OPTIMALIZATION OF A STOCHASTIC REMANUFACTURING NETWORK: THE CASE OF ATLAS COPCO

PROF. DR. MARC LAMBRECHT
DR. PIETER COLEN
DR. KRIS LIECKENS
KU LEUVEN, BELGIUM
II. ECONOMIES OF SCALE AND POOLING

Realize the same level of activity with less resources due to economies of scale and the mitigation of risk (pooling)

- Pooling in field service operations
  - Grouping of service territories, grouping of maintenance tasks, grouping of customers, …
- Pooling in the spare part supply chain
  - Centralization of inventory, determine the right hierarchy of products and locations
- Pooling in repair capacity
  - Centralization of repair / remanufacturing centers
• PROBLEM DESCRIPTION: The Remanufacturing Process
• MODEL: Demand & Logistics sub-model
• DATA Requirements and OUTPUT of the model
• Managerial INSIGHTS

Optimization of a stochastic remanufacturing network with an exchange option, Decision Support Systems, 2013, pp. 1548-1557
REMANUFACTURING

The Original Equipment Manufacturer replaces worn parts, installs any enhancements and upgrades, reassembles the product, checks quality, etc…

3D PRINTING, ADDITIVE MANUFACTURING

Manufacture replacement parts ON DEMAND in small local Fabs located all over the world using data supplied by the manufacturers.
REMANUFACTURING/ REFURBISHMENT

Genuine parts
A summary of the process

Remanufacturing center
Objective: profit maximization

Production Plant

Remanufacturing Centers
operators

Service Centers (planned overhauls & ad hoc repair jobs) : technicians

Demand
The profit maximization model consists of a

DEMAND SUB-MODEL

and a

LOGISTICS NETWORK SUB-MODEL
THE DEMAND SUB-MODEL

No service  Ad hoc (Time & Material)  Full Responsibility Contract

Demand for service (overhaul & Repair)

Full responsibility contracts (omnium service contract):
Customer pays a yearly fixed fee and Atlas Copco maintains the equipment (repairs and overhaul) with an uptime guarantee
Technical Note

Multinomial LOGIT models can be used. These models are used to model consumer choices (e.g. FRC, Ad Hoc, No Service) given prices, number of downtime hours, reliability characteristics of the machine). After a regression analysis we obtain probabilities, which are in turn translated into demand (given the installed base).
Demand (FRC, Ad Hoc, No Service) = function of

- Price FRC, Ad Hoc, No Service
- Average Downtime with FRC, Ad Hoc, No Service
- Price sensitivity and downtime sensitivity (reflecting the willingness to pay and the opportunity cost of downtime)

Downtime depends on the logistics sub-model
This “demand” (contracts) results in a demand for **overhauls** (depending on the overhaul interval) and a demand for **repairs**.

The reliability of the machines is modelled through the **Power Law Process**

\[
\frac{\beta}{\alpha} \left( \frac{t}{\alpha} \right)^{\beta-1}
\]

This results in a “**workload**” for our Logistics Network Sub-Model
Technical note

In order to link the failure rate with the maintenance policy we use the Power Law process. It determines the time to failure since the last preventive maintenance intervention.
Technical note

(S-1,S) policy (also known as base-stock policy) means that each time a unit is taken from stock, it will be replenished by either a (refurbished) used or a new part.
It is important to notice that the sub models interact through the remanufacturing lead-time.
The interaction effect
## Data requirements

- Customers aggregated to one location in each service region
- Endogenous demand for FRC, AdHoc and NoService (prices, elasticities,...), Installed Base, Power Law Functions,....

- Yearly fixed cost per technician
- Stochastic processing time

- Yearly fixed **facility** cost + Yearly fixed costs per operator
- Scrap rate, stochastic **processing** time, unit production cost
- Inventory holding costs

- Scrap rate
- Cost new parts

- Third party logistics company: Drop-off and variable costs
- Unit transportation
- Stochastic transportation times
## Output of the model

- **Profit**
- **Number of remanufacturing facilities opened**
- **Number of technicians and operators**
- **Demand FRC, Ad Hoc, No Service**
- **Prices of the contract**
- **Downtime for each type of contract**
- **Inventory parameters (Base Stock Level)**
MANAGERIAL INSIGHTS

(DE)CENTRALIZATION ISSUE

Demand volume is the key determinant for the number of remanufacturing facilities to open. Having sufficient scale in services allows low cost local presence.

A volume threshold value is determined to decide to open/close a remanufacturing facility.
MANAGING THE DEMAND FUNCTION

- Customers with low price sensitivity and a high downtime sensitivity are the most profitable to target (FRC). Segmenting customers based on their price sensitivity is advised.
- The higher uptime is realized by shortening the time between overhauls.
- The downtime of the NO SERVICE option greatly affects profits of FRC and Ad Hoc service.
• *Segmenting customers based on price sensitivity is advisable but setting uptime guarantees is preferable based on machine reliability aspects.*

• *High operator labor costs are detrimental to remanufacturing activities especially for price sensitive customers.*
Moral Hazard is a situation where a customer with a FRC takes additional risks in the use of the equipment because he will not be charged for the associated cost.
In a moral hazard scenario the machine reliability characteristics change: lower scale value and a higher shape value.
Impact of Moral hazard

Shorter overhaul intervals (to guarantee the uptime requirement), invest in a more responsive decentralized network with more operators, resulting in lower profits
We learn from inventory theory that centralization of inventories create statistical economies of scale and consequently less inventory = the well-known POOLING EFFECT.
As a result of centralization, the transportation times increase, the replenishment lead times are longer and more inventory is required. Moreover, the longer lead times have a negative impact on the amount of downtime.

All this favors more a more decentralized network
CONCLUSION

The issue of remanufacturing is more than a “location (open/close)” problem. A multi-facet approach is needed including pricing decisions linked with logistics issues such as lead times, downtime, investment decisions, inventory decisions and reliability characteristics of the machines.