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Re-thinking Competency Based Training:

Building skills to support resilient performance

International Railway Safety Conference, Perth 2019

13-18 October

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The rail industry is currently seeing rapid advances in technology, increased automation, and substantial change associated with asset renewal programs. In this environment, training must also evolve to reflect the most relevant needs of current and future safety-critical workers. The shortage of skills across many safety critical roles gives rise to a need to expedite the development of performance and expertise among safety-critical workers when they join the industry. Traditional approaches to competence management have focused heavily on technical and procedural requirements, without properly integrating the underlying professional skills that are known to contribute to safe, effective performance in safety-critical environments. When identifying training needs, it is important to understand the characteristics of effective human performance, along with the challenges faced in the operational environment, and to approach skills development in this context.

This paper describes several principles that could transform the future of competence management and assist in meeting the emerging challenges in developing and maintaining skills in an increasingly automated industry. With advances in technology and system reliability, it becomes more difficult to predict the types of system failures that operators may need to deal with. Rather than simply training for known, predictable failures or events, we must focus on building underlying competence, to equip safety-critical workers with the skills to deal with any situations they may face. Lessons can be drawn from other industries, including aviation, where the introduction of highly automated systems has led to similar human performance challenges.

The proposed approach advocates the development of underlying competencies that are associated with expertise, and that contribute to safe, effective performance in a safety-critical environment. Training should be based on a systematic analysis of needs, using evidence gained through analysis of operational data, to understand the challenges of the operating environment. This understanding of training needs assists in the effective use of simulation technology to build resilient human performance through data-driven realistic scenarios. This, in turn, can better prepare safety-critical workers for the real-life challenges faced in operations.

Evolving Competence Requirements

The rail industry is currently seeing advances in technology, including an increased use of automation, and substantial changes associated with asset renewal programs. In this environment, training must also evolve to reflect the most relevant needs of current and future safety-critical workers.

A recent report commissioned by the Australasian Railway Association (ARA) (BIS Oxford Economics, 2018) highlighted a rapidly developing skills shortage in the Australasian rail industry. The report suggested that the current approach to training across the industry is not producing fit-for-purpose results, requiring substantial reform to support the ongoing major investments in rail infrastructure, rollingstock and expanding operations. Adding to concerns about the current skills shortage, is the forecast that more than 20 percent of the current rail workforce will retire by 2028. Figure 1 illustrates the increasing workforce gap forecast across the next decade (BIS Oxford Economics, 2018). The shortage of skills across many safety critical roles gives rise to a need to expedite the development of performance and expertise among safety-critical workers when they join the industry or transition to new types of roles.

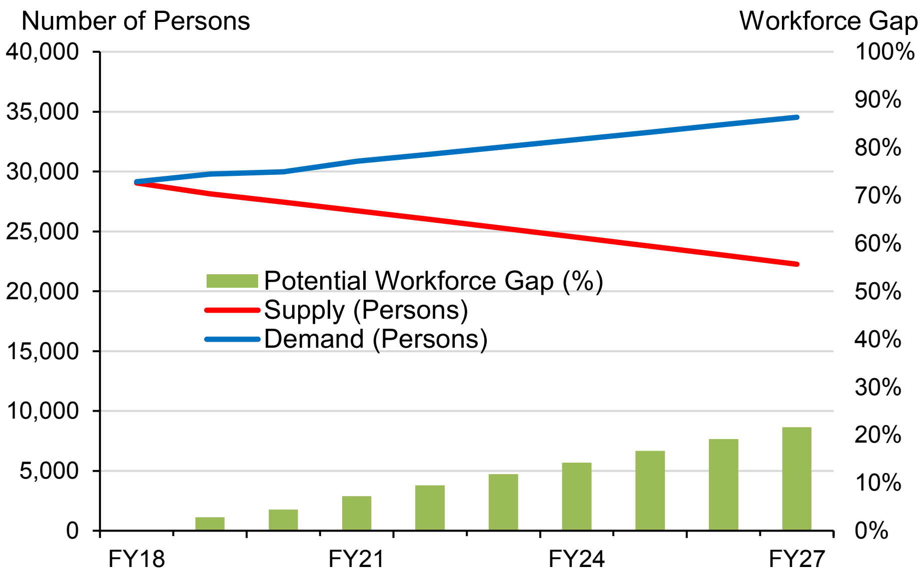

Figure 1. Australian Rail Workforce Gaps – Operations and Maintenance (reproduced with permission from: BIS Oxford Economics, 2018).

In the coming decade, the industry also faces substantial changes in the types of job roles and skills required to operate rail systems, as a result of the adoption of new technology, including greater automation. Rapidly advancing technology and greater use of automation is likely to change the skills profile of a number of safety-critical roles and has the potential to supersede some traditional roles and/or skill sets.

Research on automated systems highlights that automation produces both performance benefits and challenges (Bahner, Huper and Manzey, 2008; Onnasch, Wickens, Li and Manzey, 2013; Parasuraman and Wickens, 2008). Automation has benefits in assisting operators to manage workload and can produce highly reliable performance, particularly in repetitive and closed-loop tasks. It also can provide effective decision support to assist operators in processing information and evaluating options. However, higher levels of automation typically change the human operator's role to one of monitoring, which only requires intervention in rare situations when the automation does not behave as intended. This poses a challenge for maintenance of skills that are infrequently used (Onnasch, et al., 2013), particularly when the skills need to be used proficiently in degraded operations. Higher levels of automation can also pose a challenge for human operators in maintaining situation awareness, that is, to remain 'in-the-loop' when they are not actively involved in the task (Onnasch, et. al., 2013). These adverse effects on performance are exacerbated when personnel have high levels of trust in the automated system, and as a result, engage less in monitoring and checking. Research has demonstrated that this risk can be mitigated somewhat by including exposure to automation anomalies during training (Bahner, et al., 2008).

These performance challenges have already been faced by other industries for a number of decades following the introduction of automated systems. For example, the aviation industry has grappled with the need for pilots to maintain manual flying skills to enable them to take control of the aircraft when automation is degraded or the when human intervention is required. The industry has also faced the challenge of keeping human operators 'in the loop' when the focus of their tasks is no longer the active operation and control of systems, but instead one of monitoring automated systems (Federal Aviation Administration, 2013; Flight Safety Foundation, 2014).

There is evidence of manual skills degradation among airline pilots, and the adverse effects of automation surprises when operating highly automated systems have been observed both in simulator-based research (Casner, Geven, Recker, & Schooler, 2014) and in major aircraft accidents (BEA, 2012). Where operators are required to occasionally operate systems manually, due to technical failures, the operators need to draw upon skills that they rarely use, often in a system that is less well protected due to the system's degradation.

Within the rail industry, the introduction of new technology also means that entirely new roles and skills may be required, particularly when dealing with highly automated systems. As technology becomes increasingly reliable, it is likely that rail personnel will encounter fewer predictable faults and failures, and more of the events encountered are likely to be 'unforeseeable', when technology fails in unanticipated ways.

While the rail industry has a strong record of applying thorough, competency-based training, this often relies upon lengthy training periods (for example, up to 18 months for a train driver, and typically requiring substantial rail experience in other roles prior to entering driver selection and training processes).

The industry faces a substantial challenge in sustaining and improving upon current rail safety performance, considering the human performance challenges that are likely across the next two decades:

- Shortage of skilled roles, and lower experience base in rail organisations
- New technology means that completely new skills may be required, and traditional skills may be less relevant
- Manual skills retention in highly automated systems.
- Fewer predictable faults and failures, and more 'unforeseeable' events

In order to optimise human performance in future systems, the discipline of Human Factors needs to play a key role. This role should involve understanding the role of human operators in these future systems, defining effective performance, and making sure that systems are designed in a way that supports effective performance. The focus first and foremost must be on human-system integration in design processes. Then, it is also important to understand the training needs for operators of future systems. We need to understand what characterises competence in these future roles. Training will be important to ensure that human operators are prepared to manage the challenges of operational complexity and are prepared for situations that are not experienced frequently in normal operations.

In preparing to meet these current and future human performance challenges, training systems need to adopt a structured, systems-based approach to training management. This may be achieved by:

- Understanding and training human performance in the context of the whole operational system and its challenges
- Developing effective systems to collect and analyse data to inform training
- Conducting formal, structured analyses of training needs
- Utilising an integrated system of underlying competencies and detailed performance indicators to measure performance
- Making training decisions based on scientific and industry evidence

There is much that we can learn from other industries that are facing similar challenges. For example, the aviation industry continues to face similar challenges and has already embarked upon a paradigm shift in pilot training, focused on building resilient human performance through the development of underlying competencies. The competencies and associated training requirements are based on an analysis of industry operational and safety data, which identified the most relevant training needs and priorities according to the challenges that pilots face in today's operations. Training is moving from being solely task and manoeuvre focused, to focusing on the development of underlying competencies. The underlying competencies are used as a framework to consider individual and population-based training needs, which are addressed through structured exposure to realistic, challenging scenarios to expedite the development of expertise.

Developing Expertise

There is a substantial body of research on human performance and the development of expertise, particularly within the field of sport. 'Expertise' refers to the ability to sustain exceptional or outstanding performance in a particular domain (Ericsson & Pool, 2018; Magill, 1998). Previous research has identified a number of broad characteristics associated with expert performance (Ericsson & Pool, 2018; Klein, 2008; Magill, 1998):

- well-developed knowledge structures or mental models of their domain, which enable faster and more accurate situation assessment and problem solving
- the ability to prioritise what cues to attend to, making processing of information more efficient and effective
- automatic processing of basic skills, that is, skills are performed without conscious thought

Experts are able to recognise or match patterns and features of a situation to their knowledge structures and mental models built through past experiences, which helps in faster situation assessment, and more effective problem solving and decision making (Hoffman, et al., 2014; Klein, 2008; Klein et al., 2010).

These characteristics of expertise are developed through extensive exposure to varied, rich experiences, combined with deliberate practice, and performance feedback (Ericsson & Pool, 2018; Feltovich, Prietula, & Ericsson, 2018; Hoffman et al., 2014).

While a certain amount of proficiency can be developed through experience, repetition and trial and error, the learning process is made more effective and efficient with deliberate practice. Deliberate practice is not simply the repetition of tasks, or accumulation of experience by working for a number of years in a particular domain. It involves focusing practice on specific areas of performance that are identified as needing improvement. Deliberate practice involves the help of a coach and includes opportunities for self-reflection and exploration of alternative approaches (Feltovich, et al., 2018). The training goals relate to improving performance to a level that the individual hasn't previously reached, that is, continuous performance improvement rather than training to a minimum standard of proficiency. Scenario-based or problem-based training in a realistic context has been demonstrated to be an effective tool for accelerating the development of expertise (Hoffman et al., 2014).

Research on expertise, conducted across a range of disciplines (Ericsson & Pool, 2018; Feltovich, et al., 2018; Hoffman et al., 2014; Salas, et al., 2012; Williams, 2006), has identified tools that are effective in its development:

- Having specific, measurable performance goals
- Learning through exposure to challenging situations
- Scenario-based, or problem-based training in a realistic context
- Stretching performance beyond the person's 'comfort zone'
- Providing feedback and encouraging self-reflection
- Using mental rehearsal, visualization, 'what-if' scenarios
- Learning to manage stress / pressure (e.g. relaxation, breathing, self-talk, building confidence)

Training should be focused on specific aspects of performance that would benefit from improvement, rather than simply providing repetition of tasks or motor skills. That is, specific training needs should be identified, and these training needs should form the basis of training, in challenging, realistic scenarios. Underlying competencies provide a basis for both measuring and describing specific aspects of performance that are important for the successful performance of a particular job role or task.

Underlying Competencies

While expertise has traditionally been developed through the accumulation of experience and exposure to different situations and conditions on the job, this process may be accelerated by focusing on identified training needs, using structured exposure to a variety of challenging and realistic scenarios, in a simulated environment. Scenarios should involve the need to assess or diagnose situations, apply knowledge, and practise dealing with ambiguity. In doing so, this aims to expedite the process of developing expertise, rather than simply waiting for personnel to gain sufficient exposure to challenging situations in normal operations. It also provides a means for addressing training needs in an efficient and structured way, as scenarios can be designed to focus on specific areas of underlying competence. A framework of underlying competencies provides a valuable basis for identifying and addressing training needs.

Underlying competencies describe the underpinning knowledge and skills required to perform a range of different tasks, rather than describing the performance of a specific task or procedure. Developing underlying competencies, rather than simply focusing on tasks, is likely to lead to more resilient performance, as the skills and knowledge are transferable across tasks and situations, even if the situations are novel and not previously experienced or practised. This is particularly important as technology rapidly becomes more reliable, and fewer predictable failures are encountered, making it difficult to train rote-learned procedural responses for every possible situation that safety-critical workers may encounter.

In order to illustrate the concept of underlying competencies, it is useful to contrast a traditional train driver competency framework with an example framework of underlying competencies for a train driver. Table 1 lists the core units of competence extracted from the Certificate IV in Train Driving (Department of Education and Training, 2019), and Table 2 provides an example set of underlying train driver competencies.

Table 1.

Core units of competence Certificate IV in Train Driving

Certificate IV in Train Driving (TLI42613)
Inspect and prepare a motive power unit
Apply awareness of railway fundamentals
Identify, diagnose and rectify minor faults on motive power units and rolling stock
Identify and respond to signals and trackside signs
Operate train with due consideration of route conditions
Operate and monitor a motive power unit
Use communications systems
Work effectively in a train-driving environment
Follow work health and safety procedures
Apply fatigue management strategies
Apply safeworking rules and regulations to rail functions

Respond to abnormal situations and emergencies when driving a train

Table 2.

Example Train Driver underlying competencies (McDonald & Gehrke, 2019).

Underlying Competencies
Application of Procedures
Communication
Leadership & Teamwork
Operation of tools / equipment
Problem Solving and Decision Making
Route Knowledge
Self Management
Situation Awareness
System Knowledge
Train Handling
Workload Management

Whereas the traditional approach to competencies focuses heavily on describing tasks, underlying competencies describe the underpinning knowledge and skills that are important for effective performance across a range of tasks. They are defined through detailed performance indicators, which describe how each competency is demonstrated in practice. The competencies represent both technical and non-technical skills, however it is important to note that within this framework each competency is equally important, and there is no separation into categories of technical and non-technical skills. Within many organisations, nontechnical skills are trained through stand-alone programs such as Rail Resource Management (RRM), rather than through an integrated approach to competence management.

All underlying competencies (those traditionally considered to be technical and nontechnical) should be given equal weight, integrated within all forms of training, and properly embedded in the context of actual operations and the challenges that personnel face in the operation. Many of the underlying competencies, particularly the nontechnical skills, represent transferable skills that are important across safety critical roles. Developing strength in these competencies is likely to create greater flexibility and portability of skills across different roles. It is interesting to note that underlying nontechnical skills are not only similar across different roles within an industry, but also across industries, with similar nontechnical skills being demonstrated to be important in commercial and military aviation, air traffic control, rail, emergency services, anaesthesia, and other medical settings (e.g. Butler, Honey & Cohen-Hatton, 2019; Flin, Patey, Glavin & Maran, 2010; IATA, 2014; ICAO, 2016). While training of these skills needs to be contextualised to specific roles and integrated with technical training, the fundamental nontechnical skills concepts and behaviours are similar across job roles and industries, making them reasonably transferable once they have been developed.

The underlying competencies approach can be illustrated using the task of a train driver managing a system fault. The traditional task-based competency (extracted from the Certificate IV in Train Driving) “Identify, diagnose and rectify minor faults”, has three task-based elements:

- Identify faults, defects and deficiencies
- Rectify minor faults
- Check and report minor repairs and/or isolations

Traditional training in fault management has typically involved the requirement to learn and practise a lengthy list of most of the possible faults that could be encountered on a particular type of rollingstock. In contrast to the traditional task-based perspective, the following examples illustrate the application of some of the underlying competencies to a simple scenario of a train driver encountering a brake fault that may affect the stopping performance of the train:

- **System Knowledge:** knowledge relating to the brake system and its functionality is used in interpreting symptoms and diagnosing a brake fault, including knowing the possible indications that assist in diagnosing the fault, for example, indicator lights, alarms, interface / screen, brake gauges, etc.
- **Problem Solving and Decision Making** includes the ability to diagnose and problem-solve, and may include working through a process of problem solving to diagnose the fault, particularly where different types of brake faults may have similar indications. Decision making skills are important in selecting a suitable course of action in managing the fault, for example deciding whether to, and/or where to stop the train to manage the fault.
- **Communication** skills are important during fault management in communicating with train control, other onboard staff (e.g. a guard or second person), or with maintenance controllers if additional remote maintenance assistance is required.
- **Application of Procedures:** the driver needs to apply a range of applicable procedures, for example safeworking procedures, fault management procedures, operational procedures, communications protocols, and minimum operating or serviceability standards relevant to the fault.
- **Situation Awareness** is initially involved in detecting the fault, through monitoring of train performance and the state of relevant train systems. Consideration may need to be given to whether the fault limits train performance, identifying threats to safety, thinking ahead about the effects of the fault on continued train performance or the operation (e.g. does the fault need immediate action such as stopping the train, or can the train continue safely to another location for rectification).
- **Workload Management:** effective task prioritisation may be important in fault management in an environment where there are competing tasks and priorities, for example acknowledging fault alarms or warnings, navigating train management computer interfaces, accessing procedures, communicating with others on the train and remotely, and maintaining appropriate attention allocation and visual scanning inside and outside the cab. Cross-checking may be utilised after taking fault rectification actions, to ensure that the rectification process was actioned correctly.
- **Self Management** skills are important in remaining calm under pressure, particularly when the fault may result in a significant operational disruption. Self-management also relates to understanding personal limitations and having confidence in making decisions and asking questions or asking for support from others when required.
- **Route Knowledge** may be important in determining where to stop the train, if required, to manage the fault. Considerations may include the location of neutral sections, crossovers, passing loops, or track grade if required to move the train after the initial response to the fault.
- **Train Handling** includes the ability to adjust driving / handling to account for degradation in a system's performance if required to move the train while the fault is still present.

The same competencies are likely to be relevant across many train driving tasks, and a training need in a particular competency is likely to affect performance across a number of different tasks. For example, if a person is having difficulty in problem solving and decision making during fault management, it is likely that they may also have difficulty in problem solving and decision making in performing other tasks such as train preparation, managing operational disruptions, or managing emergency situations. By focusing training on repetition of the fault scenario until it is completed successfully, the underlying competency that requires training may be neglected. If training is focused on the underlying competency, and exposure provided to additional scenarios that specifically target that competency, the training process is likely to be expedited. This focus on the underlying competency, rather than simply the task, forms the basis of how training needs should be identified and addressed.

Training Based on Needs

Rather than waiting for expertise to develop through the accumulation of experience and 'one-size-fits-all' training programs, it is proposed that the development of expertise may be expedited by focusing training on evidence-based training needs, identified at an industry, operator and individual level. At an individual level, training needs should be identified based on assessment of underlying competencies. A training need in an underlying competency, for example workload management, is likely to affect performance across a range of given tasks, therefore training is likely to be more effective and efficient when focusing on the developing the trainee's workload management skills, rather than simply repeating the affected task. In applying this approach, the trainer's role is very important, as they need to be able to diagnose the underlying competency that is contributing to an issue that they have observed with task performance.

In simulator-based training, operationally relevant scenarios should be designed to focus on specific competencies, allowing trainees exposure to a range of situations and realistic operational challenges that provide the opportunity to practice the competencies that specifically need development. Scenarios should not be known to trainees in advance. In traditional simulator-based training programs, it is common for simulator scenarios or events to be known to the trainees in advance. This encourages trainees to operate in a rule-based or rote-learned manner and provides no opportunity to practise diagnosing or analysing problems or generating suitable solutions.

The use of realistic, challenging and unbriefed scenarios aims to develop skills in critical thinking, analysis, and response generation, and ultimately builds confidence in dealing with unexpected situations. As predictable faults and failures become less likely, the focus of training should be less on rote learning of tasks and procedures, and more on developing the underlying competencies that will help the trainees to handle any situations they face, even those that are difficult to predict.

Examining the Evidence

Evidence from training, operations and safety data sources can be considered when identifying population-level competencies that represent training needs, and/or to contextualise training scenarios with relevant operational challenges. In order to identify training needs at an organisational or industry level, it is important to analyse data sets of sufficient size, rather than making decisions about training needs based on a single high-profile accident or a small cluster of incidents. When examining safety data, it is important to look deeper than standard safety performance indicators, which usually only provide information about the outcomes of performance (for example, rates of incidents or near-misses). They typically give little indication of the threats and competency-related factors contributing to the events. Data should be recorded and analysed at the level of specific threats, how they were managed or mismanaged, variations in expected performance and the associated competencies involved. Normal operations monitoring programs such as Confidential Observations of Rail Safety (CORS) can provide a rich and detailed source of data on the types of threats and errors encountered in normal operations and how they are managed (McDonald, Garrigan & Kanse, 2006). CORS is a rail industry adaptation of the aviation safety program, LOSA (Line Operations Safety Audit). LOSA has been used effectively to collect valuable performance data and to profile competency strengths and areas for development within individual airlines and at an industry level (IATA, 2014; FAA, 2006).

Evidence should be examined across large data sets and corroborated using multiple data sources before making decisions about training needs. When analysing evidence, and prioritising training needs, it is also important to recognise that training is not the solution to all organisational or safety issues, and that system design solutions should be considered where possible, in order to have a more effective and sustainable influence on performance outcomes.

Learning from Positive Performance

Traditionally, many organisations' safety efforts have focused almost solely on analysing adverse events, or "what goes wrong". It is important to understand and learn from adverse events, and prevent similar occurrences in the future, however, if the sole focus of safety analysis is on what goes wrong, organisations are missing out on valuable learning about how work is really done, and why things go right. Figure 2 provides a representation of the relative proportion of failure and non-failure events in a system where the probability of failure is 1 in 10,000 (in commercial aviation, the probability of being in a fatal accident is 1 in 10^{-7}) (Eurocontrol, 2013).

Figure 2. "The imbalance of things that go right and things that go wrong" (reproduced with permission from Eurocontrol White Paper, 2013, p.6).

When changing a system or introducing new technology, it is important to understand why the existing system works effectively and ensure that this is considered when making changes. When system designers and managers imagine how work is performed, it is generally imagined that systems are used in accordance with what the system designers intended and that work is aligned with the way procedures are documented. Tasks are often imagined to be linear, sequential, organised and simple. However, most safety-critical work is associated with substantial complexity, variability, and ambiguity. People adapt their performance to manage operational variability, to maintain safe, effective operations. Without understanding how human performance variability contributes to maintaining safety and operational effectiveness, including in normal operations, it is not possible to know what these variations and adaptations are, and how people are making the system safe and effective. Without this understanding, operational changes can have unintended consequences.

Normal operations monitoring programs such as CORS or LOSA provide a highly valuable source of data on human performance and system resilience. That is, it can be a valuable source of data about how work is really performed, 'what goes right', why things go right, and how people adapt effectively to variability and complexity. The data can help in identifying training needs at an organisational or industry level and provides an evidence-based means for prioritising training more effectively and efficiently. It can also be a valuable source of data to understand expert performance (e.g. expert strategies, rules of thumb, and techniques), which can be utilised as the basis for future training.

In addition to studying normal operations, much can be learned from studying serious incidents or events in which effective human performance has contributed to successful management of a challenging situation. While investigations can be a valuable source of data about positive performance and effective strategies, successful human performance generally receives very little attention in published investigation reports, in favour of a focus on what went wrong. Whilst it is important to understand failures, and focus on preventing further occurrences, it is also important to learn from positive performance and understand what is making systems resilient to failure.

Summary

In order to support effective performance in future rail systems, and minimise the impact of a growing skills shortage, lessons can be learned from recent work in other industries facing similar challenges. The following four principles represent a shift in the focus of competency-based training, to build greater human performance resilience:

- learning based on underlying competencies;
- using evidence / data to understand training needs;
- focusing training on identified training needs, both individual and population-level; and
- learning from positive performance.

Training systems that are based on these principles may help in accelerating the development of expertise and build resilience in future operations. This resilience is important as the industry adopts technological advances that will require the underlying knowledge and skills to be able to manage less predictable and less frequently encountered operational scenarios.

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