

**Individual markers of resilience in train traffic control: The role of operators' goals and strategic mental models and their implications for variation, expertise and performance.**

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1 **Individual Markers of Resilience in Train Traffic Control: The Role of Operators’**  
2 **Goals and Strategic Mental Models and Implications for Variation, Expertise and**  
3 **Performance**

4  
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10 Individual Markers of Resilience

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24

## Abstract

25

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**Objective:** To examine individual markers of resilience and obtain quantitative insights into the understanding and the implications of variation and expertise levels in train traffic operators' goals and strategic mental models, and their impact on performance.

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**Background:** The Dutch railways are one of the world's most heavy utilized railway networks and have been identified to be weak in system and organizational resilience.

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**Methods:** Twenty-two train traffic controllers enacted two scenarios in a human-in-the-loop simulator. Their experience, goals, strategic mental models and performance were assessed through questionnaires and simulator logs. Goals were operationalized through performance indicators, and strategic mental models through train completion strategies.

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**Results:** A variation was found between operators for both self-reported primary performance indicators and completion strategies. Further, the primary goal of only 14% of the operators reflected the primary organizational goal (i.e. arrival punctuality). An incongruence was also found between train traffic controllers' self-reported performance indicators and objective performance in a more disrupted condition. The level of experience tends to impact performance differently.

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**Conclusion:** There is a gap between primary organizational goals and preferred individual goals. Further, the relative strong diversity in primary operator goals and strategic mental models indicates weak resilience at the individual level.

46           **Application:** With recent and upcoming large-scale changes throughout the  
47 socio-technical space of the railway infrastructure organization, the findings are useful to  
48 facilitate future railway traffic control and the development of a resilient system.

49

50   **Keywords**

51 goal competition, diversity, organizational resilience, railway, socio-technical system

52

53   **Précis**

54 This study investigated the variation in goals and strategic mental models of train traffic  
55 controllers as individual markers of resilience. Individual differences in experience  
56 within goals and strategic mental models and their link with performance were also  
57 investigated.

58

59 **INTRODUCTION**

60 Resilience engineering studies are relevant in multiple domains, especially those  
61 that are highly complex and known for their hazards (Nemeth, Wears, Patel, Rosen, &  
62 Cook, 2011). Domains that are most heavily investigated are aviation (22%), healthcare  
63 (19%), the chemical and petrochemical industry (16%), nuclear power plants (10%) and  
64 railway (8%) (Righi, Saurin, & Wachs, 2015).

65 For the Dutch railway infrastructure managing organization ProRail, the notion of  
66 resilience and robustness strongly resonates in the organization to improve the system  
67 along these concepts (Meijer, 2012). The idea is that when the system cannot maintain  
68 the regular way of working, resilience is required to respond through the adaptation of  
69 strategies (Burnard & Bhamra, 2011; Hollnagel & Woods, 2005; Hollnagel, 2014).

70 However, resilience is linked across different levels with influencing mechanisms  
71 on the industry at the highest level, followed by plant and operations (organization), and  
72 teams and individuals at the lowest level (Back, Furniss, Hildebrandt, & Blandford, 2008;  
73 Sheridan, 2002). Research often focuses on a specific unit of analysis, as it is yet not well  
74 understood how resilience is linked across these different levels (Righi et al., 2015). The  
75 study of cross-level interactions inside the system is, however, crucial to prevent  
76 brittleness in the overall system, which can be facilitated through proactive safety  
77 management (Gomes, Woods, Carvalho, Huber, & Borges, 2009).

78 An analysis of railway safety operations in the Netherlands revealed poor to  
79 mixed resilience levels (Hale & Heijer, 2006). The debundling and privatization of the  
80 railway system that was widely introduced across Europe in the 1990s, causing extensive  
81 institutional fragmentation of the system, is a possible reason for the low resilience levels

82 (Hale & Heijer, 2006; Knieps, 2013). The debundling of the railway system inextricably  
83 led to more brittle operational processes for railway traffic operators, resulting in, for  
84 example, unclear and conflicting goals and the development of multiple coping strategies  
85 (Steenhuisen & De Bruijne, 2009; Veeneman, 2006). This phenomenon can be also be  
86 labelled as a gap between the system as designed or imagined and the system as it is  
87 actually operated, which results in a distance between the various levels (Dekker, 2006).

88         At an individual level, resilience engineering can help operators to develop robust  
89 yet flexible responses to disturbances inside or outside the organization (Chialastri &  
90 Pozzi, 2008; Lengnick-Hall & Beck, 2005). As such, performance variability is normal,  
91 though it needs to be controlled. Performance variability that leads to positive outcomes  
92 should be promoted (Hollnagel, 2008; 2014). Having shared goals, experiences, robust  
93 responses to simple problems and flexible responses to complex problems is essential to  
94 the development of a resilient organization (Lengnick-Hall, Beck, & Lengnick-Hall,  
95 2011).

96         Departing from resilience studies in the Dutch railways at a system and  
97 organizational level, this study focused on the individual level of railway traffic  
98 operators, in order to provide recent and quantitative insights to further the understanding  
99 of variations in their cognition and behavior and the implications thereof. The central  
100 research questions were: to what extent do organizational and individual goals  
101 correspond? What is the level of diversity in the goals and strategic mental models of  
102 train traffic operators given operators' work experience, and how does this relate to their  
103 performance?

104           The following section briefly introduces the Dutch railway system from a number  
105 of perspectives. This is followed by a brief presentation of the theoretical background to  
106 goals and strategic mental models. The subsequent sections present the method, results,  
107 and discussion and conclusion.

108

109                   **A MULTILEVEL OVERVIEW: RAILWAY TRANSPORT IN THE**  
110                                   **NETHERLANDS**

111           The Dutch railways transport more than one million passengers and operate about  
112 350 freight trains per day in a relatively small country, making it one of the busiest  
113 railway systems in Europe and even the world (Meijer, 2012; ProRail, 2013; Ramaekers,  
114 De Wit, & Pouwels, 2009). The debundling and privatization of the Dutch railway sector  
115 in 1995 initially led to a decrease in the performance of the system: between 2000 and  
116 2001, arrival punctuality dropped from about 87% to 80% (Algemene Rekenkamer 2012;  
117 Steenhuisen, 2009). Although the punctuality of trains has recovered over the years,  
118 reaching 92% in 2014, both the principle passenger transport manager (Nederlandse  
119 Spoorwegen; NS) and the infrastructure manager (ProRail) were penalized for  
120 performing insufficiently on the agreed performance indicators – NS for passenger  
121 dissatisfaction in terms of punctuality and quality of service (e.g. number of available  
122 seats, crowdedness during peak hours), and ProRail for the insufficient availability of the  
123 infrastructure due to malfunctions (Rijksoverheid, 2015).

124

125 **Organizational performance indicators**

126 Safety, reliability, service and capacity use can be seen as key public values in the  
127 railway domain (Wilson, Farrington-Darby, Cox, Bye, & Hockey, 2007). The general  
128 public values that are held in the governance of railway transport are rather stable over  
129 time, unlike the operationalization and quantification of these values into goals or  
130 performance indicators (Veeneman & Van de Velde, 2006). For instance, reliability can  
131 be conceptualized in a number of ways, such as punctuality, which can be further  
132 operationalized in terms of, for example, arrival, departure or overall (arrival and  
133 departure) punctuality. Departure punctuality was a performance indicator until 2006,  
134 when arrival punctuality became the indicator (Veeneman, 2006). However, both railway  
135 infrastructure and passenger transport managers set different thresholds in arrival  
136 punctuality, namely < 3 minutes and < 5 minutes, respectively (NS, 2015; ProRail,  
137 2015a). The formalization of performance indicators is an annual iterative process with  
138 occasionally ad hoc organizational reactions throughout the year in the case of  
139 unexpected large-scale disruptions that are subject to media scrutiny.

140

141 **Train traffic control**

142 Railway traffic operations differ between European countries in a number of  
143 ways, such as organization, roles and responsibilities, and level of automation (Golightly  
144 et al., 2013). In the Netherlands, a train traffic management system is used to execute the  
145 timetables, which are operated by train traffic controllers. The primary responsibility of  
146 these controllers is to execute train timetables in an accurate and punctual manner  
147 (Sulmann, 2000). Maintaining the operational safety of the rail system and recovering



148 after disruptions and accidents is an essential part of their job (Crawford, Toft, & Kift,  
149 2014). Train traffic controllers do not perceive their primary task as challenging as long  
150 as routes are already scheduled (Roth & Patterson, 2005). However, a more active role is  
151 needed in unsafe situations that cannot be controlled by the automated safety system or  
152 when there is a system malfunction (Sulmann, 2000).

153

#### 154 **Future developments**

155 In terms of future developments, ProRail and the government stated their  
156 intention to double the railway track capacity between 2008 and 2020 (now extended to  
157 2028), which should lead to a timetable that supports both an intercity and a local train  
158 service six times per hour in both directions between major cities (Meijer, Van der  
159 Kracht, Van Luipen, & Schaafsma, 2009; ProRail, 2015b). Given the restriction of a  
160 capacity increase through the mere addition of tracks, a change in the organizational  
161 processes is also required. As such, process optimization programs are being  
162 implemented that focus on, for instance, increasing the centralization of decision making  
163 to the national control center (operational control center rail; OCCR) for disruption  
164 mitigation procedures and restructuring the roles and responsibilities of operators.  
165 Switches are increasingly being removed at major stations (e.g. 110 of the 170 switches  
166 are being removed at Utrecht Central station) in order to, for example, facilitate corridor  
167 management, shorter travel times and more reliable traffic control, while bottleneck areas  
168 in the infrastructure are being expanded and upgraded. Finally, the replacement of the  
169 current traffic management system is being explored.

170

## GOALS AND MENTAL MODELS

171

### 172 **Goals**

173 Goals are states or ends that someone wants to achieve (Latham & Locke 1991;  
174 Mohammed, Klimoski, & Rentsch, 2000; Popava & Sharpanskykh, 2011). Operators'  
175 goals influence their mental model selection and therefore their decision making and  
176 performance (Endsley, 1995). In a dynamic environment, individuals focus on elements  
177 in the environment that are goal related. Deriving the meaning of the elements and the  
178 projection to the future is done in light of the goal and the active mental models (Endsley,  
179 1995). Goals influence the valuation of multiple options during decision making  
180 (Mohammed et al., 2000). In order to achieve resilience, operators need to have a  
181 common set of goals (Lengnick- Hall, Beck, & Lengnick Hall, 2011).

182

### 183 **Mental models and expertise**

184 Mental models are mental representations of humans, systems, artifacts and  
185 situations formed by experience, observation and training (Endsley, 1995; Schaffernicht  
186 & Groesser, 2011; Wilson, 2000). Mental models store knowledge that is necessary for  
187 human–environment interaction (Klimoski & Mohammed, 1994; Mathieu, Heffner,  
188 Goodwin, Salas, & Cannon-Bowers, 2000). This knowledge is crucial for solving  
189 problems effectively, such as those faced by train traffic controllers when confronted  
190 with multiple disruptions to the train schedule. Visual attention and evaluation of relevant  
191 information in complex problem situations improves when mental models are well  
192 developed.

193           The degree of development of mental models differs between novices and experts.  
194   Experts with extensive domain knowledge have developed the ability to perceive  
195   important patterns and features that are not seen by novices (Glaser & Chi, 1988;  
196   Bransford, Brown, & Cocking, 2000; Bogard, Liu, & Chiang, 2013). Experts also have  
197   the capacity to better recognize meaningful patterns due to their superior knowledge  
198   organization and extensive domain knowledge (Glaser & Chi, 1988). In contrast, novices’  
199   knowledge consists of facts, procedures and formulas that are not as well organized, as  
200   they do not have integrated mental models. Novices are therefore oriented towards  
201   surface characteristics in problem solving (Glaser & Chi, 1988; Bogard, Liu, & Chiang,  
202   2013). Furthermore, experts have developed a condition–action ability through practice.  
203   Experts have conditioned knowledge: the recognition of specific patterns triggers an  
204   appropriate response that is useful for problem solving (Glaser & Chi, 1988; Bransford,  
205   Brown, & Cocking, 2000). Different levels of expertise may influence the performance of  
206   train traffic controllers and therefore resilience at an individual level (Lengick-Hall,  
207   Beck, & Lengnick-Hall, 2011).

208

209

## **METHOD**

### **Experimental setting**

211           A simulator session was used to familiarize train traffic controllers with the new  
212   infrastructure that would result from the removal of 66 switches in three months’ time.  
213   The simulator was strongly focused on the logistical aspects of train traffic control and  
214   much less on technical safety-related aspects. The infrastructure that was simulated was  
215   the train traffic area around Utrecht Central Station. This area is operated by two train

216 traffic workstations. One controller was responsible for the trains that belong to the ‘turn’  
217 (in Dutch: *keer*) area, and a second controller was responsible for the ‘through’ (in Dutch:  
218 *door*) area. The role allocation was reversed in the second round.

219 Two scenarios were designed for the participants: scenario 1 consisted of a light  
220 disruption in the train traffic flow caused by minor train delays, whereas scenario 2  
221 represented a moderately to severely disrupted flow. In the first round, 22 controllers  
222 participated in scenario 1. In the second round, 10 participants participated in scenario 1  
223 and 10 participated in scenario 2. Both scenarios were designed in collaboration with two  
224 senior train traffic controllers. Train traffic controllers were asked to perform their job as  
225 they typically would at their actual workstation. No interaction between the train traffic  
226 controllers was needed to conduct their tasks.

227

## 228 **Participants**

229 All 22 train traffic controllers (18 males, 4 females) worked at Utrecht Central  
230 Station. They took part in a 2 (workstation area: turn or through) x 2 (severity of  
231 disruption: high versus low level of train delays) within-subject experimental design.

232

## 233 **Materials**

234 *Work experience* and *job role* were assessed using questionnaires. Participants  
235 were assigned to a high or a low experience group based on their work experience as train  
236 traffic controllers. The cut-off point was set at 10 years, as a new traffic management  
237 system had been implemented 10 years earlier (Bary, 2015).

238            *Operator goals* were operationalized through performance indicators (Popova &  
239    Sharpanskykh, 2011). A list of performance indicators for train traffic controllers was  
240    created prior to this session by six senior train traffic controllers. Participants ranked  
241    these performance indicators on a scale of 1 to 7 (1 = most important, 7 = least  
242    important).

243            *Speed of acquaintance* was included to find out how fast the participants were  
244    able to get accustomed to the new infrastructure. This item was measured on a 5-point  
245    Likert scale, ranging from fully disagree to fully agree. Participants could also opt for ‘I  
246    do not know’ as an answer.

247            *Performance* was measured using five performance indicators, namely arrival  
248    punctuality, departure punctuality, amount of arrival delay, amount of departure delay,  
249    and platform consistency. Arrival and departure punctuality was operationalized through  
250    trains that arrive at (or depart from) Utrecht Central Station on time or with less than a 3-  
251    minute delay. These trains were counted, summed up and divided by the total number of  
252    arrived/departed trains. For the arrival and departure delay in minutes, the amount of  
253    delays in minutes was summed up and divided by the total number of arrived/departed  
254    trains. With regards to platform consistency, all trains that did not arrive at the planned  
255    track were counted and summed up, and the same was done for all trains that did not  
256    arrive at the planned platform. Secondly, the total number of trains that did not arrive at  
257    the planned platform and at the planned track were summed up and divided by the total  
258    number of arrived trains for each train traffic controller.

259            *Strategic mental models*. Mental models can be conceptualized as declarative  
260    (knowledge of what), procedural (knowledge of how) or strategic (knowledge of what

261 and how, and applied to the context) (Mohammed, Ferzandi, & Hamilton, 2010; Salas,  
262 Stout, & Cannon-Bowers, 1994). Strategic mental models can also be operationalized by  
263 generating lists of actions with subject matter experts (Webber, Chen, Payne, & Zaccaro,  
264 2000). As such, the completion strategies of a train traffic controller could be an indicator  
265 of the controller's strategic mental model. Simulator logs were used to analyze the  
266 completion strategies where different ways of dealing with the train delays (i.e. the  
267 different order of departure of trains that were handled given their delay) were expected  
268 to be possible. Given the length of scenario 1, three conflict points for completion  
269 strategies for the through workstation and one conflict point for the turn workstation were  
270 identified; for scenario 2, one and two completion strategies were identified for the  
271 through workstation and the turn workstation, respectively. Different completion  
272 strategies were subsequently assessed by analyzing whether the completion strategies  
273 were followed according to the preferred completion strategy (as was scheduled) and the  
274 different strategies applied, to assess the variability per operator and per conflict point.  
275 Analyses were done based on participants who enacted scenario 1 in both rounds and  
276 those who enacted scenario 1 and subsequently scenario 2, in order to obtain four conflict  
277 points per individual.

278         *Simulator validity* was measured through three components: structural validity  
279 (the degree of similarity in structure between the simulated and the reference system),  
280 processes validity (the degree of similarity in processes between the simulated and the  
281 reference system) and psychological reality (the degree to which the participants  
282 perceived the simulated system as realistic) in line with Raser (1969), using a  
283 questionnaire designed by Lo, Sehic and Meijer (2014). An example of a structural

284 validity item is: ‘I can apply the information from the information sources in the  
285 simulator in a similar way as in the real world’ ( $\alpha = .65$  with the removal of one item).  
286 The item ‘The train traffic flow in the simulator is similar in their processes to the real  
287 world train traffic flow’ represented process validity ( $\alpha = .60$ ). An example of  
288 psychological reality ( $\alpha = .67$ ) is ‘The simulation environment feels more or less like my  
289 own work environment’. These items were measured on a Likert scale.

290

### 291 **Procedure**

292 The participants completed a questionnaire before the start of the session. They  
293 then enacted the two 40-minute scenarios. At the end of each round, they completed  
294 another questionnaire. During the second round, knowledge probes were administered for  
295 the purpose of another study. Video recordings were made throughout both sessions.

296

297

## **RESULTS**

298 Six of the 22 participants were excluded from the analysis because they had  
299 known about the train delays. Two of the 16 participants included in the analysis had  
300 enacted scenario 2 twice. As there were a few problems with the simulator, not all train  
301 traffic controllers received the same number of trains. This issue was controlled for by  
302 using an average score of the objective performance measures and reviewing the severity  
303 of issues through video recordings for events that hindered participants in their options or  
304 decision making.

305 The average score of the participants’ work experience in their current function  
306 was 10.3 years ( $SD = 9.24$ ).

307 **Simulator validity**

308           The findings show that the participants tended to be slightly positive about the  
309 validity of the simulator considering the task they were given (see Table 1). The  
310 participants also indicated that they had quickly got used to the simulator.

311

312 **TABLE 1:** Descriptive statistics of the validity of the simulator on the three validity  
313 components and speed of acquaintance with the simulator and the two workstations,  
314 measured on a 5-point Likert scale.

	<b>N</b>	<b>M</b>	<b>SD</b>
<b>Structural validity</b>	21	3.5	.92
<b>Process validity</b>	20	3.6	.66
<b>Psychological reality</b>	22	3.7	.71
<b>Speed of acquaintance with the simulator</b>	20	4.2	.83
<b>Speed of acquaintance with the turn workstation</b>	21	3.9	.62
<b>Speed of acquaintance with the through workstation</b>	21	4.0	.59

315

316           Regarding learning effects between scenarios, the participants indicated that they  
317 had got used to both workstations relatively quickly.

318

319

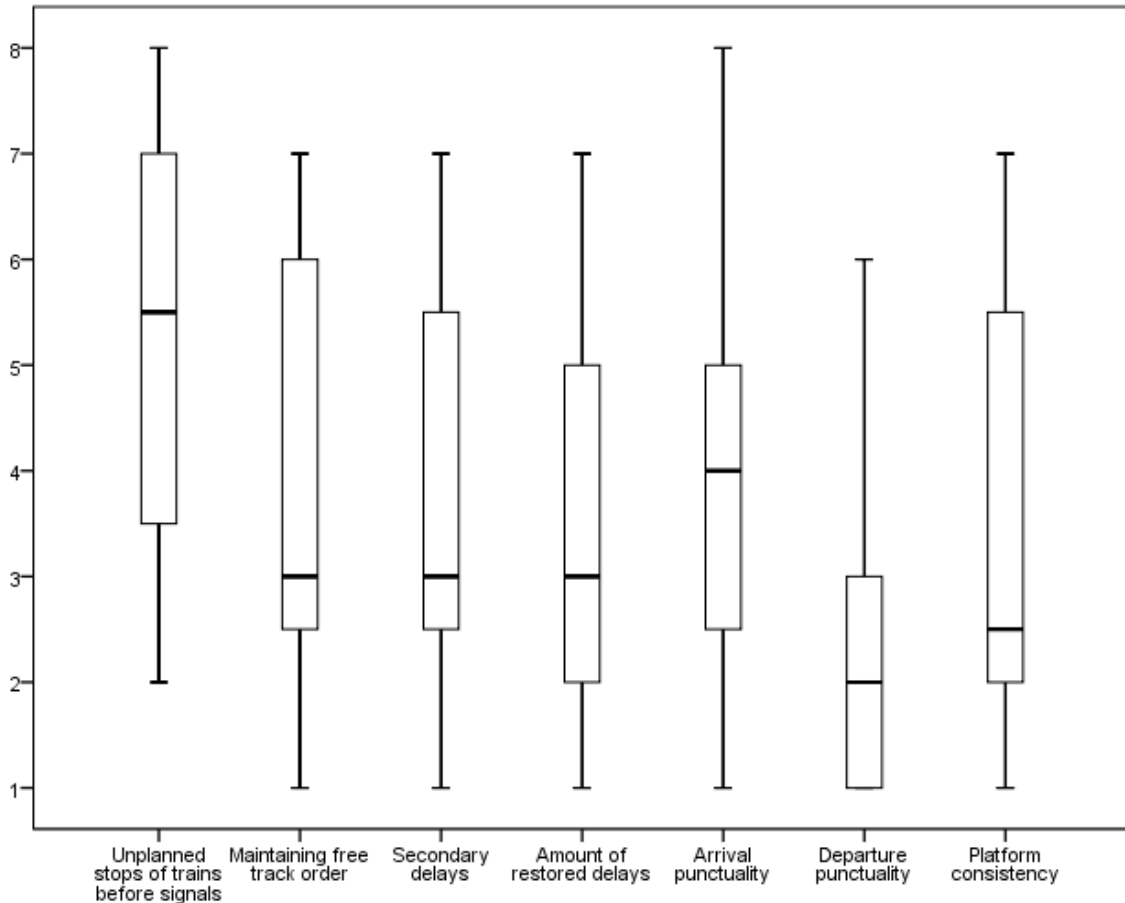


320 **Goals**

321 Figure 1 shows a relative moderate goal consistency among the train traffic controllers.

322 Three controllers added two more performance indicators, but these were not included in  
323 the analysis.

324



325

326 *Figure 1.* Median distribution of self-reported performance indicators (x-axis) with the  
327 ranking scale depicted on the y-axis (N=20).

328

329 In the assessment of primary preferred performance indicators, however,  
330 departure punctuality was consistently perceived as most important (36%). This was

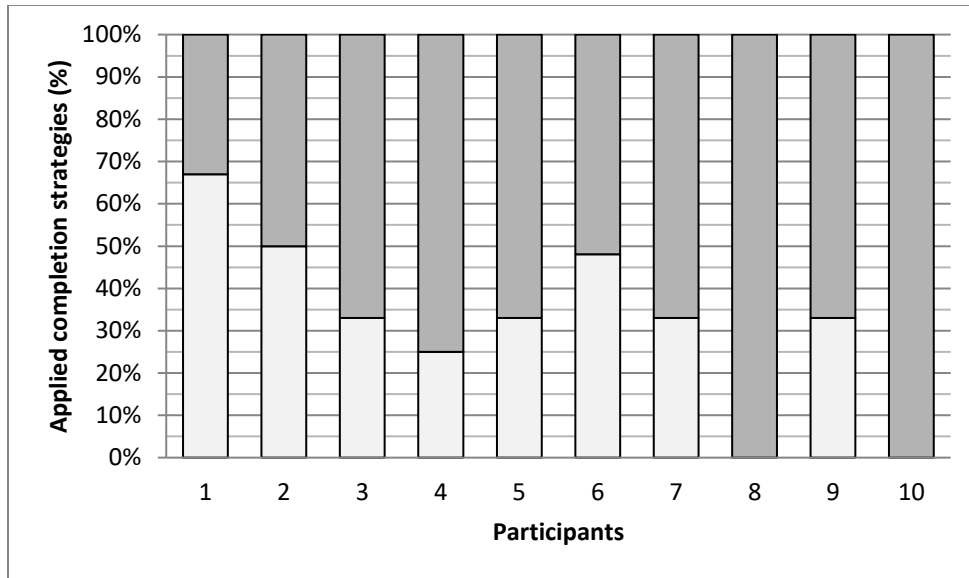
331 followed by achieving high platform consistency (18%), arrival punctuality (14%),  
332 maintaining free track order (i.e. track use between stations in the planned order) (9%),  
333 the number of restored delays and secondary delays (both 5%) and the avoidance of  
334 unplanned stops of trains before signals (0%). As such, these results show a very  
335 fragmented preference with regards to primary key performance indicators.

336

### 337 **Strategic mental models**

338         The operators' strategic mental models were analyzed to obtain insights into the  
339 diversity of their individual completion strategies. The overall findings show that  
340 participants handled on average 61% of the completion strategies in the preferred manner  
341 ( $SD = 31.5$ ). Those who enacted scenario 1 twice handled 53% of the completion  
342 strategies in a deviating manner ( $SD = 21.1$ ). Participants who enacted scenarios 1 and 2  
343 handled on average 37% of the completion strategies in the preferred manner ( $SD =$   
344 14.2), and 65% in an alternative manner ( $SD = 24.2$ ) (see Figure 2). Based on Figure 2, a  
345 qualitative assessment supports the variation in completion strategies with regards to the  
346 operators' individual completion strategies.

347



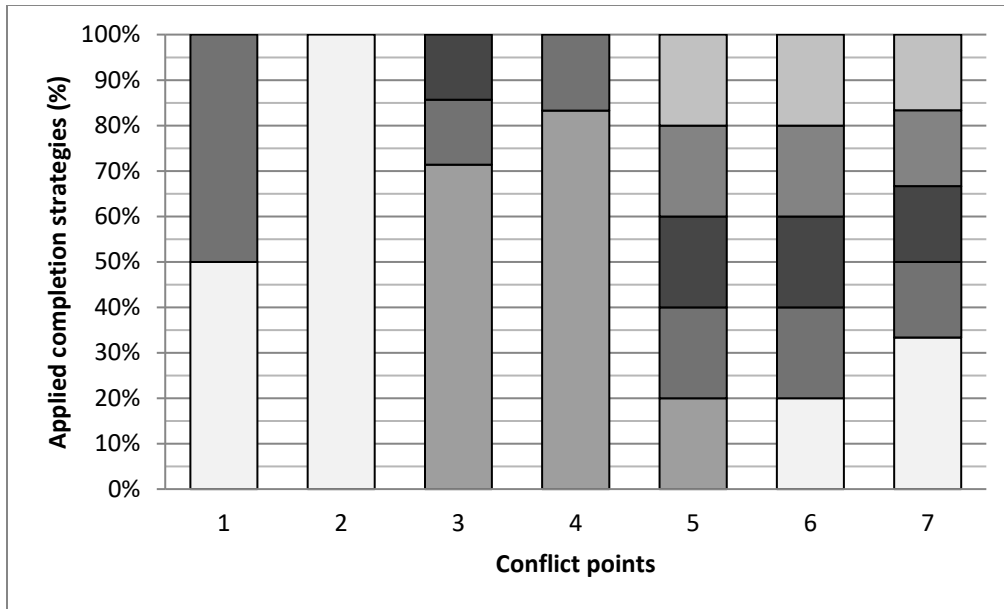
348

349 *Figure 2.* Applied completion strategies per participant for operators who enacted  
 350 scenarios 1 and 2. A white band indicates a preferred completion strategy being followed,  
 351 and a grey band indicates alternative completion strategies. Even numbers represent  
 352 participants from the through workstation, odd numbers those from the turn workstation.

353

354 An analysis of the level of variation in completion strategies for each conflict  
 355 point revealed diversity based on between one and three different completion strategies  
 356 for four conflicting points in scenario 1, and on five different variations of completion  
 357 strategies for three conflicting points in scenario 2 (see Figure 3). A qualitative  
 358 assessment would show that there is a level of variation in the completion strategies with  
 359 regards to different conflict points and that this differs between scenarios: operators dealt  
 360 with these conflict points with more diverse completion strategies in the moderately  
 361 disrupted scenario than in the lightly disrupted scenario. Further, it is notable that  
 362 preferred completion strategies were implemented more frequently in scenario 1.

363



364

365 *Figure 3.* Applied completion strategies per conflict point for scenario 1 (1–4) with N  
 366 =14 and scenario 2 (5–7) with N = 10. A white color indicates a preferred completion  
 367 strategy being followed, while different shades of grey indicate different completion  
 368 strategies. Numbers 1, 2, 5 and 6 represent conflict points from the through workstation  
 369 and numbers 3, 4 and 7 represent conflict points for the turn workstation.

370

### 371 **Performance**

372 Spearman correlation tests were performed to test whether there is a congruence  
 373 between the self-reported relative importance of performance indicators and objective  
 374 performance (see Table 2). Although scenario 1 does not reveal any significant  
 375 correlations, scenario 2 does, namely a strong positive correlation between self-reported  
 376 departure punctuality and objective arrival delay. Also a strong negative correlation was  
 377 found between self-reported arrival punctuality and objective departure delay. A trend for  
 378 a negative correlation between self-reported platform consistency and objective arrival  
 379 delay was also found.

380

381 **TABLE 2:** Correlation between self-reported performance indicators and objective

382 performance indicators for scenario 2.

<b>Self-reported performance indicator</b>	<b>Objective performance indicator</b>	<b>N</b>	<b>r</b>	<b>p</b>
Departure punctuality	Arrival delay	10	.79	.007**
Arrival punctuality	Departure delay	10	-.73	.018*
Platform consistency	Arrival delay	9	-.59	.097

383

\* $p \leq .01$ , \*\* $p \leq .05$

384

385 Although unexpected, these results provide interesting insights into goal  
386 competition, as they suggest that arrival punctuality and departure delay, departure  
387 punctuality and arrival delay, and platform consistency and arrival delay are competing  
388 goals.

389 A Spearman correlation test was also performed between the applied preferred  
390 and alternative completion strategies and performance. No significant relations were  
391 found.

392

393 **Experience**

394 It was expected that the more experienced controllers would outperform the less  
 395 experienced controllers due to their better organized mental models. The analyses showed  
 396 a significant tendency in scenario 1 for controllers with less experience in their current  
 397 function to have a higher arrival punctuality score than the more experienced controllers  
 398 (see Table 3). An opposite tendency was found in scenario 2: the controllers with more  
 399 experience in their current function have a higher arrival punctuality score than the  
 400 controllers with less experience in their current function.

401

402 **TABLE 3:** Differences in objective performance between more and less experienced  
 403 train traffic controllers in their current function.

Scenario	Objective performance indicator	Experience	Mean Rank	N	U	p
1	Arrival punctuality	Low	13.8	11	13.0	.005*
		High	6.4	9		
2	Arrival punctuality	Low	3.9	5	4.5	.09
		High	7.1	5		

404 \* $p \leq .01$ , \*\* $p \leq .05$

405

406 It was also investigated whether the applied completion strategies and  
 407 performance indicators preference differed between the high and the low experience  
 408 group. No significant difference was found for the variation in applied completion

409 strategies, indicating that both more and less experienced operators show diversity in  
410 their completion strategies. For the different primary performance indicators, a trend was  
411 found for a difference in the importance of maintaining free track order ( $U = 17.0, p =$   
412  $.073$ ) and unplanned stops of trains before signals ( $U = 20.5.0, p = .095$ ). More  
413 experienced operators indicated these goals as being more important compared to the less  
414 experience operators. This is possibly because both goals are felt to be of importance to  
415 achieve a good performance in their train traffic operations, whereas less experienced  
416 controllers do not yet feel this.

417

418

## **DISCUSSION AND CONCLUSION**

419 This study investigated the following research questions: to what extent do  
420 organizational and individual goals correspond? And what is the level of diversity in the  
421 goals and strategic mental models of train traffic operators given operators' work  
422 experience, and how does this relate to their performance?

423 First, the level of correspondence between organizational and individual goals  
424 was explored. This correspondence appeared to be moderate when looking at the median  
425 distribution. However, when assessing the preference for arrival punctuality, this goal  
426 ranked in the third position with 14% of the controllers adhering to the primary  
427 organizational goal. Operators indicated that they value departure punctuality (36%)  
428 and platform consistency (18%) as more important than the primary organizational goal  
429 arrival punctuality. The low absolute percentages spread over multiple goals revealed a  
430 strong diversity in operators' goal preference. A diversity between operators in  
431 completion orders was also found: as many as five different completion strategies were

432 identified in the moderately to severely disrupted scenario. It is notable that in this study,  
433 the level of diversity in strategic mental models could not be related to worse or better  
434 performance.

435         The valuation of the controllers' goals was not reflected in their performance. The  
436 results show that in a moderate to severe traffic condition, controllers who highly value  
437 arrival punctuality showed more departure delay. Controllers who focused on departure  
438 punctuality had less arrival delay, and those who focused on a high level of platform  
439 consistency had less departure delay. Although these results do not confirm the  
440 expectations, they are in line with the fact that individual goals do not always lead to the  
441 system performance that corresponds to their personal goals. In fact, the presence of  
442 multiple and competing goals can be seen as characteristics of complex, ill-structured  
443 environments, as they have to be weighed and prioritized and compromises have to be  
444 made (Amelung & Funke, 2013; Funke, 1991; Hong, 1998). To obtain resilience,  
445 performance requires certain goals to take precedence over other goals (Woods, 2006).  
446 The moderate to severe traffic condition was a more complex situation and the controllers  
447 possibly had to make more compromises. These goals were probably not as conflicting in  
448 the less complex situation because the scenario did not cause a conflict between arrival  
449 and departure goals.

450         This study also revealed a difference in the valuation of the goals 'maintaining  
451 free track order' and 'unplanned stops of trains before signals' between the more and the  
452 less experienced operators: the former considered these goals to be more important. As  
453 such, more experienced operators appear to be more comfortable about satisfying lower  
454 prioritized organization goals. A trend was found for the level of experience impacting



455 performance: less experienced controllers showed better arrival punctuality than  
456 experienced controllers when no complex disruptions were introduced (scenario 1). In  
457 contrast, the opposite trend was found when more train delays were introduced (scenario  
458 2). The results of scenario 2 are in agreement with previous studies, following the line  
459 that more experienced controllers perform better in complex situations because of their  
460 well-developed mental models (Bogard, Liu, & Chiang, 2013).

461         Some limitations to this study should be mentioned. Although the simulator  
462 problems were controlled for, they nonetheless necessitated a small sample size. Also,  
463 given the length of each scenario, the number of conflict points per workstation was  
464 rather low. A limitation of this study in terms of goals trade-off consequences is that the  
465 level of violations was not assessed; we did not assess when a certain goal was violated  
466 during the simulator study or what the implications were of prioritizing one goal over  
467 another in these scenarios. These points should be taken into consideration in future  
468 studies.

469         Further, in line with the measured individual markers of resilience in this study,  
470 future research could investigate the diversity of strategic mental models in the actual  
471 work environment. The level of diversity of completion strategies between workstations  
472 could also be further investigated.

473         In sum, the primary organizational goal was not reflected at the operational level.  
474 An explanation for this might be the difference in the realization of operator's goal versus  
475 the evaluation of operator's performance. In an exemplary case, train traffic controllers  
476 may recognize arrival punctuality as both a primary organizational goal and an individual  
477 goal; however, due to external factors influencing the train traffic flow, a high arrival

478 punctuality cannot be guaranteed by the operator alone. As such, operators may develop  
479 different preferences and coping mechanisms to better reflect their performance.

480           Although variability in cognition and behavior is both healthy and allowed, it can  
481 be argued that the revealed goals and strategic mental models of operators are too diverse  
482 and therefore unpredictable, and most probably weaken the resilience at the system level.  
483 These results could be used as an indicator of brittle points that prevent the creation of a  
484 resilient organization (Gomes et al., 2009). It is observable that there are gaps between  
485 the work that is expected and the work that is done. Especially with the upcoming and  
486 planned large-scale changes in the railway system, it could be undesirable to continue  
487 with the redesign without involving the operational layer. Participatory design could be  
488 used as a joint approach to shape these changes (Falzon, 2008), enabling a new  
489 generation to work in a restructured work environment and to resonate these changes  
490 throughout all the levels.

491

#### 492 **Key points**

- 493       • There is an incongruence between organizational and individual goals, indicating  
494       a gap between the work that is expected and the work that is done.
- 495       • The resilience of the Dutch railway system is low due to rather strong variations  
496       in the goals and strategic mental models as the behavior of operators becomes  
497       more unpredictable.
- 498       • In a more complex state of the traffic system, there is an incongruence between  
499       train traffic controllers' self-reported performance indicators and objective  
500       performance, possibly indicating goal competition.

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