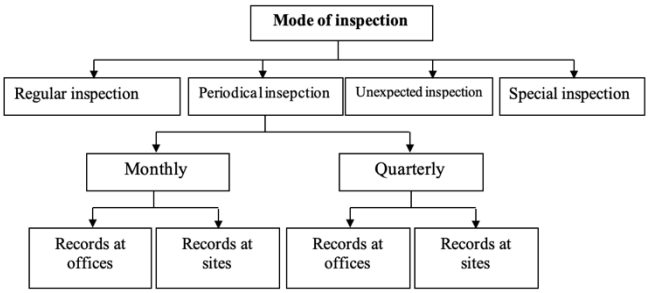

Fig. 5. Mode of inspection

Sources: [10]

- Regular inspection: by a team of staff, technical workers directly managing the works. The inspection is supported by the naked eyes and some simple equipment.

- Periodic inspection: including quarterly inspection and annual inspection.

- Unexpected inspection: occurs in the event of an incident during the exploitation process or the impact of nature (hurricane, flood, earthquake, accident, fire,

explosion...) that threatens to cause unsafety for the project. The direct management entity establishes an inspection team or is decided by a competent state agency. Testing with specialized equipment.

- Special inspection:

+ For works with state capital: decided by the investor (the Ministry of Transport, the People's Committee of the provinces or cities) or the tunnel management unit.

+ Works not under state ownership: during the exploitation process, when it is suspected that the work may cause unsafety incidents, the investor can directly set up an inspection team. In addition, specialized agencies representing the local state management of construction can issue inspection decisions (with the participation of representatives of the investors).

All types of inspection must have records and reports to superiors and specialized ministries according to regulations.

3.1.1.3. Classification and assessment of technical condition of tunnel works

This is necessary to achieve the following goals:

- Determine the safety level of the works being exploited.
- Issues that affect the architecture, structure, function of the work and equipment serving traffic safety when vehicles pass through the tunnels.
- Make a repair plan if the work is found to be different, damaged or degraded compared to the design.
- Calculate the cost for the repair.
- Re-examination of works when there are decisions of specialized agencies.

3.1.1.4. Registration and archiving records - Precautionary measures

Registration and archival records provide original documents for engineering management of works. Tunnel works, when starting exploitation, must conduct "work registration" to determine the initial technical conditions, and after 10-15 years, it needs to be re-registered to determine the change of geometrical and elemental elements. techniques, etc. in the exploitation process.

Warnings in mining operations, notes on objects that need to be monitored.

3.1.2. Management of traffic tunnel protection and maintenance

3.1.2.1. Plans to ensure traffic safety, reduce congestion and accidents

The organization, operation and exploitation of tunnel works must be planned on plans to ensure traffic safety during operation, including:

- Measures to ensure traffic safety, traffic clearance, traffic speed, incident handling, fire and explosion, damaged vehicles, congestion, flooding, traffic accidents, ...
- Measures to coordinate with concerned agencies (lane division, channel separation, tunnel closure) to repair, renovate, connect, solve problems in tunnels, etc.
- Statistical and monitoring "black spots" (if any) in the tunnel, the tunnel management unit monitors the black spots, analyzes the causes, proposes a plan to renovate and repair to overcome the black spots, and to deal with the problem, monitoring and archiving.

3.1.2.2. Management of tunnel protection measures and areas affecting traffic tunnels

In order for the exploitation and operation of the tunnel work to meet the requirements, first measures to protect the work must be taken, including the following contents:

- Objects to be protected: tunnel works in the process of exploitation, subject to many objective and subjective impacts affecting the function and service life of the works such as:

+ Objectively:

- Rain, storm, flood cause local inundation, destruction of works or impacts of geology, flow, displacement, cracking, subsidence, water overflowing

into tunnels, etc., causing destruction of public structures submit.

● Impacts of climate change (increased temperature, abnormal rain and flood, saltwater intrusion, etc.) cause damage to the inside of the tunnels (cracking the tunnel shell, subsidence, equipment systems, etc.), corrosion, and rust (damage to the traffic safety warning devices).

+ Subjectively:

● Consciousness of using the traffic tunnel of the subjects (overloaded vehicles, vehicles carrying explosive materials, bulky goods trucks).

● The irresponsibility, loose management of the authorities and tunnel management agencies.

Therefore, all work items must be protected to ensure the safety of tunneling operations.

- Scope of protection: including the works themselves on the tunnel surface, in the tunnel (ventilation, lighting, signal lights, signs, medians, safety warning devices, etc.) aerial part, part underground road surface in tunnels (drainage system, foundation, wells, manholes, water pumps, etc., emergency exits, related to the safety of works during exploitation.

- Protection responsibilities:

+ The responsibility to protect traffic tunnel works belongs to all specialized agencies and society.

+ The protection of construction safety is also to ensure the issues of construction quality, safety and social security. Any act of infringing upon the tunnel works without the permission of the state is a violation of the law.

* Patrol to detect damage and loss of traffic safety early

Patrol is the content of tunnel protection in order to early detect damage when it is just a phenomenon to promptly prevent, to ensure the safety of human life and property.

Requirements:

- Patrol must ensure traffic safety 24/24.

- The person performing the patrol duty must be proficient in the tasks performed according to the assigned tasks.

- Check the cement concrete pavement in the tunnels.

+ Cleanliness of cement concrete pavement in the tunnel

+ The phenomenon of concrete cracking

+ The phenomenon of changing the color of concrete

+ The phenomenon of water seepage from the bottom up.

+ Unusual sound when using hammer to check

+ etc...

- Check the tunnel shell

+ Cracks, crack shape, crack width, crack development ability, crack elongation, etc.

+ The phenomenon of water seepage through the tunnel shell

+ The change in color of concrete tunnel shell

+ The phenomenon of concrete peeling, peeling size, development ability

- Check railings - pedestrian curbs

+ Similar concrete test

+ Check the insurance railing (curved, warped, cracked, other deformation)

- Emergency exits and doors

+ Cleanliness and dryness of the exits

+ Ventilation and lighting of emergency exits

+ Signposts indicating the exits

+ Safety warning for exits

- Safety devices in tunnels

+ Light for vehicles to circulate

+ Horizontal and vertical ventilation equipment in traffic tunnels

+ Fire alarm device

+ Fire pump equipment

+ Drainage pump equipment in the tunnel

+ Etc...

Depending on the nature and characteristics of the tunnel, the patrol must be drafted into a separate process for each type of tunnel.

3.1.2.3. Management of tunnel maintenance

Tunnel maintenance: is the obligatory compliance with processes, standards and legal documents in order

to ensure the safety of exploitation in terms of quality and efficiency, for the purpose of maintaining the ability of structures to withstand high pressure power, aesthetics, longevity of the building and ensure traffic safety for people and vehicles traveling through the tunnel.

The tunnel management unit has the responsibility and obligation to maintain the work in accordance with the provisions of the design, approved by the competent authority.

Time limit for maintenance of road tunnel works:

- The construction maintenance period is counted from the date of acceptance of the work to the end of its useful life as prescribed by the design.
- If the works exceed the useful life, if the investor requests to continue using it, he/she must make a written request to the State management agency and carry out procedures for re-inspection of the quality of the works, from there decide whether the work is allowed to exist or not, which items need to be repaired or upgraded, the length of time,...

Construction maintenance level: According to the Government's Decree 06/2021/ND-CP on quality management and construction maintenance [2], construction maintenance work is carried out at the following levels: maintenance; minor repair; medium repair; major repair. Particularly for tunnel works, maintenance work is divided into:

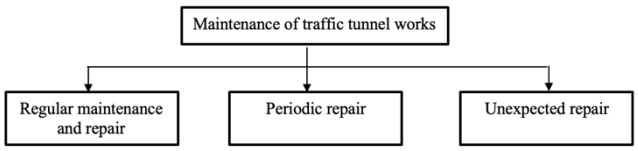

Fig. 6. Traffic tunnel maintenance

1. Regular maintenance and repair: is the activity of taking care of and preserving the work, detecting minor structural damage, service ability to take immediate repair measures, in order to maintain the technical condition of the works. , including the following main contents: repair and maintain foundation-tunnel surface, railings, sidewalks,...; system of signs, signal lights, medians, guardrails; drainage system; exits, exit doors, exit lights, etc.

2. Periodic repair: is a certain periodic repair activity based on the failure rule of the building, whereby people have to repair the work once in a certain number of years. Based on the rule and degree of damage to the work, periodic repair is divided into medium repair and large repair.

+ Medium repair: is carried out every 2-3 years, usually only treating the road surface in tunnels (automobile roads), drainage, repairing sidewalks used to patrols, railings, escape routes.

+ Major repair, also known as overhaul: performed every 5 - 10 years. In major repairs, one must repair the inner shell system of the tunnel, renovate and upgrade damaged items of cement concrete pavement, bearing system, and prevent water from submerged tunnels; replace ventilation, lighting, warning, etc.

3. Unscheduled repair: during the exploitation process, unexpected repair is conducted when an emergency occurs, caused by subjective (human) or objective (natural) causes. To ensure traffic safety, unexpected repairs are unavoidable. Management units must have contingency plans (risk management) and pre-prepared plans to prevent incidents. implemented as planned.

* Management methods for maintenance of road tunnels: Currently, there are two different concepts of management in general: management by objectives (MBO) and management by process (Management by Process) program. To distinguish the two concepts, the following diagram can be used:

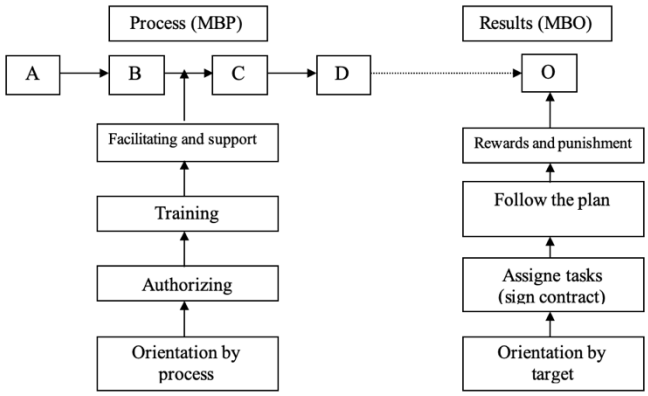

Fig. 7. Diagram of Governance by Process and Governance by Objectives [10]

The characters: A, B, C, D are the work steps of the product manufacturing process. O is the end result of the product.

- Management by process (MBP): focus on the process of performing each work item; everyone clearly understands the plan for each item and is authorized to implement it.

+ Advantages: trust and peace of mind about quality.

+ Disadvantages: many work items, costs incurred, responsibilities spread to many subjects, lengthy administrative procedures.

- Management by objectives (MBO): concerned with the end result of the product; respect the contract, the plan set out in the contract, identify the main responsible subject.

+ Advantages: reduce intermediate workload, save costs, assign the main responsibility for quality, suitable for works with many similar small items.

+ Disadvantages: not applicable to jobs with large volumes, complex jobs, related to national defense and security, social security.

The two management concepts mentioned above exist at the same time. On the basis of reality and the application must also depend on each job, each type of product as well as the nature of the product to apply.

The maintenance of the tunnel works, if the process management method is applied, the nature is still like a miniature construction project, with the cycle: survey; design; construction (strictly controlled from input materials, construction methods, construction equipment,...); acceptance test of items, overall; This method goes through many administrative procedures, incurs costs, but the quality responsibility is spread to many subjects, but it still has to be applied because the traffic tunnel has many items, Complex jobs need detailed control.

It is necessary to study and apply the management method according to the objectives for a number of small, similar items in the maintenance of the tunnel works, because the essence of the management method according to the objectives is to manage the quality of the work according to the contract requirements, only interested in the final results according to the set goals and quality will be responsible for the investor and the construction contractor.

Application of PBC contract in traffic tunnel maintenance: many countries around the world have studied and applied the form of contract based on the results and performance of PBC (Performance Based Contract) for the past 20 years. For a PBC contract, the contractor is allowed to decide on the implementation content, from where, how and when to perform. Contractors are paid based on results and performance. The payment is agreed in the contract instead of the input volume and unit price in the form of monthly scoring and monthly payment.

Compared with the traditional contract form, the PBC contract will save costs for the intermediary stages (design, supervision, testing, ...).

PBC contracts are often designed to transfer responsibility for quality control and project maintenance to organizations or contractors, because the packages are often small in volume and cost, with many similar small work items.

The form of payment can be divided equally monthly according to the formula:

$$X_i = \frac{X}{N} \quad (1)$$

X_i: Amount the contractor is entitled to 1 month

X: Total contract value

N: Number of months in the contract

Or pay in the form of accumulation

$$\sum_{1}^{n} X_i = X \quad (2)$$

$X_1 < X_2 < X_3 \ldots\ldots\ldots\ldots < X_n$

3.1.3. Managing costs and socio-economic benefits

3.1.3.1. Manage maintenance costs, management operating costs (with retraining and advanced training costs)

Expenses for the operation of urban road traffic works include direct costs for maintenance and operational costs of the management team. Therefore, in order for economic management to be economically effective, it is very important to plan maintenance costs for tunnels, which should be studied on a scientific basis (correct calculation, sufficient calculation) right from the planning step.

- Methods of determining construction maintenance costs: Construction maintenance costs are determined according to the following methods [11]:

+ Method of determining by volume estimate and unit price: On the basis of the volume of work performed according to the maintenance plan and the corresponding unit price for each work content, to make a cost estimate for each task.

+ The method of determination according to the percentage: applied to determine the cost of the following jobs: Planning maintenance work; Inspecting works regularly, periodically and irregularly; Project maintenance; Prepare and manage project maintenance records. This method can be applied to a management contract (PBC) that determines maintenance costs.

- Structure of construction maintenance costs

+ Construction maintenance costs include: Costs of planning maintenance work, regular - periodical - irregular works inspection, expenses for making and managing maintenance records; monitoring, taking care of and repairing minor damage such as: Patching potholes in tunnels, repainting road markings, etc. and the cost of construction equipment (excluding technological equipment) calculated according to the investment capital rate of works of the same grade and of the same type at the time of making the work maintenance plan.

+ The cost of maintenance of the technological equipment part of the work is based on the maintenance process of the work of the technological equipment supplier.

- Controlling construction maintenance costs: Construction maintenance costs are paid according to the estimate made and appraised before the maintenance work is carried out. Payments for contractors by volume are carried out under the control of the State Treasury and independent audit (if necessary).

3.1.3.2. Managing capital recovery activities and socio-economic benefits

a) Managing capital recovery activities

Funding plays a very important role, in order to exploit the tunnel works to achieve the set goals, it is necessary to ensure the capital source for the annual maintenance and repair; capital for management; reserve fund in case of emergency. The lack of capital will lead to damaged construction items not being repaired in time, while still subject to exploitation load, growing damage, rapid deterioration of works, incurring maintenance and repair costs, lost traffic safety. Therefore, the article deeply analyzes capital sources, capital recovery, maintenance costs to maintain the function of tunnel works and bring efficiency through socio-economic benefits.

Capital for management and exploitation of tunnels: All road traffic systems are invested by the state or privately (in the form of PPP), in theory, the state has a uniform policy to ensure capital for development investment, repair and renovation works and expenses for management staff. Due to the ownership nature of the work, the formation and arrangement of capital sources in economic management activities are as follows:

- For tunnel works under the management of the State, the capital source for management and maintenance shall be arranged from the central budget capital and other capital sources as prescribed by law.

- Funds for the management and maintenance of road tunnels managed by the locality shall be allocated from the local budget and partly from the central maintenance fund.

Funds for maintenance of tunnels are formed from the following sources:
- State budget.
- Source of collection of fees for using works, through vehicle inspection fees.
- The investor's capital is deducted from toll collection (for projects serving business purposes such as BOT, BTO, BT, etc...).
- Other legal capital sources.

b) Socio-economic benefits
Investment in construction of traffic tunnels has high costs, time-consuming and large management and exploitation costs. But in the long run, tunnel investment brings high socio-economic benefits for the following reasons:
- Tunnels are often invested to overcome obstacles on hills, mountains and large rivers, in order to shorten travel time and ensure traffic safety when vehicles pass through precarious hillsides.
- Tunnels can be submerged tunnels crossing the river when the height and width of the navigable gauge are limited due to the large number of large boats traveling or causing loss of urban landscape, etc.
- The intersections in urban areas with large vehicle density easily cause traffic congestion and unsafety.
- When the landscape, urban beauty or cost does not allow to build a bridge for many reasons, for example, the cost of site clearance is large, affecting the landscape, beauty, environment or losing social security when renovating old urban areas with cultural works, historical relics that need to be preserved, etc.
Therefore, the solution of tunneling in the long run will overcome the above shortcomings and still ensure efficiency in the organization of effective transport and traffic safety on the route in the long run. Although the initial investment cost is large, it will eliminate the inadequacies if investing in bridge construction, and the investment efficiency is high from both economic and social perspectives.

3.2 Legal basis in traffic tunnel management

The traffic tunnel is a component of the road route, so all regulations in the operation process are applied according to the road traffic law and Decree 06/2021/ND-CP and the system of sub-law documents (Decree No. regulations, circulars, decisions, etc.) of the relevant Ministries and sectors [11], [12], [13]. Any other errors are considered violations.
Due to the specificity of the traffic tunnel when vehicles participate in traffic through the tunnel, it is highly related to the safety of life and property when an incident occurs. So depending on the size and nature of the tunnel, it is imperative that the management levels from the Ministry of Transport to localities must have a process of managing and exploiting traffic tunnels in accordance with the provisions of law and approved by the Ministry of Transport.
Due to the characteristics, geology, ecology of regions and wind direction according to the four seasons of Vietnam's climate, when drafting procedures and regulations on tunnel operation, it is necessary to comply with warnings of the Ministry of Natural Resources and Environment (components O_2, CO_2, NO_2, CH_2, CH_4, etc. and other toxic gases).
When vehicles and people travel through road tunnels, they are required to comply with the Road Traffic Law and other regulations of the traffic industry and police in order to ensure life safety and prevent property losses when traveling through road tunnels.

IV. CONCLUSIONS

Any country that wants to develop its economy must invest in the construction and development of road transport infrastructure.
Tunnel is a component of the road route, especially at intersections in urban areas or long road routes that have to overcome large obstacles, tunnel construction is a possible solution. In addition to the advantages of the tunnel, the organization and management of the

exploitation need to pay attention to many aspects to ensure the safety of people and vehicles when traveling through the tunnel such as ventilation, lighting, leakages, water penetration, vehicle speed or major incidents such as fire, explosion, accident, etc. On the other hand, the article also proposes the contents of the tunnel operation process in terms of technical documentation management, methods tunnel maintenance in order to maintain the service function of the tunnel as well as monitor the tunnel's operation in order to provide appropriate technical solutions in maintenance and repair work, especially traffic tunnels in the complex intersections in urban areas with high traffic density; and capital recovery to ensure capital for the exploitation process. Currently, the organization and operation of road tunnel works is not managed by professional units as well as the lack of an official process applied throughout the country. Therefore, the article proposes a basic process in the management and exploitation of road traffic tunnels, which can be immediately applied to underground tunnels in urban areas of Vietnam.

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