The Drop Shunting Problem

Montaz Ali[1] & Stephen Visagie[2]
1: School of Computer Science and Applied Mathematics
University of the Witwatersrand, Johannesburg, South Africa

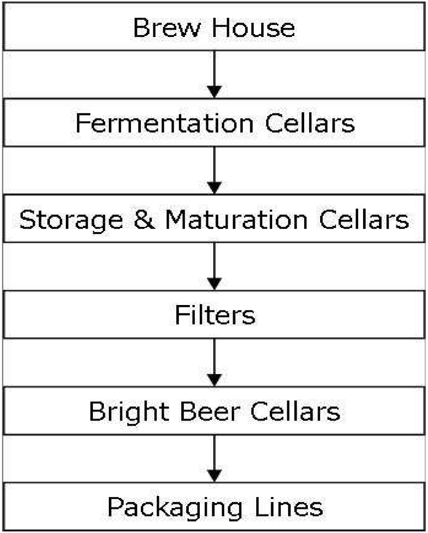
2: Department of Logistics, Stellenbosch University, South Africa

February 7, 2022

Outline

- The brewhouse (BH),
- Fermentation (FV),
- Storage and maturation (SV),
- Filtration,
- Bright beer cellars (BBT),
- Packaging lines.

Macro View of a Brewery



The Conceptual Layout

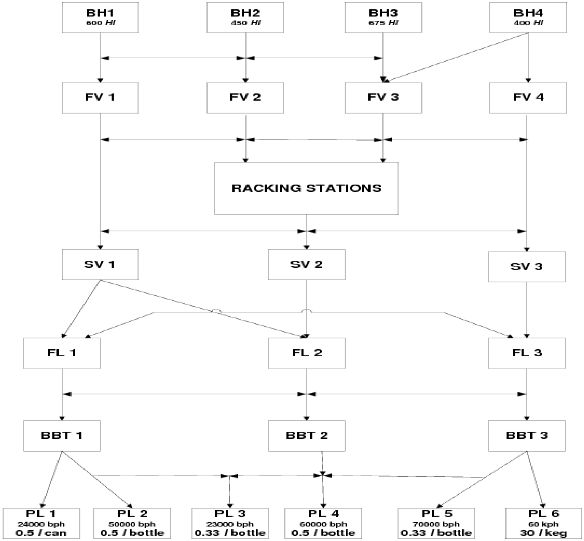


Table: Examples of SKUs

Brand	Pack Type	Demand at t_o
A	0.33 / Bottle	3897 Hl
A	0.5 / Can	3122 Hl
B	0.33 / Bottle	4865 Hl
B	0.5 / Can	3028 Hl
E	0.33 / Bottle	1465 Hl
E	0.5 / Bottle	4144 Hl
E	0.5 / Can	1012 Hl

Table: Pack Types

Pack Type	Description	PTV_j (l)
1	Keg	30
2	Bottle	0.33
3	Can	0.5
4	Bottle	0.5

Brand $A = 1$, Pack Type=2 $\Rightarrow$ SKU=12

A Weekly Scheduling Problem

#	SKU	Brand	Pack Type	Volume (*Hl*)
1	11	1	1	180
2	14	1	4	12782
3	23	2	3	3602
4	24	2	4	13574
5	32	3	2	10959
6	44	4	4	865
7	54	5	4	3732
8	64	6	4	2371
9	71	7	1	370
10	73	7	3	3674
11	74	7	4	6802
12	81	8	1	580
13	83	8	3	3616
14	84	8	4	7415
15	92	9	2	1506

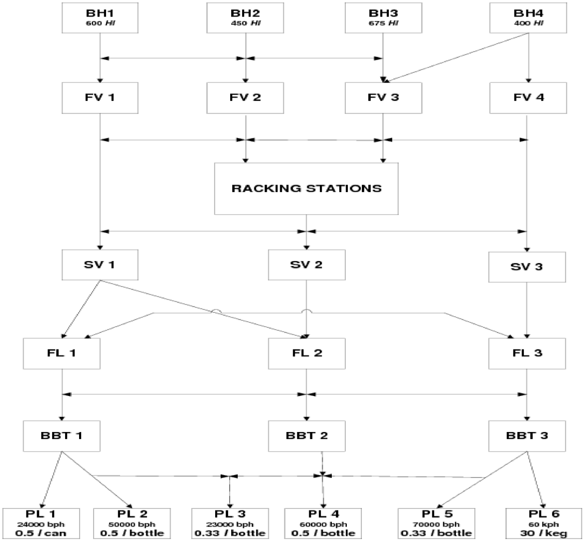

BH1
600 Hl
BH2
450 Hl
BH3
675 Hl
BH4
400 Hl
FV 1
FV 2
FV 3
FV 4
RACKING STATIONS
SV 1
SV 2
SV 3
FL 1
FL 2
FL 3
BBT 1
BBT 2
BBT 3
PL 1
24000 bph
0.5 l can
PL 2
50000 bph
0.5 l bottle
PL 3
23000 bph
0.33 l bottle
PL 4
60000 bph
0.5 l bottle
PL 5
70000 bph
0.33 l bottle
PL 6
60 kph
30 l keg

Figure: Demand Met By Efficient Use of Trucks and Trailers

Assumptions

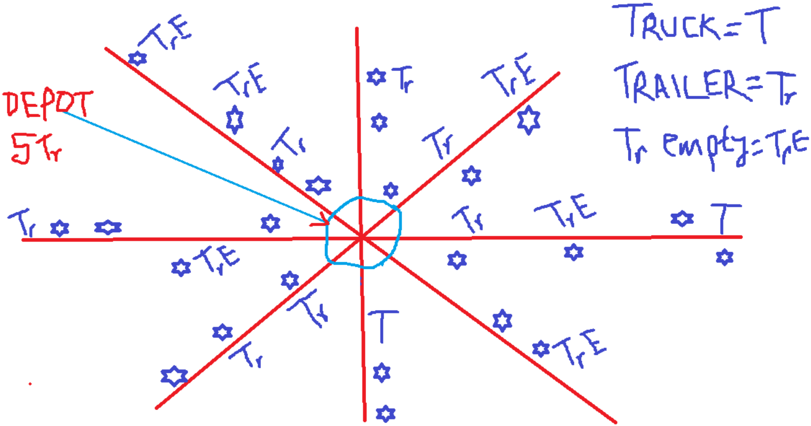
- A single Depot is considered. A geographical Area Filled by Customers
- #Trucks=p; #Trailers=q; #Customers=r; $p << q << r$.
- Demands are uploaded in Trailers and Trucks just moves Trailers around (or drop them to the Depot).
- All Trailers are uniform (all have the same Capacity).
- Capacity of the Trailer: Multiples of average demand per customer.
- Demands are such that a Trailer can Upload the maximum demand.
- A Trailer moves back and froth (from Customer to Depot)–Multiple Uploading
- Activities are Daily

- Customer 1
  - SKU=21: 25,000 Bottle
  - SKU=13: 20,000 Cans
  - ...
- Customer 2
  - SKU=34: 15,000 Bottle
  - SKU=33: 10,000 Cans
  - SKU=22: 5,000 Bottles
  - SKU=13: 5,000 Cans

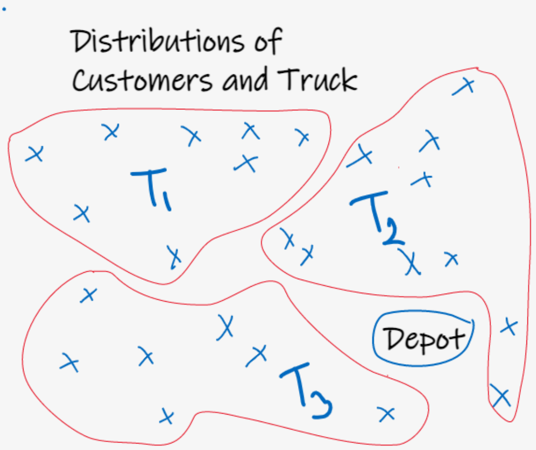
Table: Pack Types

Pack Type	Description	PTV_j (l)
1	Keg	30
2	Bottle	0.33
3	Can	0.5
4	Bottle	0.5

Figure: Location of Demands, Trucks and Trailers



$\star$=Customer; T=Truck, T_r=Trailer, T_rE=Empty Trailer

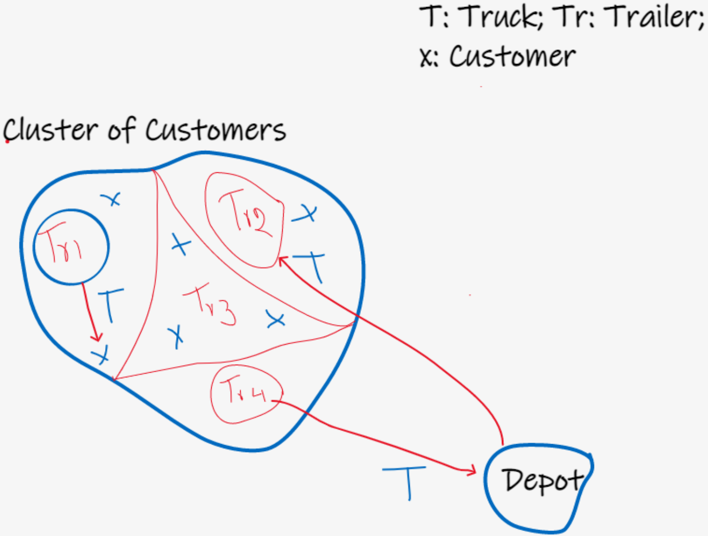

Distributions of
Customers and Truck
T_1
T_2
T_3
Depot

- Each Trailer: $\text{job}_i,\text{job}_j,\text{job}_k$ (Trip_1); $\text{job}_k,\text{job}_l,\text{job}_m$ (Trip_2) and so on
- Which Sequence is better for the Truck:

$Truck : (Tr_1,\cdot), (Tr_2,\cdot), (Tr_3,\cdot), (Tr_4,\cdot), (Tr_5,\cdot), (Tr_1,\cdot), (Tr_2,\cdot), (\cdot, TrE_1), (Tr_6,\cdot)\cdots$

$Truck : (Tr_1,\cdot), (Tr_2,\cdot), (Tr_1,\cdot), (Tr_2,\cdot), (Tr_1,\cdot), (Tr_2,\cdot), (\cdot, TrE_1), (\cdot, TrE_1), (Tr_3,\cdot)\cdots$

Distance Travelled by a Truck is dependent of the job-I assigned to Trailers in a cluster.


T: Truck; Tr: Trailer;
x: Customer
Cluster of Customers
Tr1
Tr2
Tr3
Tr4
T
T
T
Depot

- Subdivide the Customers into p number of Clusters (there are p Trucks): Use the p-mean algorithm
- Each Truck is assigned to one cluster; Assign a number of Trailers at each Cluster (e.g. q/p Trailers per Cluster)
- Consider Each Demand as a Job (Job-I); Job-II are assignment of T_rE (empty trailers) and non empty trailers to a Truck.
- Upload a number of Type-I jobs in a Cluster to each Trailer for each Trip. A sequence of Uploads is needed for Each Trailer (Optimal Decision is needed here).
- Each Truck needs to perform a sequence of Type-II jobs (Optimal Sequencing is needed here)
- Daily Demand Scenario (Created Randomly) Must Be Met

- (#Trucks, #Trailers, #Customers)=(p, q, r); Depot: $DP \in \mathbb{R}^2$;
- Customer Locations: $\{C(1), C(2), \cdots, C(r)\}, C(i) \in \mathbb{R}^2$;
- Demands: $\{D(1), D(2), \cdots, D(r)\}, \quad D(i) > 0$
- An Optimal Ordered Partition $\{R^1, R^2, \cdots, R^p\}$ s.t. $\{C(1), C(2), \cdots, C(r)\} = \bigcup_i^p R^i, \; R^i \cap R^j = \emptyset$
- The Ordered Set $R^k = \{C(r_1^k), C(r_2^k), C(r_3^k), C(r_1^k), \cdots, C(r_{(s)}^k)\}$
- Cost Function for Truck k:

$$c(R^k) = d(DP, C(r_1^k)) + d(C(r_1^k), DP) + d(DP, C(r_2^k)) \\ + \sum_{i=1}^{s-1} d(C(r_i^k), C(r_{i+1}^k)) + d(C(r_s^k), DP)) + \cdots$$

$(Tr_1, \cdot), (Tr_2, \cdot), (Tr_1, \cdot), (Tr_2, \cdot), (\cdot, TrE_1), \cdots$

$$x_{ij}^{k} = \begin{cases} 1 & \text{if } i\text{-th job-I(}i\text{-th Demand) is assigned to Trailer } j\text{ oin Cluster } k \\ 0 & \text{otherwise} \end{cases}$$

$$\min \quad \sum_{k}^{p} c(R^k) \quad s.t. \tag{1}$$

$$\sum_{i}^{r} \sum_{j}^{q} \sum_{k}^{p} x_{ij}^{k} = \sum_{i}^{r} D(i) \tag{2}$$

where

$$c(R^k) = d(DP, C(r_1^k)) + d(C(r_1^k), DP) + d(DP, C(r_2^k)) + \sum_{i=1}^{s-1} d(C(r_i^k), C(r_{i+1}^k)) + d(C(r_s^k), DP)) + \cdots$$

Thank You

***