Research on Risk Control of Subway Operation System Based on Vulnerability Analysis

Fang Yifan

School of Economics and Management, Beijing Jiaotong University, Beijing, 100044, China

Email:evanfun1993@163.com

Abstract: With the increasing importance of the subway in the urban rail transit system, it is the primary task to ensure the safe operation of the subway by studying and analyzing the vulnerability of the subway operation system to strengthen the operation risk control of the subway. By combing the concept of risk and vulnerability, the paper concludes that vulnerability includes three factors: exposure degree, sensitivity degree and adaptable degree, and based on the AHV analysis framework, the evolution mechanism of subway system vulnerability is presented. According to the different influence and effects of different types of vulnerability in the accidents, a series of typical subway accident cases at home and abroad are analyzed and the vulnerability risk control model is established.

1. Introduction

Due to the vulnerability of subway operation system, more and more accidents happened. Husdal [1] (2004) studied the vulnerability of traffic from an economic point of view, arguing that reducing the vulnerability of the transport system and enhancing the robustness of the system could be used as a revenue for transportation system construction; Jenelius [2] (2006) calculated the importance of the road and the vulnerability of a certain section according to the User Equilibrium Model. Murry.AT [3] (2008) summarized the different kinds of traffic system vulnerability assessment methods. At home Ma Ying [4] (2006) studied the performance of consequences of accidents caused by the vulnerability of urban rail transit system; Zhang Lijia [5] (2010) used GIS Software to Analyze the vulnerability of rainstorm waterlogging of underground rail transit in Shanghai; Bai Yafei [6] (2013) constructed the vulnerability evaluation index system from the aspects of exposure degree, sensitivity degree and fitness degree, and some stations of Beijing subway were analyzed empirically. But how to control the risk of the subway operation system by analyzing the vulnerability needs further studies.

2. Analysis of the Concepts of Vulnerability

2.1 The Concept of Vulnerability

The paper combs the results of the definition of vulnerability in various fields, and selects some representative descriptions of vulnerability, as shown in Table 1:

Table 1 Partial representative definition of vulnerability[7-13]

Author	Year	Descriptions
Margat	1968	Vulnerability can be understood as self-protection and debugging

Timmerman	1981	Vulnerability is the degree to which an adverse response occurs when a disaster occurs.
Shang Yanrui	2000	Vulnerability refers to the extent to which a portion of the system is adversely affected by the occurrence of a disaster event.
Sarewitz	2003	Vulnerability is an internal attribute of the system which is the source of potential damage, and it has nothing to do with the probability of any disaster or extreme event.
Sherbinin	2007	Vulnerability is the degree of damage to the system or unit that is exposed to interference or pressure.
Liu Tiemin	2010	Vulnerability refers to the degree of exposure to danger.
Song Shouxin	2014	Vulnerability is a comprehensive representation of the exposure, sensitivity and adaptability of the operating system.

The author believes that vulnerability is one component of risk, which describes the inherent level of the carrier's response to the risk. As a matter of fact, the scale of impact, bear strength, and the ability to resist of the carrier when it's threatened, which can be described as carrier vulnerability in other words, is a key factor in determining the consequences of risk.

2.2 Evolution Mechanism of Vulnerability

Based on the logical relationship of AHV model framework, the concept of vulnerability and combining the characteristics of vulnerability of subway operation system, the paper classifies the characteristic factors of vulnerability into three aspects: exposure degree, sensitivity degree and adaptability degree, and constructs the analysis framework of evolution mechanism of subway vulnerability characteristics, as shown in Figure 1:

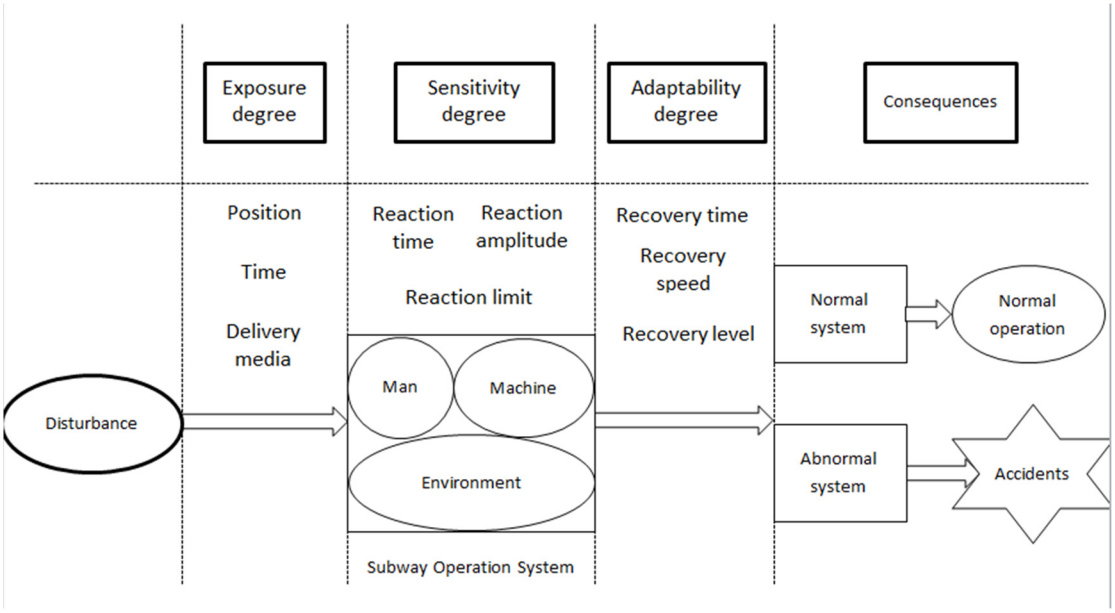

Fig.1 Evolution Mechanism of Vulnerability of Subway Operation System

3. Statistics of subway accidents and vulnerability analysis

The paper collects 99 typical subway accidents at home and abroad, and the results following were obtained:

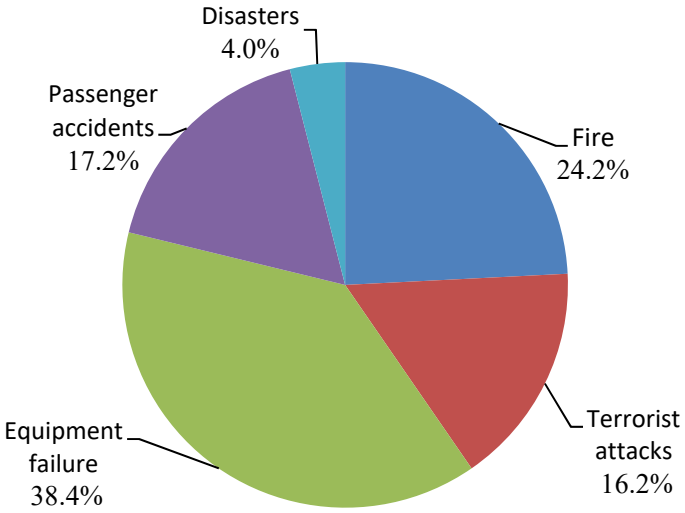

Fig.2 Statistics on the number of subway accidents

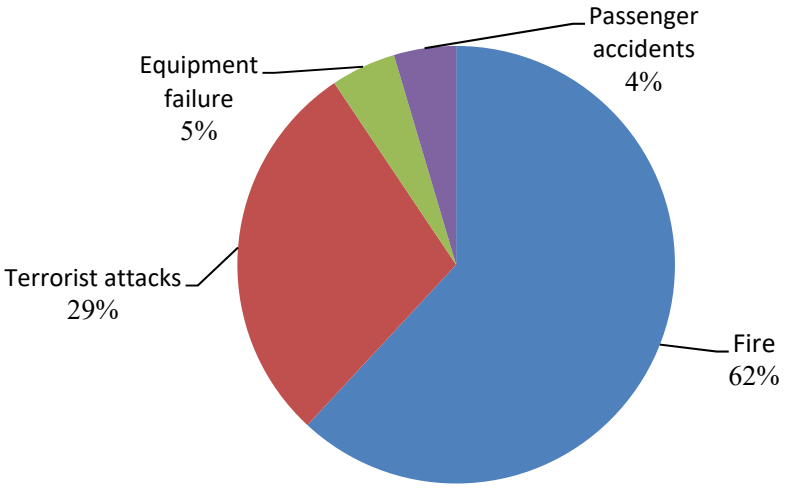

Fig.3 Statistics on death toll in the subway accidents

Combined with the characteristics and composition of the system itself, the vulnerability of subway operation system can be divided into physical vulnerability, structural vulnerability and functional vulnerability [14]. From the statistics of accidents above it is concluded that the occurrence of accidents is the result of the interaction of physical vulnerability, structural fragility and functional vulnerability, but different types of vulnerability factors shows different levels of the impact on the accidents, in other words, the impact of system vulnerability on the accidents will vary depending on the disturbance factors.

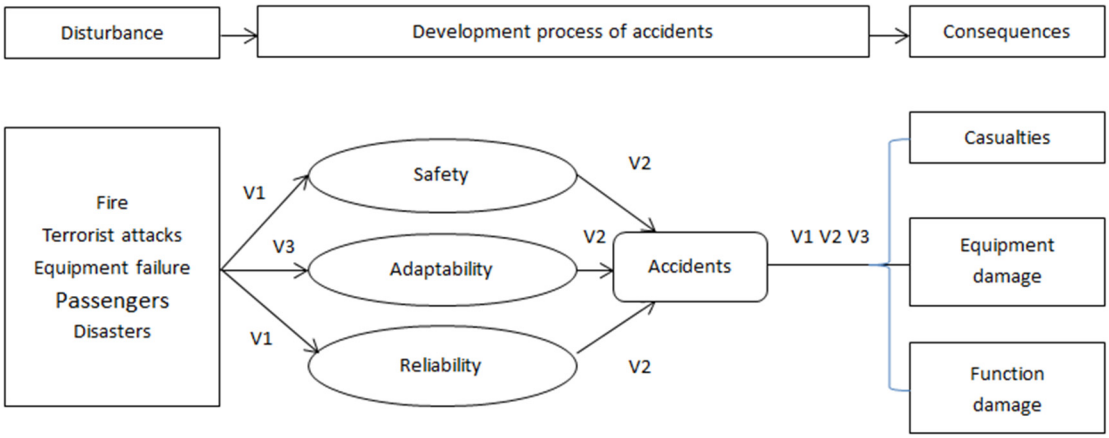

Fig.4 The Impact of Different Types of Vulnerability on Accidents
Annotations：V1: physical vulnerability; V2: structural vulnerability; V3: functional vulnerability

As shown in Figure 4, under the influence of disturbance factors, the physical vulnerability and functional vulnerability of the subway operating system will lead to some specific performance anomalies of the system, after these abnormalities occur, due to the structural vulnerability of the system, the impact of the disturbance in the entire subway network spread, and results greater losses and effects, which lead to the final accidents. These three types of vulnerability are not completely independent of each other in the process of the accidents, while they interact with each other, and lead to different consequences.

4. Risk Control for Vulnerability of Subway Operation System

According to the foregoing discussion, a subway system vulnerability risk control model can be established, as shown in Figure 5. The risk control of the subway operating system needs to proceed from the three characteristic factors of vulnerability and three different types of vulnerability. In terms of exposure degree, sensitivity degree and adaptability degree of the three elements, appropriate security measures can be taken measures to make the system safe; as for the three types of vulnerability, it is also possible to take different security measures depending on the impact of different disturbances.

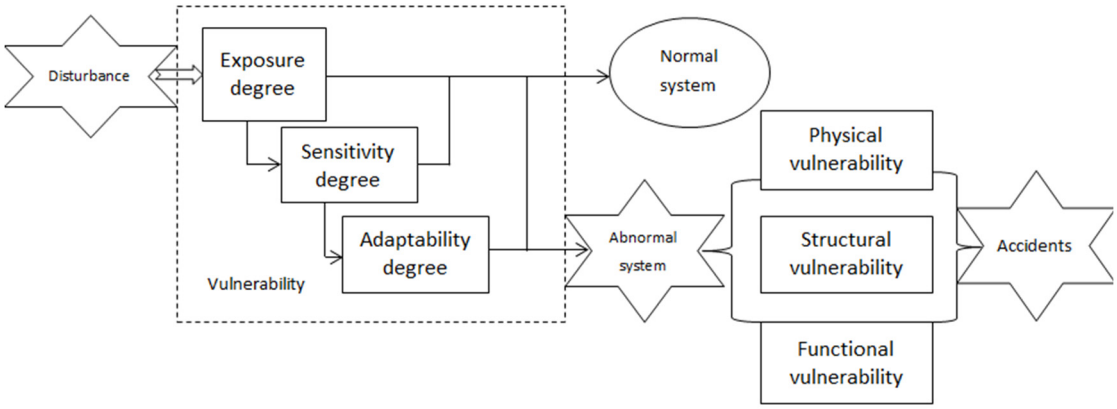

Fig.5 Risk Control Model for Vulnerability of Subway Operation System

5. Conclusion

Based on the literature research, this paper puts forward that vulnerability includes three elements such as exposure degree, sensitivity degree and adaptability degree, and that vulnerability is an integral part of risk, and shows the evolution mechanism of the three elements of vulnerability. In this paper, vulnerability is divided into physical vulnerability, structural vulnerability and functional vulnerability. The occurrence of an accident is the result of an interaction of physical vulnerability, structural vulnerability and functional vulnerability. To control the risk of the subway operation system, comprehensive measures should be taken from the both aspects of vulnerability's three elements and types.

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