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Disruption Management of Resource Schedule in Transportation Sector: Understanding the Concept and Strategy

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Abstract

Disruption in a schedule (or plan) can be managed but not all factors are visible. A study of disruption management is performed specifically to minimize the differences between the expected and actual context of execution. The purpose of this paper is twofold: first to offer an introduction and deliver a concept of disruption management in the transportation sector. Second, we aim to understand challenges in a rescheduling strategy to manage disruption in the area of resource scheduling. Real world applications from airline to railway services are used as a basis of the investigation. A discussion on the future development of disruption management with a focus on rail track inspection is provided in the final part of this paper.

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Keywords: track inspection schedule; scheduling; rescheduling; disruption management; low probability event;

1. Introduction

On December 2014, railway operators in Europe and the Asian region witnessed the consequence of recent disruptions in two geographically separated locations. In the UK, a large number of train passengers using King's Cross and Paddington services were stranded for a couple of hours during a busy Christmas holiday week due to train delays caused by a succession of equipment failures. Meanwhile, on the east coast of Malaysia, a natural disaster caused by heavy floods not only negatively affected passenger train timetables but also scheduled inspection and maintenance activities for several months. The latter situation led to a significant decline in company profits due to operation closures in the east-coast region and large spending on infrastructure repair and/or replacement work [1]. Although the public was reportedly frustrated about the service breakdown, it did not harm the local operator's

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reputation as most believed the disruption was an “act of god”. The UK railway operator, in contrast, did not receive such positive support because the incident could have been avoided if it had not underestimated its contingency planning preparation, as the company’s chief executive admitted [2]. Both incidents remind railway-related organizations that the risk of financial and reputation damages associated with disruptions are real and could appear in other parts of a railway system in the future.

This paper’s aim is to point out the practicality of employing theory of disruption management (DM) to handle disruptions when they occur particularly during schedule execution. We analysed the literature with respect to (DM) in transportation sector was brought to our discussion where a preliminary research guideline was further developed. This effort is an important guide in conducting our research to develop a rescheduling framework for handling multiple types of disruptions in the track inspection schedule operation. Future directions in DM will be addressed, notably when a disrupted schedule involves financial, human, technical, spatial and safety resources.

2. Disruption management in a transportation sector

Disruption management can be described as a process of minimizing the adverse impact of a disruption which occurs in real time in the execution phase under constraints. [3] define disruption as a situation that is likely to appear unexpectedly during the time an operation (e.g. the schedule, plan, or distribution trip) is executed in which its impact is large enough to urge the planners to revise the original operation. In such situations, a new plan is created. For example, an optimal or even feasible operation schedule cannot be maintained and material flow interruptions in the supply chain result in an abrupt cessation of the movement of goods. In the transportation sector, two applications in disruption management are broadly discussed: vehicle routing and schedule operation.

Vehicles in the transportation system are carefully coordinated as transporting occupies one-third of the logistics costs and also is the key to maximize stakeholder’s utility; e.g. manufacturer, logistic provider, customers, etc. [4]. In order to obtain a set of vehicle utilities i.e. goods and distribution routes on minimum cost routes, the problem is solved as a vehicle routing problem (VRP) with location, delivery time windows and customer demand as constraints. For a deeper inquiry into VRP, one may refer to studies by [5]. When such disruptions happen such as vehicle breakdowns, traffic congestion due to accidents, delays in receiving supplies at the depot, etc., planners must start searching for solution(s); i.e. vehicles reassignment, within and limited to the relative size of the transport [6]. In the case of delivery of a single commodity (such as gas containers or oil) that is the same item for all customers, a rerouting order is given manually based on the planner’s past experiences or common sense choosing among available vehicles. It is however far more complex to deal with as the best response to the disruption in VRP (designated as a rerouting vehicle problem) will depend on the problem characteristics such as a single or multiple depot(s), type of disruption, time window requirements, etc.

Most work on the rerouting vehicle problem involves road vehicles operated by a single or two person(s) with no passengers, which is relatively less complicated than DM in airline and railway operations, which involve a crew schedule and passenger timetable. In both flight and train services, the effectiveness of the business operation i.e. an optimal revenue point, begins to deteriorate if there is a disruption during the day of operations [7,8]. Infrastructure malfunctions, mechanical failures, accidents, vehicle (airplane or rolling stock) breakdowns, and inclement weather are some of the few events that are capable of causing flight/train delays and/or cancellations, which in turn make the planned timetable, vehicle, and/or crew schedules become unfeasible. For such disrupted situations, planners must take necessary actions to modify the timetable and the resource schedules [9]. It is reported that the total direct disruption cost in two modes of transportation is in the millions of US dollars every year [10,3]. Realising that most disruptions are unforeseeable, many studies focusing on reducing the consequences of disruptions have been conducted [4], and the focus of one study one focus is on the theory of DM.

The main goal of DM in a schedule (or plan) is to obtain solutions that minimize deterioration in the objectives of an original schedule due to the changes in the current environment in which the planned schedule is operated. Generally, the solution is not necessarily the lowest cost; recently, costs associated with solution adaptation to disruption have been included as an additional goal of DM in scheduling. The time taken to get a schedule back to normal operations was also involved considering disruption is a real-time event [11]. As presented in a recent review paper by [12], the solutions that will adapt an existing schedule to a modified situation can be found by rescheduling the resources. The key to perform rescheduling in such a way that practicality and feasibility are offered as part of the proposed solutions is to be able to determine a correct rescheduling strategy for a problem in hand before rescheduling policy is decided.

2.1. Rescheduling strategy

Rescheduling is a recovery action that takes place at the time a disruption arises during schedule execution. Practicing a proactive strategy is recommended when designing a schedule to ensure that the schedule remains feasible and is less vulnerable in the case of disruptions. There is no doubt that the "concept of avoiding disruptions" provides peace of mind to planners during the schedule (or plan) execution yet it is not always considered a priority. Under this strategy, an initial schedule is optimum subject to uncertainties in which resources e.g. crew, vehicle, etc. are underutilized. Besides the size of uncertainties, it is almost impossible to determine the probability of such uncertainties such as a terrorist attack or natural disaster in a certain region as is required to handle disruptions in a proactive way [4]. That is why many recent publications have chosen a reactive strategy by means of rescheduling to generate a provisional schedule in order to minimizing the effect of such disruptions in the performance of a predetermined schedule [9,11]. In this setting, there is agreement that both airline and railway industries have mixed opinions and experiences on how rescheduling should be performed, which is by applying either a sequential or integration style.

As [13] state, most rail-based research focuses on rescheduling the resources sequentially according to a natural hierarchy: first the timetable, then the rolling stock, and lastly the crew. The authors believe that any attempt to solve rescheduling of the timetable, rolling stock and crew schedule simultaneously will lead to problems of unsolvable complexity. Nevertheless, [14] urge that a recurring decision-making in which a resource is separately solved at a different time is a point that needs to be emphasized since global repercussions could affect all resources. Considering this statement, a flight delay does not only affect aircraft assignment but may also cause the crew and passengers to miss their flight connections. The latter approach was applied in rescheduling airline resources [15]. A work in [16] that has integrated multiple resources when solving rescheduling railway problems suggests that the approach selection is a problem-based decision and is not limited to a specific transport mode.

3. Track inspection schedule problem

Rail tracks are a common structure of railway infrastructure whose condition is regularly inspected to detect any deterioration [17]. Track inspection activities are scheduled with respect to a planner's objectives e.g. track safety, inspection costs, etc. and it takes place at the tactical level of railway management. Generally, the track inspection schedule (TIS) problem can be formulated as a constrained optimization problem and it is heuristically solved [18,19]. Fig. 1 shows an influence diagram associated with *Track*ISP where oval-shaped block represent uncertainties in the problem.

In the recent works [18,19], most uncertainties (i.e. red ovals in Fig. 1) were not considered in the TIS problem formulation. This indirectly indicates that TIS was not integrated with any proactive techniques, which means logically the pre-determined schedule is vulnerable to disruption risks. As executed in the real world setting, disruptions might occur and potentially disrupt some or all of the remaining activities in the schedule. Not only the schedule's objective(s) will be negatively affected but the impact might propagate to other states i.e. the domino effect. For instance, a worker strike is not a monthly event but if it occurs it can delay some inspection activities for a couple of days. As stated in [20], three days of operations closure is enough to trigger significant social and economic impacts.

Based on the definition and concepts of DM discussed earlier, it seems that DM could be applied to mitigate the negative impacts in TIS if disruptions occur. Furthermore, TIS is a function of the vehicle, equipment, crew and track, which is quite similar to some previous rescheduling railway problems. Still at the preliminary stage, this study has identified two elements of TIS that might spark new research interests in rescheduling. For instance:

- A TIS problem is solved not only subject to common business constraints e.g. financial, man power, etc. but spatial and safety elements are also considered. This setting requires that rescheduling solutions must also be feasible to the same set of constraints, which can directly raise the complexity (or maybe confusingly) when applying the rescheduling approach. Consider this, if a sequential approach is adopted here, where should the safety and spatial elements be placed in the hierarchy? It seems that a decision tool that incorporates risk assessment could sort out this issue to some extent.

- In TIS, an expensive machine such as an ultrasonic vehicle is a limited resource. In case of a breakdown, it is necessary to reroute the on-job vehicles to serve the remaining inspection tasks. At this point, it may be possible to propose a joint application of rerouting and rescheduling to manage disruptions in TIS. A work in [21] is among the few studies discussing the idea but none involves safety requirements.

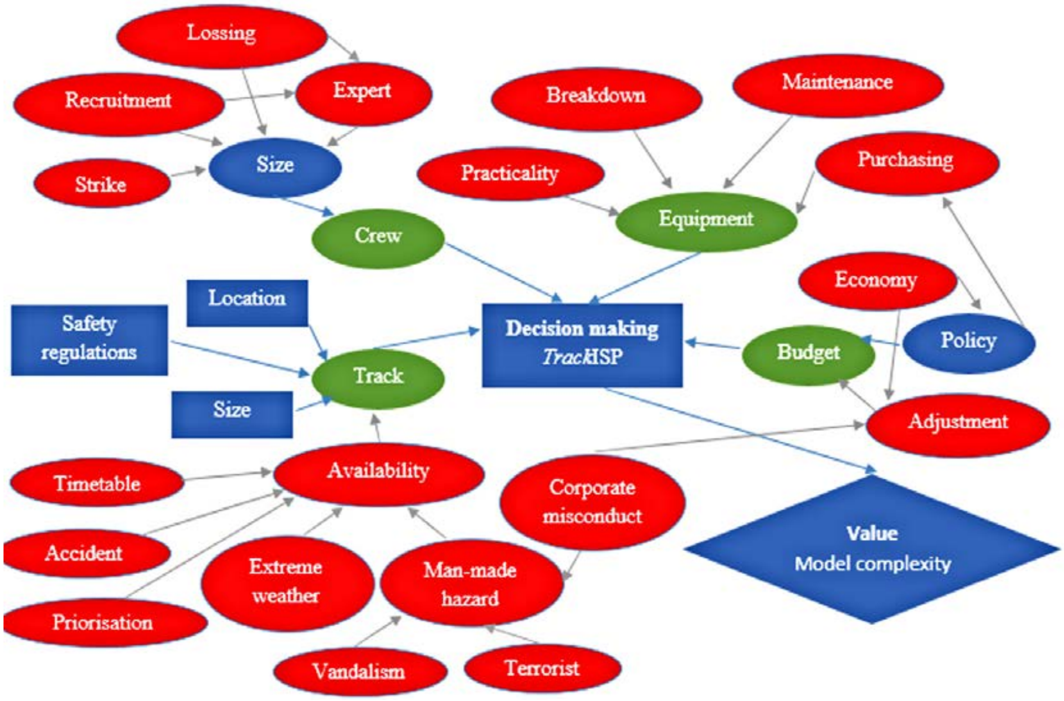

Fig. 1 An influence diagram of track inspection schedule problem.

4. Conclusions

Rescheduling is a reactive type of action which has been widely applied in response to disruptions in both airline and railway schedules, of which some examples are discussed in this paper. The central theory of rescheduling, which is to mitigate the consequences of disruption (not to avoid disruptions), offers practical and sound guidance/solutions to reflect real world operations. This feature motivates us to test the theory in our case of a track inspection schedule. For a starting point, we decided to formulate the problem in both settings; sequential and integration. Further studies on the abovementioned considerations as well as railway technical reports will be carried out in order to justify the decision.

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