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Need and Opportunities for a 'Plan B' in Rail Track Inspection Schedules

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Abstract

Track inspection is purposely performed to recover tracks from defects and damage and eliminate potential safety hazards. It is scheduled through an exhaustive process that usually integrates many disciplines such as optimization, statistics, risk management, etc. Spending so much of a monetary and an emotional investment in an original schedule (referred to as master schedule hereafter) that the scheduler wants to deliver might be a good excuse not to develop a solid 'Plan B'. Plan B here refers to scheduler responses or a contingency plan when the master schedule does not go as expected. It is found that there is often low to moderate probability of a crisis occurring when a schedule is executed in a real environment. Nevertheless, its impact can leave transportation services to the mercy of the disruption as shown by the Christmas 2014 incident where a huge volume of passengers using King's Cross and Paddington services experienced both inconvenience and discomfort due to engineering delays and train disruption. Thus, this paper aims to discuss the potential of considering 'Plan B' or contingency plan if incidents arise that were not expected during track inspection schedule execution. Benefits, general guidelines and relevant strategies for creating a contingency plan are also discussed. We highlight the rationale to support the claim that an original schedule of track inspection jobs should be adapted to respond to a new context e.g. inspection vehicle machine breakdown, new inspection requests, man-made hazards, terrorist attack, extreme weather, climate change, etc. It is however proposed to develop an appropriate set of performance measure that is used to guide rescheduling in track inspection due to financial, equipment inventory, manpower, safety regulations, time and spatial constraints.

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1. Introduction

"Time for plan B" is popular dialogue in action movies. It signals that an actor or a team needs a contingency plan because the original plan cannot proceed due to a disruption. Disruption is a state during the execution of the current operation, for which the deviation from plan is sufficiently large that the plan has to be changed substantially [1]. A fast response within a reasonable period of time could avoid permanent damage to the mission objective. Some disruptions are known in advance, but people may decide to be passive due to operational complexity and/or limited resources [2]. Contingency planning is a common term in asset management but might sound awkward to planners in other areas. For example, planners in transportation sector use rescheduling or re-planning to refer to the same concern in the event that an original schedule (or plan) is disrupted. Starting with the airline industry [1] and now the railway sector [3] planners have realized how crucial it is to have a specific methodology to handle unforeseen events during schedule execution.

In railway management, track inspection is performed on tracks to recover from defects and damages, improve ride comfort, and eliminate potential safety hazards [4]. As presented in [5], the track inspection schedule problem (*Track*ISP) is modelled as an optimization problem which incorporates various parameters of temporal, spatial, as well as physical i.e. human and machine characteristics. Taking practicality and maintainability concerns into account, some input uncertainties have not been integrated within existing mathematical models. For example, non-availability of inspection crews due to strike, time delays for vehicle or equipment maintenance, or ad-hoc inspection requests. Those examples have a low probability of occurring in reality but they have great potential to disrupt some or the entire schedule of operation as depicted in an influence diagram (will be discussed in next section). Not only the schedule's objective(s) will be impaired, but the impact might propagate to other states i.e. domino effect. It could be understood from a positive relationship between modelling uncertainty and model complexity [6]. More complex models require more stated variables, parameters and processes and generally have better performance compared with simpler models. However, most models' inputs are uncertain in reality (i.e. existence of uncontrolled factors which will increase model complexity significantly) [7].

In the same vein, some cracks are not detected by an ultrasonic inspection vehicle which might then be detected by manual visual inspection. In a case of worker strike, those cracks remain undetected whereby it leads to aggressive impact loading and then track damage, which could further cause train accident [8]. Imagine that a freight train carrying hazardous materials or petroleum products gets involved in an accident near a plantation area. Fire is easily triggered from the accident and turns the area into ashes. Losses occur not only on the rail management side but also to third parties outside the railway domain. Taking note of the potential consequences of disruptions in inspection schedules the study of a contingency plan is recommended.

2. Track inspection schedule problem

As demonstrated in the recent technical report [9], *Track*ISP has been modelled as a bi-objective optimization problem. Inspection costs and safety are schedule objectives where both optimize in opposite directions. The problem is solved under a batch environment in which modelling complexity is solved before a method of solution (e.g. a genetic algorithm operates a solution search. A straightforward approach to reduce model complexity (i.e. decreasing the computational burden) is to not use inputs that are less likely to occur in reality during the model design phase whereby reactive strategies are always possible to be adopted during an appearance of unexpected events [6,10]. Those inputs can be identified and studied from an influence diagram [11].

An influence diagram is not a flow chart but it is a simple way to understand the relationship among input uncertainties, structure and decision values. Fig. 1 depicts those relationships underlying the track inspection plan problem. Sabotage by terrorists, crew strikes, extreme weather, sudden budget cuts and other inputs (red oval in Fig. 1) are not presently considered in any *Track*ISP models. Indeed, the above examples are less likely to occur in reality but they could suddenly occur during scheduled operations. They are disruptive events whereby having a 'Plan B' is recommended to conduct the remaining activities while minimizing disruption effect as the achievement level of inspection objectives could be degraded to some extent. A similar concern was raised in [12] but there are no clear guidelines including a concise methodology to carry out a 'Plan B' in this particular case.
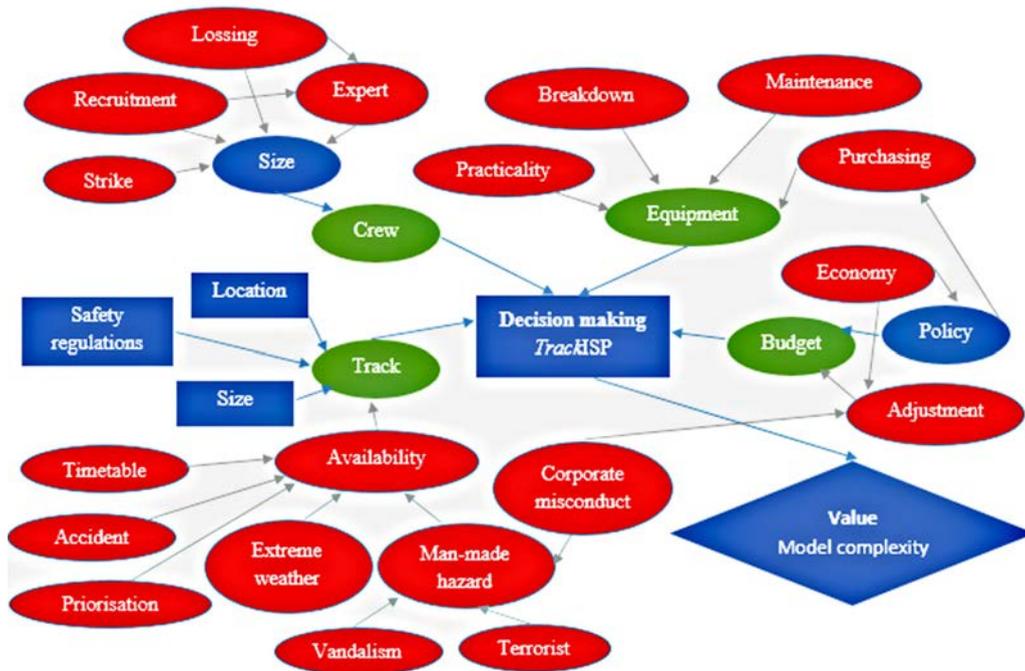
Fig. 1. An influence diagram of track inspection schedule problem.

3. *Track*ISP should get a plan B

*Track*ISP is a function of the financial budget, equipment, crew and rail track. The relationship of the variables to an inspection schedule design can be viewed in Fig. 1. Each variable is non-deterministic and has a different number of parameters. The input variable could be deterministic; for example, the financial budget of the track inspection is secured until the end of schedule timeline irrespective of other variables. As studied in [12,9] uncertainty nodes in the red oval in Fig. 1 were not part of the mathematical model for *Track*ISP. This paper posits that the exception is related to the model complexity which can be calculated using the following equation [6]:

$$I_C = \sum_{j=1}^{N} \sum_{i=1}^{n_j} p_i r_i \tag{1}$$

where N, n_j, p_i and r_i is number of state variables and number of processes flowing to or from state variable j, number of parameters used to describe process i and number of mathematical operations used to describe process i, respectively. It is clear that the complexity of the model increases as the number of input parameters increases. In addition, the probability calculation of uncertainty (refer to the arc in an influence diagram) also leads to increasing model complexity. In a case where probabilities of some events are known to be low, it is decided not to include them in the model.

In *Track*ISP, those events are referred to in red ovals in Fig. 1. The removal decision does not mean they are not interesting to *Track*ISP. It is a human tendency to underestimate disruptive risks when thinking about mitigation risks. Disruptive risk is a risk associated with disruptions, which are usually well beyond a planner's control. For instance, a worker strike is not monthly but if it occurs it can delay some inspection activities for a couple of days. As stated in [13], three days of operations closure is enough to trigger significant social and economic impacts. Terrorist attacks,

which have not been a threat to railway operations until 20 years ago, could prevent some tracks from receiving inspections. During the closure time, undamaged tracks will be increasingly used to minimize losses in business, and consequently, those tracks require additional inspection and maintenance as well. Losing crews, machine breakdown and special inspection requests potentially present disruption to inspection schedule execution in various ways. Climate-related extreme weather events are also in a potential list of disruption [4] where the Malaysian east coast train line closure in late 2014 is among the recent examples. The natural disaster from heavy floods not only disrupted passenger timetables but also scheduled inspection and maintenance activities.

In the context of scheduling, investments in reschedule knowledge and technology seem beneficial in managing schedule performance deterioration [10]. Rescheduling can be seen as an objective action for schedule recovery. A substantial number of review articles either link to rescheduling or re-planning associated with various disciplines to support this claim. An excellent review on reschedule methods applied in the transportation sector can be found in [14]. To design a successful rescheduling action (Plan B) to mitigate disruption risk in a track inspection schedule, the following challenges should be addressed:

- Feasible solutions to the rescheduling program could be difficult to achieve using conventional methods due to the existence of technical, safety, spatial, temporal and physical resource constraints. A powerful methodology and solution tool could potentially be developed for this limitation.
- As mentioned earlier, rescheduling is an additional investment made by railway firms in an effort to reduce the impact of disruptive risk i.e. an upfront investment in risk mitigation. It is obviously not practical to prepare for all disruptions. Establishing a mechanism to categorize disruptive risks might help organizations to systematically invest their limited budget in the risk management of disruptive events. The recent Renn approach which provides a better guideline in mitigating different sources of risk as pointed out in [15] is a good example to learn.
- Disruptive risks force the development of specific innovations in risk management. Unique properties of disruptive events such as low probability but with high impact, high unpredictability, unlimited sources of uncertainties and multi-level relationships degrade the usefulness of some existing methods and tools. It is required for the firms to adapt to modern technology, especially for data analysis and scenario simulations. Thus, big data and building information management are further explored.

4. Conclusion

It is easily understood how the complexity of the *Track*ISP mathematical model is reduced by not considering some uncertainties such as the crew and track availability, inspection equipment breakdown, etc. Those events are assumed to have a low probability of occurrence but their presence could impact negatively on the ongoing track schedule operation. Also categorized as high impact, low probability events, they are sources of disruptive risk for which an additional cost is required for risk mitigation. As track inspection activities are performed to avoid infrastructure failures in the railway business, it is very important to make sure the schedule survives disruptive events, or that proactive steps are taken to mitigate the arising consequences. Contingency action preparation by means of developing a specific rescheduling methodology is potentially a good investment for a railway firms due to the nature of the disruption itself i.e. rare events, beyond expectation. Further exploration will discover many aspects such as the method, technical constraints and decision-making preferences to construct a reliable rescheduling program for the track inspection schedule.

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