MODELLING THE EFFECTS OF URBAN FREIGHT TRANSPORT SCHEMES

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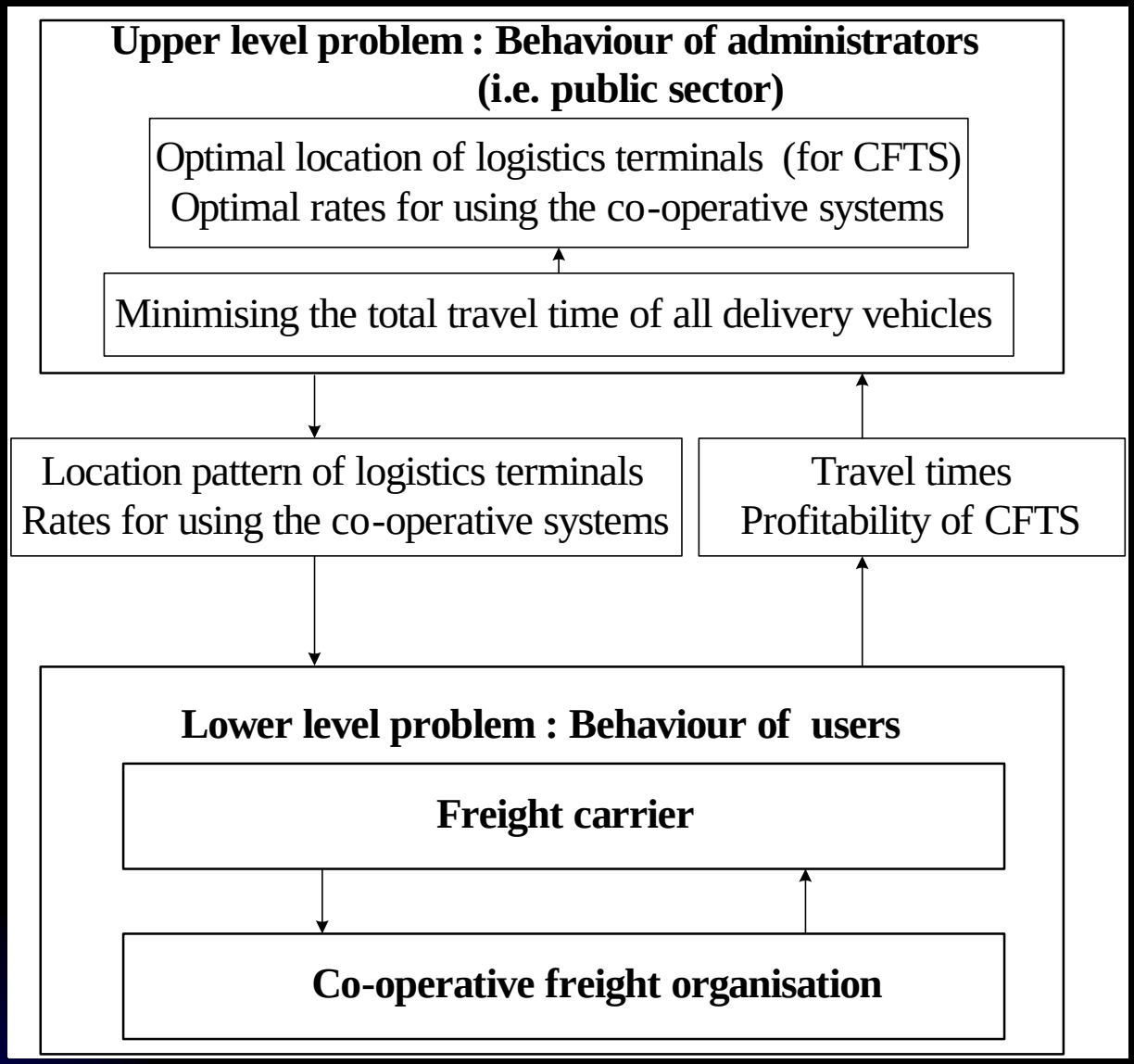
Background

- Road-based urban freight transport
  - Traffic congestion
  - Negative environmental impacts
  - Energy consumption
- Urban freight transport schemes for City Logistics
  - Co-operative freight transport systems (CFTS)
  - Advanced vehicle routing and scheduling systems (AVRSS)
    - ITS-based freight transport measures
  - Access restrictions to the city centre
  - Road pricing
    - e.g. London Congestion Charge and the Singapore Area Licensing Scheme

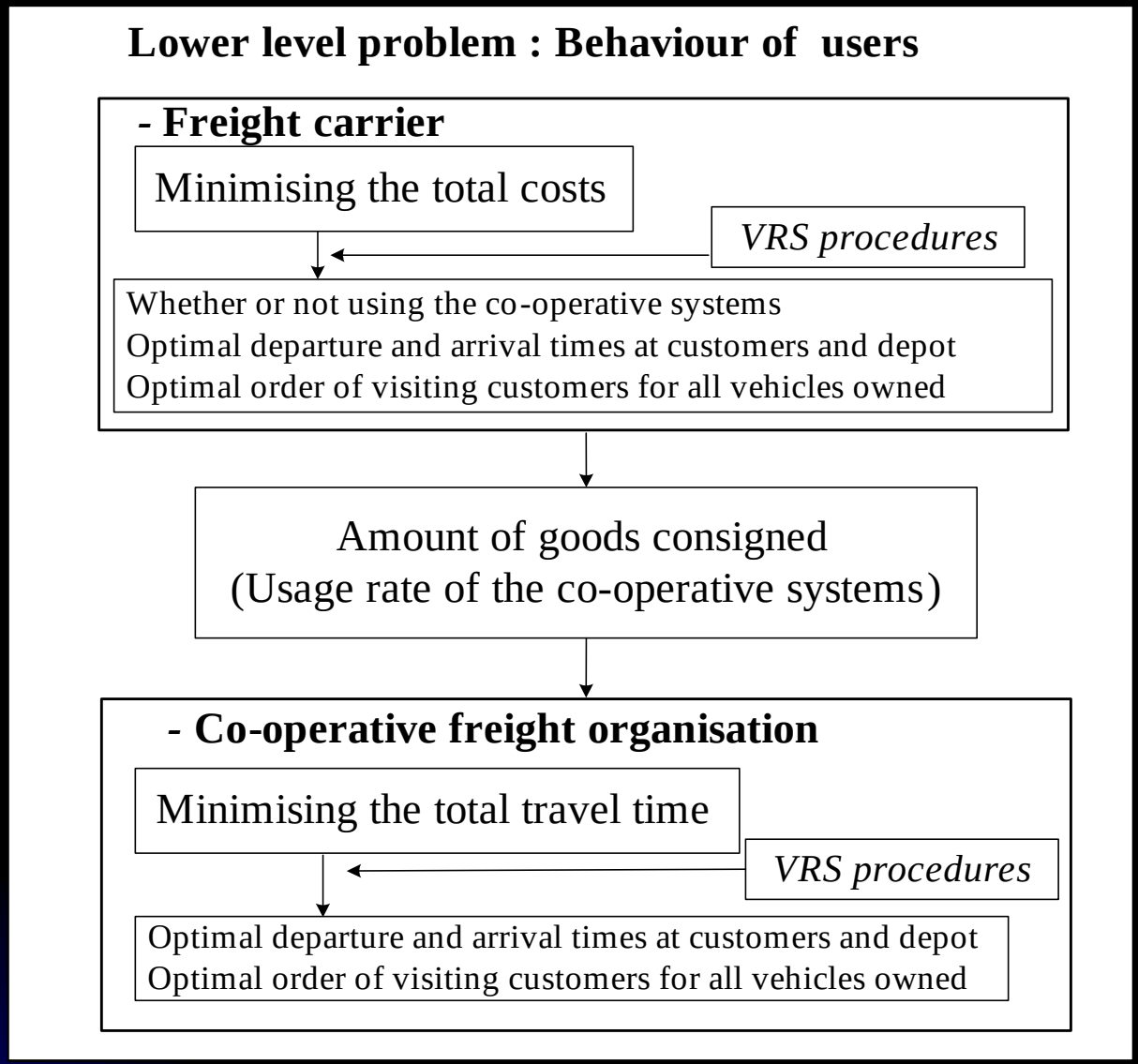
Objectives

- To investigate and compare the effects obtained from freight transport schemes
  - Indicators: total travel times of delivery vehicles and delivery costs incurred by freight carriers
  - Simulation model: developed on the basis of the vehicle routing and scheduling problem with time windows (VRPTW)
    - The behaviour of several stakeholders : incorporated within the model

Model structure - Case of CFTS -



Model structure (cont.)



Formulation (for freight carriers) - Case of CFTS -

$$\min \quad TC\left(\mathbf{X}, \boldsymbol{T}^{\boldsymbol{d}}, \boldsymbol{T}^{\boldsymbol{a}}, \boldsymbol{a}\right) = \sum_{l} \left\{ a_l \times SC_l + (1 - a_l) \times CC_l \right\} \quad (1)$$

where,

$$SC_l = FC_l(c_l^f, \mathbf{x}_l) + RC_l(c_l^t, D_{n(i)}, \mathbf{x}_l, \boldsymbol{t}_l^{\boldsymbol{d}}, \boldsymbol{t}_l^{\boldsymbol{a}}) + PC_l(c_l^p, t_{n(i)}^s, t_{n(i)}^e, \mathbf{x}_l, \boldsymbol{t}_l^{\boldsymbol{d}}, \boldsymbol{t}_l^{\boldsymbol{a}}) \quad (2)$$

$$CC_l = FC_l(c_l^f, \mathbf{x}_l) + RC_l(c_l^t, D_{n(i)}, \mathbf{y}, \mathbf{x}_l, \boldsymbol{t}_l^{\boldsymbol{d}}, \boldsymbol{t}_l^{\boldsymbol{a}}) + UC_l(D_{n(i)}, \mathbf{x}_l, \mathbf{y}, \mathbf{p}) \quad (3)$$

subject to

$$W_l(\mathbf{x}_l) / W_l^c \le r \quad (4)$$

$$\cdots\cdots \quad (5)$$

$$\cdots\cdots$$

***r* =1 : advanced vehicle routing and scheduling (AVRS)**

***r* =0.32: practical vehicle routing and scheduling (PVRS)**
(*based on the surveys within urban areas in Japan)

Formulation - Case of CFTS - (for co-operative freight organisation)

$$\min TT^{cop}\left(\mathbf{X}^{cop}, \boldsymbol{T}^{d,cop}, \boldsymbol{T}^{a,cop}\right) = \sum_{l'} RT_{l'}^{cop}\left(\mathbf{x}_{l'}, \mathbf{y}, \boldsymbol{t}_{l'}^{d,cop}, \boldsymbol{t}_{l'}^{a,cop}\right) \quad (1)$$

subject to

$$W_l\left(\mathbf{x}_l\right)/W_l^c \le r \quad (4)$$

$$\cdots\cdots \quad (5)$$

$$\cdots\cdots$$

$$\sum_{l'}\left(FC_{l'}^{cop} + RC_{l'}^{cop} + PC_{l'}^{cop}\right) + LC(\mathbf{y}, \boldsymbol{a}) \le \sum_{u}\sum_{l} UC_l^u \quad (10)$$

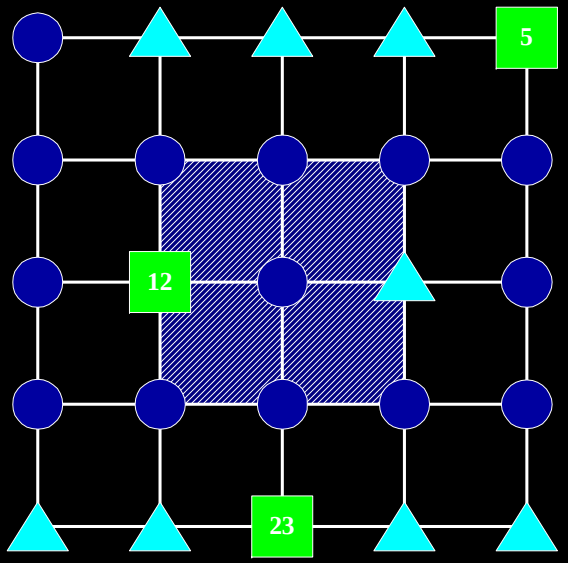
Constraint for profitability

Test road network

customer

depot

candidate node for logistics terminal



- Urban goods delivery
- 20 km x 20 km road network: distances between nodes = 5 kilometre
- Link travel times : peak hours and off-peak hours,
  - City centre: relatively congested
- Eight freight carriers: 1 depot and 20 customers
- Customers: mainly distributed within the city centre
  - Time windows designated by customers: two hours length, a.m. (8:00-12:00) or p.m. (13:00-17:00), no time windows.
- Trucks: 2-ton, 4-ton
- Hypothetical, but based mostly on the results from recent studies of goods movement and truck operations in Japan

Logistics systems investigated

Case A :All goods are delivered directly to customers by individual freight carriers without any schemes implemented. (i.e. using Practical VRS procedures: PVRSS)

Case B : Case A + CFTS

Case C : Case A + AVRSS

Case D : Case A + CFTS + AVRSS

Case E :Case A + CFTS + Access restrictions of delivery trucks to the city centre

*city centre, between 7a.m. and 7 p.m.

Logistics systems investigated (cont.)

Case F-1-1 : Case A + Road pricing

*Charge (1000 yen) is levied at each entrance to the city centre between 7a.m. and 7 p.m. with the automatic tolling systems (Cordon pricing).

*Travel speed within the city centre increases by 15%.

(c.f. Congestion charging schemes in central London)

Case F-1-2 : Case F-1-1 + CFTS

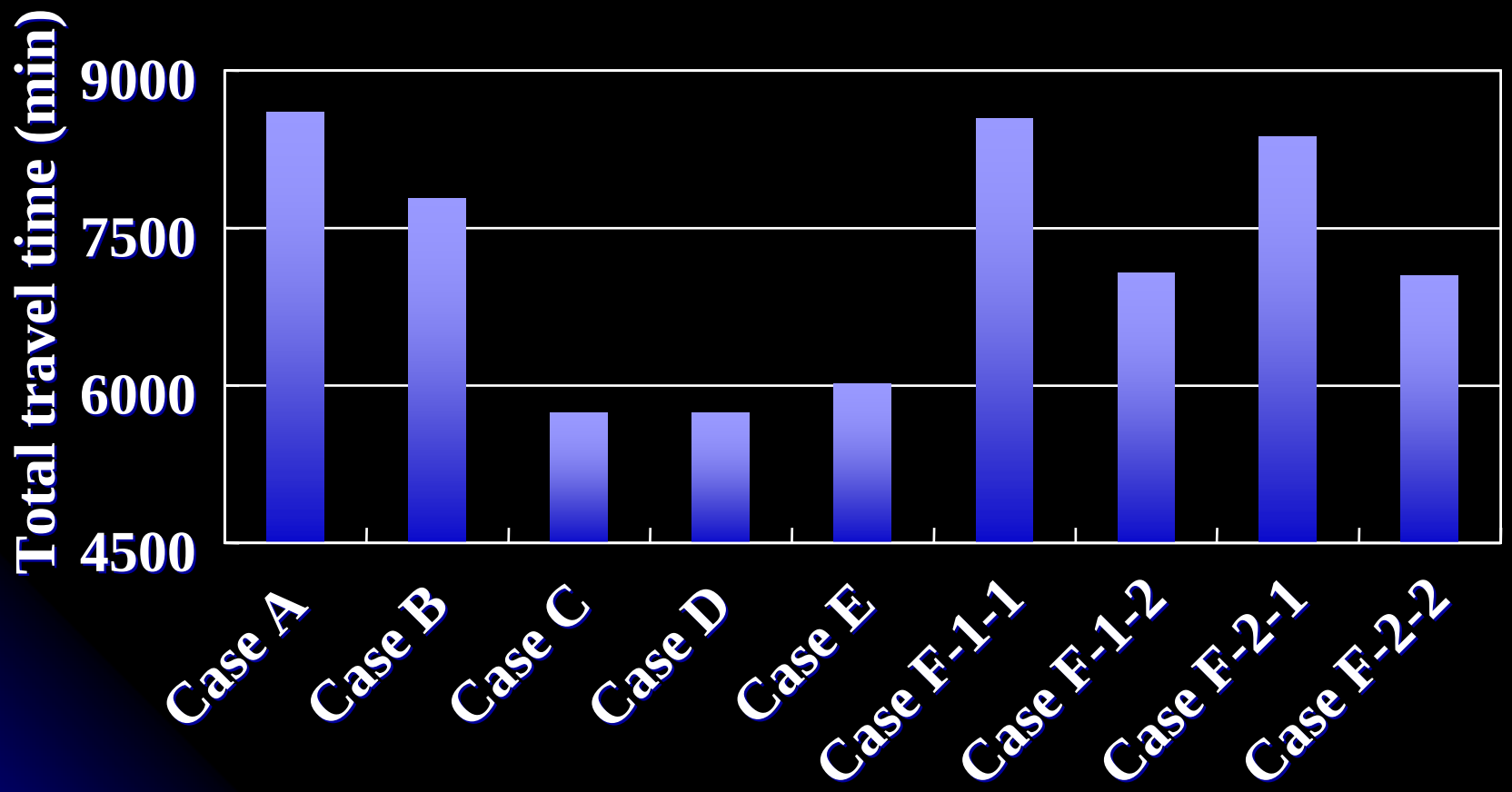
*Co-operative freight organisation can deliver goods without paying the charge.

Case F-2-1 : Case A + Road pricing

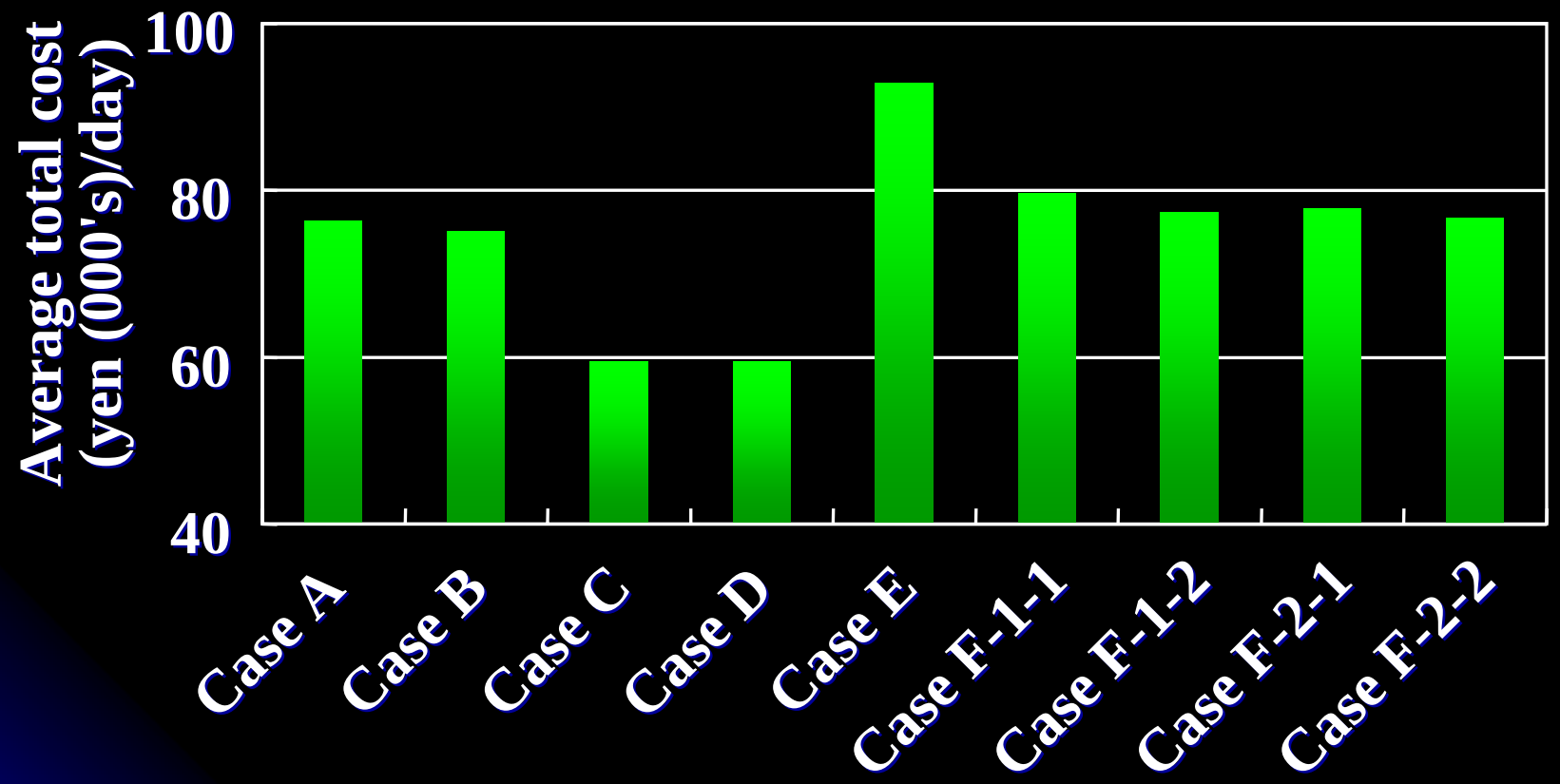
*Delivery vehicles can enter into the city centre as many times as they like, once the charge (1000 yen) is levied at their first entrance (Area pricing).

Case F-2-2 : Case F-2-1 + CFTS

Case comparison: Total travel time



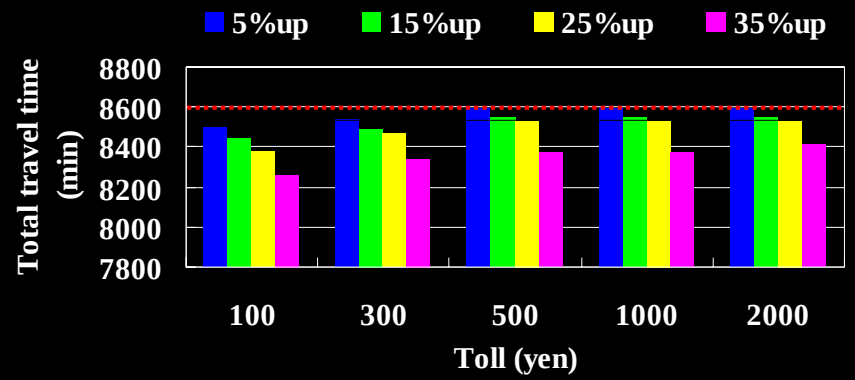
Case comparison: Average total costs

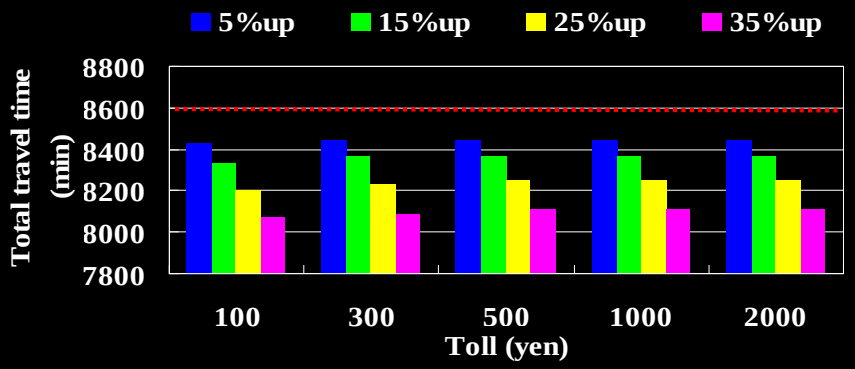


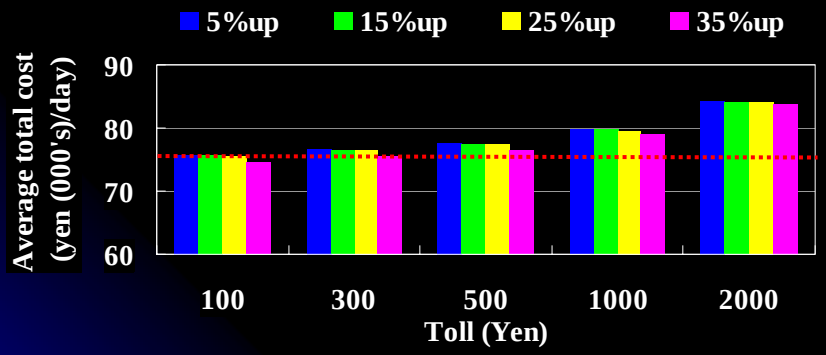
Detailed analyses on road pricing

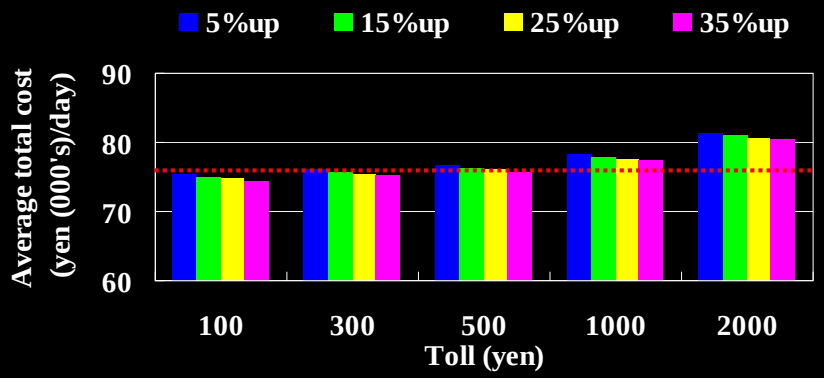
- Case F-1-1, F-1-2, F-2-1, F-2-2
- By varying the charge from 100 (yen) to 2000 (yen)
- By increasing travel speed within the defined area from 5% to 35%

Results (Case F without CFTS)









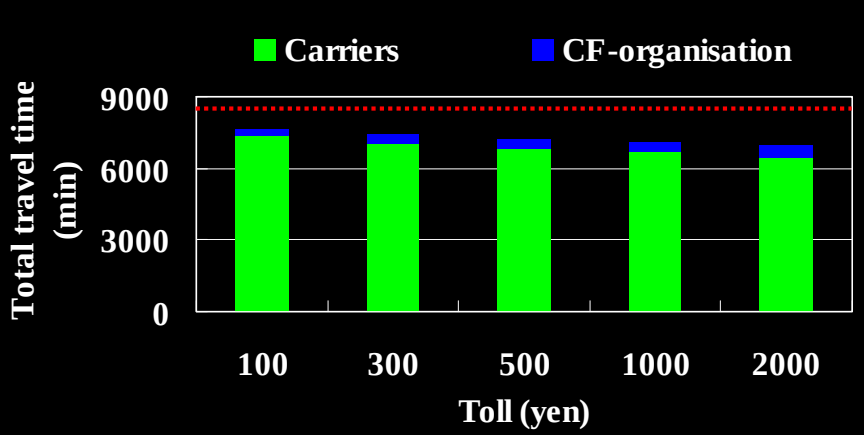
Case A

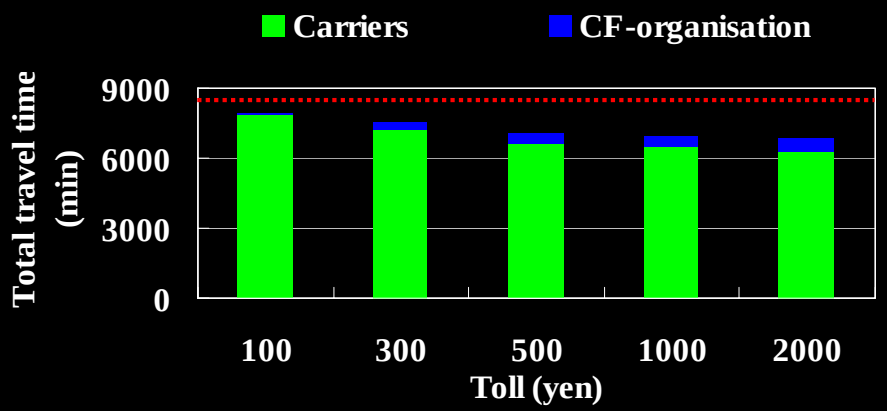
Case F-1-1 (Cordon pricing)

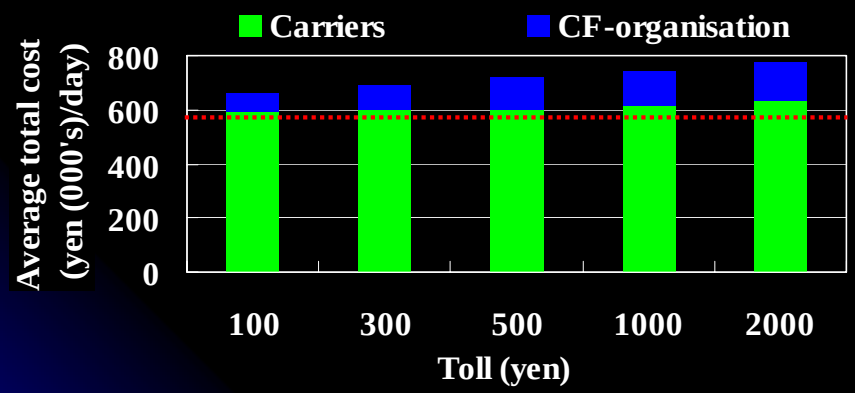
Case F-2-1 (Area pricing)

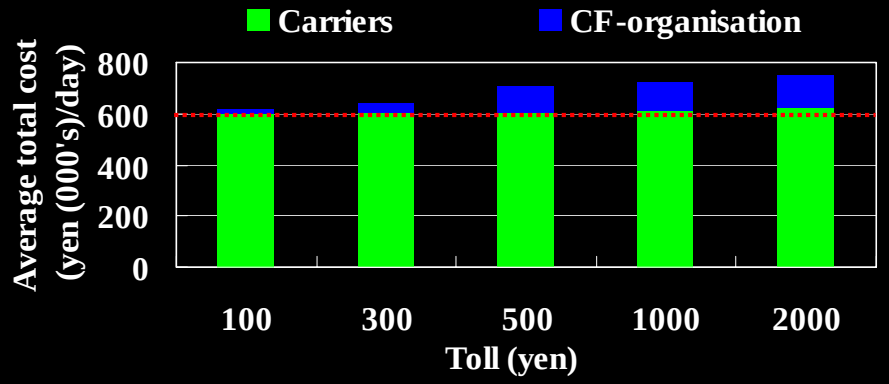
Results (Case F with CFTS)

- travel speed: 15% up -









Case A

Case F-1-2 (Cordon pricing)

Case F-2-2 (Area pricing)

Conclusions

- Co-operative freight transport systems
  - Benefits to the whole community & freight carriers
  - CFTS < AVRSS
- Access restrictions to the city centre
  - Decrease total travel time
  - Increase delivery costs (likely to make freight carriers in financial difficulties)
- Road pricing
  - Benefits to the whole community & freight carriers (more if implemented with CFTS)