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Optimal Locations Of High-Speed Railway Stations Along Australias East Coast

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Contents

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1 Abstract

This Summer Research article investigates optimal locations for high-speed railway stations between Melbourne and Sydney along Australias East Coast. The current conventional travel times between capitals are as follow; Melbourne-Sydney 10.5 hours and Sydney-Brisbane 14 hours. If high-speed rail were implemented both Melbourne-Sydney and Sydney-Brisbane trips are expected to be reduced to under 3 hours. With the forecast timesaving and increasing pressure on other modes of transit its expected that the Australian Government will commit to a high-speed rail network between Australias East coast Capital cities in the near future. In order to achieve the most efficient high-speed rail network, research is needed into the optimal station locations. To analyse the optimal station locations it has been proposed to use a mixed-integer optimization model that maximizes the travel cost savings introduced from the high-speed rail network, see [3]. The maximization of the cost savings is subject to multiple constraints and aims to capture all costs savings produced from the new network i.e. taking into account the costs of deceleration and acceleration phases near origin and destination stations.

2 Introduction

In Hugo *et al.* (2011) a mixed integer optimization model is presented taking into account the full dynamic effects of a train during transit. The objective function and constraints below aim to maximise the travel cost savings made possible when the new high-sped rail network is implemented.

3 The Model

For a detailed explanation of the model refer to; Hugo M. Repolho, Antnio P. Antunes, and Richard L. Church (2011) *Optimal Location of Railway Stations: The Lisbon-Porto High-Speed Rail Line.* Transportation Science, Vol. 47, pp. 330-347

3.1 Parameters and Variables

Here are the parameters and variables presented by Hugo *et al.* (2011).

- J, the set of traffic generation centers - $\{1, \ , \text{number of stations}\}$;
- M the set of possible locations for the railway stations $\{1, \ , \text{M}\}$;
- R_{mn}, the set of possible intermediate stations between stations m and n;
- r_{mn}, the maximum number of stations between m and n;
- c_{ij} the (least) travel cost between centers i and j through existing options;
- c^k_{imnj} the travel cost between centers i and j through a route that includes two segments of the existing network, im and jn and a segment of the new railway line, mn that will have k stops;
- S^k_{imnj}, the cost savings made when a segment of the new high-speed railway network is used;
- c_{im}, the travel cost through the existing transportation network from traffic generation center i to station m;
- c_{mn} the cost between stations m and n, the cost of a train ticket;
- c_{nj} the travel cost through the existing transportation network from station m to traffic generation center i;
- v the monetary value of time;
- t^e the time lost when embarking and disembarking the train;
- t^s the time lost from intermediate stations;
- q^k_{imnj} the estimated number of trips made for a particular route through im with k stops;
- $y_m \in \{0, 1\}$ a decision variable with $y_m = 1$ if a station m is selected and
- $g^a_m andg^e_n$ are the upper limits on the number of routes that use a station and can be assumed to be arbitrarily large;

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3.2 Objective Function

The objective of the model is to maximise travel cost savings, i.e
Maximize

$$\sum_{i\in J}\sum_{m\in M}\sum_{n\in M}\sum_{j\in J}\sum_{k=0}^{r_{mn}} s^k_{imnj} q^k_{imnj} x^k_{imnj} \tag{1}$$

Where

$$s^k_{imnj} = c_{ij} - c^k_{imnj} \tag{2}$$

and

$$c^k_{imnj} = c_{im} + c_{mn} + c_{nj} + 2vt^e + kvt^s \tag{3}$$

3.3 The constraints

The objective function is maximized subject to the following constraints.

$$\sum_{m\in M}\sum_{n\in M}\sum_{k=0}^{r_{mn}} x^k_{imnj} \leq 1 \quad \forall i,j \in J, \tag{4}$$

$$\sum_{i\in J}\sum_{n\in M}\sum_{j\in J}\sum_{k=0}^{r_{mn}} x^k_{imnj} \leq g^a_m y_m \quad \forall m \in M : g^a_m > 0, \tag{5}$$

$$\sum_{i\in J}\sum_{n\in M}\sum_{j\in J}\sum_{k=0}^{r_{mn}} x^k_{imnj} \leq g^e_n y_n \quad \forall n \in M : g^e_n > 0, \tag{6}$$

$$y_m + y_{m+1} \leq 1 \quad \forall m \in M : d_{m,m+1} \leq l_{min}, \tag{7}$$

$$\sum_{k=0}^{r_{mn}} (r_{mn} - k) x^k_{imnj} \leq r_{mn} - \sum_{u\in R_{mn}} y_u \quad \forall i,j \in J, m,n \in M : x^0_{imnj} exists, \tag{8}$$

$$y_1 = 1 \tag{9}$$

$$y_4 = 1 \tag{10}$$

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4 Applying the Model to Australia

The Australian Government has invested a considerable amount of time and money into researching the implementation of High Speed Rail along the East Coast. The Department of Infrastructure and Transport released High Speed Rail Study-Phase 1 in July 2011 and High Speed Rail Study-Phase 2 in April 2013. From these studies it's believed that a High Speed Rail alignment could be implemented between Melbourne and Brisbane and be fully operational by 2065, for an estimated $114 Billion. These reports contain relevant data for the trial model investigated for this project. In High Speed Rail Study-Phase 2 the preferred alignment with shortlisted stations is presented. For the model investigated over the summer research project only the Southern segment of the alignment form Melbourne to Sydney was investigated with possible intermediate stations at Shepparton, Albury-Wodonga, Wagga Wagga Canberra and Southern Highlands. The Southern segment alignment from High Speed Rail Study-Phase 2 is shown below in Figure 1.

Figure 1: High Speed Rail Study-Phase 2 South Alignment

High Speed Rail Study-Phase 2 also contains estimates of the 2065 populations for the major cities based on recent censis data and predicted growth rates. The report also gives expected travel demands from each trip generation center. The expected travel demands from High Speed Rail Study-Phase 2 are shown in Figure 2.

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Figure 2: High Speed Rail Study-Phase 2 Travel Demand 2065

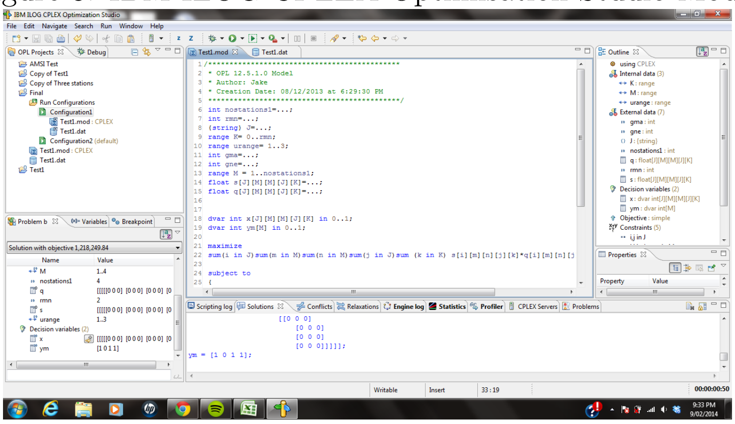
Table ES-5 HSR travel market matrix for 2065 ('000 trips in both directions per year)

Sectors	Brisbane	Gold Coast	Intermediate	Newcastle	Intermediate	Sydney	Intermediate	Canberra	Intermediate	Melbourne	Total
Brisbane	X	2,210	1,650	750	600	10,860	1,240	1,130	730	2,490	
Gold Coast		X	900	520	580	3,830	610	190	440	340	
Intermediate			X	810	X	5,500	190	330	X	850	
Newcastle				X	170	1,760	220	250	150	330	
Intermediate					X	2,990	20	300	X	730	
Sydney						X	2,690	5,190	2,290	18,760	
Intermediate							80	480	100	2,320	
Canberra								X	640	2,720	
Intermediate									X	4,660	
Melbourne										X	
Total											83,600*

4.1 IBM ILOG CPLEX Optimisation Studio Model

The model and relevent data was applied to IBM ILOG CPLEX Optimisation Studio as shown in Figure 3.

Figure 3: IBM ILOG CPLEX Optimisation Studio Model



4.2 Results

After running the optimisation model computational time was approximately 2min on my HP Pavilion with an i7 core processor. The results were to adopt stations at Melbourne, Shepparton, Wagga Wagga Canberra and Sydney and remove stations from Albury Wodonga and Southern Highlands.

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References

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