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Application of Human Error Assessment and Reduction Technique to Learn Organizational Influence and Human Factor Perspectives of Railway Transportation Accidents

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Abstract

110 accident cases were collected, based on the Human factor analysis and classification system (HFACS), the work trying to learn the active failure and latent failure in the Britain railway accidents. The generations of the human factor analysis method are reviewed, and the HFACS method was also illustrated the first analysis task of organizational influences, such as, the organizational process, climate and resource management factors.

During 2020-2024, there were 15 freight and passenger train derailment, 23 occupation accident, 19 collisions, 15 SPADs and 38 accidents caused by other factors. In the accident analysis, the perception and decision error were frequently identified in the unsafe acts; the inadequate supervision and planned inappropriate operation learned in the unsafe supervision were contributed to the accidents. In the safety climate, the safety culture, equipment and facility resource in the resource management and the operation in the organizational process were the main reasons depicted the organizational influence.

The revised Human Error Assessment and Reduction Technique (HEART) and utilization of Error Producing Conditions (EPCs) as the analysis method to be the comparison with the HFACS, to learn the overall failure probability of human factors in statistics analysis, the section was discussed in the forth part.

Keywords: Human Reliability Analysis, organizational influence, accident investigation model, systemic theory, HFACS, HEART.

1 Introduction

This work collected 110 cases from the year of 2020 to 2024, ranging from occupation accident (workers were struck by train or near miss) (in total 23 cases), derailments (15 cases), collisions (19 cases), SPADs (15 cases) and other factors (38 cases). The other accidents included the passenger drag and trap in the train doors, the run away vehicle or wagons, and train struck structural debris. The classification and analytical method chose the Human factor analysis and classification system (HFACS) to learn the organizational influence and human factor perspective as the systemic approach.

Category	Numbers of accidents
derailment	15
collision	19
SPADs	15
Occupation accidents	23
Others (passenger trap in doors, runaway vehicle, and train struck structural debris)	38

Table 1: Case study in total

In the annual health and safety report (2023/24), the number of near misses with track worker (occupation accidents) were reduced from 2019/20 (Figure 2), and there are the comprised statistics of the operational accidents, derailments and collision shown below. The operational accidents are happened much more frequently than derailment and collision.

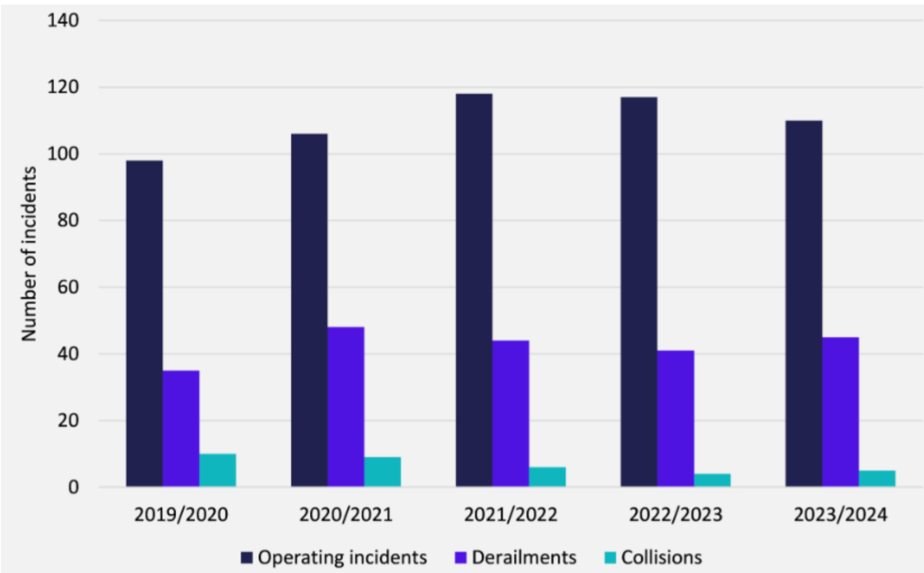

Figure 1: number of incidents extract form annual health and safety report

The Human Factors Analysis and Classification System (HFACS) application was developed by the Swiss cheese model, the causal method learned the unsafe acts, the precondition for unsafe acts, the unsafe supervision and the organizational influence. There are detailed error types under the four subsections, such as, the error and violation are the main errors of unsafe acts, and skill based, decision and perception error are the three prime errors, then the routine and exceptional violation are the two basic violations.

The condition of operators, personnel factors and environmental factors are the divisions of preconditions for unsafe acts. Unsafe supervision includes the inadequate supervision, planned inappropriate operations, failed to correct a known problem, and supervisory violations. In the organizational influences, there are resource management, organizational climate, organizational process demonstrated the classified types. Meanwhile, the human cognitive process was invented by Rasmussen [1], the skill-rule-knowledge based model was discussed in Hollnagel (1998), and he further invented the Cognitive understanding of human error [5].

Reason (1990; 1997) developed the Swiss cheese model to structure the human error factors. There are active error at the operator side, and the latent error designed in the system, named as the organizational influence. The method demonstrated the theoretical background of HFACS, then Wiegmann and Shappell (2003) analyzed the aviation accident reports into the four levels of failure, concluded the human erroneous, in terms of the cognitive, ergonomic, behavioral, individual, psycho-social and organizational. Furthermore, Reinach and Viale developed the railway analysis model based on the HFACS model [4].

Baysari (2008) utilized the HFACS to learn the Australia railway accidents and incidents, he distinguished the human failure and equipment failure accidents, and defined 300 more human error identifications in 40 accidents [2]. Recent years, many researches suggested the application of HFACS method in the railway accidents analysis procedure. Akyuz (2016) established the relation between the error producing condition (EPCs) and HFACS, and introduced the HEART method as the modified framework to obtain the human failure probability [3].

The analysis process presented in this paper focuses on various scenarios reviewed, based on the accident investigation reports from derailment Llangennech (R012022), the failure of track geometry deterioration at Heworth (R162015), the Camden derailment due to the organizational influence (R212014), the wheel flats defect mentioned at Pencoed (R032023) and Petteril Bridge (R102023) were discussed later [7].

2 Methods

There are the five parts of HFACS application and analysis results in this chapter.

2.1 Derailments

There were 15 derailment cases from 2020 to 2024: such as, of these 15 derailments, 2 cases caused by gauge spread and track twist, A further 5 were derailments that occurred in S&C, 3 were due to the failure of fastening system, 2 were due to the wheel flat defect, Of the leading vehicle derailments, 2 were due to obstructions on the line (1 of which related to material deposited by landslip). There was one derailment caused by longitudinal compression force imbalance.

In contrast, the derailments occupied less human factor failures to the occupation accidents, in terms of the unsafe acts (23 to 43) and organizational influences (28 to 36). That is due to the equipment failures are much more frequent in the typical accidents type, and most of the occupation accidents falls because of the human factor failure and organizational process failure, such as, operation or procedure executive.

			derailments
unsafe acts	errors	skill based	6
		decision	5
		perception	4
	violations	routine	3
		exceptional	5
	total unsafe acts		**23**
preconditions for unsafe a	condition of operators	adverse mental states	
		adverse physiological states	
		physical/mental limitation	
	personnel factors	crew resource management	5
		personal readiness	1
	environmental factors	physical environment	6
		technological environment	1
	total precondition		**13**
unsafe supervision	inadequate supervision		7
	planned inappropriate operations		3
	failed to correct a known problem		5
	supervisory violations		1
	total unsafe supervision		**16**
organizational influences	resource management	human resources	
		monetary/budget resources	1
		equipment/facility resources	11
	organizational climate	structure	
		policies	1
		culture	
	organizational process	operations	8
		procedures	5
		oversight	2
	total organizational		**28**

Table 2: derailment cases in the HFACS analysis

Whilst freight train derailments present a different risk profile to passenger derailments, they are still important to control and could result in safety risks to staff and the public; they also can cause significant disruption to railway operations and damage to rolling stock and infrastructure.

It is worthwhile to mention that Rasmussen's opinion about major accidents is an organizational migration to cross the boundary of acceptable performance. The freight train derailment can cause serious consequences to the track side, for instance, the Llangennech derailment caused three wagons to catch fire. Around 446,000 litre of petroleum products were spilled. The accident happened in August 2020, and the extensive damage to the track and the underlying formation, and the need to remove contaminated soil, meant that the route was not fully reopened until 5 March 2021.

The other case (Gloucester, R202014) was in 2013, the train derailed on track with regularly spaced dips in both rails, a phenomenon known as cyclic top, and there was damage to four miles of track, signaling cables, four level crossings and two bridges.

The examples of scenario demonstrated the analysis part:

- Eastleigh (R022021)

The design of the track fastening system made the cast iron shoulder stem more prone to fatigue failure under high lateral forces. (equipment/facility resource management)

Routine maintenance inspections were not capable of detecting and addressing broken shoulder stems. (violation: routine)

the failures occurred below the surface of the bearers, so were not visible to staff undertaking visual inspections until the shoulder detached (paragraphs 63 to 65). Measurements undertaken as part of inspections had not identified adverse track geometry (paragraphs 66 to 69) despite previous similar failures, Network Rail had not introduced an effective inspection regime which could have detected these failures (paragraphs 70 to 77). (personnel factors: crew resource management)

The track maintenance department at Eastleigh MDU was not effectively managing the maintenance of its assets. (unsafe supervision: failure to correct known problem)

- Pencoed (R032023)

Network Rail had not taken any precautions to ensure an adequate level of railhead adhesion was available when reopening the Swansea District line. (environment factor: technological environment)

Network Rail's adhesion-related standards only consider the management of railhead adhesion during the leaf fall season. (equipment facility resource)

The train was allowed to continue in service from Cardiff to Bristol, despite the presence of wheel flats having been detected. (unsafe supervision: failure to correct known problem)

- Petteril Bridge (R102023)

Train 6C00 was not stopped before reaching Petteril Bridge Junction, after the wheelset on the ninth wagon had stopped rotating. (organizational process: operation)

There was no engineered system in place to detect wheelsets that were not rotating and to either automatically stop the train or to alert the signaler along the route to the issue. (equipment/ facility resource management(organizational influence))

Axle counters use sensors mounted on the rails to detect the passage of wheels, by the distortion of a magnetic field. They are designed to detect wheels with a profile that is compliant with Railway Group Standard GMRT2466 (Railway wheelsets). This standard allows wheels to have a flange profile that is up to 6.5 mm deeper than nominal. (organizational process: Procedure)

Although it is technically possible to fit freight wagons with systems to detect non-rotating wheelsets, this is not routinely done due to the additional cost and potential complexity of such equipment. (monetary/budget resource)

The creation of wheel flats on freight wagons appears to be more common than on passenger trains because wagons are not fitted with WSP systems. (physical environment)

- London Gateway (R142023)

VTG Rail’s inspection and maintenance regime for Ecofret 2 wagons comprised a weekly in-service inspection, which is essentially a visual examination of the overall wagon condition, and a more detailed annual vehicle inspection and brake test (VIBT). The triple-wagon comprising wagons 11, 12 and 13 entered service on 19 April 2021. The first VIBT was not due until 19 April 2022, after the derailment. (equipment/facility resource management)

The design process for Ecofret 2 wagons did not fully recognize the need for there to be a change in design from the Ecofret 1 wagon to improve behaviour under longitudinal compressive forces. (organizational process: operation)

A double brake application, made shortly after passing LG11 signal, resulted in a sudden and large longitudinal compressive force being generated that acted on wagon 12. This coincided with wagon 12 approaching the point of derailment. (technological environment)

2.2 Occupation accidents

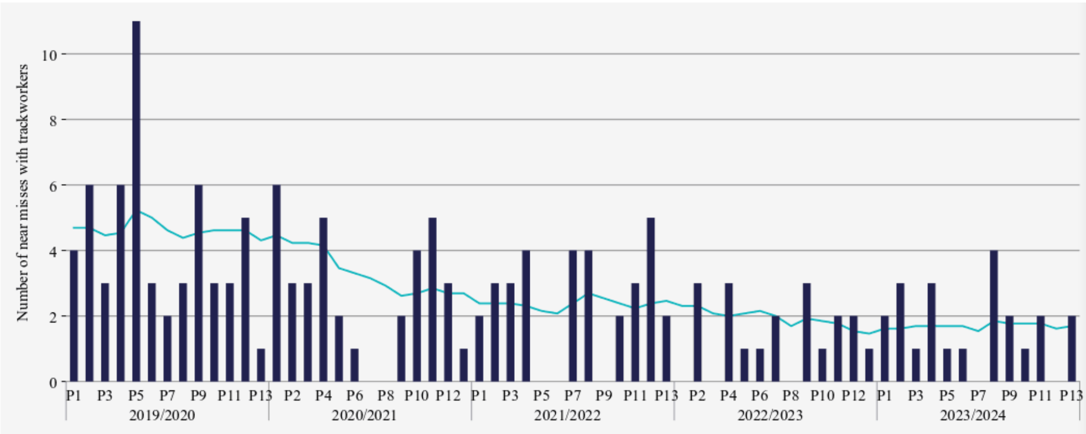

Figure 2: Numbers of near misses with track worker based on the annual health and safety report 2023-24

The number of near misses with track worker were gradually reduced from 2019/20 to 2023/24, as shown in the ORR annual health and safety report.

There were 23 cases related to the occupation accidents. The decision (13), skill-based errors (8) were occupied immediate causal factors, then the unsafe supervision (17) and organizational process (17) were discussed as the underlying causes in the scenario analysis.

			near miss with
unsafe ac	errors	skill based	8
		decision	13
		perception	13
	violations	routine	3
		exceptional	6
	total unsafe acts		**43**
precondi	condition of opera	adverse mental states	
		adverse physiological states	
		physical/mental limitation	
	personnel factors	crew resource management	7
		personal readiness	6
	environmental fact	physical environment	2
		technological environment	1
	total precondition		**16**
unsafe su	inadequate supervision		7
	planned inappropriate operations		6
	failed to correct a known problem		
	supervisory violations		4
	total unsafe supervision		**17**
organiza	resource managemen	human resources	5
		monetary/budget resources	
		equipment/facility resources	6
	organizational cli	structure	1
		policies	1
		culture	6
	organizational pro	operations	9
		procedures	5
		oversight	3
	total organizational		**36**

Table 3: occupation accidents analysis in HFACS

Furthermore, in the occupation accidents, the Decision error included: poor decision, procedure errors, and problem solving errors, such as, in "fatal passing close to train vehicle", train drivers fail to effectively control the risks to which they are exposed when walking or working in depots, yards and sidings, and the second driver would not have been able to see the first driver as he crossed the yard and entered the gap between the trains (urgent safety advice 012020).

- on the other hand, Duty holders should also be aware that using the GE/RT 8000 Rule Book as the only basis of track safety training for train drivers and other operational staff is inappropriate because: the Rule Book contains no rules, regulations or instructions relating to passing between or close to the end of stationary rail vehicles, represented the organizational process failure (operational procedures) and oversight.
- The standard of safety critical communications was poor throughout, resulting in no party having a clear understanding of the location of the tamper or the actions

to be taken, and Network Rail's management of the PICOP role has been ineffective. (R012020)

- The presence of protocol 0338 in the current suite of Network Rail documents, and the absence of a review process for standard NR/L3/MTC/SE0207, have the potential to cause unnecessary risk to track worker safety. (SD032020)
- MECX decided that it would still need to undertake a track walk / survey to photograph and record areas along the route that would require vegetation clearance work. The company made arrangements, including preparing a safe system of work pack (SSOW), for the work to be done between 16 and 19 June, the closing date for the tender proposal bids. MECX was not able to explain why the work had been approved without Network Rail's knowledge or sanction. (SD052020)

According to the severity analysis, the occupation accidents, the vehicle derailments, and other accidents have the severe consequences. There were 23 cases related to the occupation accidents. Example of HEART calculation listed below, the skill-based error and decision error are assessed by the error producing conditions, and the nominal likelihood of failure are estimated.

	epc	affect	proportic	assessed	likelihood of failure	
skill based and decision error	5. no means of conveying spatial and functional information to operators in a form which they can readily asssimilate	8	0.3	3.1	0.044686128	
	9. a need to unlearn a technique and apply one which requires the application of an oppsing philosophy	6	0.3	2.5		
	16. an improverished quality of information conveyed by procedures and person/person interaction	3	0.3	1.6		
	23. unreliable instrumentation	1.6	0.3	1.18		
	36. task pacing caused by the intervention of others	1.06	0.3	1.018		

Table 4: Failure probability estimation through HEART (occupation accidents)

2.3 Collisions and Others

			derailments	collisions	others	SPADs	near miss wi	train struck	total
unsafe acts	errors	skill based	6	10	8	9	8	1	42
		decision	5	12	15	9	13	1	55
		perception	4	6	16	7	13	2	48
	violations	routine	3	1	4	1	3	1	13
		exceptional	5	7	10	6	6		34
	total unsafe acts		**23**	**36**	**53**	**32**	**43**	**5**	**192**
preconditions for unsafe	condition of operators	adverse mental states			2	1			3
		adverse physiological states		1		1			2
		physical/mental limitation		5		3			8
	personnel factors	crew resource management	5	6	3	6	7	1	28
		personal readiness	1	3	3	3	6		16
	environmental factors	physical environment	6	1	4	3	2	1	17
		technological environment	1	2	5	3	1	1	13
	total precondition		**13**	**18**	**17**	**20**	**16**	**3**	**87**
unsafe supervision	inadequate supervision		7	4	9	5	7		32
	planned inappropriate operations		3	3	6	3	6		21
	failed to correct a known problem		5	2	2				9
	supervisory violations		1	3	3	1	4		12
	total unsafe supervision		**16**	**12**	**20**	**9**	**17**	**0**	**74**
organizational influences	resource management	human resources			1	2	5		8
		monetary/budget resources	1		2				3
		equipment/facility resources	11	10	19	7	6	2	55
	organizational climate	structure			2		1		3
		policies	1		3	1	1		6
		culture		1	5	1	6	1	14
	organizational process	operations	8	8	18	9	9	2	54
		procedures	5	2	13	3	5	2	30
		oversight	2	1	10	3	3		19
	total organizational		**28**	**22**	**73**	**26**	**36**	**7**	**192**

Table 5: HFACS in five categories of accidents

The collision accident analysis indicated 36 of unsafe act, 18 of precondition of unsafe acts, 12 of unsafe supervision, and 22 of organizational influence. In contrast, the other accidents demonstrated 53 of unsafe act, there are 16 of perception errors, 15 of decision errors; 17 of precondition of unsafe acts; 20 of unsafe supervision and 9 of inadequate supervision; 73 of organizational influence and 19 of the equipment/facility resource management.

As shown in the table 5, unsafe acts and unsafe supervision occupied higher scores in the others accidents, meanwhile, the organizational influence (such as, the equipment/facility resources, organizational process) affect the other accident as well.

The most frequent causal factors are the unsafe acts of operators. There are the decision error (55), perception (48) and skill based error (42) occupied the top three relative factors. And the exceptional violation (34) also illustrated the important reasons for the accidents.

On the other side, the organizational influences are the direct causal factors, such as, in the resource management, the equipment/facility resources (55) are the main causes. Then in the organizational process, the operation deficiencies (54) and procedure deficiencies (30) are the known problems.

The crew resource management (28) and inadequate supervision (32) are mentioned in the railway accident investigation, as the main contribution causal factors.

Through the analysis of the accidents causes, the previous work undertaken by Zhou (2023) extracted five main accident causes, including unsafe behavior of people, unsafe state of wagons, adverse environmental conditions, negligence in management and improper rescue, and delved into detailed statistics. The work collected 155 cases involved with freight train accidents in China from 1986 to 2020.

For example, unsafe acts occupied 389 cases, about 40% of the total main causal factors; unsafe state of wagons occupied 183 cases, about 19% of the total accidents; adverse environmental condition occupied 92 cases, about 9%; negligence in management occupied 272 cases, about 28%; and improper rescue are about 35 cases, stated as 4% of total accidents.

The unsafe acts divided into 12 types of reasons: such as, overloading, improper maintenance and poor maintenance, irregular operation of packaging, dereliction of duty of freight operator, improper loading and unloading, driver operational violation, lack of operational skill and risk perception, and violation or errors of station manager, etc.

2.4 SPADs accidents

Hence, the author specified the accident analysis in SPADs accidents. There have been 15 cases since 2020. firstly, the author reviewed the Unsafe Acts undertaken by drivers or operators.

- Skill based error and precondition for unsafe acts (environmental factor: physical): The industry investigation report identified numerous causal factors, including the signaler's distraction and time pressure in dealing with the failed freight train, sub-standard safety-critical communications, and the layout of equipment in the signal box which could have hindered the signaler’s acquisition of critical information. It further cited concerns with signaller monitoring and competence management, associated with organization problems at local management level (paragraph 29). (RAIB report: R032020)
- Decision based error and perception: The train manager was not alerted to the brake problem until the train was passing through Edinburgh Waverley station (paragraph 92). The brake pipe isolation cock was closed, removing control of the coach brakes from the driver (paragraph 54). (R052020)
- Condition of operator, physical/mental limitation: The hazard of a driver losing awareness while operating a tram was not recognized by Thales when it risk assessed the new layout at the tram stop or by Transport for Greater Manchester when it approved the new layout for service. KAM, Thales and TfGM either did not recognize the hazard of a driver losing awareness while operating a tram on the Metrolink system or did not fully control the associated risk. (R062020)
- Exceptional violation: The running brake test did not alert the driver to the lack of wagon brakes because the driver did not check that he had achieved a reduction in speed during the test. The Rule Book states that a running brake test is to be undertaken to be sure that the brake is operating effectively and ‘the speed of the train is being reduced’. (SD 062020)
- Perception error and organizational process (operations): The braking applied by the driver was insufficient, for the speed at which the train was travelling, to stop the train before it passed the red signal. ROG’s management assurance processes

did not detect a lack of compliance with its own safety management system in areas that resulted in the driver and shunter being inadequately prepared for the movement of the train. (R102020)

- Inadequate supervision: The distance between the warning board and the speed indicator for a speed restriction, the braking distance, should be based on the highest permissible speed that any train can approach. (SD 022021)
- Skill based error: Chiltern Railways' competence assessments did not identify that the driver lacked knowledge about tripcock activation processes and had a relatively high risk of being affected by fatigue, so these issues were not addressed. (R042021)

The HFACS analysis results in collision and SPADs were shown in the Table 5.

3 Accident Analysis Results

3.1 The HEART application

In this section, the author will discuss the combination between HFACS and EPC methods, to learn the overall failure probability of each unsafe actions in the operational process. The matrix relations were learned from Akyuz (2016) [3].

			derailments	case study	overall probabil
unsafe ac	errors	skill based	6	R122020, R072021, R012022, Interim report 012022, R102022, R022024	0.0254
		decision	6	R072020, R122020, SD 082020, R072021, R102022, R022024	0.0275
		perception	4	R072020, SD 082020, Interim report 012022, R022024	0.0199
	violations	routine	3	R072020, R022021, R012022	0.0119
		exceptional	5	SD 082020, Interim report 012022, R102022, SD 012023, R022024	0.0121
	total unsafe acts		24		
precondit	condition of operator	adverse mental states			
		adverse physiological states			
		physical/mental limitation			
	personnel factors	crew resource managem	5	R072020, SD 082020, R022021, R072021, R022024	0.0305
		personal readiness	1	SD 082020	0.0085
	environmental factors	physical environment	6	R102023, Urgent safety advice 012024, Urgent safety advice 02202	0.0346
		technological environ	1	R142023	0.0207
	total precondition		13		
unsafe su	inadequate supervision		8	R072020, Urgent safety advice 022020, R122020, Interim report 012	0.0213
	planned inappropriate operations		3	SD 082020, R102022, R022024	0.0253
	failed to correct a known problem		5	R072020, R022021, R012022, R102022, R102023	0.016
	supervisory violations		1	SD 082020	0.0032
	total unsafe supervision		17		
organizat	resource management	human resources			0.0336
		monetary/budget resou	1	R102023	
		equipment/facility re	11	R072020, Urgent safety advice 022020, R122020, SD 082020, R022021, R072021, R012022, R	
	organizational climat	structure			0.0107
		policies	1	R012022	
		culture			
	organizational proces	operations	8	R072020, R122020, SD 082020, R072021, SD 012023, R102023, R142023, Ur	0.0336
		procedures	3	R072020, R072021, R012022	
		oversight	2	SD 082020, R072021	
	total organizational		26		

Table 6: Derailment accident analysis and failure estimation

Firstly, the cases study of derailments in human factor analysis and classification system are described above. The skill based error are listed in the cases study for examples: R122020, R072021, R012022, Interim report 012022, R102022, R022024.

- R122020: The track was unable to maintain the correct gauge as train 6Z54 passed over it. track recording vehicles identified a wide gauge fault but output derived from this data did not result in track maintenance staff repairing faults at the correct location (paragraph 74).

The process is dependent on the mobile phone's accuracy when receiving the GPS signal. In this case, although the GPS co-ordinates put the fault on bridge 456 (figure 26), staff undertook work about eight meters west of the actual fault location and on a section of track with concrete sleepers. (paragraph 80)

- R072021: The failed track screws had not been identified by the routine inspection regime.

- R012022: The relay valve on wagon GERS 89005 was further susceptible to loosening because it was not being maintained as specified by the brake equipment manufacturer. This was able to happen because Touax's management of its ECM requirements was inadequate.

ORR had concluded that the wagon maintenance facilities at Robeston were capable of supporting basic maintenance, following a previous incident involving wheel flats on a loaded oil train.

- R102022: wrong side signaling and derailment.

The pre-installation checks in the specified maintenance test plan did not identify the need to alter the internal wiring in the re-serviced point machine.

- R022024: NTL did not have an effective process to inform drivers of points failures; its policy was incomplete, not understood by control room staff and the informal process which was used instead was inconsistently applied.

The skill based error are mostly related to the operator's failure in the organizational process, such as, the deficiencies in the track or vehicle maintenance procedures. It is usually caused by improper use of equipment during manufacturing, omission of standard operational procedures, or distraction of the staff's attention.

It is worthwhile to distinguish the violation and unsafe error. For example, in the case of R012022, the the supervision and audit of subcontracted activities were not effective, and the development and implementation of the Touax maintenance system had not been effective, as omissions within the Touax maintenance manual DT 432 had not been identified since December 2015, then the unsafe acts describes the error and violation at the same time.

Secondly, the overall probability of failure estimated from the EPC and HFACS subsections, for example, the skill based error failure probability was affected by no means of conveying spatial and functional information to operators in a form which they can readily assimilate (epc 5), a need to unlearn a technique and apply one which requires the application of an opposing philosophy (epc 9), an impoverished quality of information conveyed by procedures and person/person interaction (epc 16), unreliable instrumentation (epc 23), and task pacing caused by the intervention of others (epc 36). As we can see, the resource management in organizational influence, organizational process (operation, procedures, etc.) and physical environment affect the failure probability most in the table.

As shown in the table 7, the collision most caused by the unsafe acts, such as, the perception and decision failure.

			collisions	case study	overal failure proba
unsafe acts	errors	skill based	10	R142020, SD 062021, SD 082021, R062022, R07202	0.0207
		decision	12	R132020, R072022, R082022, R092022, R112022, R1	0.0364
		perception	6	R132020, R062022, SD 032022, R082022, R132022,	0.0387
	violations	routine	1	R122023	0.00805
		exceptional	7	R132020, SD 062021, R112022, R122022, R082023,	0.0089
	total unsafe acts		36		
preconditions for	condition of opera	adverse mental states			
		adverse physiologi	1	R132022	0.0159
		physical/mental li	5	R132020, R142020, R062022, R082023, R092022	0.034
	personnel factors	crew resource mana	6	SD 082021, R062022, SD 032022, R092022, R09202	0.0302
		personal readiness	3	R132020, R072022, R092022	0.01
	environmental fact	physical environme	1	R092024	0.0157
		technological envi	2	R132020, R082023	0.0182
	total precondition		18		
unsafe supervision	inadequate supervision		5	R112022, R132022, R122023, SD 062024, R132024	0.026
	planned inappropriate operations		2	SD 082021, R122023,	0.0271
	failed to correct a known problem		2	R112022, R092024	0.0202
	supervisory violations		3	SD 062021, SD 082024, R122024	0.0044
	total unsafe supervision		12		
organizational inf	resource managemen	human resources			0.0329
		monetary/budget resources			
		equipment/facility	10	R142020, R072022, R082022, R112022, R122022, R122023, SD 062024, SD 0	
	organizational cli	structure			0.0122
		policies			
		culture	1	R122023	
	organizational pro	operations	7	R132020, SD 032022, R082022, R122023, R092024,	0.0389
		procedures	3	R132020, R062022, R132024	
		oversight	1	R062022	
	total organizational		22		

Table 7: Collision and failure estimation

In the occupation accidents, the unsafe supervision stated the effectiveness to the accident failure probability, as shown in the table 8 and 9.

			near miss with	case study	overall probability of fa
unsafe acts	errors	skill based	8	R012020, SD032020, SD 032021, R062021, R052023, SD	0.0229
		decision	12	urgent safety advice 012020, SD052020, R112020,	0.032
		perception	11	R012020, SD032020, SD052020, R112020, R032021, SD	0.0266
	violations	routine	3	R012020, R032021, R052022	0.0137
		exceptional	6	R112020, R022023, SD 022023, R092023, SD 012024, R	0.0109
	total unsafe acts		40		
preconditions for unsafe acts	condition of operators	adverse mental states			
		adverse physiological states			
		physical/mental limitation			
	personnel factors	crew resource management	7	SD 032020, R112020, SD 032021, R062021, R0220	0.0174
		personal readiness	6	SD 052020, R062021, SD 022022, R022023, R052023, R	0.0147
	environmental factors	physical environment	2	R112020, R082024	0.0225
		technological environment	1	SD 032024	0.0136
	total precondition		16		
unsafe supervision	inadequate supervision		7	SD 052020, R112020, R062021, SD 072022, R022023, S	0.033
	planned inappropriate operations		7	SD 052020, R112020, SD 052021, R052023, SD 032023	0.029
	failed to correct a known problem				
	supervisory violations		4	SD 072022, SD 022023, SD 012024, SD 072024	0.0232
	total unsafe supervision		18		
organizational influences	resource management	human resources	5	R012020, urgent safety advice 012020, SD 052021	0.0453
		monetary/budget resources			
		equipment/facility resources	5	R012020, urgent safety advice 012020, SD 032021, R062021, R082024	
	organizational climate	structure	1	R112020	0.0153
		policies	1	SD 032020	
		culture	5	R012020, SD 032020, R112020, R032021, R052023	
	organizational process	operations	9	SD 032020, SD 052020, R112020, R032021, R052022, S	0.0168
		procedures	5	urgent safety advice 012020, SD 052020, R052022, SD 032024, SD 042024	
		oversight	3	R012020, urgent safety advice 012020, R052022	
	total organizational		34		

Table 8: Occupation accident and failure estimation

In the organizational process,the collision and derailment occupied the higher failure probability. In the resource management, occupation accidents stated failure probability at 0.045, especially the equipment and facility resource management. In the precondition for unsafe acts, the derailments occupied higher failure probability in terms of the physical environment and crew resource management. The collision demonstrated higher failure probability in the unsafe acts.

unsafe supervision	inadequate supervision		7	13,17,20,22,26,28	poor, ambiguous or ill-matched system feedback 4	little or no independent checking or testing of output 3	an impoverished quality of information conveyed by procedures and person-person interaction 3	little opportunity to exercise mind and body outside the immediate confines of the job 1.6	no obvious way to keep track of progress during an activity 1.4	little or no intrinsic meaning in a task 1.4			
				0.012	0.18	0.16	0.12	0.03	0.18				
					1.54	1.32	1.24	1.018	1.072		0.033009591		
	planned inappropriate operations		7	2,8,14,16,18	a shortage of time available for error detection and correction 11	a channel capacity overload, particularly one caused by simultaneous presentation of non-redundant information 6	no clear direct and timely confirmation of an intended action from the portion of the system over which control is to be exerted 3	an impoverished quality of information conveyed by procedures and person-person interaction 3	a conflict between immediate and long-term objectives 2.5				
				0.007	0.1	0.06	0.15	0.1	0.03				
					2	1.3	1.3	1.2	1.045	0.02966964			
	failed to correct a known problem												
	supervisory violations		4	1,12,14	unfamiliarity with a situation which potentially important but which only occurs infrequently or which is novel 17	a mismatch between perceived and real risk 4	no clear direct and timely confirmation of an intended action from the portion of the system over which control is to be exerted 3						
				0.003	0.2	0.17	0.11						
					4.2	1.51	1.22	0.02321172					
	total unsafe supervision		18										

Table 9: unsafe supervision EPC calculation

The failures estimated probabilities were illustrated above, and the summarized report mentioned the operational failure based on the RAIB report. There are Barrier description of the track and vehicle inspection functions. To identify the system reliability, the author collected 110 cases for the last five years across the UK. As the complementary support to the Safety Risk Modelling (SRM), the work calculated the failure probability on the operational side, based on the definition of HFACS and estimation value of HEART model. The methodology of CREAM were surveyed, and the model considered the environmental factors, to estimate the failure probabilities.

Furthermore, the author collected 29 railway accident in US data base (National Transportation Safety Board) since 2020. There are 6 collision, 4 derailments and 19 occupation accidents.

			collision	derailment	occupation
unsafe acts	errors	skill based	3	1	4
		decision	3		9
		perception	2		1
	violations	routine			1
		exceptional			4
	total unsafe acts		**8**	**1**	**19**
preconditions for uns	condition of operators	adverse mental states			1
		adverse physiological states			
		physical/mental limitation			1
	personnel factors	crew resource management			4
		personal readiness			1
	environmental factors	physical environment		1	1
		technological environment			1
	total precondition		**0**	**1**	**9**
unsafe supervision	inadequate supervision				1
	planned inappropriate operations		1		
	failed to correct a known problem				1
	supervisory violations				1
	total unsafe supervision		**1**	**0**	**3**
organizational influ	resource management	human resources			
		monetary/budget resources			
		equipment/facility resou	2	1	2
	organizational climate	structure			
		policies		2	2
		culture			
	organizational process	operations	1	1	5
		procedures			2
		oversight			
	total organizational		**3**	**4**	**11**

Table 10: analysis based US data base

In the occupational accidents, the unsafe acts occupied 19, 9 of 19 are the decision error undertaken by operators, and 4 of 19 are exceptional violation. There are 9 preconditions for unsafe acts, 4 of 9 are the crew resource management deficiencies. About 11 organizational influence in the last category, mostly are the equipment/facilities resource management, organizational process operation (5) and procedures (2).

The analysis procedure integrated the three models and techniques shown below:

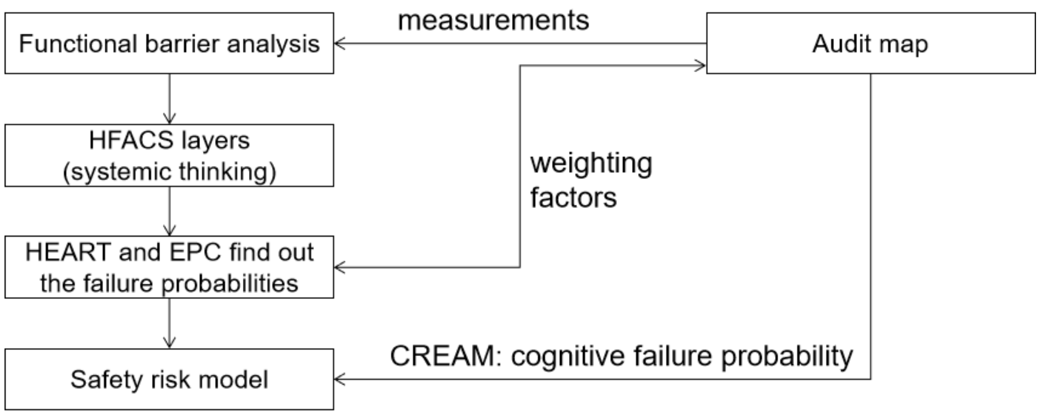

Figure 3: analysis procedure

4 Conclusions

In this work, the systemic theories and human factor models contributed to learning the accident consequences, and the derailment failure mechanism is discussed. The author reviewed the 2020-2024 railway accident reports based on the RAIB investigation and briefly analyzed the organizational influence through interpretative structural understanding of HFACS.

The key results should be concentrated on the Audit of the maintenance delivery system, to learn the vehicle and track maintenance functions, the human reliability and performance aspects are discussed, through classifying and quantifying failure probability of the unsafe acts in HEART model.

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