Improving the Trade-Offs Between Network Availability and Accessibility

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Abstract
Passenger and freight traffic growth on Britain's railways has led to increased needs for maintenance, renewal and enhancement of the national railway network, and reduced opportunities for access to the network to conduct these engineering activities without disrupting operations. As a result, the costs of compensation to operators for service disruption and revenue loss have been increasing in line with traffic levels. There tends to be a trade-off between the cost efficiency of engineering activities and the compensation costs for the operational disruption caused, since longer track possessions are typically more efficient, but also more disruptive, reducing network availability for operations. There is thus a need to reduce and, ideally, minimise the total costs of engineering activities and compensation for the disruption caused. The current possession planning process does not actively aim to minimise service disruption and compensation costs, much less the combined engineering and compensation costs. This paper describes the detailed review of the current possession planning process, including data availability and needs, that is being undertaken. It also outlines a methodology that will be applied in order to (i) amend the current possession planning process to reduce its disruptive impact and compensation costs, thus increasing network availability for operations, and (ii) identify data requirements to enable the assessment of duration, engineering costs and timetable impacts/compensation costs associated with alternative possession strategies, and apply these in combination with scheduling techniques to reduce and, ideally, minimise combined engineering and compensation costs, and the detrimental impacts on railway users and funders.

Keywords
Railways, Maintenance and Renewals, Engineering Access, Network Availability, Possession Planning, Costs

Paper Type
Type B: Professional paper (i.e. applied research)

1 Introduction

In Britain, as elsewhere, growth in railway passenger and freight traffic in recent decades, while welcome, has presented the railway industry with various operational, management and performance challenges. Among these is the increased need for network access for infrastructure maintenance, renewals and other engineering activities as a result of greater traffic volumes and infrastructure wear and tear, combined with reduced opportunities to carry out these necessary works, as user expectations move towards 24/7 network availability for travel and transport, and the network is more intensively used. Further compromises are required between the efficiency with which engineering activities can be conducted (typically maximised by lengthy engineering 'possessions' of the track, or 'blockades'), and network availability to users (typically maximised by short, overnight possessions).

This paper reviews the current situation regarding engineering access planning in Britain and identifies needs, opportunities and means for improvement. Following this introduction, the problem statement and objectives of the work are set out, and relevant literature is briefly reviewed. Our intended methodology is then summarised, including data sources and needs. Finally, the practical relevance of the work is described, followed by a list of references.

2 Problem Statement and Objectives

In common with some other countries, railway traffic levels in Britain have increased dramatically over the past 25 or so years, following decades of decline. This otherwise welcome growth in traffic, as well as presenting capacity challenges, results in increased infrastructure wear and tear and associated maintenance and renewals (M&R) needs, while also reducing opportunities for access to the infrastructure for M&R and enhancement purposes. As summarised by Andrew McNaughton (2018), the strategic technical adviser to HS2 Ltd., the company responsible for building High Speed Two, the second phase of Britain's high-speed railway network,

> *the challenge now facing the UK is how to transform the capacity and efficiency of our network to support future growth within the available financial resources without creating wholesale disruption for millions of passengers. The UK will need a variety of solutions that provide greater capacity, improved reliability and better value for both passengers and taxpayers.*

This challenge statement mirrors the strategic goals for Britain's railways, sometimes summarised as the '4Cs', as explained by the Technical Strategy Advisory Group (TSAG, 2009):

1) Reduced Costs
2) Increased Capacity
3) Improved Customer satisfaction
4) Reduced Carbon emissions

As well as being essential for the maintenance, renewal and enhancement of the network, engineering access to the railway infrastructure affects at least three of the 4Cs: it increases costs (via compensation to train operators for loss of network availability for operations, as well as directly-incurred engineering costs); it temporarily reduces capacity; and it can seriously affect the customer experience, since users may be subjected to service cancellations or extended journey times via diversionary routes, including, in some cases, the use (and further inconvenience) of substitute road transport. While M&R and network enhancements are necessary to maintain and increase network capacity, it is clearly in the interests of the railway industry and its users to reduce the costs and temporary capacity loss associated with these works, and to reduce their impact on users.

In Britain, train operators are compensated for the disruptive effects of engineering possessions of the infrastructure, and their potential long-term impact on user demand and revenue, by means of the Schedule 4 Compensation System (S4CS; Network Rail, 2018a), as set out in Schedule 4 of operators' Track Access Contracts (TACs) with Network Rail, the infrastructure manager (IM) of Britain's heavy rail network. There are three main components of the S4CS payments and calculations, determined by means of a comparison between the normal and possession-affected train timetables: cancellations of scheduled stops; extended journey times; and changes to operating costs. The first two directly affect and potentially deter users, and usually result in payments from the IM to operators; the third affects the operators only, and usually results in a 'negative payment' from the IM to the operators, set against the first two elements, since the total number of train km operated is typically reduced as a result of full or part cancellations of trains, reducing operating costs. Other costs, such as the running of replacement bus services, are also considered in the compensation process.

The effects of increasing traffic levels on S4CS costs can be seen from Figures 1 and 2, based respectively on data produced by the Office of Rail and Road (ORR, 2018, Table 12.13) and Network Rail (2018b): Figure 1 shows annual passenger train km (excluding Heathrow Express (HEx) airport train services) between 2011/12 and 2016/17 inclusive, while Figure 2 shows the annual Schedule 4 payments made by Network Rail during the corresponding time period. It can be seen that, despite declines in both from 2015-16 to 2016-17, (i) the annual S4CS payments are large, at approximately £300m per annum for the most recent data shown (although this constitutes only approximately 2.7% of total annual expenditure (Network Rail, 2018c)), and (ii) their pattern is similar to that of the annual passenger train km values.

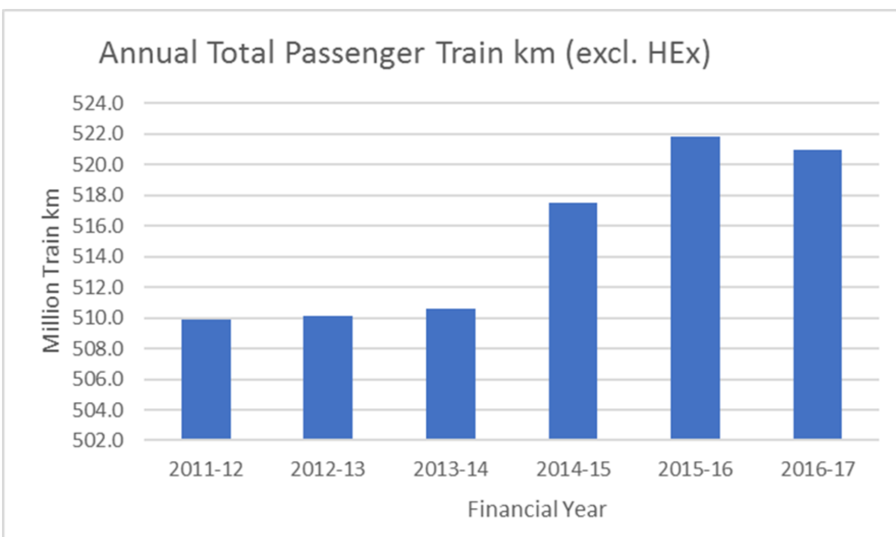


Figure 1: Annual Passenger Train km, 2011-2017
HEx = Heathrow Express

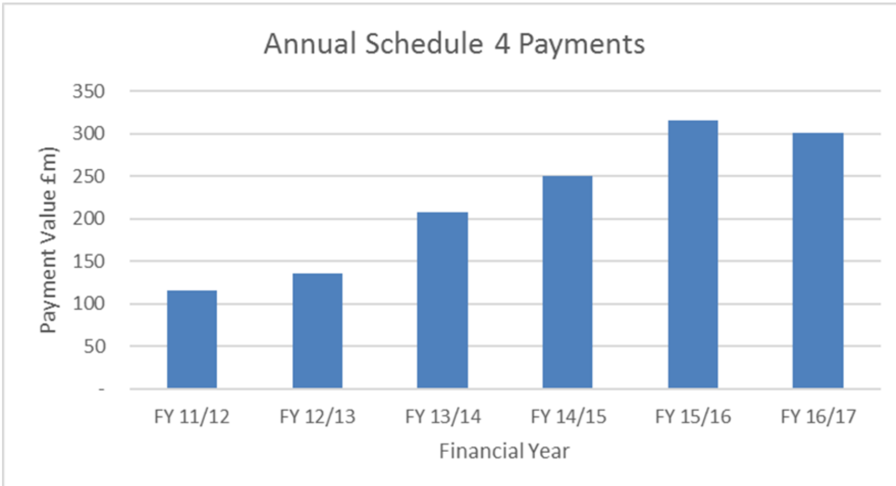


Figure 2: Nominal Annual Schedule 4 Payments, 2011-2017

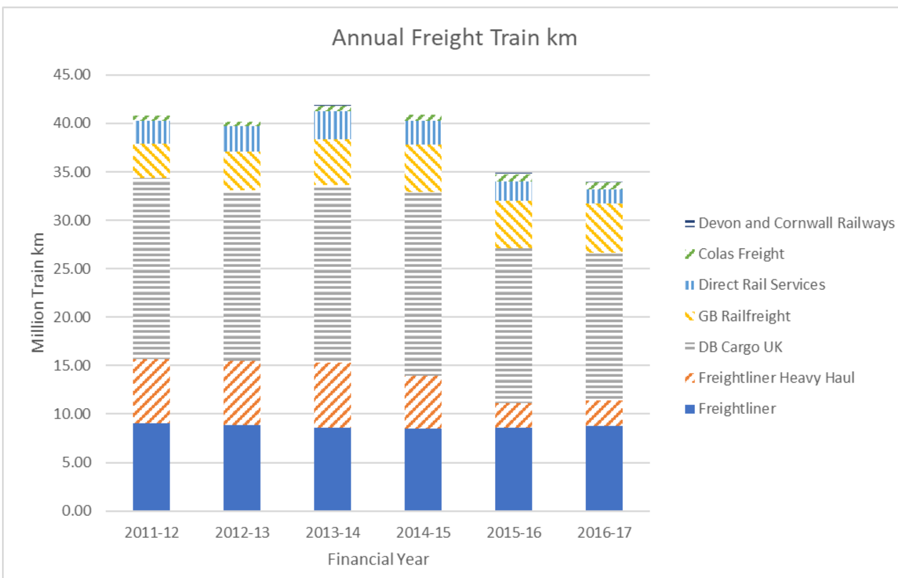


Figure 3: Annual Freight Train km, 2011-2017

Annual freight train km during the same period are shown in Figure 3. It can be seen that freight traffic, as well as being an order of magnitude smaller in volume than passenger train km, has declined in recent years, due mainly to a reduction in coal traffic as a result of the de-commissioning of coal-fired power stations, which has particularly affected DB Cargo UK and Freightliner Heavy Haul. Freightliner intermodal traffic has increased slightly in recent years, and these services are relatively time-critical and tend to use busy passenger routes at night and weekends, and are thus vulnerable to engineering-related disruption.

If and when overall traffic growth is resumed (a desirable outcome for the railway industry, and for society, if modal shift from more polluting and less safe forms of transport is to be achieved), engineering-related compensation costs for both passenger and time-critical freight services are likely to increase further, in the absence of measures to prevent this. There is thus a need for improved planning and scheduling of M&R and other work requiring access to the infrastructure, to reduce disruption to users and the associated S4CS costs. However, reducing the duration of individual track possessions may also have an effect on the efficiency with which engineering activities can be undertaken, since a higher proportion of the time available will typically be required for the processes of taking possession of the infrastructure and subsequently restoring it to operational use, reducing the proportion of productive time on site. Consideration therefore also needs to be given to the trade-off between network availability for operations and the productivity with which engineering activities can be undertaken. This issue also presents challenges in terms of the availability of (i) cost and construction programme and duration data for alternative possession approaches, and (ii) the associated amended timetable data upon which the S4CS calculations are based.

The work described here thus has two main objectives:

1) Improve the planning and scheduling of engineering possessions to reduce (i) their impact on network availability for operations and (ii) the resulting S4CS payments, including the scheduling in parallel of activities affecting the same sections of the network, where possible
2) Develop means of including the timescales, costs and timetable impacts of alternative possession approaches, and include these in the planning and scheduling process, with a view to reducing, and ideally minimising, the combined engineering and compensation costs, and thus maximising the overall benefit:cost ratio of civil engineering activities and the necessary associated possessions and network availability restrictions

3 Review

The then-current approach to engineering access planning on Britain’s railways was reviewed by Armstrong et al. (2015), who noted that the available measures of network availability for operations were being calculated retrospectively to reflect the effects of engineering possessions, rather than being used pro-actively, to assess, review and reduce the impact of planned possessions. However, they also observed that the Industry Access Programme (IAP) then being put in place had considerable potential to remedy this issue. A subsequent report by Europe Economics (2017) confirmed the ‘lag variable’ nature of the network availability calculations, and also their complexity and inflexibility (e.g. the calculations cannot be performed at a disaggregate level for individual network routes, despite the fact that possession planning takes place at this level, and responsibility for network operation, maintenance and performance is being devolved by the IM to individual routes). The report also observed that implementation of the IAP appeared to have stalled. Network Rail confirmed this, and indicated that their Transformation and Efficiency Team (TET) is continuing to work in this area, and is receptive to useful input and contributions.

The Europe Economics report acknowledges that possession planning is a complex optimisation process, and it confirms that the current approach is unlikely to produce an optimal outcome, which is a cause of particular concern in the context of diminishing opportunities for engineering access and increasing concerns about M&R costs. The report notes that the possession planning system is based upon staff experience (and is thus potentially vulnerable to staff turnover) rather than possession planning tools, and that route-based possession planning tends to be undertaken in isolation, rather than considering potential synergies with work being undertaken elsewhere on the network. This increases the likelihood of sub-optimal outcomes, and (p9) "may lead to the overall volume of possessions being higher than it needs to be", whereas

> *reducing the number of possessions should be driven by the Schedule 4 [S4] incentive, whereby planners are incentivised to optimise the use of possessions (e.g. by using them for more than one type of work where this is efficient) in order to reduce the number of possessions and resulting S4 payments.*

The report considers alternative measures of network availability, including route-based metrics and comparisons of normal and possession-affected timetables (already the basis of the Schedule 4 calculations), and measures of possession efficiency, to ensure that possessions are used productively. However, as noted above, engineering efficiency tends to be maximised in longer possessions, and the effects on network availability also need to be considered. Ideally, and as also proposed by Li et al. (2013), such an improved metric should consider both factors by including both the engineering costs and the Schedule 4 costs (as a measure of the operational disruption caused) for individual pieces of engineering work and overall, for individual routes and, ultimately, for the network as a whole.

The chances of achieving optimal outcomes are not necessarily improved by the fact that the process is based upon negotiation and compromise between Network Rail, as IM, and (sometimes multiple) train operators, as well as being generally undertaken on a route-by-route basis, as noted above, without usually considering wider network effects. Considerable work in this area has been done elsewhere though, dating back at least to the 1960s (e.g. Wagner et al., 1964), and including various approaches to the solution of the Preventive Maintenance Schedule Problem (PMSP), and the combination or clustering of maintenance tasks, as described by Peng and Ouyang (2014).

Li (2017) presents a broad overview of railway maintenance scheduling, and proposes two decision support systems (DSSs). The first DSS includes five phases: data collection; technical optimisation to identify minimum maintenance requirements; economic optimisation to minimise the cost of the identified minimal maintenance requirements; constrained optimisation to include the effects of operational conditions and enable input parameter adjustment; and, finally, evaluation. The second DSS takes account of life-cycle costs in planning and evaluating possession strategies. Both were found to have considerable potential for reducing total infrastructure-related costs, while maintaining infrastructure quality, and these approaches appear to have considerable potential for application in Britain, adapted as required to local conditions, and subject to the availability of the necessary data.

4 Methodology

The planned methodology builds and improves upon the current approach to possession planning in Britain, drawing upon international research and practice, while taking account of and complementing the work done for IAP and subsequently by TET. It uses S4CS/network availability measures to plan possessions pro-actively for reduced impact, rather than using them solely as retrospective measures and means of compensation for their disruptive effects. It includes four main elements and stages of work:

1) A review of the existing processes, planned improvements (as applicable, including outputs from the IAP and work being undertaken by the TET) and available data. This includes the potential for and possible means of extending datasets to include alternative possession and timetable options, and/or opportunities to relax these requirements and adopt a simplified approach (avoiding, for example, the need for the production of detailed timetable data to assess the S4CS costs associated with alternative engineering and possession strategies)
2) The development of a simplified network model for possession planning purposes and use in stages 3 and 4, identifying the required extent of route closures corresponding to possession locations (and thus the potential for the scheduling of simultaneous possessions on those route sections), and available diversionary routes, taking account of constraints such as electrification, loading gauge and route availability for different axle load categories
3) The development of a method and tool for improving the scheduling of possessions based upon current engineering workbank data, with a view to reducing S4CS payments and the associated disruption as a first step in the improvement process – this will include consideration of the simultaneous scheduling of possessions on affected route sections where possible. The results obtained will be compared with those produced by the current possession planning system, to assess the scale of potential benefits and efficiency gains
4) The extension of the stage 3 methodology on the basis of alternative possession and timetable scenarios, employing extended/simplified programme, cost and timetable datasets, using these to reduce and, ideally, minimise the total engineering and compensation costs

This methodology will be developed, applied, reviewed and refined as necessary in cooperation and collaboration with Network Rail staff.

5 Data types and sources

Three main categories of data are required:

1) Historic and planned possessions data: dates (and constraints/interdependencies between different elements of work), durations, locations and costs, and the associated timetable impacts in terms of train diversions and full/part cancellations of services, and thus the effects on train km operated, and operating costs
2) Network data: information needed to generate a representation of the national network sufficient for possession planning purposes, including electrification status, loading gauge, route availability (by axle load) for freight, identification of ‘isolatable’ route sections within which multiple pieces of work can be undertaken within a single possession, and potential diversionary routes (most of this data is already in the public domain and thus readily available)

3) Estimates of the durations and costs associated with alternative construction approaches, and the associated variations in their impacts upon normal train timetables – this data is likely to be the most difficult to obtain

The source for most, if not all of the data is Network Rail, in its capacity as IM. Some of the data (e.g. network characteristics and constraints) is freely available online, but the remainder will be obtained by discussion with Network Rail staff. (Note: since the abstract for this paper was submitted, less progress has been made than was originally anticipated in obtaining data from and agreeing methods and objectives with Network Rail; the authors anticipate being able to provide further updates in these respects at RailNorrkoping2019.) It may also be useful to employ actual, historic cost and timetable data for comparison with calculated alternatives, to facilitate the development, testing and demonstration of the planned approach and tools. In some cases, cost (as indicated above and also noted by Li and Roberti, 2017), duration and timetable data for alternative construction approaches may not be readily available, and it may therefore be necessary to generate artificial, realistic datasets for the purposes of developing, testing and demonstrating initial models and tools. This would build upon work previously done by the authors to produce estimates of future S4CS costs (Armstrong et al., 2015), as shown in Figures 4 and 5. As can be seen in Figure 4, the S4CS calculation process entails the comparison of two timetables, the 'Corresponding', or normal, timetable (T1) and the 'Applicable', or possession-affected timetable (T2), and the calculation for each affected train service group (SG) of the changes in the number of stops at the SG's specified monitoring points (MPs) in each direction of travel (the MPs are weighted by their historic proportions of alighting passengers, which vary by direction). Changes in journey times and operating distances are also calculated.

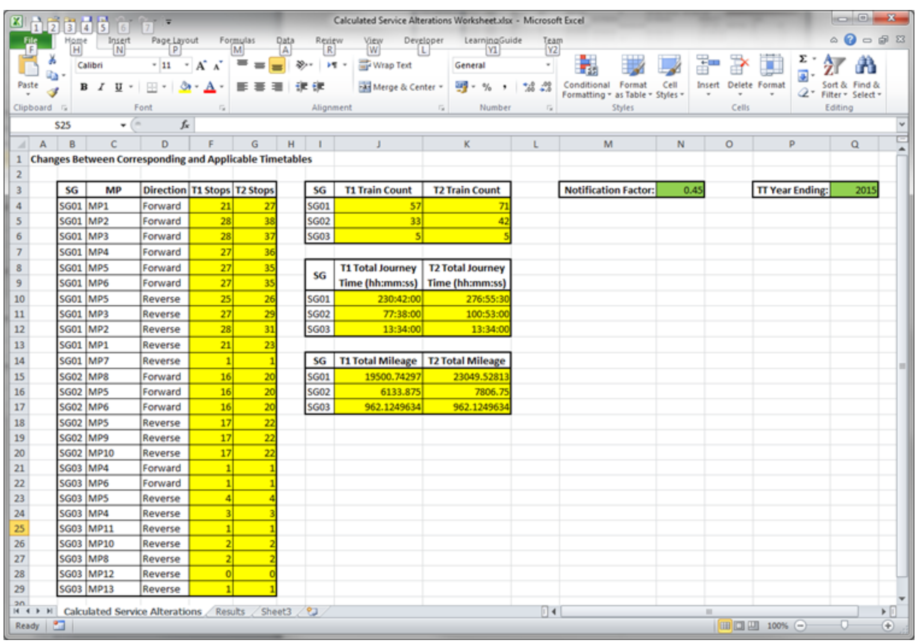
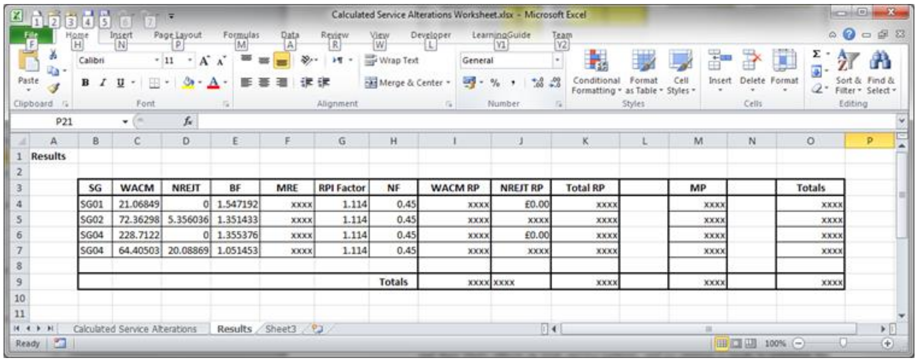


Figure 4: Train Service Alterations Worksheet


Calculated Service Alterations Worksheet.xlsx - Microsoft Excel

Results

SG	WACM	NREJT	BF	MRE	RPI Factor	NF	WACM RP	NREJT RP	Total RP		MP		Totals
SG01	21.06849	0	1.547192	xxxx	1.114	0.45	xxxx	£0.00	xxxx		xxxx		xxxx
SG02	72.36298	5.356036	1.351433	xxxx	1.114	0.45	xxxx	xxxx	xxxx		xxxx		xxxx
SG04	228.7122	0	1.355376	xxxx	1.114	0.45	xxxx	£0.00	xxxx		xxxx		xxxx
SG04	64.40503	20.08869	1.051453	xxxx	1.114	0.45	xxxx	xxxx	xxxx		xxxx		xxxx
						Totals	xxxx	xxxx	xxxx		xxxx		xxxx

Figure 5: Summary Results Worksheet

In the results sheet shown in Figure 5, for each service group, the calculated weighted average cancellation minutes (WACM) and extended journey times due to Network Rail activity (NREJT) are shown. These are combined with a busyness factor (BF), marginal revenue effect (MRE) value, Retail Price Index (RPI) measure of inflation, and a notification factor (NF, reflecting the length of notice given by Network Rail to the operator of the planned disruption) to calculate the revenue payments (RPs) due to WACM and NREJT, and the total RP and the mileage payment (MP, usually negative, as noted above), and the resulting overall total payment (the calculation process is described in more detail in Armstrong et al., 2015).

6 Scientific and Practical Relevance of Planned Work

The focus of this work and professional paper is primarily on the practical application of existing knowledge in an industry context, but it does have some potential scientific relevance in terms of the extension and modification of techniques to meet the needs of the railway engineering and possession planning environment in Britain.

The work has considerable practical relevance in terms of its potential to enable and deliver improved planning of engineering activities and track possessions to reduce their impact on railway users and their overall costs to the industry. This is consistent with the objectives of the Rail Safety and Standards Board (RSSB, 2014) Operational Philosophy for Britain's railways, one of whose requirements is for the 24/7 operation of passenger and freight trains. Meeting this requirement will necessarily "significantly reduce access to the network for maintenance and renewal of assets", requiring improved operational flexibility, including bi-directional operation and the use of diversionary routes, and efficient access arrangements, and the work described in this paper should make a useful contribution to the achievement of that goal.

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