

MATCHING PRODUCTION PLANNING AND SHIP ARRIVAL SCHEDULING BY SIMULATION

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ABSTRACT

There are several challenges involving the representation of an ore loading port system using a simulation package. This kind of port handles bulk material, much more adequately represented by continuous flow than discrete flow, as in opposite to the case of a container-handling port. This paper addresses specifically the impact of meeting product mix requirements in the delivery and the ship arrival schedules. A method to model this feature is presented. Also, the modeling approach of these aspects is presented, and the experimentation in the case of Porto do Açu, located at Rio de Janeiro, is performed to check the method's efficiency.

1 INTRODUCTION

Some of the most favorable applications of simulation studies, are the port projects. Ports involve expensive equipment, large scale cargo movement and heavy fines for delays. Also, the efficient use of ports is critical to countries, since they usually are the most important structure demanded to drain the export production.

This kind of simulation study is even more important if the port is still being designed. The simulation of the chosen design can help to find problems or improve its performance. It can save millions only by avoiding some design or operation mistakes, that would be much more difficult to fix in an operating port.

Countries that are great commodities producers and exporters have ports specially designed to load bulk products like grains or coal into ships that are also specially designed to carry these type of products. An ore loading port system has special features not usually found on other kinds of ports:

- The product to be loaded is bulk material. Thus, a very specific system is needed to move the material from one place to another. Usually, it is done by conveyor belts.
- The bulk material must be stored in piles. These piles must be handled by equipment specially designed for this purpose: stackers, that store material and build the pile, and reclaimers, that remove material from it.

- A specially designed equipment is necessary to load ships: the shiploader. It is fed by a conveyor belt that transports ore from the pile into one of the ship's compartments.

Also, bulk material ports present other usual problems that are common to regular ports:

- Ship arrivals must follow traffic rules involving weather, channel occupation and tide variations.
- There must be balance between product arrivals and ship arrivals, or the storage space might not be enough.

This particular problem demands special treatment when there is no real system to collect the data. It is important for the simulation user to have a way to “draw” the production planning pattern and the scheduling of ship arrival.

By doing this, the user can test the storage/loading system on many scenarios, determining the best equipment to be installed or the maximum capacity of the system. In fact, this approach can be used on any study of no-existing systems, where there is a production plan or transport arrival.

This technique was validated over a real case, which is presented below. Also, other important features are presented.

2 THE PRODUCTION PLANNING VS. SHIP ARRIVAL PATTERN

In many simulation studies, the system starts with a single, unlimited, “source” of jobs, and ends on an unrestricted sink point, like the one at Figure 1. This kind of simulation is commonly used to study the system performance, assuming that the jobs arrivals are known.



Figure 1: Simulation with a simple jobs arrival, ending on an unrestricted sink point

Also, it is very common to have studies with a more sophisticated source of jobs, that mimic a production plan, with more than one product type. Even these studies have an unrestricted production sink, because the main goal is to check how the production will perform under different production plans. This system is illustrated at Figure 2

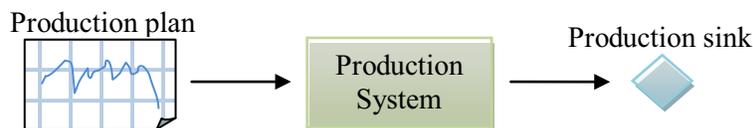


Figure 2: Simulating a production plan

In some rare cases, like this one, the production sink is not unrestricted. The output is determined by another arrival: the schedule of transportation equipment, like the one presented on Figure 3. In this case, it is mandatory to match the production planning with the transportation arrival.

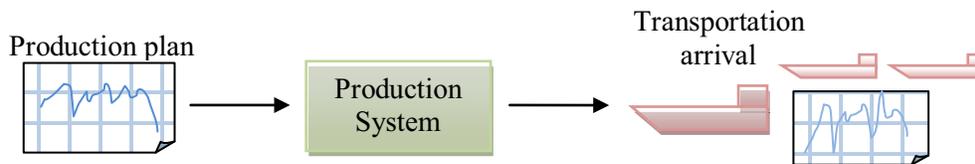


Figure 3: Simulating a production plan with restricted output

When it occurs in a port simulation study, the system has an additional problem: delayed ships incur fine. So, different than a truck or rail car arrival, the ship arrival does affect the monetary results, and cannot be ignored. This means that if the production plan provides a product A, but there are only ships waiting for product B, someone will be in trouble.

On a real, existing system, all these follow sales information. The sales area generates the production plan for product A or B, and, knowing the production system times and behavior, the dispatcher creates the ship arrival schedule.

On a simulated, non-existing system, this must be generated in a different way, because the “production system times and behavior” are not known: they vary on every scenario when testing new equipment or production strategy. And the Sales department do not exist too, so there is no precise information to support a detailed production plan.

The next section proposes a method to provide both plans for a simulation model of such system.

3 PLAN INPUT

3.1 Production Plan

The representation of the production plan is not a challenge, since there is an assumption that it will be presented to the production system as-is. Assuming the system works on one task a time, the production plan is just a list of the products to be produced, and its quantity.

The following example, presented on Figure 4, comes from an iron ore beneficiation plant, which has 4 product types.

Sequence 1 to 25			Sequence 26 to 50			Sequence 51 to 75			Sequence 76 to 100		
Sequence	Product	Ton	Sequence	Product	Ton	Sequence	Product	Ton	Sequence	Product	Ton
1	1	300.000	26	4	100.000	51	2	300.000	76	4	100.000
2	1	100.000	27	1	300.000	52	3	100.000	77	3	300.000
3	3	300.000	28	4	200.000	53	2	300.000	78	4	200.000
4	1	100.000	29	1	430.000	54	3	100.000	79	3	430.000
5	2	300.000	30	4	200.000	55	2	300.000	80	4	200.000
6	1	100.000	31	1	430.000	56	3	100.000	81	3	430.000
7	2	300.000	32	4	200.000	57	2	300.000	82	4	200.000
8	1	100.000	33	1	430.000	58	3	100.000	83	3	430.000
9	2	300.000	34	4	89.000	59	2	300.000	84	4	123.000
10	1	94.000	35	1	430.000	60	3	94.000	85	3	430.000
11	2	300.000	36	4	89.000	61	2	300.000	86	4	89.000
12	1	94.000	37	1	430.000	62	3	94.000	87	3	430.000
13	2	300.000	38	4	89.000	63	2	300.000	88	4	89.000
14	1	94.000	39	1	390.000	64	3	94.000	89	3	390.000
15	2	400.000	40	4	89.000	65	2	400.000	90	4	34.000
16	1	94.000	41	1	390.000	66	3	94.000	91	3	390.000
17	2	400.000	42	4	89.000	67	2	400.000	92	4	89.000
18	1	120.000	43	1	390.000	68	3	120.000	93	3	390.000
19	2	400.000	44	4	89.000	69	2	320.000	94	4	490.000
20	1	120.000	45	1	390.000	70	3	120.000	95	3	390.000
21	2	400.000	46	4	89.000	71	2	400.000	96	4	89.000
22	1	120.000	47	1	204.000	72	3	120.000	97	3	204.000
23	2	400.000	48	4	89.000	73	2	400.000	98	4	89.000
24	1	120.000	49	1	204.000	74	3	222.000	99	3	204.000
25	2	400.000	50	4	89.000	75	2	400.000	100	4	89.000

Figure 4: Example of a Production Plan

Once such a plan is available, the model will just follow the sequence, producing the specified product type on the requested quantity. The impact and procedures on changing from one product to another must be in the model.

3.2 Ship Arrival Generation

To model the ship arrival is a greater challenge than modeling the production plan, because the ship arrival is subject to many interferences outside the scope of the model, like other ports delays, breakdowns, bureaucratic problems, weather on the way, etc. Also, other studies like the one from Asperen et al. (2003) have proven that a simple exponential interarrival time is the worst choice to represent it.

Every system that relies on cargo ships to dispatch products, has a storage system to keep the product waiting for the ship in advance. The idea is to always have the product ready to avoid ship delays and fines payment. Of course this storage space and its use must be carefully designed. The fact is that there is not a precise control, or a safe forecast on the ship arrival.

Assuming there is not an operational simulation, where every specific ship must be modeled and considered, the ship arrival generation can be represented as seen on Figure 5.

	Ship types:	Type 1	Type 2	Type 3	Type 4	TOTAL
Historic percentage	%	10%	20%	70%	0%	100%
Ship size: MINIMUM	K Tons	30	51	131	151	
Ship size: MOST COMMON	K Tons	40	91	140	201	
Ship size: MAXIMUM	K Tons	50	130	150	220	
# of ships	# / year	22	44	155	0	222
Volume to transport	K Tons	888	4,018	21,756	0	26,662,200

Figure 5: Example of a Ship Arrival Generation

The proposed arrival plan is based on general information about the ships, that is available to the simulation user like:

- Percentage of each type of ship (different types mean different sizes),
- Minimum, most common, and maximum size of each type of ship,
- Total product volume to be dispatched

To create the arrival pattern, the user must first fill in the ship size information for each type. Then, is necessary to choose (based on historic data from other ports, or an strategic plan) the percentage of each type of ship. These percentages must sum to 100% and total volume to transport must match the total production plan presented in earlier section.

Smaller ships means faster operations, lower delay fines, but much more maneuver and mooring operations. They are also easier to find. Bigger ships are the opposite, with less mooring maneuvers but bigger delay fees (if happen). So the user can describe the exact pattern desired for the ship arrival.

Inside the model, the time between arrivals will use an exponential distribution, whose mean is calculated as follows:

$$mean = \left(\frac{simulation\ time}{total\ number\ of\ ships} \right)$$

Each arriving ship will have its type determined by an discrete distribution based on the percentages defined in the “historic percentage” row in Figure 5.

Once the type has been determined, the ship size will be given by a triangular distribution using the minimum, most common and maximum values as its parameters.

4 REAL CASE APPLICATION

4.1 The case of Porto do Açú of AngloFerrous Brasil

Anglo Ferrous is the iron division of the well known Anglo American mining company.

Porto do Açú is currently in design and construction phase, developed to receive very large ships and to handle several different types of cargo, including containers and also ore from the Anglo Ferrous mines in the state of Minas Gerais.

First of all, the simulation of an ore handling port is very different from other kinds of ports, at which discrete cargo like containers are received, stored and loaded. This class of problem has been extensively studied, and some reference work is that of Meisel & Bierwirth (2009) and Karlaftis, Kepaptsoglou, & Sambracos (2009). The solutions and algorithms proposed in these studies do not apply to a continuous cargo flow port. This being the case, new developments were required to achieve a correct process representation.

The focus of the simulation developed for the case of Anglo was:

- Validating the projected conditions for the equipments and operational rules of the port, and verifying if the volume loaded is in accordance with what is being budgeted. The operational times of ships are also subject to validation.
- Verifying the impact on the overall indicators of operating two different products and not only one.
- Verifying the possibility of, in a longer future, increasing the port's capacity only by installing a larger shiploader equipment.
- Verifying the impact on the overall indicators of operating larger ships vs. smaller ones.

4.2 The Model

The major challenges that have emerged from the simulation of Porto do Açú are all results of the need to represent operational rules and details that have a significant impact on the overall indicators that are the main object of the simulation.

The navigation restrictions have a direct impact on the time that each ship spends in each phase of the process in the port. This has an impact not only over the total time spent by each ship in the system, but also over the occupation rates of resources such as berths and the total volume loaded annually at the port.

Furthermore, the correct representation of the movements of stackers, reclaimers and shiploaders across yards and ship compartments is essential for the correct assessment of the real hourly capacity of these equipments. Were the time spent on these movements very short, they would be irrelevant. However, these movements have consumed up to 15% of certain equipment's available time in some simulated scenarios, which has a clear impact on the annual loading capacity of the port, as well as in these equipment's utilization rates. Other ore yard studies, like Fioroni et al. (2007) and Coelho and Fioroni (2005), do not go further on that detail level.

Moreover, the need to test the port's indicators in situations where more than one product is being handled makes it inevitable for the simulation analyst to deal with the problem of meeting required product mix. While this aspect had not yet been effectively taken in hand, in the model validation phase, the simulation developed for Anglo Ferrous presented several scenarios of deadlock results due to the excess of one type of product and the lack of another. It is also important to note that although the stocking areas capacities were represented in the model, the goal was not to check if the stocking area had been correctly sized. If this was so, it might have been necessary to face the product mix challenge in a different way.

In short, it must be said that the approach chosen to represent the process at Porto do Açú allowed the correct assessment of the main indicators of the simulation.

4.3 Results

The experimentation phase followed the process proposed by Valentin et al. (2005) to simulate maritime infrastructure, where a simulation expert builds the model and performs the experiments. Then, the results are analyzed by the port expert.

The results presented in Figure 6 show the production and the dispatch (ships loaded) for each scenario. It involves many other parameters that are not in the table. They were removed for confidentiality reasons.

Each scenario had a calibration phase to adjust the ship schedules to the desired production and system infrastructure, and this table shows that every scenario could successfully dispatch the production (input ships per year vs. output ships loaded).

Also, every scenario provided information about the storage space (courtyard level), that supported decisions involving the system.

SCENARIOS		1	2	3	4	5	6
INPUT DATA	Loading System						
	Number of different products	2	2	2	2	2	2
	Ships per year	135	194	135	323	135	167
	Production						
	Production (Tons/Hr)	1,700	2,465	1,700	4,080	1,700	2,104
MODEL RESULTS	Loading System						
	Ships loaded	135	194	135	321	135	166
	Average ship capacity (Mtons)	44.8	45.3	44.8	45.8	43.5	45.1
	Average ship time in system (h/ship)	8.3	8.9	8.3	10.8	14.8	19.9
	Average queue time per ship (h/ship)	0.1	0.8	0.1	1.6	0.1	2.3
	Production						
		Courtyard level (%)	44%	44%	44%	38%	38%

Figure 6: Results comparison.

5 CONCLUSIONS

The experimentation proved that the proposed method is efficient enough to support experimentation on simulation systems that have production planning variation and dispatch restrictions based on transportation arrival.

Despite the use of a port system as an example, the method can be used on every system with a production plan or arrival of transportation equipment.

In this specific case, it is mandatory to consider both the production plan and the ship arrival on the same model, because of some aspects of the system were the ship loading system that could impact directly on the storage system. On simpler systems, the process could be cut in half, with studies being performed with the system until the storage, and others from the storage to the ship loading system.

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