Originale

Examination:	Reverse Logistics Management (1624)
Semester:	Summer Semester 2006
Examiner:	Prof. Dr. Karl Inderfurth
Permitted Aids:	English dictionary (English into to any other language) without any handwritten entries !
Instructions:	Complete exactly two (2) of the following three (3) questions. If all three are completed, only the first two will be evaluated. All questions will be weighted equally and are designed to be completed within 30 minutes.

Question 1: Product Recovery Network Model

Formulate a network model for a firm which manufactures and distributes its product to customers, and after use, collects the products from the customer and uses the parts. More specifically, the firm has to decide on plant locations, locations for warehouses (for forward distribution) and disassembly center locations (for the reverse chain). Forward product flow is from plants, to distribution centers to customers. Reverse flow is from customers, to disassembly centers, and then either to a plant or to a secondary market (disposal option). Unserviced demand (stockouts) and uncollected returns are penalized by per unit costs.

Use the following notation:

Indices

$i = 0,...,I$ Potential Plant Locations ($i = 0$ for disposal)

$j = 1,...,J$ Potential Warehouse Locations

$k = 1,...,K$ Customers with demands or returns

$l = 1,...,L$ Potential Disassembly Facilities

Parameters

d_k Demand (in units) from customer k, $k = 1,...,K$

r_k Returns (in units) from customer k, $k = 1,...,K$

a Maximum Disposal Fraction $0 \le a \le 1$

$c^f_{i,j,k}$ Unit variable cost of serving demand from plant i via warehouse j to cutomer k, $i = 1,...,I$ $j = 1,...,J$ $k = 1,...,K$

$c^r_{k,l,i}$ Unit variable cost of collecting return from customer k and sending to plant i via disassembly center l, $k = 1,...,K$ $l = 1,...,L$ $i = 0,...,I$

c^u_k Unit variable cost for unserviced demand from customer k, $k = 1,...,K$

c^w_k Unit variable cost for uncollected return from customer k, $k = 1,...,K$

f^p_i Fixed cost for opening plant i, $i = 1,...,I$

f^w_j Fixed cost for opening warehouse j, $j = 1,...,J$

f^d_l Fixed cost for opening disassembly center l, $l = 1,...,L$

M a very large number

Decision Variables

$x^f_{i,j,k}$ Forward Flow: Amount of product delivered to customer k via warehouse j from plant i, $i = 1,...,I$ $j = 1,...,J$ $k = 1,...,K$

$x^r_{k,l,i}$ Reverse Flow: Amount of product taken back from customer k via disassembly center l to plant i, $k = 1,...,K$ $l = 1,...,L$ $i = 0,...,I$

y^p_i Open plant indicator (binary), $i = 1,...,I$

y^w_j Open warehouse indicator (binary), $j = 1,...,J$

y^d_l Open disassembly center indicator (binary), $l = 1,...,L$

u_k Units of unsatisfied demand from customer k, $k = 1,...,K$

w_k Units of uncollected returns from customer k, $k = 1,...,K$

Instructions

a) Formulate the objective function (sum of all costs) and all of the constraints for the MILP model.

b) Suppose that each plant, warehouse, and disassembly plant had a given capacity in units of product which can be produced (new or remanufactured), distributed, or disassembled, respectively. What changes would be necessary to the notation, objective function, and constraints of the MILP model?

Question 2: Disassemble-to-order model

A firm engaged in remanufacturing requires parts gained from the disassembly of returned products as an input for the remanufacturing process. A certain demand for each part (or leaf) is given over a multi-period planning horizon. The firm faces a so-called *disassemble-to-order* problem, where parts can be gained either through disassembly or external procurement. Objective function will be cost minimizing and the constraints will keep track of inventory for all items (cores and leaves), ensure that the maximum amount of core available from the market is observed, define starting and ending inventories for cores and leaves, and ensure decision variables take on meaningful values. For the moment, we assume that disassembly and procurement occur instantaneously (no lead times), and that minimum or maximum inventory levels are not specified.

Instructions

a) Use the following notation to derive the objective function and constraints:

$i \in I$ Root items
$k \in K$ Leaf items
$t = 1,...,T$ Time periods (T = Planning horizon)

c^p_i : Purchase cost of root i $i \in I$

c^p_k : Purchase cost of leaf k $k \in K$

c^s_i : Separation cost of root i $i \in I$

c^h_i : Holding cost of root i $i \in I$

c^h_k : Holding cost of leaf k $k \in K$

c_k^d : Disposal cost of leaf k $k \in K$

$D_{k,t}$: Demand for leaf k at time t $k \in K$ $t = 1,...,T$

$R_{i,t}$: Amount of core i available to procure from market at time t $i \in I$ $t = 1,...,T$

$\pi_{i,k}$: Amount of leaf k obtained from disassembly of root i $i \in I$ $k \in K$

y_i^0 : Inventory of core i at start of period 1 $i \in I$

y_i^T : Inventory of core i at end of the planning horizon $i \in I$

y_k^0 : Inventory of leaf k at start of period 1 $k \in K$

y_k^T : Inventory of leaf k at the end of the planning horizon $k \in K$

$x_{i,t}^p$: Procurement of root i at time t $i \in I$ $t = 1,...,T$

$x_{k,t}^p$: Procurement of leaf k at time t $k \in K$ $t = 1,...,T$

$x_{i,t}^s$: Separation of root i at time t $i \in I$ $t = 1,...,T$

$x_{k,t}^d$: Disposal of leaf k at time t $k \in K$ $t = 1,...,T$

$y_{i,t}$: Inventory of root i at end of period t $i \in I$ $t = 0,...,T$

$y_{k,t}$: Inventory of leaf k at end of period t $k \in K$ $t = 0,...,T$

b) For a problem with 3 cores, 4 leaves, and 3 time periods in the planning horizon, write out the inventory balance constraints for the *second* leaf item in the *third* period (t = 3).

c) Suppose that the firm specified (1) a *minimum* inventory of leaves and (2) a *maximum* inventory of cores which can be held in every period (not period specific), as well as (3) a disassembly lead time (the amount of time between a core separation decision and its leaves being harvested) for each core. What changes would be necessary to the notation, objective function, and constraints of the MILP model?

Question 3: Product recovery in spare parts management

Discuss the following aspects of spare parts management:

a) List the 5 options specified in Hesselbach, et al. (2002) to satisfy demand for spare parts. Describe each of the options and provide its disadvantages.

b) Describe the specific advantages of product recovery in this context.

c) In a particular product recovery for spare parts management system, returned items are held in a core stock until disassembled and the parts are tested. The firm is deliberating whether to use a *push* or *pull* system for disassembly. Describe the difference between the two and a possible advantage and disadvantage of each.