

# Supply Chain Engineering

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**Errata First Edition, Springer, 2011.**

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## Foreword

**05-Sep-2011**

Replace “missing” by “mission’ in line 4.

**27-Aug-2011**

Replace “breath-first” by “breadth-first”. Note that this error also appears in the introductory description on Internet sites such as Amazon, but has already been corrected in the printed version.

## Introduction

**18-May-2014**

On page 18, replace “disposal time is the required” with “disposal time is the time required”.

**09-Dec-2011**

In the References on page 14, reference 2, replace “upply chain” with “supply chain”. Update publisher information to “Pitman Publishing, London.”

Page 4, replace first sentence with “For an organization to become a long term component of a supply chain requires that the relationship between them is beneficial in the long run for the organization and for the rest of the supply chain, i.e. it is a win-win relationship.”

Page 4, first paragraph, change “In the manufacturing industries, examples are” to “In the manufacturing industries, examples of supply chains are”.

**31-Aug-2011**

In Figure 1.5, change “Stratetic” to “Strategic” in the top left cell of the matrix.

## Engineering Planning and Design

**18-May-2014**

On page 30, replace “recyclable materials collected for” with “recyclable materials collected from”.

On page 55, replace “higher- level” with “higher-level” without the extra space.

#### **24-Oct-2012**

On page 34, second paragraph, replace “articles and book has been published” with “articles and books have been published”.

On page 38, last paragraph, replace “There exist a separation” with “There exists a separation”.

#### **09-Dec-2011**

On page 16, in the second paragraph, replace “Quick sort” with “Quicksort”.

On page 57, first true-false question, replace “such budgets or deadlines” with “such as budgets or deadlines”.

On page 23, in the second paragraph, replace “their three-digit ZIP codes” with “the first three digits of their ZIP codes”.

On page 18, last sentence before Section 2.1.3, replace “This cost sometimes also all” with “This cost is sometimes also called”.

#### **08-Dec-2011**

On page 19, replace “must create a least” by “must create at least”.

#### **19-Oct-2011**

On page 38, first paragraph, third line replace “the value of some decision variables” by “the value of the decision variables”.

#### **30-Sep-2011**

On page 23, last paragraph, third line replace “date” by “data”.

On page 36, replace “analog systems” with “analog models” and “analog system” with “analog model” in the second paragraph on model classification.

## **Transportation Systems**

#### **24-Oct-2012**

Page 138, first paragraph replace “more and three fourths” with “more than three fourths”.

#### **09-Dec-2011**

Page 136, in section 5.2.3 Rail, replace “gauge is the distance between the tracks” with “gauge is the distance between the rails”

#### **24-Oct-2011**

On page 128, first paragraph, change “relative inexpensive” to “relatively inexpensive”.

On page 128, first paragraph, next line, change “change” to “changes”.

On page 130, first paragraph, change “on a either distance” to “on either distance”.

On page 134, second paragraph, change “than can be transported” to “that can be transported”.

On page 135, second paragraph, change “variable cost include” to “variable costs include”.

On page 136, third paragraph, change “a diameter of 36 inch” to “a diameter of 36 inches”.

On page 136, third paragraph, change “fuels such diesel” to “fuels such as diesel”.

On page 136, fourth paragraph, change “locomotive is rail vehicle” to “locomotive is a rail vehicle”.

On page 137, second paragraph, change “switching yard is freight facility” to “switching yard is a freight facility”.

Page 138, third paragraph, change “In 2008 the only” to “As of 2008, the only”.

Page 142, first paragraph, change “20 km per hours” to “20 km per hour”.

Page 146, last paragraph, change “Only the ports” to “The ports” and change “east coast are ranked” to “east coast are the only U.S. ports ranked”.

Page 147, first paragraph, change “which carry” to “which carries”.

Page 152, first paragraph, change “common example of free” to “common example of a free”.

Page 152, first paragraph, change “brought into country” to “brought into the country”.

## Single Flow Routing

### 26-Oct-2011

Page 162, second paragraph, change “Dijkstra’ algorithm” to “Dijkstra’s algorithm”.

Page 165, second paragraph, change “Dijstra’s” to “Dijkstra’s”.

Page 165, third paragraph, change “abstracted to the either the” to “abstracted to either the”.

Page 166, third paragraph, change “no longer will a have” to “no longer will have”.

Page 167, second paragraph, change “successor node had permanent” to “successor node had a permanent”.

Page 176, first paragraph, change “larger than the total demand” to “larger than or equal to the total demand”.

Page 176, first paragraph, change “The arc flow has to no larger” to “The arc flow cannot be larger”.

Page 176, first paragraph, change “difference between the out flows and the in flows.” to “difference between the outflows and the inflows.”

Page 176, last paragraph, change “on the arc (1,7) and (7,1)” to “on the arcs (1,7) and (7,1)”

## Single Vehicle Routing

### 18-May-2014

On page 240, replace “all calculations be redone” with “all calculations must be redone”.

### 14-Dec-2011

On page 222, next to last paragraph, replace “on some the largest” with “on some of the largest”.

On page 223, text paragraph, replace “was chosen as so that the algorithms” with “was chosen so that the algorithms”. In the same sentence, replace “but the same time” with “but at the same time”.

On page 230, First step in the algorithm, replace “Start a point” with “Start at a point”.

On page 230, first paragraph after the algorithm, replace “inserted but not lie” with “inserted but do not lie”.

On page 236, second paragraph, replace “(1-2-3-4-6-5)” with “(1-2-3-4-6-5-1)” to clearly indicate that this is a closed tour.

Replace everywhere in text and captions “spacefilling” with “space-filling”.

On page 237, in the caption of the figure, change “TSP” with “TSP6”. In the second paragraph, change “is space-filling curve” to “is a space-filling curve”. In the same paragraph change “can be used on very large problem” with “can be used for very large problem”.

On page 239, the calculations for the computation of the cheapest insertion penalties are correct but confusingly formatted. The line breaks should be place after the comma, not before the equation sign.

On page 241, first paragraph, replace “outer minimization over the free points” to “outer maximization over the free points”.

### 09-Dec-2011

On page 213, third line of second paragraph, replace “a small as possible” with “as small as possible”.

### 08-Dec-2011

On page 214, third paragraph, replace “a large variety of heuristic algorithms has been developed” to “a large variety of heuristic algorithms have been developed”.

### 26-Oct-2011

On page 213, first paragraph, change “where the customer correspond” to “where the nodes correspond”.

On page 215, first paragraph, change “as distinguished of” to “as distinguished from”.

On page 216, second paragraph, change “On of the steps” to “One of the steps”.

On page 218, first paragraph, change “common case arise” to “common case arises”.

### 06-Sep-2011

On page 230, substitute in the last line “do east” with “to due east”.

### 02-Sep-2011

On page 221, substitute in the first paragraph “his inventory of items equal zero” with “his inventory of items equals one when he arrives at the last node and equals zero after he has sold his last item”.

Insert as the next to last sentence in the first paragraph just before the sentence starting with “As a consequence...” the sentence “Only one tour can depart from node 1 and all nodes must be part of a tour.”

## Multiple Vehicles Routing

### 18-May-2014

On page 294, replace “to optimal ity” with “to optimality” without the extra space.

### 07-Apr-2014

On page 279, 6<sup>th</sup> line from the bottom, replace “change” with “chance”.

### 14-Dec-2012

On page 316 in step 3 of the algorithm 9.2 change the formula reference from (9.31) to (9.34).

### 02-Nov-2012

On page 307, changed in the headers for the improvement algorithms “Improvements Algorithms” to “Improvement Algorithms” both for intra-route and inter-route improvements.

### 13-Aug-2012

On page 315, in the first paragraph, replace “A candidate service request is desirable” with “A candidate service provider is desirable”.

### 04-Jan-2012

On page 326 in equation (9.47), for the boundary conditions of the inventory  $q$ , the lower bound for the value of  $q$  is the demand of the corresponding customer.

$$LB_i = dem_i \quad \forall i$$

$$UB_i = cap \quad \forall i$$

On page 367, in Section 9.4 on the vehicle routing problem with time windows, added the constraint ranges. Also eliminated the last constraint which is redundant since  $x$  decision variables are specified as binary variables.

### General Vehicle Routing Formulation

$$\text{Min} \quad \sum_{k \in K} \sum_{(i,j) \in A_k} c_{ijk} x_{ijk}$$

$$\begin{aligned}
s.t. \quad & \sum_{k \in K} \sum_{j \in N \cup D_k} x_{ijk} = 1 && \forall i \in N \\
& \sum_{k \in K} \sum_{j \in N} x_{o_k jk} \leq V \\
& \sum_{j \in N \cup D_k} x_{o_k jk} = 1 && \forall k \\
& \sum_{i \in N \cup O_k} x_{ijk} - \sum_{i \in N \cup D_k} x_{jik} = 0 && \forall k, \forall j \in N \\
& \sum_{i \in N \cup O_k} x_{id_k k} = 1 && \forall k \\
& x_{ijk} (h_{ik} + t_{ijk} - h_{jk}) \leq 0 && \forall i, \forall j, \forall k \\
& a_i \leq h_{ik} \leq b_i && \forall i, \forall k \\
& x_{ijk} (q_{ik} + dem_j - q_{jk}) \leq 0 && \forall i, \forall j, \forall k \\
& dem_i \leq q_{ik} \leq cap_k && \forall i, \forall k \\
& x_{ijk} \in B && \forall i, \forall j, \forall k
\end{aligned}$$

#### 14-Dec-2011

On page 359, in the example calculations of the updated row prices, change the route length of route 56 in all calculations from 1508.81 to 1508.51, and change value of p8 from 589.58 to 489.58. This value is consistent with the value shown in the stage 3 row price calculations in Table 9.78.

On page 360, first paragraph, third line, replace “have to updated” with “have to be updated”.

#### 13-Dec-2011

On page 351, the examples of the savings calculations have the incorrect (opposite) sign in the formulas and in the terms of the expression, but the value and the sign of the savings result is correct.

$$\begin{aligned}
savings &= (d_{d1,c1} + d_{c1,c2} - d_{d1,c2}) + (-d_{c4,c1} - d_{c1,s3} + d_{c4,s3}) \\
&= (292.03 + 628.79 - 461.86) + (-766.07 - 635.41 + 305.98) = -636.54
\end{aligned}$$

$$\begin{aligned}
savings &= (d_{c5,s1} + d_{s1,d1} - d_{c5,d1}) + (-d_{s3,s1} - d_{s1,d1} + d_{s3,d1}) \\
&= (265.89 + 412.72 - 163.78) + (-308.00 - 412.72 + 355.82) = 149.93
\end{aligned}$$

On page 351, replace “in link (s3-d1) or route 2” to “in link (s3-d1) of route 2”.

### 08-Dec-2011

On page 276, replace “If each vehicle can only a single route” with “If each vehicle can only execute a single route”.

On page 276, replace “the a warehouse management system” by “the warehouse management system”.

On page 276, replace “collect the products of the warehouse” by “collect the products in the warehouse”.

On page 281, replace “each of the customer facilities and the returns to the depot” by “each of the customer facilities and then returns to the depot”.

### 07-Dec-2011

On page 287 in Table 9.12 in the row for step 4, the third facility in the route is  $c1$  instead of  $c10$ .

On page 404 in Table 9.140 in the line for step 7, the last facility on the route has to be  $d1$  rather than  $s1$ .

### 18-Oct-2011

On page 321 in the first text paragraph, substitute “In the latter case” for “In the later case”.

## Inventory Systems

### 18-May-2014

On page 442, replace “must by definition” with “must be by definition”.

### 30-Nov-2012

Pages 472 and 473, replace the product  $d.LT$  in formulas 10.76 through 10.79 with either  $d.lt$  or  $D.LT$ . The two products will yield the same value provided consistent time units are used. The product with capital letters indicates annual values and the product with lower case letters indicates weekly values in the example.

### 04-May-2012

Page 486, line 6, replace “lead for ordering” with “lead time for ordering”

Page 453, next to last line, replace “expected excess or  $E[NS(Q)]$ ” with “expected excess or  $E[NE(Q)]$ ”

### 29-Apr-2012

In Equation (10.89) the upper bound of the summation sign “ $t=k+lt+1$ ” is replace by “ $t=k+lt$ ”. In the preceding equation the upper bound of the summation signs is changed from 8 to 7. This is consistent with the preceding two equations and the fundamental principle holds that there are  $(lt+1)$  terms in the sum.

True False question 8, replace “less than or equal to than the safety” with “less than or equal to the safety”.

## Supply Chain Systems

18-May-2014

On page 497, replace “objectives often conflicted” with “objectives often conflict”.

On page 498, in the fifth line “self-serv ing” should be replaced with “self-serving” without the extra spaces.

On page 506, replace “The smaller is the value of the A parameter, the more skewed is the curve becomes” with “The smaller the value of the A parameter is, the more skewed the curve becomes”.

On page 511, replace “just in item” with “just in time”.

On page 512, replace “while to role of the distribution” with “while the role of the distribution”.

On page 513, replace “have to be distributed of large” with “have to be distributed to large”.

On page 517, replace “processing of the date” with “processing of the data”.

On page 517, replace “have described in” with “have been described in”.

## Supply Chain Models

18-May-2014

On page 522, replace “the recommendations derived at after all the processing and design work may be faulty” with “the recommendations, derived after all the processing and design work, may be faulty”

On page 525, replace “products are process” with “products are processed”.

On page 525, replace “such as month or a week” with “such as a month or a week”.

On page 526, replace “may also a minimum quantity” with “may also have a minimum quantity”.

On page 527, replace “solver may be standalone application” with “solver may be a standalone application”.

On page 528, replace “the number supply chain components” with “the number of supply chain components”.

On page 531, the variables for average origin and destination cycle inventories are defined as  $OCI_{mp}$ ,  $DCI_{mp}$ . They denote product quantities. In the next line, the annual costs associated with the origin and destination cycle inventories are defined as  $OCIC_{mp}$ ,  $DCIC_{mp}$ , with the additional capital C letter at the end.

On page 547, replace “allocate of customers to warehouses” with “allocation of customers to warehouses”.

On page 539 in table 12.2, the in-transit inventory is denoted as “In-transit” without the extra spaces.

On page 539 in table 12.2, the number of standard deviations is indicated by lower case z, not upper case Z.

#### 04-May-2012

In the arc-based multi-echelon supply chain design model, the summations of the transportation flows have to be executed over specific subsets of the facilities in the supply chain. This requires an update to the notation and the model.

The following notation will be used.

$M$	set of suppliers
$N$	set of transformation facilities
$K$	set of customers
$O$	set of origin facilities of transportation channels $O = M \cup N$
$D$	set of destination facilities of transportation channels $D = N \cup K$
$y_j$	the status of transformation facility $j$ , equal to one if the facility is established, zero otherwise
$x_{ijp}$	amount of flow being transported directly from facility $i$ to facility $j$ of product $p$
$v_{jp}$	amount of flow throughput through facility $j$ of product $p$
$pc_{ip}$	cost rate for purchasing one unit of product $p$ from facility $i$
$tc_{ijp}$	cost rate for transporting one unit of product $p$ from facility $i$ to facility $j$
$hc_{jp}$	cost rate for handling or processing one unit of product $p$ through transformation facility $j$
$res_{jp}$	resource consumed by one unit of product $p$ when it is processed through transformation facility $j$

## Model

The arc-based supply chain model is then as follows.

### Model Error! Bookmark not defined..1. Arc-Based Multi-Echelon Supply Chain Model

$$\min z = \sum_j^N f_j y_j + \sum_i^M \sum_j^N \sum_p^P pc_{ip} x_{ijp} + \sum_{i \in O} \sum_{j \in D} \sum_p^P tc_{ijp} x_{ijp} + \sum_j^N \sum_p^P hc_{jp} v_{jp}$$

$$\begin{aligned}
s.t. \quad & \sum_j^N \sum_p^P x_{ijp} \leq sup_i && i \in Suppliers \\
& \sum_{i \in O} x_{ijp} = v_{jp} && j \in Transformers, \forall p \\
& \sum_{k \in D} x_{jkp} = v_{jp} && j \in Transformers, \forall p \\
& \sum_p^P res_{jp} \cdot v_{jp} \leq cap_j \cdot y_j && j \in Transformers \\
& \sum_j^N x_{jkp} = dem_{kp} && k \in Customers, \forall p \\
& y_j = \{0,1\}, x_{ijp} \geq 0
\end{aligned}$$

In the path-based supply chain design model, the summations have to be executed over the transformation facilities by echelon. This requires the definition of the set of transformation facilities by echelon. The new notation and model are given next.

$N_i$	Set of transformation facilities that make up echelon $i$ , where the set of all transformation facilities is $N = \bigcup_i N_i$
$x_{ijklp}$	amount of flow being transported directly from supplier $i$ through facilities $j$ and $k$ to customer $l$ of product $p$
$pq_{ip}$	amount of flow being supplied by supplier $i$ of product $p$
$tc_{ijklp}$	cost rate for transporting one unit of product $p$ from supplier $i$ through facilities $j$ and $k$ to customer $l$

## Model

### Model 12.2. Path-Based Multi-Echelon Supply Chain Model

$$\begin{aligned}
\min z = & \sum_j^N f_j y_j + \sum_i^M \sum_p^P pc_{ip} pq_{ip} + \sum_i^M \sum_{j \in N_1} \sum_{k \in N_2} \sum_l^C \sum_p^P tc_{ijklp} x_{ijklp} + \sum_j^N \sum_p^P hc_{jp} v_{jp} \\
s.t. \quad & \sum_{j \in N_1} \sum_{k \in N_2} \sum_l^C x_{ijklp} = pq_{ip} && i \in Suppliers, p \in Products
\end{aligned}$$

$$\sum_p^P pq_{ip} \leq sup_i \quad i \in Suppliers$$

$$\sum_i^M \sum_{k \in N_2} \sum_l^C x_{ijklp} = v_{jp} \quad j \in N_1, \forall p$$

$$\sum_i^M \sum_{j \in N_1} \sum_l^C x_{ijklp} = v_{kp} \quad k \in N_2, \forall p$$

$$\sum_p^P res_{jp} \cdot v_{jp} \leq cap_j \cdot y_j \quad j \in Transformers$$

$$\sum_i^M \sum_{j \in N_1} \sum_{k \in N_2} x_{ijklp} = dem_{lp} \quad l \in Customers, \forall p$$

$$y_j = \{0,1\}, x_{ijklp} \geq 0$$

On page 562, last full text paragraph, replace the last two sentences with “The constraints can be written for every individual customer or for all the customers serviced from a single warehouse. The corresponding variants of the WLP are called the disaggregate and the aggregate WLP, respectively.”

#### 29-Apr-2012

In Model Characteristics, second bullet point, replace the next to last sentence with “More commonly, the products are processed in a production facility and delivered to the customer through a distribution center.”

#### 07-Dec-2011

The following changes apply to the channel selection model starting on page 529. The computation of the fixed storage cost must use the unit storage *location* cost in all of its formulas.

$$FSC_{mp} = OFSC_{mp} + DFSC_{mp} = OMI_{mp} \cdot slc_{pO} + DMI_{mp} \cdot slc_{pD}$$

$$FSC_{mp} = TB_{mp} \cdot slc_{pO} + [TB_{mp} + SI_{mp}] \cdot slc_{pD}$$

The cycle inventory and the corresponding cycle inventory cost are tied to a particular facility. Removed the subscript i and j to indicate the origin and destination facility, respectively, by inserting O and D in the name of the variable.

$$OCI_{mp} = (TB_{mp} / 2)$$

$$OCIC_{mp} = (TB_{mp} / 2) \cdot v_p \cdot HCR = OCI_{mp} \cdot v_{mpO} \cdot HCR$$

### 10-Sep-2011

All of the following changes apply to the tactical supply chain planning model starting on page 540. In summary, the throughput flow cost of a product through a facility was added and the notation was made more consistent.

In the parameter list add the following definition

$fc_{jpt}$  throughput flow cost for a unit of product  $p$  through transformation facility  $j$  during period  $t$

In the objective function, add the throughput flow cost for products through a facility ( $fc_{jpt} \cdot otq_{jpt}$ ), change the output flow quantity from a facility from  $tq_{jpt}$  to  $otq_{jpt}$ , change the unit throughput resource cost from  $rc_{jrt}$  to  $trc_{jrt}$  and the unit resource requirement for a throughput resource by a product from  $res_{jprt}$  to  $tres_{jprt}$ . Finally, reformat the objective function expression to more clearly show the structure. The updated objective function expression is then as follows.

$$\begin{aligned}
 \min \quad & \sum_{i \in S} \sum_p \sum_t pc_{ipt} \cdot pq_{ipt} + \\
 & \sum_{i \in O} \sum_{j \in D} \sum_p \sum_t tc_{ijpt} \cdot x_{ijpt} + \\
 & \sum_{j \in TR} \sum_p \sum_t ac_{jpt} \cdot aq_{jpt} + \sum_{j \in TR} \sum_p \sum_{r \in AR} \sum_t arc_{jrt} \cdot ares_{jprt} \cdot aq_{jpt} + \\
 & \sum_{j \in TR} \sum_p \sum_t fc_{jpt} \cdot otq_{jpt} + \sum_j \sum_p \sum_{r \in R} \sum_t trc_{jrt} \cdot tres_{jprt} \cdot otq_{jpt} + \\
 & \sum_{j \in TR} \sum_p \sum_t hc_{jpt} \cdot iq_{jpt} + \sum_{j \in TR} \sum_p \sum_{r \in IR} \sum_t irc_{jrt} \cdot ires_{jprt} \cdot iq_{jpt} + \\
 & \sum_k \sum_c \sum_p \sum_{t \in T, t \geq 2} \sum_{u \in T, u < t} bc_{kptu} \cdot bq_{kptu}
 \end{aligned} \tag{12.26}$$

### 25-Apr-2012

In the arc-based model for multi-echelon supply chain design (Model 12.13) the summation in the demand satisfaction constraint is over  $j$ , corresponding to transformation facilities, and not over  $k$ , corresponding to customers. There is a demand satisfaction constraint for every combination of customer and product.

$$\sum_j^M x_{jkp} = dem_{kp} \quad k \in Customers, \forall p \tag{12.106}$$

## Advanced Supply Chain Models

### 04-May-2012

On page 655, third text line from the bottom, replace “in the domestic cast” with “in the domestic case”.

**01-May-2012**

On page 648 in the Notation section, replace “cenario” with “scenario”.