A MULTI-DIMENSIONAL BI-SECTION SIMULATION-OPTIMIZATION APPROACH FOR LONGITUDINAL INVENTORY SPACE PLANNING IN REMANUFACTURING FACILITIES

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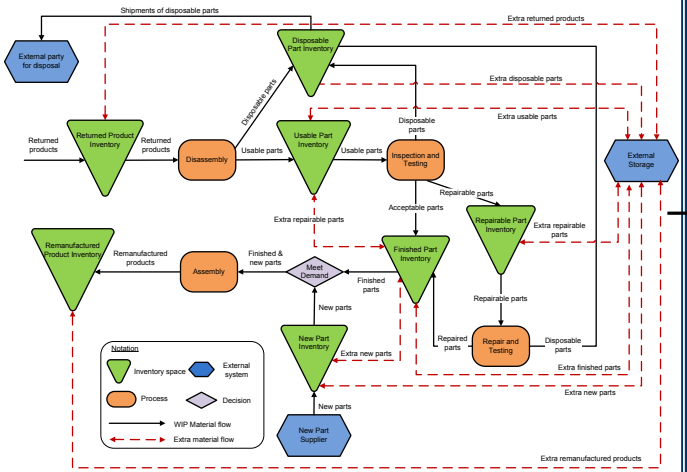
BACKGROUND

Objective

- Implement a multi-dimensional bi-section search algorithm in order to identify the optimal storage capacities and subsequent reconfiguration decisions that minimize long-term expected total cost.

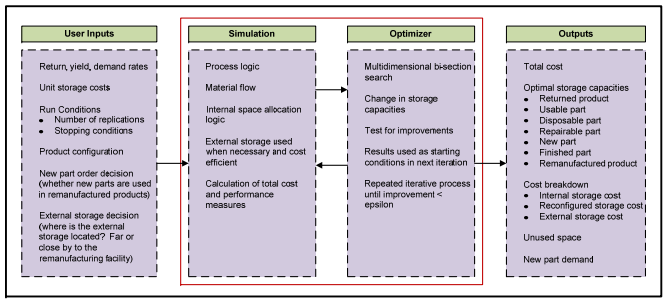
Generalized reconfigurable remanufacturing system



Model assumptions

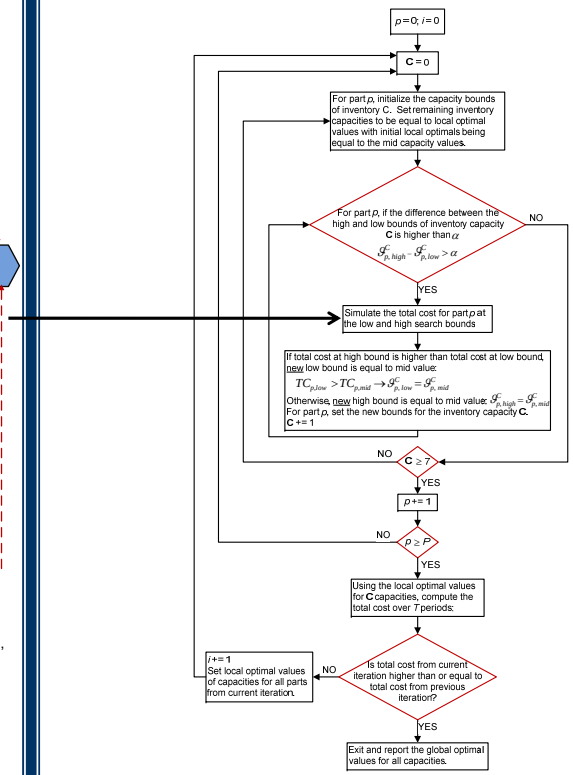
- Material flow into disposable part inventory has three sources: disassembly, inspection & testing, and repair & testing processes.
- Supply of new part is infinite.
- Acceptable and repaired parts are directed into 'finished part inventory'.
- Demand is always satisfied, meaning that no backorder is allowed.

Overall optimization framework



MODEL

Multi-dimensional bi-section search algorithm



Pseudo code of multi-dimensional bi-section search algorithm

```
For i = 0 To infinity

    For p = 0 To PartType -1

        'Initialize inventory capacity C and all others set at their local optimals
        'with initial optimals being equal to the mid values.
        CapInv_Low = ---
        CapInv_High = ---
        CapInv_Mid= (CapInv_Low + CapInv_High) / 2

            For C = 0 To Inv -1

                Do while CapInv _High – Inv _Low > α
                        'Call TotalCost function over T periods
                        If TotalCost_Low > TotalCost_Mid Then
                            CapInv_Low = CapInv_Mid
                        Else
                            CapInv_High = CapInv_Mid
                        End If
                    Loop

                'Report local optimal for inventory capacity
                CapInv_Opt

                Next C

    Next p

    If Total cost at i >= Total cost from previous (i – 1)
        Exit For
    End If

Next i
```

RESULTS

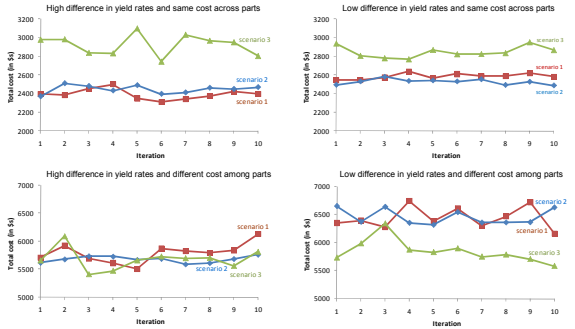
Design settings

Capacities	Low level	High level
Returned product inventory space	50	250
Usable part inventory space	50	200
Disposable part inventory space	0	50
Repairable part inventory space	0	30
Finished part inventory space	50	200
New part inventory space	0	30
Remanufactured product inventory space	80	200

	High difference in yield rates		Low difference in yield rates	
Uncontrollable variables	Part 1	Part 2	Part 1	Part 2
Mean for number of returned products	150		150	
Standard deviation for number of returned products	10		10	
Usable part yield percentage	90	70	95	90
Acceptable part yield percentage	80	65	70	65
Repairable part yield percentage	75	95	60	65
Repaired part yield percentage	80	90	80	85
Mean for demand	100		100	
Standard deviation for demand	5		5	

	Cost is the same across all parts						Cost is different among parts					
	Internal cost		Reconfiguration cost		External cost		Internal cost		Reconfiguration cost		External cost	
	Part 1	Part 2	Part 1	Part 2	Part 1	Part 2	Part 1	Part 2	Part 1	Part 2	Part 1	Part 2
Scenario 1	$1	$1	$1	$1	$2	$2	$3	$1	$3	$1	$6	$2
Scenario 2	$1	$1	$2	$2	$2	$2	$3	$1	$6	$2	$6	$2
Scenario 3	$1	$1	$2	$2	$4	$4	$3	$1	$6	$2	$12	$4

Summary of results



Conclusions

- The preliminary results indicate that the total cost does not converge.
- The run times vary from 110 to 140 minutes for 10 iterations.
- The effect of an increase in unit external storage cost has a more distinguishable effect on total cost when the cost across parts is the same.
- When the cost among parts is different, the total cost is higher.

Publications

1. **"Development of Pseudo-Optimal Heuristics for Inventory Space Planning in Remanufacturing Facilities,"** (working journal paper).

2. **"A Multi-Dimensional Bi-Section Simulation-Optimization Approach for Longitudinal Inventory Space Planning in Remanufacturing Facilities,"** (working journal paper).

3. **"Stochastic Programming Recourse Models for Reconfigurable Multi-Period Storage Allocation in Remanufacturing Facilities,"** (working journal paper).

4. Topcu, A., Cullinane, T. P. and Benneyan, J. C., **"Design-of-Experiments (DOE)-Based Heuristics for Remanufacturing Reconfigurable Storage Requirements,"** *INFORMS Annual Meeting*, Washington, DC, October 2008.

5. Topcu, A., Benneyan, J. C. and Cullinane, T. P., **"Stochastic Programming Recourse Models for Reconfigurable Multi-Period Storage Allocation in Remanufacturing Pull Facilities,"** *Proceedings of the 2008 Industrial Engineering Research Conference*, Vancouver, BC, Canada, May 2008, pp. 1718-1723.

6. Topcu, A., Benneyan, J. C. and Cullinane, T. P., **"Facility and Storage Space Design Issues in Remanufacturing,"** in *Environment Conscious Manufacturing*, S. M. Gupta (ed.), Taylor & Francis CRC Press, 2007, pp. 413-444 (Book Chapter).

7. Topcu, A. and Cullinane, T. P., **"Understanding Facilities Design Parameters for a Remanufacturing System,"** *Proceedings of the SPIE International Conference on Environmentally Conscious Manufacturing V*, Boston, MA, October 2005, pp. 163-173 (Refereed).