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Title: Optimal Assignment of Personnel to Tasks in a Preventative Maintenance Program

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Author(s): S. I. Ahmed, R. Perlas and R. Wise

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Abstract: This report investigates personnel assignments in preventive maintenance programs. A Linear Programming model was developed to determine optimal personnel assignment to tasks for one of five product lines in a food manufacturing plant. Subjective assessments of task requirements and personnel skills are made, and a matrix developed that displays the efficiency of a technician in the performance of any given task.

OPTIMAL ASSIGNMENT OF PERSONNEL TO TASKS IN A PREVENTATIVE MAINTENANCE PROGRAM

S. Ahmed, R. Perlas, and R. Wise

EMP - P8908

INTRODUCTION

The assignment of personnel to accomplish specific tasks is one of the many responsibilities of the engineering manager. The manner in which he allocates his human resources has direct impact on the success of the organization as well as the achievements of his own department. It is essential that he be able to utilize some of the many powerful management techniques that will lead to the optimization of these valuable assets.

One such technique, and the subject of this project, is the application of linear programming for the assignment of personnel. Specifically, the preventive maintenance program for one of the five product lines of a Frito-Lay salty snack manufacturing plant is examined. Skills to perform the required tasks are identified, assessments of personnel skills are then made, and a resultant "efficiency" matrix is developed. This efficiency matrix becomes the "relative value" multiplier of the objective function decision variables, the Xi,j's, which for our model, represent the time spent by technician "i" working on task "j". The constraints of equipment availability and time to perform the various tasks are determined, as are man-hour levels for the maintenance personnel. Our model goal, then, is to maximize the product of the efficiency and decision variable matrices so that the technician with the highest skills will be assigned to the tasks that require those skills.

MODEL DEVELOPMENT

The building of our model began with a detailed analysis of the processing equipment that comprises the potato chip production line of the Frito-Lay food manufacturing facility located in Vancouver, Washington. By identifying the general attributes of the individual pieces of machinery, we were able to establish a relatively small number of categories, and combinations of categories, into which equipment with similar features could be placed. These categories are:

(A) Mechanical/Power Transmission
(B) Electrical/Electronic
(C) Hydraulics/Pneumatics
(D) Mechanical/Power Transmission and Electrical/Electronic (combination of categories 1 and 2)
(E) Mechanical/Power Transmission, Electrical/Electronic and Hydraulics/Pneumatics (combination of categories 1, 2, and 3)
(F) Start-ups/Mandatory Inspections

Next, a subjective assessment of the skills necessary to effectively perform the preventive maintenance (P.M.) procedures on each piece of equipment was made. This was accomplished utilizing the constant-sum method of pairwise comparisons that was presented during the second term of the Engineering Management Program. The skills that correspond to the decision elements of the pairwise comparisons are:

(1) Mechanical/Power Transmission
(2) Electrical/Electronic
(3) Hydraulics/Pneumatics
(4) Operating Knowledge
(5) Troubleshooting Skill
(6) Self Discipline

In a similar manner, a subjective assessment of these same skills was made for the maintenance technicians who would be performing the P.M. tasks, again using the constant-sum method. Combining these two matrices using a simple multiplication operation produces a matrix that displays the relative efficiency of each technician to perform the various procedures. These efficiences represent the "relative values" associated with the assignment of a task to a technician. Since our desire is to optimize the effectiveness of the P.M. program for this line, our objective function seeks to maximize the product of this matrix multiplication.

With the objective function established, it then became necessary to identify the constraints that form the boundaries within which our system operates. Some of this information, such as average time to perform the P.M. tasks, was extracted from the data base of the plant computerized Maintenance Control System (MCS). Summing these times for the equipment in each of the six categories for a one month period provided the right hand side values.

Finally, the time available for each technician to perform P.M. tasks had to be ascertained. Here, some assumptions had to be made. First, since this lines operates continuously Monday through Friday, it is available for down time corrective and preventive work on Saturday and Sunday only. This availability if further restricted to first and second shift because cleaning and sanitizing is performed on third shift, where the use of strong chemical agents and high pressure washing systems prevent the technicians from entering the area. While overtime is sometimes offered on a seniority basis to technicians not normally scheduled for these two days, we limited our model to include only those technicians who are required to work these days, namely Mark, Dean, and Butch on first shift, and Jack, Del, and Dave on second shift.

A second assumption made was that one third of all available maintenance time would be devoted to preventive work, the remaining two thirds would be consumed by corrective and emergency work. A review of the MCS historical data base showed this to be a reasonable assumption. However, since two other processing lines also run five days a week, only a percentage of the first and second shift technicians' time could be dedicated to the potato chip line, obviously the other areas also requiring maintenance attention. Because the potato chip fryer represents approximately 40 percent of the total throughput for these three lines, this value was used as the second multiplier for establishing the right hand side values for each technician.

With these assumptions made, we now had established our basic model, and we moved to the next phase of the project, that of inputting our objective function and associated constraints into the Lindo program that would provide our solution.

DESCRIPTIONS/DEFINITIONS

TASK CATEGORIES

(A) Mechanical/Power Transmission

Equipment included in this group are:

(1) Flat belt conveyors
(2) Plastic segmented conveyors
(3) Vibrating pan conveyors
(4) Flighted screw auger conveyors

These conveyors are electric motor driven with reduction provided by roller chain and sprockets, v-belt or HTD (high torque drive) and sheaves, and right angle miter or worm gearboxes.

(B) Electrical/Electronic

Components in this category are:

(1) Electrical power and control system panels containing circuit breakers, magnetic motor starters with overload relays, switching relays, and operators.
(2) Alternating current frequency inverters
(3) Direct current rectifying and controlling circuitry
(4) Combustion system safety circuitry

(C) Hydraulics/Pneumatics

This group includes:

(1) Hydraulic and pneumatic cylinders
(2) Hydraulic and pneumatic control systems
(3) Fluid pumping systems

(D) Mechanical/Power Transmission and Electrical/ Electronic

This category contains equipment with components or features included in categories A and B.

(E) Mechanical/Power Transmission, Electrical/Electronic, and Hydraulic/Pneumatic

This category contains equipment with components or features included in categories A, B, and C.

(F) Start Up/Mandatory Inspections

Start up is a term used to describe a component by component operational check of equipment prior to the beginning of each week's production run. Mandatory inspections include bi-weekly combustion system safety tests and corporate mandated product safety inspections.

SKILL CATEGORIES

(1) Mechanical/Power Transmission

This skill represents a technician's knowledge of conveyor construction, bearing types and uses, and drive systems.

(2) Electrical/Electronic

This skill reflects knowledge of electrical power and control circuitry, integrated circuits as used in alternating current frequency inverters and direct current rectifying and controlling circuits and combustion system safety circuitry.

(3) Hydraulics/Pneumatics

This skill deals with hydraulic and pneumatic systems including cylinders and controlling valves, as well as fluid pumping and pressure systems.

(4) Operating Knowledge

This category represents a technician's knowledge of how systems operate, where controls are located and idiosyncrasies of existing plant systems.

(5) Troubleshooting Skill

This skill reflects knowledge of each of the above categories and how they interact in the operation of a given system. It also deals with system logic and how a technician would find and address malfunctions.

(6) Self Discipline

This somewhat intangible attribute describes an individual's motivation and thoroughness in the completion of assigned tasks.

EFFICIENCY MATRIX DEVELOPMENT

Technicians/Skills Matrix (Normalized)

Tech/Skill	S1	S2	S3	S4	S5	S6
Mark	.158	.175	.170	.223	.192	.180
Dean	.117	.230	.125	.182	.193	.114
Butch	.169	.106	.175	.154	.115	.147
Jack	.229	.078	.223	.134	.124	.157
Del	.158	.191	.143	.154	.163	.163
Dave	.169	.219	.164	.154	.213	.239

Skills/Tasks Matrix (Normalized)

Skill/Task	T1	T2	T3	T4	T5	T6
S1	.274	.228	.026	.077	.164	.142
S2	.314	.351	.395	.095	.369	.357
S3	.009	.019	.034	.261	.046	.021
S4	.124	.116	.197	.165	.111	.150
S5	.205	.207	.219	.329	.246	.249
S6	.073	.080	.129	.075	.064	.081

Efficiency Matrix (Tech/Skill Matrix X Skill/Task Matrix)

Tech/Task	T1	T2	T3	T4	T5	T6
Mark	1.800	1.806	1.891	1.861	1.818	1.846
Dean	1.807	1.800	1.911	1.650	1.849	1.859
Butch	1.346	1.325	1.268	1.427	1.297	1.291
Jack	1.427	1.376	1.183	1.575	1.321	1.287
Del	1.690	1.703	1.714	1.583	1.706	1.705
Dave	1.948	1.996	2.042	1.893	2.008	2.026

(Note: Efficiencies are multiplied by a factor of 10)

BASE CASE:

As described in the report, the problem statement was designed to provide the production line foreman with a recommendation for staffing assignments to preventative maintenance tasks. The objective function results in a figure (that can be referred to as efficiency-hours) that is unique to the specific mix of tasks, technicians, and time available. Because the efficiency ratings are based upon individual-vs-individual comparisons, their transferability to comparisons of other technicians and job combinations is not intended.

The engineering manager and/or foreman familiar with the program development and the resultant LINDO outputs should analyze the value of the objective function, pattern of hours/task assigned to each available shift technician, and the dual price and other LINDO sensitivity data. A review of these results can challenge and compliment the manager and foreman's intuitive and subjective capability by providing "hard data" as well as insights into alternative actions that can potentially increase crew productivity and flexibility.

The linear program, LINDO outputs, solution summary, and analysis follow.

```
MAX   1.800AMARK + 1.806BMARK + 1.891CMARK + 1.861DMARK +
      1.818EMARK + 1.846FMARK + 1.807ADEAN + 1.800BDEAN +
      1.911CDEAN + 1.650DDEAN + 1.849EDEAN + 1.859FDEAN +
      1.346ABUTCH+ 1.325BBUTCH+ 1.2682CBUTCH+1.427DBUTCH+
      1.297EBUTCH+ 1.291FBUTCH+ 1.427AJACK + 1.376BJACK +
      1.183CJACK + 1.575DJACK + 1.321EJACK + 1.287FJACK +
      1.690ADEL  + 1.203BDEL  + 1.714CDEL  + 1.583DDEL  +
      1.706EDEL  + 1.705FDEL  + 1.948ADAVE + 1.996BDAVE +
      2.042CDAVE + 1.893DDAVE + 2.008EDAVE + 2.026FDAVE

SUBJECT TO

2)    AMARK + BMARK + CMARK + DMARK + EMARK + FMARK  <= 8
3)    ADEAN + BDEAN + CDEAN + DDEAN + EDEAN + FDEAN  <= 8
4)    ABUTCH+ BBUTCH+ CBUTCH+ DBUTCH+ EBUTCH+FBUTCH  <= 8
5)    AJACK + BJACK + CJACK + DJACK + EJACK + FJACK  <= 8
6)    ADEL  + BDEL  + CDEL  + DDEL  + EDEL  + FDEL   <= 8
7)    ADAVE + BDAVE + CDAVE + DDAVE + EDAVE + FDAVE  <= 8
8)    AMARK + ADEAN + ABUTCH+ AJACK + ADEL  + ADAVE <=15.5
9)    BMARK+  BDEAN + BBUTCH+ BJACK + BDEL  + BDAVE <= 4.0
10)   CMARK+  CDEAN + CBUTCH+ CJACK + CDEL  + CDAVE <= 3.0
11)   DMARK+  DDEAN + DBUTCH+ DJACK + DDEL  + DDAVE <= 3.5
12)   EMARK+  EDEAN + EBUTCH+ EJACK + EDEL  + EDAVE <= 7.0
13)   FMARK+  FDEAN + FBUTCH+ FJACK + FDEL  + FDAVE <=19.0
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CASE DESCRIPTION: BASE CASE, MANAGER'S EFFICIENCY COEFFICIENTS. EACH TECHNICIAN LIMITED TO 8 HOURS PREVENTATIVE MAINTENANCE FOR THE MONTH, PM TASKS TOTALLING 52 HOURS.

EMPLOYEE/TASK	A	B	C	D	E	F
MARK						8
DEAN			3		2	3
BUTCH	8					
JACK	4.5			3.5		
DEL	3				5	
DAVE						8
TOTAL/TASK	15.5	0	3	3.5	7	19

TOTAL/SHIFT: 48

BASE CASE:	15.5	0	3	3.5	7	19
TOTAL REQUIRED:	15.5	4	3	3.5	7	19
UNPERFORMED:	0	4	0	0	0	0

VALUE OF OBJECTIVE FUNCTION: Z=95.3040

ANALYSIS: LINDO DISTRIBUTED THE TECHNICIAN'S TIME ACCORDING TO THEIR HIGHEST PROFICIENCY UNTIL THE TIME REQUIRED FOR THE TASK WAS FULFILLED. IN THIS CASE, THE TIME ALLOCATED FOR PM TASKS WAS INADEQUATE, THEREFORE LINDO PICKED TASK B TO GO UNCOMPLETED. IF THE TIME ALLOCATION WAS INCREASED TO 52, THE TIME REQUIRED TO ACCOMPLISH ALL THE TASKS, THE OBJECTIVE FUNCTION VALUE, Z WOULD INCREASE TO 103.4795.

THESE RESULTS WILL BE USED AS A BASIS FOR COMPARISON WITH THE ALTERNATIVE CASES.