P A R T

III Case Study Assignments

These case studies have been used in senior- or graduate-level simulation classes. Each of these case studies can be analyzed over a three- to five-week period. A single student or a group of two to three students can work together on these case studies. If you are using the student version of the software, you may need to make some simplifying assumptions to limit the size of the model. You will also need to fill in (research or assume) some of the information and data missing from the case descriptions.

CASE STUDY 1

TOY AIRPLANE MANUFACTURING

A toy company produces three types (A, B, and C) of toy aluminum airplanes in the following daily volumes: A = 1000, B = 1500 and C = 1800. The company expects demand to increase for its products by 30 percent over the next six months and needs to know the total machines and operators that will be required. All planes go through five operations (10 through 50) except for plane A, which skips operation 40. Following is a list of operation times, move times, and resources used:

Opn	*Description*	*Operation Time*	*Resource*	*Move Time to Next Operation*	*Movement Resource*
10	Die casting	3 min. (outputs 6 parts)	Automated die caster	.3 min.	Mover
20	Cutting	Triangular (.25, .28, .35)	Cutter	none	
30	Grinding	Sample times: .23, .22, .26, .22, .25, .23, .24, .22, .21, .23, .20, .23, .22, .25, .23, .24, .23, .25, .47, .23, .25, .21, .24, .22, .26, .23, .25, .24, .21, .24, .26	Grinder	.2 min.	Mover
40	Coating	12 min. per batch of 24	Coater	.2 min	Mover
50	Inspection and packaging	Triangular (.27, .30, .40)	Packager	To exit with 88% yield	

After die casting, planes are moved to each operation in batch sizes of 24. Input buffers exist at each operation. The factory operates eight hours a day, five days per week. The factory starts out empty at the beginning of each day and ships all parts produced at the end of the day. The die caster experiences downtimes every 30 minutes exponentially distributed and takes 8 minutes normally distributed with a standard deviation of 2 minutes to repair. One maintenance person is always on duty to make repairs.

Find the total number of machines and personnel needed to meet daily production requirements. Document the assumptions and experimental procedure you went through to conduct the study.

CASE STUDY 2

MI CAZUELA—MEXICAN RESTAURANT

Maria opened her authentic Mexican restaurant Mi Cazuela (a *cazuela* is a clay cooking bowl with a small handle on each side) in Pasadena, California, in the 1980s. It quickly became popular for the tasty food and use of fresh organic produce and all-natural meats. As her oldest child, you have been asked to run the restaurant. If you are able to gain her confidence, she will eventually hand over the restaurant to you.

You have definite ideas about increasing the profitability at Mi Cazuela. Lately, you have observed a troubling trend in the restaurant. An increasing number of customers are expressing dissatisfaction with the long wait, and you have also observed that some people leave without being served.

Your initial analysis of the situation at Mi Cazuela indicates that one way to improve customer service is to reduce the waiting time in the restaurant. You also realize that by optimizing the process for the peak time in the restaurant, you will be able to increase the profit.

Customers arrive in groups that vary in size from one to four (uniformly distributed). Currently, there are four tables for four and three tables for two patrons in the dining area. One table for four can be replaced with two tables for two, or vice versa. Groups of one or two customers wait in one queue while groups of three or four customers wait in another queue. Each of these waiting lines can accommodate up to two groups only. One- or two-customer groups are directed to tables for two. Three- or four-customer groups are directed to tables for four.

There are two cooks in the kitchen and two waiters. The cooks are paid $100/day, and the waiters get $60/day. The cost of raw material (vegetables, meat, spices, and other food material) is $1 per customer. The overhead cost of the restaurant (rent, insurance, utilities, and so on) is $300/day. The bill for each customer varies uniformly from $10 to $16 or $U(13,3)$.

The restaurant remains open seven days a week from 5 P.M. till 11 P.M. The customer arrival pattern is as follows. The total number of customer groups visiting the restaurant each day varies uniformly between 30 and 50 or $U(40,10)$:

Customer Arrival Pattern

From	*To*	*Percent*
5 P.M.	6 P.M.	10
6 P.M.	7 P.M.	20
7 P.M.	9 P.M.	55
9 P.M.	10 P.M.	10
10 P.M.	11 P.M.	5

Processes at the Restaurant

When a table of the right size becomes available and a waiter is free, he or she seats the customer, writes down the order, and delivers the order to the kitchen. Cooks prepare the food in the kitchen and bring it out. Any available waiter delivers the food to the customer. Customers enjoy the dinner. A waiter cleans the table and collects payment from the customers. The customers leave the restaurant. The various activity times are as follows:

Activity #	*Activity*	*Activity Time Distributions*
1	Waiter seats the customer group.	$N(2, 0.5)$ min
2	Waiter writes down the order.	$N(3, 0.7)$ min
3	Waiter delivers the order to the kitchen.	$N(2, 0.5)$ min
4	Cook prepares food.	$N(5, 1)$ min
5	Cook brings out the food.	$N(2, 0.5)$ min
6	Waiter delivers food to customer group.	$N(2, 0.5)$ min
7	Customers eat.	$N(10, 2)$ min
8	Waiter cleans table and collects payment + tips.	$N(3, 0.8)$ min

Part A

Analyze and answer the following questions:

1. What is the range of profit (develop a $\pm 3\sigma$ confidence interval) per day at Mi Cazuela?
2. On average, how many customers leave the restaurant (per day) without eating?
3. What is the range of time (develop a $\pm 3\sigma$ confidence interval) a customer group spends at the restaurant?
4. How much time (develop a $\pm 3\sigma$ confidence interval) does a customer group wait in line?

Part B

You would like to change the mix of four-seat tables and two-seat tables in the dining area to increase profit and reduce the number of balking customers. You would also like to investigate if hiring additional waiters and/or cooks will improve the bottom line (profit).

Part C

You are thinking of using an automated handheld device for the waiters to take the customer orders and transmit the information (wireless) to the kitchen. The order entry and transmission (activities #2 and 3) is estimated to take $N(1.5, 0.2)$ minutes. The rent for each of these devices is $2/hour. Will using these devices improve profit? Reduce customer time in the system? Should you invest in these handheld devices?

Part D

The area surrounding the mall is going through a construction boom. It is expected that Mi Cazuela (and the mall) will soon see an increase in the number of patrons per day. Soon the number of customer groups visiting the restaurant is expected to grow to 50–70 per day, or $U(60,10)$. You have been debating whether to take over the adjoining coffeeshop and expand the Mi Cazuela restaurant. The additional area will allow you to add four more tables of four and three tables of two customers each. The overhead cost of the additional area will be $200 per day. Should you expand your restaurant? Will it increase profit?

How is your performance in managing Mi Cazuela? Do you think Mama Maria will be proud and hand over the reins of the business to you?

Case Study 3

Jai Hind Cycles Inc. Plans New Production Facility

Mr. Singh is the industrial engineering manager at Jai Hind Cycles, a producer of bicycles. As part of the growth plan for the company, the management is planning to introduce a new model of mountain bike strictly for the export market. Presently, JHC assembles regular bikes for the domestic market. The company runs one shift every day. The present facility has a process layout. Mr. Singh is considering replacing the existing layout with a group technology cell layout. As JHC's IE manager, Mr. Singh has been asked to report on the impact that will be made by the addition of the mountain bike to JHC's current production capabilities.

Mr. Singh has collected the following data from the existing plant:

1. The present production rate is 200 regular bikes per day in one 480-minute shift.
2. The following is the list of all the existing equipment in JHC's production facility:

Equipment Type	*Process Time*	*Quantity*
Forging	60 sec/large sprocket 30 sec/small sprocket	2
Molding	2 parts/90 sec	2
Welding	1 weld/60 sec	8
Tube bender	1 bend/30 sec	2
Die casting	1 part/minute	1
Drill press	20 sec/part	1
Punch press	30 sec/part	1
Electric saw	1 cut/15 sec	2
Assembly	30–60 minutes	

Table 1 shows a detailed bill of materials of all the parts manufactured by JHC and the machining requirements for both models of bikes. Only parts of the regular and the mountain bikes that appear in this table are manufactured within the plant. The rest of the parts either are purchased from the market or are subcontracted to the vendors.

A job-shop floor plan of the existing facility is shown in Figure 1. The whole facility is 500,000 square feet in covered area.

The figures for the last five years of the combined total market demand are as follows:

Year	*Demand*
1998	75,000
1999	82,000
2000	80,000
2001	77,000
2002	79,000

At present, the shortages are met by importing the balance of the demand. However, this is a costly option, and management thinks indigenously manufactured bikes of good quality would be in great demand.

Tasks

1. Design a cellular layout for the manufacturing facility, incorporating group technology principles.
2. Determine the amount of resources needed to satisfy the increased demand.
3. Suggest a possible material handling system for the new facility—conveyor(s), forklift truck(s), AGV(s).

TABLE 1 Detailed Bill of Materials for Jai Hind Cycles
Bicycle Parts and Process List

Assembly Name	*Subassembly Name*	*Part Name*	*Operations*				
1 Regular bike			Assembly				
	1.1 Bike frame		Assembly				
		1.1.1 Top tube	Cutting				
		1.1.2 Seat tube	Cutting				
		1.1.3 Down tube	Cutting				
		1.1.4 Head tube	Cutting				
		1.1.5 Fork blade	Cutting	Bending			
		1.1.6 Chainstay	Cutting				
		1.1.7 Seatstay	Cutting	Bending			
		1.1.8 Rear fork tip	Welding				
		1.1.9 Front fork tip	Welding				
		1.1.10 Top tube lug	Casting	Welding			
		1.1.11 Down tube lug	Casting	Welding			
		1.1.12 Seat lug	Casting	Welding			
		1.1.13 Bottom bracket	Casting	Welding			
	1.2 Handlebar and stem assembly		Assembly				
		1.2.1 Handlebars	Cutting	Bending			
		1.2.2 Handlebar plugs	Molding				
		1.2.3 Handlebar stem	Casting	Cutting			
	1.3 Saddle post assembly		Assembly				
		1.3.1 Saddle	Molding				
		1.3.2 Seat post	Cutting				
	1.4 Drive chain assembly		Assembly				
		1.4.1 Crank spider	Forging				
		1.4.2 Large sprocket	Forging				
		1.4.3 Small sprocket	Forging				
2 Mountain bike			Assembly				
	2.1 Frame and handle bar		Assembly				
		2.1.1 Hub	Cutting				
		2.1.2 Frame legs	Cutting	Bending	Bending		
		2.1.3 Handlebar tube	Cutting	Welding	Welding	Welding	Welding
		2.1.4 Saddle post tube	Cutting				
		2.1.5 Handlebar	Cutting				
		2.1.6 Balance bar	Cutting	Welding	Welding		
	2.2 Saddle and seat post		Assembly				
		2.2.1 Handlebar post	Cutting				
		2.2.2 Saddle post	Cutting	Drill press			
		2.2.3 Mount brackets	Cutting	Drill press	Welding	Welding	
		2.2.4 Axle mount	Cutting	Punch press	Welding	Welding	
		2.2.5 Chain guard	Molding				

4. How many shifts per day does JHC need to work?
5. Develop a staffing plan for the present situation and for the new situation.
6. Develop a cost model and economic justification for the growth plan. Is the increased production plan justified from an economic standpoint?

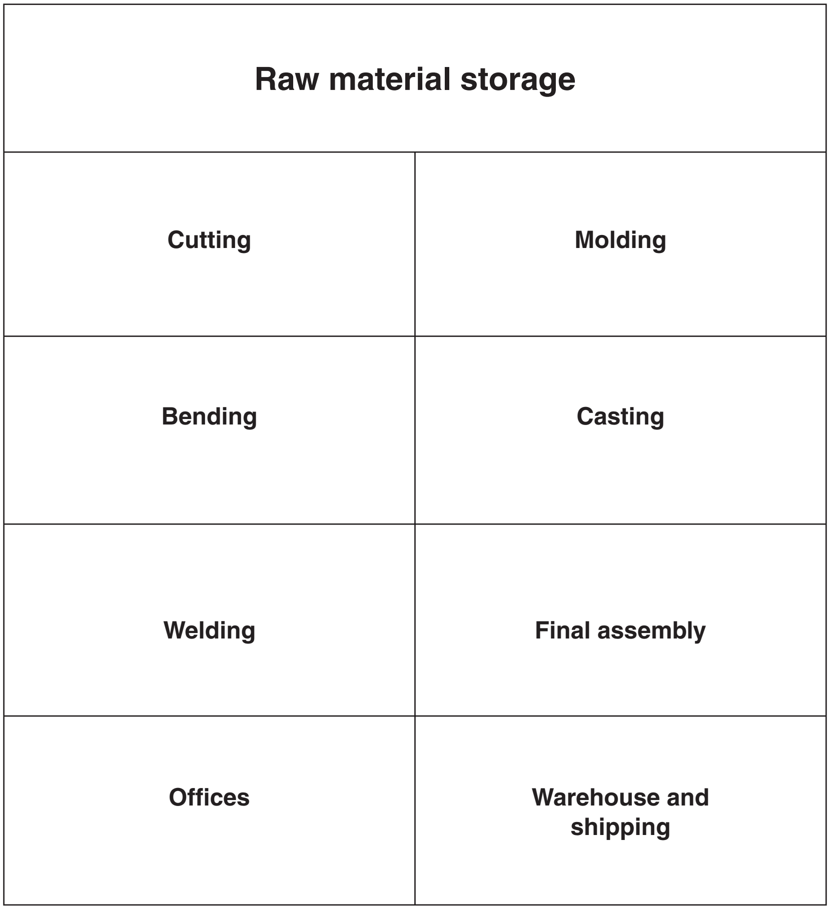


Figure 1
Floor plan for Jai Hind Cycles.

Case Study 4

The FSB Coin System

George A. Johnson
Idaho State University
Todd Cooper
First Security Bank

Todd had a problem. First Security Bank had developed a consumer lending software package to increase the capacity and speed with which auto loan applications could be processed. The system consisted of faxed applications combined with online processing. The goal had been to provide a 30-minute turnaround of an application from the time the bank received the faxed application from the dealer to the time the loan was either approved or disapproved. The system had recently been installed and the results had not been satisfactory. The question now was what to do next.

First Security Bank of Idaho is the second largest bank in the state of Idaho with branches throughout the state. The bank is a full-service bank providing a broad range of banking services. Consumer loans and, in particular, auto loans make up an important part of these services. The bank is part of a larger system covering most of the intermountain states, and its headquarters are in Salt Lake City.

The auto loan business is a highly competitive field with a number of players including full-line banks, credit unions, and consumer finance companies. Because of the highly competitive nature, interest rates tend to be similar and competition is based on other factors. An important factor for the dealer is the time it takes to obtain loan approval. The quicker the loan approval, the quicker a sale can be closed and merchandise moved. A 30-minute turnaround of loan applications would be an important factor to a dealer, who has a significant impact on the consumer's decision on where to seek a loan.

The loan application process begins at the automobile dealership. It is there that an application is completed for the purpose of borrowing money to purchase a car. The application is then sent to the bank via a fax machine. Most fax transmissions are less than two minutes in length, and there is a bank of eight receiving fax machines. All machines are tied to the same 800 number. The plan is that eight machines should provide sufficient capacity that there should never be the problem of a busy signal received by the sending machine.

Once the fax transmission is complete, the application is taken from the machine by a runner and distributed to one of eight data entry clerks. The goal is that data entry should take no longer than six minutes. The goal was also set that there should be no greater than 5 percent errors.

Once the data input is complete, the input clerk assigns the application to one of six regions around the state. Each region has a group of specific dealers determined by geographic distribution. The application, now electronic in form, is distributed to the regions via the wide area network. The loan officer in the respective region will then process the loan, make a decision, and fax that decision back to the dealer. The goal is that the loan officer should complete this function within 20 minutes. This allows about another two minutes to fax the application back to the dealer.

The system has been operating approximately six months and has failed to meet the goal of 30 minutes. In addition, the error rate is running approximately 10 percent. Summary data are provided here:

Region	*Applications*	*Average Time*	*Number of Loan Officers*
1	6150	58.76	6
2	1485	37.22	2
3	2655	37.00	4
4	1680	51.07	2
5	1440	37.00	2
6	1590	37.01	3

A weighted average processing time for all regions is 46.07 minutes.

Information on data input indicates that this part of the process is taking almost twice as long as originally planned. The time from when the runner delivers the document to when it is entered is currently averaging 9.5 minutes. Also, it has been found that the time to process an error averages six minutes. Errors are corrected at the region and add to the region's processing time.

Todd needed to come up with some recommendations on how to solve the problem. Staffing seemed to be an issue in some regions, and the performance of the data input clerks was below expectations. The higher processing times and error rates needed to be corrected. He thought that if he solved these two problems and increased the staff, he could get the averages in all regions down to 30 minutes.

CASE STUDY 5

AUTOMATED WAREHOUSING AT ATHLETIC SHOE COMPANY

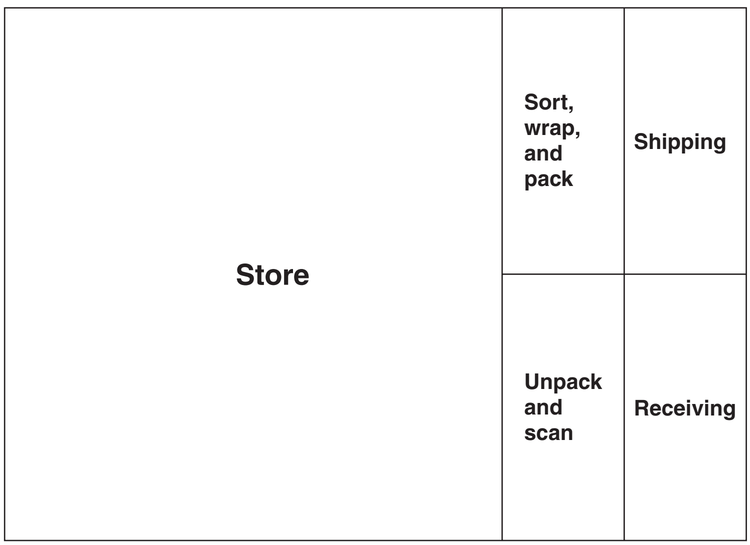
The centralized storage and distribution operation at Athletic Shoe Company (ASC) is considering replacement of its conventional manual storage racking systems with an elaborate automated storage and retrieval system (AS/RS). The objective of this case study is to come up with the preliminary design of the storage and material handling systems for ASC that will meet the needs of the company in timely distribution of its products.

On average, between 100,000 and 150,000 pairs of shoes are shipped per day to between 8000 and 10,000 shipping destinations. In order to support this level of operations, it is estimated that rack storage space of up to 3,000,000 pairs of shoes, consisting of 30,000 stock-keeping units (SKUs), is required.

The area available for storage, as shown in Figure 1, is 500,000 square feet. The height of the ceiling is 40 feet. A first-in, first-out (FIFO) inventory policy is adopted in the

FIGURE 1

Layout of the Athletic Shoe Company warehouse.



warehouse. For storage and retrieval, consider the following options:

a. A dedicated picker for each aisle.
b. A picker that is shared between the storage aisles.

For material handling in the shipping and receiving areas, and also between the storage areas and the shipping/receiving docks, consider one or more of the following options:

a. Forklift trucks.
b. Automated guided vehicles.
c. Conveyors.

You as the warehouse manager would like to discourage many different types of material handling devices. The number of types of devices should be kept to a minimum, thus avoiding complicated interface problems.

The weight of the shoeboxes varies from one to six pounds with a mode of four pounds. All the boxes measure 18" long 12" wide 5" high. Because of the construction of the boxes and the weight of the shoes, no more than eight boxes can be stacked up on each other.

The general process flow for receiving and shipping of shoes is as follows:

Receiving

1. Unload from truck.
2. Scan the incoming boxes/pallets.
3. Send to storage racks.
4. Store.

Shipping

1. Batch pick shipping orders.
2. Send to sortation system.
3. Wrap and pack.
4. Load in outgoing truck.

Tasks

1. Construct a simulation model of the warehouse and perform experiments using the model to judge the effectiveness and efficiency of the design with respect to parameters such as flows, capacity, operation, interfacing, and so on.
2. Write a detailed specification of the storage plan: the amount of rack storage space included in the design (capacity), rack types, dimensions, rack configurations, and aisles within the layout.
3. Design and specify the material handling equipment for all of the functions listed, including the interfaces required to change handling methods between functions.
4. Design and specify the AS/R system. Compare a dedicated versus a shared picker system.

5. Plan the staffing requirements.
6. How many shifts should this warehouse be working?
7. Estimate the throughput for the warehouse per shift, per day, per year. What are the design parameters necessary for each function to attain the indicated level of throughput?
8. Develop a detailed facilities layout of the final design, including aisles and material handling equipment.
9. Develop a cost estimate for the proposed design.

Case Study 6

Concentrate Line at Florida Citrus Company

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Florida Citrus Company (FCC), located in Tampa, Florida, is a subdivision of Healthy Foods Inc., which currently has 12,000 employees in 50 food production facilities around the world.

FCC has specialized in producing a wide range of juice products for the past 50 years. FCC employs about 350 employees. Its juice products are primarily divided in the following four categories: aseptic products, juice concentrate, jug products, and cup products.

Based on the product categories, the manufacturing facility is divided into four cells. Each cell has a different kind of machine setting and configuration. The machines and equipment are mostly automatic. The aseptic cell is comprised of 44£125 machine, 36£125 machine, J.J. Var., and J.J. Rainbows. Depending on the demands of these sizes, the equipment is flexible to interchange based on the customer orders. The concentrate line generally produces concentrated juices for different private labels such as Vons, Stater Bros., Ralph's, Kroger, and Lucky's. The concentrate line produces fruit concentrates such as kiwi–strawberry, apple, orange, lemonade, and grape. The jug line seldom operates as the demand is poor. The cup line is the fastest-growing product in the business. It produces mainly apple, orange, grape, and lemonade flavors.

The concentrate line is currently not able to meet the budgeted case rate standard. FCC is seeking to find the real causes that contribute to the current production problem. The company also wants to improve the facility layout and reduce inventory levels in the concentrate line.

The concentrate line is divided into five stations:

1. Depalletizer: Tri-Can
2. Filler: Pfaudler
3. Seamer: Angelus
4. Palletizer: Currie
5. Packer: Diablo

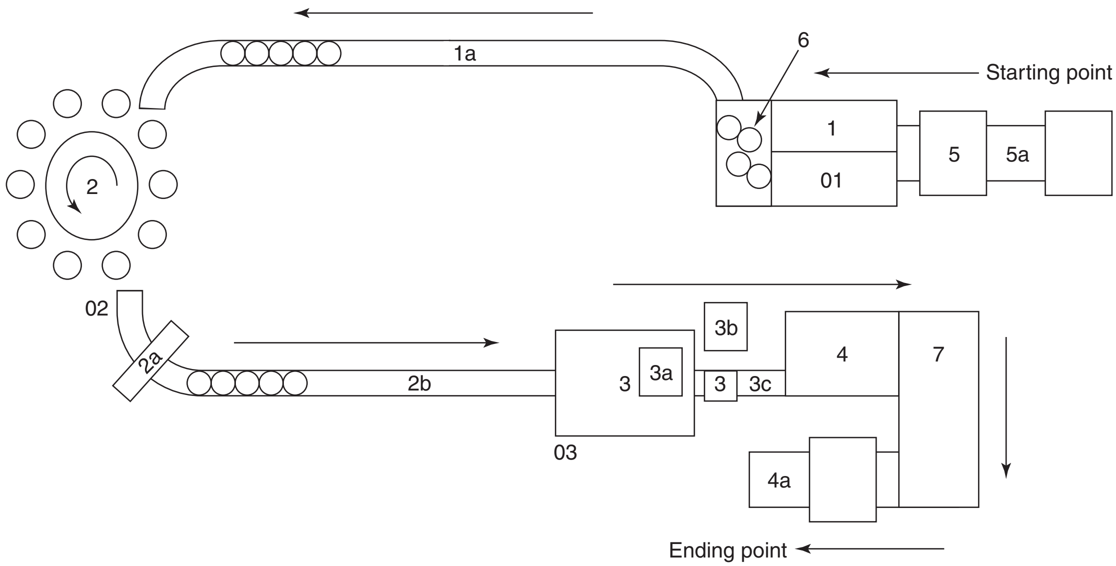
The current concentrate line production is as follows:

Equipment Description	*Rated Speed*	*Operating Speed*
Filler	1750 cases/hr	600 cans/min
Seamer	1500 cases/hr	600 cans/min
Packer	1800 cases/hr	28 cases/min
Palletizer	1800 cases/hr	28 cases/min
Depalletizer	1800 cases/hr	600 cans/min
Bundler	1500 cases/hr	550 cans/min

The concentrate line stations and the flow of production are shown in Figure 1. The concentrate line starts from the receiving area. Full pallet loads of 3600 empty cans in 10 layers arrive at the receiving area. The arrival conveyor transports these pallets to the depalletizer (1). The cans are loaded onto the depalletizer, which is operated by Don.

FIGURE 1

Concentrate line stations for Florida Citrus Company.



1. Depalletizer
2. Pfaudler bowl
3. Packmaster
4. Palletizer
5. The pallet
6. The concentrate cans
7. The box organizer
8. The box

1a. Depalletizer conveyor
2a. Lid stamping mechanism
2b. Filler bowl conveyor
3a. Glue mechanism
3b. Cardboard feeding machine
3c. Packmaster conveyor
4a. Exit conveyor
5a. Conveyor to the depalletizer

01 Operator 1
02 Operator 2
03 Operator 3

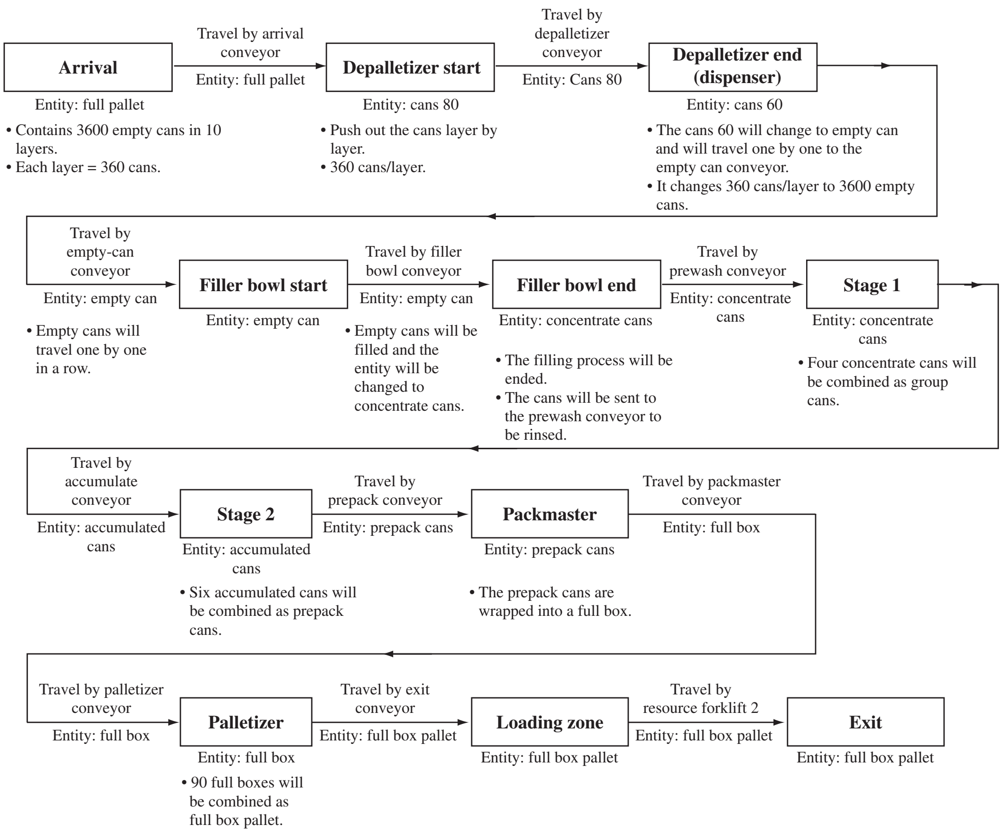
The depalletizer pushes out one layer of 360 cans at a time from the pallet and then raises up one layer of empty cans onto the depalletizer conveyor belt (1a). Conveyor 1a transports the layer of cans to the depalletizer dispenser. The dispenser separates each can from the layer of cans. Individual empty cans travel on the empty can conveyor to the Pfaudler bowl.

The Pfaudler bowl is a big circular container that stores the concentrate. Its 36 filling devices are used to fill the cans with concentrate. Pamela operates the Pfaudler bowl. Empty cans travel on the filler bowl conveyor (2b) and are filled with the appropriate juice concentrate. Filled cans are sent to the lid stamping mechanism (2a) on the filler bowl conveyor. The lid stamping closes the filled cans. As the closed cans come through the lid stamping mechanism, they are transported by the prewash conveyor to the washing machine to be flushed with water to wash away any leftover concentrate on the can. Four closed cans are combined as a group. The group of cans is then transported by the accumulate conveyor to the accumulator.

The accumulator combines six such groups (24 cans in all). The accumulated group of 24 cans is then transported by the prepack conveyor to the Packmaster (3), operated

FIGURE 2

Process flow for Florida Citrus Company.



by Pat. Pat loads cardboard boxes onto the cardboard feeding machine (3b) next to the Packmaster. Then the 24 cans are wrapped and packed into each cardboard box. The glue mechanism inside the Packmaster glues all six sides of the box. The boxes are then raised up to the palletizer conveyor (3c), which transports the boxes to the palletizer (4).

The box organizer (7) mechanism loads three boxes at a time onto the pallet. A total of 90 boxes are loaded onto each pallet (10 levels, 9 boxes per level). The palletizer then lowers the pallet onto the exit conveyor (4a) to be transported to the loading zone. From the loading zone a forklift truck carries the pallets to the shipping dock. Figure 2 describes the process flow.

A study conducted by a group of Cal Poly students revealed the cause of most downtime to be located at the Packmaster. The Packmaster is supposed to pack a group of cans into a cardboard box. However, if the cardboard is warped, the mechanism will stop the operation. Another problem with the Packmaster is its glue operation. The glue heads sometimes are clotted.

All these machines operate in an automatic manner. However, there are frequent machine stoppages caused by the following factors: change of flavor, poor maintenance, lack of communication between workers, lack of attention by the workers, inefficient layout of the concentrate line, and bad machine design.

All the stations are arranged in the sequence of the manufacturing process. As such, the production line cannot operate in a flexible or parallel manner. Also, the machines depend on product being fed from upstream processes. An upstream machine stoppage will cause eventual downstream machine stoppages.

Work Measurement

A detailed production study was conducted that brought out the following facts:

Packmaster

Juice Flavors	*Working Time (%)*	*Down Time (%)*
Albertson's Pink Lemonade	68.75	31.25
Albertson's Pink Lemonade	77.84	22.16
Best Yet Orange Juice	71.73	28.27
Crisp Lemonade	65.75	34.25
Flav-R-Pac Lemonade	76.35	23.65
Fry's Lemonade	78.76	21.24
Hy-Top Pink Lemonade	68.83	31.17
IGA Grape Juice	83.04	16.96
Ladylee Grape Juice	93.32	6.68
Rosauer's Orange Juice	51.40	48.60
Rosauer's Pink Lemonade	61.59	38.41
Smith's Kiwi Raspberry	75.16	24.84
Smith's Kiwi Strawberry	85.05	14.95
Stater Bros. Lemonade	21.62	78.38
Stater Bros. Pink Lemonade	86.21	13.79
Western Family Pink Lemonade	64.07	35.93

The production study also showed the label change time on the Packmaster as follows:

Flavor from	*Flavor to*	*Label Change Time (sec)*
Albertson's Pink Lemonade	Western Family Pink Lemonade	824
Fry's Lemonade	Flav-R-Pac Lemonade	189
IGA Grape Juice	Ladylee Grape Juice	177
Rosauer's Pink Lemonade	Albertson's Pink Lemonade	41
Smith's Kiwi Raspberry	IGA Grape Juice	641
Smith's Kiwi Strawberry	Smith's Kiwi Raspberry	66
Stater Bros. Lemonade	Stater Bros. Pink Lemonade	160

The Packmaster was observed for a total of 45,983 sec. Out of this time, the Packmaster was working for a total of 24,027 sec, down for 13,108 sec, and being set up for change of flavor for 8848 sec. The average flavor change time for the Pfaudler bowl is 19.24 percent of the total observed time. The number of cases produced during this observed time was 11,590. The production rate is calculated to be (11,590/46,384)3600, or about 907 cases per hour.

It was also observed that the Packmaster was down because of flipped cans (8.6 percent), sensor failure (43.9 percent), and miscellaneous other reasons (47.5 percent).

The following information on the conveyors was obtained:

Name of Conveyor	*Length (ft.)*	*Speed (ft/min)*
Arrival conveyor		
Depalletizer conveyor	28.75	12.6
Empty-cans conveyor	120	130
Filler bowl conveyor	10	126
Prewash conveyor	23.6	255
Accumulate conveyor	38	48
Prepack conveyor	12	35
Palletizer conveyor	54.4	76
Exit conveyor		

The Pfaudler bowl was observed for a total of 46,384 sec. Out of this time, the bowl was working for 27,258 sec, down for 10,278 sec, and being set up for change of flavor for 8848 sec. The average flavor change time for the Pfaudler bowl is 19.08 percent of the total observed time. The number of cases produced in this observed time was 11,590. The production rate is calculated to be (11,590/46,384)3600, or about 900 cases per hour.

Pfaudler Bowl

Fruit Juice Flavors	*Working Time (%)*	*Down Time (%)*
Albertson's Pink Lemonade	74.81	25.19
Albertson's Wild Berry Punch	88.20	11.80
Best Yet Grape Juice	68.91	31.09
Best Yet Orange Juice	86.08	13.92
Crisp Lemonade	53.21	46.79

(*continued*)

Fruit Juice Flavors	*Working Time (%)*	*Down Time (%)*
Flav-R-Pac Lemonade	79.62	20.38
Flavorite Lemonade	69.07	30.93
Fry's Lemonade	80.54	19.46
Hy-Top Pink Lemonade	81.85	18.15
IGA Grape Juice	89.93	10.07
IGA Pink Lemonade	45.54	54.46
Ladylee Grape Juice	94.36	5.64
Ladylee Lemonade	91.86	8.14
Rosauer's Orange Juice	64.20	35.80
Rosauer's Pink Lemonade	100.00	0.00
Smith's Kiwi Raspberry	92.71	7.29
Smith's Kiwi Strawberry	96.49	3.51
Special Value Wild Berry Punch	80.09	19.91
Stater Bros. Lemonade	26.36	73.64
Stater Bros. Pink Lemonade	90.18	9.82
Western Family Pink Lemonade	66.30	33.70

The flavor change time was observed as given in the following table:

Flavor from	*Flavor to*	*Flavor Change Time (sec)*
Albertson's Lemonade	Rosauer's Pink Lemonade	537
Albertson's Lemonade	Albertson's Pink Lemonade	702
Albertson's Limeade	Fry's Lemonade	992
Albertson's Pink Lemonade	Western Family Pink Lemonade	400
Albertson's Pink Lemonade	IGA Pink Lemonade	69
Albertson's Wild Berry Punch	Special Value Apple Melon	1292
Best Yet Grape Juice	Special Value Wild Berry Punch	627
Flav-R-Pac Lemonade	Flavorite Lemonade	303
Flav-R-Pac Orange Juice	Rosauer's Orange Juice	42
Flavorite Lemonade	Ladylee Lemonade	41
Fry's Lemonade	Flav-R-Pac Lemonade	183
Furr's Orange Juice	Best Yet Orange Juice	684
Hy-Top Grape Juice	Best Yet Grape Juice	155
Hy-Top Pink Lemonade	Flav-R-Pac Lemonade	49
IGA Grape Juice	Ladylee Grape Juice	67
IGA Pink Lemonade	Best Yet Pink Lemonade	0
Ladylee Grape Juice	Albertson's Grape Juice	100
Ladylee Lemonade	Crisp Lemonade	49
Ladylee Pink Lemonade	Hy-Top Pink Lemonade	0
Rosauer's Orange Juice	Flavorite Orange Juice	0
Rosauer's Pink Lemonade	Albertson's Pink Lemonade	98
Smith's Apple Melon	Smith's Kiwi Strawberry	382
Smith's Kiwi Raspberry	IGA Grape Juice	580
Smith's Kiwi Strawberry	Smith's Kiwi Raspberry	53
Special Value Wild Berry Punch	Albertson's Wild Berry Punch	62
Stater Bros. Lemonade	Stater Bros. Pink Lemonade	50
Western Family Pink Lemonade	Safeway Pink Lemonade	1153

Tasks

1. Build simulation models and figure out the production capacity of the concentrate line at FCC (without considering any downtime).
2. What would be the capacity after considering the historical downtimes in the line?
3. What are the bottleneck operations in the whole process?
4. How can we reduce the level of inventory in the concentrate line? What would be the magnitude of reduction in the levels of inventory?
5. If we address the bottleneck operations as found in task 3, what would be the increase in capacity levels?

CASE STUDY 7

BALANCING THE PRODUCTION LINE AT SOUTHERN CALIFORNIA DOOR COMPANY

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Southern California Door Company produces solid wooden doors of various designs for new and existing homes. A layout of the production facility is shown in Figure 1. The current production facility is not balanced well. This leads to frequent congestion and stockouts on the production floor. The overall inventory (both raw material and work in process) is also fairly high. Mr. Santoso, the industrial engineering manager for the company, has been asked by management to smooth out the flow of production as well as reduce the levels of inventory. The company is also expecting a growth in the volume of sales. The production manager is asking Mr. Santoso to find the staffing level and equipment resources needed for the current level of sales as well as 10, 25, 50, and 100 percent growth in sales volume.

A preliminary process flow study by Mr. Santoso reveals the production flow shown in Figure 2.

Process Flow

Raw wood material is taken from the raw material storage to carriage 1. The raw material is inspected for correct sizes and defects. Material that does not meet the specifications is moved to carriage 1B. Raw wood from carriage 1 is fed into the rip saw machine.

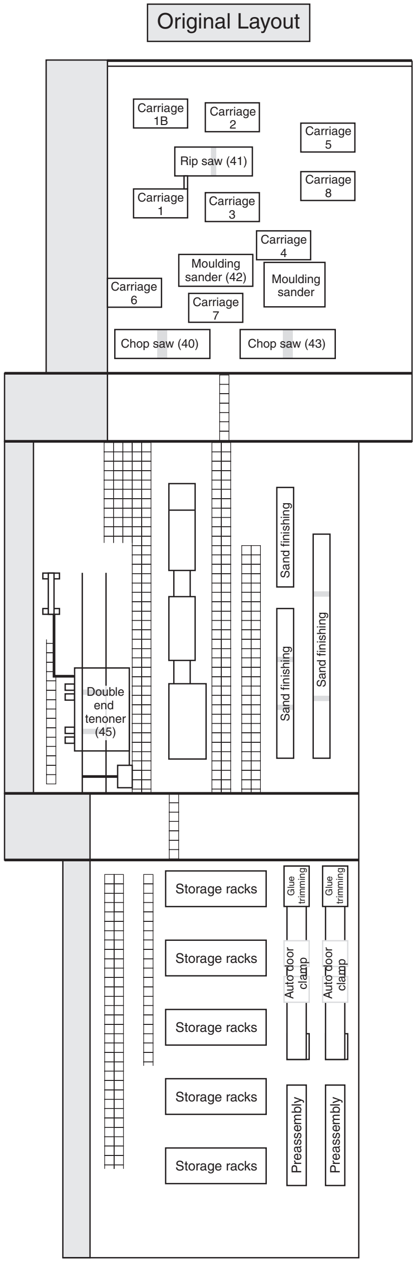
In the rip saw machine, the raw wood is cut into rectangular cross sections. Cut wood material coming out of the rip saw machine is placed on carriage 3. Waste material from the cutting operation (rip saw) is placed in carriage 2.

Cut wood from carriage 3 is brought to the moulding shaper and grooved on one side. Out of the moulding shaper, grooved wood material is placed on carriage 4. From carriage 4, the grooved wood is stored in carriage 5 (if carriage 5 is full, carriage 6 or 7 is used). Grooved wood is transported from carriages 5, 6, and 7 to the chop saw working table.

One by one, the grooved wood material from the chop saw working table is fed into the chop saw machine. The grooved wood material to be fed is inspected by the operator to see if

FIGURE 1

Layout of production facility at Southern California Door Company.

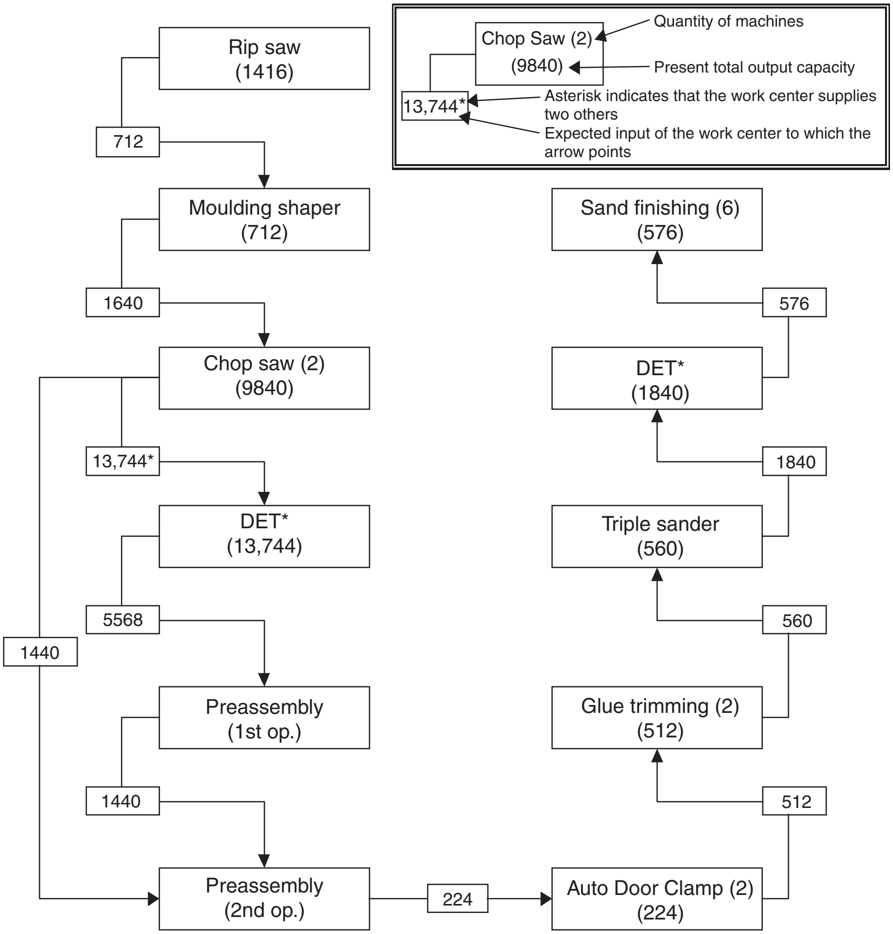


there are any defects in the wood. Usable chopped parts from the chop saw machine are stored in the chop saw storage shelves. Wood material that has defects is chopped into small blocks to cut out the defective surfaces using the chop saw and thrown away to carriage 8.

The chopped parts in the chop saw storage shelves are stacked into batches of a certain number and then packed with tape. From the chop saw storage shelves, some of the batches

FIGURE 2

Process sequences and present input/output flow for Southern California Door Company.



The present total output capacity of DET represents the number of units of a single product manufactured in an eight-hour shift. The DET machine supplies parts for two other work centers, preassembly (1st op.) and sand finishing. In reality, the DET machine has to balance the output between those two work centers mentioned; in other words, the DET machine is shared by two different parts for two different work centers during an eight-hour shift.

are transported to the double end tenoner (DET) storage, while the rest of the batches are kept in the chop saw storage shelves.

The transported batches are unpacked in the DET storage and then fed into the DET machine to be grooved on both sides. The parts coming out of the DET machine are placed on a roller next to the machine.

The parts are rebatched. From the DET machine, the batches are transported to storage racks and stored there until further processing. The batches stored in the chop saw storage shelves are picked up and placed on the preassembly table, as are the batches stored in the storage racks. The operator inspects to see if there is any defect in the wood. Defective parts are then taken back from the preassembly table to the storage racks.

The rest of the parts are given to the second operator in the same workstation. The second operator tries to match the color pattern of all the parts needed to assemble the door (four frames and a center panel). The operator puts glue on both ends of all four frame parts and preassembles the frame parts and center panel together.

The frame–panel preassembly is moved from the preassembly table to the auto door clamp conveyor and pressed into the auto door clamp machine. The pressed assembly is taken out of the auto door clamp machine and carried out by the auto door clamp conveyor.

Next, the preassembly is picked up and placed on the glue trimming table. Under a black light, the inspector looks for any excess glue coming out of the assembly parting lines. Excess glue is trimmed using a specially designed cutter.

From the glue trimming table, the assembly is brought to a roller next to the triple sanding machine (the auto cross grain sander and the auto drum sander). The operator feeds the assembly into the triple sander. The assembly undergoes three sanding processes: one through the auto cross grain sander and two through the auto drum sander. After coming out of the triple sander machine, the sanded assembly is picked up and placed on a roller between the DET and the triple sander machine. The sanded assembly waits there for further processing. The operator feeds the sanded assembly into the DET machine, where it is grooved on two of the sides.

Out of the DET machine, the assembly is taken by the second operator and placed temporarily on a roller next to the DET machine. After finishing with all the assembly, the first operator gets the grooved assembly and feeds it to the DET machine, where the assembly is grooved again on the other two sides. Going out of the machine, the grooved assembly is then placed on a roller between the DET machine and the triple sander machine.

The assembly is stored for further processing. From the roller conveyor, the grooved assembly is picked up by the operators from the sand finishing station and placed on the table. The operators finish the sanding process on the table using a handheld power sander. After finishing the sanding, the assembly is placed on the table for temporary storage. Finally, the sanded assembly is moved to a roller next to the storage racks to wait for further processes.

Work Measurement

A detailed work measurement effort was undertaken by Santoso to collect data on various manufacturing processes involved. Table 1 summarizes the results of all the time studies.

The current number of machines and/or workstations and their output capacities are as follows:

		Output Capacities	
Machine	*Number of Machines*	*Units/Hour*	*Units/Shift*
Rip saw	1	177	1416
Moulding shaper	1	89	712
Chop saw	2	615	4920
DET	1	3426	13,744
Preassembly 1	1	696	5568
Preassembly 2	1	90	720
Auto door clamp	2	14	224
Glue trimming	2	32	512
Triple sander	1	70	560
DET	1	460	1840
Sand finishing	6	12	576

TABLE 1 Time Studies Results for Southern California Door Company

Machine Name	*Machine Number*	*Operation*	*Task Number*	*Task Description*	*Task Observations (seconds)*
Rip saw	41	Cut raw material into correct cross-sectional dimensions	1	Inspect size and make adjustments	5.7,6.6,5.05,6.99,5.93,7.52, 5.37,7.21,8.96,6.68
			2	Grasp raw wood and feed into rip saw machine	6.79,6.3,7.52,6.15,6.53,6.03, 6.09,7.31,7,5.78,
			3	Cut wood with rip saw	12.4,11.53,11.26,12.88,11.56, 10.38,11.31,11.85,12.78,11.88
			4	Remove cut pieces from rip saw and place in carriage 3; throw waste into carriage 4	10.56,9.94,9.78,11.9,11.44, 8.87,7.35,10.93,12.47,10.34
Moulding shaper	42	Grooving one side of the raw material	1	Get cut material from carriage 3	11.52,12.83,14.64,8.25,12.58, 13.81,13.68,12.21,6.17,15.06, 11.93
			2	Place cut pieces onto moulding shaper	16.61,16.58,14.43,21.16, 18.17,25.14,26.15,30.06,35.16, 25.06,24.37
			3	Groove one side of material with moulding shaper	28.13,29.41,29.07,31.41,30.75, 38.95,39.83,42.27,39.32, 40.12,36.3
Chop saw	40, 43	Chop material into proper lengths	1	Inspect grooved material for size and defects	2.68,2.08,2.24,1.61,2.3,2.99, 3.02,3.11,3.21,3.02,3.06,2.79, 2.51,2.96,3.23,2.37,2.64
			2	Feed material and chop to smaller pieces	16.81,14.56,18.81,20.13, 23.25,18.53,16.53,25.56,25.3, 24.78,15.42,13.92,15.48,20.51, 17.79,23.54,17.01
			3	Throw away defective parts to carriage 8 and stack chopped parts	9.19,9.03,13.16,10.78,5.69, 4.1,6.9,9.16,3.6,3.22,8.83, 12.63,14.94,12.86,10.25,0.76, 10.63
Double end tenoner (DET)	45	Grooving frames	1	Get 2 to 4 frames from stack and feed into DET	9.33,14.7,10.18,14.47,13.12, 12.49,13.12,12.76,32.15, 33.94,13.23,11.97,9.21,24.86, 18.29,29.74,16.53,14.24, 12.78,15.38
			2	DET grooves both sides of frames	60.21,58.77,57.23,59.81, 61.64,60.29,59.85,61.43, 63.59,62.71,61.2,59.19,58.47, 60.27,59.73,60.21,61.82, 62.85,58.94,57.23
			3	Remove frames and stack	10.4,11.57,19.15,16.94,12.68, 31.47,36.97,13,14.5,14.62, 15.76,26.82,32.14,30.67,22.43, 29.61,34.92,18.27,20.31,24.88
Preassembly 1		Inspecting and matching frame parts	1	Get frame parts from storage racks	49.82,50.08,19.35,32.54, 35.31,33.43,37.84,42.17, 49.04,55.09

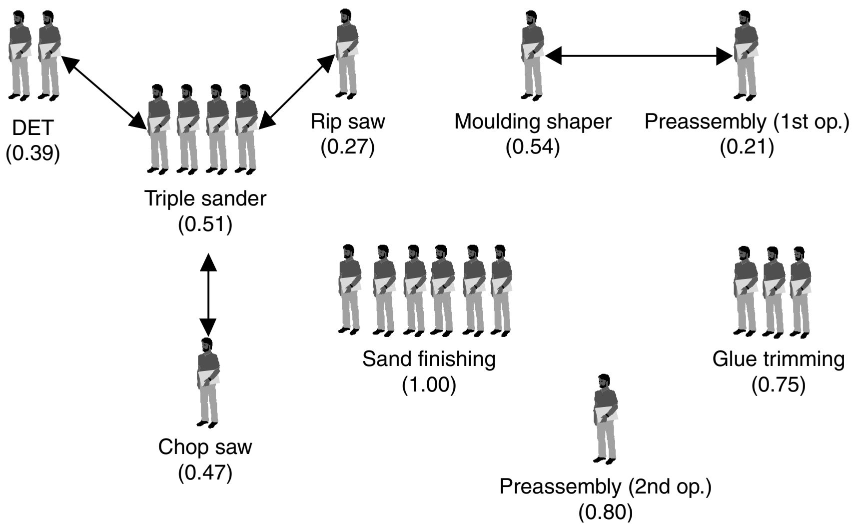
(*continued*)

Machine Name	*Machine Number*	*Operation*	*Task Number*	*Task Description*	*Task Observations (seconds)*
			2	Inspect for defects and match frame parts by color	36.52,35.99,29.09,57.43,53.6, 42.45,57.77,61.21,63.96, 56.41
Preassembly 2		Preassembling and gluing frames	1	Match center panel and four frame parts by color	8.13,8.32,7.43,10.63,6.28, 6.48,7.29,7.34,4.82,5.24
			2	Glue and preassemble frame parts and center panel	19.5,24.1,23.84,22.94,21.75, 22.47,23.66,25.63,29.59,30.09
			3	Place assembly in auto door clamp conveyor	4.38,2.71,4.35,3.69,3.04,2.62,3, 3.78,3,3.23
Auto door clamps	52, 54	Clamping preassembly	1	Conveyor feeds preassembled parts (preassy) into machine	6.55,5.05,6.86,4.77,7.68,5.33, 5.24,7.3,5.71,6.55
			2	Press the preassy	221.28,222,220.35,224.91, 194.4,231.82,213.34,206.75, 223.62,227.44
			3	Assy comes out of machine	4.22,5.69,7.15,5.78,5.1,4.75, 5.53,5.1,4.24,4.84
Glue trimming		Trimming excess glue out of the assembly	1	Remove assy from auto door clamp machine and inspect for excess glue	35.74,17.96,30.59,17.39, 21.48,10.15,16.89,10.87, 10.59,10.26,14.23,11.92, 24.87,10.91,11.77,15.48, 29.71,10.86,19.64
			2	Trim excess glue	58.53,90.87,67.93,70.78, 70.53,77.9,85.88,86.84,78.9, 95.6,78.5,72.65,72.44,91.01, 86.12,84.9,72.56,79.09,77.75
Triple sander	46, 47, 48	Sanding the assembly through three different sanding machines	1	Get assy from stack and feed into sander	2.45,3.56,3.18,3.16,3.32,3.58, 4.22,2.27,4.76,3.9
			2	Sand the assembly	30.72,32.75,34.13,35.66,37, 36.31,36.84,37.03,37.44,38.54
			3	Remove sanded assy and stack	3.31,6.54,5.03,5.51,5.22,5.84, 5.38,6.69,4.22,6.44
Double end tenoner (DET)	45	Grooving sanded assembly	1	Feed assy into DET	5.99,6.14,6.49,6.46,6.42,6.64, 3.21,4.11,3.71,4.2
			2	Groove assy	31.97,32.93,35.11,33.67, 34.06,33.21,33.43,35.23, 33.87,33.72
			3	Remove assy and stack	3.84,3,3.06,2.93,3.06,2.85, 2.88,3.22,1.87,2.41
Sand finishing		Sand finishing the assembly	1	Get part and place on table	3.49,3.42,3.47,3.29,3.36,3.2, 5.73,3.02,3.39,3.54,3.71,3.48
			2	Sand finish the part	215.8,207.57,244.17,254.28, 238.36,218.76,341.77,247.59, 252.63,308.06,221.27,233.66
			3	Stack parts	2.26,2.95,2,1.41,3.79,2.74,4.7, 3.35,3.09,2.75,2.59,2.71

FIGURE 3

Groups of operators for Southern California Door Company.

Work Center/ Machine	*Minimum Quantity Required*	*Number of Operators Working*	*Utilization (Shift)*	*Group of Operators*	*Notes*
Sand finishing	6	6	1.00	*	
Triple sander	2	4	0.51	****	
Glue trimming	3	3	0.75	***	
Auto door clamp	6	0	0.86		
Preassembly (2nd op.)	1	1	0.80	**	
Preassembly (1st op.)	1	1	0.21	*****	
DET	1 1	2 2	0.31 0.08	**** ****	Grooving assembled doors Grooving frames
Chop saw	1	1	0.47	****	
Moulding shaper	1	1	0.54	*****	
Rip saw	1	1	0.27	****	



Additional data are shown in Figures 2 and 3.

Tasks

Build simulation models to analyze the following:

1. Find the manufacturing capacity of the overall facility. What are the current bottlenecks of production?
2. How would you balance the flow of production? What improvements in capacity will that make?
3. What would you suggest to reduce inventory?
4. How could you reduce the manufacturing flow time?

5. The production manager is asking Mr. Santoso to find out the staffing and equipment resources needed for the current level of sales as well as 10, 25, 50, and 100 percent growth in sales volume.
6. Develop layouts for the facility for various levels of production.
7. What kind of material handling equipment would you recommend? Develop the specifications, amount, and cost.

Case Study 8

Material Handling at California Steel Industries, Inc.

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California Steel Industries (CSI) is located in Fontana, California, approximately 50 miles east of Los Angeles. The company's facility, which occupies the space of the old Kaiser steel plant, covers about 400 acres. The facility is connected by 8.5 miles of roads and a 22-mile railroad system. CSI owns and operates seven diesel locomotives and 140 flat and gondola cars.

Founded in 1984, CSI is a fairly new company. CSI produces and ships over 1 million tons of steel annually. Future projections are for increased production. Therefore, CSI has invested hundreds of millions of dollars in modernizing its facilities.

The basic boundary of our defined system runs around the three main buildings: the tin mill (TM), the #1 continuous galvanizing line, and the cold sheet mill (M). Within the tin mill and cold sheet mill are several important production units that will be examined (see Figure 1).

The tin mill contains a 62" continuous pickling line, the 5-stand tandem cold mill (5-stand), the box annealing furnaces, and the #2 continuous galvanizing line. The cold sheet mill contains the cleaning line and additional box annealing furnaces. The #1 continuous galvanizing line is contained by itself in its own building.

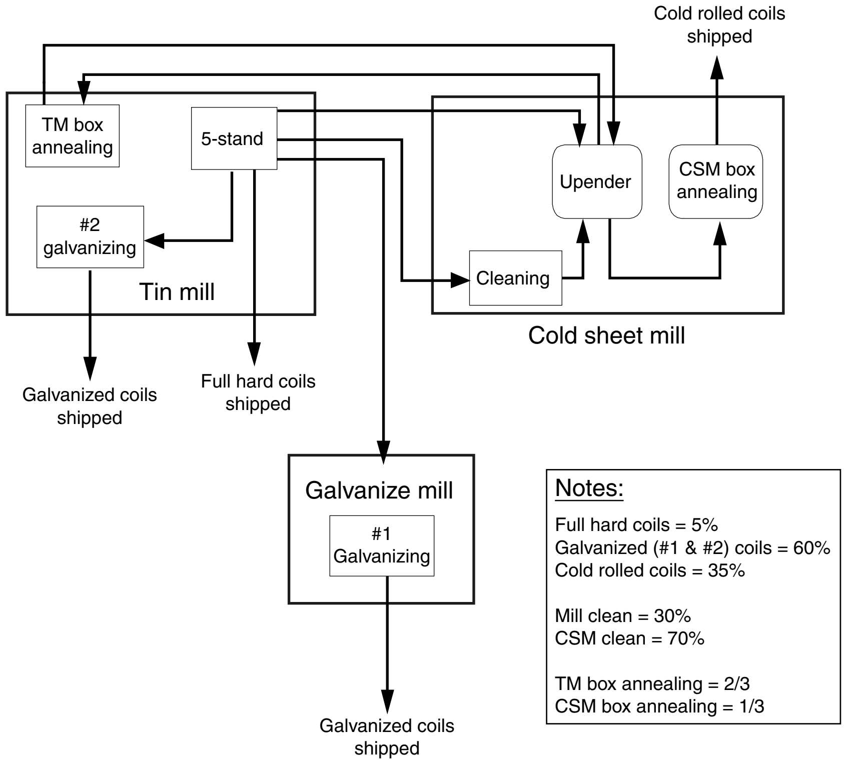
CSI produces three main steel coil products: galvanized, cold rolled, and full hard. Roughly, galvanized coils make up about 60 percent of the total coils produced. The cold rolled coils are 35 percent of the coils and the full hard are the remaining 5 percent. Coils are also categorized into heavy gauge and light gauge. Assume that heavy-gauge coils are produced 60 percent of the time and light-gauge coils 40 percent of the time.

The study will begin with the coils arriving off the 5-stand. The coils weigh from 5 to 32 tons, with a mode of 16 tons. Most of the coils, 70 percent, that will be cold rolled coils will be processed first through the cleaning line at the cold sheet mill in order to remove the grime and residue left from the cold reduction process at the 5-stand. The other 30 percent are a "mill clean" product, which will not need to undergo the cleaning process since the coils are treated additionally at the 5-stand. After exiting the 5-stand, the coils are moved by a crane to the 5-stand bay to await transportation to the next stage by coil haulers. The coils that are to be annealed need to be upended, or rotated so that the coils' core is vertical. The only upender is located at the cold sheet mill. Since about 66 percent of the coils are annealed at the tin mill, they need to be transported to the tin mill and brought back to the cold sheet mill to be upended again.

Currently, coils are transported to and from different mill buildings by human-driven diesel coil haulers that have a 60-ton payload capability. A smaller 40-ton coil hauler

FIGURE 1

Layout for California Steel Industries.



transports coils that are to be moved around within a building. There are two 60-ton haulers and two 40-ton haulers. Assume that one hauler will be down for maintenance at all times.

The following are the process times at each of the production units:

5-stand	Normal(8,2) min
#1 galvanizing line	Normal(30,8) min
#2 galvanizing line	Normal(25,4) min
Cleaning	Normal(15,3) min
Annealing	5 hr/ton

Annealing is a batched process in which groups of coils are treated at one time. The annealing bases at the cold sheet mill allow for coils to be batched three at a time. Coils can be batched 12 at a time at the tin mill annealing bases.

Assume that each storage bay after a coil has been processed has infinite capacity. Coils that are slated to be galvanized will go to either of the two galvanizing lines. The #1 continuous galvanizing line handles heavy-gauge coils, while the #2 galvanizing line processes the light-gauge coils.

The proposed layout (see Figure 2) will be very much like the original layout. The proposed material handling system that we are evaluating will utilize the railroads that connect the three main buildings. The two rails will allow coils to be moved from the tin mill to the cold sheet mill and the #1 galvanizing line. The top rail is the in-process rail, which will

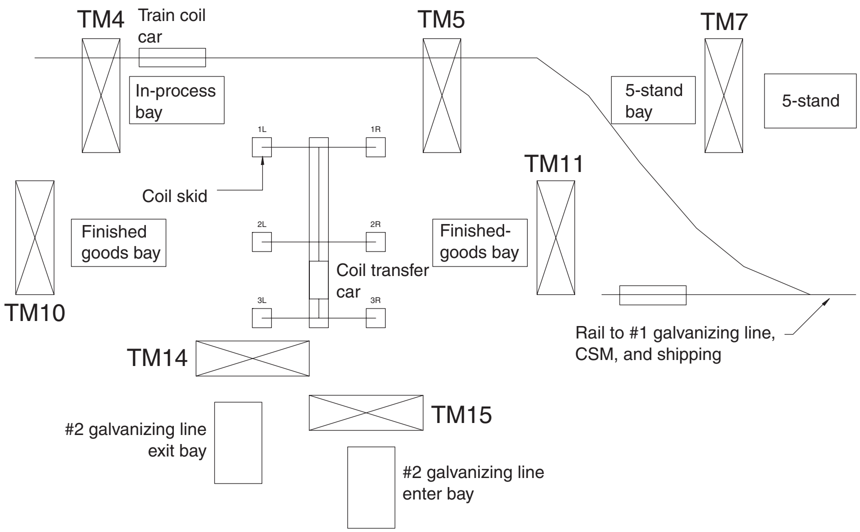


FIGURE 2

Proposed coil handling layout for California Steel Industries.

move coils that need to be processed at the cold sheet mill or the #1 galvanizing line. The bottom rail will ship out full hard coils and coils from the #2 galvanizing line. The train coil cars will be able to carry 100 tons of coils.

In addition, a coil transfer car system will be installed near the #2 galvanizing line. The car will consist of a smaller "baby" car that will be held inside the belly of a larger "mother" car. The "mother" car will travel north–south and position itself at a coil skid. The "baby" car, traveling east–west, will detach from the "mother" car, move underneath the skid, lift the coil, and travel back to the belly of the "mother" car.

Crane TM 7 will move coils from the 5-stand to the 5-stand bay, as in the current layout. The proposed system, however, will move coils to processing in the #2 galvanizing line with the assistance of four main cranes, namely TM 5, TM 11, TM 14, and TM 15. Crane TM 5 will carry coils to the coil skid at the north end of the rail. From there, the car will carry coils to the south end of the rail and place them on the right coil skid to wait to be picked up by TM 15 and stored in the #2 galvanizing line entry bay. This crane will also assist the line operator to move coils into position to be processed. After a coil is galvanized, crane TM 14 will move the coil to the #2 galvanizing line delivery bay. Galvanized coils that are to be shipped will be put on the southernmost coil skid to be transported by the coil car to the middle skids, where crane TM 11 will place them in either the rail or truck shipping areas.

One facility change that will take place is the movement of all the box annealing furnaces to the cold sheet mill. This change will prevent the back and forth movement of coils between the tin mill and cold sheet mill.

Tasks

1. Build simulation models of the current and proposed systems.
2. Compare the two material handling systems in terms of throughput time of coils and work-in-process inventory.
3. Experiment with the modernized model. Determine what will be the optimal number of train coil cars on the in-process and finished-goods rails.