Version: January 14, 2002

Chapter 4: Reverse Logistics Network Design

— Outline —

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1 Reverse Logistics Flows at IBM: An Illustrative Example [1-2 pages, MF]

- describe various RL flows at IBM: end–of–lease equipment, environmental returns, rotable spares,...
- sketch logistics network structure (global + focus on Europe)
- location issue: return centers for consolidation and dispositioning

Key references: [3, 7]

2 Network Design Issues in Reverse Logistics [2-3 pages, JB (PB)]

- delineation; scope of RL networks; figure similar to Fig.1 in [4]
- network design issues per reverse channel function: collection, testing/sorting, reprocessing, redistribution,...
- contrasting with traditional 'forward' networks and design
- issues specific of RL: (i) supply uncertainty, (ii) (de-)centralization of testing, (iii) integration of forward and reverse network
- classification of RL networks

Key references: [1, 6, 4]

3 Mixed Integer Location Models for Reverse Logistics Network Design [3 pages JB]

Key references: [5]

3.1 Literature Review

see Table 5.1 in [3]

3.2 A Basic Facility Location Model

MILP model from [5]; capacitated (?); figure/scheme for illustration

3.3 Extensions

see Section 5 from [5]

4 Stochastic Location Models for Reverse Logistics Network Design [3 pages MF (RD)]

Key references: [8]

4.1 Stochastic Mixed Integer Modelling Approaches

motivation of stochastic MILP models, brief summary of general results/difficulties, link with RL network design

4.2 A Stochastic Network Design Model

stochastic variant of model from Section 3.2; scenario-dependent return volumes and disposal fractions; two–stage approach: location decision – scenario revelation – allocation decision

4.3 Extensions

multi–stage approaches; average versus worst–case optimization; additional uncertainties

5 Continuous Approximation Models for Reverse Logistics Network Design [3 pages PB/MF]

Key references: [2, 4]

5.1 The Continuous Approximation Methodology

general motivation of continuous approximation approach, application to RL networks

5.2 Approximating Reverse Logistics Costs and Revenues

Continuous cost approximation of model from Section 3.2; optimizing network structure

5.3 Extensions

6 Numerical Analysis of Reverse Logistics Network Design Issues [4 pages MF]

6.1 An Illustrative Example

example similar to 'electronics' example in [5]; implementation for each of the three modelling approaches (Sections 3-5); on this basis, quantitative analysis of the issues identified in Section 2;

6.2 The Impact of Supply Uncertainty

consider impact of variations in return volume (and disposal rate?) on RL network and costs; compare outcome of the three approaches:

- MILP model: scenario analysis
- stochastic model: two–stage optimization
- continuous model: sensitivity analysis

6.3 Locating the Test Operation

factors favoring centralized / decentralized testing; compare the three approaches; developments affecting the balance in this tradeoff

6.4 Compliance of Forward and Reverse Logistics Networks

compare sequential versus integrated design of forward and reverse network part; consider impact of growing return volume on network design and costs for two scenarios: proportional growth for all customers versus East/West differentiation; compare outcome of the three modelling approaches

7 Conclusions and Outlook [1 page PB/MF]

Notation

MILP model

Index sets

I	=	$\{1, ..., N_p\}$ potential plant locations for re-processing and/or new production
I_0	=	$I \cup \{0\}$, where 0 denotes the disposal option
J	=	$\{1, ..., N_w\}$ potential warehouse locations
K	=	$\{1, ..., N_c\}$ fixed customer locations
L	=	$\{1, ..., N_r\}$ potential disassembly locations

Variables

X^f_{ijk}	=	forward flow: fraction of demand of customer k to be served from plant i and warehouse j; $i \in I, j \in J, k \in K$
X^r_{kli}	=	reverse flow: fraction of returns from customer k to be returned via disassembly centre l to plant i; $k \in K, l \in L, i \in I_0$
U_k	=	unsatisfied fraction of demand of customer k; $k \in K$
W_k	=	uncollected fraction of returns of customer k; $k \in K$
Y^p_i	=	indicator opening plant i; $i \in I$
Y^w_j	=	indicator opening warehouse j; $j \in J$
Y^r_l	=	indicator opening disassembly centre l; $l \in L$

Costs

c^f_{ijk}	=	unit variable cost of serving demand of customer k from plant i and warehouse j, including transportation, production, and handling cost; $i \in I, j \in J, k \in K$
c^r_{kli}	=	unit variable cost of returns from customer k via disassembly centre l to plant i; including transportation and handling cost minus production cost savings at plant i; $k \in K, l \in L, i \in I$
c^r_{kl0}	=	unit variable cost of disposing returns from customer k via disassembly centre l, including collection, transportation, handling, and disposal cost; $k \in K, l \in L$
c^u_k	=	unit penalty cost for not serving demand of customer k; $k \in K$
c^w_k	=	unit penalty cost for not collecting returns of customer k; $k \in K$
f^p_i	=	fixed cost for opening plant i; $i \in I$
f^w_j	=	fixed cost for opening warehouse j; $j \in J$
f^r_l	=	fixed cost for opening disassembly centre l; $l \in L$

Parameters

d_k	=	demand of customer k; $k \in K$
r_k	=	returns from customer k; $k \in K$
γ	=	minimum disposal fraction

Stochastic model

ω	=	scenario
Ω	=	scenario space

Continuous approximation model

$\delta(.)$	=	geographical demand density

$\rho(.)$ = geographical return density

References

[1] J.M. Bloemhof-Ruwaard and M. Salomon. Reverse Logistics. In M.J. Ploos van Amstel, J.P. Duijker, and M.B.M. de Koster, editors, *Praktijkboek Magazijnen en Distributiecentra*. Kluwer Bedrijfswetenschappen, Deventer, The Netherlands, 1997. (In Dutch).

[2] C.F. Daganzo. *Logistics Systems Analysis*. Springer, Berlin, 3rd edition, 1999.

[3] M. Fleischmann. *Quantitative Models for Reverse Logistics*. Lecture Notes in Economics and Mathematical Systems 501. Springer Verlag, Berlin, Germany, 2001.

[4] M. Fleischmann. Reverse logistics network structures and design. Management Report Series 2001-52-LIS, Erasmus University Rotterdam, The Netherlands, 2001. (To appear in *Business Perspectives on Closed-Loop Supply Chains*).

[5] M. Fleischmann, P. Beullens, J.M. Bloemhof-Ruwaard, and L.N. Van Wassenhove. The impact of product recovery on logistics network design. *Production and Operations Management*, 10(2):156–173, 2001.

[6] M. Fleischmann, H.R. Krikke, R. Dekker, and S.D.P. Flapper. A characterisation of logistics networks for product recovery. *Omega*, 28(6):653–666, 2000.

[7] IBM. Annual corporate environmental report. http://www.ibm.com, 2001.

[8] O. Listes and R. Dekker. Stochastic approaches for product recovery network design: A case study. Econometric Institute Series 2001-08, Erasmus University Rotterdam, The Netherlands, 2001.