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# Applying Systemic Accident Model to Learn from Near-Miss Incidents of Train Maneuvering and Operation

**Keisuke Fukuda*, ** . Tetsuo Sawaragi****
**Yukio Horiguchi**. Hiroaki Nakanishi****

**Safety Research Institute of West Japan Railway Company, Osaka, Japan*
*(Tel: +81-6-6627-8306; e-mail: keisuke-fukuda@westjr.co.jp).*
*** Kyoto University, Kyoto, Japan,*
*(e-mail:{sawaragi, horiguchi, nakanishi}@me.kyoto-u.ac.jp)*

**Abstract:** This study proposes a novel method for safety management in train operation and maneuvering based upon Hollnagel's functional resonance analysis method (FRAM), which assumes that components of a system interact mutually and resonantly. According to the original FRAM, the general functions of train drivers' and conductors' tasks are defined, and the normal procedure of a common case is represented. Our method first attempts to replay how fluctuations of some of the tasks propagate through the entire system. Then we examine whether a countermeasure found by replaying is valid under various situations. In this way, we demonstrate that our method is able to detect latent hazards of the system as well as to identify how the system is influenced by various external and internal changes.



*Keywords:* Safety analysis method, systemic accident model, functional resonance analysis method, human reliability analysis, human machine system, train operation and maneuvering, human error.

## 1. INTRODUCTION

Safety devices for railway maneuvering and operation have been improved and rules and organizations have been changed to prevent tragic occurrences. Although many experts have contributed to this effort, the complexity and interdependence of components of a railway system, as well as the constantly changing operating circumstances, make it difficult to predict success. When new technologies are applied for improving safety, risks related with their defects and human-related undesirable events should be considered carefully. Moreover, new technologies may introduce additional new risks, which may result in injury and loss through their interaction with components of the system. Thus, to make sure that safety is improved, safety analyses should be developed to realize remedies that take into consideration the complexities described above.

Many conventional methods of safety analysis operate on the assumption that undesirable occurrences can be represented by a linear accident model, which suggests that one factor leads to the next and so on, leading up to the accident (Hollnagel 2012). Although these methods are useful in identifying the relationships of factors, because of the complex interaction of systems it may be difficult to find explicit factors or critical causes (Carvalho 2009). Even when these are found and countermeasures are carried out, their effects may not be valid in all circumstances and may sometimes conceal fundamental or latent causes (Fan 2015).

In this work, a novel method of safety management for train maneuvering and operation tasks is proposed. Our method is based upon the concept of Hollnagel's idea of functional resonance. This idea considers a system to be composed of functions consisting of goals and means that interact mutually and resonantly, thus enabling the analysis of the emergence and evolution of unexpected activity (Hollnagel 2004 and 2012). As a target of the analysis, tasks carried out by train drivers and conductors are considered, and we attempt to apply our proposed method to reported cases that actually happened during train manuevering and operations.

First, we show the results of applying VTA (Variation Tree Analysis), a conventional linear accident method, and we discuss the limitations of the conventional method. We then implement the normal procedure of the targeted case based upon Hollnagel's FRAM (Functional Resonance Analysis Method) (Hollnagel 2004 and 2012). In this procedure, we replay how a tiny deviation is amplified and propagated through the interrelations between system components. We demonstrate the influence of countermeasures and changes introduced in the same situation as the targeted case and also in another case. Through this analysis, we show that our proposed method is useful and can play an important role in making countermeasures robust despite changing conditions.

## 2. SUMMARY OF THE DEMONSTRATION CASE

A single near-miss incident report is used to compare conventional linear analysis and our proposed non-linear analysis. An overview of the incident is provided. This case is constructed as a virtual incident case in which essential aspects of the actual incidents were reproduced.

OVERVIEW: Leaving station B, rapid train T1 reached station C and made a stop at the platform. Conductor D of train T1, who was tired because of inadequate sleep at the


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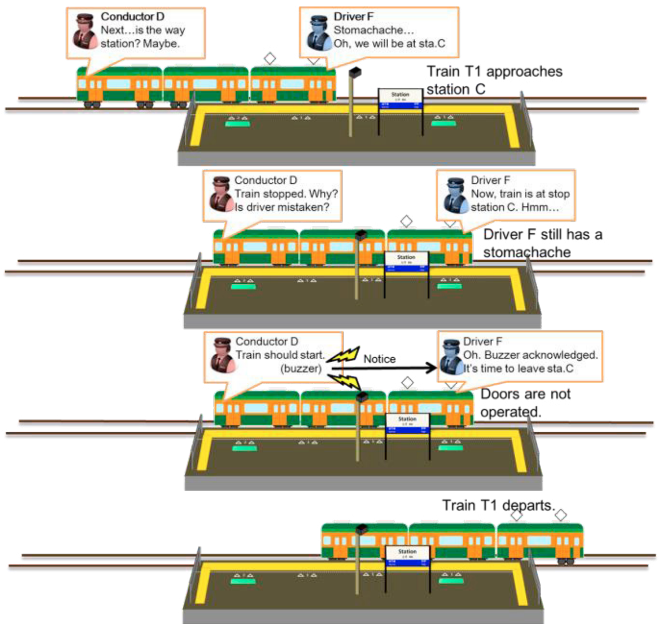


Fig. 1. Schematic view of the incident in the case.

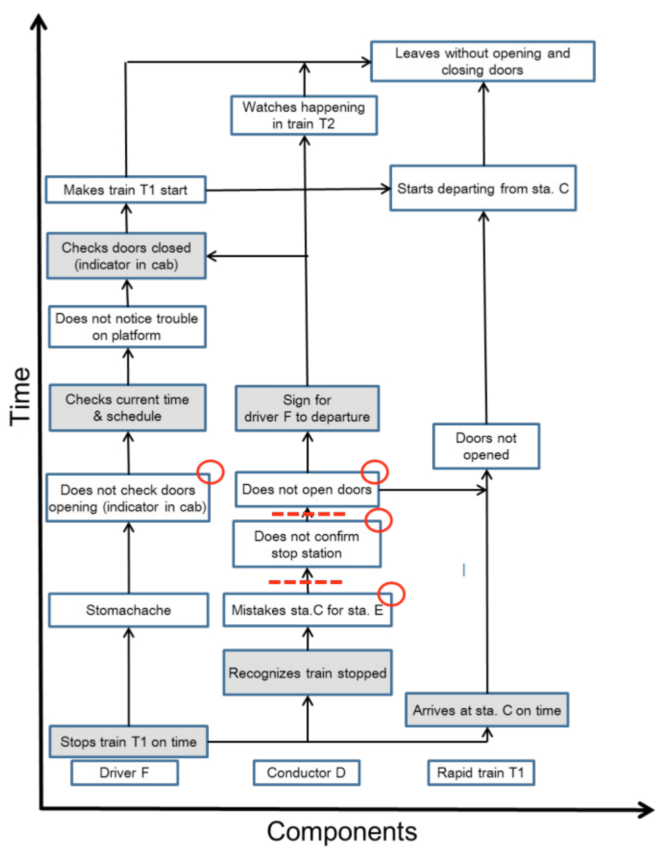


Fig. 2. Diagram of VTA application for the case.

crew lodging last night, was watching absently from inside the train mistakenly perceived station C as station E, which was a way station. Along this route, the stop stations were often changed, and some of the stations had similar scenery surrounding them. Therefore, conductor D did not open the doors for the passengers and signaled to driver F that the train was ready to depart. Driver F had a stomach ache that preoccupied him/her, and he/she did not checked the opening and closing of the doors based on the indicator light. Thus, driver F started the train in response to the signal sent by the conductor without confirming whether passengers had exited and boarded. Since he/she did not notice incoming passengers for train T1, it left the station without any passengers having exited or boarded.

## 3. LIMITATIONS OF LINEAR ANALYSIS

Most conventional accident analyses are based upon a linear accident model. One of these is the commonly used VTA. Fig. 2. shows the result of VTA applied to the present case. Events are written in boxes, and normal events are explicitly shown as colored boxes. This diagram helps to identify events which should be removed to break the chain leading to undesirable results (Leplat 1984). For instance, if one of conductor D's events, 'DOES NOT OPEN DOORS', is considered to be a removable event, a circle indicator is added to the box in which this event is written. If the connection between two events should be blocked a dotted line is added across the line that connects the two boxes on which the events are written.

For the present event, another crewmember who checks the doors opening and closing on the platform may be a possible countermeasure. If the doors of the train are not operated correctly, this crewmember could alert the conductor of the train that has stopped at the station. By this means, the event will be removed, and the final result 'LEAVES WITHOUT OPENING & CLOSING DOORS' will be prevented. However, countermeasures affect the normal procedure, which may generate another set of anomalies and variations such that an undesirable result may finally emerge. The VTA diagram provides no cues about how these events are linked, and thus we cannot identify the potential overall influence of countermeasures.

Thus, the linear method represents undesirable results by means of chains of events that are only valid if they are exactly the same as the targeted case. However the corresponding countermeasures further complicate the complex interrelations between system components. Thus, to prevent the emergence of another undesirable result, we need to develop a novel safety analysis that will make it possible to envision the influence of countermeasures, and, more important, will be applicable to a greater variety of situations.

## 4. NORMAL PROCEDURE AND EXAMINATION OF FLUCTUATIONS BY NON LINEAR ANALYSIS

Based on Hollnagel's FRAM, at first, primitive functions are defined with reference to the corresponding work manual in order to represent the normal procedure of the targeted work and to analyze the interrelations and propagation of fluctuations between functions. The functions represent the maneuvering and operation tasks of the train driver and conductor, defined as shown in Tables 1 and 2 respectively. By using this definition, the normal procedure of the targeted case described in section 2 is shown as (a) of Fig. 3. In the diagram of Fig. 3, functions and their interrelations are represented by hexagons and connection lines. Notations written in them represent the instantiated functions of Tables 1 and 2. For example, 'f73-2' means that the function is