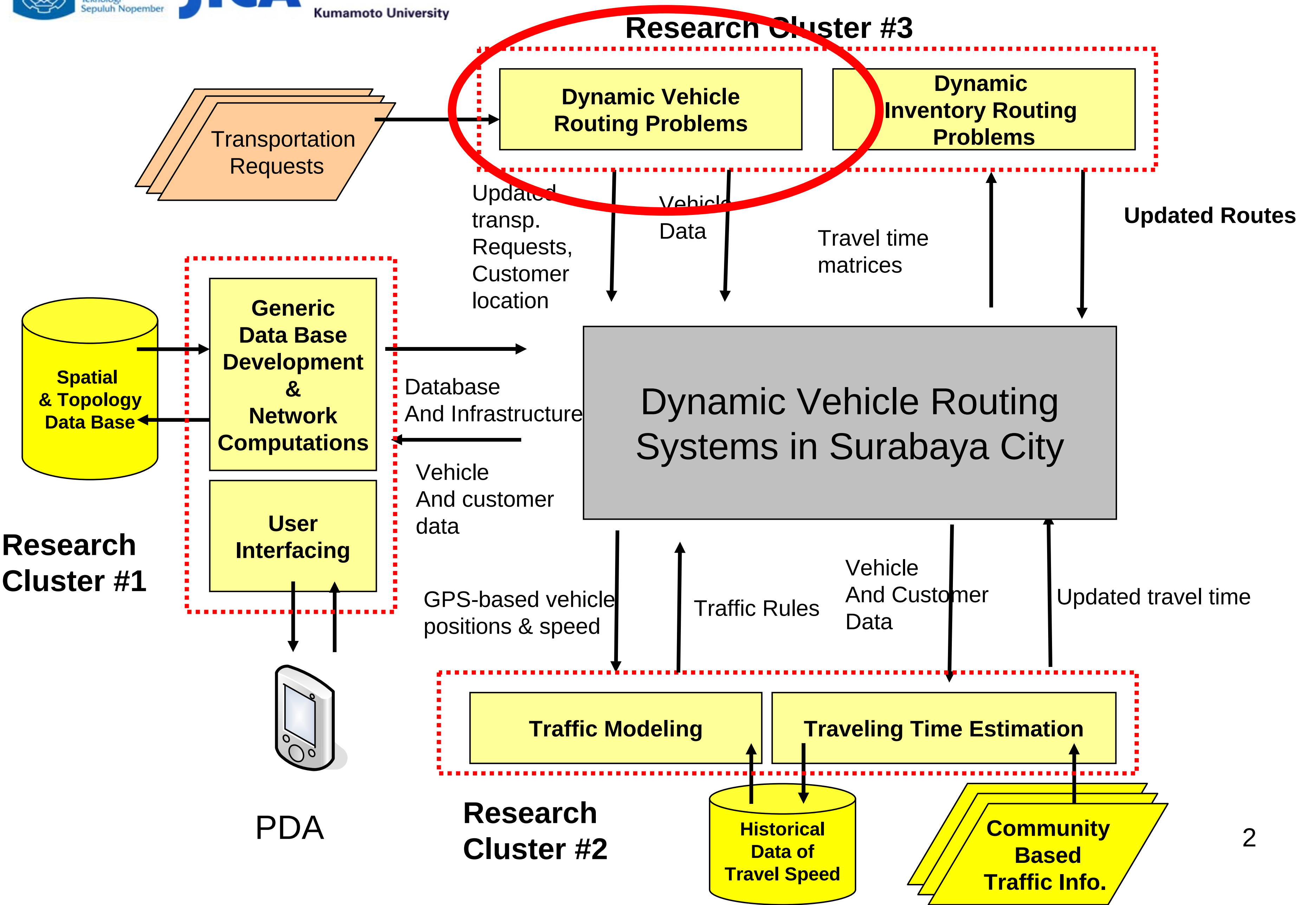
A HEURISTIC ALGORITHM FOR SOLVING DYNAMIC PICK UP AND DELIVERY PROBLEMS WITH TIME WINDOWS (DPDPTW) FOR CITY-COURIER SERVICE PROVIDERS

Ahmad Rusdiansyah 1), Fitri Karunia Rani 1), Abdullah Alkaff 2) Keiichi Uchimura 3)

1) Transportation and Distribution Logistics Research Group, Logistics and Supply Chain Management Laboratory,
Department of Industrial Engineering, ITS Surabaya -Indonesia
2) System Engineering Laboratory, Electrical Engineering Department, ITS- Surabaya, Indonesia
3) Computer Science Department, Faculty of Engineering, Graduate School of Science and Technology, Kumamoto University, Japan
Contact: arusdian@ie.its.ac.id

2nd T-LOG/EASTS Logistics IRG Seminar
Tokoname, JAPAN, 22-24 September 2008

Collaboration Research



Static Vs Real-time Vehicle Fleet Management (Larsen et al, 2007)

Static

- All information relevant to the planning of the routes is assumed to be known by the planner before the routing process begins.
- Information relevant to the routing does not change after the routes have been constructed

Real Time

- Not all information relevant to the planning of the routes is known by the planner when the routing process begins.
- Information can change after the initial routes have been constructed.

Real-Time Information

The availability of real-time information (e.g., vehicle position, traffic conditions, etc.) is thus critical.

Fortunately, the rapid growth in communication and information technologies now provide opportunities for obtaining real-time information at lower costs.

New vehicles are equipped with advanced GPS/GIS systems.

Hence, the distribution companies are now able to monitor the vehicles'

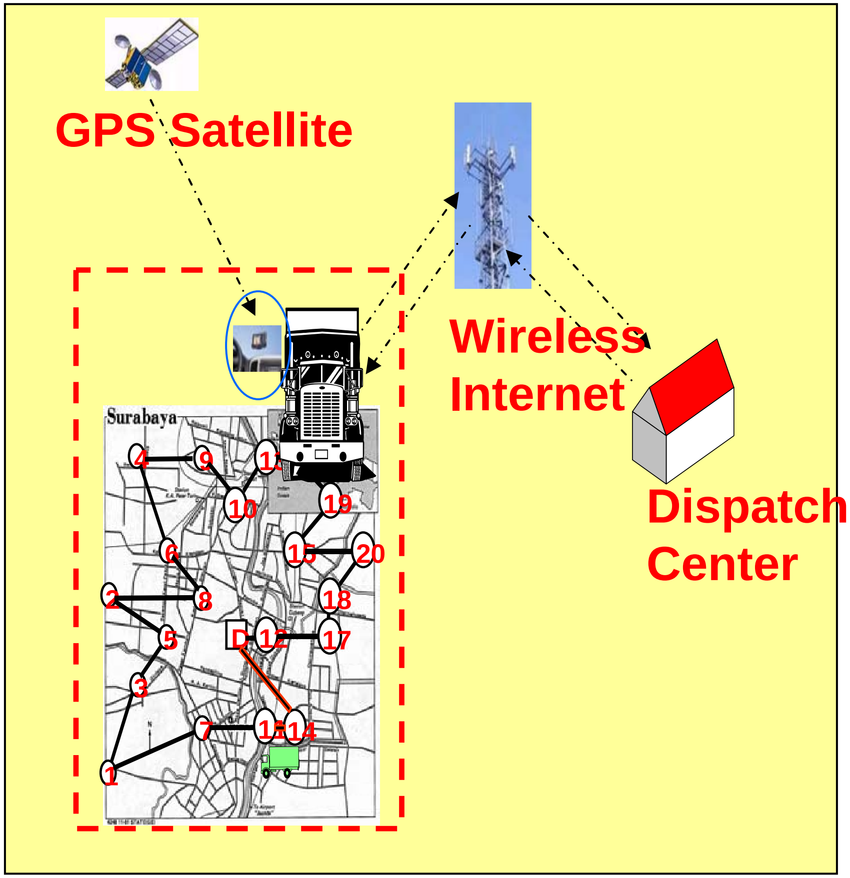
position and status at any given time

Dynamic fleet management may be implemented in practical systems by taking advantage of recent advances in satellite and mobile communication technologies

Satellite Location Identification Systems

Specifically, satellite location identification systems that use the Global Positioning System (GPS) and terrestrial mobile communication systems, such as the General Packet Radio Service (GPRS)

Enabling fleet operators to monitor the execution of a plan and to manage operations in realtime, thus improving fleet performance



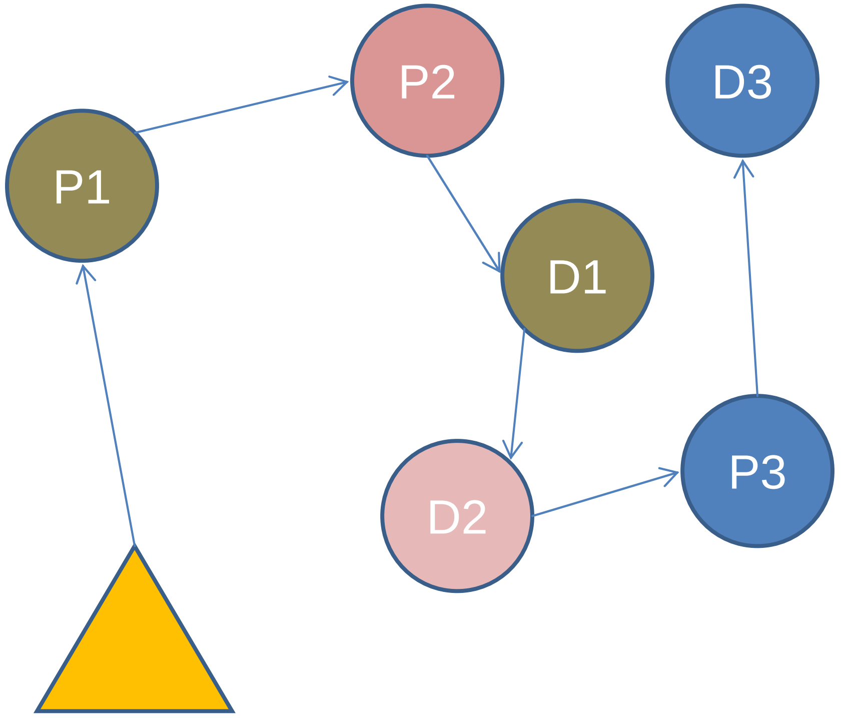
Many To Many Problems

Such local express mail services in urban areas is categorized many to many problems,

<u>Other Similar Systems</u>

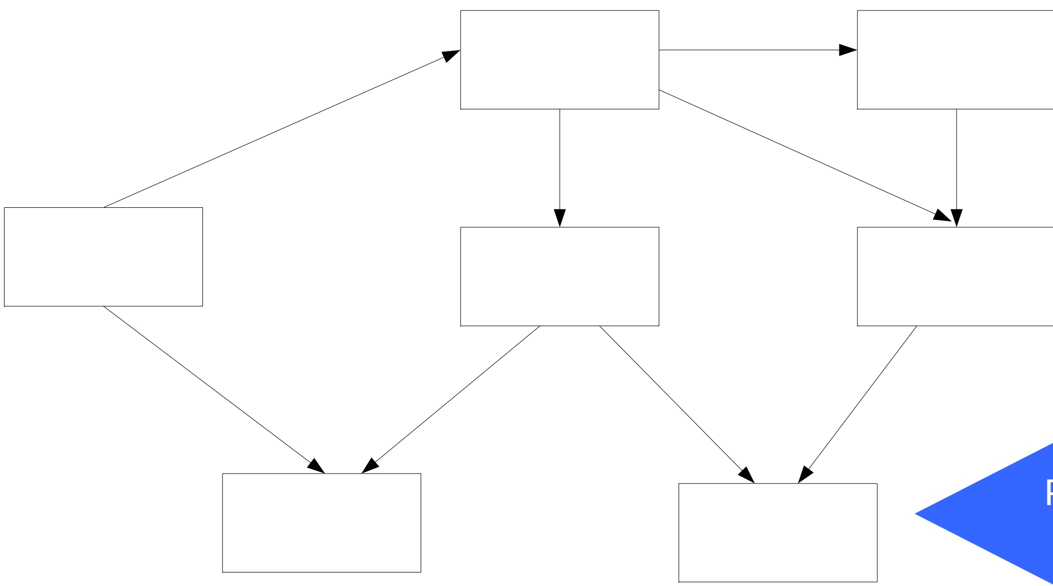
Dial-a-ride systems for transportation-on-demand services / Handicapped Person Transportation Services,

- Less-than-truckload applications where different kinds of goods and products are picked up and delivered



Taxonomy

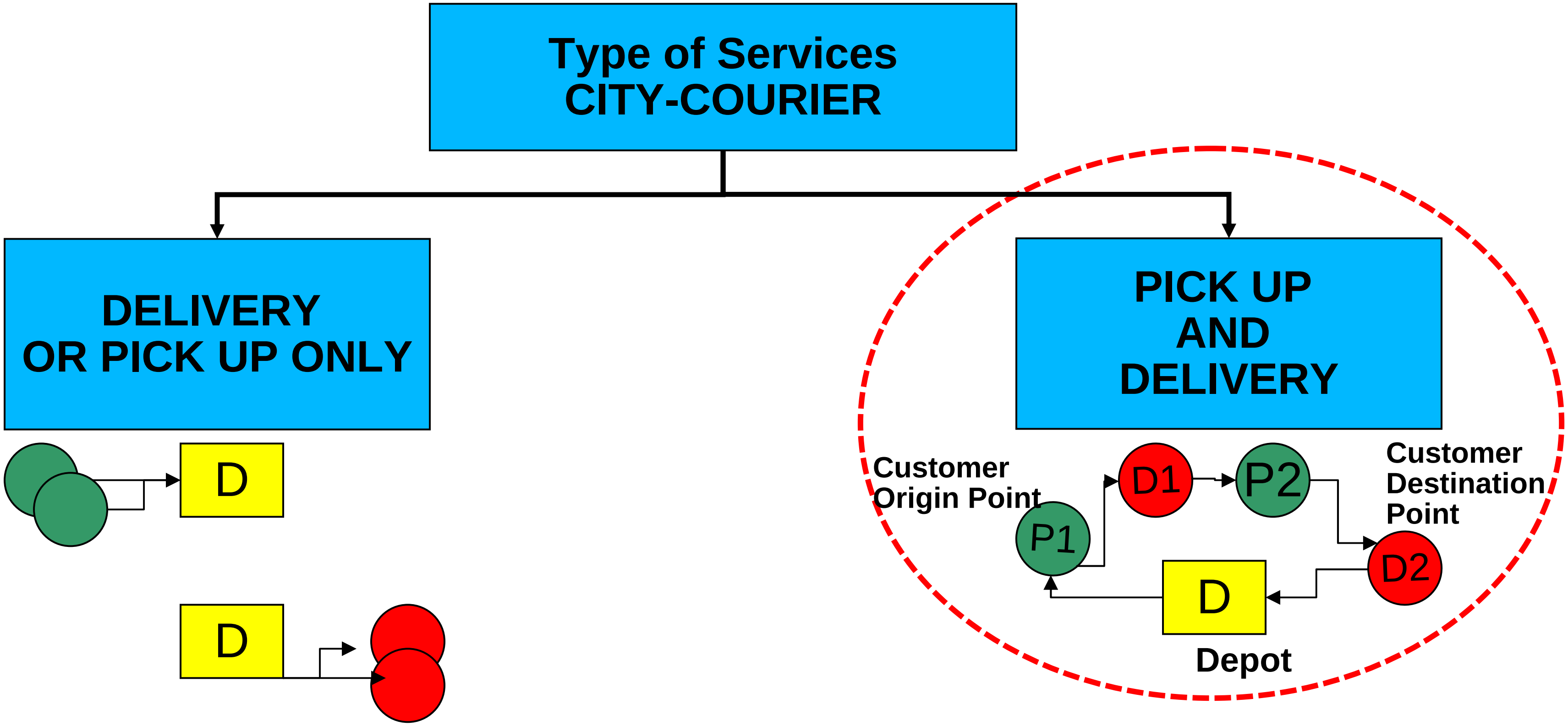
VRP Family



Pick Up and Delivery Problem
With Time Windows

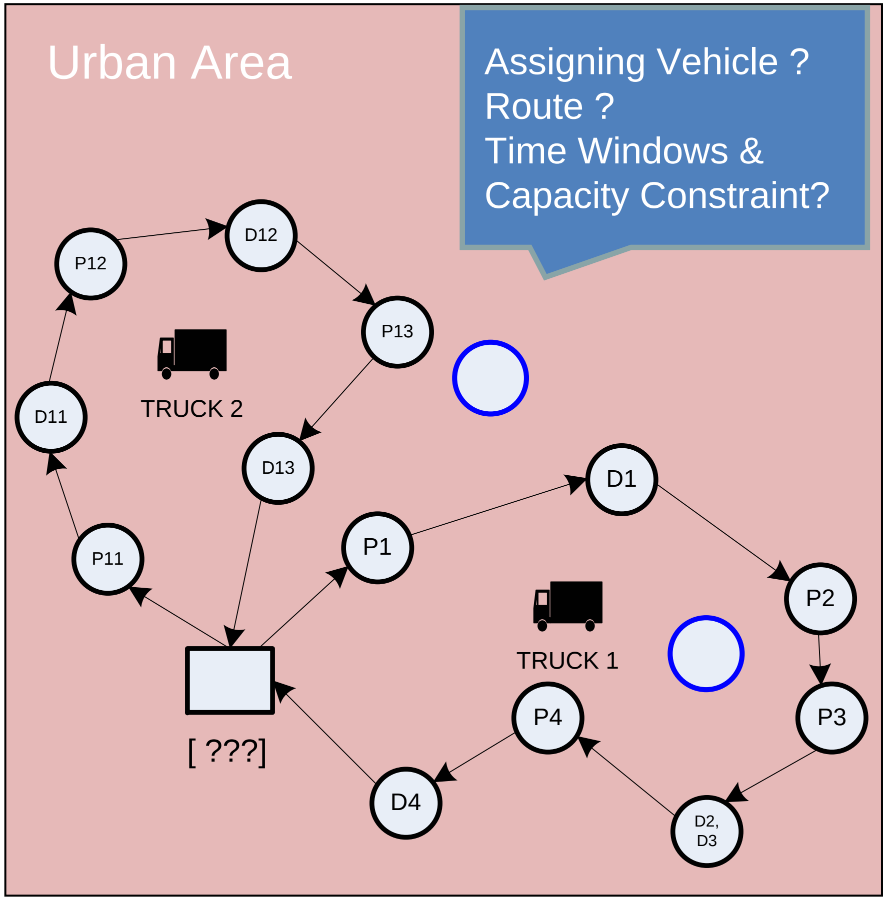
Source : Toth and Vigo, Vehicle Routing Problem, 2004

City Courier

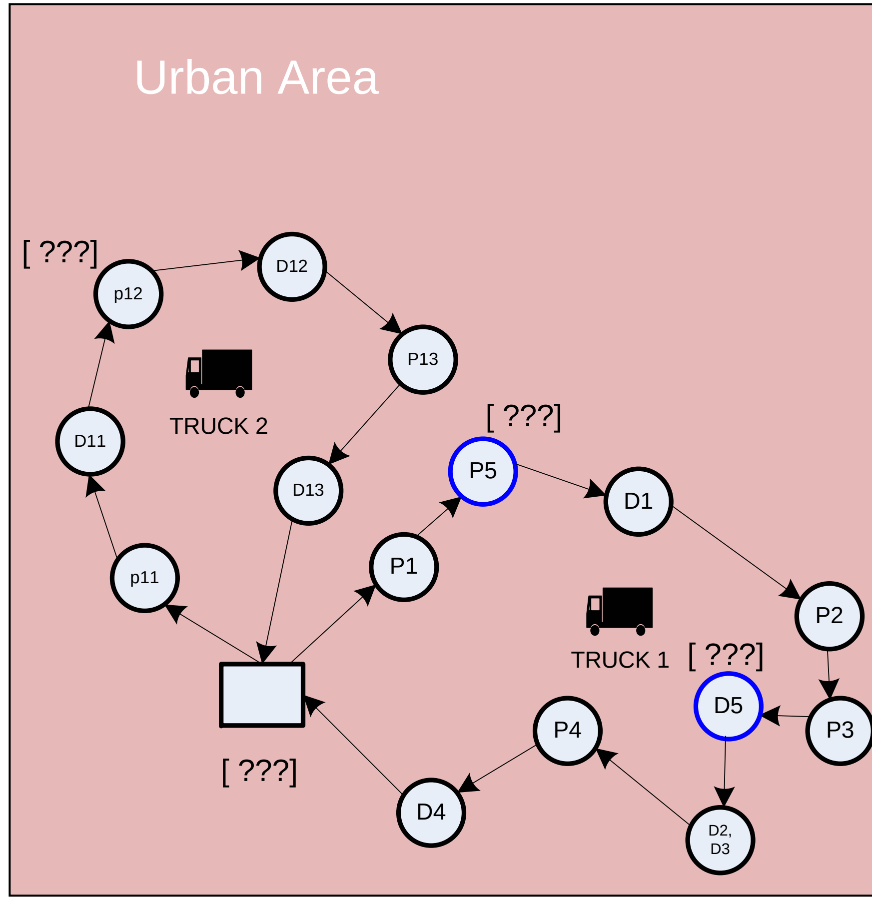


Problem Description

Initial Route



Re-route



New Pick Up & Delivery Request

Pickup and Delivery Problem (Goel,2008)

- In the *Pickup and Delivery Problem (PDP) the set of customer locations can be* partitioned into a set of pickup locations CP and a set of delivery locations CD.
- Each transportation request is specified by a load to be transported from its pickup location to its delivery location.
- The PDP deals with the construction of optimal tours in order to visit all pickup and delivery locations and to satisfy precedence and pairing constraints.
- Precedence constraints deal with the restriction that each pickup location has to be visited prior to visiting the corresponding delivery location.
- Pairing constraints restrict the set of admissible tours such that pickup and delivery locations of each transportation request are visited by the same vehicle
- {PDPTW = PDP+ the desired time window at each delivery location)

Notations

- Define a set of job nodes $N=\{1,2,..,n\}$, where n represents twice times the number of transportation requests.
- N is always an even number since the job nodes consist of a set of pairs of pickup and delivery nodes.
- Each pick-up node $i \in N$ has exactly one partner delivery node. Define a set of pickup nodes N^+ and a set of delivery nodes N^- , where $N=N^+ \cup N^-$.
- Define also V to represent a set of vehicles $\{n+1,n+2,..,m\}$.
- Define a relation $j \oplus i$ to mean node j is a partner delivery node of pickup node i.

Model Formulation

$$Minimize \sum_{i,j \in N \cup V} c_{ij} \bullet x_{ij}$$

$$\text{Subject to}:$$

$$\sum_{i \in N \cup V} x_{ij} = 1, \quad \forall j \in N \cup V$$

$$\sum_{i \in N \cup V} x_{ji} = 1, \quad \forall j \in N \cup V$$

Time Window Constraint

$$s_i - s_j + d_i + t_{ij} \le M \bullet (1 - x_{ij}), \quad \forall i, j \in N$$

$$b_i \le s_i \le e_i, \quad \forall i, j \in N$$

The rules by which the time window constraint will abide can be described as follows:

- If $s_i + d_i + t_{ij} > e_j$, then it is infeasible for jobs i and j to be consecutive.
- If $s_i + d_i + t_{ij} \le e_j$, then it is feasible for jobs i and j to be consecutive , and $s_j = \max\{ b_j, s_i + d_i + t_{ij} \}$

Maximum Ride Time Constraint

$$s_j - s_i - d_i \leq K, \ \ \forall i \in N^{+}, \forall j \in N^{-}, \ \ \mathrm{j} \oplus \mathrm{i}$$

- Let s_i be defined as the time at which service at job node i begins, i∈N. Let also s_j be defined as the time at which service at job node j begins, j ∈ N. Job node j is the delivery node of job node i.
- Given K is the allowed maximum ride time for every customer's request , the trip time from the pickup point i to the delivery point j, cannot exceed the maximum ride time K.
- Note: The maximum ride time constraint must be implemented together with the time window constraint.

Vehicle Capacity Constraint

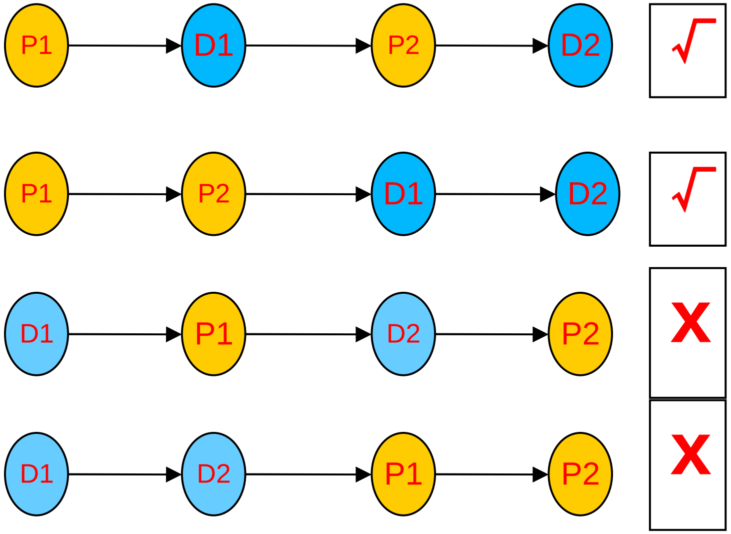
$$q_i - q_j + a_i \le M \bullet (1 - x_{ij}), \quad \forall i, j \in N$$

$$0 \le q_i \le C - a_i, \quad \forall i \in N$$

- Let q_i be defined as the cumulative load on a vehicle before visiting job i), $\forall i \in N$.
- Let also a_i be defined as the volume of spaces needed by job i, $\forall i \in N$.
- It is assumed that the vehicles depart empty from the depot.
- For each job node i , the sum of q_i and a_i cannot exceed the vehicle capacity
- For simplicity, it is assumed that the problem has a homogeneous vehicle fleet.

Precedence Constraint

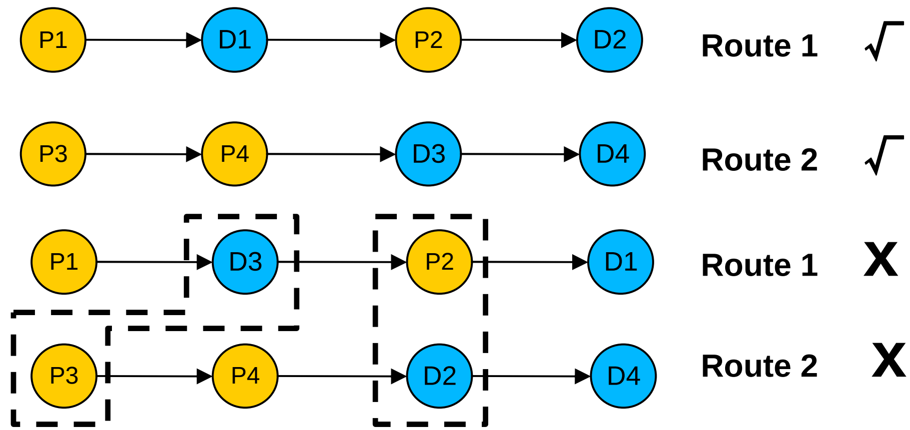
- To guarantee the parcel will be picked up before being delivered
- Let s_i be the time at which service at job node i begins, $i \in N$. Also define s_j to be the time at which service at job node j begins, $j \in N$. Job node j is the delivery node of job node i.
- The precedence constraint can be formulated as follows.



$$s_i + d_i - s_j \le M \bullet (1 - x_{ij}), \quad j \oplus i, \forall i, j \in N$$

Pairing Constraint

- To guarantee that a pair of pick-up and delivery nodes is on the same vehicle.
- Different from other constraints, this constraint uses a label instead of time or quantity.
- Let r_i be defined as the label of job i, and let r_v be the label of vehicle *v*. These constraints must be employed together with time window and precedence constraints in order to maintain the precedence of job nodes.



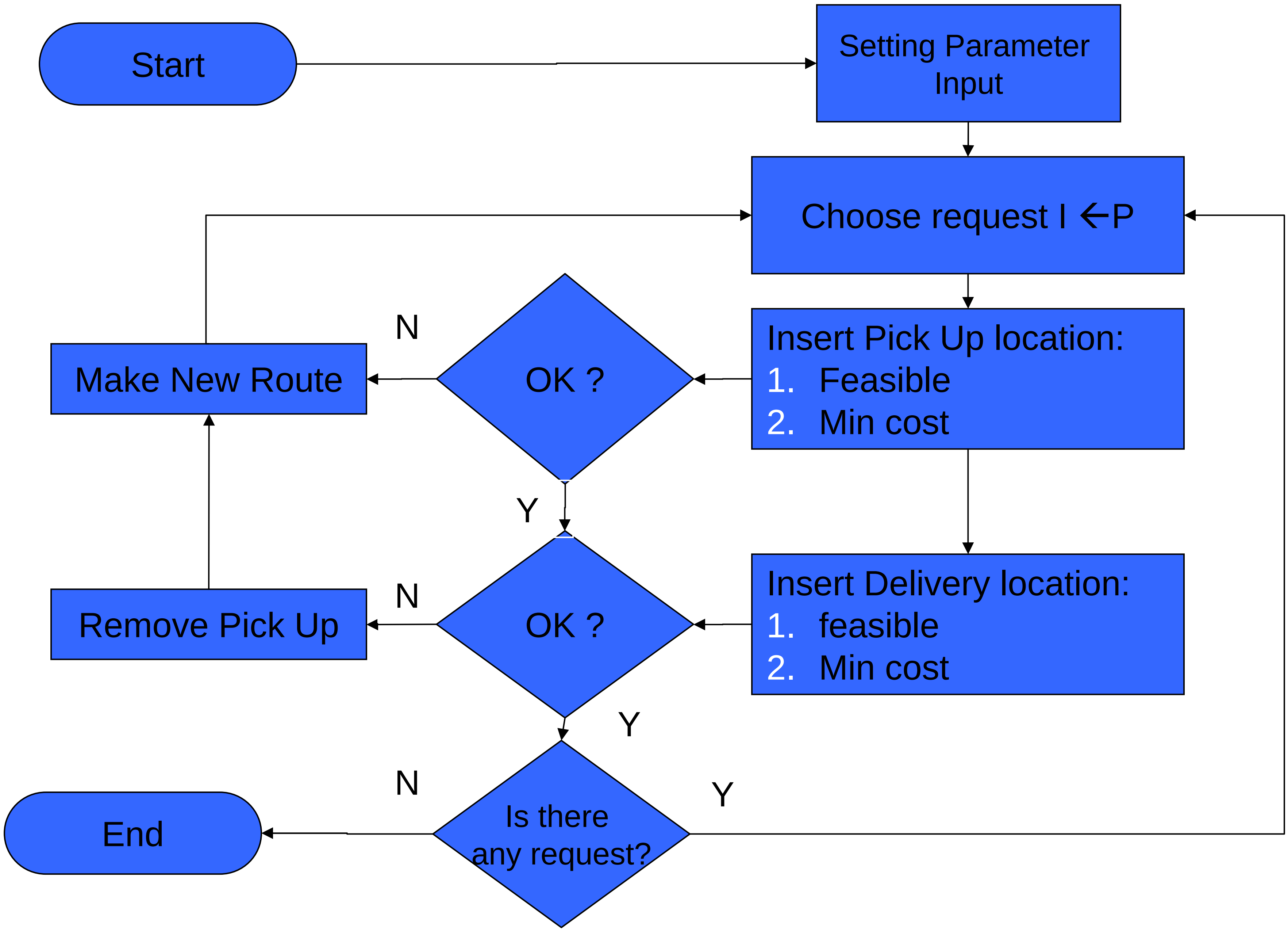
$$r_i - r_j = 0\ , \quad \forall i \in N^+, \mathrm{j} \oplus \mathrm{i}$$

$$-M \bullet (1 - x_{ij}) \le r_i - r_j \le M \bullet (1 - x_{ij}),\ \forall i, j \in N$$

$$-M \bullet (1 - x_{iv}) \le r_i - r_{\mathrm{v}} \le M \bullet (1 - x_{iv}),\ \forall i \in N^+, \quad \forall v \in V$$

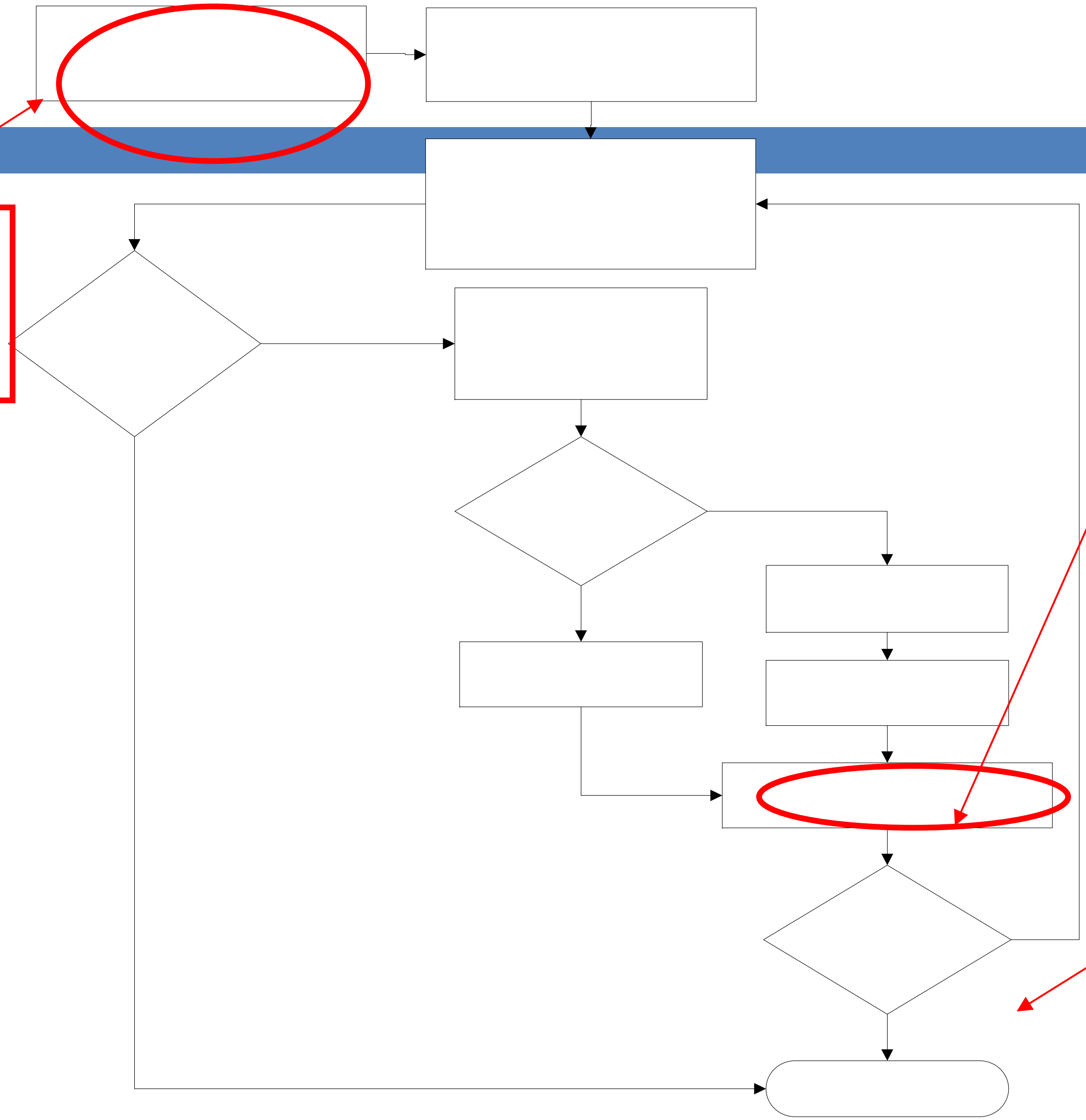
$$r_v = v\ , \quad \forall v \in V$$

Static Problem (1) : Insertion Heuristic



Static Problem (3) : Tabu Search

Initial Solution = Insertion Heuristic Output



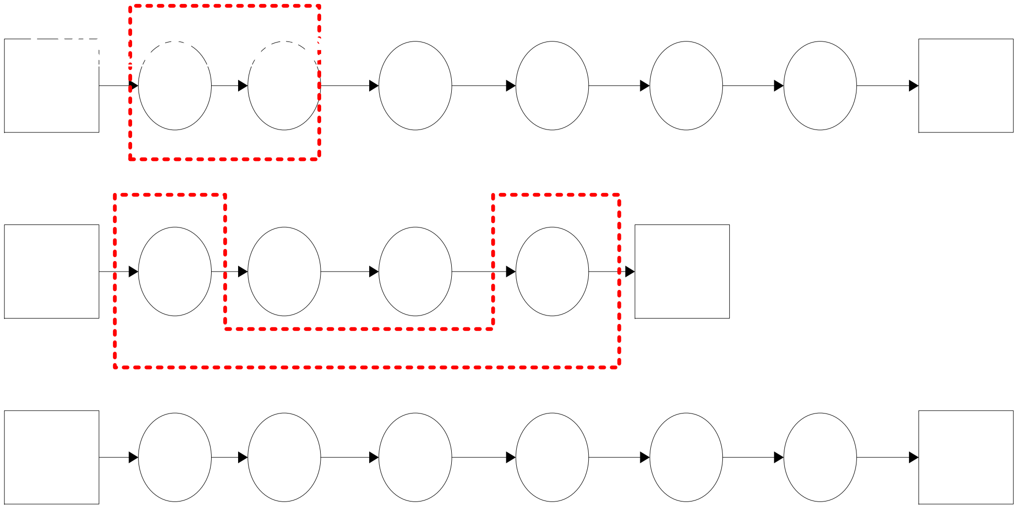
Update tabu list

Swapping = Categorized as Tabu Until t+θ

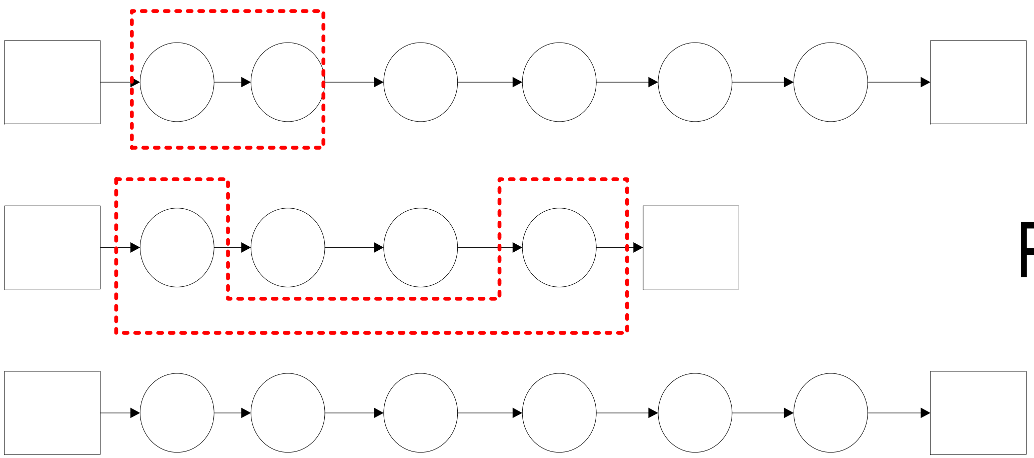
INITIAL

Stopping Criterion

Static Problem (2) : Neighborhood Structure



Route after swapping

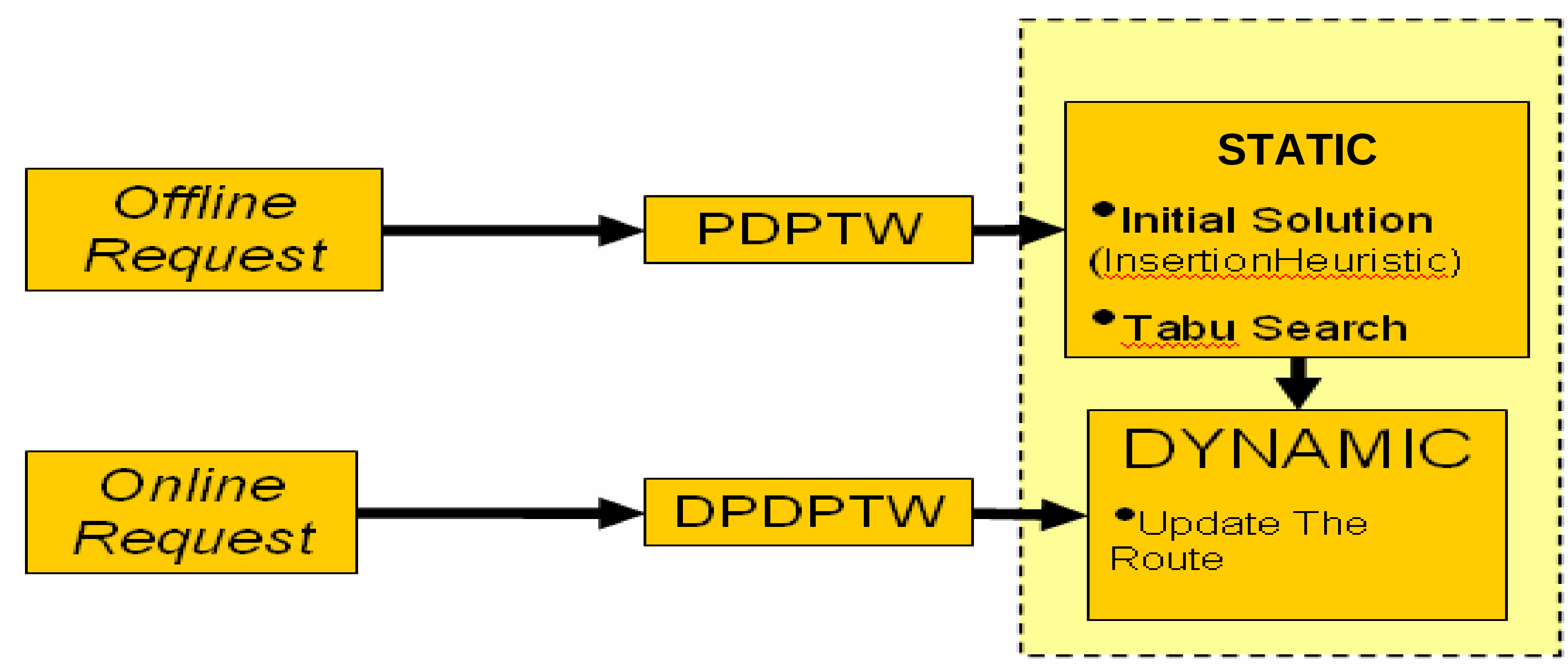


Static Problem → Dynamic Problem

(Pankratz, 2005)

Dynamic Problem is a Sequential Static Problem

Modify static problem when there is new transportation request



Degree of Dynamism with TW

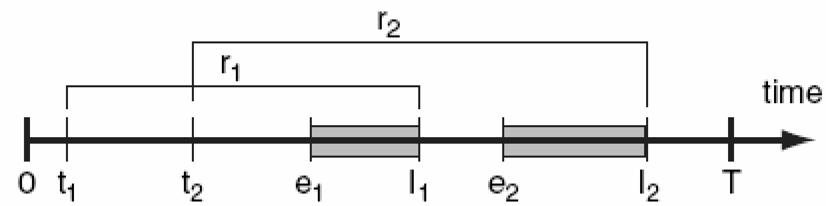


Figure 2-3. The reaction times of two dynamic customers in a DVRP with time windows.

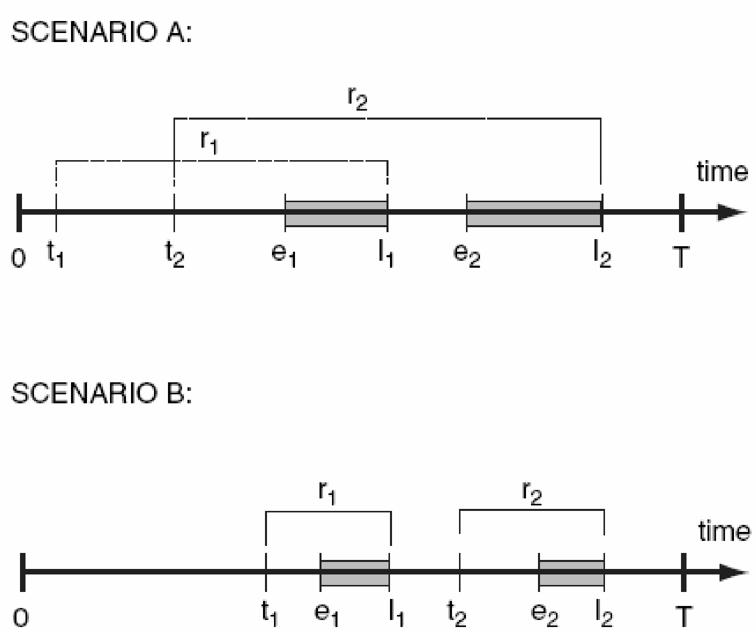
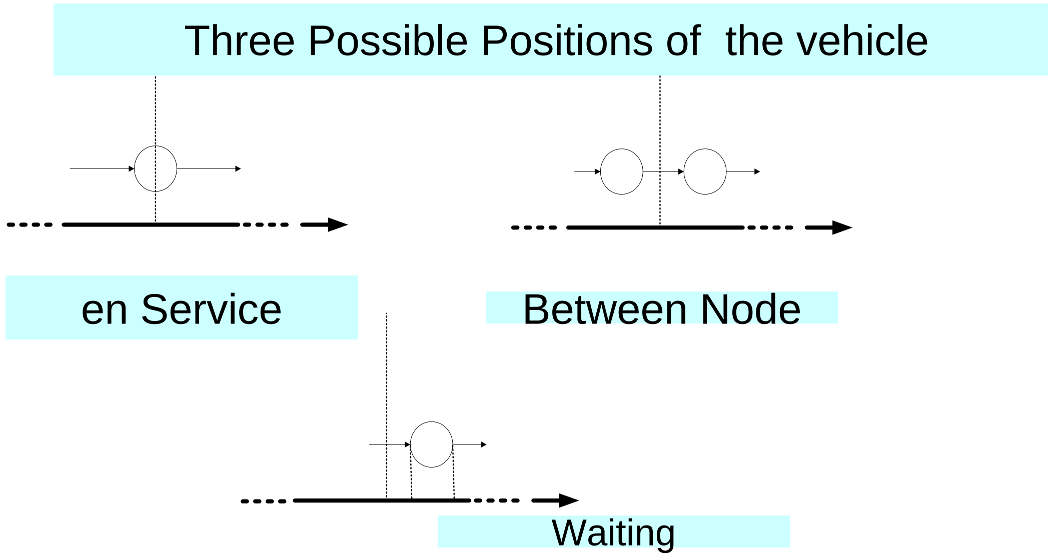


Figure 2-4. Two scenarios with two immediate requests.

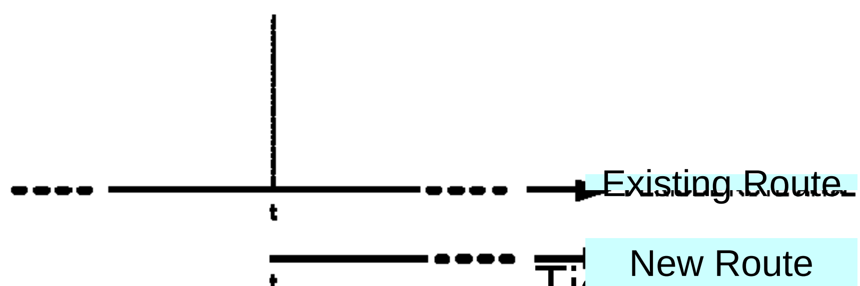
Source Larsen et al, 2007

Time Slot Considerations

- Vehicle Position

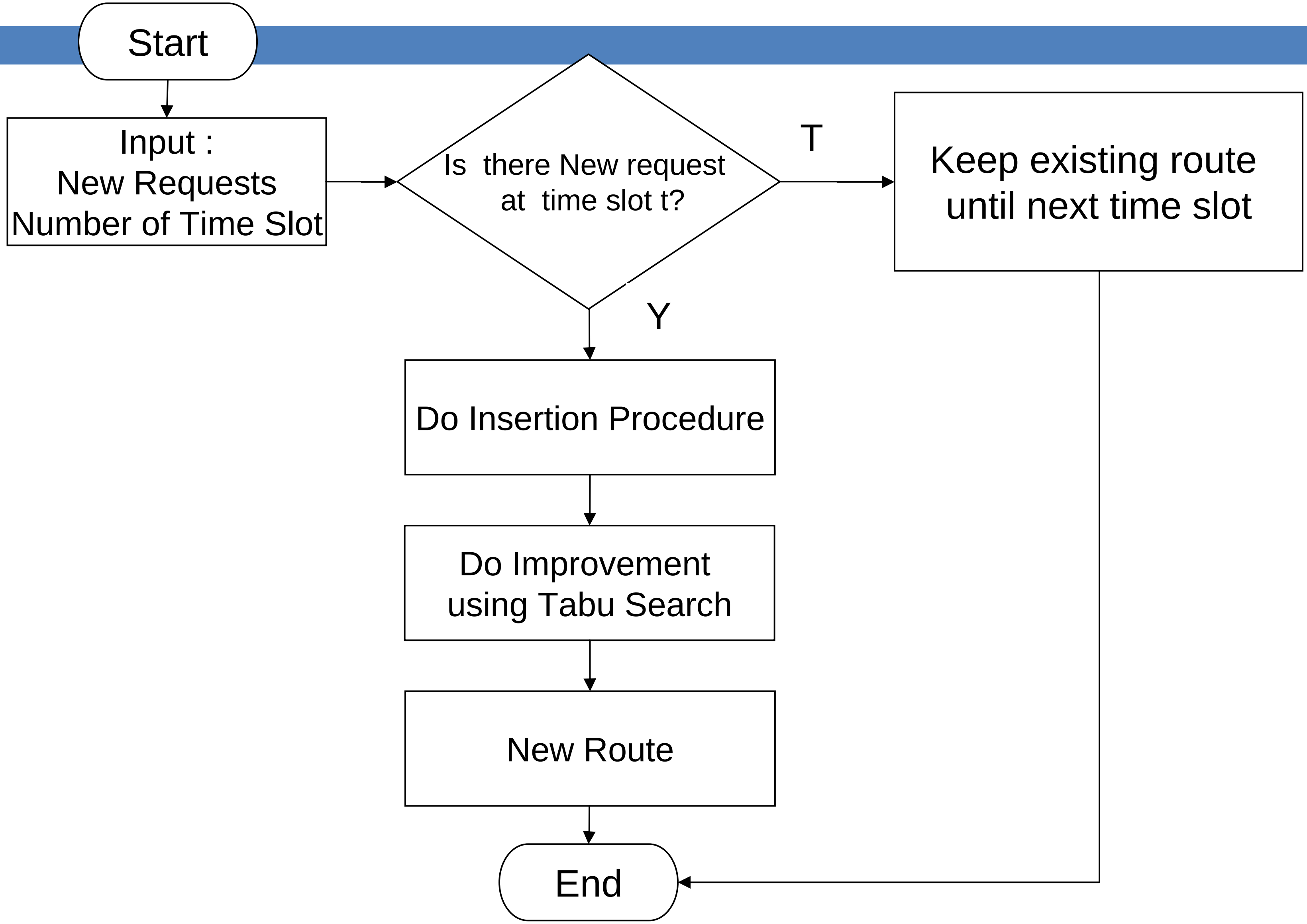


- Max Ride Time



Tiga Kemungkinan Posisi kendaraa

Dynamic Problem (3) : Dynamic Algorithm



Numerical Examples

Initial Routes (Static)
Route 1 : P9-P19-D19-D9-O0-
Route 2 : P3-P14-D14-D3-O0-
Route 3 : P5-P6-D5-P1-D1-D6-P7-D7-O0-
Route 4 : P20-P2-D2-D20-O0
Route 5 : P11-P12-P15-D12-D11-D15-O0-
Route 6 : P10-P13-D13-D10-O0-
Route 7 : P16-P17-D16-D17-O0-
Route 8 : P4-P18-D18-D4-P8-D8-O0-
[TOTAL COST] : 1577.23997151948

Updated Routes
Route 1 : P22-P9-P19-D19-D9-D22-O0-
Route 2 : P3-P23-P14-D14-D23-D3-O0-[UPDATED]
Route 3 : P5-P6-D5-P1-D1-D6-P7-D7-O0-
Route 4 : P20*P21-P2-D2-D21-D20-O0-
Route 5 : P11*P12-P15-D12-D11-D15-O0-
Route 6 : P10-P13-D13-D10-O0-
Route 7 : P16-P17-D16-D17-O0-
Route 8 : P4-P18-D18-D4-P8-D8-O0-
[TOTAL COST] : 2048.15093901739

Updated Routed(1)
Route 1 : P22-P9-P19-D19-D9-D22-O0-
[UPDATED]
Route 2 : P3-P14-D14-D3-O0-
Route 3 : P5-P6-D5-P1-D1-D6-P7-D7-O0-
Route 4 : P20*P21-P2-D2-D21-D20-O0-
Route 5 : P11*P12-P15-D12-D11-D15-O0-
Route 6 : P10-P13-D13-D10-O0-
Route 7 : P16-P17-D16-D17-O0-
Route 8 : P4-P18-D18-D4-P8-D8-O0-

Improved Routes using Tabu Search
Request Time Slot -1
Route 1 : P22-P9-P19-D19-D9-D22-O0-
Route 2 : P3-P4-P14-D14-D4-D3-O0-
Route 3 : P5-P6-D5-P1-D
Route 4 : P20-P21-P2-D2
Route 5 : P11-P12-P15-D
Route 6 : P10-P13-D13-D10-O0-
Route 7 : P16-P17-D16-D17-O0-
Route 8 : P23-P18-D18-D23-P7-D7-O0-
[TOTAL COST] : 1787.30815319543

cost decreasing (12.7%)

Reassign vehicle 1 by Insertion requests #22 and #23

Numerical Experiment using different DODs

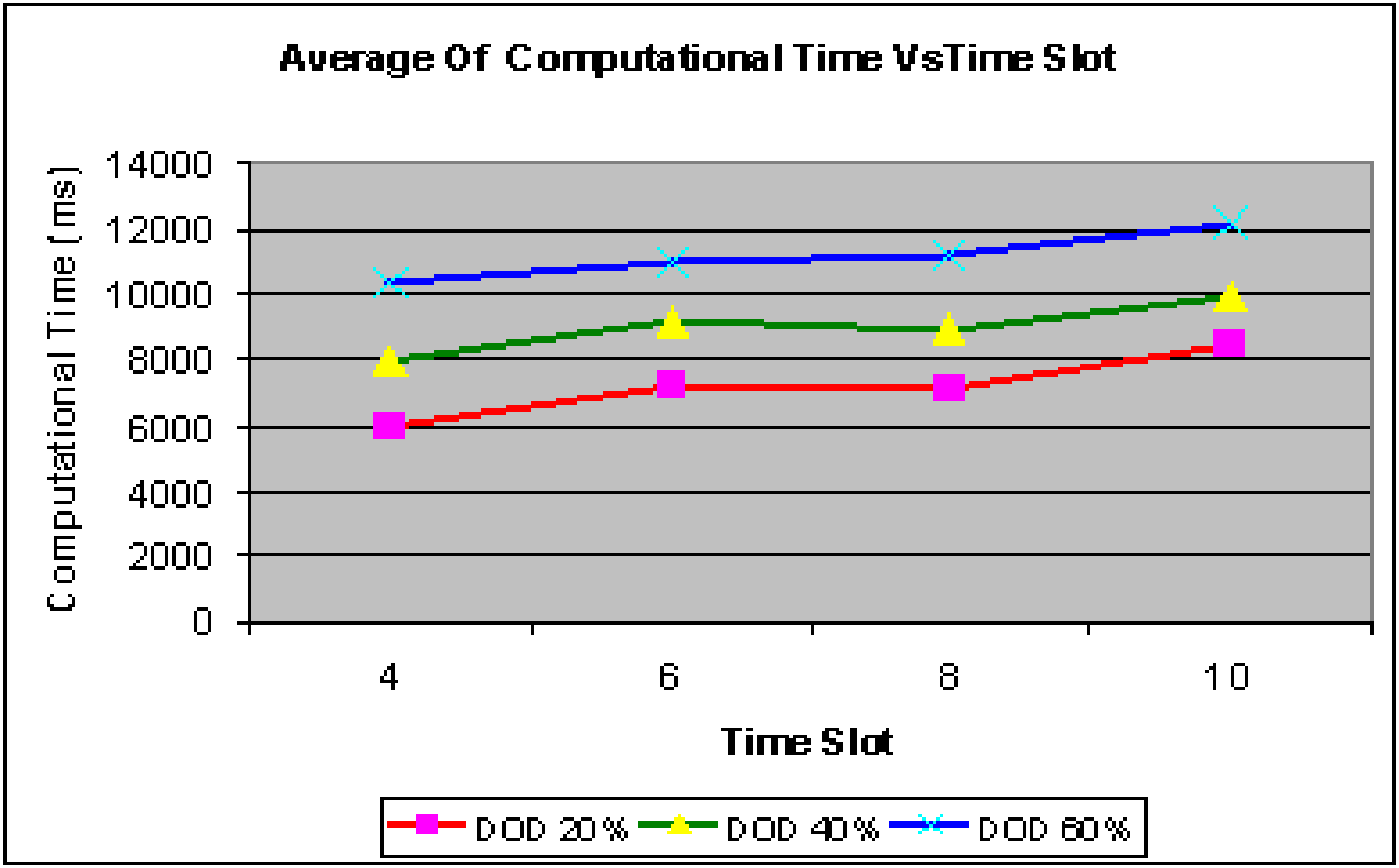
DESIGN OF EXPERIMENT (1):

- Use a problem instance with 25 pairing requests,
- tabu search iteration 10 and θ =10

To investigate the relationship between time slot, DOD, and computational time

Experiment	DOD	Offline	Online	Time Slot
1	20%	20	5	2
2	20%	20	5	4
3	20%	20	5	6
4	20%	20	5	8
5	40%	15	10	2
6	40%	15	10	4
7	40%	15	10	6
8	40%	15	10	8
9	60%	10	15	2
10	60%	10	15	4
11	60%	10	15	6
12	60%	10	15	8
13	80%	5	20	2
14	80%	5	20	4
15	80%	5	20	6
16	80%	5	20	8

Numerical Experiment



Conclusion and Future Research

- We have developed model and heuristic algorithm for *Dynamic Pick Up and Delivery Problem with Time Windows* for *City-Courier providers*
- The number of timeslots and Degree of Dynamism have a direct relationship to the computational time required.

Future Research :

To further investigate the behaviour and performance of the proposed algorithms