Title: Retail Grocery Salary Control: A Linear Programming Model

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Abstract: We developed a Linear Programming model to determine the optimum mix and numbers of employees required, and to minimize the weekly salary cost of an average supermarket operating in Portland

RETAIL GROCERY SALARY CONTROL

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EXECUTIVE SUMMARY

The project analyzes the weekly salary cost of several departments for a supermarket in the Northwest. The model used is a composite of an average supermarket operating in the Portland area under the union constraints and market demands for that area.

The objective of the analysis is to minimize the weekly operating expense by determining the optimum mix and number of employees required to operate the store. The employees are divided into functional groups depending on their job classifications and hourly salary. The constraints of the problem are based on the various tasks the individuals can perform within the union contract and the minimum employee coverage requirements which are based on industrial engineering studies for a fixed sales level.

To meet the objective of the project, a linear programming model was developed through which salaries were minimized under the constraint of the business. The model is realistic in that the input is based on a three week average cost from an actual supermarket. The linear optimization and sensitivity analysis was completed on a personal computer version of the linear programming software, LINDO.

The results show that the minimum weekly salary expense for operating the supermarket based on the original constraints is $16,609. This optimized result is slightly lower than the actual weekly salary expense from the model store of $16,878.

It is the conclusion of the team that,

1. The model is a good approximation.

2. The model is excessively constrained; therefore, the full extent of the linear program was not realized.

3. The management of salary expenses for a supermarket is a highly constrained task. The competitiveness of the industry and the present use of industrial engineers by the industry has brought about near optimization through the course of business.

4. The linear programming model is a useful tool for union negotiations when weighing the effects of salary adjustments against restrictions on job classifications.

MODEL DEFINITION - RETAIL GROCERY SALARY CONTROL

Salary control is a major function in retail grocery management. Union contract restrictions, company policies, and fluctuating business demands contribute to the complexity of the staffing task. Additionally, the overlapping of employees across departmental lines creates an even more challenging problem. Various scheduling methods have been used in the past. However, the format of the problem with its numerous constraints, is a straightforward application of a linear programming model.

A store located in Portland, Oregon was chosen for modeling. The store represents an average sales volume, customer count, size, etc. Most store employees are members of a large local union. The union contract applies to employees in the front end, grocery, produce, and variety departments. The following is a summary of hourly rates and other pertinent information for the model.

Contract Employees

Employee Classification	Dept.	Base Rate	Sunday Premium	Night Premium
Head Grocery Clerk	Grocery	11.40		
Clerk-Journeyman	Grocery	11.05	1.00	0.25

Clerk-Apprentice	Grocery	7.00	1.00	0.25
Checker-Journeyman	Front End	11.05	1.00	0.25
Checker-Apprentice	Front End	7.00	1.00	0.25
Courtesy Clerk	All	4.17	0.50	0.25
Produce Manager	Produce	11.40	1.00	0.25
Prod Clerk-Journeyman	Produce	11.05	1.00	0.25
Prod Clerk-Apprentice	Produce	7.00	1.00	0.25
Variety Clerk	Variety	7.68	1.00	0.25

Sunday Premium Hours: 12am to 12am

Night Premium Hours: 6pm to 7am

There is no compounding of premiums.

Employee mix ratios:

Checkers - 80% Journey
- 20% Apprentice

Clerks - 80% Journey
- 20% Apprentice

Prod.Clerks - 80% Journey

- 20% Apprentice

Variety Clerk - 100% at variety rate

Courtesy Clerk - hours scheduled at <= 25% of total contract hours (F.E.+ Groc.+ Prod.+ Variety)

Produce and variety clerks must work in their respective departments. Courtesy clerk functions are restricted so that they may not:

check groceries
perform file maintenance or bookkeeping
perform management functions
perform night stocking duties

Examples of courtesy clerk functions include carryout, bagging, bottles, cleaning, and stocking.

Only checking clerks may perform checking duties. Grocery clerks may perform all grocery and front end functions except checking, file maintenance, bookkeeping, and management duties. When non-union management is not in the store, a grocery clerk will be designated as head clerk and paid as such. The variety department must employ one full time variety clerk.

Non-Union Employees

	Hourly Rates
Manager	17.09
Assistant Manager	14.95
Bookkeeper	6.50
File Maintenance	10.25

Non-union employees do not receive premiums.

Hours by job function have been determined through Industrial Engineering studies and are used as restrictions to assign hours by department and function. The following hours are a function of the store characteristics and sales level.

Department	Function	Hours/Wk
Front End	Checking	560 min
Front End	File Maint	12 min 40 max
Front End	Bookkeeping	28 min 40 max
Front End	Carry/Bag/Bottles	230 min

Front End Hours Required For Minimum Coverage: 1081.

Grocery	Night Stocking	272 min
Grocery	Night Floor Maint	9 min
Grocery	Dairy Stocking	64 min
Grocery	Bread Stocking	16 min

Grocery Hours Required For Minimum Coverage: 418.

Produce Hours Required to For Minimum Coverage: 263.

Variety Hours Required to For Minimum Coverage: 44.

Company policy requires store management to schedule courtesy clerks for specific duties, to include carryout, bagging, and bottles. Furthermore, company policy defines certain functions which will be performed for a fixed number of hours. These are as follows:

Department	Function	Hours/Wk
Front End	Store Manager	48
Front End	Assistant Manager	40
Produce	Produce Manager	40 non-premium

Premium hours (by function) are allocated as a function of the percentage of business during those hours. Company policy dictates that only certain activities are required to be performed during premium hours. These include:

- checking (Sunday & Night)
- carryout/bagging/bottles (Sunday & Night)
- dairy/bread stocking (Sunday)
- produce work (Sunday & Night)
- load stocking (Night)

Except for department work defined above, no other work will be performed during Sunday or Night premium hours.

Sunday Business Percentage = 14.4%

Night Business Percentage = 27.2%

Model Formulation

Decision Variables: (Hours)

X1 = Manager

X2 = Assistant Manager

X3 = Bookkeeper

X4 = File Maintenance

X5 = Checker - Day

X6 = Checker - Night

X7 = Checker - Sunday

X8 = Clerk Groc - Day

X9 = Clerk Groc - Night

X10 = Clerk Groc - Sunday

X11 = Clerk FE - Day

X12 = Head Grocery Clerk

X13 = Produce Manager

X14 = Produce Clerk - Day

X15 = Produce Clerk - Night

X16 = Produce Clerk - Sunday

X17 = Variety Clerk

X18 = Courtesy Clerk FE - Day

X19 = Courtesy Clerk FE - Night

X20 = Courtesy Clerk FE - Sunday

X21 = Courtesy Clerk Groc - Day

X22 = Courtesy Clerk Groc - Sunday

X23 = Courtesy Clerk Prod - Day

X24 = Courtesy Clerk Prod - Night

X25 = Courtesy Clerk Prod - Sunday

X26 = Courtesy Clerk Variety

Objective Function:

Minimize Z = 17.09X1 + 14.95X2 + 6.5X3 + 10.25X4 + 10.24X5 + 10.49X6 + 11.24X7 + 10.24X8 + 10.49X9 + 11.24X10 + 10.24X11 + 11.40X12 + 11.40X13 + 10.24X14 + 10.49X15 + 11.24X16 + 7.68X17 + 4.17X18 + 4.42X19 + 4.67X20 + 4.17X21 + 4.67X22 + 4.17X23 + 4.42X24 + 4.67X25 + 4.17X26

Subject to:

Management

1) X1 = 48

2) X2 = 40

3) X3 >= 28

4) X3 <= 40

5) X4 >= 16

6) X4 <= 40

18) X1 + X2 + X12 >= 168

Front End

7) X5 + X6 + X7 >= 560

8) X6 >= 152

9) X7 >= 81

10) X18 + X19 + X20 >= 304

12) X20 >= 33

13) X19 >= 63

Grocery

15) X8 + X9 + X10 + X12 + X21 + X22 >= 418

16) X9 >= 281

17) X10 + X22 >= 12

Produce

19) X13 = 40

20) X13 + X14 + X15 + X16 + X23 + X24 + X25 >= 263

21) X16 + X25 >= 25

22) X15 + X24 >= 48

Variety

23) X17 >= 40

24) X17 + X26 >= 44

Management and Front End

14) X1 + X2 + X3 + X4 + X5 + X6 + X7 + X11 + X18 + X19 + X20 >= 1081

Union Restrictions Governing use of Courtesy Clerks

11) - 0.25X5 - 0.25X6 - 0.25X7 - 0.25X8 - 0.25X9 - 0.25X10 - 0.25X11 - 0.25X12 - 0.25X13 - 0.25X14 - 0.25X15 - 0.25X16 - 0.25X17 + 0.75X18 + 0.75X19 + 0.75X20 + 0.75X21 + 0.75X22 + 0.75X23 + 0.75X24 + 0.75X25 + 0.75X26 <= 0

Original Model Solution

The original model solution is shown in Appendix A.

The objective function value, or minimum weekly salary cost was $16,609. The hourly distributions for each personnel category are simply the values of the decision variables, which are shown on page 1 of Appendix A along with the variable definitions.

Several observations were made from the LINDO output.

1. The "Reduced Cost" values represent the amount by which the particular job classification hourly wage would have to be reduced in order for that job classification assigned hours to be greater than zero. For example, in order to assign hours to grocery clerks on Sundays, their hourly wage would have to be reduced by $0.50/hr.

2. The courtesy clerks are not assigned any hours working in variety. This is because the lower priced courtesy clerk hours are used to offset the grocery and produce clerk hours rather than the relatively lower priced variety clerks.

3. Based on the Dual Prices, only increases in the percent of courtesy clerk hours and the maximum number of bookkeeper hours will improve the solution.

4. There is very little surplus and no slack in the system. The manhour requirements established during industrial engineering studies have essentially optimized the manpower allocation for this particular store already.

5. A recent weekly salary cost for this store was $16,878. Notice that if the recommendations for employee allocations from this model had been followed, there would have been a savings of $268.96. While this is not a large amount by itself, it becomes very significant when it is extended over a year for all stores in this chain.

Sensitivity Analysis

The sensitivity analysis consisted of two phases. In the first phase the original LINDO solution was analyzed to determine what parameters could be changed and by how much without affecting the solution. In the second phase, selected parameters that are most likely to vary from the original problem formulation were changed and the problem rerun on LINDO for each change. This was performed to quantify how sensitive the optimum objective function value and variable solutions are to each parameter. The changes studied were based on possible negotiable portions of the union contract.

Phase I - Analysis of Original Solution

Analyzing the original solution (see Appendix A for solution printout) shows that changing the objective coefficients (i.e., personnel hourly rates) within the ranges given will not affect the optimal values of the decision variables. The objective function value (i.e., weekly manpower cost) may change, but the optimal number of hours allocated to each personnel category will not change.

For example, if the hourly wage of the bookkeeper (X3) is increased by more than $2.22, the hours assigned to the different personnel

categories could change. On the other hand, if the bookkeeper's hourly range decreased by any amount, the optimal assigned hours would not be affected. This agrees with common sense; because the bookkeeper's wage is relatively low to begin with, further reduction of the wage rates would not change the optimal hour distribution since it is already maximized based on other constraints.

This information could possibly be used in negotiating employee mix ratios, i.e., the proportion of apprentices to journeymen. Since the original objective function coefficients were obtained by taking the weighted average of journeymen to apprentices salaries; the "allowable ranges" of the objective function coefficients can translate into "allowable" employee mix ratios. For example, checker day hours (X5) pay can decrease as much as $1.53/hr before affecting the hours distribution. This means that the % of apprentices can be changed to 58% without affecting the optimal solution based on the following:

$$10.24-1.53 = 8.71/hr = x(11.05) + (1-x)(7.0)$$

$$x = 0.42 = 42\% \text{ Journeymen}$$

$$1-x = 0.58 = 58\% \text{ Apprentices}$$

"Allowable" here means what is possible within the problem formulation. Other constraints not included in the problem would further limit the percentage of apprentices.

Phase II - Analysis of Effects of Parameter Changes

The parameters chosen for this analysis are the parameters most likely to change due to contract negotiations or level of sales. Information provided by linear programming could be valuable to management in deciding what variables are most advantageous to negotiate and for how much. Three parameters were chosen for analysis,

1. Sunday business percentage was varied from 10 to 20%, (initially 14.4%).

2. Maximum percentage of courtesy clerks was varied from 20 to 30%, (initially 25%).

3. Contract employee base rates were increased 1%, 5% and 10% while eliminating the night and Sunday premium pay.

Parameters not chosen for analysis included the minimum hours required for each department, (essentially the right hand side

values of the constraints), which are based on historical data (called standards) and not likely to change.

Appendix B contains the computer printouts of the analyses described above.

Effects on Objective Function Value

The following table summarizes the effects of the parameter changes on the optimum objective function value.

	%	Obj Fn Value	% Change
Original Problem:	N/A	$16,609	N/A
Sunday % of Business:	0	16,493	-0.7%
	10	16,573	-0.22%
	20	16,653	0.26%
Maximum Courtesy Clerk %:	20	17,126	3.1%
	30	16,104	-3.0%
Base Rate Salary Increase % with Elimination of Premiums:	1	16,507	-0.6%
	5	17,090	2.9%
	10	17,644	6.2%

Based on the above data, the following observations were made:

1. The objective function value is relatively unaffected by changes in the Sunday business percentages as compared to courtesy clerk percentages and base rate salary increases.

2. It is not cost effective to exchange an increase in base rate salary above 1% for elimination of night and Sunday premiums.

3. During contract negotiations, it would be advantageous for management to pursue an increase in the maximum courtesy clerk percentage to offset an increase in cost such as hourly wage increases.

Effects on Decision Variable Values

1. Increasing Sunday % of Business From 14.4% to 20%.

   As to be expected, increasing the Sunday percentage resulted in moving personnel from days to Sundays.

2. Changing Percent of Courtesy Clerks

   Increasing the % of courtesy clerks simply resulted in replacing higher priced personnel such as checkers, produce clerks, and grocery clerks with lower priced courtesy clerks.

3. Changing Pay Rates and Eliminating Premium Pay

   Increasing the base pay rates along with eliminating the premium rates resulted in moving hours from days to nights and Sundays. For example, all the checker day hours were moved to night hours. This is an unreasonable result, but true to the model. In order to correct this problem, the model formulation would have to be changed to include a minimum requirement for daytime hours for each category of job function.

CONCLUSION

Presently the supermarket uses a process in which its industrial engineers establish manhour quotas per sales units by studying different stores and developing composite averages. The resource constraints in this linear program are based on those "standard" hours of each department's needs.

Because the slack and surplus values were zero in most cases shows that the composite departmental resource constraints when combined using a linear program to model a multi-departmental store are still very restrictive. In cases in which the linear program did allocate one department's manpower to a different department, a surplus and cost reduction were realized.

The difference between the optimum objective function value predicted by the model and the actual data obtained from a retail store is about 2%. The 2% value may not seem significant for a single store, but when combined with all stores over a longer period of time, the values do represent a significant cost savings.

Even with its limitations, the model is a very good tool to create "what if" scenarios. The model could be used in union negotiations to determine effects of changes in pay rates and employee mix

ratios. The model could also be used by the industrial engineers to further refine their standards.