Extending the Human-controller methodology in Railway System Accident Analysis based on STAMP

\[ a \] Chenling Li, Ph.D. candidate
\[ a \] Tao Tang, Prof.
\[ a \] Ru Niu, Dr.
\[ b \] Maria Mikela Chatzimichailidou, Dr.
\[ c \] Patrick Waterson, Dr.

\[ a \] State Key Laboratory of Rail Traffic Control and Safety, Beijing Jiaotong University
\[ b \] LRF Transport Risk Management Centre, Imperial College London
\[ c \] Human Factors and Complex Systems Group, Loughborough University
Outline

- Background and Motivation
  - Accident investigation and analysis
  - Human factor analysis based on STAMP

- Some ideas in using STAMP analysis on human factors
  - Extension: human controller state
  - Human controller model’s elements
  - Analysis procedure: the Analysis Matrix for Human Error (AMHE)

- Case study: 7.23 Yongwen railway accident
  - The accident: human factors
  - Analysis and results

- Conclusion
Background and Motivation

➢ Railway system

The complex control system and serious operation circumstance of the railway system, especially high-speed railway, make it become a typical socio-technical system (Wilson et al., 2007).

![Diagram of railway system](image)
Background and Motivation

➢ Accident investigation and analysis

Train accidents involving collisions, derailments and fires related to human factors make up a significant proportion of all train accidents (MLTM, 2009; Reinach, Viale, 2006). 

Railway signaling and interlocking (Anders, 2009)
Background and Motivation

Accident investigation and analysis
Accident causation model
STAMP
Human error: system symptom
Mental model

(Leveson, 2012)
Background and Motivation

- **Human controller model in STAMP**
  - Mental model and work process

  (Leveson, 2012)
  (France, 2017)
  (Thornberry, 2014)
Background and Motivation

- **Human controller model in STAMP**

A NEW MODEL FOR HUMAN CONTROLLERS

- Captures the controller’s goals and how decisions are made based on the mental models
- Captures specific types of flaws in the way the human controller conceptualizes the system and environment
- Captures the influence of human experiences, and expectations on the processing of sensory input

**Human controller state?**

Provides an alternative to the existing controller model which is better suited for software controllers

May be inadequate due to flaws in creation, process changes, incorrect modification or adaptation, etc.

Can be inconsistent, incomplete, or incorrect

(France, 2017)
Background and Motivation

➢ Human controller model in STAMP

Figure 11. The Updated Human-Controller Model
(Thornberry, 2014).
Background and Motivation

- Human controller status influence?

Information processing: four steps

Human controller state is a essential part of human controller model.
Background and Motivation

➢ Human controller status influence?

Information processing: four steps

![Diagram of Boyd's OODA Loop](image)

*Figure 8. Boyd's OODA Loop [16]*
Background and Motivation

- **Human controller status influence?**

Fatigue is the largest identifiable and preventable cause of accident in transport operations (Akerstedt, 2000), and now is still a fatal factors contributed to Chinese railway accidents (Taso et al., 2017).

The human cognitive experiments should that the perception of mental fatigue impacted individual’s persistence, attention and elabortative thought (Carkson et al., 2016).
Background and Motivation

➢ Human controller status influence?

![Diagram of human factors analysis and classification system (HFACS)](Figure 3.7)

![Diagram of Preconditions for Unsafe Acts](Figure 3.4)

![Diagram of Unsafe Acts](Figure 3.3)
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➢ Conclusion
Human controller model

Mental Model of the Human State: (What does the operator perceive about his/her own state?)
- Physical state
- Mental state
- Physical/mental limitations
- The attitude about safety
- …
Extension about human controller model

- **Analysis procedure: the procedure**

3. Information detection and interpretation

2. Condition recognition

1. Decision
Analysis procedure: the procedure

Last step factor(s) (LF)

Human own character(s) (HC)

Factors from other parts in the system (OF)
Analysis procedure: the Analysis Matrix for Human Error (AMHE)

<table>
<thead>
<tr>
<th>STEP 1</th>
<th>STEP 2</th>
<th>STEP 3</th>
<th>Summary</th>
<th>Linkage (Organisation)</th>
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</tbody>
</table>

Last step factor(s) (LF)

Human own character(s) (HC)

Factors from other parts in the system (OF)
Extension about human controller model

- **Analysis procedure: the content of each item**

<table>
<thead>
<tr>
<th>Items</th>
<th>Causal factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Detection and Interpretation</td>
<td>(1) Observation missed, (2) False observation, (3) Wrong Identification, (4) Faulty diagnosis, (5) Wrong reasoning, (6) Delayed interpretation, (7) Incorrect prediction</td>
</tr>
<tr>
<td>Mental Model</td>
<td></td>
</tr>
<tr>
<td>Process State</td>
<td>(1) Process models inconsistent, (2) Incomplete, (3) Incorrect, (4) Inadequate plan</td>
</tr>
<tr>
<td>Process Behavior</td>
<td>(1) Process models inconsistent, (2) Incomplete, (3) Incorrect</td>
</tr>
<tr>
<td>Environment</td>
<td>(1) Process models inconsistent, (2) Incomplete, (3) Incorrect</td>
</tr>
<tr>
<td>System operation condition and goal</td>
<td>(1) Inadequate condition recognition, (2) Inadequate operation goal (subplan)</td>
</tr>
<tr>
<td>Decision making</td>
<td>(1) Generate inadequate control action, (2) Select inadequate control action</td>
</tr>
</tbody>
</table>
Extension about human controller model

Analysis procedure: the content of each item

- Identify system(s) and system hazard(s)
- Document the system safety control structure
- Identify human errors
- Analysis individual human errors
- Recommendations (in human error level)

For organisational and regulation level analysis
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- **Conclusion**
7.23 Yongwen railway accident

- On the 23 July 2011 at 20:30:05
- Two EMU train in same direction collided together
- Cause 40 deaths, 172 injuries, interruption of traffic for 32 hours and 35 minutes
7.23 Yongwen railway accident
Dispatcher

Safety requirements and constraints violated:
- Dispatcher must not provide a command that could lead to a train to train collision;
- Dispatcher must track trains status continually;
- Dispatcher must track the route status in failure situations;
- Dispatcher must find the abnormal situations and provide adequate actions to ensure the system safety;
- Must put priority of safe train operation before on-schedule operation;
- Keep in touch with station operators and train drivers and solve the abnormal report things from station operators and train drivers;
- Must be aware of the potential risks of system continually.

Identify human errors (UCA)
### Table 4-1: Yong-wen accident causation analysis results based on HS-RAs framework

<table>
<thead>
<tr>
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<td>A2: Dispatcher did not check the maintenance status about the failure equipment</td>
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<td>CF12: Dispatcher did not have a high perception about the safety priority&lt;br&gt;CF13: Dispatcher did not know the system functions&lt;br&gt;CF14: There was not a rule to give guidance about the state track on timing&lt;br&gt;CF15: Dispatcher was overconfidence about the technical system&lt;br&gt;CF16: Dispatcher made a incorrect prediction about the real condition of track circuits&lt;br&gt;CF17: There was not a efficient guidance to solve the track circuits failure&lt;br&gt;CF18: Dispatcher was under heavy workload</td>
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7.23 Yongwen railway accident

- Dispatcher: A1: Dispatcher did not check and confirm the track condition in time.

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SC2: Dispatcher should improve his ability about the system functions [organizational method: safety management and training processes]  
SC3: Dispatcher should check track situation complying with operation procedure in timeline or chronology |
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Conclusion(1)

Find out the causal factors contributing the unsafe control actions of human operators.

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<th>Our method</th>
<th>Zhan et al, 2017</th>
<th>Official report</th>
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<tr>
<td>UCA</td>
<td>15</td>
<td>9</td>
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</tr>
<tr>
<td>Causal factors</td>
<td>55</td>
<td>9</td>
<td>3</td>
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</table>
Conclusion(2)

- More clearly about analysis process
- Easy to track back to organisational and higher levels
Reference (1)


Q&A
Thank you!

Chenling Li
chenlingli@bjtu.edu.cn  chenlinglibjtu@gmail.com

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Beijing Jiaotong University, Beijing, China
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CF20: Dispatcher thought station operator or D3115 would be proactive to report new abnormal situation  
CF21: Dispatcher’s mental model did not contain the requirement to ask the status of D3115 forwardly  
CF22: Dispatcher assumed D3115 could pass the fail section and reached at Wenzhou south station timely  
CF23: Dispatcher made a incorrect prediction about the situation of the track circuits  
CF24: Dispatcher made an incorrect prediction about the communication status with D3115 based on the channel condition with other trains nearby  
CF25: Dispatcher was overconfidence about the technical equipment  
CF26: Dispatcher did not have a high sensitive about the abnormal condition  
CF27: There was not a good way to remind dispatcher the proper way to dispatch a train under an emergency condition | ROF1: The flaws of rules and regulations  
ROF2: The absent of training and safety education | [organizational method: the communication rules]  
SC12: Dispatcher should know this responsibilities in the emergency situation  
SC13: Dispatcher should be the status of D3115 and confirm it with Wenzhou south station without clear information about the system status [System gives clear status information to Dispatcher]  
SC14: Dispatcher should know the system functions in emergency situation [Organizational method: good and completed system function description in system delivery]  
SC15: Dispatcher should know how to solve the emergency situation without expected feedback  
SC18: Dispatcher should know the risk of his operation [Organizational method: hazard analysis and Individual cognitive: realisation]  
SC19: Dispatcher should improve his understanding of system functions in emergency situations |
| A5: Dispatcher did not inform the red-light strip information to D301 driver | CF28: Dispatcher did not know the system functions clearly  
CF29: Dispatcher thought D3115 would be proactive to report new abnormal situation  
CF30: Dispatcher did not think about the communication failure  
CF31: Dispatcher was overconfidence about the Track circuits safety  
CF32: Dispatcher did not get enough emergency rule to deal with the emergency situation  
CF33: Dispatcher did not coordinate with Wenzhou south station operator in D3115 operation  
CF34: Dispatcher just thought it was the responsibility of Wenzhou south station operator to supervise the condition of D3115 based on the emergency rules  
CF35: The emergency rules did not give a clear responsibility about the control of D3115 | ROF1: The flaws of rules and regulations  
ROF2: The absent of training and safety education |
<table>
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<th>Operator</th>
<th>Condition</th>
<th>Reason</th>
<th>Conclusion</th>
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</thead>
<tbody>
<tr>
<td>Station operator did not perform the junction control with D301 and did not inform D301 about the status of D3115 in time</td>
<td>CF37: The junction control standard did not contain the abnormal situation in this accident; CF38: The station operator just waited for the D3115 driver calling in based on the standard guidance; CF39: The station operator was overconfidence about the standard</td>
<td></td>
<td>ROF2: The absent of training and safety education; ROF3: The work assignment of organisations</td>
</tr>
<tr>
<td>Station operator did not report the equipment maintenance status to dispatcher in time</td>
<td>CF40: There was not a rule to tell the station operator whether he should report the status with any new change; CF41: The station operator did not keep in touch with Dispatcher properly</td>
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<td>ROF1: The flaws of rules and regulations; ROF2: The absent of training and safety education; ROF3: The work assignment of organisations</td>
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<td>Station operator knew that D3115 failed to turn to OS mode for three times and did not report this to dispatcher</td>
<td>CF42: The station operator thought D3115 could report to Dispatcher directly; CF43: The station operator had inadequate understanding of his control authority in the emergency situation; CF44: The station operator was overconfidence about the track circuits; CF45: The station operator did not know the operator procedures under the emergency condition; CF46: The station operator did not set a high priority for safety</td>
<td></td>
<td>ROF1: The flaws of rules and regulations; ROF2: The absent of training and safety education; ROF3: The work assignment of organisations; ROF4: The flaws of technical equipment</td>
</tr>
<tr>
<td>D3115 driver insisted to select OS mode to restart the train to run out of the failed section, just waiting for the right kinds of code for the on-board equipment to OS mode for 7 minutes and 40 seconds</td>
<td>CF47: D3115 driver put the command following at a higher priority than safety; CF48: D3115 driver did not know that the command did not match the scope of the process under control in the emergency situation; CF49: D3115 driver did not think about the influence to other trains of the long-time stay; CF50: There was not any guidance for the timeliness of the dispatch command</td>
<td></td>
<td>ROF1: The flaws of rules and regulations; ROF2: The absent of training and safety education</td>
</tr>
<tr>
<td>D3115 driver failed to report the condition to dispatcher and station operator</td>
<td>CF51: D3115 driver failed to connect with Dispatcher and the station operator</td>
<td></td>
<td>ROF1: The flaws of technical equipment</td>
</tr>
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</table>
| D3115 driver should put the system safety in highest priority; D3115 driver should improve his understanding of system functions; D3115 driver should know the risk of the long-time stopping; D3115 should be given some guidance for the emergency situation; D3115 driver should realise the failure of communication channel and know how to deal with it; D3115 driver should improve his understanding of system functions and...
| A11: D3115 driver did not focus on the signal light information and the train real-time position to confirm the failure condition |
| CF52: There did not guidance requiring D3115 driver to recognize the fail section boundary |
| CF53: D3115 driver just thought there was a normal failure on the track and the signal could turn red normally |
| CF54: D3115 was overconfidence about dispatcher’s command |
| CF55: D3115 had low sensitivity about the dangerous of the abnormal situation |
| ROF1: The flaws of rules and regulations |
| ROF2: The absence of training and safety education |
| be given a clear sign about the fail section [Organizational method: give a clear sign of the fail section from Dispatcher and other controller] |
| SC31: D3115 driver should know check the failure status periodically and find the new things about the failure |
| SC32: D3115 driver should be alert in advance for the failure situation |
| SC33: D3115 driver should realize the abnormal status about the track circuits and take actions to deal with it |