

Trade-offs in the planning of rail engineering work

Pedro Ferreira¹, John Wilson², Brendan Ryan², Sarah Sharples² and Theresa Clarke³

¹CIGEST, ISG - Business School, Rua Vitorino Nemésio 5, 1750-306 Lisbon, Portugal
pnferreira@netcabo.pt

²University of Nottingham, University Park, Nottingham NG7 2RD, UK

john.wilson@nottingham.ac.uk

Brendan.Ryan@nottingham.ac.uk

Sarah.Sharples@nottingham.ac.uk

³High Speed 2 – 2nd Flr, Eland House, Bressenden Place, London SW1E 5DU, UK

Theresa.Clarke@hs2.org.uk

Planning and scheduling activities are progressively recognised as a critical element of any organisation, which often becomes exposed to many sources of business and operational pressures. The underspecified nature of operations in complex sociotechnical systems and the increased degrees of uncertainty and variability that tend to characterise them, may compromise the ability to accurately plan, as the understanding of operational settings and resource availability may also become increasingly uncertain and variable.

This paper initially describes planning activities as complex and distributed decision making processes, throughout which trade-offs emerge, mainly as the consequence of the finite nature of all resources. Based on a case study developed within the Great Britain rail industry, the impacts on planning of high complexity and the exposure to high business and operational pressures are then discussed, as well as the potential contributions of enhanced planning performance towards overall system resilience.

1 INTRODUCTION

The finite nature of all resources is an underlying aspect of every planning and scheduling activity. It is a common realisation that one cannot have everything in life and therefore, as time, money or otherwise resource availability becomes critical, choices must be made. Such choices are the result of decision making processes that give shape to business or operational objectives and priorities. Hence, planning activities are essentially decision making processes that aim to anticipate resource requirements in response to a given set of objectives.

Within many industrial domains, planning functions are faced with decision making processes that assume both business and safety critical roles. In such domains, planning is frequently exposed to significant pressures, stemming from stakeholders that at different stages, try to see their business and safety needs contemplated in the plans being developed. In line with the ETTO principle

(Hollnagel 2009), this also means that planning often assumes a critical role in balancing business objectives and commitments, against safety imperatives.

Evidence from recent research (Ferreira 2011) suggests that the underspecified nature of complex sociotechnical systems may bring about an underestimation of the limitations affecting technical, human and organisational resources. The high pace of change in complex operations can impact on the understanding of systems performance. The ability to plan accurately becomes progressively more difficult because it relies on knowing how and when given resources can be allocated.

Within research carried out in the field of GB rail engineering (Ferreira 2011), a case study was developed, based on work delivery failures and serious overruns across the country, with evidence of serious planning and engineering supervision shortfalls. This paper reports on the outcome of this study and discusses how planning decisions can lead to a poor availability of resources, as well as to the underestimation of work complexity and its deliverability risks. The relations between planning and engineering teams (responsible for the work programmes and the oversight of their delivery) are also addressed, in order to demonstrate the extent of the planning failures and their causal factors. Conclusions and events are then discussed in view of resilience engineering concepts, in particular considering the four cornerstones of resilience (Hollnagel 2011).

2 THE GB RAIL INDUSTRY

The GB rail industry is currently experiencing a significant growth. Between 2004 and 2011 it has registered an increase of 23% in the number of passenger-kilometres (PK), one of the highest growth rates in Europe. Within the period going from 2009 to 2014, a public investment of approximately 30 000 million pounds was planned for the modernization and enhancement of the rail network. These indicators reflect the demands for increased capacity and for heightened overall safety and reliability that are imposed on the rail industry. Despite such demands, there is a significant pressure on industry stakeholders to reduce their reliance on public finance and subsidies. Hence, the railways are currently operating under a strong scrutiny, both from government and the public in general.

This high pressure context impacts on all industry stakeholders, but in particular on the infrastructure manager, as it provides a service, relied on by the remaining industry partners. This service mainly consists on providing safe and reliable access to the rail network for the purposes of running trains or delivering engineering work. The main sources of pressure are represented in Figure 1.

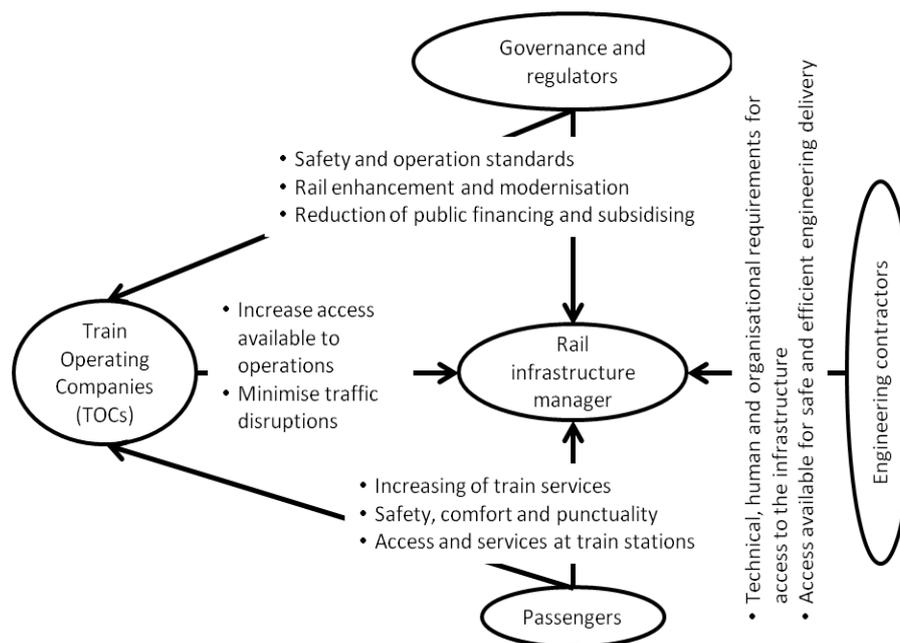


Figure 1: Main sources of pressure on rail infrastructure manager

Within this scope, the infrastructure manager must be capable of maintaining a balance between two opposing access needs:

- Providing as much access to rail operators so as to maximise revenues from access charges, as well as respond to increasing demands for rail services.
- Allocate the volume of access necessary to respond to maintenance needs and enhancement projects.

Managing this balance falls considerably under organisational units and teams responsible for both the operational (train services) and the engineering planning activities. While operational planning aims to manage and maximise the response to the first of these needs, engineering planning focuses on the second one. In practice, despite the fact that these two sides of planning are entirely independent, they actually compete for the same critical resource: access to the infrastructure. In line with the concept described by Hollnagel (2009), this emphasises the nature of rail planning as a decision making process that must constantly trade-off between favouring operational efficiency and providing the access necessary for a sufficiently thorough maintenance and engineering work.

2.1 Engineering planning

The engineering planning process focuses on managing and forecasting resource needs, in particular access to the infrastructure, for the purpose of carrying out all maintenance and renewals work. As discussed by Profillidis (2006), the planning and scheduling of rail maintenance is faced with two opposing processes:

- The traffic process which, by means of rolling stock contributes to track wear-out and thus contributing to an increase of track defects and the destabilising of the system as whole.

- The maintenance process which strives to reduce track defects and restore the safety operational conditions, thus maintaining the balance of the system.

The engineering planning process has an average duration of 90 weeks, going from the definition of a basic scope of work, down to all the necessary details of work delivery. It is structured around three main stages, which progressively integrate details regarding the different items of engineering work to be delivered. These three stages can be described as follows:

- Access planning: establishes the times and locations at which access will be granted for engineering work.
- Possession planning: consists on the integration of different work items to be carried out at a given time and location, within common protection arrangements. These arrangements essentially aim to isolate the areas of track on which engineering work will be undertaken from any part of the railway remaining open to regular train traffic.
- Worksite planning: this stage is partly developed in parallel with possession planning and it consists on the scheduling and sequencing of all aspects of work delivery.

The infrastructure manager has ownership of this process and is responsible for its entire development. However, it relies on critical input from other industry stakeholders, both from within and outside the organisation. Aiming to optimise resource allocation (e.g. machinery, haulage, staff and access), the planning process must request as much information as possible from stakeholders (contractors, maintenance units) regarding the engineering work to be carried out, in order to establish priorities and ensure the safety and reliability of access and work on the rail infrastructure. Within this context, planning must be capable of negotiating priorities and allocating access and other critical resources in the most efficient way, whilst ensuring the conditions necessary to safely deliver reliable engineering work.

3 THE CASE STUDY

The events described took place around the period of Christmas 2007, during which several major renewals and enhancement projects were planned for completion, nationally. The reduction in passenger numbers that is normally experienced between Christmas and New Year makes this period a favourable time for the delivery of work that requires significant disruptions of timetable train services. In 2007, the weeks leading up to the Christmas period were marked by an increasing pressure to complete several work programmes that were critical for an enhanced train timetable to become effective in January 2008. This was later described as the most intensive period of engineering work in the history of the UK rail network since its privatisation. The following facts and figures demonstrate the scale and complexity of this national plan:

- Between 24 December 2007 and 2 January 2008 more than 1000 pieces of work were delivered.
- More than 123 million pounds were invested.
- 414 possessions and 2300 worksites were being delivered.

- Over 1.2 million man hours were worked, which amounts to 5000 people working on the railway at any time in a 24-hour period.

Throughout this period and amongst all the work planned and delivered across the entire network, only one minor accident occurred. However, three major possession overruns occurred, causing serious disruptions to train services. These major overruns occurred at Rugby, Liverpool Street (London) and Shields Junction (Glasgow).

Evidence from investigations into events (ORR 2008) suggested that at different stages of the planning decision making process, the pressure to trade-off business objectives against safety and reliability needs, led to a work delivery scenario that greatly exceeded the available capacities of the system. In particular, during work around the area of Rugby station, numerous accumulated delays and minor incidents (as described below) caused the work programme to drift beyond the planned schedule. Mainly due to inaccurate delivery reports and poor site supervision, the seriousness of such drift went undetected up until the point where the work programme had already extended 14 hours beyond the planned completion time. Only then a serious loss of control over the work delivery was recognised. The work programme at Rugby area overran for nearly four extra days, causing serious disruptions to normal train operations. The complexity and volume of work within the Christmas period, at several locations nationwide, proved to dramatically exceed resource availability and management capabilities.

The study carried out by Ferreira (2011) consisted mainly on the analysis of archival data regarding work delivery within the Christmas period and during the previous weeks (when parts of the work programme were already being carried out), as well as planning records. The main aspects of the Rugby overrun can be summarised as follows:

- Apart from the infrastructure manager as the owner of the project, many other stakeholders were involved in the planning and delivery of the Rugby project, as well as the remaining ones across the network (train operating companies, engineering consultants, contractors, and staff agencies, among others).
- An initial scheme from 2002/2003 consisted on demolishing and relocating Rugby station. In 2004 this was replaced by a less costly scheme that worked around the current location to rebuild the station and reconfigure track layouts. Despite reducing costs, this new project introduced technical challenges with a degree of complexity never before experienced by the team responsible for the modernisation programme.
- In mid December 2007 the infrastructure manager announced that it was extending the planned possession at Rugby by an additional day (31 December). This was in response to the loss of various preliminary works on three preceding weekends, which represented an accumulated delay of the modernisation programme to be completed by January 2008. As an additional contingency, lower priority work planned for other parts of the country was deferred in order to reallocate more resources to the Rugby Christmas possessions.
- The Rugby possession itself then overran badly, until 4 January 2008. The main reason was a severe shortage of skilled and supervisory overhead line electrification engineers. Although the infrastructure manager had identified

this as a critical resource and, in an unusual step, had obtained the names of rostered individuals from its contractors in advance, many named individuals failed to turn up and many of those who did arrive worked fewer hours than planned.

- Several unexpected events took place throughout delivery, such as the discovery of buried services in the station area and the derailment of an engineering train. Although these events required minor re-planning and the deployment of contingencies, the testimonies gathered during the investigations refute these events as causes for the overrun, as each of them was considered manageable under normal delivery circumstances.
- Information provided to management by the engineering contractors during the works was badly inaccurate, partly as a result of the shortage of skilled staff. As a result managers did not appreciate that the work was running into serious difficulty until well after this should have been apparent. Under the circumstances, it may not have been possible to avoid an overrun entirely, but because of the delays in communication, effective actions to mitigate an overrun were taken too late. Train operators were not warned that an overrun was likely until the afternoon of 31 December, and accurate information about the duration was not provided until 2 January 2008. This exacerbated the disruption to rail users.

As foreseen within the planning process, deliverability risk assessments were undertaken, through which several critical aspects were identified, including the sequential nature of the work programmes and the overhead line electrification staff and resources. Mitigation measures were planned and later deployed, as delivery problems emerged (as previously mentioned). However, these measures rapidly became insufficient to recover “normal performance” in work delivery. This indicates that, not only planning may have underestimated deliverability risks, but also that mitigation actions may have been inappropriate or insufficient in view of the existing risks. Only after the deployment of management and control measures equal to those of a state of emergency (e.g. implementation of a “Gold Command”), recovery and conclusion of work was possible.

Evidence documented in Ferreira (2011) points towards the fact that the underestimation of risks was mainly motivated by the poor quality of data supplied to the team responsible for the work programme. The information that was needed depended on a large number of stakeholders and each one of them was producing delivery details for which they were responsible for at different timings. This created severe difficulties for the project team in developing an accurate and up-to-date scenario for work delivery.

Throughout the investigation reports (ORR 2008), there are several references to poor communication and difficulties in obtaining up-to-date information. There is evidence to suggest that the inter-organisational structure for the engineering work was too fragmented to respond to such demands. The scope of the Rugby project and its ambitious targets would seem to require a much more cohesive and dynamic system in order to support the complex interactions between all stakeholders that were involved and indeed necessary to successfully deliver the precise sequence of work that was planned.

4 DISCUSSION

In line with concept introduced by Pinedo (2009), engineering planning can be described as a complex decision making process, ranging from high level strategic business decisions down to the definition and scheduling of work details and its delivery on the rail infrastructure. This means that planning teams are considerably exposed to several sources of pressure, namely business and strategic targets, as well as operational and safety requirements. In hindsight, it is clear that the pressures to deliver an enhanced rail capacity by the New Year were of such degree that they encouraged the development of work plans for the Christmas 2007 period, which traded-off in favour of a maximised resource utilisation, with detriment to a more balanced and safer usage.

Regarding the unexpected events during delivery, although it was mentioned that these were considered to be within the operational capacity (ORR 2008), they required the full attention of site engineers. Being mobilised by the need to solve arising problems, site engineers were unable to properly monitor the work development and its drift away from project targets. In light of resilience engineering literature and in particular the concept of functional resonance (Hollnagel 2012), this can be interpreted as a sequence of normal (manageable) events that generated a degree of operational variability that exceeded the ability of the system to adapt.

Overall, the engineering planning function was unable to accurately estimate resource availability at national and local level, but also, planning decision making and risk assessment was supported by poor information regarding the actual development of the work programmes during the weeks leading up to the critical work period of the Christmas time. This suggests that reliable planning needs to be supported by a close contact with engineering work delivery. Such contact appears to be a fundamental support to understanding the operational settings and to be able to anticipate resource needs, in view of the established objectives. The close interaction between planning and work delivery also appears to provide the means necessary for the development and deployment of appropriate and effective contingencies and the readjustment of plans, as unexpected events arise.

These findings are similar to those observed by McCarthy & Wilson (2001) in relation to manufacturing industry contexts, where the physical and organisational proximity of planning with the shop floor can significantly contribute to the efficiency and reliability of planning activities. However, the large geographical and time scale of rail engineering planning, as well as its complex organisational structure, may render this close interaction simultaneously more essential and difficult to implement. As noted by Ferreira (2011), the fact that planning teams normally work according to regular office hours while engineering teams mainly work on night shifts (the large majority of engineering work can only be delivered during night time), already constitutes a considerable obstacle, among many other technical, organisational and human factors.

5 CONCLUSIONS

The Christmas 2007 overruns illustrate the critical role of planning in overall system performance. They also underline the nature of planning as a decision making

process, throughout which the impacts of uncertainty and variability resulting from high system complexity, become apparent. As operational and business pressures lead the system to explore the limits of its resource availability, many forms of “ETTOing” (Hollnagel 2009) emerge at the core of this complex decision making process. Many factors, other than those directly related to planning, have contributed to the loss of control over work delivery at Rugby, in particular those related to on-site management of work delivery. Nevertheless, it is clear that planning ETTOing created the settings that escalated towards delivery failure.

In view of the four cornerstones of resilience (Hollnagel et al 2011), planning may be considered as an essential support to the ability to anticipate both the critical and the potential. It therefore becomes essential to identify how lack of visibility over resource availability may emerge and understand how it may hinder planning performance and the way in which it provides reliable support to engineering work delivery. Planning can also constitute an important support to the ability to learn. In many ways, planning establishes what is expected in terms of system performance. It therefore defines what the system envisages as successful performance. Hence, planning may also represent an important support to the development of an ability to learn through success, rather than through failure, as it provides a basis on which to measure success.

Operations planning and engineering planning compete for the same primary resource (access to the infrastructure), but these two types of planning tend to be approached as independent processes. This competition ultimately results in a critical trade-off between maximising operational efficiency and thorough maintenance of the rail infrastructure. Therefore, it can be argued that a closer interaction between these two sides of planning may contribute an improved balance between two fundamental but opposing needs of the rail industry, hence contributing to enhanced system resilience.

REFERENCES

- HOLLNAGEL, E. (2009) *The ETTO principle: efficiency-thoroughness trade-off - Why things that go right sometimes go wrong*. Farnham, UK: Ashgate
- HOLLNAGEL, E. (2012) *FRAM: The Functional Resonance Analysis Method – Modelling complex socio-technical systems*. Farnham, UK: Ashgate
- HOLLNAGEL, E., PARIÈS, J., WOODS, D., WREATHALL, J. (eds.) (2011) *Resilience engineering in practice - A guidebook*. Farnham, UK: Ashgate
- FERREIRA, P. (2011) *Resilience in the planning of rail engineering work*. PhD Thesis, University of Nottingham
- MACCARTHY, B.L; WILSON, J.R. (2001) (Eds.) *Human performance in planning and scheduling*. London, UK: Taylor & Francis
- OFFICE OF RAIL REGULATION - ORR (2008) *Report of ORR’s investigation into engineering overruns*. ORR report 352, February 2008
- PINEDO, M. (2009) *Planning and scheduling in manufacturing and services*. New York, USA: Springer
- PROFILLIDIS, V.A. (2006) *Railway management and engineering*. Farnham, UK: Ashgate