7
Referências Bibliográficas

APARICIO, P. E. **Diagnóstico y Elaboración de un Programa de Producción para una Empresa Embotelladora con Restricciones de Línea y de Disponibilidad de Envases de Vidrio**. Informe de Investigación, Escuela Profesional de Ingeniería Industrial, UNSA, Arequipa-Perú, 2000.

BOMBERGER, E. E. A Dynamic Programming Approach to a Lot Size Scheduling Problem. **Management Science**, v.12, n.11, 1966.

CONWAY, R.; MAXWELL, W.; MILLER, L. **Theory of Scheduling**. Addison – Wesley Publishing Company, 1967.

CORBETT, T. **Lote Econômico – Uma Necessidade?**. © 2003 Thomas Corbett Neto, Teoria das Restrições (TOC). Disponível em: <http://www.corbett-toc.com/port/loteco.htm>. Acesso em: 15 ago. 2003.

CRYSTAL BALL 2000.2 Software, Student Edition. Decisioneering, Inc., Denver, 2000.

DELPORTE, C. M.; THOMAS, L. J. Lot Sizing and Sequencing for N Products on One Facility. **Management Science**, v.23, n.10, 1977.

DOBSON, G. The Cyclic Lot Scheduling Problem with Sequence-Dependent Setups. **Operations Research**, v.40, n.4, 1992.

DOBSON, G. The Economic Lot Scheduling Problem: Achieving Feasibility Using Time-Varying Lot Sizes. **Operations Research**, v.35, n.5, 1987.

ELMAGHRABY, S. E. The Economic Lot Scheduling Problem (ELSP): Review and Extensions. **Management Science**, v.24, n.6, 1978.

EMMONS, H.; FLOWERS, A.D.; KHOT, C.M.; AND MATHUR, K. **Storm Personal**. Version 3.0: Quantitative Modeling for Decision Support. New Jersey: Prentice Hall/Allyn & Bacon, 1992.

FRENCH, S. **Sequencing and Scheduling**. New York: Ellis Horwood, 1982.

GALLEGO, G. An Extension to the Class of Easy Economic Lot Scheduling Problems. **IIE Transactions**, v.22, n.2, 1990.

GOYAL, S. K. Scheduling a Single Machine System: A Multi-Product Multi-Item Case. **Operations Research Quarterly**, v.26, n.3, 1975.

GRAVES, S. A Review of Production Scheduling. **Operations Research**, v.29, n.4, 1981.

GUERRERO, S. **O Problema do Seqüenciamento em uma Única Máquina com Penalidades por Antecipação e Atraso e Tempos de Preparação Dependentes da Seqüência**. Tese de Doutorado, Departamento de Engenharia Industrial, PUC-Rio, Rio de Janeiro, 1999.

HAESSLER, R. W. An Improved Extended Basic Period Procedure for Solving the Economic Lot Scheduling Problem. **AIIE Transactions**, v.11, n.4, 1979.

HALLIDAY, T.; LEVY, H. Uma Orientação para Projetos de Teses ou Dissertações. n. 3. Recife: Coleção Flabel, 2002.

HELD, M.; KARP, R. The Traveling Salesman Problem and Minimum Spanning Trees. **Operations Research**, v.18, p. 1138-1162, 1970.

KRAJEWSKY, L. J.; RITZMAN, L. P. **Operations Management**: Strategy and Analysis. 6. ed. Upper Saddle River: Prentice Hall, 2002.

LARSON, R. C.; ODONI, A. R. **Urban Operations Research**. Englewood Cliffs New Jersey: Prentice Hall, 1981.

LAWLER, E.; LENSTRA, J.; RINNOOY KAN, H.; SHMOYS, D. **The Traveling Salesman Problem**. New York: John Wiley & Sons, 1987.

LINGO Software, version 7.0: Lindo Systems, Chicago, 2002.

LUNA, E. **Memoria Descriptiva de Experiencia Profesional**. Informe de Investigación, Escuela Profesional de Ingeniería Industrial, UNSA, Arequipa-Perú, 2002.

LUSTOSA L.; **Demanda Independente e Estável**. Apostila de Aulas, Departamento de Engenharia Industrial, PUC-Rio, Rio de Janeiro, 2002.

MATHUR, M.; SOLOW, D. **Management Science**: The Art of Decision Making. Prentice Hall International Inc, 1994.

MAXWELL, W. The scheduling of Economic Lot Sizes. **Naval Research Logistic**, v.11, n. 2-3, 1964.

MAXWELL, W. L.; Singh, H. The Effect of Restricting Cycle Times in the Economic Lot Scheduling Problem. **IIE Transactions**, v.15, n.3, 1983.

McGEE V. E.; PYKE D. F. Periodic Production Scheduling at a Fastener Manufacturer. **International Journal of Production Economics**, v. 46-47, p. 65-87, 1996.

MENDONÇA, F. **O Problema da Programação do Lote Econômico Aplicado a uma Indústria por Processo**. Dissertação de Mestrado, Departamento de Engenharia Industrial, PUC-Rio, Rio de Janeiro, 1996.

MICHALEWICZ, Z.; FOGEL, D. **How to Solve It**: Modern Heuristics. Germany: Springer-Verlag, 2000.

MORTON, T.; PENTICO, D. **Heuristic Scheduling Systems**. New York: John Wiley & Sons, 1993.

PEARL, J. **Heuristics**: Intelligent Search Strategies for Computer Problem Solving. Addison-Wesley Publishing Company, 1984.

PIZZOLATO, N. **O Problema do Lote Econômico de Produção: Avaliação de Uma Aplicação Real**. Publicação do Departamento de Engenharia Industrial, PUC-Rio, Rio de Janeiro, 1995.

ROUNDY, R. Rounding off to Powers of Two in Continuous Relaxations of Capacitated Lot Sizing Problems. **Management Science**, v.35, n.12, 1989.

SILVER, E.; PYKE, D.; PETERSON, R. **Inventory Management and Production Planning and Scheduling**. 3. ed. New York: John Wiley & Sons, 1998.

SINGH, H.; FOSTER, J. B. Production Scheduling with Sequence Dependent Setup Costs. **IIE Transactions**, v.19, n.1, 1987.

SOUSA, M. **Planejamento e Programação da Produção em uma Indústria de Refrigerantes**. Dissertação de Mestrado, Departamento de Engenharia Industrial, PUC-Rio, Rio de Janeiro, 2002.

WINSTON, W. **Operations Research**: Applications and Algorithms. 3. ed. California: Wadsworth Publishing Company, 1994.

ZIPKIN, P. Computing Optimal Lot Sizes in the Economic Lot Scheduling Problem. **Operations Research**, v.39, n.1, 1991.

8
Apêndice:
Otimização usando a Regra de “Iniciar em Zero”

(a) Função Objetivo:

$$\min > \frac{1}{T}\left[\sum_{i=1}^{N}\frac{h_i}{2}(p_i - r_i)(\frac{p_i}{r_i})\sum_{m=1}^{M}t_m^2\delta_{im}\right]$$

Substituindo pelos respectivos valores da tabela 4.7, obtém-se:

min = 1 / 6 [6064.2486*(t1^2+t6^2+t11^2+t16^2) + 150252.5778*(t20^2) + 41915.2965*(t10^2+t19^2) + 10895.0257*(t2^2+t8^2+t12^2+t18^2) + 716153.0694*(t7^2) + 23758.9701*(t5^2+t15^2) + 486129.6*(t4^2+t14^2) + 17262.7123*(t3^2+t9^2+t13^2+t17^2)]

Visualmente pode-se mostrar assim:

P1	P2	P3	P4	P5	P6	P7	P8
t1^2							
			t2^2				
							t3^2
						t4^2	
					t5^2		
t6^2							
				t7^2			
			t8^2				
							t9^2
		t10^2					
t11^2							
			t12^2				
							t13^2
						t14^2	
					t15^2		
t16^2							
							t17^2
			t18^2				
		t19^2					
	t20^2						
6064,249	150252,6	41915,3	10895,03	716153,1	23758,97	486129,6	17262,71

(b) Restrições do Tipo:

$$\delta_{im}\left[p_i t_m - r_i \sum_{m'=m}^{m''(m)-1}(t_{m'} + y_{m'} + s_{m'})\right] = 0, \text{O } m = 1,...,M \text{ O }, i = 1,...,N$$

b1) 10500*t1 – 2799 * (t1+0.06944+y1+t2+0.0625+y2+t3+0.08333+y3+
t4+0.05556+y4 + t5+0.0625+y5) = 0;

b2) 9600*t2-1776*(t2+0.0625+y2+t3+0.08333+y3+t4+0.05556+y4+
t5+0.0625+y5+t6+0.06944+y6+t7+0.04167+y7) = 0;

b3) 9600*t3-1033*(t3+0.08333+y3+t4+0.05556+y4+t5+0.0625+y5+t6+
0.06944+y6+t7+0.04167+y7+t8+0.0625+y8) = 0;

b4) 18000*t4-144*(t4+0.05556+y4+t5+0.0625+y5+t6+0.06944+y6+t7+
0.04167+y7+t8+0.0625+y8+t9+0.09722+y9+t10+0.05556+y10+
t11+0.06944+y11+t12+0.0625+y12+t13+0.08333+y13) = 0;

b5) 10500*t5-878*(t5+0.0625+y5+t6+0.06944+y6+t7+0.04167+y7+t8+
0.0625+y8+t9+0.09722+y9+t10+0.05556+y10+t11+0.06944+y11+
t12+0.0625+y12+t13+0.08333+y13+t14+0.05556+y14) = 0;

b6) 10500*t6-2799*(t6+0.06944+y6+t7+0.04167+y7+t8+0.0625+y8+
t9+0.09722+y9+t10+0.05556+y10) = 0;

b7) 18000*t7-98*(t1+0.06944+y1+t2+0.0625+y2+t3+0.08333+y3+t4+
0.05556+y4+t5+0.0625+y5+t6+0.06944+y6+t7+0.04167+y7+t8+
0.0625+y8+t9+0.09722+y9+t10+0.05556+y10+t11+0.06944+y11+
t12+0.0625+y12+t13+0.08333+y13+t14+0.05556+y14+t15+
0.0625+y15+t16+0.08333+y16+t17+0.08333+y17+t18+0.0625+
y18+t19+0.04167+y19+t20+0.04167+y20) = 0;

b8) 9600*t8-1776*(t8+0.0625+y8+t9+0.09722+y9+t10+0.05556+y10+
t11+0.06944+y11) = 0;

b9) 9600*t9-1033*(t9+0.09722+y9+t10+0.05556+y10+t11+0.06944+
y11+t12+0.0625+y12) = 0;

b10) 18000*t10-1563*(t10+0.05556+y10+t11+0.06944+y11+t12+
0.0625+y12+t13+0.08333+y13+t14+0.05556+y14+t15+0.0625+
y15+t16+0.08333+y16+t17+0.08333+y17+t18+0.0625+y18) = 0;

b11) 10500*t11-2799*(t11+0.06944+y11+t12+0.0625+y12+t13+
0.08333+y13+t14+0.05556+y14+t15+0.0625+y15) = 0;

b12) 9600*t12-1776*(t12+0.0625+y12+t13+0.08333+y13+t14+0.05556+
y14+t15+0.0625+y15+t16+0.08333+y16+t17+0.08333+y17) = 0;

b13) 9600*t13-1033*(t13+0.08333+y13+t14+0.05556+y14+t15+0.0625+
y15+t16+0.08333+y16) = 0;

b14) 18000*t14-144*(t14+0.05556+y14+t15+0.0625+y15+t16+0.08333+
y16+t17+0.08333+y17+t18+0.0625+y18+t19+0.04167+y19+t20+
0.04167+y20+t1+0.06944+y1+t2+0.0625+y2+t3+0.08333+y3) = 0;

b15) 10500*t15-878*(t15+0.0625+y15+t16+0.08333+y16+t17+0.08333+
y17+t18+0.0625+y18+t19+0.04167+y19+t20+0.04167+y20+t1+
0.06944+y1+t2+0.0625+y2+t3+0.08333+y3+t4+0.05556+y4) = 0;

b16) 10500*t16-2799*(t16+0.08333+y16+t17+0.08333+y17+t18+
0.0625+y18+t19+0.04167+y19+t20+0.04167+y20) = 0;

b17) 9600*t17-1033*(t17+0.08333+y17+t18+0.0625+y18+t19+0.04167+
y19+t20+0.04167+y20+t1+0.06944+y1+t2+0.0625+y2) = 0;

b18) 9600*t18-1776*(t18+0.0625+y18+t19+0.04167+y19+t20+0.04167+
y20+t1+0.06944+y1) = 0;

b19) 18000*t19-1563*(t19+0.04167+y19+t20+0.04167+y20+t1+
0.06944+y1+t2+0.0625+y2+t3+0.08333+y3+t4+0.05556+y4+t5+
0.0625+y5+t6+0.06944+y6+t7+0.04167+y7+t8+0.0625+y8+t9+
0.09722+y9) = 0;

b20) 9600*t20-158*(t1+0.06944+y1+t2+0.0625+y2+t3+0.08333+y3+
t4+0.05556+y4+t5+0.0625+y5+t6+0.06944+y6+t7+0.04167+y7+
t8+0.0625+y8+t9+0.09722+y9+t10+0.05556+y10+t11+0.06944+
y11+t12+0.0625+y12+t13+0.08333+y13+t14+0.05556+y14+t15+
0.0625+y15+t16+0.08333+y16+t17+0.08333+y17+t18+0.0625+
y18+t19+0.04167+y19+t20+0.04167+y20) = 0;

(c) Restrição do Tipo: $$\sum_{m=1}^{M} y_m = T(1-\sum_{i=1}^{N}\frac{r_i}{p_i}) - \sum_{m=1}^{M} s_m$$

y1+y2+y3+y4+y5+y6+y7+y8+y9+y10+y11+y12+y13+y14+y15+y16+
y1+y18+y19+y20 = 0.1372599

Para obter os respectivos valores dos t_m's e y_m's é preciso resolver as equações formuladas em (a), (b) e (c) através da programação quadrática. Para isto, utiliza-se o Software LINGO 7.0.

No problema apresentado o LINGO 7.0 oferece a seguinte solução:

```
Local optimal solution found at step:             45
Objective value:                              3436.053

            Variable           Value        Reduced Cost
                  T1       0.3913619           0.0000000
                  T6       0.3946870           0.0000000
                 T11       0.4054802           0.0000000
                 T16       0.4078933           0.0000000
                 T20       0.9874962E-01       0.0000000
                 T10       0.2559016           0.0000000
                 T19       0.2650964           0.0000000
                  T2       0.2815626           0.0000000
                  T8       0.2744072           0.0000000
                 T12       0.3247620           0.0000000
                 T18       0.2292639           0.0000000
                  T7       0.3266654E-01       0.0000000
                  T5       0.2510279           0.0000000
                 T15       0.2506844           0.0000000
                  T4       0.2401661E-01       0.0000000
                 T14       0.2398321E-01       0.0000000
                  T3       0.1629993           0.0000000
                  T9       0.1650257           0.0000000
                 T13       0.1166337           0.0000000
                 T17       0.2009638           0.0000000
                  Y1       0.2383321E-01       0.1426228E-03
                  Y2       0.0000000            258.6804
                  Y3       0.0000000            80.18580
                  Y4       0.0000000            80.67991
                  Y5       0.0000000            85.26003
                  Y6       0.0000000            130.9061
                  Y7       0.0000000            130.9061
                  Y8       0.0000000            66.50996
                  Y9       0.0000000            73.29711
                 Y10       0.3152697E-01       0.1704633E-03
                 Y11       0.6622045E-01       0.0000000
                 Y12       0.0000000            233.9683
                 Y13       0.0000000            51.88397
                 Y14       0.0000000            51.38987
                 Y15       0.0000000            46.80975
                 Y16       0.0000000            74.46056
                 Y17       0.0000000            428.2523
                 Y18       0.1567929E-01      -0.1085967E-03
                 Y19       0.0000000            73.29683
                 Y20       0.0000000            73.29683
```

A coluna "*value*" indica os valores que tomam as variáveis (em dias).

O valor da Função Objetivo: 3436.053, representa o custo de manutenção de estoque em uma unidade de tempo (dia). Portanto, o custo por manutenção de estoque no Período de Planejamento H (6 dias) é igual a S/.20616,32.