SUPPLY CHAIN ANALYTICS CASE STUDY

“Warehouse Lease Planning for Speciality Packaging Corporation (SPC)”

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EXECUTIVE SUMMARY

The report describes the problem of warehouse lease planning that Julie at SPC must solve to ensure minimal costs for SPC. Total cost is the sum of production costs, transportation costs, material handling costs, worker costs, overtime costs, machine costs, subcontracting costs and importantly warehousing costs. We use the provided information such as machine regular & overtime capacity, demand forecasts, working hours limit, and warehousing costs (public & private) to explain how the combination of public & private warehousing proves to be the best option for this situation. One factor of production that must be accounted for was that the 14 extruders can produce plastic sheets at 40k pounds/hr, whereas the 25 thermoforming presses (2nd step) can produce containers at 50k pounds/hr. This ensured that subcontracting would only be needed in the extruder step. Hires, layoffs, and idling of machines also had to be taken into account in order to minimize costs. Our solution does not involve the purchase of any new machines. The optional of (public + private) warehousing not only yields the lowest costs ($10.6M) but also provides cushion against excessive demand for any quarter. The principles of aggregate planning and constraint optimization were implemented to arrive at the solution and subsequently minimize costs for SPC.

INTRODUCTION

We interface the warehouse lease planning problem of Julie, a Facility Production Planning Manager at Speciality Packaging Corporation (SPC). SPC has a 2 fold production process in which resin pellets (polystyrene) are first extruded into plastic sheets and then the sheets get thermoformed into containers. The objective function we wish to minimize is the overall cost function, with the constraints of meeting demand for each quarter and having no inventory of final products (containers). Minimizing the objective function here leads to the minimal sum of transportation, worker, warehousing & production costs. Additionally, demand estimate errors also need to be considered here before we finalize a solution for Julie. The 3 scenarios are:

1. Only public warehousing (material handling costs + warehousing costs)
2. Only private warehousing (4$/1000 lbs warehousing costs)
3. Combination of public & private warehousing

The highest value for total private inventory for any given period would be our private capacity warehousing space contract while public warehousing would vary as per usage for each period. The optimal combination of public & private warehousing would yield the minimal costs ensuring complete storage for all the 12 periods (3 years * 4 quarters). The scenario that yields the least warehousing costs fulfilling all constraints, would be our solution for this problem.

METHODOLOGY

We have employed the methodology of a 2 step optimization process. In step 1: The extruders are the source of supply while the thermo-presses are the demand points. In step 2: The thermo-presses are the source of supply while the demand is the final demand for products. In our approach we treat plastic sheets as inventory, so only plastic sheets are kept in inventory, not containers. This essentially means we only produce enough containers to exactly meet demand. Below is a list of decision variables for this problem:

1. Extruder & thermo-press production ('000 lbs) per period **(2)**
2. Extruder & thermo-press, hires and layoffs per period, and regular & overtime hours **(8)**
3. (Public + private) inventory and subcontracting in all ('000 lbs) **(3)**

For this problem, We have (13*12 = 156) decision variables which are outlined in Appendix Section 1.1. Material handling & transportation costs are the same for both public & private warehousing. Our objective function here is to minimize the overall costs with the constraints of meeting demand for each period as well as having no inventory for containers for any period. The list of mathematical constraints for this problem are:

- All the above decision variables must be nonnegative [156 Equations]
- Number of extruders available for any period cannot exceed 14 [12 Equations]
- Number of thermo-presses available for any period cannot exceed 25 [12 Equations]
- Extruder employees considering hires and layoffs is constant [12 Equations]
- Thermo-press employees considering hires and layoffs is constant [12 Equations]
- Extruder inventory and production equates with thermo-press demand [12 Equations]
- All of thermo-press production equates with final product demand [12 Equations]

We solve the above 216 equations to realize the above decision variables. Refer to Appendix section **1.2** for complete information.

Some of our assumptions are below:

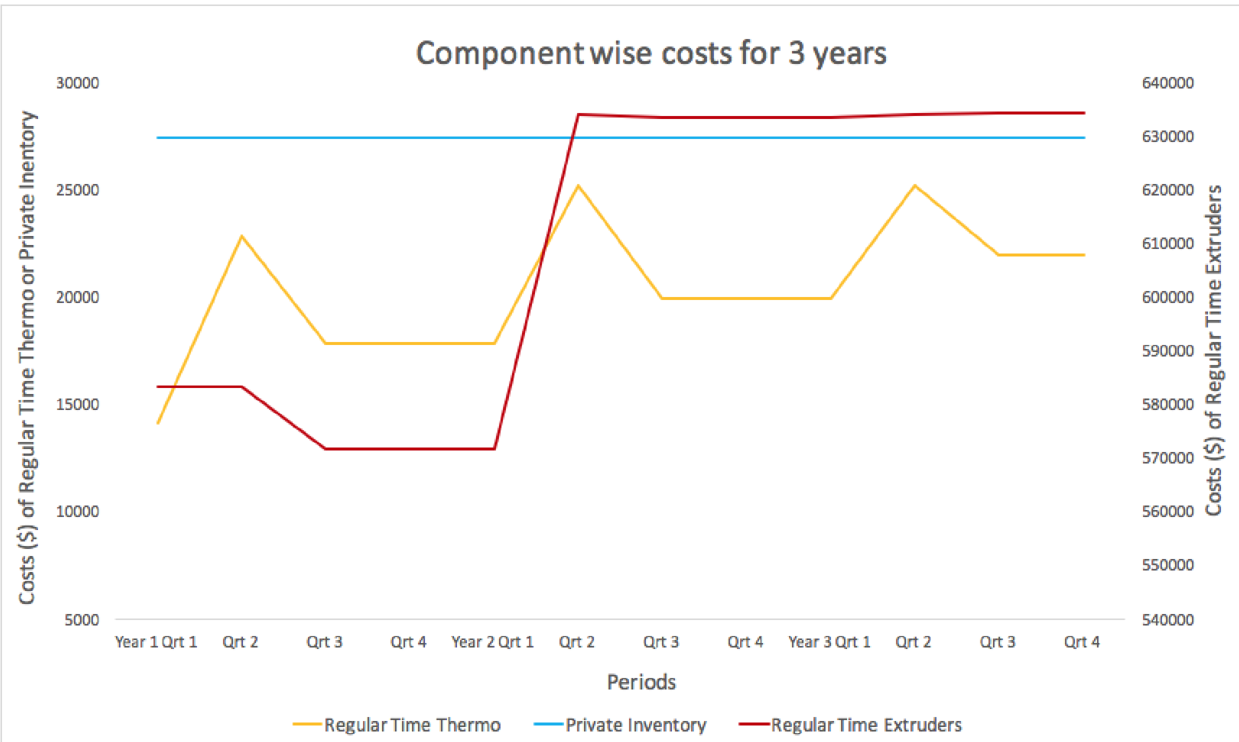
1. We have assumed the maximum costs for Public warehousing, which sums to be [$2/1000lbs (material handling) + $6/1000lbs (Transport) + $12/1000lbs (inventory)] = $20.
2. Mean Absolute Deviation (MAD) is the only uncertainty in demand.
3. No amount of inventory or material gets destroyed in the process or transportation.
4. All thermo-press production gets consumed to meet demand in any given quarter, thus there is no inventory of containers.
5. All plastic sheets get transformed into containers, so there is no wastage.
6. We are assuming 80% utilization of private warehousing space (ideal scenario).

ANALYSIS & FINDINGS

After completing our analysis and solving this problem, we have the below observations:

1. Hiring and laying off workers when appropriate in both stages (extrusion and thermoforming) helped save money compared with keeping workers idle.
2. Buying machines proved to be an expensive route and hence no machines were ever purchased, although some were kept idle for some periods
3. Subcontracting turns out to be an expensive option compared with utilizing overtime for specific quarters, so subcontracting was not needed.

The below charts indicates the component wise costs over the 3 years for each of the 4 quarters



Observations:

1. As expected, private warehousing costs remain constant at $28.5k/qtr, as they are based on the maximum price over the 3 year lease.
2. Regular machine costs rise towards the end of the 3 year period, as demand for containers increases.

For understanding the calculations involved for this problem, kindly refer to **spc_case_study.xls**.

CONCLUSION

Based on our analysis, we realize the combination of Private ($342,917) & Public ($20) warehousing yields the least warehousing costs. We require 7,144 square feet of private warehousing space on a 3 year contract, assuming an 80% space utilization. Our overall costs are $ 10,578,707 for the period of 3 years. Our final solution is conditional to the assumptions we have made and may well be at a variance with other standard solutions.

APPENDIX

1.1 Decision Variables matrix

Decision Variables (DV_i)	Qtr 1 Yr 1	Qtr 2 Yr 1	Qtr 3 Yr 1	Qtr 4 Yr 1	Qtr 1 Yr 2	Qtr 2 Yr 2	Qtr 3 Yr 2	Qtr 4 Yr 2	Qtr 1 Yr 3	Qtr 2 Yr 3	Qtr 3 Yr 3	Qtr 4 Yr 3
Regular Extruder Production	RE1	RE2	RE3	RE4	RE5	RE6	RE7	RE8	RE9	RE10	RE11	RE12
Overtime Extruder Production	OE1	OE2	OE3	OE4	OE5	OE6	OE7	OE8	OE9	OE10	OE11	OE12
Extruder Worker Layoffs	EWL1	EWL2	EWL3	EWL4	EWL5	EWL6	EWL7	EWL8	EWL9	EWL10	EWL11	EWL12
Extruder Worker Hiring	EWH1	EWH2	EWH3	EWH4	EWH5	EWH6	EWH 7	EWH8	EWH9	EWH10	EWH11	EWH12
Number of Extruders Online	NE1	NE2	NE3	NE4	NE5	NE6	NE7	NE8	NE9	NE10	NE11	NE12
Regular Thermoprocessing Production	RT1	RT2	RT3	RT4	RT5	RT6	RT7	RT8	RT9	RT10	RT11	RT12
Overtime Thermoprocessing Production	OT1	OT2	OT3	OT4	OT5	OT6	OT7	OT8	OT9	OT10	OT11	OT12
Thermoprocessing Worker Layoffs	TWL1	TWL2	TWL3	TWL4	TWL5	TWL6	TWL7	TWL8	TWL9	TWL10	TWL11	TWL12
Thermoprocessing Worker Hiring	TWH1	TWH2	TWH3	TWH4	TWH5	TWH6	TWH 7	TWH8	TWH9	TWH10	TWH11	TWH12
Number of Thermoprocessing presses online	NT1	NT2	NT3	NT4	NT5	NT6	NT7	NT8	NT9	NT10	NT11	NT12
Subcontract Production	SC1	SC2	SC3	SC4	SC5	SC6	SC7	SC8	SC9	SC10	SC11	SC12
Public Inventory	PWC1	PWC2	PWC3	PWC4	PWC5	PWC6	PWC7	PWC8	PWC9	PWC10	PWC11	PWC12
Private Inventory	RWC1	RWC2	RWC3	RWC4	RWC5	RWC6	RWC7	RWC8	RWC9	RWC10	RWC11	RWC12

The terminology for the decision variables is explained below :

RE_i, OE_i	REGULAR & OVERTIME PRODUCTION FROM EXTRUDERS (‘000)
EWH_i, EHL_i	EXTRUDER EMPLOYEES HIRING AND LAYOFFS
NE_i, NT_i	NUMBER OF EXTRUDERS AND THERMOFORMING PRESSES ACTIVE
RT_i, OT_i	REGULAR & OVERTIME PRODUCTION FROM THERMOS (‘000)
TWH_i, THL_i	THERMO PRESSES EMPLOYEES HIRING AND LAYOFFS
PWC_i, RWC_i	PUBLIC & PRIVATE WAREHOUSING (‘000)
SC_i	SUBCONTRACTING (‘000 LBS)

1.2 Mathematical constraint equations:

The constraints for this optimization problem are as below:

- All the above decision variables need be positive: $DV_i >= 0$ [156 Equations]
- Number of Extruders available for any period: $NE_i <= 14$ [12 Equations]
- Number of Thermo available for any period: $NT_i <= 25$ [12 Equations]
- Extruder Employees considering hiring & firing is constant (6 employees per Extruder): $NE_{i-1}*6 + EWH_i - EWH_i = NE_i*6$ [12 Equations]
- Number of Thermoforming Employees considering hiring & firing is constant: $NT_{i-1} + TWH_i - TWH_i = NT_i$ [12 Equations]
- Extruder Inventory & its production equates with thermopress demand: $RWC_{i-1} + PWC_{i-1} + RE_i + OE_i + SC_i + OE_i - RWC_i - PWC_i - RT_i - OT_i = 0$ [12 Equations]
- All of Thermopress production equals final demand: $RT_i - OT_i = D_i$ [12 Equations]

1.3 Programmatic approach (Incomplete):

We also attempted to solve this optimization problem using the combination of in-built functionalities of R & external packages in R. The solution is not complete and needn’t be considered for evaluation purpose for this case study. It is geared more with the intention of automating such problems, once we have more functionalities to help solve such problems. Kindly refer to the script **case_study.R** to see our R approach. We shall work on this further with the intent of programmatically solving such problems as they better align with ethos of Tech companies.