A SIMULATION TOOL FOR TRUCK LOADING AT FUEL FILLING PLANTS

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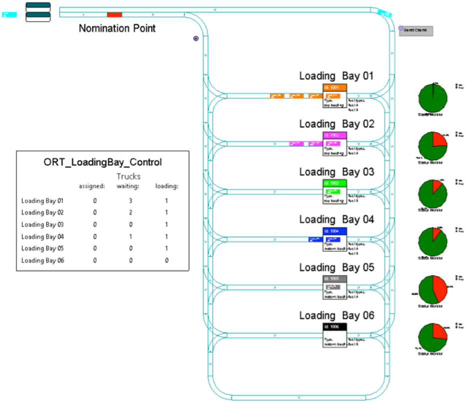
Background

A plant or refinery where trucks arrive for filling fuel in their compartments.

Truck drivers decide the sequence of bays to enter and which fuel arms to use.



Our Contribution

We have developed a software tool for simulation-based modelling, analysing, and optimizing these decision processes.

As generic as possible, without much customization.

Mimicking behaviours of truck drivers.

Running simulations for identifying bottlenecks.

Analysing assignment rules concerning truck to bay, and bay to compartment.

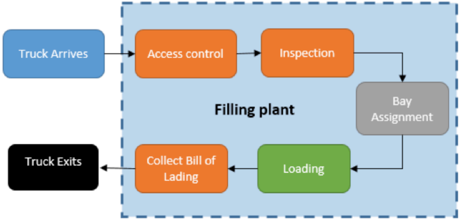
Implemented in FlexSim.

For testing: three test cases of real fuel filling plants.

And a more involved application of a lubricant filling plant in Europe.

Fuel Filling Processes

Flowchart of the processes in a typical fuel plant.



A Case Study

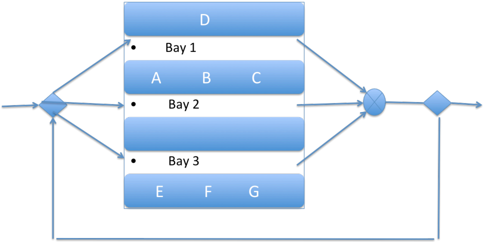
Lubricant filling plant.

3 loading bays with total of 7 lubricant arms.

3 arms are ‘swing’ arms shared by bay 1 and 2.

Extreme long waiting times because the filling process takes long (many different lubricants to fill).

Challenge to identify opportunities (assignment rules) to reduce waiting times.



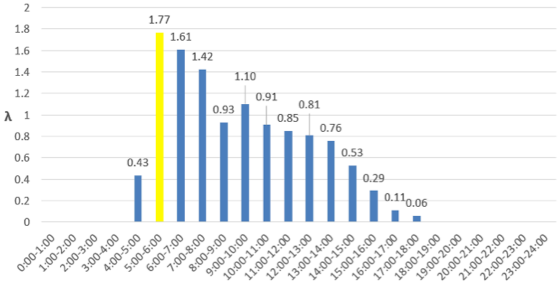
Truck Arrivals

Data gathered of hourly arrivals.

Statistically identical per day.

Three types of trucks (41%, 47%, 12%) dealing with priorities.

Simulation model simulates from empirical distribution.

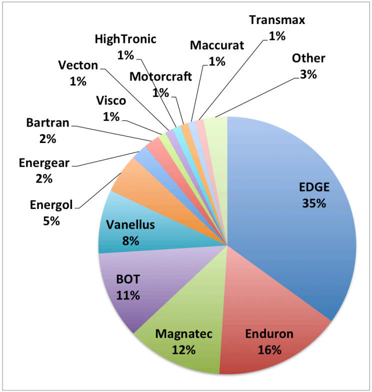


Lubricant Demand

128 different lubricants available.

Demand is skewed considered at group level.

Simulation model simulates from empirical distribution.



Splitloading

Most but not all lubricants are offered at all bays.

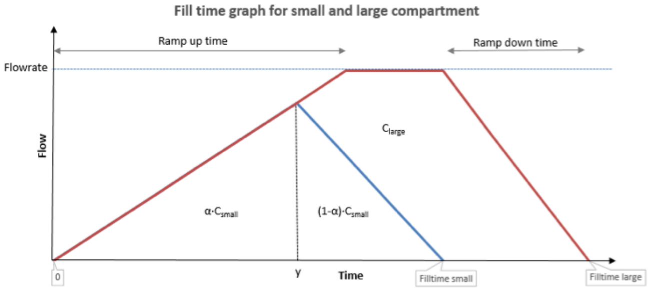
Splitloading is required when a truck cannot fill completely at one visit. It returns to one of the other bays.

Table of offerings and completeness.

			% trucks completing full order		
loading bay	arms	# lubricants	all	types 1 & 3	type 2
1	A,B,C,D	91	53 %	91 %	10 %
2	A,B,C	74	51 %	91 %	7 %
3	E,F,G	100	70 %	87 %	50 %

Filling Process

We implemented a piecewise linear function to model the filling process of a compartment.



Filltime

Notation:

T : fill time

C : capacity

F : maximal flow rate of a fuel arm

T_U : ramp-up time; time until the arm injects at the maximal rate

T_D : ramp-down time

Large capacity compartment if $C \geq F(T_U + T_D)/2$. Then

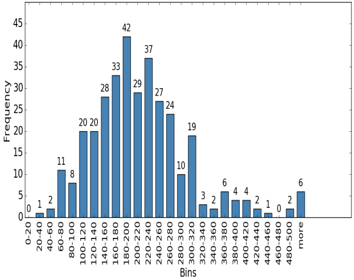
$$T = \begin{cases} \frac{C}{F} + \frac{1}{2}(T_U + T_D), & \text{large compartment;} \\ \sqrt{\frac{2C(T_U+T_D)}{F}}, & \text{small compartment.} \end{cases}$$

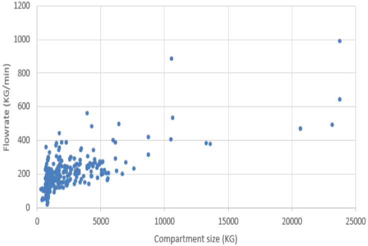
Need to estimate parameters F, T_U, T_D given a compartment C.

Flowrates

Given C and T, the average flow rate is $R = C/T$.

Data available of (C, T) pairs, from which we consider distribution of R, and correlation between C and R.





Estimation

Thus, computed and observed fill times.

Minimize the sum of squared differences for optimal values for the F, T_U, and T_D parameters.

Validation and Verification

Numerous common methods.

Example validation: average sojourn times at the filling plant.

Example verification: sampling from arrival and demand distributions.

Experimental Design

The purpose of this case study was to identify opportunities for improvement.

Compare the impact on the lubricant plant throughput time.

Several scenario experiments. We report here

- Scenario 1: make the most popular lubricants be available at more arms.
- Scenario 2: assign loading bays to trucks of specific priorities.

Scenario 1

most popular lubricants	arms currently available	arms extra available
EDGE Prof LL III 5W-30	C,E	A
Enduron Low SAPS 10W-40	A,E	C
EDGE Profess LLIII 5W-30	A,E	C
EDGE Professional A3 0W30	A,E	C
BOT 950 0W-30	A	C,F

We ran the simuation model 365 (simulated) days.

Results Scenario 1

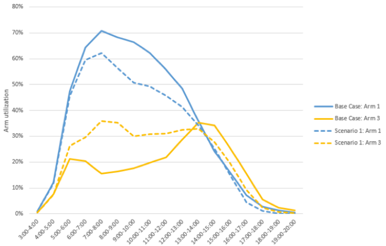
	base case			scenario 1		
type	1	2	3	1	2	3
avg time at plant (mins.)	188	268	205	173	258	188
loading process time (mins.)	131	210	149	117	200	133
loading time (mins.)	105	111	98	96.9	106	92.3
waiting time for bay (mins.)	24.7	32.7	45.7	19.4	28.0	36.1
waiting time for swing arm (mins.)	10.1	10.7	8.1	1.7	4.6	1.9
split loaders (%)	2	62	4	1	62	3

Results are promising.

Loading processes improve for all types.

Waiting times decrease.

Utilization more balanced.



Scenario 2

Assign types 1 and 3 trucks to bay 2, and type 2 trucks to bay 1 and 3.

It was hypothesized (by plant employees!) that this would speed up all processes.

We ran the simuation model 365 (simulated) days.

Results Scenario 2

	base case			scenario 2		
type	1	2	3	1	2	3
avg time at plant (mins.)	188	268	205	242	256	383
loading process time (mins.)	131	210	149	184	199	329
loading time (mins.)	105	111	98	98.4	130	93.1
waiting time for bay (mins.)	24.7	32.7	45.7	85.6	41.7	235
waiting time for swing arm (mins.)	10.1	10.7	8.1	-	-	-
split loaders (%)	2	62	4	0	21	0

The results of this scenario are worse than the base case.

The extra restriction worked in the wrong direction.

Conclusion

Discusses processes of truck filling at fuel plants.

A suitable software tool can support management and employees to model the plant, analyze performance, identify bottlenecks, and compare assignment rules of trucks to bays, and bay arms to truck compartments.

Developed a platform that is capable to build such a software tool.

Discussed a case study of a lubricant filling plant.

Implemented a simulation model in FlexSim.

Using the software tool we have studied alternative logistical scenarios at the plant for performance improvements.