Alumina supply study for a smelter expansion

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Abstract

In the scope of a planned Alba smelter expansion, the assessment of the alumina supply system for the present and projected operations was required. The alumina supply system included: ship arrivals, ship unloading at port, storage of the alumina in the port and smelter silos, trucking to the smelter and distribution of alumina to existing and projected potrooms. Within the Bechtel Mining and Metals business unit, the Technology Group provides modeling services for studies and detailed design. To demonstrate operability of future alumina handling to Alba, and jointly weigh alternatives, a discrete event model (DEM) has been developed, capturing all important elements of the targeted alumina handling and storage. Using the model, data was generated from several scenarios to size plant and smelter silos, to set number of trucks and reduce cycle time. Numerous schedules of ship arrivals, port and plant operating protocols were tested, aiding experts to corroborate unit sizes and operating strategies. Additionally, data was collected on fluctuation of vehicular traffic, vehicle servicing, and road and intersection characteristics were combined to assess traffic safety. The model proved to be a useful tool to configure a safe and efficient delivery system. The DEM can be adapted to smelters and ports with different arrangements and operating conditions.

Keywords: Alumina supply; port operation; trucking; process simulation; traffic analysis.

1. Introduction

Since the beginning of operation in 1971, Alba Smelter of Aluminium Bahrain (Alba) has systematically increased aluminium production. Preparing for the next smelter expansion, a feasibility study was completed jointly with Bechtel. A discrete event model (DEM) was developed to demonstrate how the alumina receiving, handling and transportation system from the port to the smelter behaves under present conditions (Lines 1 - 5) and smelter expansion (Line 6). The objectives were to keep all plant silos sufficiently filled, efficiently transfer alumina from port silos to plant silos and to maintain available storage capacity for arriving alumina ships. Present conditions were used for model verification and validation while data on projected operation was intended to check and corroborate early design alternatives.

Analyzing the alumina handling system chain and the alumina requirements, the study focused on the following sectors and activities:

- Ship arrival, alumina handling and unloading at port,
- Managing port silos inventories,
- Trucking alumina from port to smelter,
- Managing smelter silos inventories,
- Operation of the smelter with potline 6.

To address the study objectives, a dynamic simulation approach was proposed. The DEM demonstrated through animation the present and proposed work flow, shown dynamically changing data (e.g. inventory levels, waiting times, queue length, etc.) and calculated key measures of port and smelter operation (e.g. port and smelter silos level variation, daily ship deliveries, ship demurrage, etc.). This paper presents the structure of the DEM and those typical outcomes sought after by design and plant engineers.

The following questions are required to be answered by the model:

- Is the existing port with two berths capable of handling the additional Line 6 raw materials?
- How many alumina trucks would be required?
- Is a supplemental alumina truck loading station at the port required?
- Are there any traffic intersections that would be critical with the increased frequency of truck traffic?

2. Alumina supply system

2.1. General arrangement

The overall site layout is shown in Figure 1. Battery limits for the studied alumina supply system are selected as below:

- Berth 1 and berth 2 at port (for ship receiving)
- Plant fenced perimeter (for location and access road to smelter silos)
- Marked route between port and smelter

Figure 1. Site layout.

The granularity of the description targeted representing all key units of the alumina supply system (berths, ship unloaders, conveyors, port silos, truck loaders, fleet of trucks or tankers, designated routes, plant alumina silos, fume treatment fresh and charged alumina silos). The descriptions covered unit sizes (capacity, upper and lower limit, bypass), operational rules (schedules, delays and control logic), planned (maintenance) and unplanned (breakdown) down-periods and impacts of natural perturbance (tide, rain season).

2.2. Port

Port layout is shown in Figure 2. Simulation of ship arrivals to the berths is based on the 2012 ship handling port records defining the arrival times, cargo types, ship sizes and assignments:

- At berth 1, green coke and pitch imports are unloaded. Green coke is transferred to green petroleum coke (GPC) storage by conveyor and liquid pitch is transferred to pitch tanks via pipeline.
- At berth 2, alumina is unloaded and calcined coke is loaded. Alumina is received and transferred to silos (S510 and S520, 50 000 tonnes each) by conveyors. Calcined petrol coke (CPC) is also transferred from CPC storage by conveyor to the berth.

Alumina ship unloading is accomplished “hold-by-hold”. Each hold unloading consists of two phases:

- During free digging, the transfer rate is at the nominal rate until approximately 10 % of initial hold content is reached.
- At that point, clean-up operation begins and the transfer rate is reduced significantly, until the hold is emptied and the unloader is positioned at the next hold.

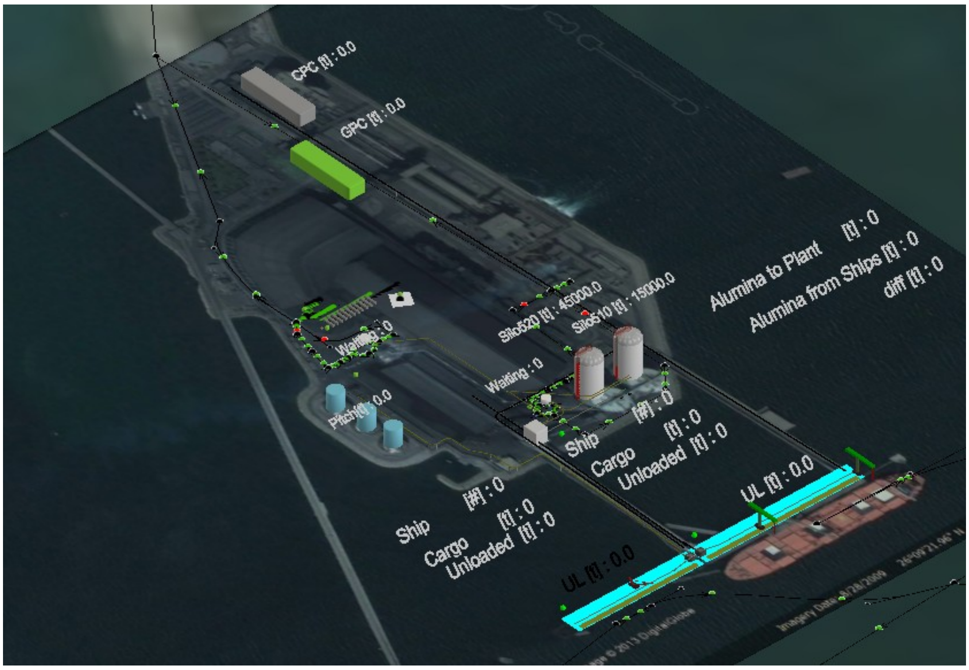


Figure 2. Port layout.

2.3. Plant

The current smelter operation has also been studied to confirm the unloading rate of the trucks, distance travelled within the plant, distance travelled on private and public roads between port and smelter, and the duration of the trips. Plant access points, routes, silo locations and unloading spots at silos were mapped. A group of smelter silos and trucks (marked red) are shown in Figure 3.

For the current operation, the following silos were in use:
Potlines: Line 1, Line 2, Line 3, Line 4 (north and south), Line 5 (north and south)
Fumes treatment centers: FTC1 and FTP5 (for fresh and charged alumina)

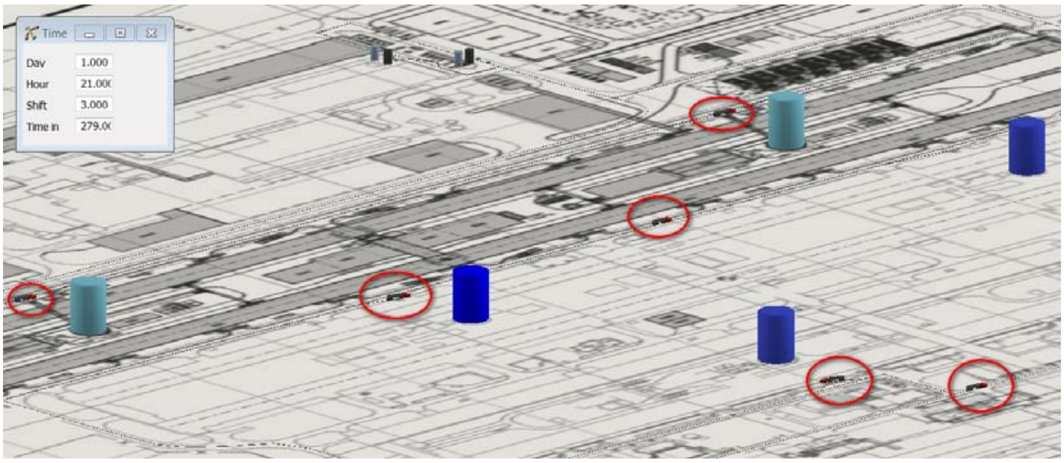


Figure 3. Trucks (circled) and plant silos of L4, L5 and L6 (partial view).

2.4. Alumina trucking

A fleet of eight trucks - six regular (gravity) tankers and two dual-mode (gravity and pneumatic) tankers was used to bring alumina from port to the smelter. One truck was considered “spare” or in repair. At the port, see Figure 4, there is only one truck loading station) with a limiting alumina transfer rate from port silos to truck loading bin. Smelter destination (silos), routes and travelling speeds (on roads and inside smelter and port) were assigned to the tanker trucks. The unloading process at smelter silos was considered as truck waiting time. Truck refueling, verification at the beginning of shifts and planned repair time was considered.

Figure 4. Truck loading station (pitch tanks in the front).

In general, all the trucks go through the following activities during a trip: truck loading at truck loading station (6 minutes loading plus 2 minutes positioning); fresh alumina unloading at a smelter silo (6 minutes unloading plus 2 minutes positioning). A selected truck also goes through one of the following: charged alumina filling to truck at FTC1 (60 minutes); charged alumina filling to truck at FTP5 (60 minutes). If a pressurized tanker is being used, the fresh alumina would be unloaded at FTC1 (4 hours).

3. Preliminary studies

In order to verify and validate the model, numerous simulations were done on the existing smelter alumina supply, with purposely selected parameters. Results on ship handling, port and smelter silo inventory and trucking were analyzed by Alba and Bechtel experts to gain confidence in the DEM.

3.1. Ship handling

The two berths handle different types of materials and receive different number of ships. Figure 5 shows the resulting ship queuing at the berths. While practically no queuing occurs at berth 1, recurring, several days long queuing is observed at berth 2.

Focusing on berth 2, Figure 6 shows the achieved ship demurrage, Table 1 summarizes the key performance factors.

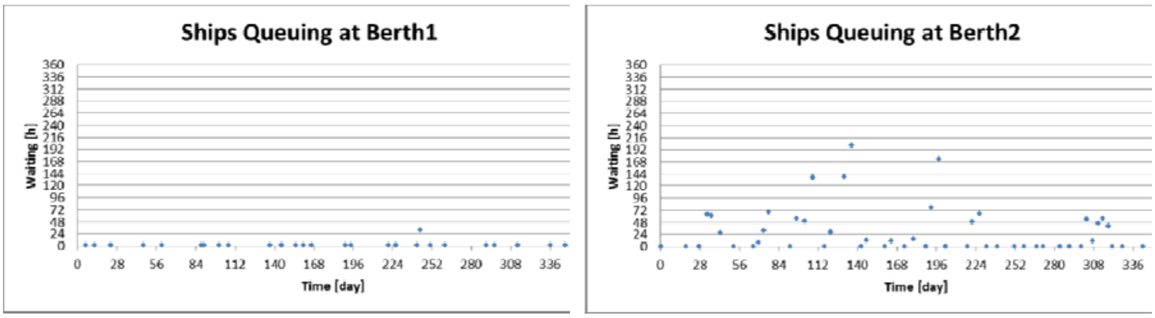
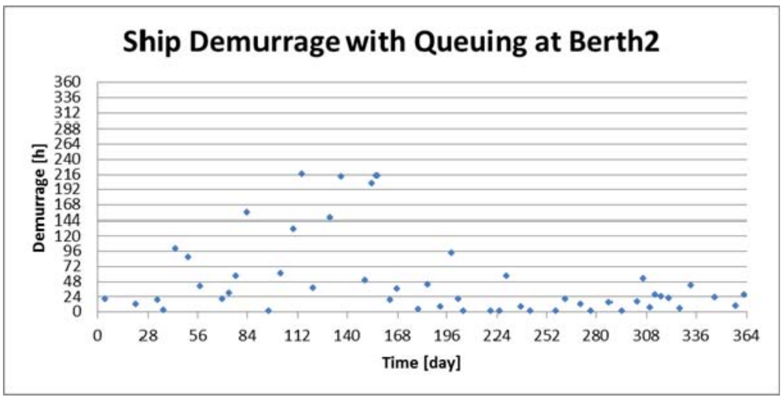


Figure 5. Ship queuing at berths.



demurrage (accumulated)	[h]	2355.8
	[day]	98.2

Figure 6. Ship demurrage at berth 2.

Table 1 Occupancy of berth 2.

Ship handled	[#]	51
Berth occupied by ship	[day]	234.64
Berth Occupancy		
reference day	[day]	365.00
occupancy	[%]	64.29

3.2. Port silos

Port silos alumina inventories vary between extremes; see Figure 7. There are periods when

- both silos are "full" (i.e. the time intervals corresponding to days 50 - 60, 80 - 84 etc.), or
- both silos are "empty" (i.e., the time intervals corresponding to days 26 - 28, 150 – 180, etc.).

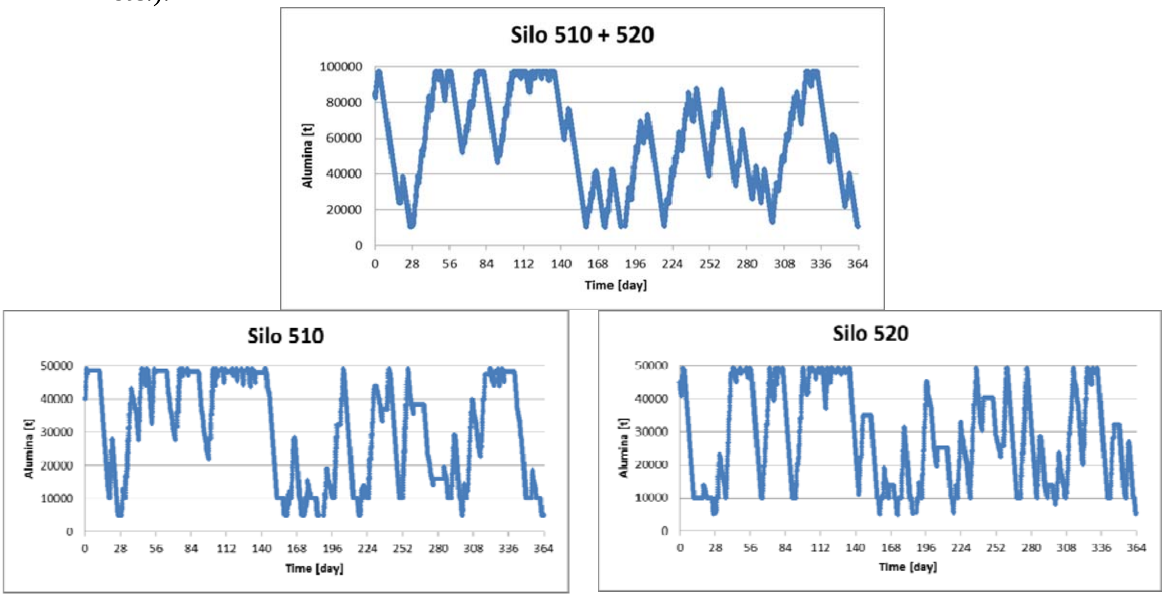


Figure 7. Inventory of port silos.

When both silos are "full", and this coincides with ship unloading, the ship unloading rate is reduced, occasionally down to trucking capacity (truck loading rate). This can cause ship delays, queuing and demurrage. The effect of "empty" port silos is already noticed in plant silo inventories. Inventory of smelter silo #3 in Figure 8 is an example for penetrating effects of "empty" port silos.

Figure 8. Plant silo #3 inventory.

3.3. Trucks

Although the trucks operate independently, they tend to arrive in waves and form “groups” at the loading station. Due to the tankers arriving at almost the same time, bin inventory level can fluctuate between being full and low, so that the bin inventory could be less than a truck’s capacity. This varying inventory level and tanker waiting times for a typical day is shown in Figure 9.

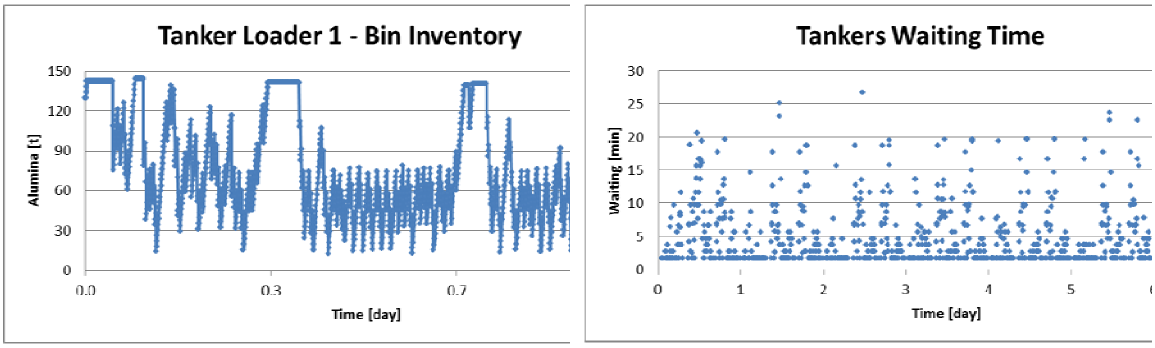


Figure 9. Bin inventory and truck waiting time (at Truck Loader #1.)

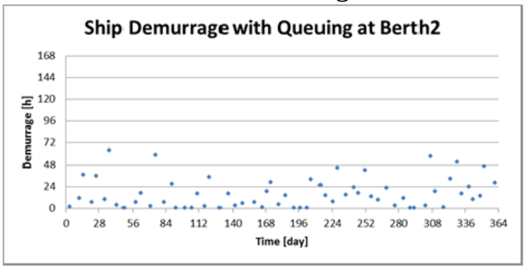
4. Line 6 expansion

After modelling the existing smelter the following additions, modifications and extensions were introduced to the DEM in connection with Line 6 expansion:

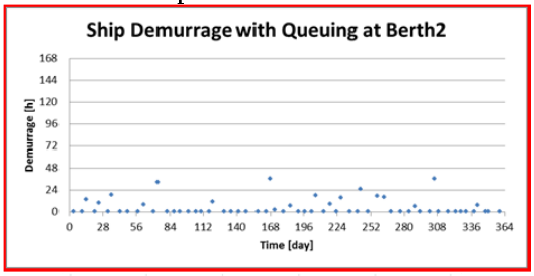
- Add two new silos (Line 6 north and south, 12 500 tonnes each) are implemented, FTC 2 (with 200 tonne plus 200 tonne capacity) is implemented.
- Add one truck loading station similar to the existing loading staton (2 in operation).
- Add six alumina bottom dump trucks. One type of tanker truck would be in use (total 14, but 13 regular tanker trucks considered in operation).
- FTC 1 & 2 fresh and charged alumina handling would be changed to a bottom dump feed system.
- The number of alumina ship arrivals using Panamax ships would increase to match increased plant demand.
- No CPC export would be required since all the CPC would be used at the smelter required for the addition of Line 6.

4.1. Improved ship handling

Ships were added to the recorded 2012 ship arrivals to meet the smelter increased alumina demand. The ship fleet would be composed of 30 000 tonne and 60 000 tonne ships (50 – 50 %). CPC export was eliminated. Ship unloading rate and “hold-by-hold” unloading profile remained unchanged. Ninety percent (90 %) of the hold would be emptied at a free digging rate of 1 000 tph. The remaining 10 % would be cleaned up at a rate equivalent to 10 % of the free digging rate (100 tph). Then, the ship unloading rate was increased to 12 000 tonnes per day. The free digging rate was kept unchanged; the improvement in unloading rate was implemented in the model by increasing the hold “cleaning” phase to 13 % of the free digging rate (at 130 tph), the planned operating hold cleaning rate. Over the duration of the ship unloading operation (with unloader breakdowns included), the average unloading rate would be 485 tph (totalling to 11 640 tpd). A comparison is shown in Figure 10 on projected demurrage (result with increased unloading rate is framed red). The resulting berth occupancy would be in the traditionally sustainable operation zone, see Figure 11. The modelled benefits may be obtained if the operation reflects the unloading rates achieved by benchmarked plants used for this scenario.

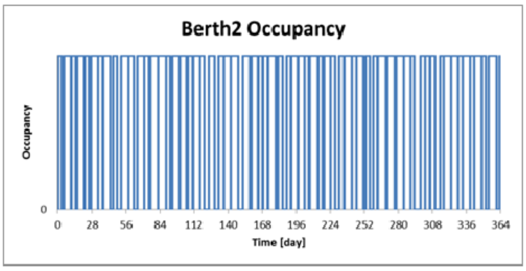


demurrage (accumulated)	[h]	1006.3
	[day]	41.9

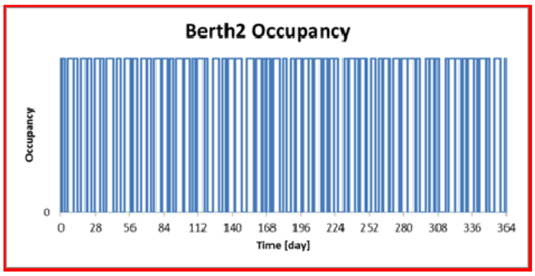


demurrage (accumulated)	[h]	283.1
	[day]	11.8

Figure 10. Ship demurrage at berth 2.



Ship handled	[#]	62
Berth occupied by ship	[day]	292.15
Berth Occupancy		
reference day	[day]	365.00
occupancy	[%]	80.04



Ship handled	[#]	62
Berth occupied by ship	[day]	250.80
Berth Occupancy		
reference day	[day]	365.00
occupancy	[%]	68.71

Figure 11. Occupancy of berth 2.

4.2. Port silos

Port silos inventory management was unchanged and the improved inventory levels are shown in Figure 12.

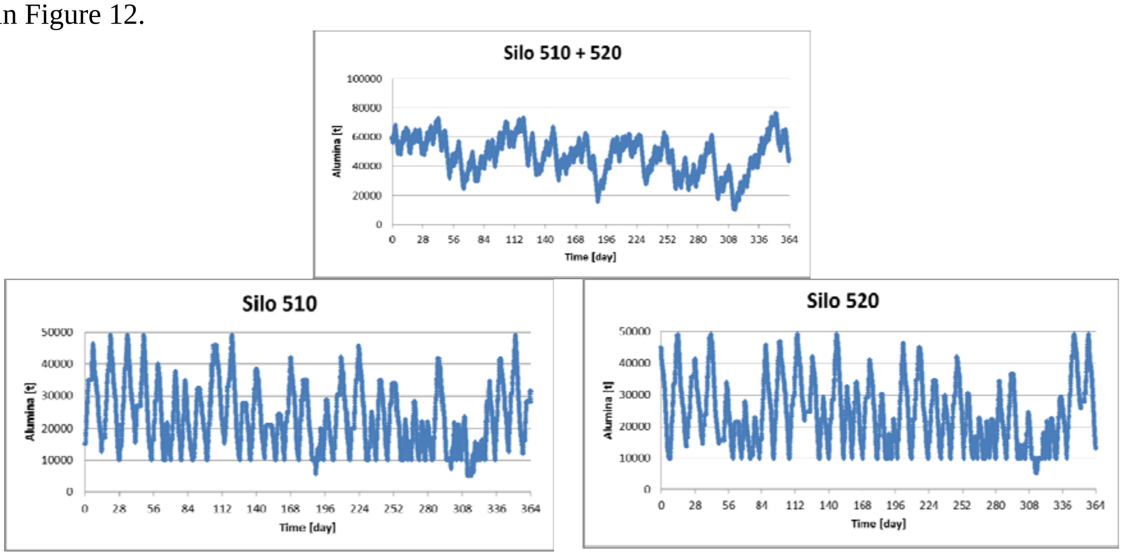


Figure 12. Port silos inventory.

4.3. Trucking / Traffic study

The discrete even modeling is a natural tool for traffic studies. The alumina supply itself generates significant road traffic between port and smelter. Inside the smelter, further services contribute to road traffic, involving vehicles of various types and sizes, travelling dedicated routes.

Failure Mode and Effect Analysis (FMEA) method is often used for assessing safety (or riskiness) of a road sector or an intersection. It is typically based on deriving risk priority numbers (RPN) for the road or intersection of interest. The RPN is the product of severity, occurrence and detection where:

- Severity: the harm or damage it could cause,
- Detection: the likelihood that it will not be detected,
- Occurrence: the likelihood that the failure will occur.

Severity is based on the traffic participants who could collide (process vehicles – trucks, truck - pedestrian, truck – bus, etc.). Detection is typically linked to road and intersection conditions and articulation (blind, uncontrolled intersection, roundabout, turning point etc.). For practical purposes, these factors are scaled (.e.g. from 1 - 10, where 10 is the most sever, more likely, less detectable). The compilation of severity and detection scales and characterizing the road sectors or intersections of interest by these scales is done by designers and plant operators.

Occurrence, however, could comfortably be gained from simulation, monitoring the movement of vehicles. Figure 13 illustrates the RPN value, varying over a day, for two intersections Figure 13. RPN numbers:

- R1 undergoes medium traffic of similar vehicles, no pedestrians present,
- B1 has low traffic of mixed vehicles, with occasional pedestrians' presence.

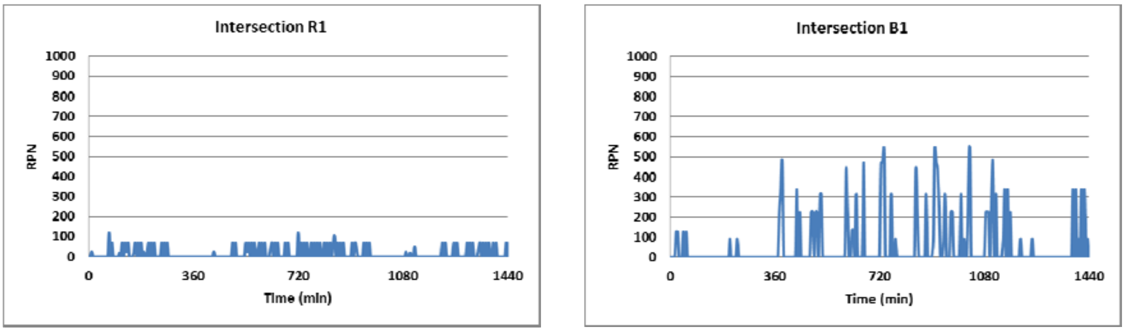


Figure 13. RPN numbers.

As scaling of factors is arbitrary, RPN numbers are for comparison and not absolute measure of risk. It is a good practice to characterize intersections considered "good, safe" by the plant staff to get a measure (RPN value) on traffic what is safely handled at the current plant.

5. Conclusions

From the case studies, recommendations for a robust operation were derived.

It was suggested for the ongoing operation, that the ship unloading process to be improved to reach a higher throughput. Adding six (6) tanker trucks to the existing fleet would enable the full use of smelter alumina silos and eliminate port silos "full" situations. Improving the transfer rate from smelter silos from the truck unloading station and the efficient use of the extra truck loading bay would manage the alumina transfer to smelter. Improved ship scheduling would alleviate the ship queuing times.

For the projected (Lines 1 - 6) operation, the ship unloader required transfer rate was determined. An additional truck loading station with two unloading bays was proposed and the optimal size of truck fleet was determined. Improvements to plant silo inventory management were suggested to keep the port silo inventory low (i.e. to unblock ship unloading due to “full” silos). Effect of improved ship scheduling on ship queuing and demurrage was quantified and demonstrated.

6. Trademarks

Flexsim is a registered trademark of Flexsim group.

7. Acknowledgements

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8. References

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