Strategic Management of Spare Parts in Closed-Loop Supply Chains

A System Dynamics Approach

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Presentation Outline

1. Introduction
2. Management of spare parts in the final-service phase
3. Closed-loop supply chains for parts recovery
4. System Dynamics Model
5. Strategies and results
6. Concluding remarks
Product life cycles in the electronic and automotive industry

- **Software - PLC**
  - Development: 10 years
  - Production: 3 years
  - Maintenance: 7 years

- **Electronics - PLC**
  - Development: 15 years
  - Production: 10 years
  - Maintenance: 10 years

- **Automobiles - PLC**
  - Development: 10 years
  - Production: 15 years
  - Maintenance: 7 years

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Management of spare parts in the final-service phase

- Producers have to assure spare parts supply for the average lifetime of the product
- Losing economies of scale
  - production volume diminishes rapidly after the production phase is stopped
- Limited flexibility of production equipment
- Discontinued supply of electronic components that are provided from outside suppliers
Strategies to ensure the ability to supply spare parts during the final service phase

- Producing Final Stocks
- Producing small lots of parts
- Redesign of spare part
- Develop and use compatible parts
- Reuse of parts
- Repairing parts that are out-of-order
Study on final orders (automobile supplier)

- normalized Inventory, 71 final orders, final service phase 15 years

Example: part discontinued 04/97, out of stock 12/2000, time to redesign 6 Month
Management of spare parts in the final-service phase

• Characteristics of Final Order Policy

  – Build up final stocks that lock up a lot of capital
    • Agfa-Gevaert: 16.5 – 22 Mio. € (30 – 40% of total spare parts inventory)

  – Underestimation of demand
    • Producers have to compensate customers for delivery delay
    • Producers often have to redesign the spare part

  – Firms often fail to monitor final stocks adequately
Integrating parts recovery in spare parts management

• More operational flexibility
• Chance to reduce final stocks and
• Chance to reduce stock-outs
• Closed-loop supply chains are difficult to control
• Uncertainties in
  – Returns volume
  – Timing of returns
  – Yield of recovery
  – ...

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Case Study:
Spare parts management in closed-loop supply chains

AGFA: ADC Compact
medical diagnosis device which scans and digitizes data from x-ray films
End of Production: 2001
End of Service: 2008
Product Life Cycle of the ADC Compact

Production phase (1998 – 2001)
Total sales: 1920 pieces of equipment
Working Example: Scan-Unit of the ADC Compact
Strategic Management of spare parts at Agfa

Development

Feasibility study
Prototype

Predefinition of electronics specifications and preselection of electronic components
Field tests

Make to stock

Product launch
Degeneration

Sales from Stock

Availability of spare parts during the service period

3-4 years
4-5 years
7-10 years

Definition spare part
Availability of spare parts
First disposition of spare parts
Longterm disposition (forecast) final stock

SOP/EOP – Start/End-of-Production
EOD – End of Delivery
EDO – End of Delivery Obligation
EOS – End of Service

Preparation of electronics specifications and preselection of electronic components
Field tests

Development

Feasibility study
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Closed Loop Supply Chain for Parts Recovery

- **Equipment in Use**
- **Equipment stored**
- **Alternative Disposal**
- **Supply**

- **Spare Parts flows in the original chain**
- **Equipment flows in the recovery chain**
- **Parts flows in the recovery chain**
System Dynamics Model

• System Dynamics
  – very effective tool in representing the dynamics of management systems
  – enables the user to develop a better understanding
    • of the effects of changes, and
    • supports him in designing alternative policies that result in an improved system performance
  – SD was developed by Jay Forrester at the MIT in the 1960’s
  – applied in many areas such as product development, project management, and supply chain management, among which is a popular explanation of the bullwhip effect
## Characteristics of strategies

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<th>Recovery of parts considered</th>
<th>Product acquisition</th>
<th>Mid-term forecast</th>
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Base case: Optimal final stock; no recovery, no redesign
**Base Case:** Optimal final stock – 20%, no recovery, redesign

<table>
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<th>Time (Month)</th>
<th>Production Rate (PR)</th>
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Production Rate (PR) Part/Month
Order Rate (OR) Part/Month
Equipment Returns Recoverable Parts (ERP) Equipment/Month
Equipment Returns total (ERT) Equipment/Month
Base Case: Optimal final order – 20%, no recovery, redesign
Comparison of results (net present value)

- SRP + EWA
- Stocking recoverable parts (SRP)
- Early warning system with acquisition (EWA)
- Early warning system waste stream
- Systemwide inventory with acquisition
- Systemwide inventory policy waste stream
- Recovery with acquisition
- Recovery waste stream
- Base case with forecast
- Base Case

Legend:
- low recoverability
- medium recoverability
- high recoverability

in thousand €
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Recovery acquisition: 60% final stock, 65% return quota, high recoverability
Comparison of results (net present value)

- Low recoverability
- Medium recoverability
- High recoverability

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Stocking recoverable parts + early warning system:
75% final stock, 50% return quota, low recoverability
Comparison of results (net present value)

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- **Early warning system with acquisition (EWA)**
- **Stocking recoverable parts (SRP)**
- **SRP + EWA**

Recoverability levels:
- Low recoverability
- Medium recoverability
- High recoverability

Net present value in thousand €:
Concluding Remarks

• Recovery of parts can be beneficial to provide customers with spare parts
• system dynamics to test various policies to control the closed-loop supply chain
• different forms of product take back (active product acquisition and waste stream)
• different policies
  – when to stop sending recoverable parts to materials recycling
  – when to acquire units of equipment with recoverable parts
  – when to begin to redesign a spare part.
• necessary to strengthen the monitoring of final stocks as well as the stocks of recoverable parts within closed-loop supply chains.
• Improving information exchange between producers of EEE and recycling companies
Attachments and Data
**Parameter**

- **Service time:** 7 years
- **Redesign time:** 6 months
- **Redesign costs:** 1,5 Mio. €
- **Production costs after redesign:** 200% of production costs during normal phase
- **Out of pocket costs for new and recovered parts:** 50 € per month and part
- **Scrapping or material recycling costs:** 22,5 € per part
- **Reverse logistics costs (transportation and deconstruction):** 42,4 € per part
- **Product acquisition costs:** depend on the proportion of discarded equipment with recoverable parts => max. 200% of reverse logistics costs
- **Out of pocket costs for disassembled scan-unit:** 1 € per month and part
- **Disassembly costs:** 45 € per scan-unit
- **Rate of interest:** 8% per year
Scenario Parameter

- **Return Quotas:** 50% - 90%
- **Final Stock:** 60% - 100%
- **Recoverability:** high, medium, low

5 % steps

9 x 9 x 3 = 243 simulation runs per strategy
Recoverability scenarios

Age of Equipment

Recoverability

- high recoverability
- medium recoverability
- low recoverability
Probability mass function of equipment return time

Age of Equipment

- Probability mass function of equipment return time

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Probability mass function of repair

Age of Equipment

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