Making matters speak: fault-finding in railway maintenance

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A very preliminary draft – please do not quote!

Abstract

Railway maintenance technicians are assigned to secure safe and timely trains. Simultaneously, maintenance work exposes railway technicians to occupational health and safety risks. Despite the tension that occupational risks bring about, most of their work is mundane and boring. However, fault-finding and repair of broken or malfunctioning equipment provides a challenging and rewarding experience. Fault-finding is rewarding because it challenges technicians' practical competence and contributes to their self-identity as handy men. Fault-finding is also rewarding because it confirms technicians importance for achieving safe and timely train traffic.

Fault-finding in railway maintenance typically involves heterogeneous engineering, where technicians align and combine competences, organizations, protection modes and artifacts. These are applied in a specific sequence, informed by specific strategies used for fault-finding, strategies that technicians learn as part of their participation in a community of practice, rather than in formal training. To save time, faults are usually compared to previous examples and technicians apply short-cuts that have been proved to work in similar circumstances. Technicians claim that in most situations, the problem is clear to them from the start: the matter speaks to them directly – "it is obvious what the fault is like". Previous experiences from similar faults therefore help to make short-cuts: knowing typical malfunctions and starting to look for them before making a structured search for the whole installation. Thus, experience makes it possible to rationalize fault-finding. Only when these short-cuts fail, technicians turn to systematic searches. The data to be presented at the workshop involve situations where the problem is not obvious from the start. Instead, technicians need to work to make matters speak to them. They need to align with other people and with different technical equipment to make the data speak.

Introduction

Railway maintenance technicians are assigned to secure safe and timely trains. Simultaneously, maintenance work exposes railway technicians to occupational health and safety risks. Despite the tension that occupational risks bring about, most of their work is mundane and boring. However, fault-finding and repair of broken or malfunctioning equipment provides a challenging and rewarding experience. Fault-finding is rewarding because it challenges technicians' practical competence and contributes to their self-identity as handy men. Fault-finding is also rewarding because it confirms technicians importance for achieving safe and timely train traffic. Fault-finding is therefore strongly committing.

In the paper, I will first outline the social and administrative shaping of technicians work and their diagnostic work. In the preceding section, I will deal with the methods and data used for the paper. Next, technicians discourse on fault-finding is analyzed, followed by two stories of puzzling diagnosis and how closure is reached through various means for heterogeneous engineering.

Trouble-shooting in the railways: administrative and occupational rationalities

Technicians are employees assigned to deal with the "empirical interface: a point at which a production system met the vagaries of the material world" (Barley, 1996: 418). They are responsible for the up keeping of infrastructures that make it possible for others to work. Following this argument, a technical fault is a broken link between different parts of a technical system and fault-finding involves repairing that link. Thus, fault-finding is an integrated, defining part of technicians' work. To be a competent technician necessitates being able to successfully perform fault-finding, to fix it.

Technicians work is to a large degree informed by their participation in communities of practice, developed from their shared undertaking of a common endeavor on a frequent basis (Wenger, 1998). Over time, the community of practice acquires a history of shared experiences and a common repertoire of "things we know and things we do and do not". The repertoire is a resource that the technicians use in order to simultaneously balance and accommodate different demands: outside demands for production and internal aspirations to develop a meaningful practice and desired identities. In a community of practice, participants learn both skills and values as part of their participation. Learning and the achievement of a desired individual identity are intimately involved and reproduced through apprenticeship.

Communities of practice are the locus for the development of practices for trouble-shooting. Research on trouble-shooting in occupational communities include photocopier repair technicians (Orr, 1996); different technicians work (Barley, 1996); and refrigeration service technicians (Henning, 1998). The repertoire that different trades of technicians have developed in the project that Barley (1996) reports, are very similar to each other: an emphasis on embodied knowledge; reliance on contextual knowledge, patterns and sensory cues, sensory-motor skills and heuristics; the importance of adhering to a certain working style or strategy; the need to know about local idiosyncrasies for specific machines or instruments, dependencies etc; and the need for access to the distributed knowledge in the occupation. Also, the technicians value real-life learning much more than formal training. These kinds of skills and values are typical for one of the culturally most well-known relations between men and machines, the mechanic, Mellström (2002) argues.

The railway technicians' work is shaped by both corporate and occupational goals and means. Railway companies became the first civil bureaucracies, in order to coordinate interdependent activities efficiently and safe across time, occupations and space (Chandler, 1977). Safety regulations and other instructions spelled out the employees' work in considerable detail and learning to work consisted to a large extent in learning these regulations. At the same time though, most employees had to rely heavily on their own experience and judgment when it came to carrying out their work (Ryggvik, 2004). Particularly the organization of railway maintenance was, and is still, very much left to workers' own discretion. Until 1962, the most reliable track workers were assigned a *lengthmen*[1] *post* with a corresponding cottage near the tracks, pertaining to a particular section of the *line* for which the lengthmen were responsible (Lindmark, 1991). The lengthmen maintained the line: cleared weeds, repaired minor faults etc. The lengthman had varied tasks and freedom to plan his work according his own initiatives and plans, as long as he achieved what he was assigned. There is still considerable occupational autonomy in railway maintenance, supporting claims to "freedom with responsibility". The practices of fault-finding has developed mainly within the railway technicians communities of practice, typically involving heterogeneous engineering (Law, 1987), where technicians align and combine competences, other people, organizations, protection modes and artifacts.

Methods and data

The data that supports this article was collected mostly in Midtown, Southern Sweden, in the year 2000 and in the years 2002-2004, totalling five months of fieldwork, followed by interviews and focus groups. As I was interested in how different activities were coordinated with each other in order to produce safe and timely trains, as well as for other ends, I divided my attention purposively between different occupations: high-voltage technicians, signal technicians, track technicians, dispatchers and train drivers, for a total of 30 days. I also attended a two-week safety-training course providing me with certification for working as *lookout man*, for safety planning, and as person in charge for work on the tracks. The observations were followed by a small number of interviews.

Getting access to the field was generally easy, probably due to the fact that the railway system is still largely state owned in Sweden, with an ethos to serve the entire nation (Kjellvard, 1949; Forsell, 1998). However, it was more difficult to achieve rapport and necessary trust between the informants and me. I came to an environment in which there was no previous experience of research and there was no relevant role for me to fit into. I intentionally took a rather passive stance, tried to explain who paid me, what the purpose of my stay was and what good it might bring. I was nicknamed, mostly jokingly but always with serious undertones that reflected expectations of my role and what could be expected from me: The Professor, The Time and Motion Study Man, The Candidate, The Trainee. I was put to test: to carry heavy stuff, to answer "scientific" questions, I was exposed to jokes and provoked through pretending racism, sexism or through questioning the point of doing research at all. In addition to testing me verbally I was also assigned work: screwing, attaching track circuit clips and ground wires etc.

The verbal testing and the work I was assigned can be seen as part of an apprenticeship process in a hazardous environment that requires mutual trust in the team. It resembled the kind of testing among the high-steel ironworkers that Haas (1977) observed. The kinds of task I was assigned were also usually simple ones that did not require a complex understanding of the whole production process, as is the case in the beginning of apprenticeships. Nevertheless, these tasks represented a minor investment in trust and if successfully carried out provided a sign of trustworthiness and a clearance to move into more central tasks within common tasks as well as increasing faith in my moral qualities and loyalties. Very early on in the project I was appointed as lookout man (watching out and warning for approaching trains for the gang that worked on or near the tracks), which indeed is a sort of test including certain risk-taking on their part. To me this risk-taking was a sign of trust in itself.

In addition to observations and interviews, I organized focus groups with participants from the same trade, since I assumed that the local teams had developed common norms for what risks are seen as relevant, what risks you can take, what rules you can bend and when etc. In this way I hoped that the focus groups intentionally created a situation similar to how the technicians would have discussed the issues as part of their normal interaction, such as during a coffee break or in the car while traveling to a work place. I hoped to be able to catch the group dynamics at work: sense making, knowledge transfer, social control etc. I organized four focus groups, one for each trade, except for the engine drivers, in order to get the informants' perspectives on certain issues that had caught my interest during the fieldwork. In each focus group, the participants were three to five member of the same local community. The focus groups took place at the facilities in Midtown, on regular working-hours. I used a set of general questions to provoke a start and also asked about their interpretations of specific events that we had all participated in or which they considered relevant and informative. The focus groups are numbered 1-4 according to their chronological order.

Observation data and focus group data complemented each other in an interesting way. The occupational discourse that prevailed in focus groups enhanced the analysis of the meaning making in fault-finding, as it informs that practice. Simultaneously, technicians' experiences of trouble-shooting also shape how they conceptualize their work. First, fault-finding is a salient part of technicians work in terms of social importance, challenges to practical knowledge, identification processes and learning. Second, there are specific strategies to deal with fault-finding, learnt at work and through seniors, strategies used for making short-cuts. Despite the social character of fault-finding practices, there is a tendency towards individual heroism in the discourse data. The observation data shows that the network of objects, relations and interactions, that is, heterogeneous engineering, which technicians draw upon in fault-finding, is down-played in discourse, especially when it comes to more problematic faults.

"Really the best school": organizing, learning and becoming

Among railway technicians there is a repertoire of embodied skills, strategies, values, work styles and story telling practices that serves to accomplish tasks and to reproduce the community. During courses, technicians learn the design and functioning of particular subsystems. They are taught how to read and make sense of drawings, to understand how a subsystem works through looking at a drawing and they are trained to construct such systems anew. These courses are of course indispensable but they are not sufficient for learning to find faults in real maintenance work, technicians argue. Experience provides skills that rationalize and standardize fault-finding such as appropriate strategies, working styles and short-cuts, my informants claim.

Knowing the default mode and being able to readily identify any problematic deviance provides a quick start. High-voltage technician Edvin simulates a diagnosis:

> EDVIN: "It looks wrong… it should work like this". Often the source of the malfunctioning is very obvious. In order to shorten a fault-finding search: "No that was wrong". It helps you not to start in the wrong end (Focus Group 4, April 2003).

If you started a fault-finding session with a look at the drawing and systematically tried to test every piece of malfunctioning equipment you would probably be starting in "the wrong end" and not where the probable fault lies. You better start with a component that looks out of default mode.

Even though every fault is specific, many of them are alike, and over time they return to the same piece or similar pieces of installation. Previous experiences from similar faults also help to make short-cuts: knowing typical malfunctions and starting to look for them before making a structured search for the whole installation, as explained by signal technician Stefan:

> STEFAN: Otherwise you might start from the scratch with… looking at the drawing and look like that but when you have experience then you can start over in that contact since perhaps… you know that there… here there has been faults (Focus Group 2, February 2003).

To efficiently perform trouble-shooting you need to be able to read an installation "directly", not through a drawing, to get a "feel". Thus, experience makes it possible to rationalize fault-finding.

In course training, everything is set and neat, simplified and straight forward, signal technician Samuel argues. By contrast, real-life fault-finding is indispensable for serving your apprenticeship, providing valuable and indispensable experience in real-life working situations (Focus Group 2, February 2003).

> SIXTEN: It is really the best… school to be on fault-finding
>
> STEFAN: Yes it is
>
> SIXTEN: And then you perhaps… you perhaps decide to bring with you someone who is new even though you perhaps… it does not feel so secure… most often we work in pairs.

Fault-finding works as unintended simulation in a system that is designed to work fail-safe: "We are not allowed to do mistakes, therefore we cannot learn from mistakes. But fault-finding provides an opportunity to learn from [naturally occurring] faults", signal technician Sven argued (Observation Protocol, September 2000). In addition, fault-finding often takes place in "difficult situations", far from the ideal situation in the class-room.

> SAMUEL*:* In former times we said that fault-finding really was the thing that made you learn the job… Measuring technique… working in difficult situations. If you with "difficult" say…. it can be any time of the day, often chaotic, trains are late, people call and persistently ask: "is it fixed soon?" (Interview, November 2000).

Emergency fault-finding often takes place outside normal working hours, sometimes at night, in the cold or during rain or snow-fall. Trains are late, standing idle behind the adjacent signals and the train dispatchers are haunted to make the trains continue their journey. This does not mean that it is easy to find the faults – this can take hours – but that it is not defined as a "difficulty". The "real" signal technician is able to fix technical troubles also in difficult situations, not only at the desktop or in training classes.

However, as we will see in the next section, it is not necessarily the circumstances that might challenge technicians' diagnostic work. It might also be the technical difficulties themselves that challenge technicians understanding and capacity to make it work. These situations are really frustrating since they challenge technicians their identification as technically competent:

> STELLAN: If you have not been able to find the fault after many hours of trouble-shooting – then your self-esteem is down to the bottom: "Damn it, I need to retake the basic course – I don't know anything about signal technology". Your brain is empty – then it is time to change into another repairman (observation protocol, September 2000).

Being unable to fix a problem is unpleasant, and potentially a threat to your identity. However, similarly to Orr's technicians, there is a collective responsibility to fix errors that goes beyond individual pride. Individual failure is explained in different ways. As "human error": fatigue, mental blackout etc. In the quotation above, Stellan argues that you need to change into another repairman after many hours of failed trouble-shooting. It is good to be two on fault-finding my informants explain, since left on your own you might get lost in the wrong track (this time in a figurative sense). Individual failure could also indicate that you haven't yet served your apprenticeship or that it is a very special problem you have not encountered before. When I was out on fieldwork, signal technician Sören readily admitted that he got aha-experiences more frequently than his colleague Stig. In the next section, I will focus on two faults that are not so obvious from the start and which requires a considerable amount of explicit sense making and social and technical interaction.

Fault-finding as heterogeneous engineering

Fault-finding in railway maintenance typically involves heterogeneous engineering, where technicians align and combine competences, organizations, protection modes and artifacts. According to the technicians, fault-finding includes working in a specific sequence, informed by specific strategies used for fault-finding, strategies that technicians learn as part of their participation in a community of practice, rather than in formal training. The data presented below involve situations where technicians are puzzled: the problem is not obvious, in contrast to how they characterized most situations in the focus groups, but still technicians have to reach closure. So they need to work to make matters speak to them through other means than their personal competences. What material and social resources and strategies can they rely upon?

Confusion and puzzlement: "I smell a rat here"

September 2000, in the vicinity of Midtown[2], Sweden. Erland and Einar, two men in their early thirties, are employed as high-voltage technicians by Banverket Produktion, a Swedish stately owned corporation that maintains and repair railway installations on a contract basis with network owners. I am following Erland and Einar when they are inspecting switch heaters at a countryside station. In a switch, switchblades are pulled to either of two sides, forcing trains to choose either track. If the blades get stuck in the winter due to ice and snow, the switches cannot be laid in the correct position, thus making train routing very difficult. Switch heaters are thin electric radiators running along the tracks in the switches, which are turned on in the winter to melt any ice and snow that lies on them.

We walk towards a switch. Erland calls the remote dispatch[3] center over his mobile phone: "We would like to have a protected work in switch 103". Einar applies track circuit clips that align the two rails, thus short-circuiting the track circuit on the section where we will be working. This will set signals around the section to stop aspect and protect us from approaching traffic. Also the dispatcher sets up protective measures. We can now safely enter the tracks.

Einar turns on the switch heaters and sprinkle water with a flower shower onto the tracks to see if the heaters work. Erland places his fingers on it: "If you get burned, it is too hot". The heaters do get warm. The two technicians check if the heaters are properly fastened and adjust some of them. Then we walk to a nearby shed where the circuits for all the heaters at a station are brought together. In the shed sensors measure humidity and temperature: at pre-specified values the sensors turn the heaters on. Erland and Einar start to measure resistance in the circuits. The circuits show different resistance readings which puzzle the technicians: "I smell a rat here", Einar says. The technicians turn instead to measure resistance in a circuit in one of the switches instead, located in a box between the rails – with the same result: "Is it the resistance meter that makes fuzz with us?"

Einar underwent a course in switch heating five years ago and has since then hardly worked with it. He calls a colleague working in another city which he thinks knows more about switch heaters.
"I get so funny results: one is hardly 200 Kohm, one nothing, one is short-circuited".
"Do you measure outbound cables?"
"If you find a fault sectionalize it [the installation]… in the switch?"
Erland is also puzzled:
"It can't be right – we can't get short-circuit – then we would not get any heat".
Einar ends the conversation and turns to Erland:
"The instrument is not certified for outdoor use. It can produce wrong values."
Then he turns to me:
"Our colleague knew about all the tricks with switch heaters. At the course I went through we learnt how to construct the system but too little about fault-finding and how to adjust it."

Einar makes a call to order another meter. He and Erland open a box in the switch: they remove the cables and look for short-circuit. But before we continue trouble-shooting, the protected work slot is over and we have to wait for a train to pass by. Einar looks into a hard binder and moves far away from the tracks, well beyond the required safe distance, advising me to do so too: "It is easy to get in the wrong place when you are busy doing something else". After the train has passed, Einar and Erland resume fault-finding and start to learn more about the reason for the fault. One of the heaters has to be replaced and one of the circuits is short-circuited.

Einar and Erland are quite inexperienced with the switch heaters and have not had the opportunity to learn from previous fault-finding. They were not assigned to fault-finding in the first place but still tried to make their best. The incident also confirms the notion of impractical training courses. Their inexperience was helpful since it prevented them from feeling frustrated: they did not expect themselves to know how to do things on their own. They asked for advice on how to carry out their fault-finding. They also attributed the fault to possible measuring errors.

"What's wrong?" obsession and challenges in fault-tracing

September 2002, in Midtown, Sweden. Signal technicians Sven and Stellan and I are off to a grade crossing in an industrial siding where the signs to the road traffic does not show white ("all clear"). Sven encourages me to wave to the cars to pass the grade since they stop when Sven and Stellan start the signal. Sven and Stellan starts fault-tracing – they check resistances and currents in different places, they check electric switches, they check the track circuit which detects trains approaching the grade and make the signals turn red so that cars stop and let the train pass the grade. They check the signal box and the lamps directed towards the train. After a while they have localized a component in the box that seems to be the problem: "LRV: the oldest part in the whole box – let's hope we can get a new one". We drive back to the workshop and Sven and Stellan talks to other signal technicians: they think that the fault is lying somewhere else. Besides, there is no such component in Midtown.

We drive back to the grade crossing, checks the lamps towards the road: one of them is broken. But why does not the signal work? Stellan calls someone for advice. Then he and Sven measure the lamp voltage, they open a small box behind the lamp: is there any damp in there? They check voltage in a different way: "Only five volts – could the cable be damaged?". They return to the signal box: check each part in the LRV separately: "No, we need to measure resistance in that cable anyway?". We return to the workshop for lunch with the other technicians. Usually lunch talk is devoted to private issues but today they have to give way for discussing the fault at the grade crossing: Stellan has even brought the drawings.

After lunch we return to the grade crossing and Sven and Stellan continue to check voltages and resistances. The box behind the lamp is more resistant than it should be: "Is this not the faulty part it must be the LRV". Two days later it was found that the LRV was indeed the faulty piece and one spare example was found.

Sven and Stellan are more experienced than Einar and Erland and they are therefore more disturbed by their puzzling experience. Still though, they are also in need for advice. Closure is similarly reached through recourse to community expertise.

Conclusions

The general problem in railway maintenance fault-finding is figuring out what technical component is faulty, causing functional failure. In a complex subsystem, this is not an easy task. In the name of efficiency, technicians have developed strategies for making short-cuts through visual or functional cues and through starting with the most common known failures first, rather than a systematic search.

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[1] Lengthmen are called platelayers in the UK.

[2] All personal and geographical names that I use in the article are pseudonyms in order not to identify the real persons who needs to be anonymous for integrity reasons.

[3] Dispatchers are called signallers in the UK. The dispatchers monitor automatic (pre-programmed) routing of trains and also perform manual when needed, to achieve safe and timely train traffic. In addition, they set up protected work sites for the railway technicians.