Modeling of Return for Remanufacturing

Ing. Pavel Gežík, PhD

Department of Operations Research and Econometrics,

Faculty of Economic Informatics, University of Economics in Bratislava

Recoverable manufacturing systems

- The uncertain timing and quantity of returns,
- The need to balance demands with returns,
- The need to disassemble the returned products,
- The uncertainty in materials recovered from returned items,
- The requirement for a reverse logistics network,
- The complication of material matching restrictions,
- The problems of stochastic routings for materials for repair and remanufacturing operations and highly variable processing times.

Return rates

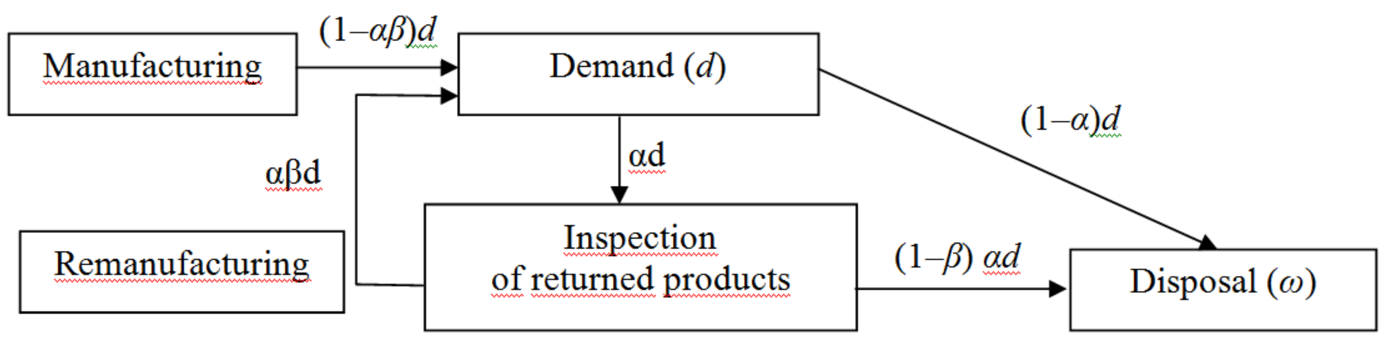

Figure 1 - Relations between material flows and their rates

- d – demand for products,
- α – rate at which products are returned to manufacturer,
- β – rate at which returned products are used,
- ω – disposal (it means the quantity of products which are not returned or reused),
- $\omega = (1-\alpha)d + (1-\beta)\alpha d$

Return from previous periods

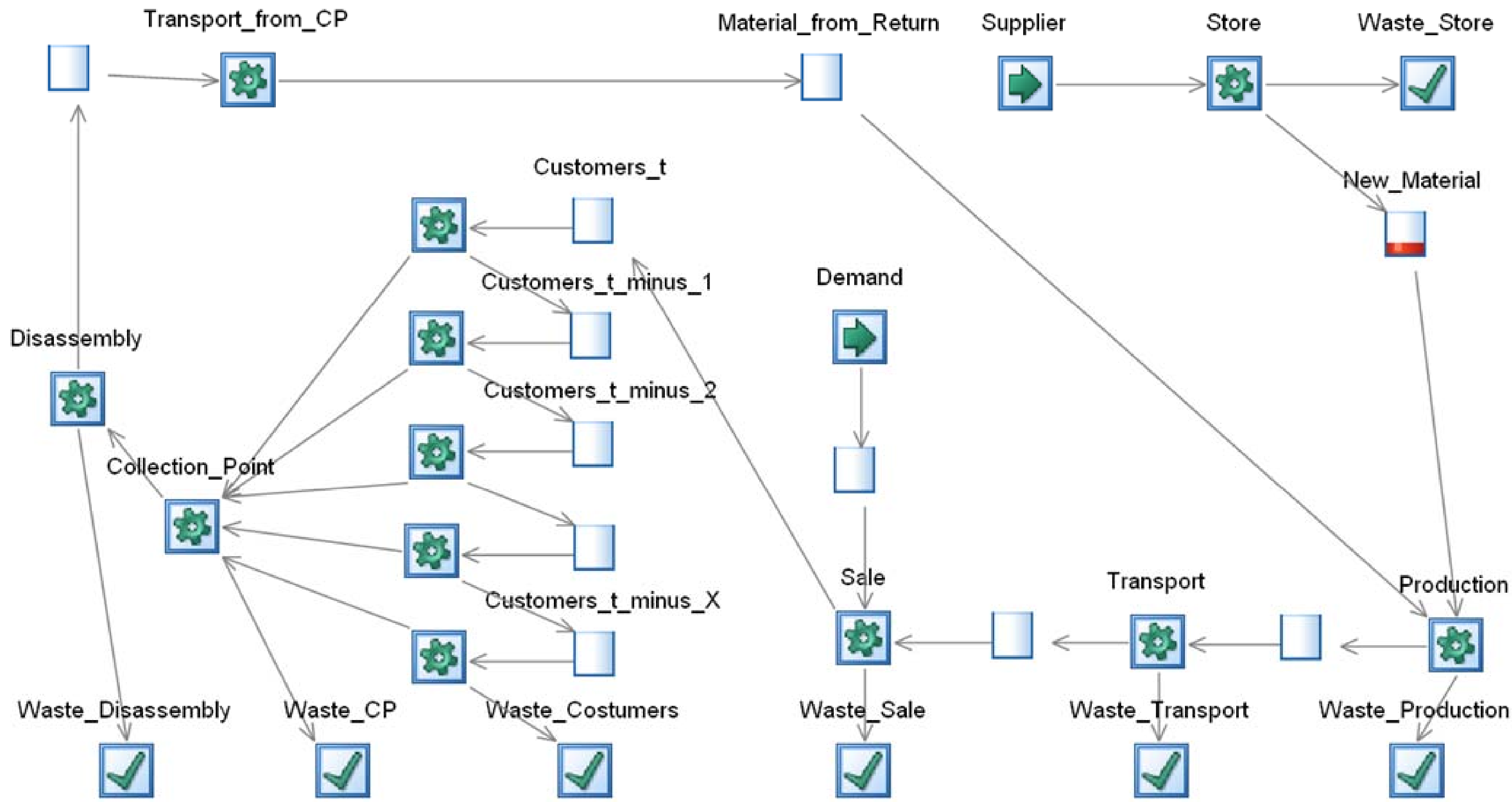

Figure 2 - Model for return of product from several previous periods (Simul8)

Return back to the manufacturer

- Return of the product back to the manufacturer is influenced by the probability $PR(R)_{it}$, determining the amount of products returned back to the manufacturer from the sale in the previous period t-1 ($D_{i(t-1)}$) in period t, therefore

  $$R_{it} = PR(R)_{it} D_{i(t-1)},$$

  for $i = 1, 2, \ldots n$; $t = 1, 2, \ldots T$.

- When the product is returned from sales in several previous time periods before period t, there is a probability $PR(Rx)_{it}$.

- Parameter x is from the range 1 to X, therefore , where upper value of X is a "limit" after which it is expected that the product will not return back to the manufacturer and ends up as waste.

Return from five periods

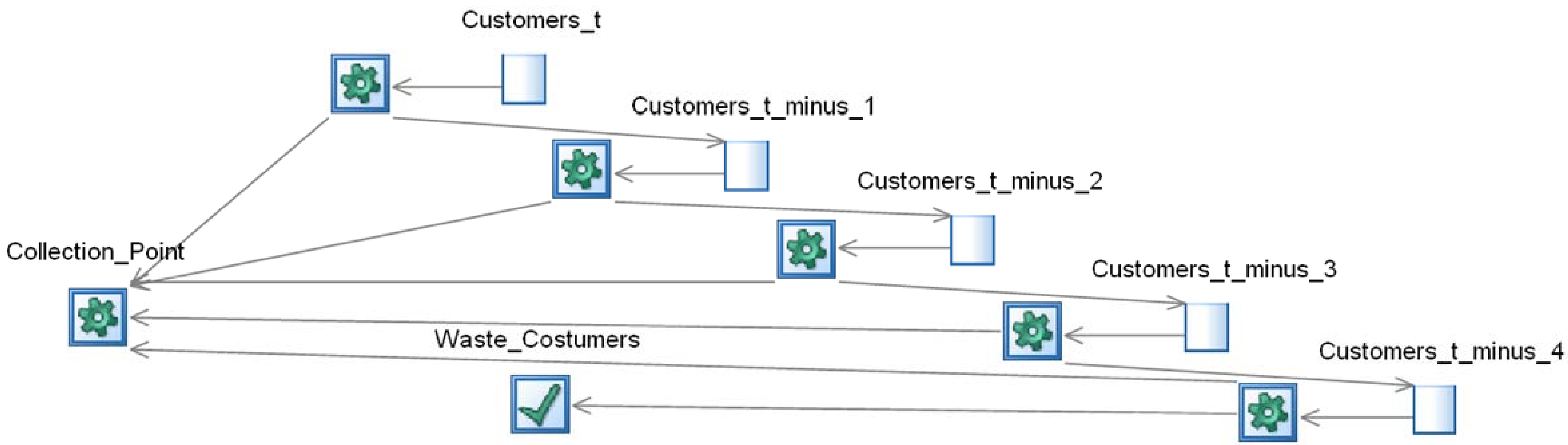

Figure 3 - Probability of return from 5 previous period

- There are many options for calculation of the probabilities of the product´s return.
- We will show three scenarious calculation of return.

The First Scenario

- The first scenario is based on calculation of return on the amount of all sold products in the period connected with certain probability of return from that period.
- In this variant the sum of the probabilities is less than one and assumes that a certain percentage of products will never return to the producer and end up as waste.

$$R_{it} = PR(R1)_{it}D_{i(t-1)} + PR(R2)_{it}D_{i(t-2)} + \dots + PR(RX)_{it}D_{i(t-X)},$$

for $i = 1, 2, \dots n$; $t = 1, 2, \dots T$; X – amount the period of return.

The Second Scenario

- The second scenario is based on that the probability $PR(R)_{it}$ is fixed and the amount of sold products is not the same in each time period.
- This variant considers the "limit" X after which it is expected that the product will not return back to the manufacturer and ends up as waste.

$$R_{it} = PR(R)_{it}D_{i(t-1)} + PR(R)_{it}(1 - PR(R)_{it})D_{i(t-2)} + PR(R)_{it}(1 - PR(R)_{it})^2 D_{i(t-3)} + \dots + PR(R)_{it}(1 - PR(R)_{it})^{X-1}D_{i(t-X)},$$

for $i = 1, 2, \dots n$; $t = 1, 2, \dots T$; X – amount the period of return.

The Third Scenario

- The third scenario is a combination of the previous two scenarios. This means that as the second variant does not calculate return from the entire amount of sold products, but only from remained amount of sold products.
- This variant also considers the "limit" *X*.

$$R_{it} = PR(R1)_{it}D_{i(t-1)} + PR(R2)_{it}(1 - PR(R1)_{it})D_{i(t-2)} + PR(R3)_{it}(1 - PR(R2)_{it})(1 - PR(R1)_{it})D_{i(t-3)} + \ldots + PR(RX)_{it}(1 - PR(R(X-1))_{it})(1 - PR(R(X-2))_{it}) \ldots (1 - PR(R(X-(X-1))_{it})D_{i(t-X)},$$

for $i = 1, 2, \ldots n$; $t = 1, 2, \ldots T$; X – amount the period of return.

Model

- The costs associated with product´s:
- CCR_{itu} - cost of collecting returned products i (i = 1, 2,... n) in the period t (t = 1, 2,... T),
- CTR_{itu} - cost of transport returned products i (i = 1, 2,... n) in the period t (t = 1, 2,... T) and
- CDR_{itu} - cost related to return and dismantling returned products i (i = 1, 2,... n) in the period t (t = 1, 2,... T).

$$\min \sum_{i=1}^{n}\sum_{t=1}^{T} CCR_{it}R_{it} + \sum_{i=1}^{n}\sum_{t=1}^{T} CTR_{it}R_{it} + \sum_{i=1}^{n}\sum_{t=1}^{T} CDR_{it}R_{it}$$

- Content for model is one of the scenarios.

Conclusion

This approach allows modeling different variants of products return back to manufacturer in the general mathematical programming model for reverse logistics and also allows different variants form simulation this model. It extends classic approach to modeling of production processes because it includes the modeling of the reverse material flows and also stochastic elements in relationships among demand for products, rate of product´s return and disposal factor.

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