

# مدل و الگوریتم یک مساله کنترل موجودی با در نظر گرفتن هزینه حمل و نقل

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## چکیده

در این مقاله، یک سیستم لجستیکی تامین کننده/خرده فروش، به عنوان یک محیط دوسطحی مورد بررسی قرار گرفته است. در هر یک از سطوح، یک موقعیت وجود دارد؛ تامین کننده یکتا در سطح اول مسئول تامین سفارشات خرده فروش در سطح دوم می باشد. ضمناً از حالت کمبود باید اجتناب شود. در این راستا یک مدل بر اساس مدل سنتی EOQ ارائه شده است. هزینه موجودی، هزینه سفارش دهی، هزینه حمل و نقل و ... در مدل منظور می گردند. در مدل، حمل چند مرحله ای در خلال دوره های سفارش دهی با تعدادی مشخص از وسایل نقلیه مجاز است. تصمیمات مدل برای مدیریت سیستم شامل تصمیمات طراحی (تعداد بهینه وسایل نقلیه مورد نیاز) و تصمیمات عملیاتی (اندازه سفارش بهینه و تعداد و مراحل حمل) می باشد. الگوریتمی جهت حل مدل ارائه گردیده است که پیاده سازی گردیده و در وب سایت این مقاله ([www.PedramSahba.com](http://www.PedramSahba.com)) قابل دسترس و اجرا می باشد. مثال عددی و تحلیل حساسیت جهت نشان دادن قابلیت های مدل و نیز تصدیق و تعیین اعتبار آن ارائه شده است.

واژه های کلیدی: مدل های یکپارچه<sup>۱</sup> - سیستم دو سطحی<sup>۲</sup> - کنترل موجودی - حمل و نقل

مقدمه

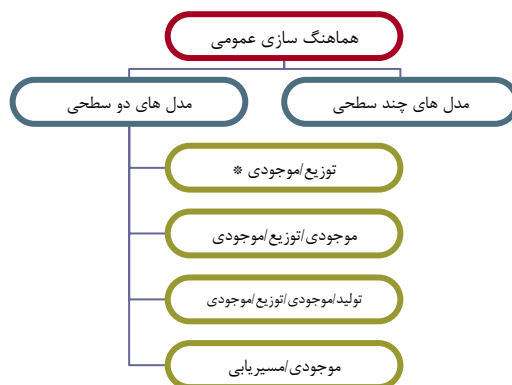
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:K<sub>f</sub>

:K<sub>v</sub>

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:p

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y

EOQ

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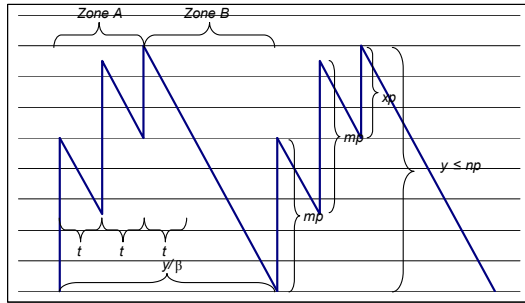
$$\beta t \left\lceil \frac{n}{m} \right\rceil$$

( )

(y)

$$(n-1)p < y \leq np$$

( )



( )

( )

$$\left. \begin{aligned} (n-1)p \leq y \leq np \\ \beta t \left\lceil \frac{n}{m} \right\rceil \leq y \end{aligned} \right\} \Rightarrow \beta t \left\lceil \frac{n}{m} \right\rceil \leq np \quad ( )$$

$$d \leq \frac{y}{\beta t}$$

( )

(n)

$$md \geq n \Rightarrow d \geq \frac{n}{m}$$

( )

( ) ( )

$$\frac{n}{m} \leq d \leq \frac{y}{\beta t}$$

( )

y n

( )

d

( )

d

( )

( )

$$\left\lceil \frac{n}{m} \right\rceil \leq \frac{y}{\beta t} \Rightarrow y \geq \beta t \left\lceil \frac{n}{m} \right\rceil \quad ( )$$

( )

n

$$\left\lceil \frac{n}{m} \right\rceil$$

y

$$\frac{n}{m}$$

( )

$$\frac{n}{m} \leq \left\lceil \frac{n}{m} \right\rceil \Rightarrow \beta t \frac{n}{m} \leq \beta t \left\lceil \frac{n}{m} \right\rceil \leq np$$

$$\Rightarrow \beta t \leq mp \quad ( )$$

n

$$t \left\lceil \frac{n}{m} \right\rceil$$

t

$$t \left\lceil \frac{n}{m} \right\rceil$$

B A ( )

A  
B

A

$\lfloor \frac{n}{m} \rfloor$

(A<sub>1</sub>) A

$$\bar{I}_{A_1} = \frac{mp + (mp - t\beta)}{2}$$

$$\bar{I}_{A_2} = \frac{((mp - t\beta) + mp) + (((mp - t\beta) + mp) - t\beta)}{2}$$

$$\bar{I}_{A_j} = \frac{(2j)mp - (2j - 1)t\beta}{2} \quad ( )$$

$K_v$   $K_f$   
 $\lfloor \frac{n}{m} \rfloor$   $K_v$   $K_f$

$$OC = K_f + K_v \lfloor \frac{n}{m} \rfloor \quad ( )$$

(h) (t)

A

$$IC_A = \sum_{j=1}^{\lfloor \frac{n}{m} \rfloor} \frac{(2j)mp - (2j - 1)t\beta}{2} . t . h = \alpha(n) \quad ( )$$

VTC = nc ( )

B

$$I_{\max, B} = y - \left( \left\lfloor \frac{n}{m} \right\rfloor t \right) (\beta) \quad ( )$$

$$\bar{I}_B = \frac{y - \left( \left\lfloor \frac{n}{m} \right\rfloor t \right) (\beta)}{2} \quad ( )$$

B

$$IC_B = \frac{y - \left( \left\lfloor \frac{n}{m} \right\rfloor t \right) (\beta)}{2} * \left( \frac{y}{\beta} - \left\lfloor \frac{n}{m} \right\rfloor t \right) * h$$

$$F_1TC = mft \lfloor \frac{n}{m} \rfloor \quad ( )$$

$$IC_B = \frac{h \left( y - \left\lfloor \frac{n}{m} \right\rfloor t \beta \right)^2}{2 \beta} \quad ( )$$

$t \lfloor \frac{n}{m} \rfloor$

$$F_1TC = mf \lceil t \lfloor \frac{n}{m} \rceil \rceil \quad ( )$$

Setup

TCU<sub>n</sub>(y)

y\*

y\*

n

$$F_1TC = mw \quad ( )$$

( )

y

y

m

TCU<sub>n</sub>(y)

$$TCU_n(y) = \frac{\gamma(n)}{y} + s\beta + \frac{h}{2} \frac{\left(y - \left\lfloor \frac{n}{m} \right\rfloor t\beta\right)^2}{y} \quad ( )$$

$$TCU = \frac{K_f}{\frac{y}{\beta}} + \frac{K_v \left\lfloor \frac{n}{m} \right\rfloor}{\frac{y}{\beta}} + \frac{sy}{\frac{y}{\beta}} + \frac{nc}{\frac{y}{\beta}} + \frac{mf \left\lfloor t \left\lfloor \frac{n}{m} \right\rfloor \right\rfloor}{\frac{y}{\beta}}$$

$$\frac{dTCU_n(y)}{dy} = 0 \Rightarrow y^* = \sqrt{\frac{2\gamma(n)}{h} + \left(\left\lfloor \frac{n}{m} \right\rfloor t\beta\right)^2} \quad ( )$$

$$+ \frac{mw}{\frac{y}{\beta}} + \frac{\alpha(n)}{\frac{y}{\beta}} + \frac{h}{2} \frac{\left(y - \left\lfloor \frac{n}{m} \right\rfloor t\beta\right)^2}{y}$$

s.t.

1.  $(n-1)p < y \leq np$

2.  $\left\lfloor \frac{n}{m} \right\rfloor t\beta \leq y$

3. n is Integer

( )

$$\frac{d^2TCU_n(y)}{dy^2} = \frac{2\gamma(n) + h \left(\left\lfloor \frac{n}{m} \right\rfloor t\beta\right)^2}{y^3} \quad ( )$$

n γ

$$\gamma(n) =$$

$$\beta \left( K_f + K_v \left\lfloor \frac{n}{m} \right\rfloor + nc + mft \left\lfloor \frac{n}{m} \right\rfloor + mw + \alpha(n) \right) \quad ( )$$

$$f(n) = TCU_n(y_n^*)$$

$$f(n)$$

$$y_1 = \max \left( (n-1)p + 1, \left\lfloor \frac{n}{m} \right\rfloor t\beta \right)$$

$$y_2 = np$$

$$f(n) = \min \{ TCU_n(y_1), TCU_n(y_2) \}$$

TCU<sub>n</sub>(y)

y\*

$$y^* = \sqrt{\frac{2\gamma(n)}{h} + \left(\left\lfloor \frac{n}{m} \right\rfloor t\beta\right)^2}$$

$$: \quad n_k = n_j + 1 \quad : \quad ( \quad )$$

$$TCU_{\min}(n_j) \leq TCU_{n_k}(y_{n_k}^*) \quad \forall y > 0 \Rightarrow \frac{d^2 TCU_n(y)}{dy^2} > 0$$

$$n_k \quad n_i \quad y_n^*$$

$$TCU_{\min}(n_j) \leq TCU_{n_k}(y_{n_k}^*) < TCU_{n_i}(y_{n_i}^*) \leq f(n_i)$$

$$f(n) = TCU_n(y_n^*)$$

$$: \quad t\beta \leq mp \quad :$$

$$( \quad )$$

$$n=1 \quad n \quad :$$

$$n \quad ( \quad ) \quad f(n_j) \quad :$$

$$( \quad ) \quad y_n^* \quad f(n_i) \quad n_j \quad n_i \quad :$$

$$y_n^* \quad : \quad f(n_j)$$

$$: \quad y_n^* \quad :$$

$$f(n) = TCU_n(y_n^*) \quad n \quad TCU_n(y_n^*) \quad y_n^* .$$

$$TCU_{\min} = \min\{TCU_{\min}, f(n)\}$$

$$( \quad TCU_{\min} \quad ) \quad n_i > n_j \quad :$$

$$: \quad y_n^* \quad :$$

$$TCU_{n_i}(y_{n_i}^*) > TCU_{n_j}(y_{n_j}^*)$$

$$y_1 = \max\left((n-1)p + 1, \left\lceil \frac{n}{m} t\beta \right\rceil\right)$$

$$y_2 = np$$

$$f(n) = \min\{TCU_n(y_1), TCU_n(y_2)\}$$

$$f(n_i) \geq TCU_{n_i}(y_{n_i}^*) > TCU_{n_j}(y_{n_j}^*) = f(n_j)$$

$$f(n_k)$$

$$TCU_{\min} = \min\{TCU_{\min}, f(n)\}$$

$$TCU_{n_k}(y_{n_k}^*) \quad n_k = n + 1 \quad :$$

$$f(n_j) \leq TCU_{n_k}(y_{n_k}^*) \leq f(n_k)$$

$$TCU_n(y_n^*)$$

$$: \quad n_k \quad n_i$$

$$TCU_{\min} \leq TCU_{n_k}(y_{n_k}^*)$$

$$n_i > n_k \Rightarrow$$

$$f(n_j) \leq TCU_{n_k}(y_{n_k}^*) < TCU_{n_i}(y_{n_i}^*) \leq f(n_i)$$

$$n$$

$$n = n + 1$$

$$TCU_{\min}(n_j) = \min\{f(n_r) \mid \text{for all } n_r \leq n_j\}$$

K = 100 \$ C++  
 β = 100 unit/day  
 s = 0.3 \$/unit EOQM  
 c = 40 \$/trip IEOQ  
 f = 40 \$(/day.vehicle)  
 h = 0.02 \$(/unit.day) EOQResults GetResults()  
 U = 8 hour/day  
 t = 4 hour/day  
 d = 2 trip/day  
 p = 200 unit Singleton Pattern GetResults()  
 L = 2 day  
 ( )

EOQResults

y\*

y\* n=13

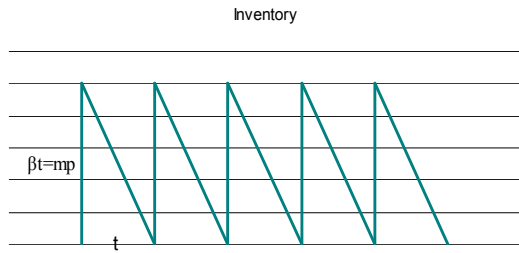
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جدول ۱: خروجی اجرای الگوریتم حل مدل اولیه.

n	Y-L	Y-U	Y*	TCU*	TCU1	TCU2	Fn
1	50	200	1360.15	57.2	400.5	124.5	124.5
2	201	400	1500	60	143.95	90.25	90.25
3	401	600	1646.21	61.92	100.59	80.17	80.17
4	601	800	1886.8	66.74	94.24	81.5	81.5
5	801	1000	1989.97	68.8	86.45	78.6	78.6
6	1001	1200	2116.6	70.33	82.77	77.33	77.33
7	1201	1400	2308.68	74.17	84.39	80.07	80.07
8	1401	1600	2393.74	75.87	82.91	79.81	79.81
9	1601	1800	2511.97	77.24	82.42	80.06	80.06
Algorithm ended before step 10							
<b>Results:</b>							
n	= 6						
y*	= 1200						
TCU*	= 77.33333333333333						
r	= 12						
x	= 200						
m	= 3						
<b>Costs:</b>							
Ordering	= 8.33333333333333						
Purchasing	= 30						
Var. Trans	= 20						
Fix. Trans	= 7.5						
Inventory	= 11.5						



(n)



- $K_f = 70$  \$
- $K_v = 30$  \$
- $\beta = 100$  unit/day
- $s = 0.3$  \$/unit
- $c = 40$  \$/trip
- $f = 30$  \$/(day.Vehicle)
- $w = 3$  \$/vehicle
- $h = 0.02$  \$/(unit.day)
- $t = 1$  day
- $p = 25$  unit/vehicle
- $L = 2$  day

( )

TCU n ( )

m=1,2,3

$\beta t \leq mp$

m=1,2,3

$100 * 1 \leq 25 * m$

m=5

$$mp \geq t\beta \Rightarrow 5 * 25 \geq 1 * 100 \Rightarrow 125 \geq 100$$

m=4

$$mp = 4 * 25 = 100$$

$$t\beta = 1 * 100 = 100$$

$$\left[ \frac{n}{m} \right] = 1$$

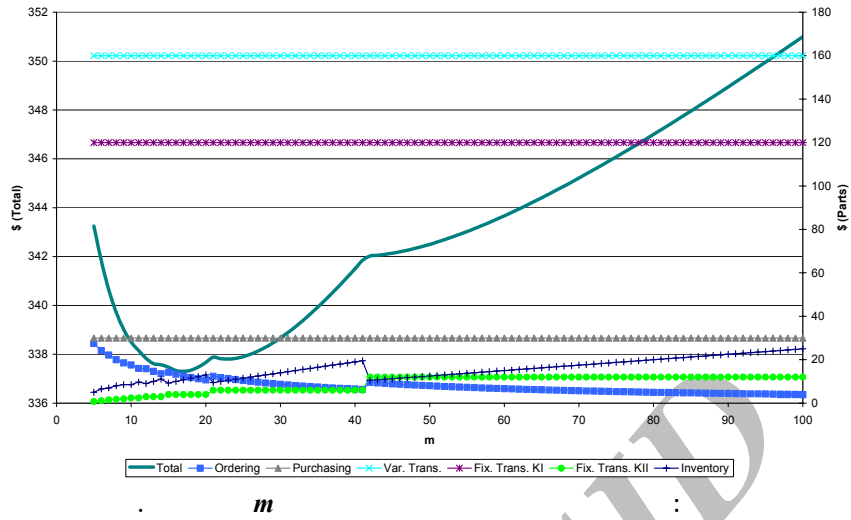
$$\left[ \frac{n}{m} \right] = 3$$

$$\left[ \frac{n}{m} \right] = 2$$

$$\left[ \frac{n}{m} \right] = 4$$

( )

Optimized Costs



m=17

( )

337.29\$

$$\left\lceil \frac{n}{m} \right\rceil = 2$$

$$\left\lceil \frac{n}{m} \right\rceil = 1$$

$$\left\lceil \frac{n}{m} \right\rceil = 3$$

51

1275

16 12,8,4 n

m

m

m

(y\*, n\*, m\*)

m

( )

m

m

( )

m TCU\*

K<sub>v</sub>

70

K<sub>f</sub>

30

m

m

$$m = \left\lceil \frac{t\beta}{P} \right\rceil + 1$$

( )

n\*

m=5

m\*

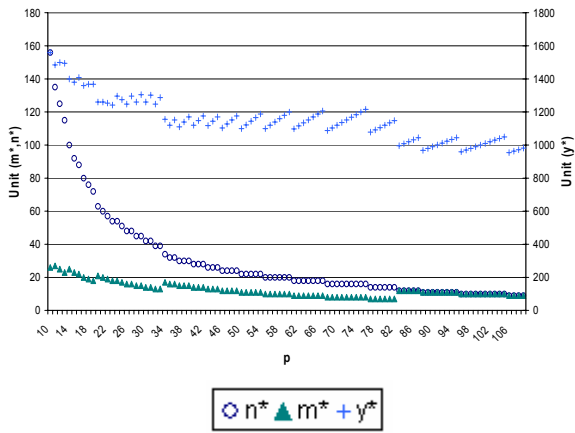
m

m=100

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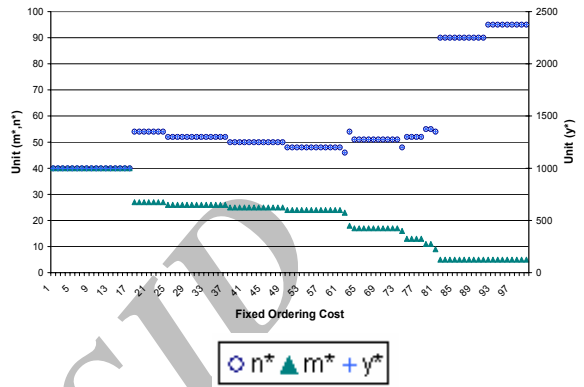
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Vehicle Capacity Sensitivity Analysis



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Ordering Cost Sensitivity Analysis

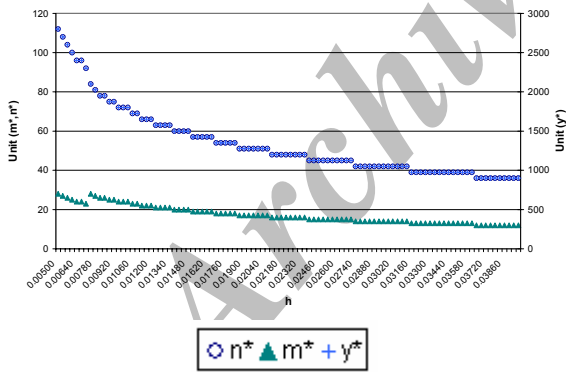


( $m$ )

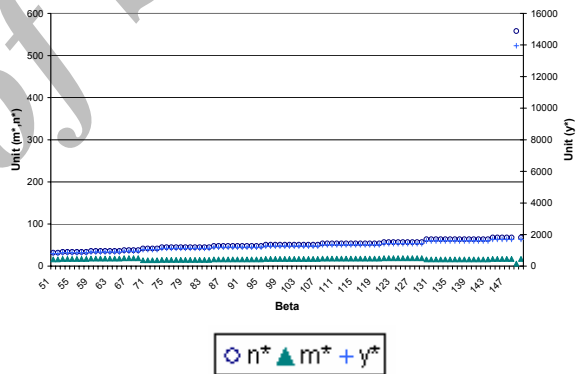
( $m^*$ )

( )

Holding Cost Sensitivity Analysis



Demand Rate Sensitivity Analysis



( $m$ )

( $\beta$ )

( )

$n^*$

( $y^*$ )

$n^*$   
( $n^*$ )

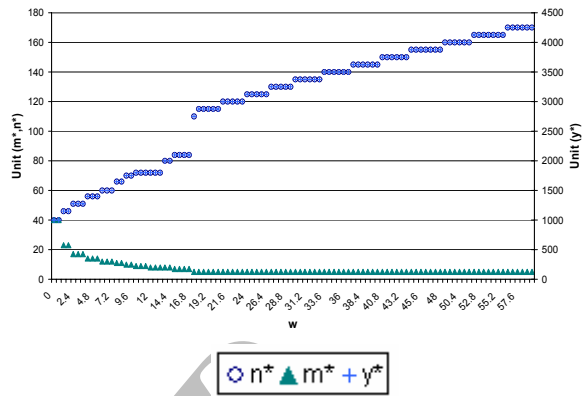
$y^*$

( $m^*$ )

$p$

( )

Fixed Trans. Cost K(II) Sensitivity Analysis



( $m^*$ )

( $y^*$ )

( $y^*$ )

( )

(p)

(t)

$y^* n^* (t)$

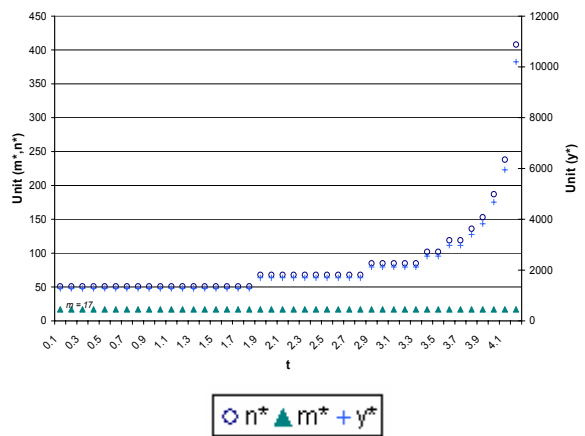
t

$y^* n^*$

( )

$y^* n^*$

Trip Duration Sensitivity Analysis



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- 1 - Cohen, M. A. and Lee, H. L. (1988). "Strategic analysis of integrated production-distribution systems: models and methods." *Operations Research*, Vol. 36, No. 2, PP.216–228.
- 2 - Mak, K. L. and Wong, Y. S. (1995). "Design of integrated production-inventory-distribution systems using genetic algorithm." *Proc., 1st IEE/IEEE Int. Conf. on Genetic Algorithms in Engineering Systems: Innovations and Applications*, Sheffield, Engl. PP.454–460
- 3 - Blumenfeld, D. E., Hall, R.W., and Jordan, W. C. (1985b). "Trade-off between freight expediting and safety stock inventory costs." *Journal of Business Logistics*, Vol. 6, No. 1, PP.79–100.
- 4 - Yano, C. A. and Gerchak, Y. (1989). "Transportation contracts and safety stocks for Just-in-time deliveries." *Journal of Manufacturing and Operations Management*, Vol. 2, PP.314–330.
- 5 - Zhao, Q. H., Wang, S. H., Lai, K.-K. and Xia, G. P. (2004). "Model and algorithm of an inventory problem with the consideration of transportation." *Computers & Industrial Engineering*, Vol.46,PP. 389-397.
- 6 - Ernst, R. and Pyke, D. F. (1993). "Optimal base stock policies and truck capacity in a two-echelon system." *Naval Research Logistics*, Vol. 40, PP.879–903.
- 7 - Blumenfeld, D. E., Burns, L. D., Diltz, J. D. and Daganzo, C. F. (1985a). "Analyzing trade-offs between transportation, inventory and production costs on freight networks." *Transportation Research*, Vol.19B, No.5, PP.361–380.
- 8 - Chien, T. W. (1993). "Determining profit-maximizing production/shipping policies in a one-to-one direct shipping, stochastic demand environment." *European Journal of Operational Research*, Vol. 64, PP.83–102.
- 9 - Federgruen, A. and Simchi-Levi, D. (1995). "Analysis of Vehicle Routing and Inventory Routing Problems." *Handbooks in Operations Research and Management Science*, Vol. 8, PP.297–373.
- 10 - Kleywegt, A. J., Nori, V. S. and Savelsbergh, M. W. P. (2002). "The stochastic inventory routing problem with direct deliveries." *Transportation Science*, Vol. 36, No. 1, PP.94–118.
- 11 - Cheng, L. and Duran, M. A. (2004). "Logistics for world-wide crude oil transportation using discrete event simulation and optimal control." *Computer & Chemical Engineering*, Vol. 28, PP.897-911.

1 - Integrated Models

3 - Functions

5 - General Coordination Problem

7 - Expedited Transportation

9 - Discrete Event Simulation

11 - Markov Decision Process

13 - Multiple Items

2 - Two-Echelons

4 - Coordination in Organizations

6 - Multi-Plant Coordination Problem

8 - Vendor Managed Inventory (VMI)

10 - Stochastic Optimal Control

12 - Economic Order Quantity (EOQ)