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# A Study on the Risk Management Tools against Infectious Diseases in the Port-Utilizing Semi-Quantitative Bow-Tie Method*

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**Abstract**: *Due to the global epidemic of infectious diseases, it has become important for all industries to respond to the risk of infectious diseases. Ports in each country are also responding to the risk of infectious diseases, but the occurrence of infectious diseases in ports of various countries is causing a lot of damage to the logistics of ports. Korea is in the same situation, and cases of infectious diseases in ports are steadily being announced. Therefore, this paper conducted semi-quantitative Bow-Tie risk assessment by substituting measures to cope with infectious disease risks in Korean ports into actual cases of port infectious diseases in Korea, deriving improvements and suggesting directions. As a result, it was concluded that it was necessary to standardize some of the countermeasures against infectious diseases and develop more countermeasures.*

**Keywords**: *risk assessment, independent protection layer, semi-quantitative Bow-Tie assessment method, port infectious disease, port of Korea*

## 1. Introduction

Since the emergence of a novel coronavirus that causes Severe Acute Respiratory Syndrome(SARS) in Wuhan, China, in late February 2019, global infections and deaths have occurred so far in 2021. The novel coronavirus was named COVID-19, and the main infection route was various transmission routes such as including droplet transmission, confined space respiratory droplet infection, aerosol infection, mediated contact infection, and direct contact infection, and high infection rates. This soon spread around the world, causing a paradigm of converting the structure of various industries around the world into non-face-to-face to prevent the spread of infectious diseases.

However, the logistics process that connects the production and consumption of products, especially ports, had no choice but to face practical limitations in which all processes were not yet performed in perfect non-face-to-face. As a result of continuing logistics activities along with preventing the spread of infectious diseases in a state where such a complete non-face-to-face conversion is impossible, cases of infectious diseases occurred at ports. These cases occurred despite the implementation of measures to prevent and reduce damage according to the port's guidelines and manuals for responding to infectious diseases, and the frequency of damage has been about 30 times over the past year. Due to the nature of the port, the port's infectious disease response plan can play an important role in preventing the inflow and spread of infectious diseases overseas because it is easy to spread to workplaces and local infections. Therefore, it hypothesized that national attention and efforts were focused on blocking and spreading infectious diseases in ports, but the cause of infection and spread was that there were complementary points in the guidelines and manuals for responding to infectious diseases in ports. Afterwards, an independent protection class will be prepared based on the port infectious disease disaster response manual and actual cases, and the semi-quantitative Bow-Tie assessment method will be implemented based on the outbreak data, and supplementary points will be presented to the existing infectious disease disaster response manual.

As a result, this study was able to quantitatively assess the port's infectious disease risk response manual, which is expected to increase the importance of infectious disease risk management in risk management of domestic ports.

This study is conducted for the purpose of assessing measures to cope with the risk of infectious diseases in Korean ports and supplementing the manual. To achieve the above objectives, prior studies on port risk management at domestic and foreign were explored, infectious disease risk response measures were explored to assess the risk of infectious diseases at ports, and cases of infectious diseases in

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domestic ports were collected through media announcements from April 2020 to March 2021.

Based on this, the semi-quantitative Bow-Tie assessment method for the preparation of independent protection layer for port infectious diseases and response to port infectious diseases was applied, and the results and actual port infectious disease disaster response guidelines were presented.

In this paper, chapter 2 deals with target infectious diseases (COVID-19), countermeasures against infectious diseases at ports, and the Bow-Tie method. Chapter 3 deals with the framework for applying infectious disease risk to the semi-quantitative Bow-Tie theory. Chapter 4 deals with the semi-quantitative Bow-Tie method evaluation of infectious disease risk, and Chapter 5 deals with the evaluation results, significance, and limitations of this study.

## 2. Infectious Diseases and Countermeasures in Port

### 2.1 Infectious Diseases and COVID-19

Infectious diseases are diseases caused by long-term proliferation of pathogens (primary causes such as bacteria, viruses, microorganisms, and parasites) or toxic products that invade the human body, and are transmitted directly from humans or animals through inanimate media. Here, the status (human, animal, soil, etc.) in which pathogens can survive and multiply and spread to hosts with sensitivity (disease-prone nature) is called a reservoir, and the escape of the pathogen from the reservoir into another reservoir is called an transmission.

In Korea, the Infectious Disease Prevention and Management Act categorizes infectious diseases into first to fourth infectious diseases and parasite infectious diseases, infectious diseases subject to World Health Organization surveillance, bioterrorism infectious diseases, sexually transmitted infectious diseases, common infectious diseases, and medical-related infectious diseases.

COVID-19 is the first coronavirus and beta viral disease that occurred in Wuhan, China in December 2019 and spread to China and around the world, and the new coronavirus was named SARS CoV-2 by International Commission on Taxonomy of Viruses (ICTV) and the resulting disease was named COVID-19 by World Health Organization (WHO).

COVID-19 transmission is the main cause of transmission by droplets of infected people, but transmission by surface contact and air contact within limited circumstances is also possible. The incubation period is 1 to 14 days and the average is 5 to 7 days. For diagnosis, negative and positive diagnosis is determined through a polymerase chain reaction (Polymerase Chain Reaction) Symptoms of the disease range from asymptomatic, mild, moderate, and severe. The main symptoms of COVID-19 infection include fever above 37.5℃, cough, difficulty breathing, chills, muscle pain, headache, sore throat, loss of taste and smell, fatigue, loss of appetite, phlegm digestive symptoms, and dizziness. There is no specific treatment for COVID-19 yet, and symptomatic treatments such as fever reducer, fluid supply, and release are performed depending on the symptoms, and oxygen supply is also performed in case of shortness of breath.

The global fatality rate varies from 0.1 to 25% due to various factors such as region, population age structure, and infection status. (In WHO, it is corrected to 0.00% to 1.63%, median 0.27)

Preventive measures include COVID-19 vaccine approved by the Ministry of Food and Drug Safety, proper hand washing, cough etiquette, no touching eyes, nose, and mouth with unwashed hands, and frequent disinfection and ventilation of the surrounding environment.

### 2.2 Case of Infection in Port of Korea

Media searches were conducted through portal sites from April 2020 to March 2021 to identify risk factors in the process of inflow and spread of infectious diseases (COVID-19) at ports. As a result, 31 cases of port infectious diseases were collected and classified as Table.1.

Table 1 Infection Case of COVID-19 in ports of Korea

| Num | Infection Reason | Infection Consequance | infectee Num | Checkup Num | Port-closed Period |
|---|---|---|---|---|---|
| 1 | R-1 | C-1 | 2 | 30 | - |
| 2 | R-1 | C-3 | 16 | 113 | 14days |
| 3 | R-1 | C-1 | 1 | 84 | - |
| 4 | R-1 | C-1 | 1 | 44 | - |
| 5 | R-1 | C-1 | 5 | 110 | - |
| 6 | R-1 | C-1 | 1 | 23 | - |
| 7 | R-1 | C-1 | 6 | 17 | - |
| 8 | R-1 | C-4 | 53 | 107 | - |
| 9 | R-1 | C-1 | 1 | 20 | - |
| 10 | R-2 | C-1 | 5 | 16 | - |
| 11 | R-1 | C-1 | 4 | 21 | - |
| 12 | R-1 | C-1 | 11 | 23 | - |
| 13 | R-1 | C-1 | 3 | 20 | - |

| | | | | | |
|---|---|---|---|---|---|
| 14 | R-1 | C-1 | 7 | 21 | - |
| 15 | R-1 | C-1 | 2 | 10 | - |
| 16 | R-1 | C-1 | 1 | 25 | - |
| 17 | R-1 | C-1 | 11 | 40 | - |
| 18 | R-1 | C-1 | 2 | 16 | - |
| 19 | R-1 | C-1 | 12 | 105 | - |
| 20 | R-1 | C-1 | 2 | 24 | - |
| 21 | R-1 | C-1 | 21 | 21 | - |
| 22 | R-2 | C-1 | 1 | 121 | - |
| 23 | R-1 | C-1 | 4 | 24 | - |
| 24 | R-1 | C-1 | 2 | 86 | - |
| 25 | R-1 | C-1 | 22 | 28 | - |
| 26 | R-2 | C-1 | 3 | 420 | - |
| 27 | R-2 | C-2 | 5 | 235 | - |
| 28 | R-1 | C-2 | 4 | 211 | - |
| 29 | R-1 | C-2 | 5 | 482 | - |
| 30 | R-1 | C-4 | 26 | 348 | 2days |
| 31 | R-1 | C-2 | 14 | 343 | - |

*R-1 : Entry of a ship through a dangerous area
*R-2 : Local community infected people enter the port
*C-1 : Block the spread of infectious diseases in the port
*C-2 : Some of the workplaces in the port are closed
*C-3 : The Dock is closed
*C-4 : Spreading to the community

Source : Searched Articles on a Portal(www.naver.com, Used Keyword- "Covid-19 Infected in Port", Period- 1. Apr. 2020-31. Mar. 2021.)

Currently, the procedures and measures for responding to infectious diseases in ports of Korea are based on the Ministry of Health and Welfare and the Ministry of Disease Control Standard Manual based on Article 345 of the Framework Act on Disaster and Safety Management and Presidential Directive No. 388. The manual above stipulates detailed response procedures and various measures to be applied by each port corporation in the event of an infectious disease crisis. Although the port's countermeasures against the risk of infectious diseases vary in detail (organization, department, etc.), they are carried out step by step according to the level of infectious disease crisis warning (attention-caution-alert-warnning). Each stage can be divided into an attention and caution stage, alert and a warnning stage according to the establishment and operation of the emergency task force (headquarters). In the case of attention and caution, the safety department collects infectious disease-related information, strengthens monitoring of infectious diseases at domestic and foreign, strengthens port access control, and prepares for installation and operation, collects information related to infectious diseases, strengthen monitoring of infectious diseases at domestic and foreign, strengthen port access control, and prepare for the establishment and operation of emergency task force (headquarters). At the alert stage, measures such as installation, operation, inspection, and quarantine activities (demand survey and support for quarantine products, quarantine of port workers and users, quarantine at workplaces, support for quarantine facilities, etc.) and on-site inspections are carried out. In the last warnning stage, the government will strengthen its internal and external transmission and reporting system, including strengthening reporting systems with the Ministry of Oceans and Fisheries (emergency headquarters) and quarantine agencies (conference response and cooperation, spread countermeasures, and report status).

## 2.3 Countermeasures of Port Authority

Table 2 The Level of Infectious Diseases Crisis Warnning

| Stages | Contents |
|---|---|
| Attention(Blue) | · When receiving a crisis alert, spread it to port-related agencies/company.<br>· Establishment of a response plan for each stage of crisis alert issuance.<br>· Identify ship trends related to countries with infectious diseases.<br>· Port access control and port facility management.<br>· Collection and dissemination of information related to infectious diseases.<br>· Prevention promotion and network inspection. |
| Caution (Yellow) | · Preparation and inspection of the establishment and operation of the emergency task force (headquarters)<br>· Reinforcement of countermeasures and monitoring system to block domestic inflow (external outflow)<br>· Control of port access and strengthen management of port facilities and ships.<br>· Collection and dissemination of telegrams related to infectious diseases (cooperation of the Ministry of Oceans and Fisheries, quarantine station, etc.)<br>· Promote rules for responding to infectious diseases inside and outside the port. |
| Alert (Orange) | · Establishment and operation of an emergency countermeasure team (headquarters)<br>· Identify incoming and outgoing ships and trends in ports.<br>· Control of access to the port and strengthen management of port facilities and ships.<br>· Support for port quarantine, inspection and quarantine resources of affiliated institutions and facilities.<br>· Support for higher-level institutions (Ministry of Oceans and Fisheries and Regional Maritime Affairs Agency) and strengthen the cooperation system of related organizations. |
| Warnning (Red) | · General manager of the operation of the emergency task force (headquarters)<br>· Strengthen the monitoring system for infectious diseases (strengthen monitoring of ships and sailors in the country of origin, identify trends)<br>· Reinforcement of access control to ports and facilities Reinforcement of port facilities and ship management.<br>· Support for higher-level organizations and strengthen cooperation with related organizations.<br>· Response to the occurrence of an infectious disease (request for establishment of a screening clinic, work system and schedule adjustment plan for the occurrence of an infectious disease, and management of personnel in the port) |

Source : Action Manual for Responding to Infectious Diseases and Disasters, BPA/YGPA/IPA, 2020.

### 2.4 Bow-Tie method in Port Risk Management

According to "Action Manual for Responding to Infectious Diseases and Disasters", the port of Korea's infectious disease risk response plays a role in blocking the spread of infectious diseases at domestic and foreign in the event of an infectious disease disaster by implementing countermeasures according to the infectious disease crisis warning stages. However, despite the risk management of infectious diseases based on the action manual, several cases of infectious diseases were reported at ports in Korea, resulting in the closure of docks and the spread of infectious diseases to local communities. In addition, it was not known how much the implementation of the infectious disease disaster response measures presented in Action Manual for Responding to Infectious Diseases and Disasters had a preventive or reduction effect on the occurrence and the loss for spread of infectious diseases in ports. Therefore, in this paper, it is necessary to present problems and improvement directions derived by setting infectious diseases as risks at ports, performing prevention and reduction measures suggested in the Action Manual for Responding to Infectious Diseases and Disasters, and assessment their results.

The exact date and time of development and use of the Bow-Tie method are not known in detail. However, it is known that David Gill of ICI plc named it Bow-Tie after developing a methodology in the late 1970s, and later appeared in the literature as a methodology in the ICI Hazen Course Note of the University of Queensland, Australia in 1979. Later, in the mid-1990s, Royal Dutch and Shell introduced Bow-Tie assessment method throughout the workplace process, which became common as other companies in the industry introduced Bow-Tie assessment method.

According to the guidelines of the Korea Occupational Safety and Health Agency, the Bow-Tie risk assessment method is a risk assessment method to analyze and explain preventive measures and reduction measures along the risk path from Hazard to Results. These risk paths can be identified, prevented, and analyzed visual risk paths through the Bow-Tie diagram, which can be confirmed in Fig. 1. below. Fig. 1. shows scenarios related to the cause of thought (FTA) on the left in the form of Fault Tree Analysis (Consequence) with major occurrences of accidents at the center from Hazard, and scenarios related to ideas (ETA) on the right, and preventive measures between causes, thoughts, and results.

The Bow-Tie method can explain the entire process of risk assessment of the process introduced as a leader and a keyword, and can help everyone understand, including evaluators, workers involved in the actual process, and local residents affected by the process. In addition, risk assessment and its management can be applied based on this, and risk assessment can be developed and improved through development with quantitative and semi-quantitative risk assessment method. As a result, Bow-Tie risk assessment method can be applied, evaluated, and managed across multiple fields such as environment, safety, sales, politics, and security.

The assessment procedure of the Bow-Tie assessment method follows the order of risk assessment according to the progress of the diagram, which was summarized as Fig.1. according to the guidelines of the Korea Occupational Safety and Health Agency.

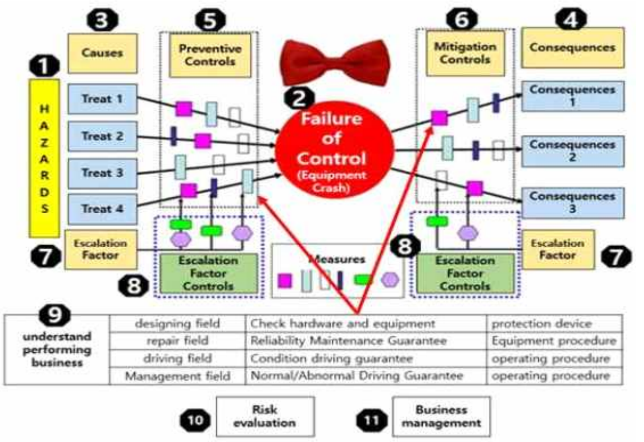


Fig. 1 Bow-Tie Risk Assessment Diagram
Source : Guide for Semi-Quantitative Bow-Tie Assessment Method, KOSHA, 2011

There have been many previous studies dealing with risk management of shipping and ports. Research has been conducted on various shipping and port risks, ranging from Risks of container at sea transport(Nam and Park, 2001), port traffic safety(Yang, 2003), marine security management(Jeong, 2012), port risk management(Kim, 1991), Assessment of the Marine Traffic Safety(Kim et al., 2002) risk about loading in port assessment(Nam et al, 2006), Management of Hazardous Substance management in port(Yoon et al., 2018), and port risk assessment(Yoon et al., 2019). However, most of the studies dealt with only the overall risks that navigation accidents and ports could have, and the research was conducted on risks that had been dealt with before. In addition, most of the methodologies used cannot be applied directly to practice, so it is considered to be inappropriate for the analysis and assessment of risks that must be applied directly to practice, such as infectious diseases.

And previous studies applying the Bow-Tie risk assessment method have been conducted on various topics across various fields. Previous studies mainly focused on science and engineering processes such as A study of Tae et al.(2013) applying the Bow-Tie assessment method to the risk assessment of chemical manufacturing process, application of the Bow-Tie assessment method to reduce risks in the acrylic acid use process by Kim(2018), and A study of Kim(2020) using the Bow-Tie assessment method in safety management plan for each risk factor and risk factor in the logistics warehouse. However, Lee(2019) studies have also been conducted to apply the Bow-Tie assessment method to the development of production worker's anxiety behavior analysis system, and to derive measures to improve safety management of container terminals in ports by Park et al.(2018). As in Mokhtari et al.(2011), it has been confirmed that there are many precedents that apply the Bow-Tie assessment method to risk management system analysis of overseas ports and container terminals, targeting human elements or qualitative topics of safety management.

Therefore, not only can the Bow-Tie assessment method be applied to a specific risk of "infectious disease" in the special industry of "port," but also the cause, preventive measures, occurrence, reduction measures, and results can be expressed schematically through Bow-Tie diagram, and qualitative or semi-quantitative assessment of each factor. So, in this study, the Bow-Tie assessment method is used as an assessment method for responding to the risk of infectious diseases in domestic ports.

## 3. A Framework of Semi-Quantitative Bow-Tie Method for Infectious Diseases Risk in Port

In order to proceed with the Bow-Tie assessment, an assessment table must be prepared after checking the target's process, preparing an assessment model, and deriving the probability and values of each element. Therefore, through the above three steps, we intend to conduct a semi-quantitative Bow-Tie assessment of the risk of infectious diseases in the port.

### 3.1 Checking the Process of Ports

In order to evaluate the risk of infectious diseases in a port, it is necessary to first check the port's process. The inflow and spread of infectious diseases into ports can be seen as two cases: ship → port → area and ship ← port ← area. The first non-infected infectious disease in Korea can be divided into two types of transmission inside and outside the port due to the entry of infected or infected people from ships entering from abroad. Since the two types of ports are in a connected position, it can be said that it is important to detect and block infectious diseases at ports. To this end, it is most important to understand how the host, who carries infectious diseases to the port, enters and moves. Although the routes of visitors to the port are all different depending on their affiliation, regular/temporary access, purpose, and status, it is possible to classify the port access process according to their role and purpose, and the results are shown in Fig. 2.

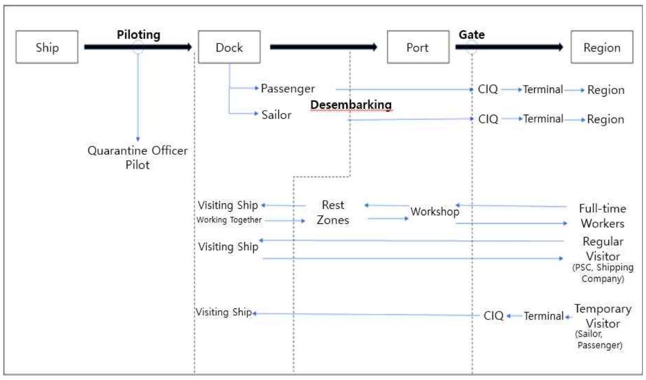

Fig. 2 The Process Chart of Port Entrance

The above process chart categorizes the identities of personnel (quarantine officers, ferrymen, passengers, crew members, workers, and visitors) and then largely categorizes the movements according to each status. As a result of synthesizing Table 1 and Figure 2, there are two main risk factors for the spread of infectious diseases at ports.

The first is the case in which a port is infected and transmitted to the local community due to the spread of infectious diseases between sailors, ship visitors, and workers in a port from a ship passing through an infection-risk country.

The second is the case where people suspected of infectious disease infection and contacts with infectious diseases visit the port from the local community and spread the infectious disease within the port during the work process.

Scenario arising from the above two risk factors was selected as the target scenario for assrssment, and a semi-quantitative Bow-Tie assessment model was created.

### 3.2 Making Semi-Quantitative Bow-Tie assessment Model(part.1)

Since the semi-quantitative Bow-Tie assessment method basically follows the concept of Independent Protection Layer(IPL), it was applied to IPL for prevention/reduction measures used in the port's countermeasures to infectious diseases. IPL is the concept that in order for any potential risk to be the worst result, it appears when all of the various protective layers surrounding the risk fail. A schematic diagram of the concept of IPL is shown in Fig. 3.

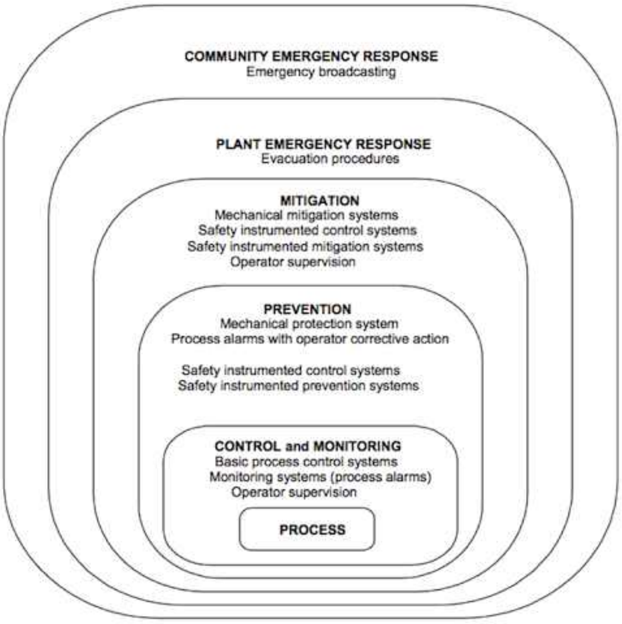


Fig. 3 The Schematic Diagram of Independent Protection Layer

Source : Guide for Semi-Quantitative Bow-Tie Assessment Method, KOSHA, 2011

However, in the case of port infectious disease risk assessment, it is difficult to introduce mechanical systems such as monitoring systems(process alarms), safety instrumented control/prevention system, mechanical protection system. Therefore, this is summarized and corrected by referring to the guidelines for responding to infectious disease disasters in the port of Korea. It was modified as shown in Fig. 4.

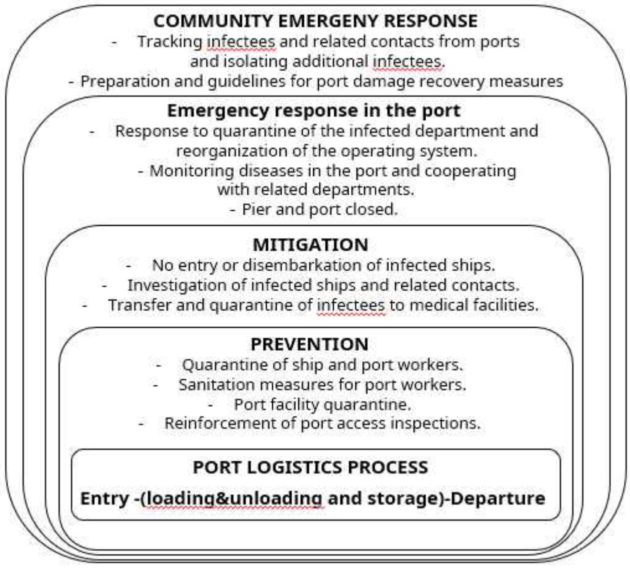


Fig. 4 The Schematic Diagram of Independent Protection Layer of Port

Factors to enter the Bow-Tie diagram through the above process are selected by referring to the action manual of PA and corrected IPL of port.

Hazard identification is a human and material factor that can cause direct or indirect damage and is at the center of risk assessment. In this study, the 'global epidemic of infectious diseases', which is the biggest threat to the occurrence of the risk of infectious diseases in ports, was selected as a harmful risk factor.

Event is the first event in risk assessment to derive a full range of results regardless of the severity of the outcome of the scenario. In this study, the most basic factor in the damage caused by the occurrence of infectious diseases, the occurrence of confirmed infectious diseases in ports, was selected as the idea.

Treat(T) is all the causes of thought. Since the idea in this study is the occurrence of infectious diseases in the port, two factors were selected as threats: entry of ships through infectious disease-risk areas, and entry of infected people outside the port(community).

Consequence(C) is the final result of an accident threat and is a step of grasping its impact. Referring to Table. 1, the results of this study derived four things: blocking the spread of infectious diseases in ports, closing some workplaces in ports, closing docks, and spreading infectious diseases to local communities.

Preventive Control(P) refers to measures that prevent the cause leading to thought before it develops into thought. The measures referred to here are elements that include not only technical measures such as facility addition and improvement, but also essential measures such as blocking, management, and education. Preventive measures in this study include quarantine of ships, use of hand sanitizers and masks when entering and leaving ports, control of separation and contact between boarding workers (loading, ship repair), control of contact with other ships and port officials (sailors, crew, passengers), quarantine of infectious diseases (basic inspection).

Mitigation Control(M) is a countermeasure to prevent the spread of accident results to the most serious stage after the accident. In order to prevent the seriousness of infectious diseases in relation to the occurrence of infectious diseases in the port, measures such as blocking infectious diseases, tracking the number of people in contact with the infectious disease source, facility quarantine, etc. were considered and included. In this scenario, eight measures were drawn to find and isolate confirmed patients, quarantine close contacts and related contacts, close and quarantine related facilities according to confirmed patients, close facilities according to confirmed movements, Facility quarantine and full inspection of facility workers are conducted, Confirmed contact with outsiders, Isolation and inspection of personnel related to movement paths are conducted.

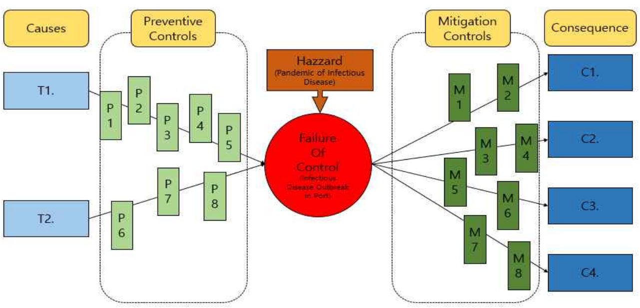


Fig. 5 The Bow-Tie Diagram about Infectious Diseases Risk in Port

*T1 : Entry of ships through infectious disease-risk areas
T2 : Entry of infected people outside the port(community)
C1 : Blocking the spread of infectious diseases in ports
C2 : Closing some workplaces in ports
C3 : Closing docks
C4 : Spreading infectious diseases to local communities
P1 : Ship quarantine
P2 : Use of hygiene and health equipment when entering the port.
P3 : Separation and contact control between the onboard operator (loading, ship repair) and the occupant.
P4 : Control of contact with other ships and port officials when disembarked (sailor, crew, passenger)
P5 : Conducting and quarantining infectious diseases of disembarkers.
P6 : Basic infectious disease tests are conducted during port access inspection.
P7 : Use of hygiene and health equipment when entering the port.
P8 : Minimize contact with workers and port officials in the port.
M1 : Finding confirmed patients and quarantine them quickly.
M2 : Investigate and isolate close contacts with confirmed patients and related contacts.
M3 : Isolating all workers related to the confirmed patient.
M4 : Closure of related facilities and inspection of related persons according to the movement of confirmed patients.
M5 : Close all facilities and isolate facility users according to the movement of the confirmed patient.
M6 : Facility quarantine and full inspection of facility workers are conducted.
M7 : Confirmed contact with outsiders.
M8 : Isolation and inspection of personnel related to movement paths are conducted.

### 3.3 Making Semi-Quantitative Bow-Tie assessment Model(part.2)

Then, the components of the Bow-Tie assessment model can be equipped by identifying and writing the escalation factors that weaken the preventive/mitigation measures and the escalation factor control that prevent them.

Escalation Factors (E) is a factor that weakens or invalidates the function of protective measures such as prevention/mitigation measures. Identification of escalation factors is a step to identify factors that indirectly affect p/m measures rather than direct prevention of ideas and reduction of results, such as p/m measures. The escalation factors derived in this study are 19 factors. Looking at some of the deteriorating factors derived, the deteriorating factors of preventive measures-ship quarantine include ship quarantine errors and insincerity in document and electronic quarantine. This can be seen as a factor that causes the failure of preventive measures such as ship quarantine due to errors or human obstruction in the system of the quarantine process.

Escalation Factor Control (EC) is a measure that maintains the normal role of prevention/mitigation measures by managing deterioration factors, and acts as an additional barrier on the p/m measures to strengthen the safety of p/m measures. The escalation factors prevention measures derived in this study were derived from 22 escalation factors prevention measures, including reference to previous infectious disease quarantine results after the epidemic, refusal to comply with quarantine.

Table 3 The Measures for P/M, E, EC.(Part.1)

| Preventive or Mitigation Controls(P/M) | Escalation Factors(E) | Escalation Factors Controls (EC) |
|---|---|---|
| P1: Ship quarantine | E1: Quarantine error | EC1: Refer to the quarantine results of infectious diseases at the previous stopover. |
| | E2: Failure to comply with document or electronic quarantine. | EC2: Penalties are imposed in case of non-compliance with quarantine or detection of insincereness. |
| | E3: Exposure of the risk of infection to the pilot and quarantine officer. | EC3: Compliance with the health and hygiene rules of the pilot and quarantine officers. |
| P2: Use of hygiene and health equipment when entering the port. | E4: Poor hygiene and health equipment. | EC4: Supplies and carries extra health and hygiene equipment. |
| | | EC5: Inspection of health and hygiene equipment before entering the port and working. |
| | E5: Not used due to environmental factors such as weather | EC6: Penalty for non-use. |
| P3: Separation and contact control between the onboard operator (loading, ship repair) and the occupant. | E6: Refusal to comply with the control of passengers and boarding workers | EC7: Penalties imposed on the departure of passengers and workers. |
| P4: Control of contact with other ships and port officials when disembarked (sailor, crew, passenger) | E7: Out of control of the disembarker and refusal to comply with the test. | EC8: Imposition of penalties for departure from control or inspection |
| P5: Conducting and quarantining infectious diseases of disembarkers. | E8: The disembarker's departure from control and refusal to quarantine | EC9: Penalties for departure or rejection |
| P6: Basic infectious disease tests are conducted during port access inspection. | E9: The entry's writing down false symptoms or refusing to comply with the test | EC10: Penalties for false entry or refusal to comply with the prosecutor |
| P7: Use of hygiene and health equipment when entering the port. | E10: Poor hygiene and health equipment | EC11: Provision of extra hygiene and health equipment only for those who enter the port. |
| P8: Minimize contact with workers and port officials in the port. | E11: Unauthorized contact with port officials of entrants and violation of hygiene and health rules. | EC12: Penalties for refusal to comply with instructions and controls. |

Table 4 The Measures for P/M, E, EC.(Part.2)

| Preventive or Mitigation Controls(P/M) | Escalation Factors(E) | Escalation Factors Controls (EC) |
|---|---|---|
| M1: Finding confirmed patients and quarantine them quickly. | E12: Refusal and escape/disappearance of the confirmed patient. | EC13: Resolving rejection of measures through safety education for infectious diseases in advance |
| M2: Investigate and isolate close contacts with confirmed patients and related contacts. | E13: Refusal to investigate/isolate contacts. | EC14: Resolving rejection of measures through safety education for infectious diseases in advance |
| M3: Isolating all workers related to the confirmed patient. | E14: Refusal to comply with confirmed patients/related workers and escape/disappear. | EC15: Resolving rejection of measures through safety education for infectious diseases in advance |
| M4: Closure of related facilities and inspection of related persons according to the movement of confirmed patients. | E15: Refusal to investigate the movements of confirmed patients/related persons and refusal/disappearance. | EC16: Resolving rejection of measures through safety education for infectious diseases in advance |
| M5: Close all facilities and isolate facility users according to the movement of the confirmed patient. | E16: Opposition to closure due to anxiety over the decrease in income of workers due to the closure of facilities. | EC17: Resolving rejection of measures through safety education for infectious diseases in advance |
| | | EC18: Implementation of import preservation due to facility closure |
| M6: Facility quarantine and full inspection of facility workers are conducted. | E17: Refusal to comply with the full inspection of facility workers and refusal/disappearance. | EC19: Resolving rejection of measures through safety education for infectious diseases in advance |
| M7: Confirmed contact with outsiders. | E18: In the case which the contact between the confirmed person and the outsider is unclear | EC20: By tracking the visit record and communication record of the confirmed patient, the route of movement is inferred. |
| M8: Isolation and inspection of personnel related to movement paths are conducted. | E19: The number of people related to the movement is unknown. | EC21: Mandatory visit records to prevent infectious diseases. |
| | | EC22: Based on communication records, inferring the movement path |

## 4. An Assessment of Infectious Disease Risk by Semi-Quantitative Bow-Tie method

### 4.1 Determining the Target Levels.

After selecting the scenario, the severity was set to the target level based on the severity-loss cost of the result according to the KOSHA guide. To this end, each loss cost must be calculated for each scenario result, and It can be assumed that losses occur in four dimensions as below.

1. Individual level suffered by infected people working at workplaces in the port and their related persons.
2. Corporate level suffered directly or indirectly by companies inside and outside the port that suffered losses due to the occurrence of infected people.
3. Port level in which losses occurred due to the occurrence of confirmed infectious diseases in the contracted company.
4. The port target commercial districts affected by the occurrence of confirmed infectious diseases in the port and the local level of residents.

Problems arise, such as where the liability for compensation for losses occurring within these four dimensions is located, and to what extent the scope and level of compensation are possible for each dimension. This is a practical problem such as data collection, determination of responsibility, and blurring the specification of the scope of calculation, making it impossible to accurately calculate. Therefore, the loss cost was divided into Cost of Personal Loss in Port (PC) and Cost of Corporate Loss In Port (CC) and calculated by substituting items (infected persons, inspectors, dock closure days) that can be found in the collected data.

$$PC = TN \times TC + AHP(AHC + AMI)$$
$$CC = CP \times APSR \times ASPC$$

$PC = Cost\,of\,Personal\,Loss\,in\,port$,
$TN = Test\,Number$,
$TC = Test\,Cost$,
$AHP = Average\,Hospitalization\,Period$,
$AHC = Average\,Hospitalization\,Cost$,
$AMI = Average\,Median\,Income\,per\,day$,
$CC = Cost\,of\,Corporrate\,Loss\,in\,port$,
$CP = Closed\,Period$,
$APSR = Annual\,Port\,Sales\,Ratio$,
$ASPC = Annual\,Sales\,of\,Port\,loading$ and $unloading\,Company\,in\,Shipping$ and $Port\,industry\,Sector$.

In above formulas, value of Test Cost(TC), Average Hospitalization Period(AHP), Average Hospitalization Cost(AHC), Average Median Income per day(AMI) in Cost of Personal Loss in Port(PC) derivation formula is refferred from Central Disease Control Headquarters, Media reports, KOSTAT. Their value were calculated for each KRW 106,480, 13.2 days, KRW 3,510,000, 78,000 won. And value of Annual Port Sales Ratio(ASPR), Annual Sales of Portloading and unloading Company in Shipping and Port Industry Sector(ASPC) in Cost of Corporrate Loss in Port(CC) derivation formula is depended on case of closing port.The only case in which the port was closed is Gamcheon Port (the proportion of Gamcheon Port's sales to the total sales of unloading companies among shipping and port industries in Busan Port is 16.9%). Therefore, the result of calculating the amount of damage by substituting the daily sales of a loading company in the shipping and port industry of Busan Port for KRW 6,054,224,658 is as Table. 5.

Table 5 Loss Costs due to the Occurrence of COVID-19 in the Port of Korea

| Num | Infection Consequance | Infectee Num | Checkup Num | Port-closed Period | PC (₩) | CC (₩) |
|---|---|---|---|---|---|---|
| 1 | C-1 | 2 | 30 | - | 12,273,600 | - |
| 2 | C-3 | 16 | 113 | 14days | 84,665,840 | 5,371,610,827 |
| 3 | C-1 | 1 | 84 | - | 13483920 | - |
| 4 | C-1 | 1 | 44 | - | 9224720 | - |
| 5 | C-1 | 5 | 110 | - | 34410800 | - |
| 6 | C-1 | 1 | 23 | - | 6988640 | - |
| 7 | C-1 | 6 | 17 | - | 29047760 | - |
| 8 | C-4 | 53 | 107 | - | 251,992,160 | - |
| 9 | C-1 | 1 | 20 | - | 6,669,200 | - |
| 10 | C-1 | 5 | 16 | - | 24,401,680 | - |
| 11 | C-1 | 4 | 21 | - | 20,394,480 | - |
| 12 | C-1 | 11 | 23 | - | 52,384,640 | - |
| 13 | C-1 | 3 | 20 | - | 15,748,400 | - |
| 14 | C-1 | 7 | 21 | - | 34,013,280 | - |
| 15 | C-1 | 2 | 10 | - | 10,144,000 | - |
| 16 | C-1 | 1 | 25 | - | 7,201,600 | - |
| 17 | C-1 | 11 | 40 | - | 54,194,800 | - |
| 18 | C-1 | 2 | 16 | - | 10,782,880 | - |
| 19 | C-1 | 12 | 105 | - | 65,655,600 | - |
| 20 | C-1 | 2 | 24 | - | 11,634,720 | - |
| 21 | C-1 | 21 | 21 | - | 97,567,680 | - |
| 22 | C-1 | 1 | 121 | - | 17,423,680 | - |
| 23 | C-1 | 4 | 24 | - | 20,713,920 | - |
| 24 | C-1 | 2 | 86 | - | 18,236,480 | - |
| 25 | C-1 | 22 | 28 | - | 102,852,640 | - |
| 26 | C-1 | 3 | 420 | - | 58,340,400 | - |
| 27 | C-2 | 5 | 235 | - | 47,720,800 | - |
| 28 | C-2 | 4 | 211 | - | 40,625,680 | - |
| 29 | C-2 | 5 | 482 | - | 74,021,360 | - |
| 30 | C-4 | 26 | 348 | 2days | 155,084,640 | 767,327,975 |
| 31 | C-2 | 14 | 343 | - | 100,077,040 | - |

The results of calculating the average cost for each scenario result classification and calculating the target level according to the target level setting criteria according to the severity of the results of the KOSHA Guide are as follows.

Table 6 Determining the Target Levels of Infectious Diseases

| Scenario Consequance | Average Loss Cost of Conquance (₩) | Criterion of Loss Cost (₩) | Setted Level | Determined Target level |
|---|---|---|---|---|
| C-1 | 41,171,058 | 10 ~ 100 million | 3 | 4 |
| C-2 | 83,505,904 | 10 ~ 100 million | 3 | 4 |
| C-3 | 5,456,276,667 | 1 billion ~ 10 billion | 1 | 6 |
| C-4 | 587,224,888 | 100 million ~ 1 billion | 2 | 5 |

## 4.2. Determining the probability of occurrence of consequences and threats

Determining the probability of occurrence of results and threats is difficult to derive quantitative probabilities due to the nature of the risk of infectious diseases. Therefore, the frequency of occurrence was extracted from Table 1, and the probability of occurrence of the KOSHA Guide and the formula for deriving the converted value (Table. 8, 9), and the converted value were derived.

Table 7 Converting Example for Probability of Occurrence

| Conversion Fomula | Converted Value | Meaning of Probability |
|---|---|---|
| $10^{-x} \rightarrow x$ | $10^{2} \rightarrow -2$ | Probability of occurrence 100 times a year. |
| | $10^{1} \rightarrow -1$ | Probability of occurrence 10 times a year. |
| | $10^{0} \rightarrow 0$ | Probability of occurrence 1 times a year. |
| | $10^{-1} \rightarrow 1$ | Probability of occurrence once every decades. |
| | $10^{-2} \rightarrow 2$ | Probability of occurrence once per century. |
| | $10^{-3} \rightarrow 3$ | Probability of occurrence once per millennium. |
| | $10^{-4} \rightarrow 4$ | Probability of occurrence once per 10,000 years. |

Source : Guide for Semi-Quantitative Bow-Tie Assessment Method, KOSHA, 2011

Table 8 Determining Example for Converted Value of Probability of Occurrence

| Conversion Fomula | Simple Converted Value | Converted Value of Probability of Occurance |
|---|---|---|
| $(0.50\text{~}0.99)\times10^{x}$ | $1.0 \times 10^{x}$ | $-X$ |
| $(1.00\text{~}4.99)\times10^{x}$ | $1.0 \times 10^{x}$ | $-X$ |
| $(5.00\text{~}9.99)\times10^{x}$ | $1.0 \times 10^{x+1}$ | $-(X+1)$ |
| $(0.50\text{~}0.99)\times10^{-x}$ | $1.0 \times 10^{-x}$ | $X$ |
| $(1.00\text{~}4.99)\times10^{-x}$ | $1.0 \times 10^{-x}$ | $X$ |
| $(5.00\text{~}9.99)\times10^{-x}$ | $1.0 \times 10^{-x+1}$ | $X-1$ |

Source : Guide for Semi-Quantitative Bow-Tie Assessment Method, KOSHA, 2011

Substituting the frequency of each cause and result extracted from Table 1 into the above probability of occurrence and conversion value derivation equation results in the values of Table. 9, 10.

Table 9 Converted Value for Probability of Occurrence of Threat

| Frequency of Threats | | Simple Converted Value for Probability of Occurrence | Converted Value |
|---|---|---|---|
| T-1 | 23 | -1 | -1 |
| T-2 | 8 | -1 | -1 |

Table 10 Converted Value for Probability of Occurrence of Consequence

| Frequency of Consequence | | Simple Converted Value for Probability of Occurrence | Converted Value |
|---|---|---|---|
| C-1 | 23 | -1 | -1 |
| C-2 | 5 | -1 | -1 |
| C-3 | 1 | 0 | 0 |
| C-4 | 2 | 0 | 0 |

## 4.3 Analysis of the performance of the Independent Protection Layer of preventive measures and mitigation measures.

Semi-quantitative Bow-Tie risk assessment requires appropriate current measures if the value obtained by multiplying the probability of cause of a scenario by the probability of failure of the protection layer for that scenario is less than the probability of result. If we summarize this process into a formula.

$fk = fi \times PFD1 \times PFD2 \times PFD3 \times \cdot\cdot\cdot\cdot\cdot\cdot\cdot \times PFDk$

or

$fk = fi \times y1 \times y2 \times y3 \times \cdot\cdot\cdot\cdot\cdot\cdot\cdot \times yk$

If $fk > fi \times y1 \times y2 \times y3 \times \cdots\cdots \times yk$,

the current countermeasures are appropriate.

If fk f $fi \times y1 \times y2 \times y3 \times \cdots\cdots \times yk$, additional measures are needed.

fi : Probability of cause occurrence

y1, y2, y3.... (or PFD1, PFD2, PFD3...): Probability of failure of each protection layer.

fk (f1, f2, f3...): Probability of occurrence of results

It can be expressed as above.

In the case of deriving the performance (IPL) of prevention and mitigation measures, the performance score of prevention and mitigation measures was imposed in accordance with the KOSHA guidelines.

Table 11 Determining the target level of Infectious Disease

| Category | Category Name | Score | Contents |
|---|---|---|---|
| Preventive Control (P) | P1 | 1 | Operation measures (when there is no warning value)-measures for abnormal conditions periodically collected by the checklist. |
| | P2 | 1 | In the case where strict disciplinary measures are not taken when wearing protective gear and not wearing protective gear. |
| | P3 | 1 | Door interlock device - 1 point for an easy-to-release rescue. |
| | P4 | 0.5 | When appropriate driving procedures or programs are prepared for each task and necessary training is performed appropriately, |
| | P5 | 0.5 | |
| | P6 | 0.5 | |
| | P7 | 2 | Wearing protective gear-A sign for wearing protective gear is attached to the site necessary, and strict disciplinary measures are taken when not wearing it. |
| | P8 | 0 | Criteria don't exist. |
| Mitigation Control (M) | M1 | 0.5 | When appropriate driving procedures or programs are prepared for each task and necessary training is performed appropriately, |
| | M2 | 0.5 | |
| | M3 | 0.5 | |
| | M4 | 0.5 | |
| | M5 | 0.5 | |
| | M6 | 0.5 | |
| | M7 | 0.5 | |
| | M8 | 0.5 | |

## 4.4 Semi-quantitative Bow-Tie assessment and results.

An assessment table is prepared and assessed based on the performance and probability of the factors derived in the previous step.

Table 12 Semi-Quantitative Bow-Tie Risk Assessment Table about Infectious Disease(COVID-19) in Port of Korea(Part. 1.)

| Scenario Routes | Target Level (A) | Converted Value of Probability of Occurance(B) | Prevention Measures(IPL) | | | | | | | | Total (C) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | P1 | P2 | P3 | P4 | P5 | P6 | P7 | P8 | |
| T1-C1 | 4 | -1 | 1 | 1 | 1 | 0.5 | 0.5 | | | | 4 |
| T1-C2 | 4 | -1 | 1 | 1 | 1 | 0.5 | 0.5 | | | | 4 |
| T1-C3 | 6 | -1 | 1 | 1 | 1 | 0.5 | 0.5 | | | | 4 |
| T1-C4 | 5 | -1 | 1 | 1 | 1 | 0.5 | 0.5 | | | | 4 |
| T2-C1 | 4 | -1 | | | | | | 0.5 | 2 | 0 | 2.5 |
| T2-C2 | 4 | -1 | | | | | | 0.5 | 2 | 0 | 2.5 |
| T2-C3 | 6 | -1 | | | | | | 0.5 | 2 | 0 | 2.5 |
| T2-C4 | 5 | -1 | | | | | | 0.5 | 2 | 0 | 2.5 |

Table 13 Semi-Quantitative Bow-Tie Risk Assessment Table about Infectious Disease(COVID-19) in Port of Korea(Part. 2.)

| Mitigation Measures(IPL) | | | | | | | | Total (D) | Appropriateness test. (B+C+D)-A | |
|---|---|---|---|---|---|---|---|---|---|---|
| M1 | M2 | M3 | M4 | M5 | M6 | M7 | M8 | | Score | If≥0, OK |
| 0.5 | 0.5 | | | | | | | 1 | 0 | OK |
| | | 0.5 | 0.5 | | | | | 1 | 0 | OK |
| | | | | 0.5 | 0.5 | | | 1 | -2 | Fail |
| | | | | | | 0.5 | 0.5 | 1 | -1 | Fail |
| 0.5 | 0.5 | | | | | | | 1 | -1.5 | Fail |
| | | 0.5 | 0.5 | | | | | 1 | -1.5 | Fail |
| | | | | 0.5 | 0.5 | | | 1 | -3.5 | Fail |
| | | | | | | 0.5 | 0.5 | 1 | -2.5 | Fail |

As a result of the assessment, the results of T1-C3, T1-C3, T2-C1, T2-C2, T2-C3, T2-C4, and T2-C4 were derived due to the failure to meet the IPL scoring criteria of P8 (Minimize contact with workers and ports in the port) and lack of mitigation measures in every scenario route. In order to supplement this Risk Assessment, it was found that it would be necessary to meet IPL standards through standardization of P8 and prepare more reduction measures.

## 5. Conclusion

From the end of 2019 to the present, the risk response of infectious diseases in all industries has been dealt with in the work process since the outbreak of infectious diseases worldwide (COVID-19). This was no exception to domestic ports, but the spread of infectious diseases could not be avoided during port logistics activities. With 31 cases of infectious disease infection and transmission occurring in domestic ports over a year, it is believed that it is necessary to assess the port's risk of infectious diseases, and it is expected that improvement measures can be derived through this.

This study attempted to collect and analyze cases of infectious disease infection at domestic ports during the period from April 2020 to March 2021 from media data through portal sites to assess risk and suggest improvement directions for countermeasures. As a result of analyzing the case, the assessment found that T1-C3, T1-C4, T2-C1, T2-C2, T2-C3, and T2-C4 were inappropriate for scenario execution due to insufficient IPL score criteria for P8 (minimizing contact with workers and port officials) and lack of mitigation measures in every scenario route. In order to supplement this risk assessment, it was found that it would be necessary to meet IPL standards through standardization of reduction measures P8 and prepare more reduction measures in the every scenario.

In order to secure empirical data, this study limited it to cases of infectious diseases (COVID-19) during one year (2020.04-2021.03) of domestic ports. Therefore, there are limitations in the study data itself (one target infectious disease, not many occurrence periods and numbers, large variations in causes and results of each case, and the exact amount of loss cannot be calculated), and the infection rate of infectious diseases (COVID-19) was high but not low. In addition, it is estimated that the loss amount in the entire scenario was underestimated because it was impossible to designate and derive data on the calculation of the loss amount by ports and communities in the process of estimating the loss amount. In addition, in the case of a partial closure scenario of a port workplace, delays and losses in work that occur between shift and inspection of workers after partial closure of the workplace will inevitably occur. However, there was no announcement about it, so it was impossible to include it in calculating the loss cost of a company. As a result, it is estimated that the loss cost of companies in the port was measured by a slight reduction in the amount of loss because there were no other than two cases of closure. In futher studies, it is considered necessary to expand cases after the expansion of the risk of infectious diseases, and additional studies and quantitative supplementation (precision of frequency, depth criteria, and loss calculation) are needed.

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