Science and Engineering Technology: Railway Engineers' Moral Responsibilities for Passenger's Safety Travel

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***Abstract*— *In India, majority of people prefer rail transportation service to travel a short distance (i.e., within a city) and a long distance (i.e., from one state to another). India has the fourth largest railway network in the world, with a total length of 92,952 kilometers. A triple-train accident occurred on June 03, 2023 in India. In this dreadful accident, two superfast express trains' bogies and a freight train's wagons collided. Nearly 290 passengers were declared dead, while about 1300 suffered severe injuries. In this context, the paper critically examines Indian railway signaling and interlocking operating system and finds out the possible reasons for the train accident. It analyses how the train accident could have been avoided if signal and telecommunication engineers had incorporated their professional codes of ethics into their decision-making and actions. It analyses safety and reliability conditions of railway transportation. In the end, the paper suggests some important technological measures and ethical guidelines to avoid train accidents in future and thereby safeguard passengers' lives.*

***Keywords*— Decision-making, Railway Signaling System, Railway Transportation, Train Accident, Engineering Ethics.**

I. INTRODUCTION

In India, majority of people prefer rail transportation service to travel a short distance (i.e., within a city) and a long distance (i.e., from one state to another). India has the fourth largest railway network in the world, with a total length of 92,952 kilometers. On June 03, 2023, a train accident occurred in India. Two express trains (i.e., the Coromandel Express and the Yeshwantpur-Howrah Express) and a freight train collided. The Coromandel Express train veered to the loop line and crashed into the parked freight train. Consequently, its engine jumped onto the parked freight train, derailed its bogies, and threw some of its bogies to the opposite track where the Yeshwantpur-Howrah Express train passed by with a 128-kilometre-per-hour speed limit. Nearly sixteen bogies of the two express trains collided with each other. This accident led many members of the public to question rail safety in India. The National Disaster Response Force (NDRF) team arrived at the spot to rescue the survivors.

The honourable Railway Minister of India, Mr. Ashwini Vaishnaw, visited the accident spot and, by examining the accident's prima facie reports, said that "there is no error found from trains' loco pilots' side. The accident happened due to deliberate interface with the electronic interlocking system" (The Times of India, June 04, 2023). Three pictures are places below for the tragic train accident.

IMAGE 1: The Express train engine jumped onto the freight train wagons

IMAGE 2: Aftermath of the accident in Odisha, India

IMAGE 3: Accident site in Odisha, India

Research Questions

- How did engineers give the Coromandel Express train a green signal to divert its route to the loop line of the up-tracks despite a freight train already parked on it?
- If the green signal is given to the Coromandel Express train to move on a straight line of the up-track, can the loco pilots of this train veer the train to the loop line of the up-tracks?
- What are the signal and telecommunication railway engineer's ethical duties and moral responsibilities to maintain safe train movement on the track and provide safety and well-being of train passengers?
- What are the signal and telecommunication railway engineers' professional responsibilities towards signaling and computer-based interlocking systems?

The first and second questions are related to engineering tasks, whereas third and fourth questions deal with engineers' ethical and professional responsibilities for these tasks. These four questions summarily aim to analyze and identify railway engineers' ethical and professional responsibilities for providing passengers' safety during train travel.

II. METHODOLOGY

This paper considers scientific induction and inductive method to answer the research questions. According to J.S. Mill (1872), a scientific induction is meant to find a causal link among many empirical facts (premises), and based on the causal link, we can infer a logical, reliable, and justifiable conclusion. A scientific induction relies on the theory of causation that holds the following four true suppositions (Sethy, 2021). They are;

a) A cause exists; therefore, an effect exists.

b) A cause does not exist; therefore, an effect does not exist.

c) A cause can produce a particular designated effect.

d) If there are changes in the cause, there will be a change in the effect.

III. LITERATURE REVIEW

In 1856, John Saxby developed a mechanical interlocking system. This system controlled the signals, switches, and alerts about the wrong operation (Kon, 2004). In 1978, a computer-based interlocking system was developed and installed at Gothenburg station (Zhixi, 1999). It took care of signals, switches, and routes with simple maintenance and had high reliability, efficiency, and safety.

Railway interlocking system is the most fundamental and essential part of the signalling system (Huang, 2020). An interlocking system ensures train movements on the right track with the specified time sequence and the safety of passengers travelling from one station to another. India witnessed the development of a railway signalling system from a mechanical interlocking system to a computer-based interlocking system. A mechanical interlocking system is a situation where signal and telecommunication railway engineers' are required to manually lock the train's track for the train's movement. In the computer-based interlocking system, the computer gives the command, and a train's movement on a designated track gets locked from one station to another. In other words, the interlocking system refers to the restricted relationship between the signals, switches, and routes (Huang, 2020).

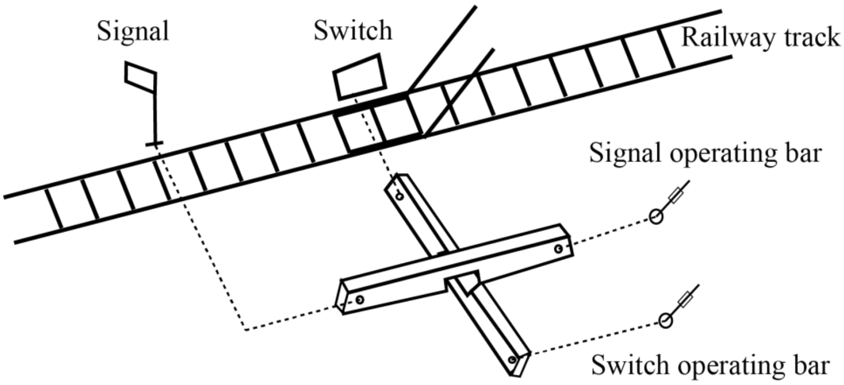

FIGURE 1: Mechanical Interlocking System (refer to Huang, 2020)

A railway interlocking system takes place in a four-step process: control panel, interlocking devices, actuators, and outdoor devices. In the Indian railway station, the signal and telecommunication railway engineers observe the control panel and its circuit indication point, providing information about the clearing state of a railway track, circuit, and conflicting route, if any. Considering moral and professional responsibilities, the signal and telecommunications railway engineer interlocks the system at the control panel. This, in turn, sends commands to actuators to lock the train track and provide the correct route and signal for a train's movement. The basic structure of the interlocking system is depicted in Figure-2 for reference.

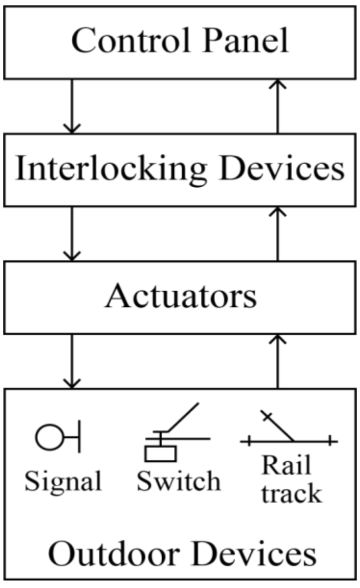

FIGURE 2: The basic structure of the interlocking system (refer to Huang, 2020)

The purpose of the interlocking system is to keep the train movement on track safely by connecting and arranging the switches, signals, and routes correctly so that train movements on track will not encounter conflicting situations about track diversion. According to Pachl (2002) and Sun et al. (2015), in the railway signalling system, an interlocking route is set when all points are correctly positioned and tracks are free; only then does the green signal appear for a train movement on an allotted track. In short, the green signal cannot be set if the route ahead of the train is not free (Sun et al., 2015, p.1). In this way, the interlocking system ensures the correctness of a train's movement on the right track to prevent accidents.

An electronic unit or board controls outdoor equipment in the computer-based interlocking system, such as switches, signals, and routes. Figure-3 below depicts a computer-based interlocking system.

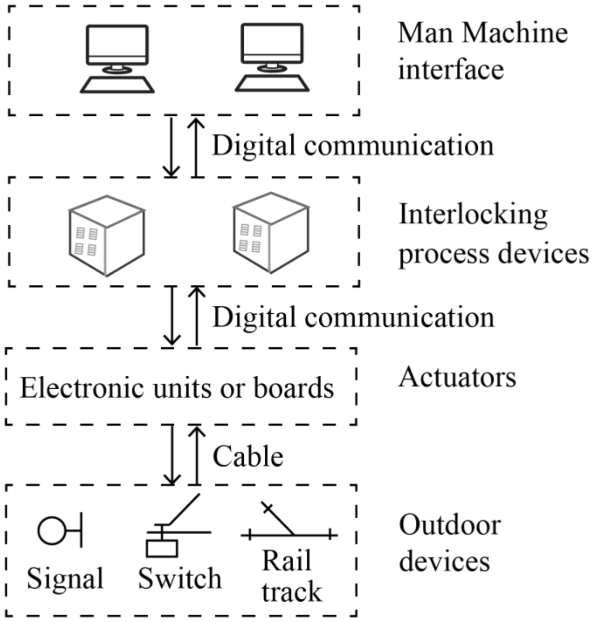

FIGURE 3: Computer-based Interlocking System (refer to Huang, 2020)

3.1 Aftermath of the Train Accident:

As per the Indian Railways official report, about 290 passengers were declared dead on the spot, 1300 were severely injured, and some lost their body parts and became disabled permanently. Many passengers lost their family members and kin. The accident's aftermath was so devastating that Odisha state and its neighbouring states declared mourning days on June 04, 2023. The central (federal) and state governments announced financial support for the deceased family and passengers undergoing hospital treatment for serious injuries. A considerable amount of economy was lost because the immediate restoration of railway tracks was started and completed on time, electrification of railway tracks was carried out and completed in a few days for train movements on track, and money was spent on buying new train bogies, installing required facilities in the train bogies for passengers' travel, removing damaged bogies from the accident site and transporting those to the railway coach factory, etc. Due to this horrific train accident, people lost their trust in railway safety and suspected railway engineers' professionalism practices. They raised concern about railway engineers' ethical duties and responsibilities for the passengers' safety travel in the express train.

3.2 Analyzing Reasons for the Triple-Train Accident:

The Coromandel Express (Train No 12841) run on the up-track. The train was scheduled to travel from Howrah station to Chennai station. The Yeshwantpur-Howrah Express (Train No 12864) was running on the down-track and was scheduled to go from Yeshwantpur station to Howrah station. These two trains were passing each other at the Bahanaga Bazar station, where there was no stop for these trains. Hence, they were running within their speed limit on their respective tracks as per Indian railway manual guidelines. A freight train carrying iron ore was parked on the loop line of the up-track at Bahanaga Bazar station, allowing these two trains to run on their respective tracks and maintain their scheduled arrival time at the next station. A green signal was given to the Coromandel Express train to veer its route to the loop line of the up tracks, where a freight train was already parked. Therefore, the Coromandel Express train diverted its route to the loop line of up-track and crashed into the freight train. As a result, its engine jumped onto the parked freight train waggons, its derailed bogies were made upside down and rammed into one another, and some of its bogies were thrown to the opposite track where the Yeshwantpur-Howrah

Express train was passing by. When the Coromandel Express train derailed bogies crashed into the Yeshwantpur-Howrah Express train's rear bogies, some of the Yeshwantpur-Howrah Express train bogies were derailed, made upside down, and rammed into Coromandel Express bogies. About sixteen bogies of both trains derailed and collided with each other. This caused the major triple-train disaster in India in June 2023.

3.3 Railway Signaling System and Its Functions:

The railway signalling system has four signals about train movement on the track. These signals are represented in three colours: green, yellow, and red. The green colour means the railway track ahead is clear, and the train can run at its prescribed speed limit to reach the next scheduled station. A single yellow signal means the train should run on the track slowly. The loco pilots should stop the train at the next signal, which may be red. A double yellow colour signal means the train should move slowly until the next signal, which may be either yellow or green. The red colour signal indicates to stop the train immediately.

It is the professional duty of signal and telecommunication railway engineers to maintain the railway signalling system perfectly and update it from time to time. This would help correctly signal the train movement on the track without ambiguity. Further, this would help train loco pilots to run the train on a track with the prescribed speed limit and take passengers safely from the boarding station to their destination.

The interlocking system is one of the crucial parts of railway transit safety (Sun et al., 2015). In the Indian railway system, the logic of the computer-based interlocking system's functions and operations will not allow setting a green signal for a train movement on a track when the track is not clear. But the Coromandel Express train loco pilots said a green signal was given to divert the train to the loop line of the up track. Now, if we consider the green signal as a technological failure, then this failure could have been found in the same station for other trains and other stations. Since we do not see this error (i.e., a green signal set for train movement on the wrong route) in any other railway station, logically, we rule out that it was a technological failure or machine error. Instead, by applying the scientific induction rule, we submit that it was a human error that was chosen voluntarily to carry out.

The interlocking system ensures safety in railway operations. The above discussions indicate that railway signalling interference is only possible if someone chooses to do so. There is every reason to assert that a green signal was set for the Coromandel Express train to divert its route to the loop line near Bahanaga Bazar station by the signal and telecommunication railway engineer. Top-level railway officials and investigating officers also mentioned that "deliberate interference and tampering with the interlocking system caused the crash" (The Times of India, June 05, 2023). Railway officials found that manual tinkering was done with the 'logic' of the interlocking system in the Bahanaga Bazar railway station. The investigation team also found that interference with interlocking systems and switches was the root cause of the triple-train disaster (The Times of India, June 06, 2023).

3.4 The Role of a Loco Pilot for an Express Train in India:

It is important to note that in the Indian railway system, it is not the train's loco pilots who decide the track on which a train runs. Instead, it is set and controlled by the signal and telecommunications railway engineer from a control panel board in the railway station. The control panel board is connected electronically to the rail tracks. The interlocking system sets the signal and trains movement on an allotted track. In other words, the interlocking system guides loco pilots to run the train on a designated track. From this analysis, we submit that the Coromandel Express train can only divert its route to the loop line of the up track if a green signal is given to do so. Further, since the switch is fixed for the Coromandel Express train to run on the loop line of the up track, the loco pilots do not have any choice but to change the train track and run the train as per the signal and interlocking system information. Hence, it would be a logical error to proclaim that a green signal was given for the Coromandel Express train to run in a straight line, but loco pilots diverted the train to the loop line of the up track voluntarily. These analyses assert that the change in the Coromandel Express train route at Bhanaga Bazar station was caused by the signal and telecommunication railway engineer and not due to technological glitches.

Further, the investigating team found that the Coromandel Express train loco pilots were running the train at the prescribed speed limit. After receiving a green signal to do so, the train diverted to the loop line of the up track in the Bahanaga Bazar railway station. Indian Railway Board Member Jaya Varma Sinha confirmed that the Coromandel Express train loco pilots diverted the train to the loop line of the up track after getting the green signal. India's Railway Minister Mr. Ashwini Vaishnaw said that "setting up the switch machine was changed, and this resulted in the train disaster" (The Times of India, June 07, 2023). A switch machine is a vital signalling device that enables a train to move from one track to another.

The investigators found relevant information about the triple-train accident from the 'data logger' device. The data logger is a device kept in the railway station near the control panel board to monitor and record all the activities concerning the signalling and interlocking system. A data logger acts like a ‘black box’ of a flight, which can scan, store, and process the data for generating user-friendly reports. The data logger is also known as the 'event logger.’ To put it differently, a data logger is a microprocessor-based system that monitors the railway signalling system. It scans, stores, and processes data and is used to generate reports. In their report, investigators and railway officials mentioned that, in point number 17A, “deliberate interference with the electronic interlocking system” caused the train tragedy. Mr. Rinkesh Roy, a divisional railway manager of Khurda railway station in Odisha state, said that “the loco pilots can get a green signal when all the pre-conditions are fulfilled, such as the route is clear, the switch is set correctly, and everything is right. If there is a minor problem, technically and logically, there cannot be a green signal in any circumstance; it would always be red." It cannot go green unless someone voluntarily tampered with it (June 07, 2023, The Time of India). While getting treatment in the hospital, the Coromandel Express train loco pilots also reiterated that the green signal was given for the loop line. As a result, the train diverted to the loop line of the up track. Their views were checked with a data logger, and it found that a green signal was set for the Coromandel Express train to move its route from a straight line to a loop line of the up track at Bahanaga Bazar station.

It would be an illogical, unconvincing, and paradoxical argument if we believe the Coromandel Express train bogies were derailed much before it veered to the loop line. The reason is that a train could change its route to a loop line if switches are set for a straight line. Further, train loco pilots cannot change the track based on their desires. Again, if the Coromandel Express train bogies were derailed much before it diverted its route to the loop line, then derailment effects would have been noticed from the train track itself. In this case, the derailed bogies would have been found much before the accident spot. Further, the Coromandel Express train engine would not have jumped onto the parked freight train waggons, the train bogies would not have been thrown out to the opposite track with a heavy force, and the bogies would not have been rammed into the Yeshvantpur-Howrah express train bogies. Thus, we submit that the signal and telecommunication railway engineer’s irresponsible and unprofessional behaviour (i.e., tampered with the signalling and interlocking system) caused the horrific triple-train disaster.

3.5 Signal Engineers’ Ethical Responsibilities:

Engineers are professionals, so as railway engineers. All professionals (e.g., engineers, doctors, lawyers, accountants, and so on) must fulfil two conditions to practice their profession. First, they must have expertise in their respective field and second, they must adhere to their professional code of ethics. Failure to satisfy these conditions suggests they are accountable and responsible for the consequences of their actions (Harris et al., 2019, p.2; Coeckelbergh, 2020).

Harris et al. (2019) state that one cannot imagine a modern society without the service of doctors and lawyers; similarly, one cannot imagine our society without highways, computers, railway transport, aeroplanes, and other technological artefacts designed by engineers (p.4). Since engineering is a professional task, the primary obligation of an engineer is to do good to the public by considering ‘aspirational ethics’ and ‘preventive ethics’. Aspirational ethics states that engineers must use their expertise, knowledge, and skills to promote human well-being, and preventive ethics states that engineers must integrate engineering codes of ethics into their work and prevent harm to the public. In this context, the National Society of Professional Engineers (NSPE) code of ethics[1] mentions that a fundamental canon for engineers is to hold paramount safety, health and welfare of the public. Violating this code of ethics makes an engineer summarily accountable for the consequences of his actions. In the triple-train accident case, had the signal and telecommunication engineer performed his/her tasks following the engineering code of ethics, the train disaster would have been avoided, and many lives would have been saved.

In the triple-train tragedy incident case, it was found that the signal and telecommunication railway engineer did not use ‘aspirational ethics’ and ‘preventive ethics’ while carrying out his/her job. In this context, it may be stated that if an engineer acts voluntarily, he/she must be responsible and accountable for the consequences of his/her action. Further, if an engineer performs an activity that does not conform to the code of ethics and, thereby, the professional practice, he/she is responsible and accountable for his/her actions. In this context, it is to be noted that engineers’ work is not free from moral issues. Moral issues are related to engineers’ duties and handling the risks involved in engineering tasks. Ethical issues are important to engineers because they have created technology for public use and benefit. Further, engineers are expected to carry out their duties professionally and accurately for public safety and well-being.

[1] Please see page 5 of this document;
https://www.nspe.org/sites/default/files/resources/pdfs/Ethics/EthicsReferenceGuide.pdf

Concerning taking 'responsibility' for an action, Aristotle, in his work The *Nicomachean Ethics*, argues that a person is responsible for his/her actions when he/she fulfils two conditions. First, he/she voluntarily decides to perform an action. Second, he/she must be aware of what he/she is doing in a given situation. In the triple-train disaster case, the signal and telecommunication railway engineer could have acted by conforming to the code of ethics but failed to do so. Due to the tampering with the interlocking system, the wrong signal and switch were set for the Coromandel Express train to divert its route to the wrong track, and as a consequence, a triple-train tragedy occurred. Many people lost their lives and body parts, the economy was lost, the environment was contaminated, and people lost trust in train travel. Train disaster rescue (the National Disaster Response Force) officials say around 60 bodies were retrieved from the derailed bogies that did not have any external visible injuries or bleeding from anywhere. But all of them are dead, presumably due to electrocution by overhead railway cables. The low-tension (LT) electric lines snapped after the Coromandel Express train derailed bogies crashed into the Yeshvantpur-Howrah express train bogies.

The railway transport system is complex because it comprises people, processes, assets, procedures, rules, and organisations (Appicharla, 2006). In the complex system, railway safety is given priority for passengers' safe travel (Appicharla, 2006, p.9). According to Benjamin (2004), a complex system's elements interact in a planned way to deliver an operational capability. When these interactions do not occur in a planned way, accidents happen. In the railway transport complex system, it is stated that when an action is rendered, many people endorse it, so many hands are involved in performing it. If the consequences of this type of action result in a tragedy, who will be responsible for the action? This problem is known as the 'problem of many hands' or 'organisational accidents' (Peterson, 2019). Organisational accidents are caused by 'latent failures' and 'active failures' (Reason, 2000). Latent failure is considered a potential failure hidden in the system, known to the actor who voluntarily ignores it and performs the action. For example, an engineer knows a circuit was damaged, and this shall not be used to manufacture a technological artefact, as it may result in harmful consequences. However, the engineer decides to use the circuit for a technological artefact because it still functions within specification (Hellstorm, 1998). If the result of the technological artefact is a tragedy, it is due to latent failure. In other words, latent failure is a human error where an individual voluntarily avoids the error while working in a system, and the consequences of his/her action led to tragedy.

On the other hand, active failures are human errors where an individual voluntarily avoids taking care of his/her responsibilities while performing a task. In this case, the person who committed the mistake could have avoided it. For example, a driver drives a car on the wrong route to reach the destination quickly. Consequently, the driver had a car accident, and the passengers died. This type of human error is known as an individual's active failure.

Concerning a complex system, a question arises: How do we fix responsibility on an individual or individuals? To find out the actual cause of a tragedy, we need to consider the human and technological failures of the equipment. According to Hart (2008), Sethy (2018), and Martin (2020), there are six types of responsibility found in the engineering field relating to safety matters, and role responsibility is one of them. Role responsibility states that an engineer who does not act to confirm his/her role by adhering to the professional code of ethics is morally and legally responsible for the consequences of his/her action. Rasmussen (1994) said it is necessary to understand the overall context shaping the human behaviour elements within a complex system. According to Appicharla (2006), a complex system may be approached from three perspectives: the technical, the organisational, and the personal. To find out the actual cause of the triple-train tragedy, these three perspectives were considered, and it was found that the train accident could have been avoided had signal and telecommunication railway engineers acted, confirming the code of ethics. In the Indian Railway Manual, it is mentioned that railway engineers endeavour at all times to protect the engineering profession from misrepresentation and misunderstanding. Further, a railway engineer will not associate with engineering work that does not conform to ethical practices. In addition, a railway engineer will act professionally as a faithful agent or trustee.[2]

Where should moral responsibility and legal liability lie in the triple-train tragedy case? Liability and accountability are only some of the questions raised for railway engineers. How safe is train travel when the interlocking system does not fulfil its purpose for public safety? To answer this question, we may consider consequentialism theory, a method, to answer this question. The consequentialism theory is a part of the utilitarianism theory, which states that whether an act is morally right or wrong depends on the consequence of the action. If something results in harm, it is treated as a bad action; if something results in good, it is treated as a good action. An action's evaluation focuses on the public's overall good rather than individual gains and losses. In the triple-train accident case, the signal and telecommunication engineer's actions in handling the interlocking

[2] Refer to page numbers 40-42; https://iete.org/Byelaws.pdf

system and signal system resulted badly. Hence, the engineer may be considered morally and legally responsible for his/her action.

3.6 Railway Engineers' Professional Responsibilities:

About the fourth question, "What are the signal and telecommunication railway engineer's professional responsibilities towards signaling systems and computer-based interlocking systems?" The duties of signal and telecommunication railway engineers are mentioned in the railway manual.[3] I am excerpting some of the important sentences from the document for readers' immediate reference.

a) The signal and telecommunication engineers must satisfactorily take care of the equipment under their charge.

b) He/she should prepare plans, estimates, and execute work in his/her charge.

c) He/she shall coordinate with officers and staff of other branches in all other matters to ensure the smooth functioning of the signalling and telecommunication systems.

d) He/she should inspect all signalling and telecommunications installations periodically.

e) He/she is responsible for interlocking the plans of a station under his/her charge.

f) He/she should be involved in the maintenance and testing of all equipment under his/her charge, such as signalling equipment, telecommunication equipment, etc.

The triple-train mishap was reported to be a gross violation of signal and telecommunication railway engineers' ethical duties and moral responsibilities for public safety and train movement on the track. The top-level railway officials and investigating team found that the interlocking system was tampered with, and that caused the tragedy. The investigating team said that manual tinkering was done with the logic of the interlocking system. The railway engineer (i.e., signal and telecommunication engineer) oversaw signaling on the stretch, violating the professional codes of ethics (The Times of India, June 06, 2023).

In the triple-train mishap case, one may ask whether the triple-train disaster was an accident or sabotage. Since this question falls outside of this paper's aim and objectives, I aim to desist from it. However, I am informing you that a case has been registered at the local police station for the train tragedy. The case has been handed over to the Central Bureau of Investigation (CBI) for its probe and to find out the truth, whether the accident was caused by human error, signal failure, or other possible reasons. The investigation is on.

IV. CONCLUSION

The Indian railway system is the fourth-largest railway system in the world. It is divided into eighteen zones. People in India mostly prefer to travel by train to reach their workplace and return home from the office. People mainly depend on the railway to travel to other states and destinations. Since people trust train travel, the signal and telecommunication railway engineer's moral duty is to act professionally and take all measures for passengers' safety in train travel.

In the triple-train mishap case, it is found that the signal and telecommunication railway engineer is morally and professionally responsible for his/her actions. The reason is that the Coromandel Express train was running on the track as per the signaling system and within its prescribed speed limit. Due to deliberate interference with the computer-based interlocking system, the tragedy occurred. The top-level railway officials and investigating team also found similar findings. That is, tampering with the interlocking system caused the triple-train disaster. The investigating report says that at Bahanaga Bazar station, close to the accident site, the signal and telecommunication railway engineer oversaw signaling on the stretch and violated the professional codes of ethics.

To prevent this kind of train accident in the future, signal and telecommunications railway engineers should act promptly, ethically, and professionally. The signal and telecommunications railway engineers should take responsibility for providing safe train movement on track and for passengers' well-being. They should follow the code of ethics and be vigilant in the signaling and interlocking systems to rebuild people's trust in the Indian railway system.

[3] https://scr.indianrailways.gov.in/uploads/files/1342378102421-DUTIES%20OF%20SIGNAL%20AND%20TELECOMMUNICATION%20ENGINEERS.pdf

DECLARATION

The author has no conflicts of interest in this paper.

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