MODELLING WILDFIRE ASSET PROTECTION TO ASSIST WITH REAL-TIME RESOURCE ALLOCATION

Martijn van der Merwe*, James Minas, Melih Ozlen and John Hearne
School of Mathematical and Geospatial Sciences, RMIT, Victoria
*martijn.vandermerwe@rmit.edu.au

Overview

The development of decision support tools to assist with the management of wildfires is an active field. Published research to date largely focuses on long term planning, with considerably fewer studies concerned with short term incident management level decision-making. Models developed to support short term wildfire decision making have been concerned with the dispatch of resources to fires and with fire-line construction. Alternative tasks, besides direct fire suppression, that fire agency resources can perform, such as asset protection, are not so well studied.[2]

In our research we consider the problem of assigning resources to asset protection activities when large wildfires are burning out of control and direct suppression is not a viable option. [1]

We formulate a mixed integer programming model assigning resources to asset protection with the aim of maximising the total saved asset value. The model allows for mixed vehicle types with interchangeable capabilities with vehicle travel times determined by vehicle specific speeds and road network information. The protection requirements of locations are defined in terms of the vehicles' capabilities. [3]

The model outputs an optimal assignment of vehicles to assets, an example is shown in the figure below.

Future work

The presented model is a first step towards a decision support tool to aid IMTs managing the available resources. Further research will investigate methods for replanning when disruptions occur (such as vehicle breakdowns) and planning under uncertainty.

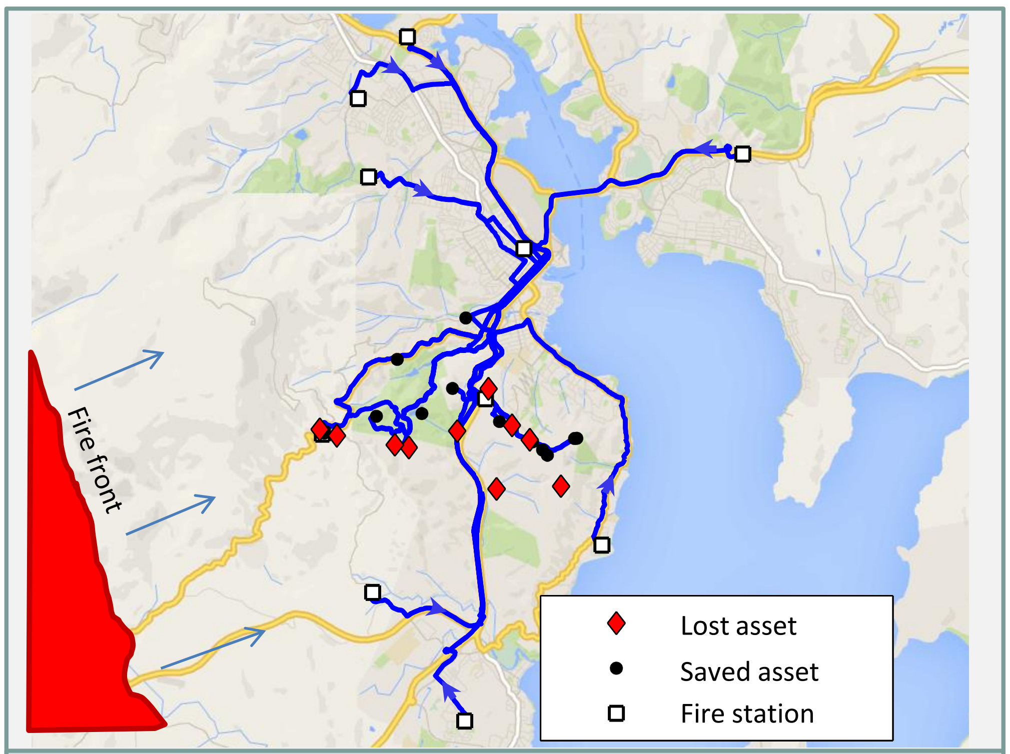

FIGURE:
Scheduling fire fighting resources during bushfires to protect community assets and infrastructure. The routes of tankers are indicated in blue.

References

1. Killalea D, (2009) Operational priorities: when it's out of control what do we do? Retrieved July 30, 2013, from *http://www.bushfirecrc.com/blog/damien-killalea/operational-priorities-when-it%E2%80%99s- out-control-what-do-we-do*

2. Minas JP, Hearne JW, & Handmer JW (2012) A review of operations research methods applicable to wildfire management. *International Journal of Wildland Fire 21*(3), 189–196.

3. Van der Merwe M, Minas JP, Ozlen M, and Hearne JW 2014. A mixed integer programming approach for asset protection during escaped wildfires. Optimization Online, May 2014.

The Mixed Integer Programming Model

Decision variables

X_{ijq} - number of vehicles of type q travelling from location i to location j

$PROTECTED_i \in \{0,1\}$, indicates wether asset i is protected or not.

Protection requirements

An asset is protected if the vehicles assigned to the asset collectively meet the protection requirement. A vehicle's capability is defined as a vector. For example, combining a vehicle with $cap_1 = (2,1)$ and a vehicle with $cap_2 = (0,1)$ would meet the protection requirement $r = (2,2)$.

$$\sum_q \sum_i X_{ikq} cap_q \geq r_k PROTECTED_k \text{ for all } k \in assets$$

Objecitve function

The objective is to maximise the total protected asset value.

$$\text{MAX} \sum_{i \in assets} assetvalue_i \times PROTECTED_i$$

Depots constraints

Vehicles are initially stationed at depots.

$$\sum_j X_{kjq} = stock_{kq} \quad \forall\, k \in depots, q \in vehicletypes$$

Vehicle flow constraint

The number of vehicles arriving and departing from a location must be equal.

$$\sum_i X_{ikq} = \sum_j X_{kjq} \;\forall\, k \in assets, q \in vehicletypes$$

Timing constraints

Takes into account travel time and the duration of protection activities. The travel time from i to j for vehicles of type q is t_{ijq} and $Z_{ijq} \in \{0,1\}$. Protection activities at location i commence at time S_i.

$$X_{ijq} \leq p_q Z_{ijq}\,;$$
$$S_i + t_{ijq} + a_i - S_j \leq M(1 - Z_{ijq});$$
$$for\ all\ q \in vehicletypes, (i,j) \in locationpairs.$$

Time windows

Protection activities at each location i must commence within a period specified by a time window. The earliest and latest possible start time of protection activities are determined by the fires anticipated time to impact.

$$earliest_i \leq S_i \forall i = 1, \ldots, n$$
$$S_i \leq latest_i \forall i = 1, \ldots, n$$