Automated Scheduling and Routing of Road Network Maintenance

# Introduction

## Road network maintenance

*DM Roads* is one of three brands that together comprise Downer’s Road Services business operations across Australia. DM Roads provides management services, including the maintenance, refurbishment, renewal and replacement of road and civic related assets for both government and private clients. DM Roads currently services circa 15 multi-year asset management and maintenance contracts across eastern and southern Australia.

A common element for each maintenance contract is a requirement for asset condition inspection against an agreed level of service, and then planning, scheduling and carrying-out maintenance works to rectify any identified defects or deficiencies (see Figure 1). Work activity planning and scheduling, collectively referred to as *work packaging*, is a complex constrained decision-making process that involves assigning available resources (rostered crew members, raw materials, and equipment) to identified defects, often by a nominated deadline, considering shift timing (day vs. night work), curfew periods, specialised machinery required, and crew skillsets. Often, multi-year maintenance contracts will include an abatement in the form of a financial penalty when the contractor fails to satisfy Service Key Performance Indicators (KPIs) or meet rectification response times. Current practices use experienced supervisors to manually create work packages for each crew daily.

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Figure : Typical maintenance and defect works include the fixing of road defects (potholes), clearing dangerous road and drain obstructions, replacing road barriers and signage, etc.

Given the challenging nature and complexity of the task, the manual creation of work packages does not guarantee adequate let alone optimal packaging. Even for experienced supervisors with intimate knowledge of the local network, the *planned* schedule can deviate significantly from the *actual* performance. This might arise from poor judgement in what crews can complete, or the common occurrence of critical emergency rectifications that must be attended to as priority. Inconsistency in planned versus actual execution makes it difficult to benchmark work performance and have constructive conversations about work efficiency.

## Analytics opportunities, both internally and in the industry

A recent multi-year contract awarded in Victoria has presented an opportunity to develop a decision support tool that automates the work packaging task and provide efficiency and consistency benefits for DM Roads. This was a major step in developing a workflow that integrates advanced, in-house analytics capabilities into Australia’s road maintenance industry, and an opportunity to challenge the industry with a new standard. Beyond Downer, we observe similar initiatives taking place in the broader engineering and construction industry as organisations come to terms with maintaining and gaining market share in an increasingly data orientated society. By example, companies such as Boral or using data an analytics to optimise concrete truck haulage.

Many commercial tools and field management software offer standard routing solutions for problems such as technician routing or pick-up and delivery. These tools incorporate many traditional business constraints such as time windows, shift times of workers and skill matching of technicians to tasks. However, as with most problems of complexity and significance, these tools are not suitable for the type of problem presented in road maintenance, even though they are ostensibly similar to routing tasks in other industries. Specifically, DM Roads needs to perform routine inspections on road segments. A tool that can incorporate both the traversal of arcs for road inspections, as well as visiting point jobs to fix defects is required. A bespoke solution, developed in-house, integrated with the Downer IT infrastructure, was therefore considered.

Current work practices combine *routine inspection routes* with these *work packages*. *Routine inspection* is where crews drive along a pre-planned route to inspect assets. On the other hand, attending to defects and hazards are called *find and fix* *rectification*. When rectification and inspection works are packaged, crews must often deviate from their inspection routes to attend to their rectification works. Since defects arise naturally over time with no reliable way to predict the location of these defects beforehand, this presents a substantial *daily* challenge for planners. Significant planning, judgement, and expertise is required when producing work packages for crews performing routine inspections such that they can comfortably fulfill their obligated routes while attending to jobs in an efficient manner.

For example, a common dilemma faced by supervisors is to decide between assigning time to complete a cluster of lower priority defects located near the home depot or invest that time to travel further away to rectify a more urgent task. Aside from locality decisions, trade-offs must also be made with respect to time availability and due dates (doing immediate work or proactively doing jobs now to ease future pressures), productivity (doing many small jobs or fewer large jobs) and workload equity (ensuring an even amount of work is distributed to each crew each day).

Within five months, an initial version of the work packaging tool was developed from the ground up, and deployed within the Victorian operation which encompasses five depots, dozens of crews, and spans approximately 8,500 km of road across the Hume and Gippsland regions. This initial version only solved for point defects and was used to assess the feasibility and capability of Downer’s internal analytics team. It produced a precursor product with highly positive results, which has given us confidence in progressing to build the final product.

This report is divided into two main sections. The first section explores technical implementation and details our approach to addressing and modelling the many operational constraints faced by the project. The second section describes the overall impact of this project and the benefits achieved by fully adopting advanced analytics methodology in our business domain. We end with a conclusion and reflections of our experience on this project.

## Integration and further tools

Figure 2 represents an overview of the overall process. Our project included multiple digital products and services, including the development of a Microsoft Power App for use by crews in the field, cloud infrastructure to ingest, store and orchestrate data pipelines, our optimisation model and integration of results into DM Road’s control centre planning. We were able to leverage our relatively mature IT and cloud infrastructure as well as strong relationships with our technology partners, such as Microsoft.

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Figure : Overall workflow. Our contribution (blue) was multi-faceted, including the creation of a mobile app used the field, integration with our cloud data warehouse and third-party databases, an optimisation model and digital products that fed back to our operations control centre.

# Problem definition

As stated in the introduction, road maintenance is comprised of two main tasks; *routine inspection*, and *rectification works*. Figure 3 shows the geographical magnitude of the problem, and how it can be abstracted to a graph.



Figure : A section of the Victorian DM Roads network. Blue sections represent inspection roads (line segments), and black dots represent defects (points).

The inspection segments for each day must be completed, while attending to point defects are additional add-ons for most crews’ work package. However, supervisors and planning leads must ensure that these point defects are also completed before the due date set by the client. A daily, time-consuming effort is spent choosing which defects to rectify based on due date priority, vicinity to inspection segments and crew capabilities.

A generic service management tool is not designed to optimally solve for how to traverse an inspection route with defects sprinkled on, or around, that road. Treating inspection segments as point jobs would also be drastically misrepresenting the problem to solve at hand and would produce solutions that are operationally inaccurate and sub-optimal.

## **Problem categorisation**

The problems presented within our domain are common problems reported in operations research literature, specifically combinatorial optimisation and integer programming. We summarise several sub-problems relevant to our context below.

**The Vehicle Routing Problem (VRP)**: Road maintenance where we only attend to point defects would fall under the Vehicle Routing Problem (VRP). The initial tool developed was a variant of the VRP, which is a generalisation of the well-known Travelling Salesman Problem (TSP) for multiple vehicles, but only one depot. This solves for the optimal set of routes to traverse all nodes on a graph.

**The Rural Postman Problem (RPP)**: Road inspections can be modelled with the Rural Postman Problem (RPP). This is where a subset of edges in a graph must be traversed at minimum cost. This falls under the category of arc routing problems, and is considered more complex than node routing problems. Applications of arc routing problems in general include bus routing, snow ploughing, garbage collection and police patrolling. The most well-known example being the Seven Bridges of Konigsberg.

**The General Routing Problem (GRP)**: Road network maintenance within DM Roads falls under the General Routing Problem (GRP). The GRP is where a minimum cost tour is to be found on a network, where some arcs must be traversed, and some nodes must be visited. Both the VRP and RPP are special cases of the GRP. Much research has been done over the last several decades on variants of either the VRP and RPP, reflecting the diverse range of applications and its economic impact. With each problem variant comes with it a myriad of heuristics and evolutionary algorithms approaches.

# Methodology

As stated above, we build upon the GRP MILP framework, with numerous constraints introduced to model business logic and enforce operational requirements. To follow nomenclature within the literature, the model created would be a multi-depot, time windowed, capacitated, windy General Routing Problem.

* Shift times (Capacitated)
* Inspection direction (Windy)
* Multi-depot
* Job due dates (Time window)
* Non-homogenous crews

A problem like Figure 3 can be abstracted into a graph, where nodes are physical locations on the map. We treat each point defect as a single node on the graph, while segments are represented as an arc, with a starting and ending node. This is, in principle, a complete graph. The cost to traverse along an arc is calculated by the shortest travel distance between location using a commercial routing service API (described in Section 4.1.2).

## Nomenclature

### Sets/Indices

|  |  |
| --- | --- |
|  | Set of routine inspection segments |
|  | Set of point defects |
|  | Set of all job nodes (Start and end of each segment, as well as the point defects) |
|  | Set of all nodes including depots |
|  | Set of all crews |
|  | Set of all jobs for the crew type of crew can do |

### Constants

|  |  |
| --- | --- |
| where | Job score of defect |
| where | Job estimated completion time of defect |
| where | Time from location to using crew |
| where | Penalty score for job |
| where | Job due time |

## Formulation

### Decision variables

The model makes three types of decisions simultaneously; the selection of *what* jobs to undertake, the assignment of *who* should do these, and in *which* sequence these should be scheduled.

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| --- | --- |
|  | 1 if node is visited by crew |
|  | Completion time of job |
|  | Penalty indicator of job going overdue |

### Objective function

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The objective function combines the score of each job, travel time, and the cost of potentially missing contractually nominated response times.

### Constraints

* **Inspection segments must be completed by one crew:** Some roads can also be inspected in either forwards or backwards direction. If segment is bidirectional, then we either traverse it from start to end or vice versa. If it is not bidirectional, we must traverse it from start to end.

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|  |  | (1) |
|  |  | (2) |
|  |  | (3) |

* **Conservation of flow:** If a crew enters a job, it must also leave.

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| --- | --- | --- |
|  |  | (4) |

* **One crew per job:** At most only one crew and leave and enter a job.

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| --- | --- | --- |
|  |  | (5) |
|  |  | (6) |

* **Crew tour:** If a job is completed, then ensure that we leave and enter the job.

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|  |  | (7) |
|  |  | (8) |

* **Crew tour:** A crew cannot visit itself.

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| --- | --- |
|  | (9) |

* **Designated depots:** Crews must depart and return to their designated depots.

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| --- | --- | --- |
|  |  | (10) |
|  |  | (11) |

* **Non-designated depots:** Crews cannot enter or leave a depot that is not designated to that crew.

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|  |  | (12) |
|  |  | (11) |

* **Temporal constraints**: The time to complete job is greater than or equal to the sum of the completion time of the prior job , the estimated job duration as well as the travel time. If job is not the prior job, the big-M constraint just ensures that the time a positive value.

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| --- | --- | --- |
|  |  | (14) |

where . is a tight upper bound as completion times will always be less than the shift end times.

* **Shift time constraints:**

**Shift start**: The first job (Immediately leaving the depot) completion time must be completed at a time greater than or equal to the sum of the shift time start of that crew, the estimated job duration as well as the travel time. If job is not the first job, this constraint just ensures the time is a positive value.

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| --- | --- | --- |
|  |  | (15) |

**Shift end**: The last job (Immediately before returning to the depot) completion time must be less than or equal to the shift end time of that crew subtract the travel time. If job is not the last job, then the big-M constraint ensures the time is a positive value.

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|  |  | (16) |

* **Penalty constraints:** The penalty indicator is active if and only if the job completion time is over the due date.

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| --- | --- | --- |
|  |  | (17) |
|  |  | (18) |

Where

* **Crew type constraints:** For all jobs that is not compatible with crew , we cannot enter or leave that job.

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| --- | --- | --- |
|  |  | (19) |
|  |  | (20) |

# Real-world challenges

In the following sections, we describe the operational challenges we faced and our approach to addressing them. A core contribution of our work was to proficiently translate operational constraints into a mathematical decision model. Although formulating the model was a challenging aspect of the project, we encountered many “real-world” problems that turned the project from an academic exercise to a commercial problem. We made many trade-offs to make the problem solvable in reasonable time and cost, and seemingly innocuous operational requirements resulted in significant modelling challenges.

## Data generation/preparation

### Network segmentation

*Challenge: Optimised solutions need to account for point defects and road segments without excessive backtracking to be operationally acceptable.*

The treatment of inspection segments is one of the main points of challenge when balancing tractability and operational practicality. Our formulation ideally would like to leverage the underlying graph structure of the initial version of the tool, and thus we looked to treat inspection segments as pairs of nodes on a graph.

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| (a) | (b) | (c) |

Figure :(a) Once an inspection segment is entered, it must be followed to the end. (b) Defects (x) along an inspection introduces backtracking. (c) Judiciously segmenting the road helps to minimise backtracking along inspections.

Depending on whether the inspection can be done travelling in a specified direction of the road, or an enforced direction of travel, there would be a start node and an end node for that segment. Once the vehicle enters the start node, it must travel to the end node for that inspection segment (Figure 4(a)).

However, given some programmed road inspections stretch on for kilometres on end, this can introduce a large amount of backtracking -- as once the model enters the start node of the inspection, it must travel on that segment for the full length before it can do anything else (Figure 4(b)). This is particularly problematic in situations where there is a defect in the middle of the segment or on an adjacent road close to that inspection. We want the ability for the model to pause its inspection route to rectify defects that are conveniently located nearby. To address this issue, we worked closely with asset managers and engineers to break apart inspection roads into smaller segments at major intersections, resulting in smaller but more granular, segments. This allows the model to leave an inspection midway, then re-join it when it sees fit (Figure 4(c)).

The resulting table contains over 6,200 segments, covering the entire contractual region in north-eastern Victoria. Within this dataset, indicators of asset type, inspection direction and geographical coordinates would be fed into the mathematical model as input.

### Distance and time calculations; caching

*Challenge: The distance matrix is a core component of the decision model, but computing it is itself difficult. Complexity and cost scale quadratically with the number of nodes.*

Computing the shortest distance between nodes is a central task as our approach is completely based on the shortest path graph. This is a very computationally intensive task, so we use a commercial distance service (Matrix Routing service of the Microsoft Azure Maps API) to fulfill this task.

These services charge based on the matrix size. The complexity and cost scale quadratically with the number of nodes - an optimisation job with 500 nodes would result in a distance matrix containing 250,000 cells - so for our problem scale, it is prohibitively expensive to compute the distance matrix for each optimisation run.

Our solution was to cache the times and distances of the static network, incurring a once-off cost on the first run. Every subsequent optimisation run is then set up to reuse cached values were appropriate, and only compute values from new point defect rectification works on the jobs list. An average crew run has about 250 segments. By caching these values, on average, we save over 50% of running costs.

Furthermore, we have performed heavy pre-processing such that the representation of the problem is not a complete graph. For example, we geo-fenced the depots, meaning we do not compute parts of the matrix that go across depot zones. We also do not compute parts of the matrix where it makes no sense to drive to. This includes the start of each inspection segment, given that if you enter the start of an inspection, you must traverse to the end of it. Computing values to go anywhere else is of no use. This modification alone reduced the initial once-off cost by over 90%, which was over $100,000.

### Job score

*Challenge: Not all defects carry equivalent weighting. Their value is a non-linear function of their nature, their due date and overdue status.*

Heavy financial penalties will occur if assigned jobs are not completed and certain KPIs are not reached. We developed a scoring function that would consider a job’s urgency and relative significance in relation to its completion date in our objective function. The scoring function varies according to due date where priority initially grows exponentially, but then immediately drops if it becomes overdue. It then follows a periodic rise and fall pattern to prevent it from myopically consuming attention (and crew resources) that could otherwise be used to attend to other urgent jobs (see Figure 5).

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Figure : A non-linear periodic function is used to score jobs based on due date and job type. Scores are also functions of job type so that a pothole should be worth more than a shrub trimming job.

### Continuous improvement of job time estimates

*Challenge: Solutions are untrustworthy if the input data are inaccurate. We also need a way to adjust estimates over time as the contract matures.*

Optimisation solutions are ultimately untrustworthy if the underlying data are inaccurate. Default estimated completion times of different types of jobs, relative to the quantity or size of the job, were initially used as part of our bid submission. Constant underperformance and missed jobs may indicate we are failing to allocate sufficient time to complete the jobs, and as such, the values should be adjusted over time.

Other independent initiatives within DM Roads are already underway to improve data capture on resource utilisation, such as gathering data on crew activity, time spent on jobs and cost from a digital journal, called *Site Diary*. The data generated will feed into the optimisation of more accurate values in the future.

## Solving

Tractability of the problem was considered early in the project even before we had finalised a formulation. *Having a high-quality solution in reasonable time is a core expectation of the tool*. We explored several avenues to grapple with the complexity including commercial solvers, warm starts, and heuristics. These are described in more detail below.

### Choice of optimisation solver

*Challenge: The choice of solver can mean the difference between finding a solution in reasonable time or not finding one at all.*

Initial development of the model used an open-source solver to prove out small problem instances and functionality, but we soon faced difficulty when attempting to solve larger problems. Routing problems are very difficult combinatorial problems to solve, and become significantly tougher when incorporating multi depots, dozens of crews, shift times, business logic and other constraints. We also considered the possibility of incorporating heuristics and decomposition techniques from literature, but the stringent deadlines of commercial operations meant we had little time and capacity to adequately explore these ideas in-house.

Rather than attempting to navigate these challenges alone, we decided early on to use a commercial solver (Gurobi) as then we could more effectively focus our time on accurately modelling the problem domain. This allowed us to leverage a powerful off-the-shelf tool and it also opened a collaboration between their experts and our analytics function. They provided us with a wealth of knowledge, helping us improve our formulation, as well as providing us insight on how to maximise the output of the solver. Without their expertise, much of this would not be possible. We successfully tested it for up to 150 point defects, a dozen vehicles and several depots.

|  |  |
| --- | --- |
| alt text | alt text |
| (a) | (b) |

Figure : Initial point defects (a) and a test scenario (b)

### Warm-starts

*Challenge: The full formulation is too complex to solve in reasonable time. We needed a way to guide the solver with an operationally relevant baseline.*

Although the commercial solver is more powerful than open-source alternatives, we initially struggled to solve inspection routes (RPP instead of the VRP) as the size of the problem made it difficult to find an initial feasible solution within our prescribed solving time limit. Given that we already have access to feasible prior solutions – in the form of existing inspection routes from crews – we looked to provide this information to the solver in the form of a warm start. That is, we translate an inspection route from the field into a form that a subset of our model’s decision variables can be pre-fixed, which acts as the starting point for the solution process. This both drastically reduced the difficulty of the problem for the solve as well as provided an operationally sensible baseline to work from. By observation in Figure 7(a), there is naturally 3 clusters of roads for the 3 vehicles. This can be viewed as the trucks designated *work zone* or *geo-fence*. We can use this initial assignment of inspections as a *partial solution*, then let the solver optimise for a *full solution*. In our implementation, we fix values for some variables and then let the solver optimise for the variables. Figure 7(b) shows a tour solution produced by the solver.

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| --- | --- |
| (a) | A map with a blue line  Description automatically generated with low confidence |
| (b) | A map with a route  Description automatically generated with low confidence |
| (c) | A picture containing map, text, atlas  Description automatically generated |

Figure 7: Road inspection (RPP) problem and a solution of 2 depots & 3 crews. (a) Three inspection clusters are naturally observable. (b) We produce an initial tour solution using the local inspection structure as a starting point. (c) Using the inspection tour warm start to solve the GRP with point defects.

### NoRel Heuristic

*Challenge: Solving for optimality is too slow and is often operationally unnecessary. It is better to generate reliable (near-optimal) solutions quickly.*

Further improvements can be obtained if we recognise that is it often unnecessary to obtain a globally optimal solution. For operational purposes, crews value a sensible feasible solution that can be obtained in a few minutes as opposed to the best solution, which might take several hours to find. This is reasonable considering the dynamic environment that crews operate in.

To accommodate for this, we looked to use a heuristic solution method that could iteratively improve upon an initial feasible solution. We set this up by first finding a reasonable warm start solution of inspection routes from Section 4.2.2, and then using this in a second phase to find feasible tours including rectification (point) defects. The second phase of this solution involved us using Gurobi’s *NoRel heuristic* solver – a general-purpose MILP solver that uses a heuristic as opposed to the traditional branch-and-bound process. We found it to be extremely powerful for loose formulations and an excellent method for finding new solutions. Figure 7(c) is then an example of the final output.

# Evidence of impact

We are currently in the early stages of deployment of this new workflow within our Victorian contract, and as such believe there are more benefits (in terms of cost minimisation, productivity, quality, and customer experience), that what we can presently measure. The benefits of our approach are achieved at multiple stages in the contract lifecycle and are summarised below.

## Increased competitiveness in bids

Securing work is the first important step for all contracting service providers and early involvement from the analytics team proved to be an important factor in DM Roads’ bid success. The bidding process often begins with an initial Expression of Interest stage, followed by a highly competitive open tendering process, in which organisations must demonstrate competency in how they will manage and service the network, in addition to submitting a price to provide services that align with the contract. Balancing service delivery and price is critical to ensure providers remain in contention for each contract award.

For our recent Victorian contract win, our bidding and analytics teams worked closely to create a bid submission with a robust analytical approach to maintaining the client’s asset networks, which included the development of a decision support system to optimise work packaging. The benefits of this approach were two-fold. Firstly, it demonstrated competency and understanding of the requirements for service delivery to the client. Secondly, it helped us drive our own cost estimates down, reducing our risk allowances and giving confidence of a market competitive price submission.

Other analytical techniques used within the submission were time series forecasting to better predict workload and seasonality, and clustering for optimal depot locations.

## Optimised work efficiency in road management

The work packaging tool assists in saving planning time – a work package, encompassing multiple depots and crews, can be generated in less than 20 minutes compared to several hours manually – but also results in an optimal plan that can be objectively measured and benchmarked against. Several of these comparisons have been run on historical scenarios and are summarised below.

The benefits of the tool on work efficiency are widespread. With an optimal plan, crews can be doing more jobs, in less time, and in less distance. Given this known ceiling of performance, it also produces objective targets for each crew in the contract. These targets can be used by contract managers to manage conversations with individual crews and the client to set realistic performance expectations. Performing an extra 2-3 jobs per crew a day would lead to 10-20% increase in productivity. Over 5 depots, this results in hundreds of extra jobs attended to per year.

In addition, we observe a significant reduction in fuel and carbon emissions derived from optimal routes planning between scheduled activities. Figure 8 demonstrates the quantifiable benefit based on real data obtained from a crew in Wangaratta.

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| --- | --- |
| (a) | A map with a blue line  Description automatically generated with low confidence  Tour length 555 km, ~6.5 h travel time  17 completed jobs |
| (b) | A map with a blue line  Description automatically generated with low confidence  Tour length 291 km, ~3.5 h travel time  15 completed jobs |

Figure : Tour comparison. (a) Actual (human) tour. (b) Optimised tour

 In this instance, the optimised tour achieves roughly the same level of productivity (15 jobs compared to 17 jobs) with ~47% less driving and travel time. The optimised tour solution is also more intricate and would have unlikely been produced by a supervisor alone.

Figure 9 shows an example schedule of tasks planned to be completed (generated from the optimisation model) against their due date/time (open circles) recorded in our database. The x-axis is time and thus the gap between points shows the difference between the latest time it *must* be completed, and when it *can* be completed. Large gaps indicate there is proactive completion of future tasks that might avoid a defect evolving into an urgent task later.

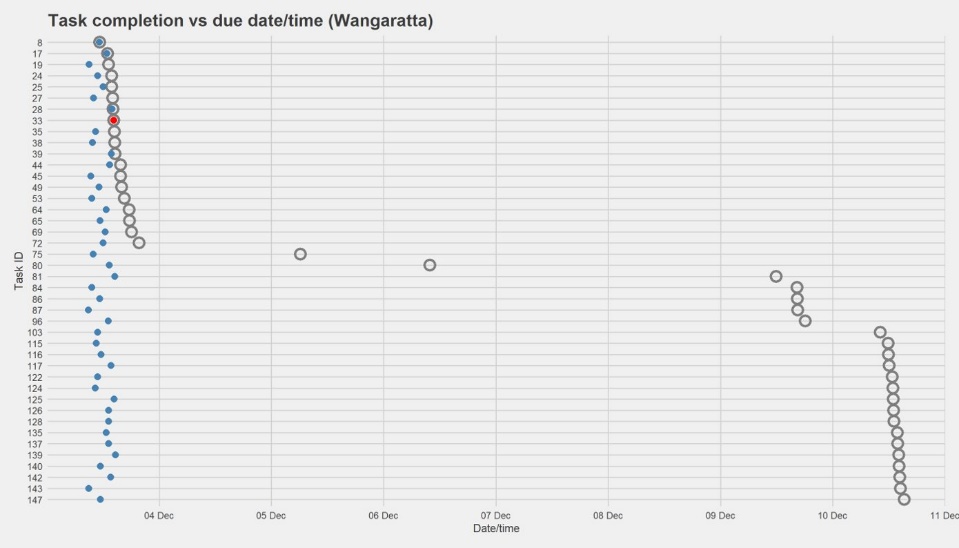


Figure : Open circles represent defect due dates/times, whereas filled circles represent the actual completed datetime of the defect.

## Scale and configurability

The final benefit of this approach extends beyond the current contract. Downer maintains 25,000 km and 28,000 km of road in Australia and New Zealand, respectively. The network described in this work contributes 8,500 km but is one of 15 contracts that DM Roads currently maintains.

Although each contract will define their own operational requirements, classifications, agreements and conditions, the core activities of work packaging is constant across all contracts. Through the utilisation of internal capabilities and in-house developed tools, we can maintain full autonomy and flexibility, and can create a tailored work packaging optimisation solution for all current and future contracts across our business. This solution scales very naturally to many similar activities throughout Downer’s service offerings and is already being earmarked for future bids in other regions in Victoria.

# Conclusion

This project has been in operation for just under six months, and thus we are in the early stages of its lifecycle. As the contract matures, and we can collect more history, our business will continue to explore ways to improve the network planning solution. From a technical perspective, we aim to enhance solution performance and would like to develop custom heuristics and high-quality initial feasible solutions as fallbacks to make the overall model more robust. Other decomposition techniques, such as column generation, are also being considered.

Beyond the mathematical details of the tool, the project required our analytics practice to be fully engaged over the entire project lifecycle. We participated in a wide range of activities with individuals across the business, including on-site excursions working with crews on rectification works, discussions and demonstrations with our customers and senior executives; and integrating the tool into existing IT and data infrastructures. This has emphasised the importance of skills beyond mathematical modelling ability, combining business communication and technology fluency to make this project successful.

These interactions have strengthened both our operational teams – in terms of improved productivity, transparency, and a new way of work – as well as our analytics team – in terms of valuable experience deploying analytics in real-life situations and understanding the critical role that analytics plays in the modern business. Business analytics and data science is often viewed as a “dark art” outside of those in select industries such as consulting, banking, retail, and insurance.

Having an internal capability also reduces our reliance on external consultants and commercial tools, which, based on recent experience, can mean a significant cost saving for the business.

Ultimately, the benefits of analytics are often communicated in terms of bottom-line performance and efficiency, but in our context this also leads to better roads and safer journeys for our customers and society.