IRis

Northeastern University

Mechanical and Industrial Engineering Faculty Publications

Department of Mechanical and Industrial Engineering

January 01, 2010

Preemptive goal programming for solving the multi-criteria disassembly-to-order problem under stochastic yields, limited supply, and quantity discount

Amre Z. Massoud
Northeastern University

Surendra M. Gupta
Northeastern University

Recommended Citation

Massoud, Amre Z. and Gupta, Surendra M., "Preemptive goal programming for solving the multi-criteria disassembly-to-order problem under stochastic yields, limited supply, and quantity discount" (2010). *Mechanical and Industrial Engineering Faculty Publications.* Paper 5. http://hdl.handle.net/2047/d20000253

This work is available open access, hosted by Northeastern University.

Laboratory for Responsible Manufacturing

Bibliographic Information

Massoud, A. Z. and Gupta, S. M., "Preemptive Goal Programming for Solving the Multi-Criteria Disassembly-To-Order Problem under Stochastic Yields, Limited Supply, and Quantity Discount", ***Proceedings of the 2010 Northeast Decision Sciences Institute Conference***, Alexandria, Virginia, pp. 415-420, March 26-28, 2010.

Copyright Information

Copyright 2010, Surendra M. Gupta.

Contact Information

Dr. Surendra M. Gupta, P.E.
Professor of Mechanical and Industrial Engineering and
Director of Laboratory for Responsible Manufacturing
334 SN, Department of MIE
Northeastern University
360 Huntington Avenue
Boston, MA 02115, U.S.A.

(617)-373-4846 ***Phone***
(617)-373-2921 ***Fax***
gupta@neu.edu ***e-mail address***

http://www.coe.neu.edu/~smgupta/ ***Home Page***

PREEMPTIVE GOAL PROGRAMMING FOR SOLVING THE MULTI-CRITERIA DISASSEMBLY-TO-ORDER PROBLEM UNDER STOCHASTIC YIELDS, LIMITED SUPPLY, AND QUANTITY DISCOUNT

Amre Z. Massoud, Northeastern University, Boston, MA, 02115, (617) 373-7635, massoud.a@neu.edu
Surendra M. Gupta*, Northeastern University, Boston, MA, 02115 (617) 373-4846, gupta@neu.edu
(*corresponding author)

ABSTRACT

This paper considers the disassembly-to-order (DTO) problem where end-of-life (EOL) products are purchased for disassembly in order to satisfy the demand for specified numbers of components. Previous work in the literature solved the DTO problem with multiple uncertainties under a single objective while others solved the multi-criteria model with a single uncertainty. This paper develop a multi-criteria DTO model that would takes into consideration multiple system uncertainties and variability. The multi-criteria DTO model was solved using preemptive goal programming (PGP). The main objective was to determine optimal number of take-back EOL products in every period from each supplier in order to satisfy the demand of components and materials while trying to achieve the aspiration levels of multiple goals. A numerical example is considered to illustrate the model approach.

INTRODUCTION

In recent years, the idea of properly managing waste generated from end-of-life (EOL) products has caught the attention of government officials and law makers. Throughout the world, waste generated from EOL electronic products has grown incredibly large over the past few years. Fully functional electronic products such as personal computers, televisions, batteries, appliances, and cell phones are being dumped into landfills every year. Recent data and studies from the US Environmental Protection Agency (EPA) show an increase in the amount of waste generated by residents, businesses, and institutions. In 2006, the amount of Municipal Solid Waste (MSW) generated in the US was more than 251 million tons which translates into 4.6 pounds of waste per person per day.

Technology plays an essential role in people's lives because it has simplified their lives in many ways. Additionally, the cost of technology has been declining steadily over the years making them more readily accessible to wider range of consumers. As a result, demand in recent years for products with higher technologies has surged. This has motivated manufacturing companies to continuously develop newer products with technologies that would surpass pervious products. Consequently, consumers are tempted to upgrade their old products and acquire new products even though the older products are still in good functioning condition. This rush to upgrade the products with lower technologies has shortened the products lives and has led to the premature disposal of those products.

In order to minimize the negative impact on the environment, it is vital to properly manage the waste generated from the premature disposal of EOL products. Therefore, new laws and

regulations have been established by governments that aim to control the amount of waste being sent to landfills. In addition, consumers' awareness has forced manufacturers to become more environmentally conscious. As a result, manufacturers have thought of different ways to deal with waste generated from EOL products. Some of the options include: remanufacturing, reusing, recycling, or disposing of EOL products. If EOL products are remanufactured, reused, or recycled; then manufacturers can help decrease the rate of depletion of virgin nature resources and reduce their dependency on the natural resources in addition to cutting on the amount of harmful waste sent to landfills. However, disposal of EOL products contributes to the problem and therefore is used as a last resort.

Manufacturers first need to estimate the number of EOL products required to fulfill the demand of components. After that, they need to obtain the EOL products through the disassembly process. Then, the EOL products need to be disassembled into individual components and subassemblies. However, a lot of uncertainties exists in the process which complicates the process and make it difficult to know in advance the exact number of EOL products needed for disassembly. Models and techniques have been developed to address some of the uncertainties in the process however, they suffer from some limitation. Most of the previous models consider only one uncertainty which was the yield of retuned products. However, there are a number of other uncertainties that exist in the process such as the number of suppliers offering EOL products, ready-to-use components offered by an independent outside supplier, inventory capacity limit, and quantity discounts offered by suppliers. A limited number of models considered more than one uncertainty but solved the model under a single objective function.

Our paper focuses on the disassembly-to-order (DTO) system where a variety of EOL products are purchased for disassembly. We develop a multi-criteria DTO model that takes into consideration the above mentioned uncertainties and solve it using preemptive goal programming (PGP). The main objective is to determine the best combination of take-back EOL products to be purchased from every supplier for disassembly in order to satisfy the demand of components and materials while trying to achieve the aspiration levels of multiple goals. A numerical example is considered to illustrate the model approach.

LITERATURE REVIEW

The area of disassembly has sparked a lot of interest recently. Some researchers have examined the disassembly process and how it affects the environment while others focused on the financial aspects of the process. Gungor and Gupta [1] presented a comprehensive study of the different issues in environmentally conscious manufacturing and product recovery. Imtanavanich and Gupta [2] considered the DTO problem where the main objective was to determine the optimal number of returned products to be disassembled in order to fulfill the demand for a specified number of parts. Massoud and Gupta [3] considered the multi-period DTO problem under stochastic yields, limited supply, and quantity discount. The main objective was to determine the best combination of EOL products to be taken back in order to maximize total profit. Inderfurth and Langella [4] developed two heuristics for solving DTO problems with stochastic yields. The heuristic procedure transformed the stochastic yields into their equivalent deterministic yields. Imtanavanich and Gupta [5] developed a multi-criteria decision making approach for a DTO system under product deterioration and stochastic yields. Imtanavanich and Gupta [6] used a

multi-criteria decision making approach in order to model the DTO problem with stochastic yields and used heuristic procedures to convert the stochastic yields into their deterministic equivalents. Kongar and Gupta [7] presented a multi-criteria decision making approach for DTO system. Goal programming was used to determine the best combination of EOL products to be disassembled in order to fulfill the demand for items and materials under a number of financial, environmental, and physical constraints.

PROBLEM DEFINITION

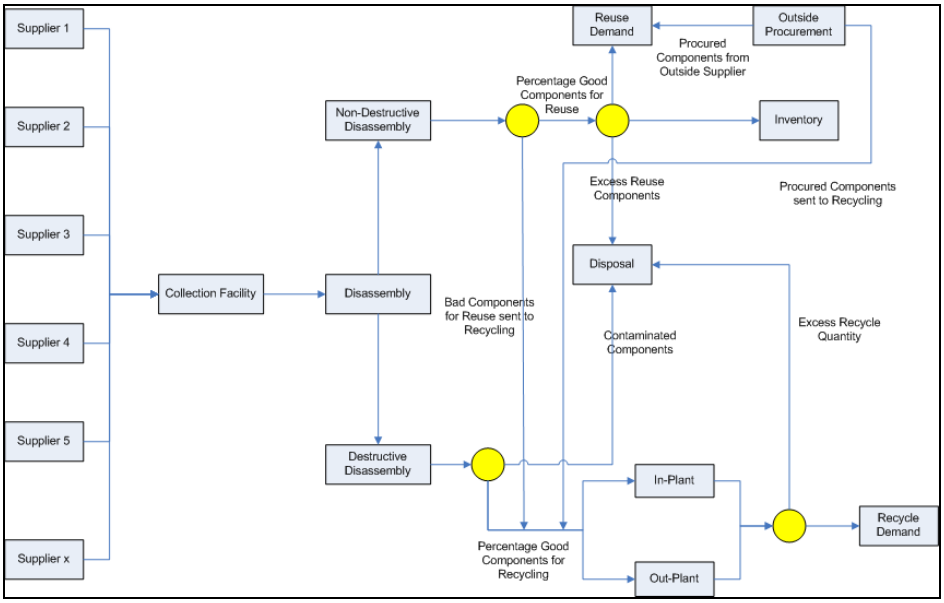

Figure 1: Disassembly-to-Order System

In a DTO problem, a variety of returned EOL products are considered for disassembly in order to satisfy the demand for certain components. The DTO process starts with the purchased of EOL products from a predetermined number of suppliers (see figure 1). The EOL products are then sent to the collection facility to be inspected and prepared for disassembly. Once they have been cleaned and inspected, they are sent to the disassembly process where components are separated using one of two processes: non-destructive or destructive disassembly process. Reuse demand along with components sent to storage are going to be satisfied with components from the non-destructive disassembly process. The number of stored components is limited by the available storage space. Recycling demand is going to be satisfied with components from the destructive disassembly process.

The yield of components from non-destructive disassembly is stochastic. Components obtained from non-destructive disassembly are sorted and tested for functionality. Next, they are divided into two types according to their functionality: good non-destructive components and bad non-destructive components. Again, the percentage of functional components is stochastic. Only good non-destructive components are used to satisfy the demand for reused components and storage. Since demand shortage is not allowed, all demand must be met. If reuse demand cannot be met from the good non-destructive components, additional components may be purchased at a premium cost from an outside supplier. Damaged components along with components that are

not worthy of non-destructive disassembly are considered bad non-destructive components. Components obtained from destructive disassembly are also inspected and divided into two types: good destructive components and bad (contaminated) destructive components. Good destructive components along with bad non-destructive components are sent to the recycling process. Components are recycled either in-plant or out-plant in order to satisfy the recycling demand. In-plant recycling process has a capacity limit on the number of components that can be processed. Components are going to be sent first to the in-plant recycling process since it is cheaper than out-plant recycling. If the demand is greater than the in-plant processing capacity, additional components are sent to the out-plant process. Finally, components that exceed the demand for reuse, recycle, and storage are sent to disposal along with the contaminated components from the recycling process.

In this paper, we develop a multi-criteria DTO model which takes into consideration the different system uncertainties. PGP is used to solve the multi-criteria DTO model. The main objective is to determine the best combination of take-back EOL products to be purchased from every supplier that would satisfy the demand while achieving the aspiration levels of multiple goals.

NUMERICAL EXAMPLE

This section presents a numerical example to illustrate the application of the multi-criteria DTO model. The main objective is to determine the best combination of take-back EOL products purchased from every supplier that would satisfy the demand while achieving the aspiration levels of 4 different goals. In this example, we have 2 suppliers, 6 products, and 10 components. Each supplier is going to be offering 3 different types of products and each product will consist of 8 different components. The price and condition of products will differ across supplier and each supplier is offering a different discount schedule that is based on the total dollar amount of products purchased. Input data for our model is summarized in tables 1 though 5.

Table 1: Product Purchase Price & Capacity

Product	Supplier 1		Supplier 2	
	Purchase Price	Capacity	Purchase Price	Capacity
1	$30	250	$39	486
2	$21	352	$30	459
3	$34	381	$32	268

Table 2: Component Yields from Both Suppliers

		A	B	C	D	E	F	G	H	I	J
Supplier 1	Produc 1	0.00	0.67	0.61	0.76	0.79	0.53	0.00	0.52	0.53	0.65
	Produc 2	0.66	0.00	0.58	0.74	0.76	0.58	0.64	0.27	0.00	0.29
	Produc 3	0.75	0.72	0.51	0.00	0.00	0.52	0.59	0.53	0.50	0.62
Supplier 2	Produc 1	0.00	0.72	0.63	0.81	0.84	0.54	0.00	0.53	0.57	0.67
	Produc 2	0.69	0.00	0.66	0.87	0.90	0.65	0.66	0.31	0.00	0.33
	Produc 3	0.78	0.85	0.59	0.00	0.00	0.60	0.61	0.59	0.60	0.70

Table 3: Discount Schedule Supplier 1

Discount Schedules	Discount Rate
0 < 5,000	0.0%
5,000 < 10,000	3.0%
10,000 < 15,000	5.0%
>= 15,000	8.0%

Table 4: Discount Schedule Supplier 2

Discount Schedules	Discount Rate
0 < 5,000	0.0%
5,000 < 10,000	2.5%
10,000 < 15,000	6.0%
>= 15,000	7.5%

Table 5: Component Input Data

Component	Reuse Demand	Reuse Sell	Reuse Perc.	Recycle Demand	Recycle Sell	Recycle Perc.	Holding Cost	Proc. Cost	Non-Dest. Cost	Dest. Cost	Disposal Cost
A	400	$23	80%	280	$13	98%	$3.45	$10	$0.55	$0.35	$2.60
B	400	$23	85%	221	$16	95%	$3.40	$9	$0.50	$0.30	$2.40
C	550	$22	85%	240	$16	99%	$3.35	$8	$0.45	$0.25	$2.70
D	300	$18	80%	220	$13	96%	$3.35	$7	$0.50	$0.30	$2.70
E	310	$22	75%	280	$15	98%	$3.45	$10	$0.60	$0.40	$2.80
F	560	$21	90%	260	$15	97%	$3.40	$8	$0.65	$0.35	$2.50
G	400	$22	85%	240	$17	97%	$3.55	$11	$0.60	$0.30	$2.90
H	550	$20	85%	360	$15	99%	$3.25	$10	$0.55	$0.35	$2.40
I	320	$21	80%	260	$14	99%	$3.35	$8	$0.50	$0.30	$2.55
J	590	$23	80%	360	$15	99%	$3.40	$9	$0.45	$0.25	$2.65

Additional data needed to solve the model: in-plant recycling cost = $1.00, out-plant recycling cost = $1.80, contaminated disposal cost = $2.00, and inventory capacity = 50 for each component.

Lingo 11.0 was used to solve the multi-criteria PGP problem. The total purchase and discount rates for supplier 1 and 2 were $16,170 with 8% discount and $8,825 with 2.5% discount respectively. The quantity of procured components for reuse and recycle, quantity of stored components, and quantity of disposed components from reuse, recycle, and contamination are summarized in table 6. Finally, table 7 presents the aspiration levels for each goal along with the model results at each stage.

Table 6: Model Output for PGP problem

Component	Outside Procurement		Ending Inventory	Disposal Quantity		
	Reuse Procurement	Recycle Procurement		Excess Reuse	Excess Recycle	Contaminated Quantity
A	28	12	0	0	0	4
B	14	15	0	0	0	7
C	108	0	0	0	203	4
D	0	13	21	0	0	5
E	0	59	0	0	0	2
F	107	0	0	0	164	12
G	60	0	0	0	57	7
H	202	0	0	0	175	5
I	53	0	0	0	69	3
J	203	0	0	0	137	4

Table 7: Aspiration Levels for each Goal in PGP Model

	Aspiration Levels	Initial Run	1st Goal	2nd Goal	3rd Goal	4th Goal
Profit	**>= 93,000**	93,523.85	**93,000.00**	**93,000.00**	**93,000.00**	**93,000.00**
Procurement Cost	**<= 8,000**	11,502.22	8,515.47	**8,000.00**	**8,000.00**	**8,000.00**
Purchase Cost	**<= 25,000**	22,014.00	24,347.00	24,558.00	**24,995.00**	**24,995.00**
Disposal Cost	**<= 2,200**	1,651.62	3,714.35	2,309.79	2,185.69	**2,185.69**
Disassembly Cost		2,913.29	3,164.54	3,225.01	3,183.67	3,183.67
Inventory Cost		70.35	60.30	233.55	70.35	70.35
Recycling Cost		4,778.68	5,217.61	5,226.01	5,145.51	5,145.51
Non-Destructive Cost		2,126.52	2,308.41	2,363.68	2,341.98	2,341.98
Destructive Cost		786.77	856.13	861.32	841.69	841.69

CONCLUSION

In this paper, we evaluated the multi-criteria disassembly-to-order (DTO) problem where a variety of returned end-of-life (EOL) products were purchased for disassembly. The main objective was to determine the best combination of EOL products to be purchased from every supplier that would satisfy the demand while achieving the aspiration levels of multiple goals. A number of factors were considered including the condition of returned products, the variety of products from different suppliers, and quantity discounts offered by suppliers. Preemptive Goal Programming (PGP) was used to solve the multi-criteria DTO problem.

REFERENCES

[1] Gungor, A. and Gupta, S. M., "Issues in environmentally conscious manufacturing and product recovery: a survey," *Computers & Industrial Engineering*, Vol. 36, No. 4, 811-853, 1999.

[2] Imtanavanich, P. and Gupta, S. M., "Multi-criteria decision making for disassembly-to-order system under stochastic yields," *Proceedings of the SPIE International Conference on Environmentally Conscious Manufacturing IV*, Philadelphia, Pennsylvania, 147-162, 2004.

[3] Massoud, A. Z. and Gupta, S. M., "Solving the multi-period disassembly-to-order system under stochastic yields, limited supply, and quantity discount," *Proceedings of 2008 ASME International Mechanical Engineering Congress and Exposition*, Boston, MA, 2008.

[4] Inderfurth, K. and Langella, I. M., "Heuristics for solving disassemble-to-order problems with stochastic yields," *OR Spectrum*, Vol. 28, No. 1, 73-99, 2006.

[5] Imtanavanich, P. and Gupta, S. M., "Multi-criteria decision making approach in multiple periods for a disassembly-to-order system under product's deterioration and stochastic yields," *Proceedings of the SPIE International Conference on Environmentally Conscious Manufacturing V*, 10-21, 2005.

[6] Imtanavanich, P. and Gupta, S. M., "Calculating disassembly yields in a multi-criteria decision making environment for a disassembly-to-order system," *Proceedings of the 2005 Northeast Decision Sciences Institute Conference*, Philadelphia, Pennsylvania, 2005.

[7] Kongar, E. and Gupta, S. M., "A multi-criteria decision making approach for disassembly-to-order systems," *Journal of Electronics Manufacturing*, Vol. 11, No. 2, 171-183, 2002.