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DISTRIBUTION LOGISTICS IN THE PROCESS INDUSTRIES: ESTABLISHING RAILCAR REQUIREMENTS

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ABSTRACT

The Manufacturing World is often classified into Discrete Manufacturing and Process Operations.Process Industry Operations generally are classified as 'Batch' or 'Continuous'; we can think of these as producing 'stuff' as opposed to the discrete individual 'things' produced in Discrete Manufacturing Operations. These Manufacturing World's clearly have much in common, but there are areas in which they can be quite different. They certainly have overlap, but at the extremes they can be fundamentally different and present unique challenges. Continuity of Operations is one of these areas; some Continuous Chemical plants may operate 'around-the-clock' for several years between 'shutdowns'. This means that they literally continue to operate even when there are maintenance difficulties. They may slow down for grade changes or unusual operating conditions, but they do not stop altogether as this could force the entire production train down for a major overhaul/restart which can be very expensive and/or time consuming. For some chemical plants a total shutdown can poison the reaction catalyst. For some polymer plants a total shutdown can mean the molten polymer 'freezes' in the lines. Each of these will result in a long period of total outage while the plant is refurbished and restarted. When a Process is 'Continuous' in this sense, it certainly can create some unusual challenges from a "Logistics Viewpoint". Aspects of these challenges are JIT/WIP Inventory, Material Handling, and Product Distribution. This paper will (1) discuss these challenges with emphasis on Final Product Distribution and Railcar Requirements, and (2) briefly describe two cases where careful Analysis and Modeling helped lead to substantial improvements in Operations Understanding and to significant Financial Savings (both Investment and Cost).

1. INTRODUCTION

In the Process Industries there are often many steps along the production chain as we move from original raw materials (such as unrefined oil) through to finished products (such as refined petroleum products, plastics, pharmaceuticals, synthetic fibers, and food additives). At each step in the production chain, in addition to the main product we are trying to produce, we can also have both co-products and by-products which need to be further processed (for sale) or treated (for disposal). Many Process Industry plants are large complex production systems which carry out a series of integrated chemical processing steps. These plants often generate very large production flows which can present significant handling, storage, and distribution challenges. As was once observed by one of my colleagues "a flow of a few tons per hour of chlorine can really get your attention!"

Large integrated chemical companies often operate large-scale plants serving both to supply external customers and to be sources of intermediate feedstocks for internal down-stream plants which then further process these intermediates into one or several finished products. From a Manufacturing Logistics viewpoint the objective is to operate the intermediates plant as a reliable source of high quality intermediates to both external and internal customers at the lowest possible cost. In this increasingly competitive world marketplace 'reliable source', 'high quality', and 'lowest possible cost' are all key business drivers and important to remaining in business.

A relatively simple Manufacturing Chain is illustrated in Figure I where we see two intermediates plants supplying four internal finished product plants and several external customers. For simplicity all co-product and by-product streams have been omitted (at both the intermediates producing plants as well as for the finished products plants) and the production chain has been limited to two steps (many real world systems are indeed much longer).

From a Manufacturing Logistics viewpoint some of the key goals are to (1) operate each of the internal finished product plants so as to meet the allocated production tasks, (2) operate each of the intermediates plants so as to supply the demand requirements of all of the external and internal customers, and (3) plan and

DISTRIBUTION LOGISTICS NETWORK:
Two Producer Plants & Four Consuming Sites

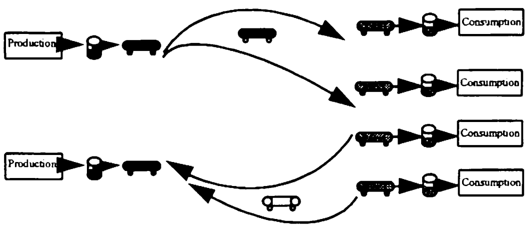

Figure I

manage the logistics system so that all materials are stored and distributed in a timely and cost effective manner. It is not an easy task to plan and operate such Manufacturing Logistics Chains for a number of reasons, including: (a) all of these plants may be subject to periodic production upsets and/or maintenance slowdowns, (b) the production tasks (such as weekly or monthly production quantities) are not always smooth and constant, (c) the railcar transit times on the distribution routes may vary significantly, and (d) the railcars used for making many of these moves are themselves subject to both unplanned and planned maintenance downtimes. It is in this context we approach the problem of determining the Railcar Requirements for effective low cost logistics operation of Process Industry Production Systems.

At this point you may ask "Why the big focus on Railcar Requirements in Process Industry Operations?". Many of the railcars used to move chemicals, refined petroleum products, and even foodstuffs are solely dedicated to a single product (sometimes even to a single grade of product) in order to strictly avoid any possible cross-contamination problems. These railcars often represent both a large long-term investment as well as a significant annual operating cost. Many of these fleets are large (sometimes many hundreds of cars in a single fleet supporting a multi-plant system), complex (serving several plants with disparate needs, conditions, and scheduling policies), old (some of these fleets have grown over many years as operations expanded and new customers were added), and they often operate in highly dynamic and variable conditions. This certainly can result in both a challenge and an opportunity. On a positive note our experience has shown that a program of careful analysis, simulation modeling, and coordinated fleet improvements can both reduce costs and improve fleet operations service levels.

2. ANALYSIS AND MODELING

Simulation Modeling has proven to be a valuable tool for helping to understand and improve Railcar Fleets. However we need to start by emphasizing that preceding the development of any simulation model there needs to be a careful Operations Analysis that first determines the key questions to be addressed, and then guides information gathering about how the system operates. This information gathering should focus on the system components: how they individually behave, how they interact, the rules for operating the both the individual components and the total system, and all of the sources of uncertainty and variability impacting the performance of the total system. The major operating and scheduling assumptions need to be agreed upon and documented along with all of the relevant data and parameters. The variable parameters need to be studied, the available data needs to be thoroughly analyzed, and additional data often must be gathered and analyzed. It should however be noted that the whole effort doesn't need to wait until all of the data has been gathered and analyzed; some of the model structuring and early development tasks can go along in parallel once the key data gathering tasks have been planned. Approximate data can be used during early model development once the task of gathering and analyzing better data has been agreed upon and people assigned to the task.

When planning for modeling a stochastic (dynamic with variability) system and planning the information gathering tasks, we must strongly focus on the questions the model will be used to address. The issue of level of detail to be in the model is a critical one; this can be the difference between a successful and mediocre modeling activity. Too little detail can lead to an incomplete or even inaccurate model that could lead to erroneous conclusions (or confusion altogether); whereas too much detail can lead to the modeling taking too long, costing too much or even failing altogether by getting bogged down in the detail. Correct balance is important; this can be the difference between success and failure. Certainly this is the case as seen from the eyes of the decision makers we are trying to help. This is an area that is sometimes not carefully planned; all novice modelers are cautioned to discuss this with their colleagues before getting 'in too deep'. It is generally better to build a reasonable model fast and to then incorporate additional details as needed to gain realism and get implementation acceptance. However, it is also important that to the best extent possible these details should be considered and weighed early. This means the information can at least be roughly estimated and the model can be built in a fashion that will allow these details to be added without undue difficulty. This is certainly one area where consulting with others early is time well spent. Cost effective models are desirable, but avoiding inaccurate models is even more important. There are a number of excellent references available on how to go about planning and carrying out a good valid simulation modeling study. In addition to papers and sessions in the *Winter Simulation Conference Proceedings,* the reader is directed to (1) seek out help from your fellow WSC attendees and (2) to start your literature search with the books Askin, Banks, Harrell, Law, Schriber and Shannon. (See References)

3. GENERAL OBJECTIVES

In modeling these railcar fleets what are the key questions we are attempting to address? Generally we want to know the best fleet size under a range of different conditions (different market demand rates, different plant configurations and rates, different travel transit time and variabilities, ...). Do we need to buy/lease more railcars as the business grows? Can we reduce the fleet and still provide continuing good service levels? If we improve maintenance operations can we reduce the fleet? What if we can get better travel transit time? What is the impact of the times cars wait to be unloaded and turned around at the consuming sites - will improvements allow us to reduce fleet sizes ? What are the major sources of variability and what is their impact of fleet size requirements? What is the impact of buffer tanks - what is the impact if we reduced inventory levels at either or both of the ends of the pipeline?

Many of these questions and our overall objectives can be discussed in the framework of Figure II.

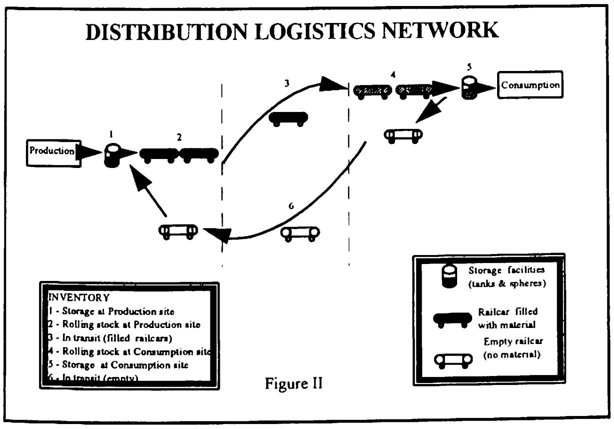

Figure II

Here we see a simple two plant-site system with just one producing and one consuming plant with buffer tanks at each site; a simple railcar fleet services the material movements between them, and a single maintenance branch-site is present to handle all maintenance on the railcars. Real-world systems, such as in our two case studies discussed later, are certainly bigger and more complex, but in principal they operate essentially the same way. Material is produced, stored in a tank, loaded into a railcar, moved to a consuming site (internal plant or an external customer), unloaded, and used while the railcar is sent back to the/a producing site (in some cases the material is consumed directly from the railcar and the car then can be sent back only after it is emptied and sealed off). In multi-plant systems the issue of where the empty car is sent can be an important one; it may be that the car should go back to where it was originally loaded, or it may be better to send it to another producing site that needs it more urgently. Use of a fleet operating policy that determines where best to send a car each time one is unloaded and available for routing back to a producing site can be powerful. Another important area is often the one of "when" to dispatch a loaded car from a producing site to a consuming site; the specific decision rules and criteria that are used can have a significant effect on service levels for customers throughout the whole system. We could end up with loaded cars in locations where we don't want them if we are not careful about our scheduling and dispatch policies, and as a result, not have the cars available to send to other locations where we do urgently need them.

4. TWO CASES STUDIES

Case studies will be used to illustrate two rather different situations where simulation modeling proved to be a valuable tool for helping to achieve significant investment and operating cost savings. Before getting into the specifics of these two cases, I want to strongly note that these successes were very much the result of good team efforts with many varied and valuable contributions. Simulation modeling was the guiding process and a tool for quickly and objectively comparing alternatives, but the system knowledge as well as the ideas to be evaluated came from the manufacturing and logistics members of the team. I am pleased to report that through this good work each of these illustrative cases had savings over $1 million.

4.1 Tool Set

Our Operations Research Group has been doing simulation modeling for many years. We have used a wide range of simulation modeling tools across the full range of computers. We started on the early engineering and technical computers, moved to mainframes, then to VAX's, and now work primarily on high-end PC's. There are many good simulation modeling tools available these days and we use several of them. However, in undertaking any important modeling job, it is important to first focus on a good understanding of the problem needs, and, to then be sure to select a tool with enough power to deal with all aspects of the problem. By all aspects, I include both technical capability and user interface features.

We have found that Pro-Model is a good tool for our Manufacturing Logistics modeling work. It has many "user friendly" features and, even more importantly, it has sufficient modeling power (both modeling constructs and language capabilities) to allow us to model very complex systems. In addition to these modeling features three additional important capabilities for us are: the ability to read external files, to generate graphic presentations, (via its own features and by exporting to spreadsheet packages), and very importantly the ability to present concurrent dynamic animations. These dynamic animations have three advantages that we find important: (1) they clearly help us with initial management buy-in and help the team "sell the job", (2) they help the whole team work together by serving as excellent communication aids and debugging tools and then (3) they help the team efficiently evaluate alternatives and gain good acceptance for the conclusions. Certainly I must note animation is not a substitute for the careful review and analysis needed to thoroughly debug a model and reach statistically valid conclusions from a stochastic simulation. This solid analysis definitely must be carried out by modelers, but the whole team will often not be a part of this. Dynamic animations can greatly help other team members understand the complexity and variability of the system interactions, this can result in their feeling much more comfortable with the statistical based conclusions. The active support, based on this visual evidence, by the non-modeling members of the team can be an enormous strength during the implementation phase. It is often their strong recommendations that really 'wins the day' with the key decision makers.

4.2 CASE 1: Evaluating Expansion Requirements

In this case the situation involved two large production sites (with a total annual capacity of over 200 million pounds) supplying five internal consuming sites plus a significant number of external customers. The business was doing well and a planned expansion was scheduled to come on-stream with a 20% annual capacity increase. There were people who believed this would require also adding 20% more railcars to handle the distribution logistics; others believed the needs would be smaller, and some who felt that because of the complexity the railcar expansion needs would be even higher.

Based on previous successes involving modeling work we were asked to join the logistics team to help them determine the railcar needs under a number of different scenarios. This was important to the business as a 20% increase would add close to 35 more cars to the fleet at a cost that could be $ 4.4 MM. In addition to the investment required for more railcars, a fleet increase would also increase the annual operating costs (more cars to be maintained, etc...), and there would be a significant dollar value tied up in the material that would be in these cars. Clearly there was incentive to find the best fleet size under different possible operating scenarios.

The final version of the model is quite large and detailed, but the essence is still quite well captured in Figure I (which shows a multi-plant system as discussed above). A very noteworthy point is that for this specific model we now have tied it to a separate Production Planning/Scheduling Model (a Mathematical Programming based Optimization Model) that produces a time phased Master Schedule which is used to drive the Logistics Simulation Model. Thus for each time period (week, month,...) we have both a planned production task for each of the two producing sites and planned demand quantities for each of the consuming sites, internal plants and external customers.

The simulation then is a more detailed dynamic model that is driven by the Master Schedule, but it also takes into account additional details such as equipment outages, transit time delays, plant car loading limitations, care maintenance activities/delays, and other sources of variability too detailed to explore further in this forum. Suffice it to say that each of the internal producing and consuming plants is modeled in some detail and each of the external customers is modeled focusing on the demand and the 'time spent at the location for car movements and unloading'. As you can well imagine it required a real a team effort to gather this information, and there was significant variability in the data so uncertainty was modeled carefully.

One of the areas that we found requiring a thorough team exploration is the one of dispatching policies. Specifically, the consuming plants have monthly production goals, finite storage capacity, periodic production slow-downs (for maintenance type activities), and they are supplied by railcars that have rather long and variable transit times. Specifically, for instance, we had good transit time data showing times ranging from 5 to 29 days along one of the frequently traveled routes. In general these routes pass through several rail yards and most of the time delays are at these "pass off" points; the cars can be significantly delayed when passing from one rail carrier to another. Now the dispatch policy question is simply "what set of conditions(rules) should cause us to send a car from a producing site to the consuming site?"

A set of overlapping and sometimes contradictory rules had evolved since this was a large and complex system (there were two large plants supplying several consuming sites). All of these were well intentioned and shared the goal of keeping the system running smoothly. However, taken altogether they sometimes did not produce the best results. Sometimes cars were sent to consuming sites that were already well supplied (with adequate material on hand and cars on the way) while other plants were running low. Some people felt more cars were necessary to insure smooth operations and timely distribution; others felt it was possible to meet service needs without buying additional cars.

In the model we explicitly treated: (1) periodic plant slow-downs and shut-downs (i.e. planned and unplanned), (2) plant car load/unload limitations (i.e. only x cars could be handled per day) , (3) car maintenance delays (i.e. cars were taken out of service for both planned and unplanned maintenance), (4) random car transit times (i.e. these were often not standard well-behaved distributions), (5) plant storage capabilities (these were varied via cases) and (6) car dispatch scheduling rules.

After running many scenarios the team concluded that (1) we did not need to add more railcars to the 200+ car fleet in order to meet distribution needs as the new capacity came on-stream, (2) that specific improvements in transit times and customer stay times were possible, and (3) that further fleet improvements were possible by using a better set of coordinated dispatch policies. These, plus other fleet utilization ideas, have improved asset utilization with a bottom line impact of $4.4 MM of avoided new investment, $225,000 of reduced operating cost, and the added benefit of avoiding the additional material that would have been sitting in those new railcars, plus the team gained a better understanding of the distribution system to the point that new opportunities on the "spot market" could be pursued (considered a significant benefit by the business).

4.3 CASE II: Fleet Consolidation

The second case involves a simpler system with one producing plant feeding four consuming plants (three internal and one external). These plants were for historical reasons fed with cars "owned" by the consuming plants. The key business driver for digging into this situation was that a significant number of the cars were reaching the replacement point and had to be replaced at a potential cost of several million dollars. The business leaders were open to a thorough analysis and recommendation on the most economic way to maintain service levels. Maintaining service was critical, but reducing the needed new investment was also important if possible.

Each of the five plants was individually modeled with focus on outages, rate variations, and car movement and load/unload capabilities. Much of the focus was on upset conditions at the plants and on the rail dispatch and transit time aspects. The cars were not all identical; due to differences in size (some cars were too big for some plants), filling attachments (some cars had unusual placement of the filling nozzles), some cars could not be used at some of the plants.

The model was fairly detailed so that cars were only sent on 'legal routes' where the car both met the size restrictions and had appropriate load/unload attachments. Car maintenance was incorporated and was actually based on car age and condition. In addition to the size/attachment, the model dealt with the policy issue of which cars were available to be used for each of the plants. This way cases could be run with different fleet consolidation rules. For instance, the cars servicing the external customer were kept in a separate pool in almost all of the cases analyzed; whereas, the cars originally dedicated to the other three plants were consolidated in different ways as the team evaluated different alternatives. It was possible when running cases to allow plant A's cars to be used by plant B, but not vice-versa.

In this model there was a strong focus on individual car characteristics and differences so each car was actually modeled as a separate entity. This way there was no ambiguity about which cars could service the different plants or pass over specific rail routes. In addition, this allowed for maintenance activity to focus on the individual cars which differed in age and total miles traveled.

Good work by the entire team on analyzing the system, determining car and plant differences, establishing innovative ways to deal with upset conditions, and modeling the entire system lead to great success. By consolidating part of the fleet, finding creative ways of handling unusual plant upsets, and improving fleet operations, the team was able to recommend a 25% fleet reduction and thus avoid a $1 MM investment in new railcars.

5.0 CONCLUSION

Process Industry Operations are frequently large scale plants with continuity characteristics quite different from much of the discrete parts manufacturing and assembly plants. Further, the materials consumed and produced often need to be moved in dedicated railcars across long distances to service plants which do not have large storage tank buffers. This often results in large railcar fleets that are difficult to plan and manage due to many sources of variation and interaction between the system components.

Experience has shown that the first step toward success is to assemble a good team with logistics, plant operations, and modeling capabilities. This team should study the situation at hand, determine the specific needs and establish what are the opportunities and where are the system boundaries. They should carefully work to describe the entire system: what are the components, how do they operate, how do they interact, where are the sources of variability, what are the concerns of the people running the day-to-day operations? If we can adequately describe these logistics systems, then we know that we can indeed model them. The key is to build the minimum essential model: one that contains enough detail and realism to adequately address the questions at hand but not so detailed that it takes too long or costs too much. Finding that correct balance is often the key to successfully modeling these often complex systems. It is clear also that benefits flow from the increased operations understanding that the team develops even before the final model results are generated; these can be as significant as any specific results from the model. In the two cases we have briefly visited the modeling activity was the main guiding process, but the team learning's were the real key to success. In both cases it was the logistics people whose advice was the 'final convincer' in changing how the businesses were going to operate the systems. We have seen that the results were significant and certainly it can be said that "Modeling Does Pay".

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