دانشگاه صنعتی اصفهان
دانشکده مهندسی حمل و نقل

حمل و نقل ریلی

مسئله تشکیل قطارها

Train Formation Problem

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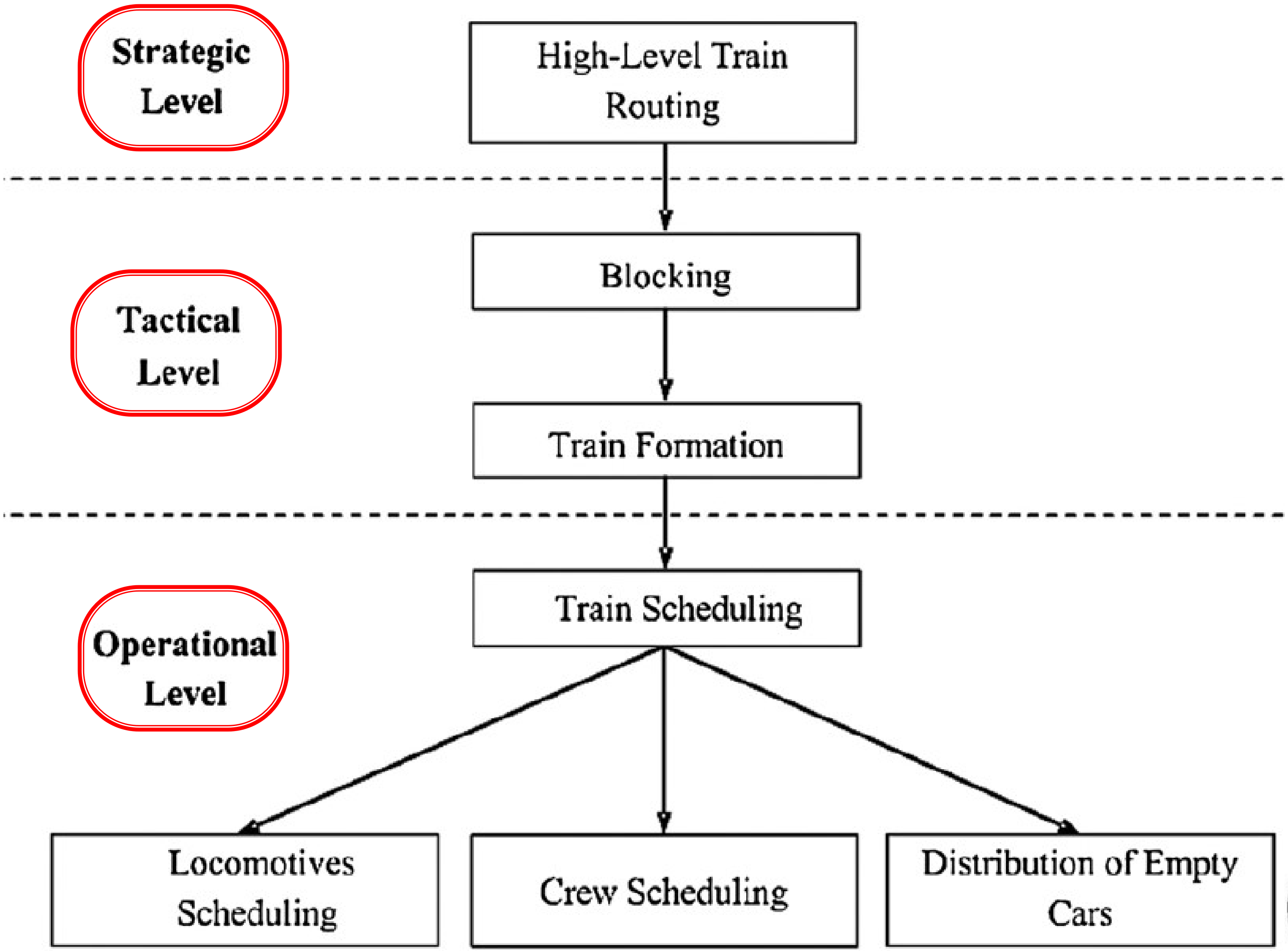
بهار ۱۳۹۴

Railroad Blocking Problem:

- ✓ Introduction
- ✓ Description
- ✓ Example
- ✓ Mathematical model
- ✓ References

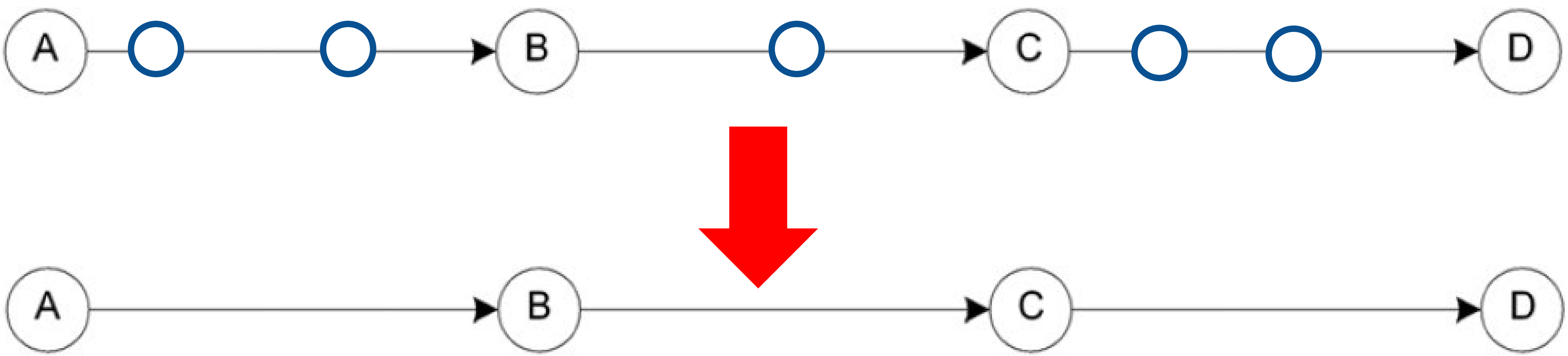
Train Formation Problem (TFP)

Hierarchical planning in demand-driven railways



NOTE:

- ✓ At the tactical level, only the large yards handling relatively large amount of traffic are considered.
- ✓ Facilities located in the same area are aggregated into a single yard together with their traffic data.



- There is **intensive interactions** between:
  - ✓ Railroad routing,
  - ✓ Railroad Blocking,
  - ✓ Train makeup,
  - ✓ Train frequency,
  - ✓ Empty car distribution process.
- However, models that simultaneously consider all these aspects often get extremely complex if not simply intractable.

Haghani, 1987

“Blocking problem”

Determining how to aggregate a large number of commodities into blocks of commodities as they travel from origins to destinations

(Which potential blocks? Which commodities for each block?)

“Train Formation (Make-up) Problem”

Assignment of blocks to specific trains.

(In which trains the blocks should travel?)

- ✓ **Blocking policy may be either determined endogenously, or be given as an input**
- ✓ **RBP is a special case of service Network Design Problems.**
- ✓ **TFP is a special case of service Network Design Problems.**

Train Formation Problem (TFP)

The main goals of TFP:

- To minimize classifying operations in shunting stations.
- To minimize the idle time of wagons waiting for trains in shunting stations.
- To maximize the railroad track capacity for train movements.
- To share almost equal wagon classification operations in all shunting stations.

following strategic planning also would be obtained:

- To develop critical shunting stations.
- To build new shunting stations if required.
- To provide more locomotives if required.

Objective of TFP:

to minimize total operating costs
- Fixed Costs
- Variable Costs

Fixed Costs:

Associated with operating a train, independent of number of wagons and blocks assigned. (wages of train crew + cost of a single unit of locomotive)

Variable Costs:

consisting of fuel and additional units of locomotive, which increases with train size.

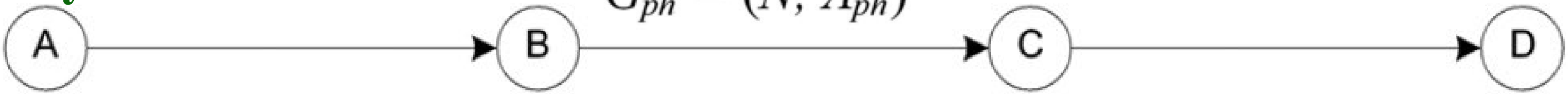
✓Due to fixed costs, it is not economical to provide all pairs of yards with direct train connections.

✓Thus, many wagons must change trains in intermediate yards (incurring delays)

So, how to assign blocks to trains?

Physical Network:

$$G_{ph} = (N, A_{ph})$$



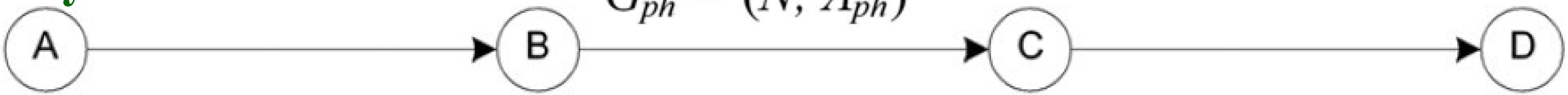
Service Network:

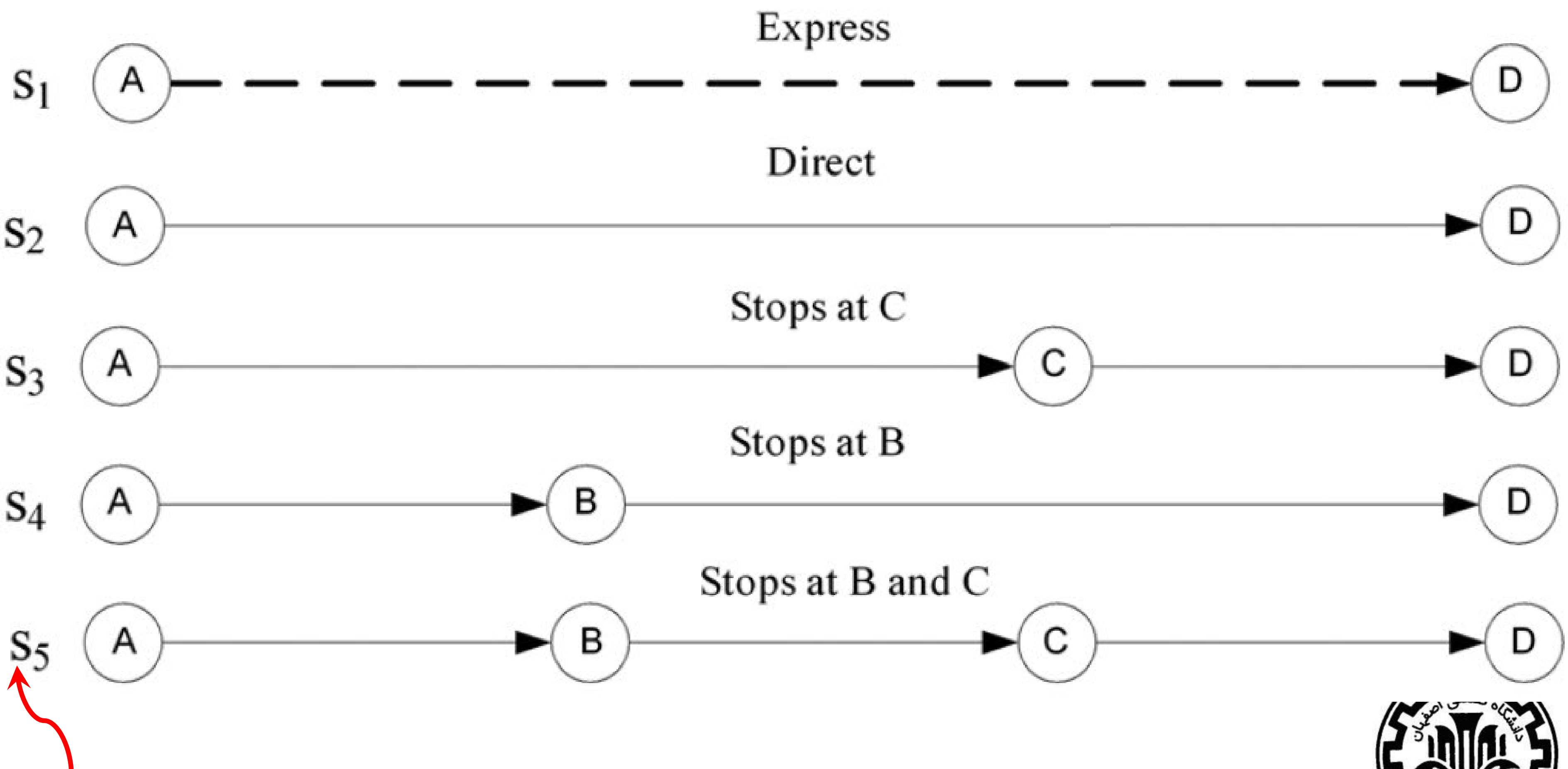
consists of set of **feasible routes** on which train services may be operated

Example — Train Formation Problem (TFP)

Physical Network:

$G_{ph} = (N, A_{ph})$





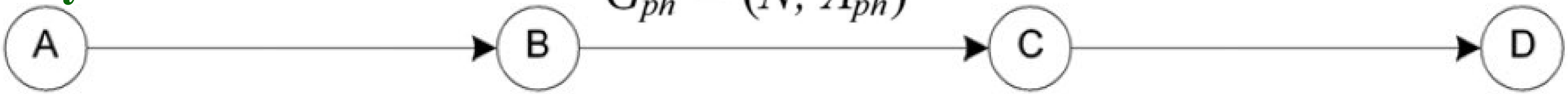
Freight Trains

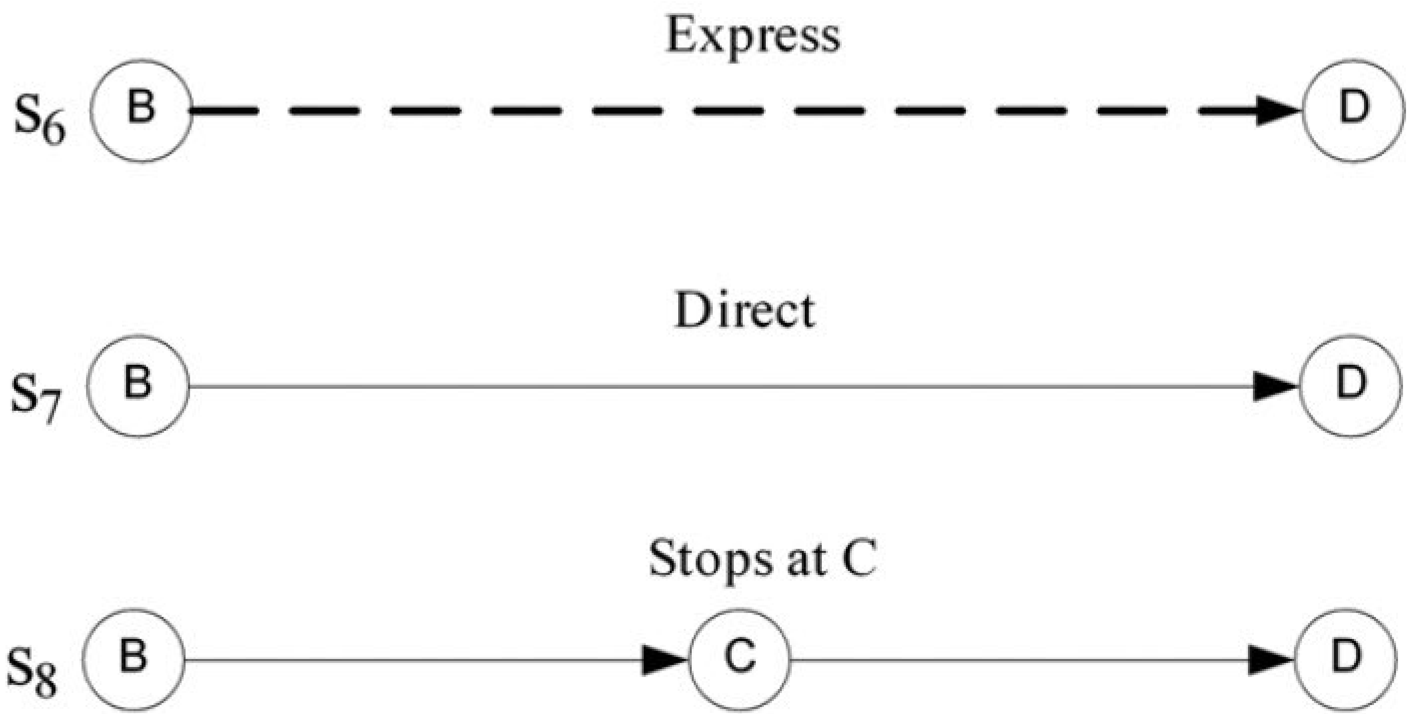
Train Services from Yard A to Yard D

Example — Train Formation Problem (TFP)

Physical Network:

$$G_{ph} = (N, A_{ph})$$



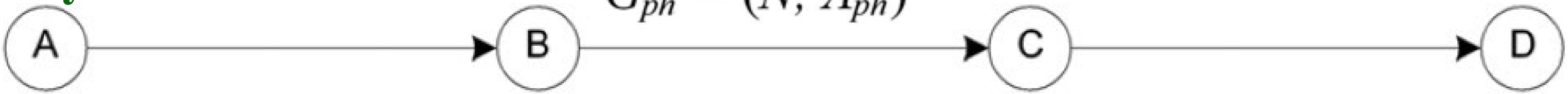


Freight Trains

Train Services from Yard B to Yard D

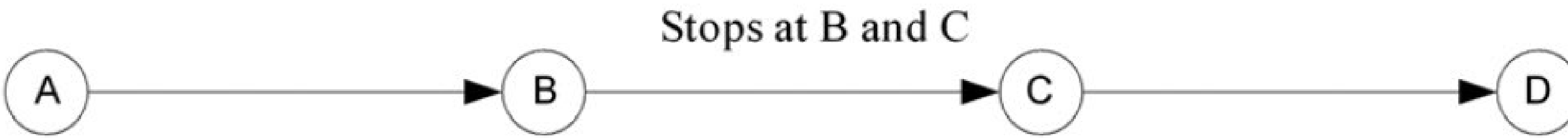
Physical Network:

$G_{ph} = (N, A_{ph})$



A train service characterized by:

S_5

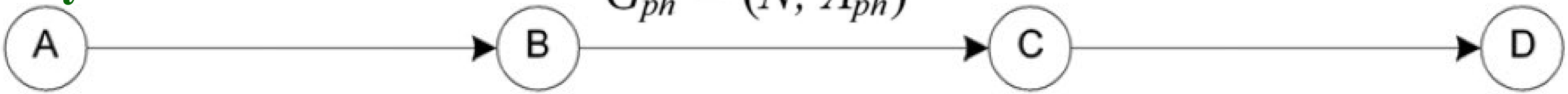


- ✓ an origin
- ✓ a destination
- ✓ a path (sequence of arcs in physical network)
- ✓ a set of intermediate stops
- ✓ type of service in terms of speed and priority

Example — Train Formation Problem (TFP)

Physical Network:

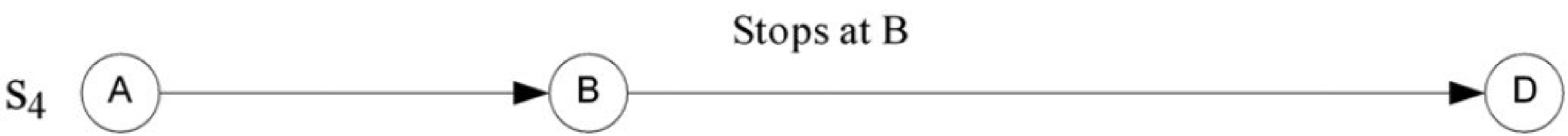
$$G_{ph} = (N, A_{ph})$$

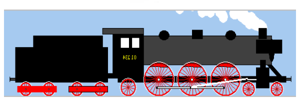


✓ For a given train service:

a train is formed at its origin

and **maintains its identity** throughout its route until its destination.





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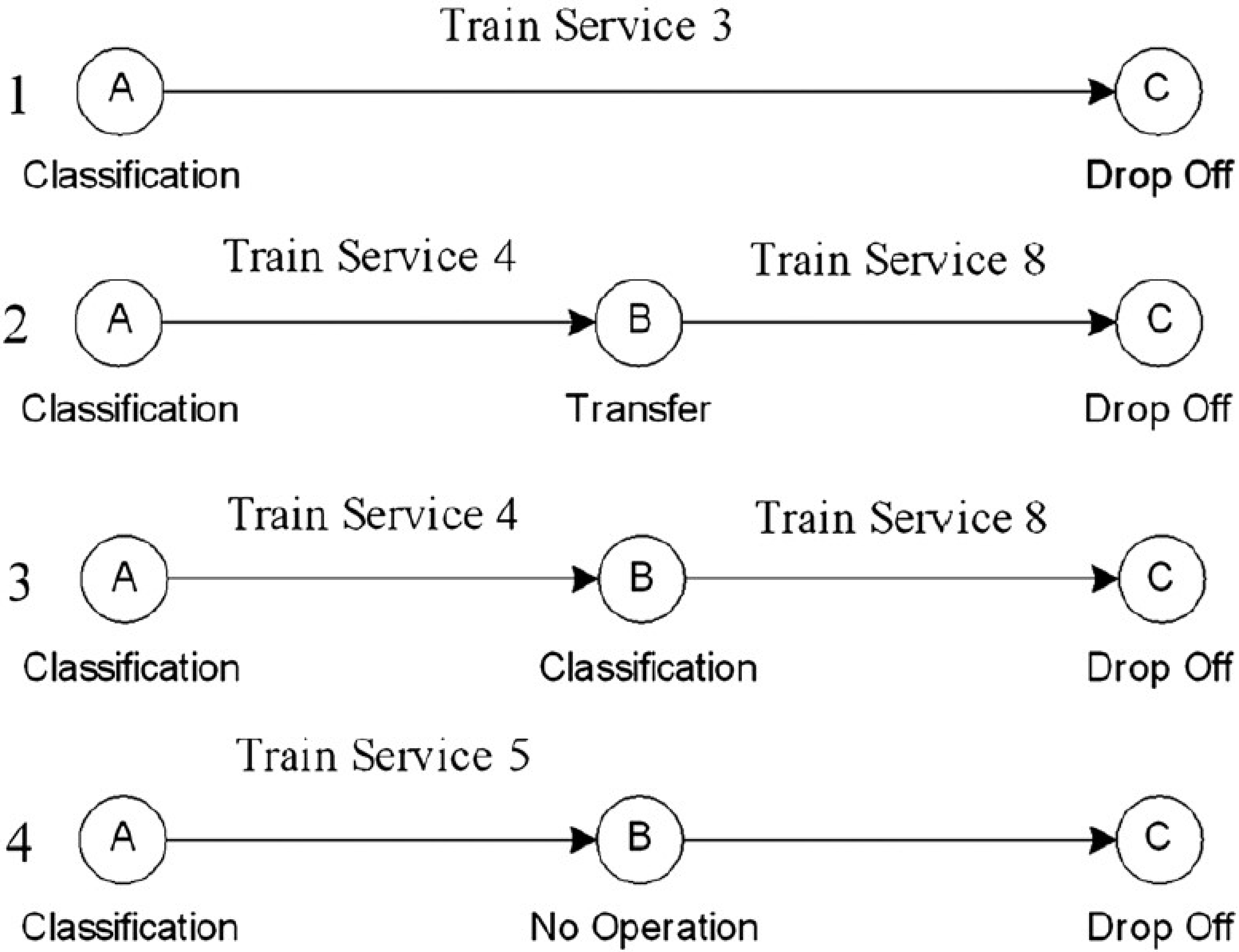
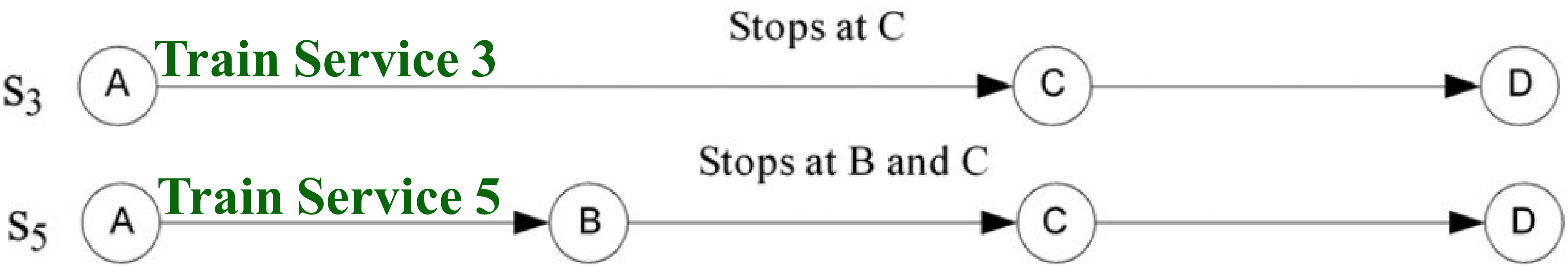
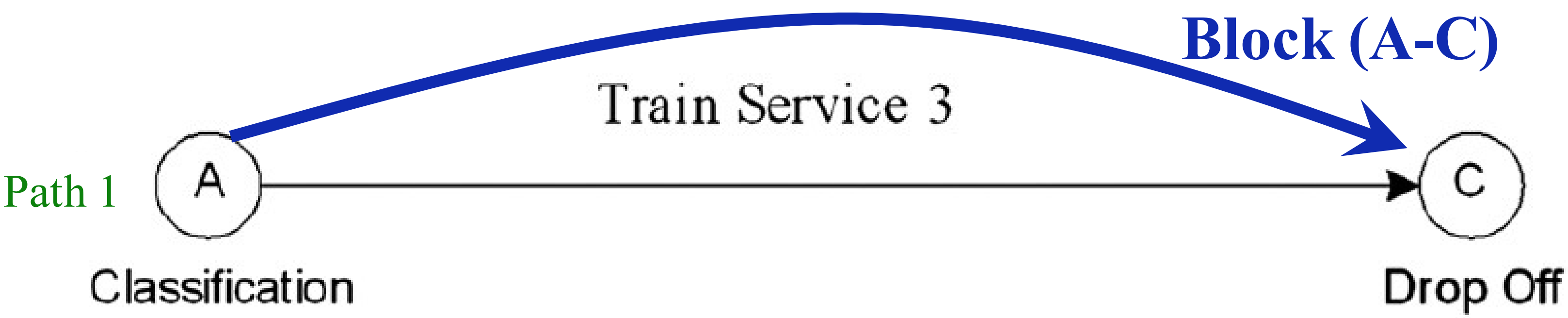
four of the feasible paths for a traffic class from A to C

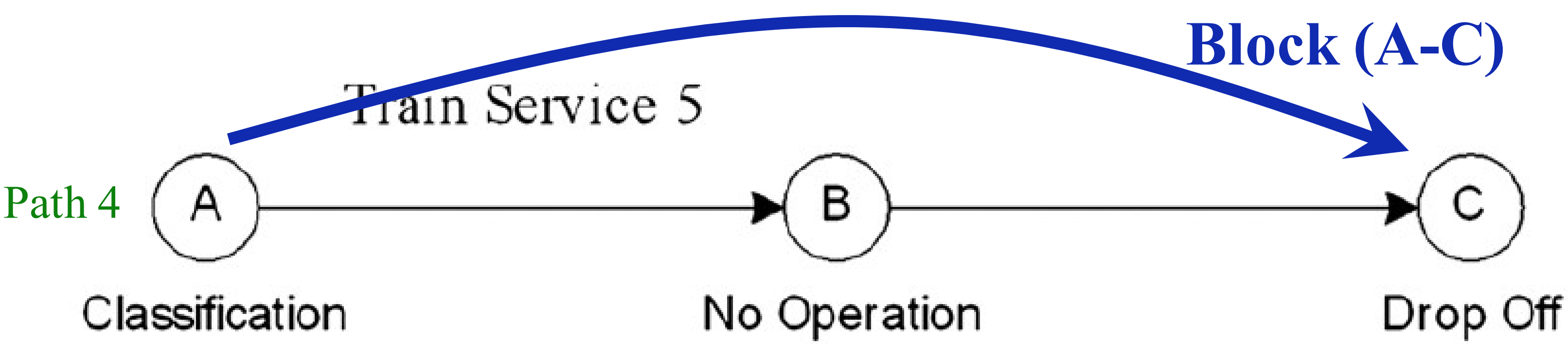


Train Formation Problem (TFP)

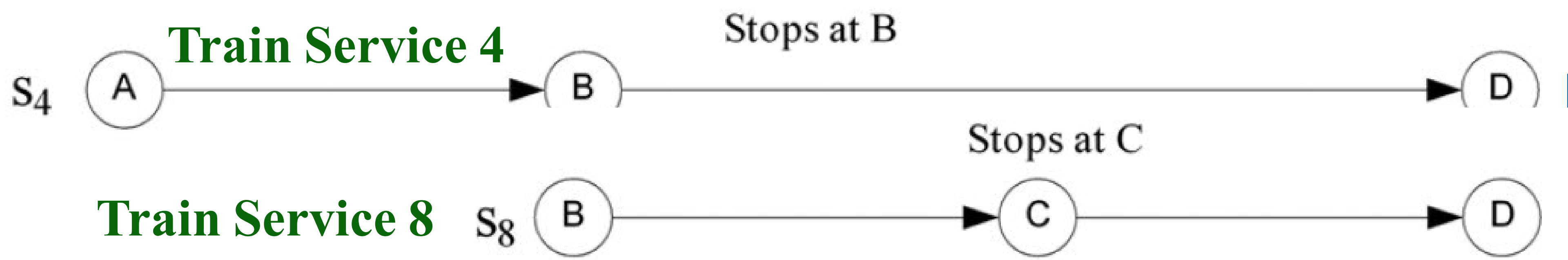


Both Path 1 and Path 4:
Block (A-C) travels on a single service to destination

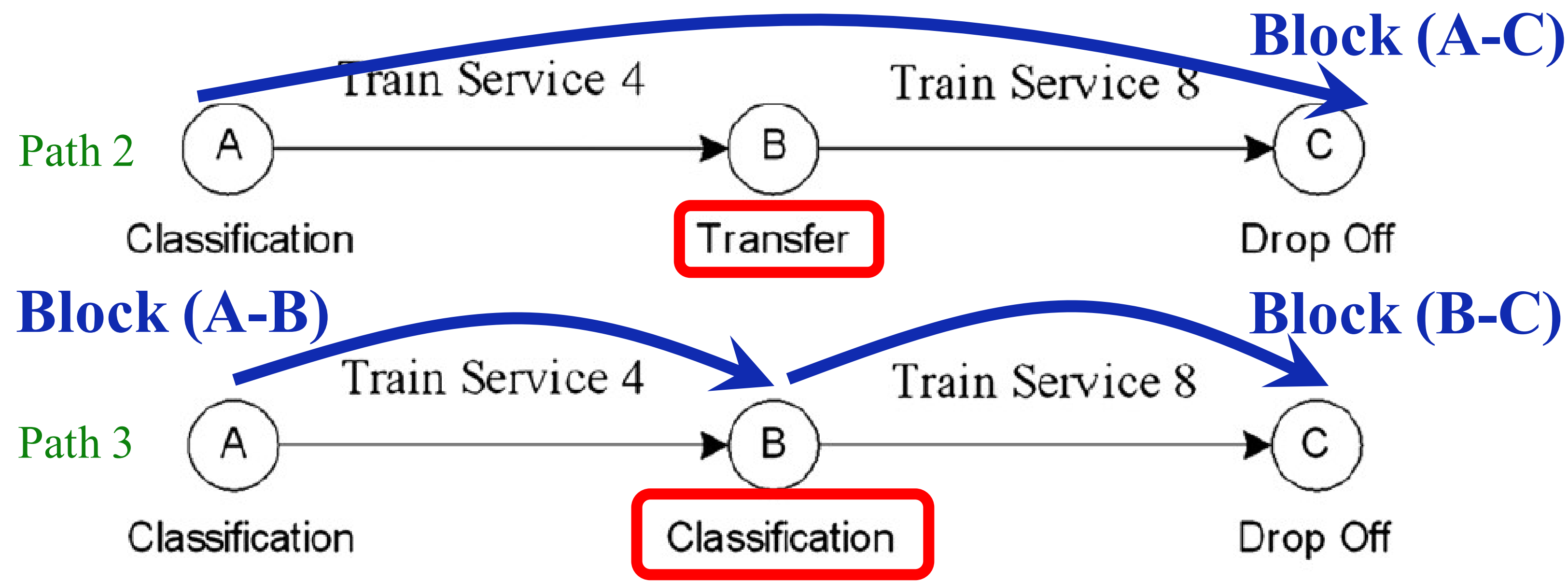




Example — Train Formation Problem (TFP)



- ✓ Paths 2 and 3 share same train service sequence.
- ✓ Path 2 forms one block, which merely changes train at B,
- ✓ Path 3 classifies traffic into block (A, B) at A then reclassifies it at B into another block (B, C)



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Node-Arc Formulation

$G = (S, T)$: service network with a set of yards S and a set of trains T
K = a set of blocks.
Each train t has a capacity u_t .
Each block k is characterized by a given amount d_k from origin o(k) to destination d(k).

Objective Function:

$$\text{Minimize } z(x, y) = \sum_{k \in K} \sum_{t \in T} c_t^k x_t^k + \sum_{t \in T} f_t y_t$$

Variable cost (cost of shipping 1 unit of block k on train t + Shunting cost)

(D.V.) amount of flow of demand k on train t

Fixed cost is to be paid if train t carried demand.

(Binary D.V.) equals 1if train t is formed

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Yaghini, 2014

Node-Arc Formulation

Constraints

✓ Flow conservation equations for each yard and each block

$$\sum_{t \in S^+(i)} x_t^k - \sum_{t \in S^-(i)} x_t^k = \begin{cases} d_k & \text{if } i = o(k) \\ -d_k & \text{if } i = d(k) \\ 0 & \text{otherwise} \end{cases} \quad \text{for all } k \in K, s \in S$$

Each block k is characterized by a given amount d_k from origin o(k) to destination d(k).

Node-Arc Formulation

Constraints

- ✓ Total flow of block on a train cannot exceed capacity of train
- ✓ No demand is allowed on a train unless fixed cost is paid

$$\sum_{k \in K} x_t^k \le u_t y_t \quad \text{for all } t \in T$$

(D.V.) amount of flow of demand k on train t

Capacity of train t

(D.V.) Train t to be formed

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Node-Arc Formulation

Constraints

Limiting number of trains that can be formed in each yard

$$\sum_{t \in T: o(t)=s} y_t \leq l_s \quad \text{for all } s \in S$$

(D.V.) Train t to be formed

maximum number of trains that can be formed in yard s

Node-Arc Formulation

Constraints

Ensuring that number of cars, assembled in each yard, does not exceed yard capacity.

$$\sum_{k \in K} \sum_{\substack{t \in T: \\ d(k) \neq d(t),\ d(t)=s}} x_t^k \leq \tau_s \quad \text{for all } s \in S$$

(D.V.) amount of flow of demand k on train t

maximum number of cars that can be assembled in yard s

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Mathematical Model (2) Train Formation Problem (TFP)

Akhavan, 2011

$$Min \sum_{p} \sum_{(i,j)\in A_p} c_{ij}^{p} x_{ij}^{p} + \sum_{k} d_k t_k \qquad (1)$$

subject to

$$\sum_{j\in N_p} x_{1j}^{p} = 1 \qquad \text{for all } O-D \text{ pairs } p \qquad (2)$$

$$\sum_{j\in N_p} x_{ij}^{p} - \sum_{j\in N_p} x_{ji}^{p} = 0 \qquad \text{for } i \neq 1 \text{ and } |N_p| \qquad (3)$$

$$\sum_{i\in N_p} x_{i|N_p|}^{p} = 1 \qquad \text{for all } O-D \text{ pairs } p \qquad (4)$$

$$x_{ij}^{p} - t_k \leq 0 \qquad \text{for } k = K_{ij}^{p} \text{ for all } (i,j)\in A_p, \text{ for all } p \qquad (5)$$

$$\sum_{p\in p_k} r^{p} x_{ij}^{p} \leq \tau_k \qquad \text{for } k = K_{ij}^{p} \text{ for all trains } k \qquad (6)$$

$$\sum_{k\in Y_m} \alpha_k t_k \leq \beta_m \qquad \text{for all yards } m \qquad (7)$$

$$\sum_{(i,j)\in A_p} S_{ij}^{p} x_{ij}^{p} \leq \sigma_p \qquad \text{for all } O-D \text{ pairs } p \qquad (8)$$

$$x_{ij}^{p} \in (0,1), t_k \in (0,1) \qquad (9)$$

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Assignment

Train Formation Problem (TFP)

For the following physical network:

- Specify a good blocking plan? (Note: consider 1 short strategy, 1 long Strategy and at least 3 Intermediate Strategies and select the best of them)
- Based on the selected blocking plan, specify the optimal train formation plan (Number of train services, route of train services, blocks moved by each train service)?

Suppose that all trains have the same priority

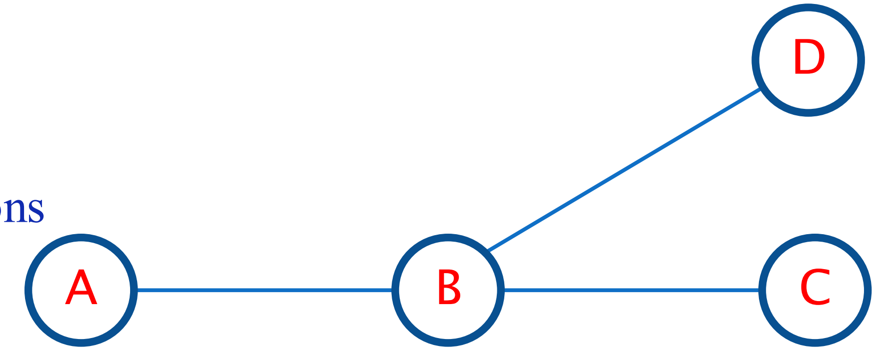
Cost of each classification operation= 5 $

Flow capacity of each potential block = 250 wagons

Fixed cost for each train formation = 100$

Variable Cost for train formation= 2 $

Capacity of each train = 80 wagons



OD Traffic Demand (wagon)

	A	B	C	D
A	--	150	100	120
B	60	--	70	60
C	90	40	--	100
D	80	50	110	--

Terminals	Wagon capacity	Blocking capacity
A	370	2 blocks
B	500	3 block
C	230	2 block
D	240	3 block

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References

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A. Jamili, A Mathematical Model for Train Routing and Scheduling Problem with Fuzzy Approach, Proceedings of the 2012 International Conference on Industrial Engineering and Operations Management Istanbul, Turkey.

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