学　位　論　文　内　容　の　要　旨

博士の専攻分野の名称　　博士（工学）　　氏名　杜 倩倩

学　位　論　文　題　名

Vulnerability Scanning Methodologies Applied to Logistics Transportation Network
(物流ネットワークにおける脆弱性評価手法の構築)

Logistics activities play one of the most important roles, especially economically. Transport is a fundamental part of logistics activities, which services link a set of facilities in a logistics system. A reliable and efficient connection between each element of logistics system is becoming increasingly important. However, transportation infrastructure networks are under threats from either human interference or natural disaster. "Threats" may be cyclical disruptions such as daily congestion and maintenance activities, or unexpected events such as traffic accidents, structural breakdowns, natural hazards, or even more rare events like terrorist attacks, to mention a few. Under these threats that may cause a logistics facilities failing or degrading severely, reliability and efficiency are difficult be guaranteed in logistics transportation networks including thousands of links and nodes and complex transit systems. The vulnerability of transportation networks under unexpected threats has been the subject of growing attention in recent years. However, network vulnerability assessment has been focused on passenger transport mode. Logistics transportation networks have not yet been treated as specific subjects even if their definitions of trip failure and degradation are different from passenger transport. What matters most for the logistics case is different from the passenger case. In freight transportation networks, the best case is similar to passenger transport networks, but trip failure is not limited to when there is no route between origin and destination. The objective of logistics transport is to get the right materials to the right place at the right time while optimizing the total operational costs of this process. Some detour or increase in cost may cause the product to be damaged or have excessive cost resulting in selling failure, which also means the logistics transport fails. Logistics transportation networks are more sensitive to time and cost compared to passenger transport. The methodology used to assess vulnerability of logistics transportation networks should be developed in a different way to passenger or other transport mode.

This study attempts to find a methodology to properly address the character of logistics transportation network vulnerability. In order to evaluate the performance of logistics transportation networks, time value is included in the generalized cost of logistics transportation. The generalized cost of logistics transport network is proposed considering both time value and transport cost. From the logistics transport network user perspective, the generalized cost represents the trade-off between time consumption and travel cost because it includes both time value and cost. Moreover, network vulnerability assessment is impacted by the nature of the component degradation. The performance of logistics transportation networks is evaluated in different transportation facility degradation scenarios, including link and node degradation scenarios. Link degradation scenario is based on assumption that the single link disrupt pattern supposing that the attacks from nature or human society only result in single

link disrupted. However, the attack are also probably area covering and result in several links nearby disrupted. So the node vulnerability scanning is proposed to reflect this situation. The disruption of node representing intersection failure involving all links connected to it failed too.

The concept of vulnerability analysis is related to evaluating the consequences of network degradation caused by incidents such as social or natural disasters. Many methodologies have been proposed to evaluate transportation network vulnerability by quantifying the consequence of partial network degradation. These vulnerability indices consider only the consequences of incidents but not their probability. In practice, however, the probabilities of degradation between different parts, especially in large scale networks like inter-city logistics transportation networks, are quite different. Some components may have significant consequences in the event of degradation, but have very low probability of degradation occurring, so it may not be reasonable to say these parts are vulnerable to this disaster. There are different approaches for resisting different threats. For example, traffic control measures can be applied to reduce threats from daily traffic congestion, and structural measures can be taken to reinforce transportation networks to resist seismic disasters. If vulnerability is evaluated under specific disasters, the results would be helpful to take reinforcement measures to improve the network's ability to resist that disaster. In this study, Seismic Vulnerability Index (SVI) is proposed to measure vulnerability of logistics transportation networks under seismic disasters. This index considers both the difference caused by component degradation and also the probability of component degradation caused by seismic disaster. A seismic vulnerability scanning methodology is developed to evaluate the vulnerability of logistics transportation networks under seismic disaster.

All these methodologies mentioned above are applied in study networks, Hokkaido logistics transportation networks. This multiple logistics transportation network consists of express highway, national highway, prefecture arterial highway, railway, and maritime routes. Efficient vulnerability scanning algorithms are developed to make them applicable to transport network including thousands of nodes and links. Finally the infrastructures of logistics transportation networks are classified into different vulnerable categories and visual results of are demonstrated using Geographic Information System (GIS) technology. The visualize vulnerability categories are useful tool to detect the vulnerable spots of transportation network and corresponding policies can be made to mitigate vulnerability under threats.

The results of this study are expected to describe the vulnerability distribution in logistics transportation networks and provide assistance for making reinforcement policy to improve the reliability of transportation networks by reducing influence of potential threats. The research was undertaken to assist logistics managers, researchers and transportation planners to define and comprehend the basic views of vulnerability of logistics transportation networks and their various applications.