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Optimising Product Swaps in Urban Retail Networks

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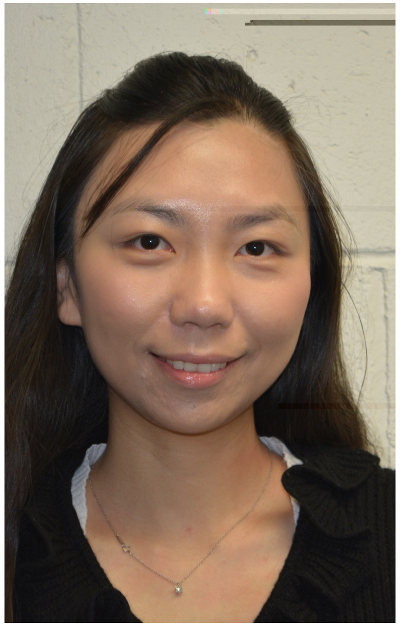

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Mathematical Model

To design vehicle routes with loads and transhipment timing

Decision variables

- v $y_{v,ij} \in \{0,1\}$ $v \in \mathcal{V}, i, j \in \mathcal{M}$
- n $z_{v,n,ij} \in \{0,1\}$ $v \in \mathcal{V}, i, j \in \mathcal{M}, n \in \mathcal{N}$
- v i $\omega_{v,i} \geq 0$ $v \in \mathcal{V}, i \in \mathcal{M}$
-

Multiple objectives

To minimise

- $$F_{voc} = \underbrace{VC_f \sum_{v\in\mathcal{V}} \sum_{i\in\mathcal{M}} y_{v,if_v}} + \underbrace{VC_d \times V \sum_{v\in\mathcal{V}} \sum_{i\in\mathcal{M}} \sum_{j\in\mathcal{M}} y_{v,ij} T_{ij}}$$

- $$F_{lc} = \underbrace{LC_d \sum_{v\in\mathcal{V}} \left(A_{v,f_v} - \omega_{v,f_v}\right)} + \underbrace{LC_f \sum_{v\in\mathcal{V}} \sum_{i\in\mathcal{M}} \left(\mu_{v,i} U_i + \lambda_{v,i} L_i\right)}$$

F_{voc} and F_{lc}: \$

- $$F_{urc} = \underbrace{\frac{1}{2} \sum_{i\in\mathcal{M}} \sum_{v\in\mathcal{V}} \sum_{n\in\mathcal{N}} \left(p\mu_{v,n,i} + p\lambda_{v,n,i}\right)} - |\mathcal{N}|$$

$$\min_{\mathbf{y},\mathbf{z},\boldsymbol{\omega}} \left(F_{\$}, F_{urc}\right)$$

Constraints (selected, cont.)

- $$\max_{v\in\mathcal{V}} \underbrace{\sum_{u\in\mathcal{V}\setminus\{v\}} \mathbf{1}\left(A_{u,i} < D_{v,i} \,\&\, A_{v,i} < D_{u,i}\right)}_{v} + 1 \le l_i \qquad \forall i \in \mathcal{M}$$

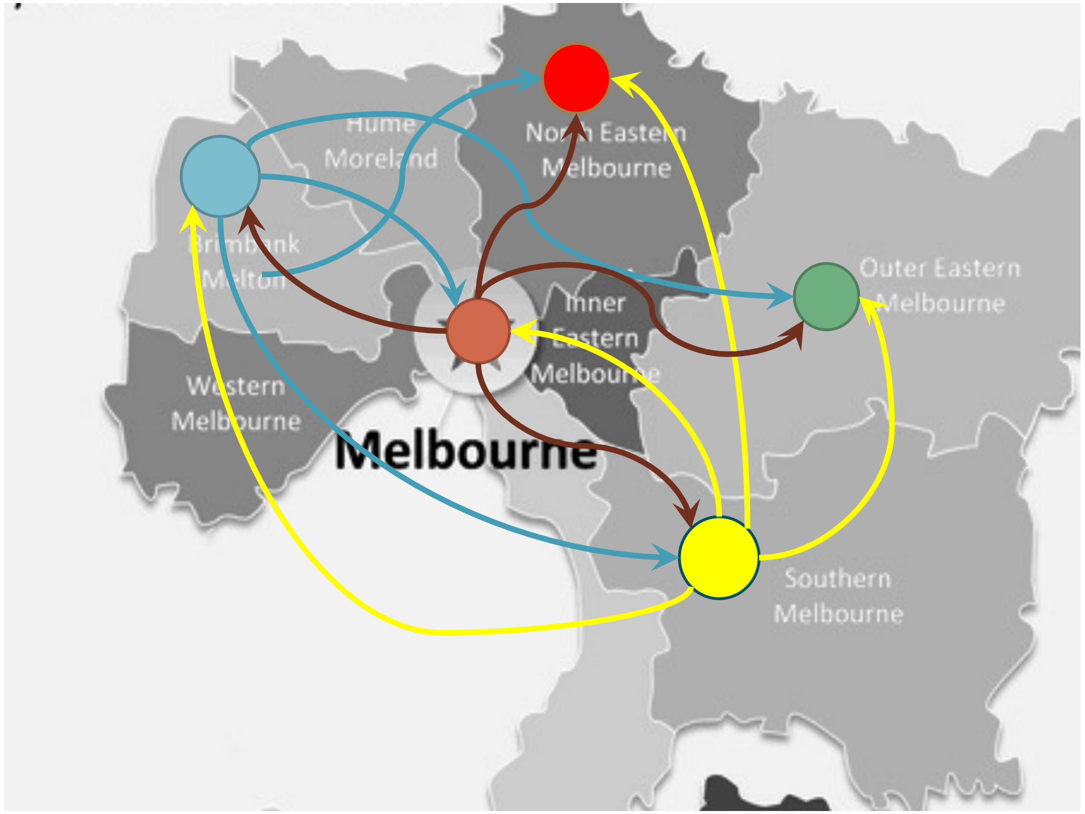
- $$\sum_{n\in\mathcal{N}} s_n z_{v,n,ij} \le c_v \qquad \forall v \in \mathcal{V}$$

- $$\sum_{j\in\mathcal{M}\setminus\{i\}} y_{v,ij} = \sum_{k\in\mathcal{M}\setminus\{i\}} y_{v,ki} \qquad \forall i \in \mathcal{M}, v \in \mathcal{V}$$

$$\sum_{v\in\mathcal{V}} \sum_{j\in\mathcal{M}} z_{v,n,ij} = \sum_{v\in\mathcal{V}} \sum_{k\in\mathcal{M}} z_{v,n,ki} \qquad \forall i \in \mathcal{M}\setminus\{o_n, d_n\}, n \in \mathcal{N}$$

Numerical Experiments

- Melbourne network with 5 nodes
- Three strategies
  - Dedicated delivery (DD)
  - No transhipment (NT)
  - Transhipment (TR)
- Solutions obtained by Gurobi 9.2



Strategy	Financial cost	# of Vehicles	VKT	Load factor

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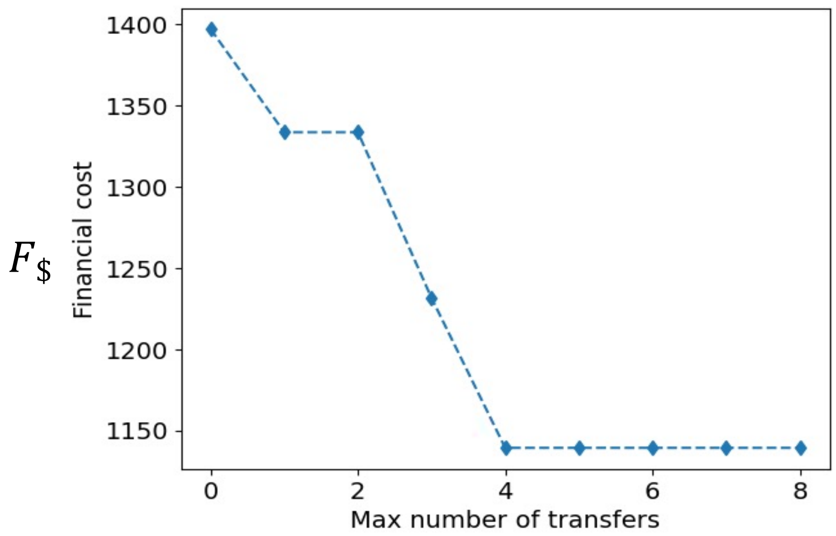
Pareto front

- Modify the multi-objective optimisation problem $\min\ (F_{\$}, F_{urc})$ to

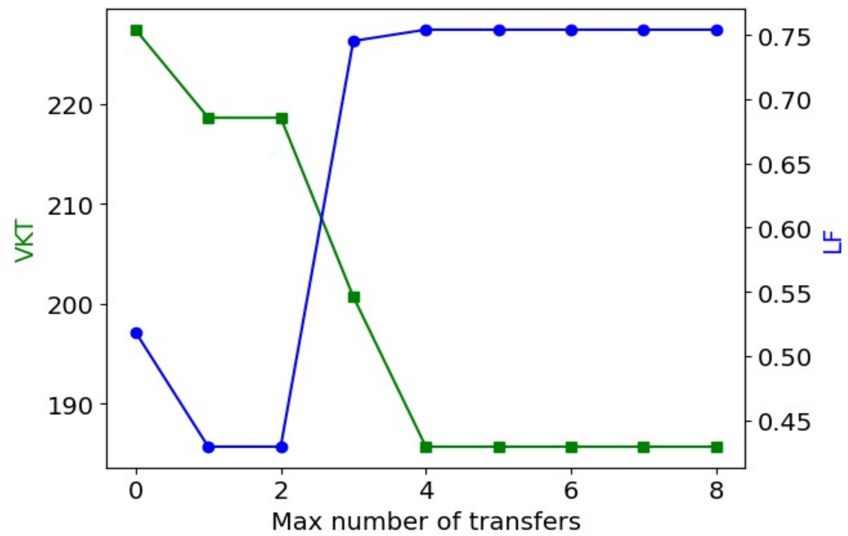
$\min F_{\$}$ s.t. $F_{urc} \leq B$ and existing constraints

Upper bound of total swap number

- Financial cost and VKT decrease with B, and load factor generally increases.
- Goods transhipment benefits the delivery efficiency.



B (proxy of F_{urc})



B (proxy of F_{urc})

Conclusions

- Allowing products to be transhipped at stores can provide significant savings in financial cost and vehicle travel distances (and hence environmental cost).
- Designing efficient goods transfer networks requires consideration of OD patterns as well as locations of and facilities at stores.
- Transhipment may bring more uncertainties in the network. For improving the network reliability, it needs
  - Consideration of vehicle coordination;
  - Models incorporating with stochastic elements such as demand, travel time, and loading time.

Thank you

Questions? Contact at lele.zhang@unimelb.edu.au