Journal of Contemporary Issues in Business and Government Vol. 27, No. 3, 2021
https://cibg.org.au/
P-ISSN: 2204-1990; E-ISSN: 1323-6903
DOI: 10.47750/cibg.2021.27.03.154

Aggregate Planning of Batch Plant Operations

DR.ANKUSH SHARMA

Department of Management,Jagran Lakecity University, Bhopal
Email: jagraneip@gmail.com

Abstract: Aggregate planning is an analytical tool offering a strategy to meet demand based on capacity constraints. Production and supply of building materials plays an important role in delivering constructed facilities, particularly for concrete and asphalt batch plants. The supply chain of construction materials (e.g., concrete) presents unique challenges, but is a key factor in the successful delivery of facilities. This paper addresses the production and implementation of an integrated planning approach focused on simulation that enables the modeling and organization of the supply chain of a batch factory. The tool is applied to a true case of asphalt production operations, where fluctuating demand affects the production plant's level of service and makes production planning and inventory processes a challenging task. The model quantifies the impact of the asphalt processing plant's different parameters on its level of operation and tries to determine the right solutions for the processing, procurement and delivery processes of the factory.

Keywords: Aggregate planning, Transportation model, TORA transportation and Vogel Approximation Method (VAM)

INTRODUCTION

The aggregate planning problem is the output planning problem of a company trying to follow a changing trend over a limited period of time. The capability choices can be taken on three occasions in an enterprise such as long term decision, intermediate term decision and short term decision. Most corporate entities create a strategic strategy that includes both long- term and intermediate-term planning. Considering the rules and policies of the organization, aggregate planning creates strategies for the organization, creates demand data for the products or services of the organization. Aggregate planning is in essence a larger planning style. Generally speaking, aggregate planners want to sidestep focusing on a discrete product or service, except that the organization only focuses on one main product or service. We usually choose to rely on a set of complementary products or services[1].

Regular time production capacity, subcontracting capacity and overtime capacity are the different capacities which are normally used to manufacture products. Other possible capacities are also used if the regular time production capacity is not sufficient to manage with demands of different products. The aggregate planning starts with a forecast of aggregate intermediate-range demand. A common plan is then surveyed to address the demand requirements for setting output and inventory levels or finished goods service capacities. The consistency and timing of the anticipated demand are of interest to aggregate planners. If overall projected demand for the planning period ranges considerably from the available resources for the same period, the planners' key solution would be to attempt to find a compromise by adjusting capacity, production or both. On the other hand, even if the capacity and demand for the planning horizon as a whole are approximately equal, planning maystill faces the problem of dealing with uneven demand within the planning interval. In some periods the expected demand may exceed the projected capacity, in others the expected demand may be less than the projected capacity, and the two may be equal in some periods. Aggregate planners are tasked with achieving rough equality of demand and capacity across the entire planning horizon. In addition, planners are usually concerned with minimizing the aggregate plan cost, though plan, although cost is not the sole consideration[2].

Clear knowledge requires efficient collective preparation. Firstly, the services available during the forecasting period must be known. Then, a prediction of anticipated demand must be possible. Finally, plans must take into account the policies on shifts in job levels. Companies in the transportation sector and several other sectors also face repeat requests from consumers that make several reservations but only wish to retain one of them at most[3].

A supply chain describes a network of organizations involved in various processes and activities that generate valuable products and services for consumers, tracing all stages and functions involved in meeting customer needs, including manufacturers and suppliers, as well as transporters, warehouses, retailers and the customers' own actions regarding each of these points on the network. Supply Chain Management (SCM) defines the collection of systematic approaches to the architecture, planning, maintenance and execution of entire supply chain processes. Aggregate preparation is the method of designing a development schedule to meet consumer demand, taking into account operating hours, efficiency, manufacturing capacity of warehouses, availability of raw materials and all other supply chain constraints[4].

Aggregate planning synchronizes the movement of goods across the supply chain and facilitates efforts to use manufacturing and distribution capital, storage infrastructure and equipment efficiently; this strategy aims to handle supply and demand effectively. For many construction projects, batch plants, such as asphalt plants or concrete plants, are critical subsets of the supply chain, where cement, water, aggregates and selected ad-mixtures are mixed together to produce asphalt or concrete, loaded into trucks via silos and transported to the construction site. Batch plants serving construction projects have their own distinct supply chains; batch plant production methods are made-to - order, not made-to-store, and order quantities and specifications are highly variable. This increases the complexity of aggregate planning, so that mathematical models and linear programming are not enough to produce effective plans. In such instances, simulation models should capture the complexity and special relationships between supply chain points in order to provide alternatives for decision taking[5].

Simulation techniques used in past construction operations do not explicitly target aggregate planning of the supply chain, but adjust certain decision variables that fall within this scope. An author developed a simulation model for a concrete batch plant using Micro CYCLONE, Purdue University, United States, to evaluate possible resource management solutions. Lu et al. used discrete event modeling to model single plant/multisite ready-mixed concrete production processes with focus on the relationships between the plant and various work sites to increase the supply support rates and the use of plant resources. Sawhney et al. used place / transition nets for the study of a ready-mix concrete plant with further emphasis on the benefit and capability of Petrinets as a modeling method. Other applications outside the construction domain explicitly employ simulation modeling to facilitate SCM and aggregate planning. Tiger and Simpson, for example, developed a modeling supply chain model for a technology-based business. Bagchi developed a simulator for IBM supply chains to assist managers in making strategic decisions about the design and operation of the supply chain and providing modeling functions for the processes of distribution and transport[6].

Van der Zee reexamined several simulation methods for SCM and introduced a new simulation system for supply chains using intelligent agent principles. In summary, the supply chains of batch plants supporting building projects are dynamic and require specific modeling approaches to help management and preparation processes and efficiently capture complexity. While simulation-based SCM is used in other sectors, the use of simulation to provide exclusive support for aggregate planning of batch plants in the construction domain has been ignored. Simulation-based approaches do not offer generalized approaches to all SCM problems, but may be customized to suit a particular building problem. This paper discusses the development of a simulation method for modeling batch plants in support of aggregate planning decisions and illustrates the possible advantages of the built method by examining the case of an existing asphalt plant. This paper, addressing the following research questions 1) what is aggregate planning and what are its planning strategies? And 2) what is production and implementation of an integrated planning?

This article includes the use of value stream mapping (VSM) and simulation to improve batch production system efficiency commonly found in small and medium-sized enterprises. VSM is a system representation tool which identifies areas for improvement. The simulation model imitates a real production system so that alternatives for improvement can be assessed without disrupting the actual production. The simulation can also optimize the resource levels required for operations in bottleneck. As a case study is used the production cycle at a roasted and ground coffee plant that had serious power shortage problem. Three options for change are evaluated: (1) growing the workforce in bottleneck operations; (2) use a new workplace management strategy derived by VSM and computer modeling and (3) investing in a system to eliminate manual operations at bottlenecks. Results of the analysis show the ability of those tools to formulate effective solutions for the case study system[7]. For the management of output planning, preparation and maintenance, a medium-term optimization-based approach is introduced. The problem presented in this work considers a single-stage multi-product batch process plant with parallel units and limited resources. An ongoing MILP formulation is developed based on the main ideas of traveling salesman problem and precedence-based constraints, sequence-dependent unit performance decline, flexible recovery operations, resource availability and product lifetime. Specific scheduling scenarios were solved and compared with modified literature formulas, based on discrete-time and global-time events, demonstrating the feasibility of the proposed approach to the solution. Through consideration of several time periods, additional planning and scheduling problems were proposed. The model has effectively solved multi-period examples showing the applicability of the solution approach to medium-size problems[8].

METHODOLOGY

1. Design:

Aggregate Planning

For con-structured facilities and project performance aggregate planning is an important SCM process. It needs feedback from all Supply Chain components. The following parameters are generally included:

- Input to demand: demand expected
- Plant production rate: number of units to be completed per unit of time
- Inventory holding: planned inventory in the planning timeline, carried over the various periods
- Workforce: number of employees / computer power units needed for production
- Contractions: payroll quotas, outsourcing, subcontracting and warehouse space, and manufacturer and customer plant restrictions.

Total planning approaches include trade-offs between inventory, contracting, production volume, labor-levels, and capacity: raising one parameter helps to decrease the other, and the aim is to maximize trade-offs. Given that demand varies over time, one parameter will be identified as the key factor in meeting customer demand by relative parameter levels. The following strategies can be applied:

A. Changing production levels: The introduction or removal of plant facilities synchronizes output and demand levels as appropriate. It is troublesome in practice, because it is costly and difficult to change the services on short notice.

B. Varying overall working hours: If excess working time is available (i.e. machines are not constantly being used), the production rate remains stable, but over time working hours are varied to synchronize production with demand. This approach results in low inventory costs and steady equipment and staff with high daily overtime rates.

C. Using inventory and backlogs: Working hours, workers, and output levels are kept at a constant pace, but supply is not aligned with demand: inventories are either built up in expectation of potential demand during times of low demand, or left to run down, generating backlogs to be filled in a subsequent era. It results in reduced production transition costs but, as demand fluctuates, it creates problem inventories or backlogs over time.

D. Subcontracting: A plant can accommodate a high demand per- fil by subcontracting certain jobs, but subcontracting is costly, and, as a daily procedure, avoids sacrificing clients to rivals.

E. Workforce change: Workers can be hired or laid off to suit production needs (i.e., hiring new employees in peak demand periods and laying off in low demand periods). Nevertheless, the recruitment of new hires is expensive, and frequent hiring and firing as competition fluctuates is also destructive and demoralizing to the work- force.

A robust development plan's output has a direct effect on the profitability of the batch factory. A poor plan may result in loss of sales and profits if the available inventory and capacity cannot meet demand, or in excess inventory and capacity, resulting in cost increases. The following parts explain how a simulation model is built to facilitate quantitative planning process[9].

Aggregate Planning Variables

An intermediate demand forecast is based on aggregate planning or the development of a month-by-month intermediate range schedule for family of product service bundles. When demand meets trends, future demand may be expected, or "predictable" The accuracy with which future demand can be anticipated, however, reduces the further one tries to look into the future. Depending on the planning system a business uses, this forecasting feature may be more or less important like the following systems:

- System Make-to-Stock
- Customization system
- System of assembly-to-order.

The whole timetable in a Make-to - Stock framework is based on forecasted market figures. In a Make-to - Order system, when planning, managers have purchase orders in hand so they know the demand for products and services at least as far forward as their lead times for processing. Assembly-to-order systems are a combination of the approaches to making-to-stock and make-to-order. Customer orders are planned to be manufactured using assemblies and subassemblies that have been stored in stock. The set of planning variables available to the aggregate planner is quite limited: it shows only the inventory account, the monthly rate of production, the size of the work force and the extent of the subcontracting[10].

General Aggregate Planning Strategies

To meet anticipated consumer demand, aggregate planners can employ several techniques, such as:

- Production strategy at the level
- Demand strategy for Chase
- Plan for high demand

Demand is met in a production level strategy by altering the inventory account only. Demand is encountered in the chase demand strategy by balancing forecaster demand with the planned monthly output, while the inventory level is kept unchanged. In a peak demand strategy, particularly useful is service setting, capacity is varied at particular times to meet the highest level of demand. Aspects of these methods may also be blends with individual use. Khulna follows the chase demand strategy from the manufacturing industry that is investigated in this paper, Bangladesh Cable Shilpa limited. Changes in overtime utilization and the size of the work force are used in the chase demand strategy to adjust monthly output to match changes in forecast demand. Inventory level is kept constant. This strategy is suitable for both manufacturing and service operations where it is costly or impossible to hold inventories or keep a backlog.
Template Simulation of the Batch Plant Supply Chain
A simulation framework (template) has been developed and applied using the Simphony simulation environment, based on the principles outlined in the previous section. The template models a batch plant's supply chain through two main phases: demand modeling and operation of plants, and modeling of distributions. Figure 1 displays these stages, each with its own input and output. The section below explains the computational architecture of the simulation method

Demand Modeling
Modeling demand is the first step in the modeling process for the batch plant supply chain. The demand trend over a given time period can be created by three methods available in this template:

- Historical database: This approach enables simulation of the market for future based on historical market and a factor pattern. The raw data found in the historical demand is stored in a database and anticipated growth in demand is expressed by a user-defined trend factor:
  ED ¼ HD × TF
  Where demand for ED is expected; where historical demand is for HD; and where trend factor is TF
- Statistical distribution: Expected demand may be produced randomly from a statistical distribution (constant, uniform, triangular, regular, exponential, or beta) and the related parameters over a period of time.
- User specified formula: A formula can also be specified by the consumer to represent anticipated demand.

Plant operation and distribution
Four main criteria in batch plant operations are production, operating hours, product delivery, and base-line inventory volume. The template allows plant operations to be modelled by simulation of discrete events, with simulation time measured in minutes and running until all operations of the plan are complete. The simulation model produces the plant's actions at varying output levels, operating hours, delivery systems and setting of inventories

A. Production
The template models a make-to – order production method typical for batch plant production. Prior to delivery, customers place their orders and schedule their desired day of pickup. The batch plant plans its daily production based on orders from everyday customers. The following production-related factors are included in the model:
(i) production rate: overall quantity of product a facility will manufacture in unit time; (ii) use: fraction of capacity currently in use; (iii) conversion time: total time needed for the facility to transition from one standard to another (e.g., from one form of asphalt mix to another); (iv) level of customer service: fraction of orders delivered on schedule and in full; and (v) lack of sale;

B. Operating hours
Working hours represent the amount of hours a day at which the plant works to satisfy customer requirements. If the work hours needed to meet demand are higher than the actual normal working hours available (obtained by multiplying shift hours by the number of shifts a day), the discrepancy between the two is proportional to the overtime. The following considerations related to working hours are monitored in the model:
(i) Normal working hours: normal regular working hours needed to satisfy the daily demand of the customer; (ii) Average overtime: average overtime necessary to fulfill daily demand; (iii) Overall needed hours: cumulative working hour's necessary on any given day to meet demands in that day;

C. Distribution
Distribution involves the flow of batch plant pro-ducts to a number of clients. It affects plant sensitivity and productivity as on the same pick-up day scheduled by the consumer or sales would drop the plant needs to deliver the goods. Distribution also affects manufacturing capacity when storage capacity is limited. Unless the delivery is not coordinated with output, the latter would be disrupted after use of all storage space. However, some products (e.g., asphalt and concrete hot mix) can only be kept for a short time span. The prototype takes into account two delivery elements:

(i) Delivery mode: as almost all batch plants move goods via truck, this prototype focuses solely on the shipment of trucks; (ii) distribution network: two distribution network alternatives, direct shipping and shipping by distribution center, can be represented individually or in combination in this template.
The customers transport products directly from the batch plant with direct shipment; the major benefit is the elimination of intermediate storage space and simplified operations. Shipping through a distribution center divides customers by geo-graphic region, and batch plants transfer their shipments to the regional distribution center, which forward appropriate shipments to customers. The advantage of shipping is that it can serve distant customers through a distribution center. The template contains the following transport- related factors:
(i) I truck size: load size of each truck; (ii) truck inter-arrival time: time interval between trucks arriving for loading.

D. Baseline Inventory Level

Demand may be volatile at a batch plant and may appear shortly before production. Preparation time for a product (e.g. manufacturing a combination form with certain requirements) and constant juggling between different product configurations can lead to delays in consumer orders, leading to loss of revenue, and unsold inventory can only be kept at the factory for a very short period. The manufacturing and delivery processes thus need to be coordinated, and the intermediate inventory must be managed in order to minimize missed revenue and backlog. Two variables are taken into account with respect to inventory management, the replenishment quantity and the baseline quantity. The quantity replenishment controls order-up-to-level, which is held to circumvent excessive cost of replenishment. Baseline quantity defines the required inventory levels to prevent bottleneck in the face of unpredictable demand.

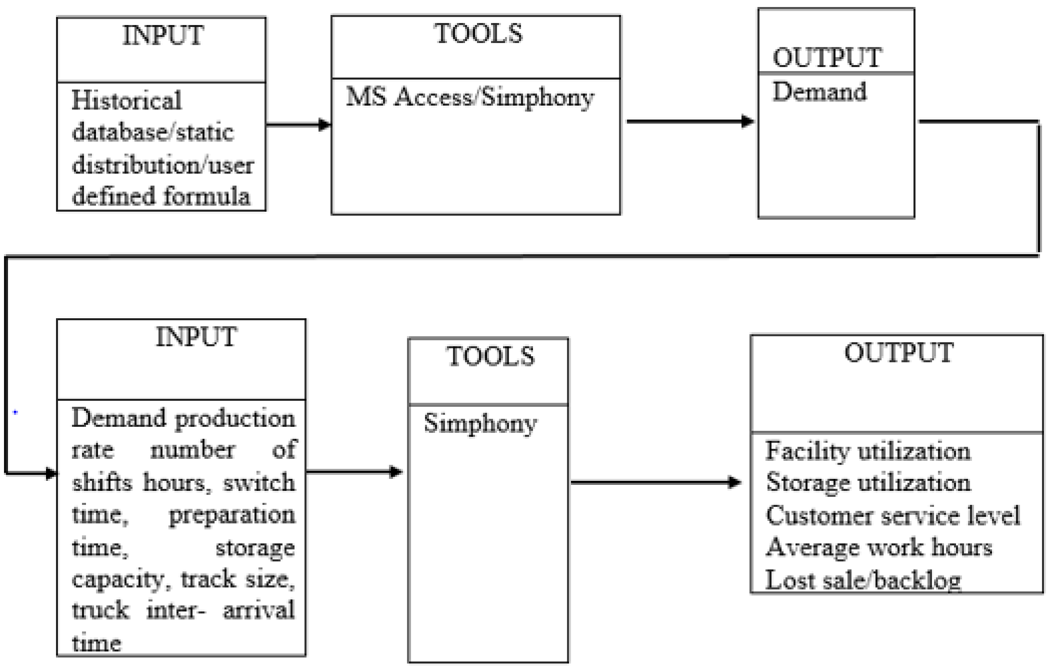

Figure 1. Main Components of Simulation Template.

2. Instrument used:

The instrument which is used in this paper is symphony.

Boundaries and Assumptions

The supply chain template for the batch plant includes the constraints and assumptions of following:

- Overtime constraints: These restrict the overall amount of overtime possible by allowing no employee to work more than a specified number of hours in any cycle, as defined by labor legislation or company rules.
- Labor constraints: Hiring and firing may have a huge negative effect on the workforce's productivity, so they must be limited.
- Restrictions on production capacity: This set of constraints limits overall production capacity to the total internal capacity available in each period.
- Constraints on storage space: The inventory volume cannot surpass the storage capacity available.
- Configuration constraints: Configuration requirements limit growth in storage space, improvements in processing facilities and changes in the delivery schedule.

- Customer constraints: Consumers have unique commodity re-quests, such as blend sort, date of delivery and place of pick-up.
- The simulation method is defined by two assumptions: In the template, the raw material supply at the batch plant is not considered. It is assumed that in advance of production a plant can obtain the raw materials.

Under this template subcontracted production is not included. Capacity for production is limited only to plant capacity.

Implementation of and Testing Of Simulation Models

The simulation template was implemented using the Sim-phony simulation environment. The template includes a number of modeling elements allowing the user to model the production and supply chain of batch plants. Additionally, elements from the Simphony. "General Purpose Model" can be developed into the layout. The elements in the supply chain template for the batch plant are given in Table 1.

Validation of Design Simulation

The validation method used as a reference model a batch plant model from published literature, HKCONSIM, Hong Kong Polytechnic University, Hong Kong, feeding the same initial input into the built prototype and comparing its output to the reference model. HKCONSIM is a computer program running in Hong Kong for the simulation of ready-mixed concrete (RMC) development. The feedback for both versions is based on data from one day of real service at an actual factory, with one batch bay serving 21 pours with 22 truck mixers. The Truck mixer fleet consists of 11 trucks with 5 m3 capacity and 11 trucks with 7 m3 capacity. The total volume of orders the fleet handles is 522 m3. The outputs generated by the developed model are similar to those of the HKCONSIM model — finish times and resource utilization rates. Table 2 outlines the outputs and their differences from both models. In Table 2, end-of-day finishing time is the total working time from the arrival of the first truck mixer at the concrete plant to the return of the last truck mixer from the site, the utilization rate at the plant is the fraction of time for which a bay is productive over the total working time and the utilization rate for truck mixers is the fraction of time for which a truck mixer is prod.

Although close, the output of both models shows consistent differences of around 7 percent, which are attributable to modeling approach differences, especially the method used to unload trucks. As the main purpose of the HKCONSIM model is to model concrete ready-mix operations, it takes into account the use of five different methods of unloading (pump, backhoe, direct tip, hoist and barrow, and crane and skip(s). The supply chain model focuses primarily on the overall supply chain and inventory levels and thus allows only one method (in this case, pump) to model the unloading process at a higher level. Despite the variations in the scale of modeling and degree of detail between the two models, the performance of the supply chain simulation model was deemed appropriate and ideal for evaluating and comparing different theories for a batch plant's overall supply chain.

Asphalt Plant Case Study

Problem description

Asphalt manufacturing is a traditional batch supply chain with plants consisting with processes of procurement, processing, inventory and delivery, but fluctuating procurement makes project preparation a difficult task. The case study concerns an asphalt manufacturer supplying a major Canadian city with two factories, one situated in the north of the city and one in the south. A recent producer study shows potential savings if a transfer depot is converted to the south plant. If the plant and warehouse would satisfy all the demand formerly met by two factories, though, is a major issue, as is if additional efficiency and storage space are currently required, so the optimal way to reduce inventory volume and yet fulfill the orders must be sought. The model was developed to simulate this scenario and find the best plant and depot layout to match current and potential demand trends.

The model assumes that consumer demand and storage space in the south depot would be the same as the current parameters for the south facility. The demand, production, storage and distribution processes for this particular case study are described in the following sections based on the actual practices of the producer:

Demand: Customers at both the plant and the depot place their orders one day ahead of time. The production of asphalt for the south depot begins after the orders from the north plant, which have higher priorities, have been filled in.

- **Production**: The northern plant currently produces 300 t / h and it takes an average of 30 min to switch mixtures. There are two working phases at the north factory, from 0600 to 1400 and from 1400 to 2200.
- **Storage**: Finished mixtures are processed up to 72 h in silos. A silo cannot be filled to more than 90 percent of its capacity and must be replenished immediately once emptied, unless the demand has been met. Unable to cover the silo when it is engaged in truck filling activities.
- **Distribution**: Trucks start to arrive at the northern plant from 0700 and are served in a FIFO (first in, first out) method after distribution of the last order from the north plant, transfer of asphalt to the south depot begins, occupying trucks from the plant.

Table 1: Batch Plant Supply Chain Model versus HKCONSIM.

Description	Validation Model	HKCONSIM	Difference (%)
End-of-day finish time (min)	640	690	7.40
Plant resources utilization rate (%)	40.11	36.70	7.59
Truck mixers utilization rate (%)	66.90	63	6.80

3. Data Collection and Analysis:

The analysis used a sample of real orders that were handled by the two operating plants. Table 2 provides a list of documents in the database including a total of 530 re-cords of truck loads from north (ID 370) and south (ID 371) plant sites dated January 2004 to December 2004. The order code is the number of codes for specific orders. In the database both the date and time for each load is re-corded. Brand ID and type of mix differentiate between different types of products which customers need. The load size represents the amount of asphalt (in tons) transported at any given time out of the factory. Specific customers are identified by customer name and customer number. The relevant data shall be filtered out and sorted before input into the simulation model to generate order information.

Table 2: Database of Truck Loading Records

Plant ID	Order code	Date load	Time of load	Product ID	Mix type	Load size (t)	Customer No.	Customer name
378	37073	2004–1–6	1445	8654	Cold mix	9.60	234232	MACO
379	37098	2004–1–9	1238	8632	16 mm	14.19	823445	MACO
371	37134	2004–1–5	1259	8832	Mix A	9.10	234552	METRO

Simulation model

A model was developed using the template described above, simulating the proposed plan of a northern production facility and a southern storage depot. Figure 3 displays a sample flow map. Rectangles are primary procedures, triangles are phases of action, ovals are procedures at the end of the day and hexagons are the beginning of the planning process.

The model, using a historical database from 2004, generates orders for both the north plant and the south depot. Orders from the north plant have a higher priority than those from the south depot. In a priority-based queue, the orders have not yet produced wait. Orders are shipped either from the north plant or from the south depot. Transport to the south depot is included in the simulation, but external distribution details are not, due to the difficulty in capturing the wide variation in that process.

The production rate and the switching time between mixtures determine the production time for the order. The mixer ma- chine is treated as a resource and is captured in the process of production. Then each type of mixture is deposited in various silos which are often known as capital. If all the silos are full it will interrupt production. The number and capacity of the silos at the north plant and south depot is specified in the model as data. The model is generating enough trucks automatically for the daily orders. Three different load sizes as input parameters are user-definable. Once the silo is ready, trucks load asphalt; trucks are supposed to be ready but truck loading and silo filling cannot occur at the same time. Silos are refillable if customer demands have not yet been met; the dumping rate for the supply truck determines refill speed at the south depot. The number of loading bays at the north plant and south depot must be defined in the simulation model, as well as the loading preparation time between trucks.

The real application of the model assumes a hierarchical structure. The first level in the simulation model is comprised of three main modelling elements: plant, transfer and depot. Bottom rates within each element define the element's de-tailed phase. Figure 4 displays a top-level screenshot and a section of the model under the feature "Plant'.

DISCUSSION

To quantify the effects of the factors affecting the plant's production capacity, a sensitivity analysis was performed. The ranges utilized by the producer are possible practical values. The following sections describe the key determinants of the results of the analysis.

Intermediate storage capacity

The first two factors investigated affecting intermediate storage capacity are capability and number of silos. Four curves represent 4 different capacities for the silo. Obviously, the work hours of the plant increase as the number of silos approaches zero; without intermediate storage, the production process can hardly be synchronized with the distribution process. When the number of silos increases, working hours gradually hit a fixed amount, and additional changes do not impact working hours. This is an expected behavior of working hours, as a function of the asphalt plant's intermediate storage capacity. Working time thresholds for the various intermediate storage capacities. Working hour thresholds are 6.46 and 12.89 h, respectively, at 200 and 300 t per silo, and the thresholds are reached at six silos. Working hour thresholds at 150 and 250 t per silo are 12.13 and 7.62 h respectively and the thresholds are reached at eight silos. Such values are critical in deciding the number and ability of silos needed in the northern factory.

The model shows, when comparing silo capacities ranging from 150 t to 300 t, that using 300 and 200 t silos results in maximum and minimum working hours, respectively. As the silo capacity decreases, intermediate storage replenishment occurs at a higher frequency, causing more interruptions to truck loading activities. As silo capacity reduces, however, so does replenishment time, and trucks have to wait longer to be filled. The simulation results show that 200 t is the most acceptable silo capacity for the set of parameters listed in Table 4, and that six silos are the most suitable number.

Production rate

The next variables considered in the sensitivity analysis are the rate of production and the time to switch between different settings of mixture. Nevertheless, since no more than three types of asphalt mixtures are used in a single day, swapping time is not a highly reactive determinant of working hours. If the rate of production increases, the hours of operation at the plant should decrease.

Distribution capacity

The following factors decide the plant's processing capacity: Truck loading preparation period and number of bays the number of bays represents the number of trucks that can be filled at the same period. The parameters assumed for the sensitivity analysis. If the inter-arrival time for the vehicle is limited to zero, the operating hours of the factory reach a set value reflecting stand-by time for trucks. Increasing inter-arrival time for trucks can obviously increase working hours for the plant. In addition, the work hours of the plant are sensitive to the number of bays when the number of bays changes from one to two, but when it changes from two to three bays, they are less sensitive.

Service Level

The final component is level of service, percentage of fulfilled demand on schedule and in full. The improvement in the standard of service relating to an increase in demand (the original demand from the 2004 order data) of up to 20%. If the demand remains consistent with the historical results, it meets about 95 percent of customer demand by converting the south plant to a transfer depot and then using the north plant for production. If the demand drops by 5%, the level of service will drop to about 84%, and if it increases by 20%, the level of service will drop to nearly 60%. Consequently, if demand is expected to increase by more than 5 percent, the northern plant’s facilities and capacity are insufficient to meet customer demand and the company should invest in new machinery and/or more storage space.

CONCLUSION

This paper described an approach based on simulation for batch plant modeling and aggregate planning. A simulation template is presented along with a real case study showing the use and benefits of that template. The simulation-based approach models the dynamics and constraints of a batch plant's growth, storage, and delivery processes and encourages testing with each of these processes with different parameters and configurations. The case study models an asphalt batch plant using the simulation template developed to examine the effect of various planning decisions on the level of service and working hours at the plant. The model demonstrated sensitivity to the number and capability of storage silos, and to any rise in consumer demand, within the ranges of model parameters defined by the asphalt manufacturer. The model also helped calculate optimal storage configurations (6 silos, 200 t each) and production rate (300 t / h) to ensure an appropriate quality of operation for the facility. The stated case represented a real world example where plant management required a detailed assessment of various change scenarios, and the model offered it, while taking into account much of the variables that con- strain the supply chain of the batch plant.

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