FORECASTING DEMAND: A CAPACITY AND WAREHOUSING DILEMMA IN THE LUMBER INDUSTRY

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ABSTRACT
The organization is experiencing a rapid level of growth and the resultant strain placed on production's ability to adapt to this growth will be presented in this case. This case was designed to give students an opportunity to suggest ideas that will assist in new market penetration and the resultant problems incurred when the organization experienced increased levels of demand. The organization needs to determine if current capacity is sufficient given this level of increasing demand. The case has a difficulty level appropriate for senior or first year graduate students and is appropriate for classes in operations management, quantitative analysis and general management. It is designed to be taught in two class hours with three hours of outside preparation by students.

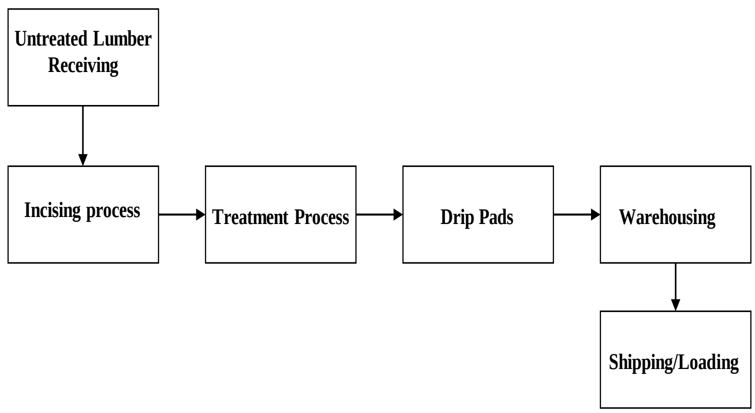
INTRODUCTION
The organization started operation in 1971 with minimal equipment, three employees, and a rundown wood preserving plant in Alabama. By 1976, delivery trucks were making over half their deliveries to the Mobile area and as a result opened its second treating plant in that city. Nine years later the organization expanded again by opening a new plant in Georgia.

When the Georgia plant was opened, the organization entered a period of rapid growth adding full-service treating facilities in Florida, Texas, Missouri and Arkansas as well as additional locations in Alabama and Georgia. These locations strategically positioned the organization to provide prompt and efficient service to lumberyards and building supply stores across a broad geographic region. The organization enjoyed phenomenal growth based on the reputation it earned for producing superior building products; however the newest facility in Texas has encountered capacity problems attributable to the rapid growth in sales volume.

THE PRESSURE TREATING PROCESS
The primary purpose of wood pressure treatment is to force preservative chemicals deep into the cellular structure of wood. The chemical acts as a barrier between the wood and any biological deterioration agents, so that the service life of the wood can be substantially increased. A primary objective is to match the best preservative and application method to the wood species and to end use of the finished product. A variety of lumber preservatives and application methods are in use worldwide. Application methods include high pressure impregnation, low pressure impregnation, vacuum methods, dip treatments and brush or spray-on application. The organization's primary wood species has been southern yellow pine lumber and the treatment process is a high pressure impregnation process.

Lumber arrives for impregnation in standard lengths. Incoming products are checked for quality and stacked in the lumber yard, or moved directly to the impregnating process. A schematic of the impregnating process is shown in Figure 1.

Figure 1 – Steps in the Pressure Treatment of Wood



Incising is a process to prepare wood for treatment. Sharp steel teeth are pressed into the sides of the timber to increase chemical penetration into the wood during the treatment process. A track system is normally employed to load the cylinder allowing lumber to remain in shipping bundles. Size of the cylinder used depends on the quantity of lumber needed to replenish inventory or to meet customer orders. The organization has two cylinders; one is 8' x l00' and can treat about 50,000 board feet (bft) of lumber. The other cylinder is 8' x 50' and can treat about 25,000 (bft) of lumber. The cylinder is sealed, flooded with the chemical preservative followed by a cycle of pressurization and vacuuming. Typical treatment methods can be classified as full-cell or empty-cell processes.

The full-cell method is typically used where the application involves a significant exposure to rain or moisture (examples include utility poles, farm fences and bridge timbers.) In a full-cell treatment, there is an initial vacuum to rid the cylinder of air, afterwards the tank is filled with preservative and pressurized to 140-150 psi for several hours. The cylinder is drained and then the lumber is vacuumed to clean away any excess chemicals left on the surface of the lumber.

By contrast the empty cell method requires an initial pressurization (35-40 psi). This forces air into wood cell lumens with the ultimate purpose of pulling out preservatives injected into the wood at the end of the treatment process. The cylinder is filled with preservatives while the initial pressure is maintained. Afterwards, the pressure is increased to 140-150 psi and held for several hours. After pressure treating, cylinder pressure is released and the final vacuum is applied to clean any surface preservatives remaining on the wood. After treating, lumber is moved to drip pads where treated lumber is allowed to dry prior to storage in the warehousing facility.

WAREHOUSING AND SHIPPING VOLUME

The current layout of the warehouse is presented in Figure 2. This layout pattern allowed fork-lift operators to travel back and forth from the warehouse and the loading area. High volume products included 2 x 4x 8, 1 x 6 x 6 DE, and 2 x 4 x 8 #2 prime. Other lengths of 2 x 4, 2 x 6, 2 x 8, 2 x 10, and 2 x 12 have lower yearly volumes. The design layout consists of seven rows for material storage that are broken down into sixteen block sections. There are six aisles for traveling back and forth. Closeness factors were determined for inventory items based on volume

sold, see Table 1. The distance measurement is the distance from the inventory item's block section to the loading/shipping area. High volume items listed above were placed at the back of the warehouse closest to the drip pad. The warehousing manager thought that storing high volume items closer to the drip pads, would speed the clearing of the drip pad for future use.
The loading process consists of two forklifts dedicated to truck loading. The facility operates five days a week, 52 weeks of the year. The forklift operators work 8 hr shifts. The warehouse currently has two shifts for inventory loading/shipping. The average time to load a truck is 46 minutes. The average truck can hold 15,000 (bft) of treated lumber. The two year sales volume averaged is around 120,000,000 (bft), which means 8,000 trucks on average have been loaded per year.

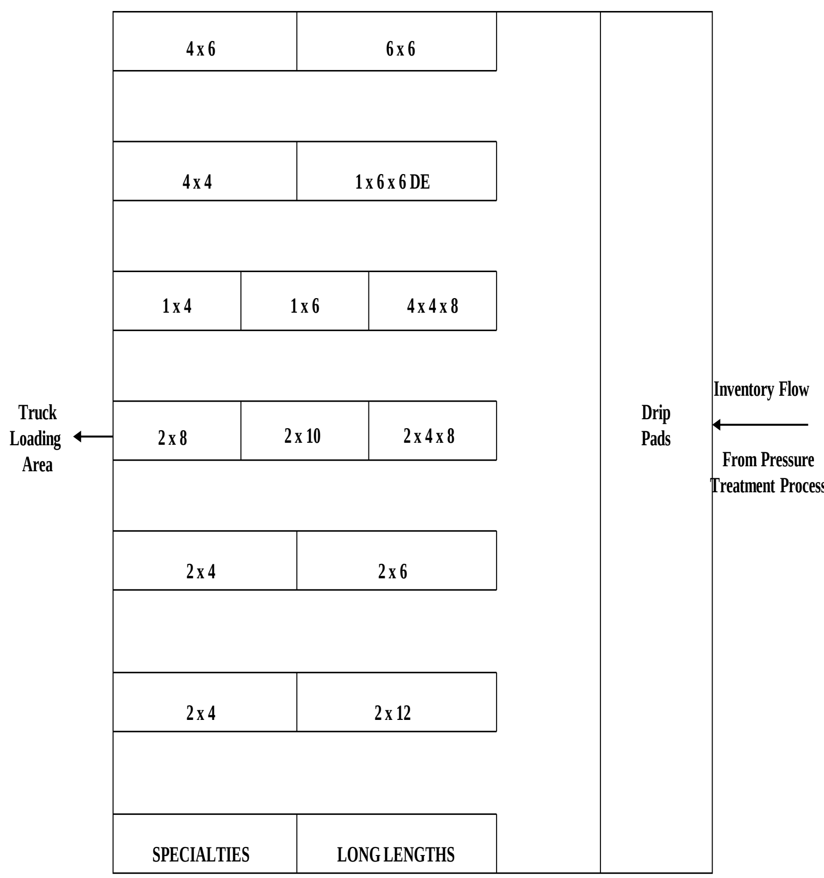


Figure 2: Warehouse Layout and Inventory Flow

TABLE 1 – Current Inventory, Closeness Factors and Distance to Loading/Shipping Area

Inventory Item	Closeness[1] Factor	Distance (ft)
2 x 4 ACQ	8	100
2 x 6 ACQ	8	200
2 x 8 ACQ	4	100
2 x 10 ACQ	2	150
2 x 12 ACQ	3	200
4 x 4 ACQ	7	100
4 x 6 ACQ	6	100
6 x 6 ACQ	2	200
1 x 4 ACQ	5	100
1 x 6 ACQ	6	150
1 x 6 x 6 DE	10	200
2 x 4 x 8 #2 Prime	10	200
4 x 4 x 8	9	200
Specialties	1	100
Long Lengths (22'–24')	1	200

[1]Closeness factor determination for 2 x 4 ACQ:

1) Largest yearly volume items were assigned a value of 10.
   Volume of 1x 6 x 6 DE/Volume of 2 x 4 ACQ = 10/X
   Solving for X would result in the closeness factor for 2 x 4 ACQ.

ENVIRONMENTAL CHANGES AND WAREHOUSING OPERATIONS

The primary chemical used in pressure treating (Chromated Copper Arsenate, CCA) was banned in residential applications due to its arsenic properties. A new chemical, Alkaline Copper Quaternary (ACQ) was the replacement chemical and as a result the warehouse layout had to segregate lumber stocks into residential lumber treated with ACQ and lumber for non residential use.

A second problem in the warehousing layout was introduction of borate treated lumber. Borate treated lumber is used for the bottom sill plate in housing. Lumber treated with this preservative cannot be stored outside because inclement weather will wash away the protective chemical. Consequently, it must be stored in the finished lumber warehouse. In fact, the organization is one of a few industry members that keep 90 % or more of treated inventory under roof. These two environmental changes coupled with the rising level of demand have created a capacity problem in warehousing operations.

Due to the expected growth of production, warehousing will need to know the maximum amount of loads they can load a day using two forklifts. Production manager has asked for a projected level of sales for the next year.

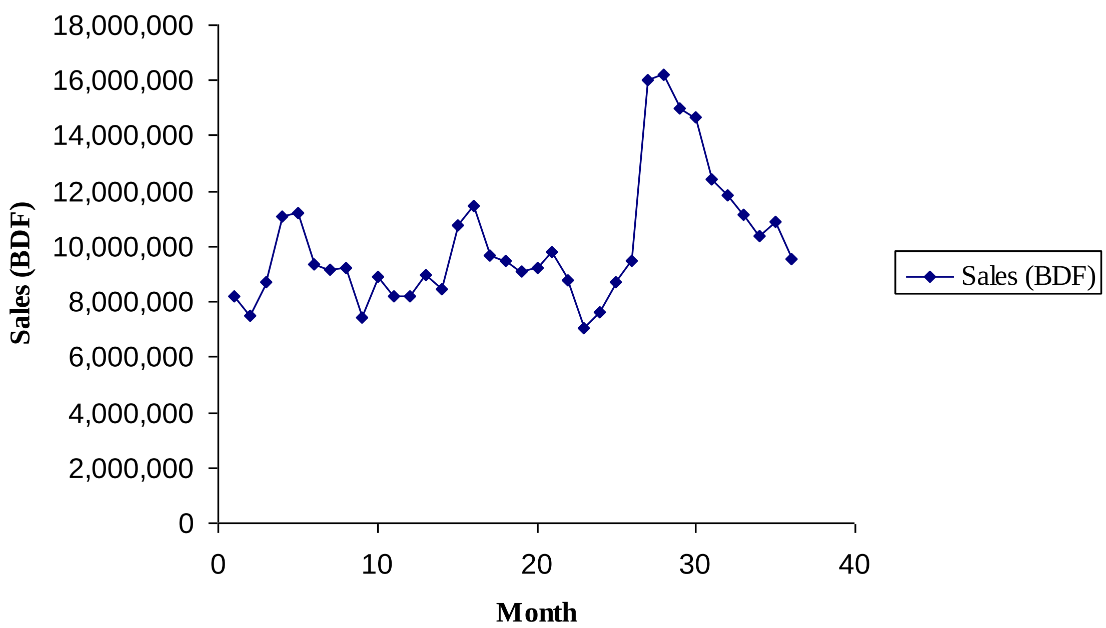
GROWTH IN SALES

Sales growth for the past two years has fluctuated within a few customer types, but overall volume has grown. Warehousing needs to know next year's sales volume. With this information, warehousing will be able to calculate number of shifts to handle the expected growth. Demand for board feet of lumber is presented in Table 2 along with a graph of sales volume in Figure 3.

Table 2: Three Year Sales Volume (Board Feet, BFT)

Month	Year 1	Year 2	Year 3
January	8,231,218	8,953,999	8,687,643
February	7,506,737	8,424,947	9,503,976
March	8,731,336	10,760,412	16,014,978
April	11,108,172	11,490,163	16,218,415
May	11,196,626	9,656,253	15,006,708
June	9,365,374	9,475,104	14,689,315
July	9,143,151	9,074,696	12,454,828
August	9,212,190	9,228,455	11,858,030
September	7,402,707	9,832,683	11,128,742
October	8,920,306	8,748,438	10,385,114
November	8,220,209	7,047,088	10,894,929
December	8,225,487	7,638,360	9,560,288
Total:	107,263,513	110,330,598	146,402,966

Figure 3: Three Year Sales Volume



Questions:

1. *Reconfigure the layout using the inventory items and closeness factors shown in Figure 2 and Table 1.*
2. *Forecast the sales volume for Year 4.*
3. *Calculate the average number of trucks loaded in a day. What considerations should one make in using this calculation?*

LUMBER PRESERVING: A CAPACITY AND WAREHOUSING DILEMMA TEACHING NOTE

CASE DESCRIPTION

The organization is experiencing a rapid level of growth and the resultant strain placed on production's ability to adapt to this growth will be presented in this case. This case was designed to give students an opportunity to suggest ideas that will assist in new market penetration and the resultant problems incurred when the organization experienced increased levels of demand. The organization needs to determine if current capacity is sufficient given this level of increasing demand. The case has a difficulty level appropriate for senior or first year graduate students and is appropriate for classes in operations management, quantitative analysis and general management. It is designed to be taught in two class hours with three hours of outside preparation by students.

CASE SYNOPSIS

The case will discuss changes in the industry with regard to chemicals used in the treating process and its resultant impact on production, plant layout and capacity of the loading operation. The forecasted demand of the facility will have to be determined to develop production requirements for the facility. Finally, a determination will have to be made regarding the capacity of the current facility.

RECOMMENDATIONS FOR TEACHING APPROACHES

The subject matter in this case is recommended for senior level and first year graduate students. The students should have knowledge of designing line flow layouts as well as flexible —flow layouts, and the weighted distance method. Students should have knowledge of forecasting models.

SUGGESTED ASSIGNMENTS

Question 1: Reconfigure the layout using the inventory items and closeness factors shown in Figure 2 and Table 1.

It is readily apparent that the current warehousing layout does not take into consideration loading of outbound trucks for delivery to customers. A simple modification would be to reconfigure the layout so that the inventory items with the larger closeness factors are closer to the shipping/loading docks. Additionally, the 2x4 Borate inventory used for sill plates should be segregated from 2x4 ACQ. Taking into account these two factors, a modified warehouse layout is presented in Figure 4.

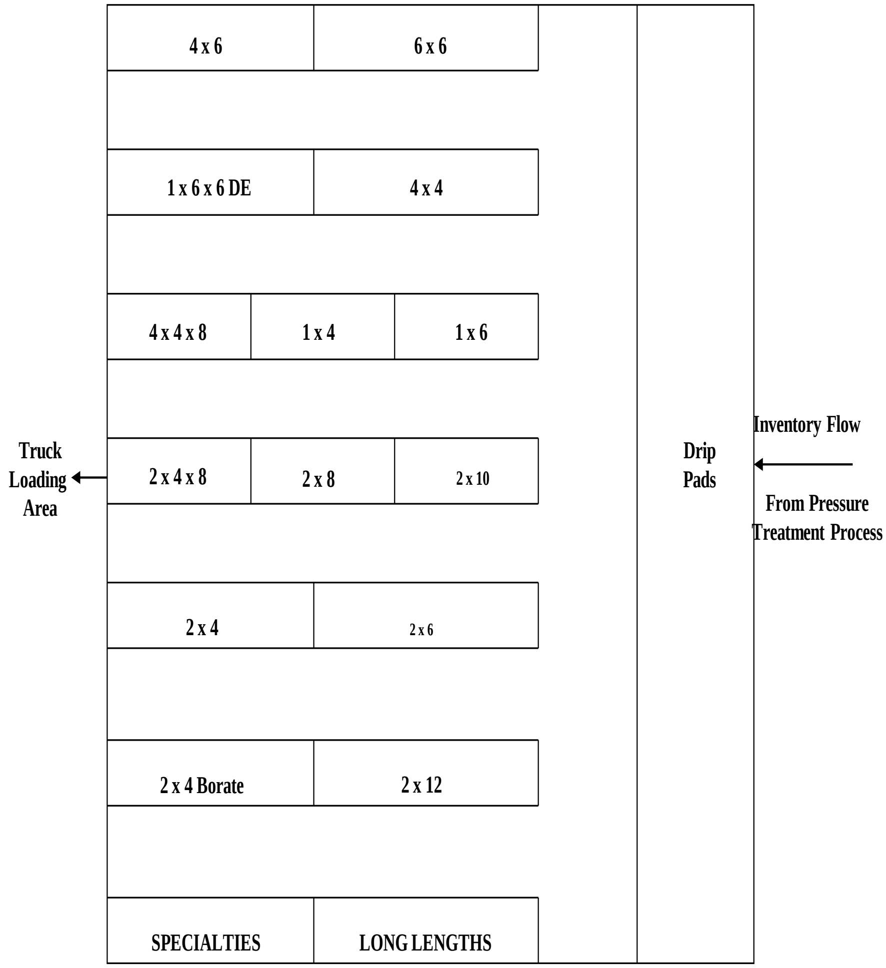


Figure 4 – Modified Warehouse Layout

Additionally, one can use the closeness ratings and the distance measurements for each of the inventory areas to determine a weighted distance score for the two warehouse layouts. The weighted distance score for the two warehouse layouts are given in Tables 3 and 4
This is not a unique layout solution. Students should experiment with layouts of their own to see if a better layout can be configured for the organization.

Question 2: Forecast sales volume for Year 4.
There are many ways to approach the forecast for Year 4 and what follows in this teaching note is only one approach. Since the organization is in the wood products (lumber) business, one would expect to see a very seasonal demand pattern. By casual observation, one can verify that demand increases dramatically during the months of March through August which can be attributed to the prime time for new home construction and/or renovation as well as other construction projects that would use products from the organization. Additionally, data provided in Fig 3 indicate that trend is present in the data. Given these two observations from Fig 3, our analysis will commence with determining the monthly seasonal indices for the data in Table 2. This analysis is presented below in Table 5.

Table 3 – Weighted Distance Score for Current Warehouse Layout

Inventory Item	Closeness Score	Distance (ft)	Weighted Distance Score
2 X 4 ACQ	8	100	800
2 X 4 ACQ	8	100	800
2 X 6 ACQ	8	200	1600
2 X 8 ACQ	4	100	400
2 X 10 ACQ	2	150	300
2 X 12 ACQ	3	200	600
4 X 4 ACQ	7	100	700
4 X 6 ACQ	6	100	600
6 X 6 ACQ	2	200	400
1 X 4 ACQ	5	100	500
1 X 6 ACQ	6	150	900
1 X 6 X 6 DE	10	200	2000
2 X 4 X 8 #2 Prime	10	200	2000
4 X 4 X 8	9	200	1800
Specialties	1	100	100
Long Lengths	1	200	200
		Weighted Distance:	13700

Table 4 – Weighted Distance Score for Modified Warehouse Layout

Inventory Item	Closeness Score	Distance (ft)	Weighted Distance Score
2 X 4 ACQ	8	100	800
2 X 6 ACQ	8	200	1600
2 X 8 ACQ	4	150	600
2 X 10 ACQ	2	200	400
2 X 12 ACQ	3	200	600
4 X 4 ACQ	7	200	1400
4 X 6 ACQ	6	100	600
6 X 6 ACQ	2	200	400
1 X 4 ACQ	5	150	750
1 X 6 ACQ	6	200	1200
2 X 4 Borate	8	100	800
1 X 6 X 6 DE	10	100	1000
2 X 4 X 8 #2 Prime	10	100	1000
4 X 4 X 8	9	100	900
Specialties	1	100	100
Long Lengths	1	200	200
		Weighted Distance:	12350

Table 5 – Calculation of Monthly Seasonal Indices

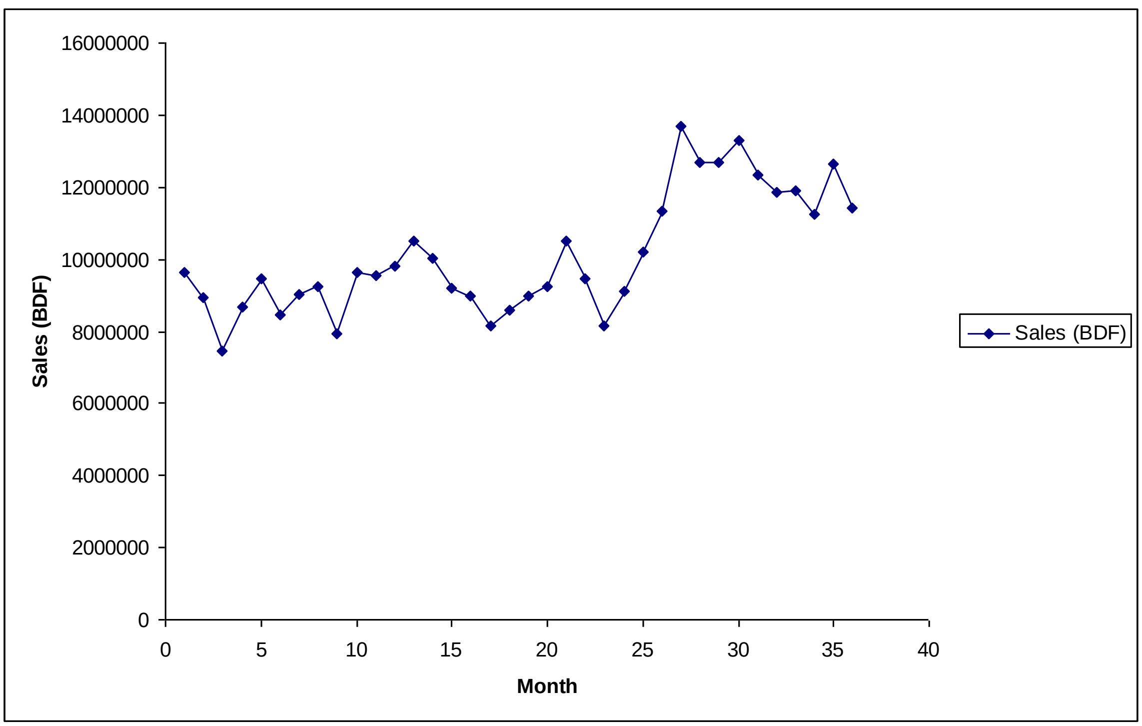
Month	Year 1	Year 2	Year 3	Monthly Mean	Monthly Seasonal Index
January	8,231,218	8,953,999	8,687,643	8,624,287	0.852958278
February	7,506,737	8,424,947	9,503,976	8,478,553	0.838544975
March	8,731,336	10,760,412	16,014,978	11,835,575	1.170560806
April	11,108,172	11,490,163	16,218,415	12,938,917	1.279683353
May	11,196,626	9,656,253	15,006,708	11,953,196	1.18219368
June	9,365,374	9,475,104	14,689,315	11,176,598	1.105386668
July	9,143,151	9,074,696	12,454,828	10,224,225	1.011195208
August	9,212,190	9,228,455	11,858,030	10,099,558	0.998865439
September	7,402,707	9,832,683	11,128,742	9,454,711	0.935088784
October	8,920,306	8,748,438	10,385,114	9,351,286	0.924859888
November	8,220,209	7,047,088	10,894,929	8,720,742	0.862497893
December	8,225,487	7,638,360	9,560,288	8,474,712	0.838165027
Total:	107,263,513	110,330,598	146,402,966		
		3 Yr Grand Mean	10,111,030		

The next step in the forecasting analysis was to divide the monthly sales data for the three year period by the monthly seasonal indices to remove any seasonal fluctuation. This resulted in Table 6 and a graph of these data is found in Figure 4.

Table 6 – Deseasonalized Data for Years 1, 2, 3

	Time	Year 1 Deseasonalized Data	Time	Year 2 Deseasonalized Data	Time	Year 3 Deseasonalized Data
January	1	9650200.03	13	10497581.45	25	10185308.27
February	2	8952098.241	14	10047102.12	26	11333889.39
March	3	7459105.031	15	9192527.155	27	13681457.56
April	4	8680406.738	16	8978911.051	28	12673771.96
May	5	9471058.921	17	8168080.377	29	12693950.45
June	6	8472486.844	18	8571755.275	30	13288847.63
July	7	9041924.771	19	8974227.654	31	12316937.32
August	8	9222653.666	20	9238937.141	32	11871498.94
September	9	7916581.964	21	10515240.02	33	11901267.77
October	10	9645035.007	22	9459203.616	34	11228851.13
November	11	9530700.383	23	8170556.771	35	12631832.6
December	12	9813684.336	24	9113193.406	36	11406212.01

Figure 4 – Deseasonalized Sales Plot (BDF)



The final step in the forecasting analysis was to use the deseasonalized data to produce a time series forecast for 48 months, using the thirty six months of deseasonalized data plus the calculation of the deseasonalized forecast for months 37 through 48. After this calculation, the data that was produced was multiplied by the monthly indices to produce the sales forecast for months 37 though 48. Data produced by this analysis is presented in Table 7 with the graph of the time series forecast with seasonality provided in Figure 5.

One should note that in the first four month of each year, the time series forecast w/seasonality is less than the actual sales values. This would be an indication that the organization should possibly work overtime or extra shifts to increase the level of output in order to meet the level of demand in these periods. See Question 3.

Question 3: Calculate the average number of trucks loaded in a day. What considerations should one make in using this calculation?

The volume of wood from question 2 was calculated to be 154,332,258.2 board feet. The average truck can hold 15,000 (bdf) of treated lumber, which means that 10, 288.8 or 10.289 trucks will have to be loaded in two shifts if demand materializes. The facility works two 8 hour shifts, five days a week, 52 weeks per year. Dividing 10, 289 by 260 days (52 weeks/yr x 5 days/wk) results in 39.57 trucks loaded per day. Since there are two fork lift trucks each one would have to load 19.79 loads a day/fork truck. The average time to load a truck (time was extracted from company records) is 46 minutes. Taking this value and dividing it by 60 minutes /hr would result in .77 hrs to load one truck. Multiplying .77 hrs times 19.79 trucks/day would result in 15.24 hours of time required to load 39.57 trucks per day. This time falls within the 16 hours of available time per two 8 hour shifts.

There are many considerations that one must account for when using the 19.79 loads per fork lift truck. Consideration should be given to forecast error, maintenance schedule of the fork lift trucks, unscheduled breakdowns, worker absenteeism, and vacation time for fork lift operators. For capacity planning purposes, it is customary to allocate only a specified amount of available time per year for productive output. The percent of unallocated capacity (capacity cushion) can be used to plan for these environmental uncertainties. As an example suppose the organization wanted to use say 5% of the yearly time for these internal and external uncertainties. The number of productive days would be calculated by taking the 260 days per year and multiplying it by 90% resulting in 234 days per year. Dividing the 10, 289 trucks per year by 234 days results in 43.97 trucks loaded per day. Next, dividing this value by 2 would result in 21.99 trucks loaded per fork lift per day. Now assuming the calculations for the time required for loading an outbound truck is the same (.77 hours/fork truck) we would multiple the 21.99 trucks per day times .77 hrs resulting in 16.93 hours per day. Taking the .93 hours times the number of working days of 234 would result in 217.62 hours per year of overtime or 217.62/32 (2 forklift trucks x 16 hours/day) or about 6.8 days or 54 hours of overtime per year for each fork lift operator.

Though the demand of year 4 cannot be met by current regular time capacity, the 54 hours of overtime per year per operator can be easily attained without working a third shift. The organization could also consider putting three fork lift trucks for one shift on loading outbound trucks during peak demand periods, thus eliminating premium overtime pay for fork lift operators. This third fork lift operator would only have to work 6.8 x 4 or 27.2 days or about one month out of the year. This case is a good example of how too much of an increase in demand can cause issues for a company, just as too little of demand can as well. Accurate estimations of demand can save a company a great deal of time and effort in planning and human resources.

Table 7 - Calculation of Time Series Forecast w/Seasonality for Years 1-4

	Time	Year 1 Deseasonalized Data	Year 1 Deseasonalized Time Series Forecast	Year 1 Time Series Forecast with Seasonality Added Back	Time	Year 2 Deseasonalized Data	Year 2 Deseasonalized Time Series Forecast
January	1	9650200.03	8403739.045	7168038.785	13	10497581.45	9871739.727
February	2	8952098.241	8526072.435	7149495.201	14	10047102.12	9994073.118
March	3	7459105.031	8648405.825	10123484.9	15	9192527.155	10116406.51
April	4	8680406.738	8770739.216	11223768.97	16	8978911.051	10238739.9
May	5	9471058.921	8893072.606	10513334.23	17	8168080.377	10361073.29
June	6	8472486.844	9015405.996	9965509.592	18	8571755.275	10483406.68
July	7	9041924.771	9137739.386	9240038.279	19	8974227.654	10605740.07
August	8	9222653.666	9260072.776	9249566.656	20	9238937.141	10728073.46
September	9	7916581.964	9382406.167	8773382.77	21	10515240.02	10850406.85
October	10	9645035.007	9504739.557	8790552.365	22	9459203.616	10972740.24
November	11	9530700.383	9627072.947	8303330.133	23	8170556.771	11095073.63
December	12	9813684.336	9749406.337	8171611.429	24	9113193.406	11217407.02

	Time	Year 3 Deseasonalized Data	Year 3 Deseasonalized Time Series Forecast	Year 3 Time Series Forecast with Seasonality Added Back			Year 4 Deseasonalized Time Series Forecast
January	25	10185308.27	11339740.41	9672325.453	37		12807741.09
February	26	11333889.39	11462073.8	9611464.393	38		12930074.48
March	27	13681457.56	11584407.19	13560253.02	39		13052407.87
April	28	12673771.96	11706740.58	14980921.04	40		13174741.26
May	29	12693950.45	11829073.97	13984256.49	41		13297074.65
June	30	13288847.63	11951407.36	13210926.36	42		13419408.04
July	31	12316937.32	12073740.75	12208908.79	43		13541741.43
August	32	11871498.94	12196074.14	12182236.95	44		13664074.82
September	33	11901267.77	12318407.53	11518804.72	45		13786408.21
October	34	11228851.13	12440740.92	11505942.26	46		13908741.6
November	35	12631832.6	12563074.31	10835625.12	47		14031074.99
December	36	11406212.01	12685407.7	10632465.09	48		14153408.38

Figure 5 – Graph of Time Series Forecast for Years 1-4