Cross-dock Scheduling with Fixed Outbound Departures Known Order of Shipments and Multiple trips

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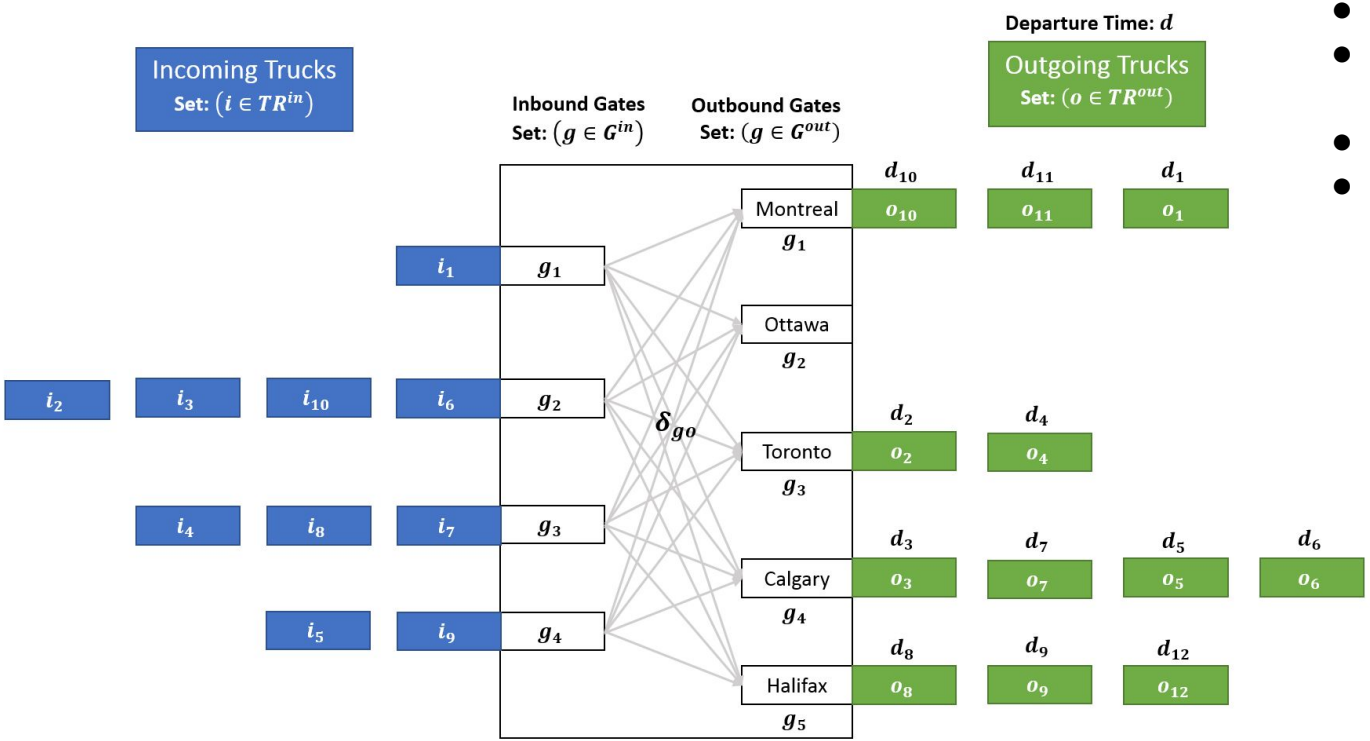
Agenda

- Cross-dock Scheduling
- Motivation
- Models
- Results

Cross-dock Scheduling



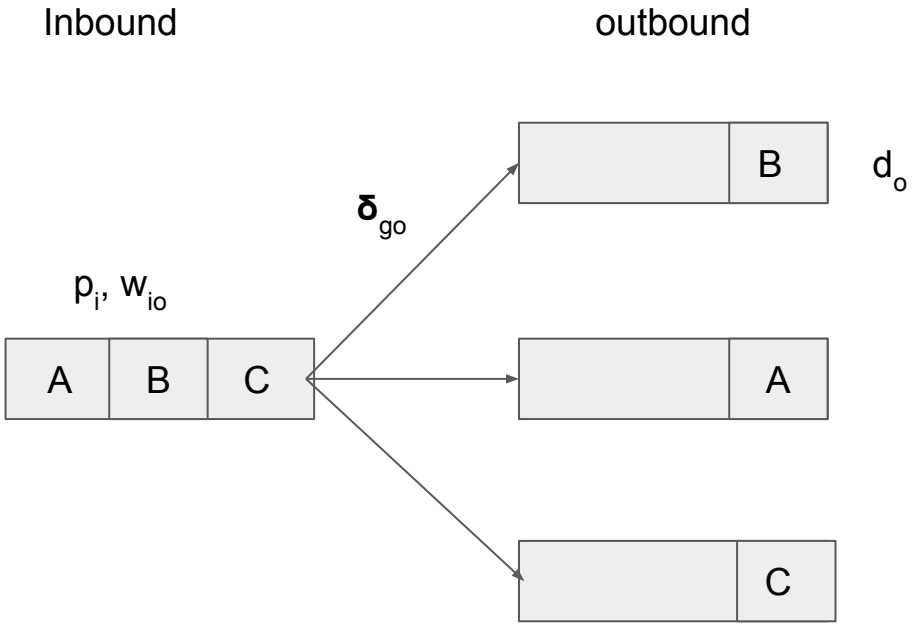
δ_{go}: transshipment time from inbound gates to <u>prescheduled</u> outgoing trucks

Objective:

- Minimize lateness
- **Minimize tardy shipments**
- Minimize makespan
- …

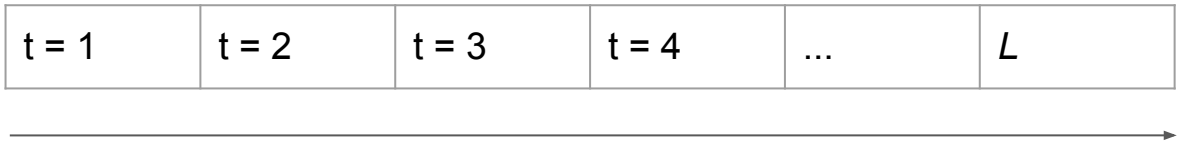
Parameters

- $\mathbf{p_i}$: processing time of incoming trucks ***i***
- $\mathbf{w_{io}}$: number of pallets for a given shipment from incoming truck ***i*** to outgoing truck ***o***
- $\boldsymbol{\delta_{go}}$: time to transfer shipment from gate ***g*** to outgoing truck ***o***
- $\mathbf{d_o}$: due date of outgoing truck ***o***



Network-based model and Time indexed model

Network-based model	Time indexed model
$\mathbf{x}^{g}_{ij}$ = 1 if incoming truck ***j*** is processed directly after incoming truck ***i*** at inbound door ***g***; 0, otherwise	$\mathbf{x}^{t}_{ig}$ = 1 if incoming truck ***i*** is processed on inbound door ***g*** at time ***t***; 0, otherwise
	Processing time p_i have to be integer



References

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- Y. Unlu and S. Mason. Evaluation of mixed integer programming formulations for non-preemptive parallel machine scheduling problems.Computers and Industrial Engineering, 58(4):785–800, 2010.
- K. Stephan and N. Boysen. Cross-docking. Journal of Management Control, 22(1):129, 2011.
- N. Boysen and M. Fliedner. Cross dock scheduling: Classification, literature review and research agenda.Omega, 38(6):413–422, 2010.

Motivation - Boysen et al. [2013] - Network-based model

$$[TSFD] \quad \text{minimize} \quad \sum_{i \in \mathrm{TR}^{\mathrm{IN}}} \sum_{o \in \mathrm{TR}^{\mathrm{OUT}}} w_{io} U_{io} \tag{1}$$

$$\text{subject to} \quad \sum_{g \in G^{\mathrm{IN}}} \sum_{i' \in \mathrm{TR}^{\mathrm{IN}} \cup \{0\} i \neq i'} x^g_{i'i} = 1 \qquad i \in \mathrm{TR}^{\mathrm{IN}} \tag{2}$$

$$\sum_{i \in \mathrm{TR}^{\mathrm{IN}}} x^g_{0,i} \leq 1 \qquad g \in G^{\mathrm{IN}} \tag{3}$$

$$\sum_{\substack{i' \in \mathrm{TR}^{\mathrm{IN}} \cup \{0\} \\ i \neq i'}} x^g_{i'i} = \sum_{i' \in \mathrm{TR}^{\mathrm{IN}} \cup \{\mathrm{LAST}\} i \neq i'} x^g_{ii'} \qquad i \in \mathrm{TR}^{\mathrm{IN}}, g \in G^{\mathrm{IN}} \tag{4}$$

$$C_i \geq C_{i'} + p_i - M \cdot \left(1 - x^g_{i'i}\right) \qquad i \in \mathrm{TR}^{\mathrm{IN}}, i' \in \mathrm{TR}^{\mathrm{IN}} \cup \{0\}; g \in G^{\mathrm{IN}} \tag{5}$$

$$U_{io}.M \geq C_i + \sum_{g \in G^{\mathrm{IN}}} \sum_{\substack{i' \in \mathrm{TR}^{\mathrm{IN}} \cup \{0\} \\ i \neq i'}} \delta_{go}.x^g_{i'i} - d_o \qquad i \in \mathrm{TR}^{\mathrm{IN}}, o \in \mathrm{TR}^{\mathrm{OUT}} \tag{6}$$

$$C_0 = 0 \tag{7}$$

$$x^g_{ii'} \in \{0,1\} \qquad i,j \in I \cup \{0, \mathrm{LAST}\}, g \in G^{\mathrm{IN}} \tag{8}$$

$$C_i \geq 0 \qquad i \in \mathrm{TR}^{\mathrm{IN}} \tag{9}$$

$$U_{io} \in \{0,1\} \qquad i \in \mathrm{TR}^{\mathrm{IN}}, o \in \mathrm{TR}^{\mathrm{OUT}} \tag{10}$$

New Time-indexed model

Pre-processing

Pre-processing

If we know the scheduling of a incoming truck, we can calculate the number of tardy shipments from this truck!

Extension 1 - Number of trips

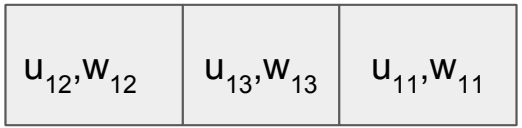
We assume that if a shipment from an incoming truck to another outgoing truck is late then all the pallets in this shipment will be late ⇒ In practice, we usually have to transfer these pallets many time!

Define J_{io} be the number of trips need to transfer all pallets w_{io}

Extension 1 - Number of trips

Extension 2 - Known order of shipments

We assume that all shipments in an incoming truck have the same unloading time (p_i) ⇒ If we take into account the order of shipments in each truck, we can schedule more precisely



Numerical results

The interval time for time indexed models is 1 hour

Set R17				$TSFD^{++}$					$TSFD^{+}$					$TSFD$				
Trucks	G^{IN}	G^{OUT}	q	%LP	%gap	%UB	B&B	Time	%LP	%gap	%UB	B&B	Time	%LP	%gap	%UB	B&B	Time
80x80	10	10	1.2	1.08	.	.	42	23.10	98.81	74.68	51.92	835	1h	100	100	483.65	29,346	1h
	10	10	1.3	0.93	.	.	3	14.12	97.94	45.21	1.39	24,787	1h	100	100	316.67	86,656	1h
	10	10	1.4	1.60	.	.	19	20.46	97.62	29.82	7.55	19,422	1h	100	100	566.04	61,796	1h
	10	10	1.5	0.0	.	.	0	6.72	96.73	0.0	0.0	0	428 s	100	100	815.00	31,813	1h
	15	15	1.2	0.30	.	.	0	14.88	97.92	73.33	33.93	186	1h	100	100	589.29	9,744	1h
	15	15	1.3	0.49	.	.	0	20.58	96.73	55.56	3.45	4,939	1h	100	100	475.86	10,580	1h
	15	15	1.4	0.0	0.0	0.0	0	18.03	96.60	48.72	8.33	3,968	1h	100	100	897.22	7,805	1h
	15	15	1.5	0.0	.	.	0	10.06	94.95	14.89	6.82	5,378	1h	100	100	1509.09	24,124	1h
	20	20	1.2	0.20	.	.	0	21.05	98.51	78.46	30.16	4	1h	100	100	364.02	3,287	1h
	20	20	1.3	0.72	.	.	0	22.14	97.88	73.91	31.97	5	1h	100	100	356.56	25	1h
	20	20	1.4	0.0	.	.	0	16.95	96.55	56.99	43.08	1,451	1h	100	100	1432.31	5,552	1h
	20	20	1.5	2.34	.	.	69	54.34	95.75	44.74	18.75	2,018	1h	100	100	729.69	3,779	1h

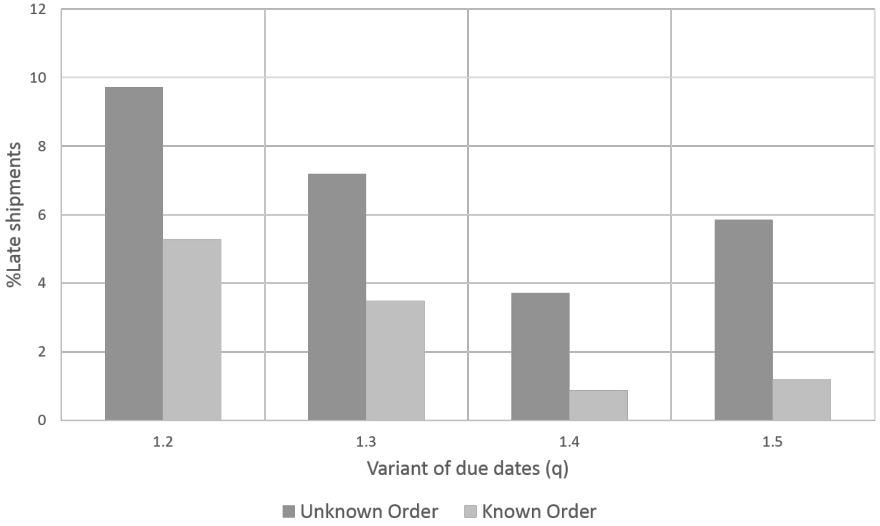
Numerical results

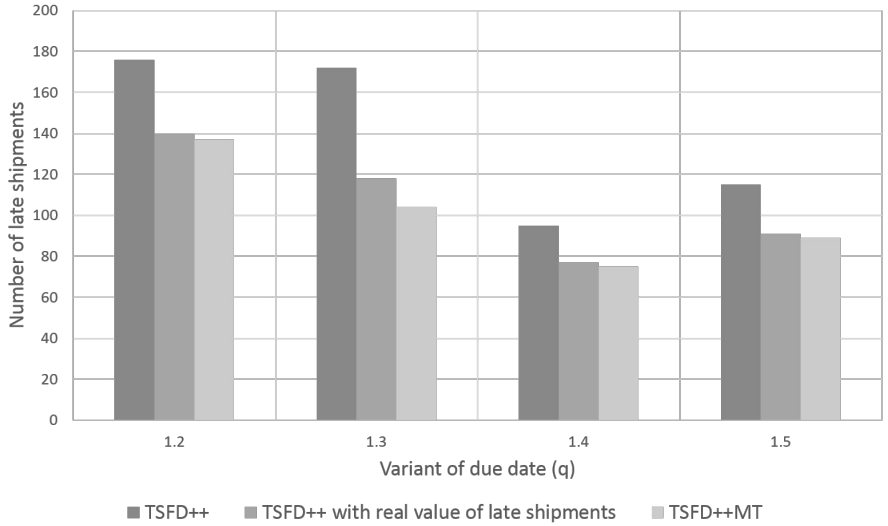
Set R13				$TSFD^{++}MT$				$TSFD^{++}$			
Truck	G^{IN}	G^{OUT}	q	%tardy	%Imp	%Diff	Time	%tardy	%Imp	%Diff	Time
80x80	10	10	1.2	1.97	57.69	98	8.08	4.66	.	.	23.10
	10	10	1.3	1.12	65.28	100	5.34	3.22	.	.	14.12
	10	10	1.4	0.85	64.15	96	5.24	2.37	.	.	20.46
	10	10	1.5	0.85	52.50	100	3.86	1.79	.	.	6.72
	15	15	1.2	2.82	43.75	100	38.68	5.01	.	.	14.88
	15	15	1.3	1.84	52.87	97	7.55	3.89	.	.	20.58
	15	15	1.4	1.21	62.50	98	9.46	3.22	0.0	0.0	18.03
	15	15	1.5	0.85	56.82	98	5.21	1.97	.	.	10.06
	20	20	1.2	4.34	48.68	100	28.49	8.46	.	.	21.05
	20	20	1.3	2.37	56.56	100	76.15	5.46	.	.	22.14
	20	20	1.4	0.94	67.69	100	15.17	2.91	.	.	16.95
	20	20	1.5	0.94	67.19	98	8.81	2.86	.	.	54.34

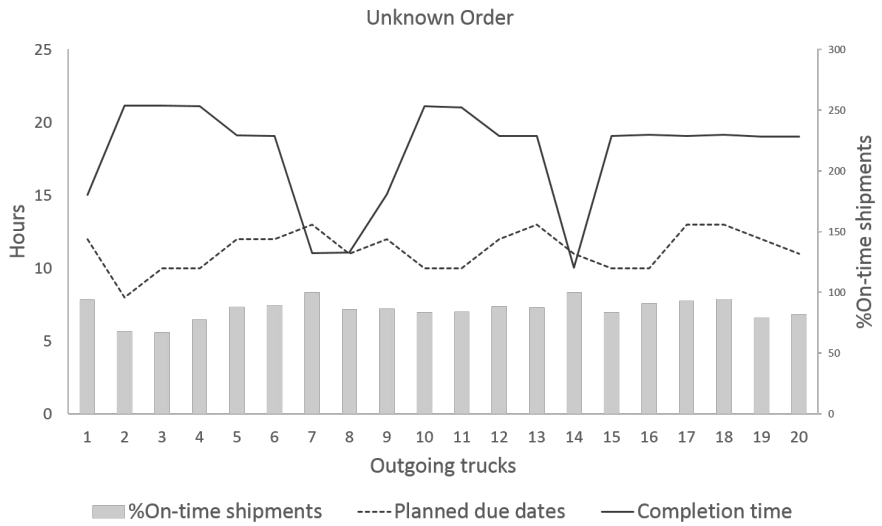
Numerical results

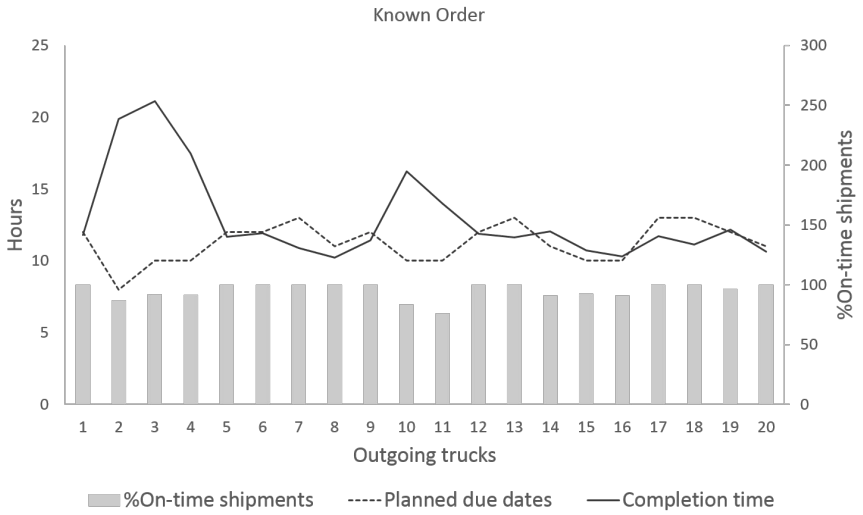
Set R13				$TSFD^{++}MTO$				$TSFD^{++}$			
Truck	G^{IN}	G^{OUT}	q	%tardy	%Imp	%Diff	Time	%tardy	%Imp	%Diff	Time
80x80	10	10	1.2	0.85	81.73	98	102.41	4.66	.	.	23.10
	10	10	1.3	0.58	81.94	100	9.89	3.22	.	.	14.12
	10	10	1.4	0.49	79.25	97	16.32	2.37	.	.	20.46
	10	10	1.5	0.31	82.50	98	4.06	1.79	.	.	6.72
	15	15	1.2	1.30	74.11	98	6.69	5.01	.	.	14.88
	15	15	1.3	0.67	82.76	100	14.55	3.89	.	.	20.58
	15	15	1.4	0.58	81.94	97	7.01	3.22	0.0	0.0	18.03
	15	15	1.5	0.58	70.45	100	4.90	1.97	.	.	10.06
	20	20	1.2	1.48	82.54	100	14.97	8.46	.	.	21.05
	20	20	1.3	0.67	87.70	100	7.15	5.46	.	.	22.14
	20	20	1.4	0.58	80.00	98	8.86	2.91	.	.	16.95
	20	20	1.5	0.67	76.56	98	6.55	2.86	.	.	54.34

Numerical results






Unknown Order
Hours
%On-time shipments
Outgoing trucks
%On-time shipments
Planned due dates
Completion time


Known Order
Hours
%On-time shipments
Outgoing trucks
%On-time shipments
Planned due dates
Completion time

The End