

Ershi Qi  
Jiang Shen  
Runliang Dou  
*Editors*

# Proceedings of the 22nd International Conference on Industrial Engineering and Engineering Management 2015

Innovation and Practice in Industrial Engineering  
and Management (Volume 2)

Proceedings of the 22nd International Conference  
on Industrial Engineering and Engineering  
Management 2015

Ershi Qi · Jiang Shen · Runliang Dou  
Editors

# Proceedings of the 22nd International Conference on Industrial Engineering and Engineering Management 2015

Innovation and Practice in Industrial  
Engineering and Management (Volume 2)



*Editors*

Ershi Qi  
Chinese Industrial Engineering Institution,  
CMES  
Tianjin University  
Tianjin  
China

Runliang Dou  
Chinese Industrial Engineering Institution,  
CMES  
Tianjin University  
Tianjin  
China

Jiang Shen  
Chinese Industrial Engineering Institution,  
CMES  
Tianjin University  
Tianjin  
China

ISBN 978-94-6239-176-5

ISBN 978-94-6239-177-2 (eBook)

DOI 10.2991/978-94-6239-177-2

Library of Congress Control Number: 2015960782

© Atlantis Press and the author(s) 2016

This book, or any parts thereof, may not be reproduced for commercial purposes in any form or by any means, electronic or mechanical, including photocopying, recording or any information storage and retrieval system known or to be invented, without prior permission from the Publisher.

Printed on acid-free paper

# Preface

It is my great pleasure to welcome all the delegates come all the way for the 22nd International Conference on Industrial Engineering and Engineering Management 2015 (IEEM 2015). It is their great efforts that bring out the proceedings of IEEM 2015 which records the new research findings and development in the domain of IEEM. What is more excited, they are the experts or scholars with significant achievements in the field. I believe that the proceedings will serve as the guidebook for the potential development in IEEM and play a great role in promoting the IEEM development.

With the ongoing dramatic paradigm shifts of industrial engineering theories and applications, more and more enterprises have realized it is the key to innovate their products by utilizing the advanced technology to enhance their core competitiveness. It is quite imperative to bring professionals from both academia and business together to share their new findings and experience.

IEEM 2015 caters to the purpose by providing a platform to exchange the state-of-the-art research, achievement exhibition, case study, and development in the field of IEEM, as well as promoting its application. The papers selected all center on the main themes of the conference: Industrial Engineering Theory, Industrial Engineering Technology Practice, Information Technology Application and Development, Automation System Theory and Application, Value Engineering, as well as Engineering Management Method and Practice. All the papers included in the proceedings have undergone rigid peer review. We have also invited some prominent experts as our keynote speakers.

The conference is sponsored by Chinese Industrial Engineering Institution, CMES, and organized by Guangdong University of Technology, China. We would like to extend our sincerest thanks to Atlantis Press for their generous support in the compilation of the proceedings. We also would like to extend sincerest thanks to Guangdong University of Technology for holding such an excellent event, and to

all the delegates, keynote speakers, and the staff of the organization committee for their contribution to the success of the conference in various ways.

Thank you very much!

October 2015

Ershi Qi  
Jiang Shen  
Runliang Dou

# Contents

## Part I Engineering Management

<b>A Comparative Study on Retailer’s Refunding Strategies Considering Products Advance Selling . . . . .</b>	<b>3</b>
Gang Wang, Zhao-chao Dong and Zhi-bao Li	
<b>Research on the Monopolist’ Repurchase and Remanufacture Decisions Based on Heterogeneous Consumer Considering Buy-Back Cost . . . . .</b>	<b>15</b>
Zhao-fang Mao, Xin-Xin Li and Wei Liu	
<b>Study on the Exchange Rate Risk of China International Construction Enterprises . . . . .</b>	<b>27</b>
Quan Fan and Xing Bi	
<b>Technology Diffusion and Acquisition Premium in M&amp;A . . . . .</b>	<b>35</b>
Rui-ye Wan and Hong Zeng	
<b>Coordinated Development Degree of County Socio-Economic System Prediction Based on GA-SVM . . . . .</b>	<b>45</b>
Jing Zhao, Ying Wang and Xing-hua Dang	
<b>Quality Safety Risk Analysis on Children’s Car Safety Seat . . . . .</b>	<b>53</b>
Xia Liu, Qian Wu, He-liang Song and Ying Li	
<b>Coupling Relationship Analysis of Economic Growth and Environmental Pollution in Western Region . . . . .</b>	<b>63</b>
Ling Lin, Qing-qing Cao and Zhong-li Zhou	
<b>The Dynamic Analysis of R&amp;D Competition Behavior of a Duopoly Under the Condition of Different Expectations . . . . .</b>	<b>75</b>
Dong-wei Huang, Yu-xia Fu and Shen-xin Yu	

<b>Strategic Human Capital in Organization: Frontier Review, Prospective Commentary, and Guiding Framework . . . . .</b>	85
Long Xu, Su-ying Gao, Lu Zhang, Hong-feng Zhang, Hui Yu and Chun-ying Song	
<b>Research on the Effects of the Fixed Asset Investment on the Nonperforming Loans Ratio . . . . .</b>	99
Guo-yi Li and Jing Sui	
<b>Research on Real-Time Cost Control in Factory in IT Environment . . . . .</b>	109
Yu-xiang Pan, Er-shi Qi and Dan An	
<b>Fuzzy Catastrophe Model of Project Selection Based on Strategy . . . .</b>	117
Bao-long Wang, Cheng-long Wang and Yuan-tao Song	
<b>Synergistic Factor Analysis of Production-City Integration . . . . .</b>	129
Shui-bin Jiang and Jiang Shen	
<b>Analysis of Industry-University-Research Cooperation Organization. . . . .</b>	137
Xiao-yu Ye and Ying Shen	
<b>Application of TOPSIS Evaluation Method in the Cultivation of Scientific and Technological Achievements . . . . .</b>	145
Hui-ming Xu, Jing-hua Wang, Meng Zhang, Chun-jie Hou, Xi Chen and Jian-fei Ji	
<b>A Study on Safety of Transportation System of Marine Dangerous Chemicals Based on Energy Concept . . . . .</b>	159
Jian-min Li, Shao-zhen Song, Ya-lin Diao and Wei Guan	
<b>Empirical Study on Key Risk Factors of Project Bidding . . . . .</b>	171
Shu-qing Liu and Chun-hua Li	
<b>A Game Analysis of Quality Supervision Over Rural Development Projects . . . . .</b>	185
Fu-jiang Sun	
<b>Analysis on the Influence Factors of Construction Enterprise Synergistic Development Based on the Ecological Perspective . . . . .</b>	193
Chong Jia, Zhi-hong Wang and Dong-mei Feng	
<b>Study on the Extended Management Methods of Outsourcing Research Projects of Enterprises . . . . .</b>	201
Qian-long Yu, Lin Chen and Lei Sun	
<b>Evaluating Agricultural Catastrophe Risk in Guangdong Province . . .</b>	207
Lei Xu	

**Research of Data Resource Description Method Oriented Provenance** . . . . . 215  
 Yan-peng Zhao, Chao-fan Dai and Xiao-yu Zhang

**Study on the Support System of Safety Hidden Hazards Warning and Countermeasures for Main Ventilator in Coal Mine** . . . . . 225  
 Xiao-yan Gong, Xin Gao and Yu-xuan Xue

**Enterprise Service Bus Based on OSGi** . . . . . 233  
 Wei Huang, Bao-cheng Sun, Ming-di Xu, Heng Zhao and Ying-song Hu

**Robust Design for Remanufacturing Logistics Network Based on Stochastic Programming** . . . . . 247  
 Hui Zheng, Wei Zhang and Jun-yu Wang

**Lateral Replenishment Strategy for Chain Supermarket Fresh Agricultural Products Inventory Optimization** . . . . . 259  
 Guang-shu Xu, Z.L. Song, S.J. Piao, H.F. Zhang and X.W. Zhang

**Part II Value Engineering**

**Study on the BP Neural Network Evaluation Model of Employability** . . . . . 273  
 Pei-lin Chen, Wei Cheng and Ting-ting Fan

**Study on the Application of Genetic Algorithm Based BP Neural Network Model in Field of Cross Selling** . . . . . 283  
 Pei-lin Chen, Wei Cheng and Ting-ting Fan

**The Design of Floating Magnetic Pendulum-Driven Robot Fish Diving and Counterweight** . . . . . 295  
 Hong-xiu Zhu, Da-feng Zhu, Tie-lei Zhao, Zi-hang Gao, Ying-ying Zhong, Ye He, Yong Wang, Jia-tong Liu and Li-jun Wang

**College Students' Life Satisfaction Evaluation Based on Structural Equation Model** . . . . . 303  
 Xiao-yan Gu and Xin-ru Pan

**Research on Rural Infrastructure Project Management of Baohe Village in Beijing of China** . . . . . 311  
 Jun-qi Hou and Yun-jiao Duan

**Owner Oriented Integration Management of Large General Hospital Construction Projects** . . . . . 317  
 Yu-cheng Pang and Li Shi

<b>Predicting Technical Communication Between Teams in GPD Project Related Redesign Components . . . . .</b>	327
Sonia Kherbachi and Qing Yang	
<b>Research of Distribution Center Site Selection Based on Fuzzy Analytic Hierarchy Process . . . . .</b>	335
Yi-hong Cheng and San-yuan Zhou	
<b>Study on Innovation and Driving Mechanism of Internet Finance . . . .</b>	343
Hu-bin Jin and Cheng-hu Zhang	
<b>Research on Cost Management of Real Estate Project Construction Phase Based on Value Engineering: The Observatory World Project of China State Construction Property Company as an Example . . . . .</b>	351
Huan-wu Yin, Hui-jiang Yang and Hui-jie Gao	
<b>Analysis on Cost Management Application of Value Engineering at Design Phase of Real Estate Projects . . . . .</b>	361
Huan-wu Yin, Hui-jiang Yang and Hui-jie Gao	
<b>Research on Application of Value Engineering in Optimization Design in the International EPC Project . . . . .</b>	373
Yan-fang He and Zi-cheng Tao	
<b>Application of Value Engineering in Urban Planning Practice—3 Cases at Different Levels . . . . .</b>	383
Jian-feng Xu, Yang Lu and Ling Huang	
<b>Research on the Key Factors of Urban Gas Repair Operation Based on Analytic Hierarchy Process . . . . .</b>	393
Xia-xi Li, Cui-mei Li, Qian Yan and Ya-hui Wang	
<b>The Efficiency of Supply Chain Technology Estimation Model Based on Malmquist Productivity Parametric Decomposition Approach . . . . .</b>	401
Heng-shan Zong, Guo-zhu Jia and Yang Cheng	
<b>Research on the Optimization of Parts Processing System Based on Queuing Theory and Value Engineering . . . . .</b>	417
Ying-wei Cui and Hai-bo Li	
<b>An Attention-Based View of Internet Business Platform Service Value . . . . .</b>	427
Xue-qing Wang and Li-ming Chen	
<b>Integrated Planning with Value Engineering for Call Centers Equipment and Workforce Capacity Expansions . . . . .</b>	437
Hong-xun Wang, Yi-bo Wang and Xiao Shang	

**An Introduction of Application of Value Engineering in Beijing-Tianjin-Hebei Traffic Integration.** . . . . . 451  
 Han-po Hou, Bei-bei Wang and Wei Yao

**Improvement of the “Bottom-up” Approach in Value Engineering** . . . . . 461  
 Zhi-wei Jiang, Hua-yan Yu and Xue-song Wang

**Development of Chinese Bonded Logistics Parks and Tax Policy Analysis** . . . . . 469  
 Suo-quan Zhang, Nian-qing Wang and Yan-jie Shu

**The Layout Optimization Model and Algorithm of Logistics Park Potential.** . . . . . 479  
 Guo-wen Ren and Ying-jie Huang

**The Control and Application of the Overbooking Strategy—Empirical Research on Air China** . . . . . 489  
 Shou Li, Lun Li and Chen-xiao Zhao

**The Impact of FDI on the Income and Income Gap of Urban Residents** . . . . . 495  
 Shuo Li and Lun Li

**Study on the Strategies of Target Cost Management in the Supply Chain of Aeronautic Complex Product** . . . . . 501  
 Hang-hang Chen and Li-xin Pan

**The Research About the Effect of Straw Resources on the Economic Structure of Jilin Province.** . . . . . 511  
 Wei-dong Xi, Yu-tao Sun, Guan-fang Yu and Ya-qing Zhang

**Information Conflicts, Ambivalence, and the Judgment of Nonprofessional Investors** . . . . . 519  
 Mao-ran Meng, Li-xin Pan and Ling-ling Tan

**Research on Performance Evaluation of Tourism Management Professionals Training.** . . . . . 531  
 Shan-shan Lv and Yan-zhang Gu

**The Risk Assessment Method and Application of Aviation Subcontract Base on Three-Dimensional Evaluation Model.** . . . . . 539  
 Si-jia Zhu and Xin Liu

**Research on Constructing the Information Platform of Customs** . . . . . 547  
 Ning Ding

**Research on Cross-Border Trade e-Commerce Taxation—A Case Study of the Diamond Industry** . . . . . 559  
 Ning Ding and Yan Wang

**Research on Schedule Risk Management of Interdisciplinary Complex Giant System** . . . . . 567  
 Jia Lei, Wan-hua Qiu, Chang-hong Ding and Wen-feng Yuan

**Research on the Application of Internet Financial Integration in China Ping An (Group)**. . . . . 573  
 Ji-qiu Xiao and Miao Yu

**Study of Chinese Luxury Import Tax Revenue-Taking Luxury Bags for Example** . . . . . 581  
 Chang-hu Liu, Ming-lu Xu and An-qi Zhang

**An Empirical Research on C2C Purchase Intention Based on Mobile Social Networking Service**. . . . . 591  
 Guo-wen Ren and Dan-dan Yuan

**Institutional Norms for Place Branding and Its Effect on Corporate Involvement Behavior** . . . . . 599  
 Wei-hong Zhao and Fan Zhang

**Study on Influential Factors of Agricultural Eco-place Brand Competitiveness** . . . . . 611  
 Wei-hong Zhao and Hui-long Zhang

**Dimensions and Formation Mechanism of Customer-Based Place Brand Equity**. . . . . 621  
 Wei-hong Zhao and Yu-dong Zhang

**The Strategy of E-Commerce Platform Based on the Perspective of Resource Orchestration: A Case Study of Haier**. . . . . 629  
 Nan Yang, Tao-hua Ouyang, Jing-bo Hu and De-lin Zeng

**Analysis on the Effect of Straw Resources in Jilin Province Based on Multi-objective Programming** . . . . . 639  
 Hong-jing Zhang, Ya-qing Zhang and Yu-tao Sun

**Index Spot Futures Arbitrage Based on Contingent Claim Analysis** . . . . . 649  
 Chao Wang and Yi Cui

**Effect Evaluation of the Whole Bidding Based on Analytic Hierarchy Process**. . . . . 661  
 Ying-wei Cui and Hui-min Li

**Study on Extensional Evaluation of Excavation Engineering Project Management Performance on OWA Operator** . . . . . 675  
 Hui Guang and Fei Ren

**A Brief Discussion on Blue Ocean Strategy of the Farm Product Electronic Business Under the Booming O2O Pattern . . . . .** 685  
 Jun Ma

**Cost Control System Building Based on Government Investment Construction Project . . . . .** 695  
 Zhen-quan Wu, Fang Liu and Xiao-yun Xu

**Preferential Mode of Import Tariff in Context of E-Commerce Cross-Border Trade . . . . .** 707  
 Shuo-quan Zhang, Ying-hui Xia and Yan-jie Shu

**Application of SPSS in EIQ Analysis . . . . .** 717  
 Xiao-juan Yang and San-yuan Zhou

**Research on Gray Fuzzy Risk Assessment in Water Transportation of Dangerous Goods . . . . .** 725  
 Xiao-li Zhao

**Supplier Selection Decision-Making Model Based on Entropy and Its Application in the Large Aircraft Project . . . . .** 733  
 Chang-hong Ding, Wen-feng Yuan, Meng Zhao and Wan-hua Qiu

**Study of Fund Performance Evaluation Based on Insurance Costs . . .** 743  
 Xin-an Fan

**Entropy-Based ERP System Selection Model Study . . . . .** 751  
 Xiao-yan Gu and Meng-xiao Wang

**Application of DEA in the Value Optimization Study of China Listed Media Companies . . . . .** 761  
 Hui-chen Jiang and Shan-cun Liu

**Research on Prediction of Transmission and Transformation Project Cost Index Based on ARIMA and Exponential Smoothing Models. . . . .** 771  
 Dong-xiao Niu and Fu-yu Hua

**Analysis of Countermeasures Negotiation Process Based on Resource Acquisition . . . . .** 781  
 Jian-fen Yan, Yong-gui Shi and Shi-meng Ma

**Research on Enterprise Innovation Behavior and Model of Regional Industry Cluster in Hebei Province . . . . .** 791  
 Shi-meng Ma, Yong-gui Shi and Hai-xia Li

**Research on the Current Situation and Innovation Mode of Land Transfer in Hebei Province Under the Background of “Internet +” . . . . .** 803  
 Hai-xia Li, Yong-gui Shi and Shi-meng Ma

**Corporate Ethics and Ethical Judgment of Earnings Management—Psychological Safety as Mediator. . . . .** 813  
Xiao-xu Zhang

**The Case-Based Reasoning Evaluating Model of Coal Resource Mining Right with Unknown Attribute Strength Function. . . . .** 823  
Shao-hui Zou, Yan-yan Yuan and Jin-suo Zhang

**Research on the Effectiveness of Intellectual Capital in Driving the Market Value of China Listed Companies—Taking Communication and Other Related Equipment Industries for Example . . . . .** 833  
Hui-chen Jiang and Shan-cun Liu

**Practice and Innovation of Engineering Construction Project Management. . . . .** 841  
Ge-ping Wang, Zhen-quan Wu and Tao Wang

**A Research on the Integrated Value Management of PPP Project Based on Hall’s Three Dimensional Structure. . . . .** 849  
Guo-zong Zhang, Jin-hua Wang, Yong-hua Wang and Wan-hua Qiu

**The Exploration of Project Management Enterprise Standard to Enhance the Enterprise Value . . . . .** 859  
Tao Wang, Ge-ping Wang, Su-ping Zhu and Ying-chun Zhu

**Research and Application of Integrated Quality System for Large-Scale Complex Equipment Manufacturing . . . . .** 871  
Cheng Li

**Research on High-End Manufacturing Innovation and Development Way Based on Cloud Computing . . . . .** 881  
You-cheng Shan, Chao Lv, Qiu-ye Zhang and Xin-yu Tian

**Part I**  
**Engineering Management**

# A Comparative Study on Retailer's Refunding Strategies Considering Products Advance Selling

Gang Wang, Zhao-chao Dong and Zhi-bao Li

**Abstract** Advance selling through pre-orders is a strategy to transfer inventory risk from a retailer to consumers. Refunding strategy can reduce strategic consumers' pre-order risk caused by valuation uncertainty so as to encourage pre-orders. A newsvendor retailer can have three refunding strategies to choose from: no refunding allowed, partial refunding and full refunding. This research studies how a retailer could design a refunding strategy in the advance selling problem to maximize her own profits. We find some interesting results. For example, compared with no refunding allowed strategy, customers in partial refunding strategy can bear higher advance selling price, which has a positive effect on the retailer's profit. In full refunding strategy, more customers will return and the margin profit earned from these customers will be lower than that in partial refunding strategy, leading to lower profit in full refunding strategy.

**Keywords** Advance selling · Refunding strategy · Strategic consumers

## 1 Introduction

Consumers become more and more rational with the aggravation of the market competition and the convenient access to market information. Even if evaluation is above current selling price, strategic consumers will not place order immediately but to compare the utility of buying products at different stages and then decide the best time to buy [1]. This waiting behavior has negative effects on the retailer's pricing and inventory decisions [2, 3]. Therefore, it's necessary to consider consumers' strategic behavior when optimizing the retailer's pricing and ordering decision.

---

G. Wang · Z. Dong (✉) · Z. Li  
College of Management and Economics, Tianjin University, Tianjin, China  
e-mail: 18601180315@163.com

© Atlantis Press and the author(s) 2016  
E. Qi et al. (eds.), *Proceedings of the 22nd International Conference  
on Industrial Engineering and Engineering Management 2015*,  
DOI 10.2991/978-94-6239-177-2\_1

Advance selling allows consumers to pre-order before the release of the products. Reference [4] mentioned an advance selling case that a pastry shop encouraged consumers to pre-order moon cakes a month before the Mid-Autumn Festival. Consumers can enjoy 25 % off and would get moon cakes one week before the Mid-Autumn Festival. Microsoft allowed consumers to advance purchase in the Amazon before the formal release of Vista [5]. Advance selling strategy is usually used in the newsvendor model where sales cycle is short and market demand is uncertain. Advance selling can transfer inventory risk from the retailer to consumers to some extent [6]. In addition, the retailer can use the advance selling information to update the sales information prediction in spot selling period, making it more close to the actual market demand.

Among literatures on advance selling problem considering the consumer strategy behavior, [7] proved that advance selling strategy can be applied as long as consumer value uncertainty exists. Reference [8] expanded [7]'s research and showed that pre-sale profit comes from the expansion of market demand. Reference [6] discussed the advantages and disadvantages of pre-sale from the angle of risk preference and proved that pre-sale strategy is beneficial for the retailer only if the difference between consumers' valuation when participating pre-sale and not participating pre-sale reaches a critical value. Reference [5] divided advance selling strategies into no advance selling allowed, moderate advance selling and deep advance selling for pre-orders. Some literatures [6, 7] mentioned refunding strategy in extension section, but there is no meticulous research on refunding strategy.

There are two types of refunding strategies: full refunding and partial refunding. In real life, full refunding is more common, but many businesses still apply partial refunding policy by charging some returning fee. In this way, consumers and businesses will undertake the cost caused by mismatching of supply and demand together [9]. Whether to full refund or partial refund does not only affect consumers' buying behavior, but also has influence on the retailer's advance selling strategy. For example, when committing full refund policy to consumers, retailers can't charge premium advance selling price, otherwise there will be speculation. But in the partial refunding strategy, there isn't this restriction. Therefore, it is necessary to analyze full refunding strategy and partial refunding strategy respectively.

We focus on seeking the retailer's optimal refunding strategy under the constraints that consumers' valuation and market demand are both uncertain and find answers to the following questions: is refunding strategy profitable or not? If yes, should the retailer apply full refunding strategy or partial refunding strategy? What should the advance selling price and refunding price be? What is the optimal order quantity?

## **2 Problem Settings**

### **2.1 Assumptions**

1. Consumers are classified into two segments depending on whether or not they concern about the advance selling information. Consumers who concern about the advance selling information are denoted as type I consumers and consumers who don't concern about the advance selling information are denoted as type U consumers.
2. The advance selling period exists before the spot selling period starts. The retailer allows consumers to place pre-orders during the advance selling period. These orders are fulfilled at the beginning of the selling season by exchanging pre-sale coupons.
3. All type I consumers arrive at advance selling period and all type U consumers arrive at spot selling period.
4. Consumers' valuation function and market demand function are known to the retailer.
5. There exist no consumers who neither exchange nor return pre-sale coupons.
6. We do not consider consumer speculation.
7. Consumers are homogeneous and have the same valuation function.

### **2.2 Notation**

Table 1 is the notation of all parameters used in this paper.

### **2.3 Decision Making Process**

1. The retailer makes optimal pricing and ordering decisions to maximize her profit under the premise that consumers are willing to pay the pre-sale price.
2. Consumers who arrive at advance selling period have two options: one is to buy pre-sale coupons and exchange for real goods (or return coupons) in spot selling period and the alternative is to wait until the spot selling period.
3. Consumers who arrive at the spot selling period should decide whether to buy or leave.

**Table 1** Notation

$N_i$	Number of type I consumers, a random variable with a normal distribution $N_i \sim N(\mu_i, \sigma_i)$
$N_u$	Number of type U consumers, a random variable with a normal distribution $N_u \sim N(\mu_u, \sigma_u)$
$\rho$	Correlation coefficient between $N_i$ and $N_u$
$V$	Consumer valuation for a product, a random variable with an uniform distribution $V \sim U(\mu_v, \sigma_v)$ . $V$ 's cumulative distribution function is $F(V)$ with upper limit $h$ and lower limit $l$
$N_a$	Number of consumers who place pre-orders in the advance selling period, a random variable with mean $\mu_a$ and standard deviation $\sigma_a$
$N_s$	Number of consumers who purchase in the spot selling season, a random variable with mean $\mu_s$ and standard deviation $\sigma_s$
$p_a^i$	The advance selling price in strategy $i$ , $i \in \{1, 2, 3\}$ . The optimal advance selling price is denoted as $p_a^{i*}$ . Strategy 1–3 represents no refunding strategy, partial refunding strategy and full refunding strategy, respectively
$p_b$	The refunding price in partial refunding strategy, $p_b < p_a^{2*}$ . The optimal refunding price is denoted as $p_b$
$p_s$	Spot selling price per unit of product in spot selling period
$U_a^i$	Expected utility of a consumer when advance purchasing in strategy $i$ , $i \in \{1, 2, 3\}$
$U_s^i$	Expected utility of a consumer when buying in spot selling period in strategy $i$ , $i \in \{1, 2, 3\}$
$\pi_a^i$	The retailer's expected profit of advance selling period in strategy $i$ , $i \in \{1, 2, 3\}$ . The optimal advance selling profit is denoted as $\pi_a^{i*}$
$\pi_s^i$	The retailer's expected profit of spot selling period in strategy $i$ , $i \in \{1, 2, 3\}$ . The optimal selling profit is denoted as $\pi_s^{i*}$
$n_a^i$	The actual sales amount in advance selling period in strategy $i$ , $i \in \{1, 2, 3\}$
$Q^i$	The retailer's order quantity for spot selling period in strategy $i$ , $i \in \{1, 2, 3\}$ . The optimal order quantity is denoted as $Q^{i*}$
$c$	The retailer's ordering cost per unit of product
$\eta$	Out of stock rate in spot selling period
$s$	Salvage price per unit of product unsold at the end of the spot selling period

### 3 Three Types of Refunding Strategies for a Retailer

In this section, the retailer's optimal profits are provided under each of the following strategies: no refunding strategy, partial refunding strategy and full refunding strategy. These three strategies are equivalent to strategy 1, strategy 2 and strategy 3, respectively.

#### 3.1 Strategy 1: No Refunding Strategy

In advance selling period, consumers' valuation for the products is not certain for they haven't seen the real products to be released. Therefore, consumers estimate

the utility of advance purchase based on expected valuation. The expected utility of advance purchase is expressed as

$$U_a^1 = \int_l^h (v - p_a^1) f(v) dv = \mu_v - p_a^1. \quad (1)$$

In spot selling period, consumers have confirmed their valuation of the products and will choose to purchase if the valuation is higher than the sale price, otherwise they will leave the market. The expected utility of waiting until spot selling period is expressed as

$$U_s^1 = E\max[(1 - \eta)(v - p_s), 0] = (1 - \eta) \int_{p_s}^h (v - p_s) f(v) dv. \quad (2)$$

A consumer places a pre-order if  $U_a^1 \geq U_s^1$  and  $U_a^1 \geq 0$ , from which we can derive that

$$p_a^1 \leq \mu_v - (1 - \eta) \int_{p_s}^h (v - p_s) f(v) dv. \quad (3)$$

According to (3),  $p_a^1$  cannot be larger than  $\mu_v - (1 - \eta) \int_{p_s}^h (v - p_s) f(v) dv$  in order to attract type I consumers to buy early. Since the retailer's objective is to maximize total profits, she sets

$$p_a^{1*} = \mu_v - (1 - \eta) \int_{p_s}^h (v - p_s) f(v) dv. \quad (4)$$

We assume that consumers are homogeneous, so the same type of consumers have consistent decision making. Under optimal advance selling price  $p_a^{1*}$ , all type I consumers will choose to advance buy. That's to say  $N_a = N_i$ . The retailer's expected optimal profit of advance selling period is given as

$$\pi_a^{1*} = [\mu_v - (1 - \eta) \int_{p_2}^h (v - p_s) f(v) dv - c] \mu_i. \quad (5)$$

The market demand for the spot selling period is given as  $N_s = \bar{F}(p_s) N_u$  where  $N_u \sim N(\mu_u, \sigma_u)$ , from which we can derive that  $N_s \sim N(\mu_s, \sigma_s)$  where  $\mu_s = \bar{F}(p_s) \mu_u$ ,  $\sigma_s = \bar{F}(p_s) \sigma_u$ . The retailer will update the market demand forecast for the spot

selling period [4]. It is well known [10] that the distribution of  $N_s^1$  given  $N_a^1$  [i.e.  $(N_s^1|N_a^1 = n_a^1)$ ] is normal with mean  $\mu_s^1$  and standard deviation  $\sigma_s^1$ , where

$$\begin{aligned}\mu_s^1 &= \mu_s + \rho(n_a^1 - \mu_a^1) \frac{\sigma_s}{\sigma_a} \\ &= \bar{F}(p_s)\mu_u + \rho(n_a^1 - \mu_i) \frac{\bar{F}(p_s)\sigma_u}{\sigma_i},\end{aligned}\quad (6)$$

$$\sigma_s^1 = \sigma_s \sqrt{1 - [\text{corr}(N_a^1, N_s^1)]^2} = \bar{F}(p_s)\sigma_u \sqrt{1 - \rho^2}.\quad (7)$$

The retailer's optimal profit in sale period is given as

$$\pi_s^{1*} = \max E_{N_s^1|N_a^1=n_a^1} [p_s \min\{N_s^1, Q^1\} + s \max\{(Q^1 - N_s^1), 0\} - cQ^1].\quad (8)$$

This is a traditional newsvendor problem with normally distributed demand. It is well known [4] that the optimal order quantity and optimal expected profit are given as

$$Q^{1*} = \mu_s^1 + k\sigma_s^1 = \bar{F}(p_s)\mu_u + \rho(n_a^1 - \mu_i) \frac{\bar{F}(p_s)\sigma_u}{\sigma_i} + k\bar{F}(p_s)\sigma_u \sqrt{1 - \rho^2},\quad (9)$$

$$\pi_s^{1*} = (p_s - c)\bar{F}(p_s)\mu_u - (p_s - s)\varphi(k)\bar{F}(p_s)\sigma_u \sqrt{1 - \rho^2},\quad (10)$$

where  $k = \Phi^{-1}(\frac{p_s - c}{p_s - s})$  and  $\Phi(\cdot)$ ,  $\varphi(\cdot)$  are the cumulative and density distribution functions of the standard normal distribution, respectively. The out of stock rate in spot selling period is given as  $\eta = \frac{p_s - c}{p_s - s}$ .

### 3.2 Strategy 2: Partial Refunding Strategy

If the refunding price is lower than the lower limit of consumers' valuation ( $p_b \leq l$ ), no one will return coupons which is the same with the no refunding allowed situation. When the refunding price is higher than the lower limit of consumers' valuation ( $p_b > l$ ), consumers will choose to return coupons and get the compensation price  $p_b$  if  $v \in [l, p_b]$  and exchange for real goods with coupons if  $v \in [p_b, h]$ . A consumer's expected utility when advance purchasing is given as

$$\begin{aligned}U_a^2 &= \int_l^{p_b} (p_b - p_a^2)f(v)dv + \int_{p_b}^h (v - p_a^2)f(v)dv \\ &= \int_l^{p_b} p_b f(v)dv + \int_{p_b}^h v f(v)dv - p_a^2.\end{aligned}\quad (11)$$

The expected utility of waiting is given as

$$U_s^2 = E\max[(1 - \eta)(v - p_s), 0] = (1 - \eta) \int_{p_s}^h (v - p_s)f(v)dv. \quad (12)$$

A consumer places a pre-order if  $U_a^2 \geq U_s^2$  and  $U_a^2 \geq 0$ , from which we can derive that

$$p_a^2 \leq \int_l^{p_b} p_b f(v)dv + \int_{p_b}^h v f(v)dv - (1 - \eta) \int_{p_s}^h (v - p_s)f(v)dv. \quad (13)$$

According to (13),  $p_a^2$  cannot be larger than  $\int_l^{p_b} p_b f(v)dv + \int_{p_b}^h v f(v)dv - (1 - \eta) \int_{p_s}^h (v - p_s)f(v)dv$  in order to attract type I consumers to buy early. Since the retailer’s objective is to maximize total profits, she sets

$$p_a^{2*} = \int_l^{p_b} p_b f(v)dv + \int_{p_b}^h v f(v)dv - (1 - \eta) \int_{p_s}^h (v - p_s)f(v)dv. \quad (14)$$

The retailer’s expected profit of advance selling period is expressed as

$$\pi_a^2 = [(p_a^{2*} - c)\bar{F}(p_b) + (p_a^{2*} - p_b)F(p_b)]\mu_i. \quad (15)$$

**Proposition 1** *In partial refunding strategy, the optimal refunding price equals the retailer’s order cost per unit of product, which can be expressed as  $p_b^* = c$  ( $c > l$ ).*

*Proofs of Proposition 1* To obtain the optimal refunding price, we first take the first derivative of  $\pi_a^2$  with respect to

$$p_b: \frac{\partial \pi_a^2}{\partial p_b} = \frac{\partial [p_a^{2*} + (c - p_b)F(p_b) - c]\mu_i}{\partial p_b}, \quad (16)$$

where

$$\frac{\partial p_a^{2*}}{\partial p_b} = \frac{\partial [h + \int_h^{p_b} F(v)dv - (1 - \eta) \int_{p_s}^h (v - p_s)f(v)dv]}{\partial p_b} = F(p_b). \quad (17)$$

Combining (16) and (17), we have

$$\frac{\partial \pi_a^2}{\partial p_b} = (c - p_b)f(p_b)\mu_i. \quad (18)$$

Then, in order to prove concavity, take the second derivative of  $\pi_a^2$  with respect to  $p_b$ :

$$\frac{\partial^2 \pi_a^2}{\partial^2 p_b} = [-f(p_b) + (c - p_b)f'(p_b)]\mu_i = -\frac{\mu_i}{h-l} < 0. \quad (19)$$

Form (19), we can demonstrate that  $\pi_a^2$  is the concave function of  $p_b$ . Solving the  $\frac{\partial \pi_a^2}{\partial p_b} = 0$  gives  $p_b^* = c$  where  $p_b^*$  represents the optimal refunding price.

**Proposition 2** *Partial refund strategy is better than no refunding strategy.*

*Proofs of Proposition 2* By substituting  $p_b$  in (16) with the optimal solution  $p_b^* = c$  got from Proposition 1, we have

$$p_a^{2*} = \int_l^c cf(v)dv + \int_c^h vf(v)dv - (1 - \eta) \int_{p_s}^h (v - p_s)f(v)dv. \quad (20)$$

Then substituting  $p_b$  in (17) with  $p_b^* = c$  gives

$$\pi_a^{2*} = [(p_a^{2*} - c)\bar{F}(c) + (p_a^{2*} - c)F(c)]\mu_a = (p_a^{2*} - c)\mu_i \quad (21)$$

Recalling that the optimal profit of the advance selling period in the no refunding strategy is  $\pi_a^{1*} = (p_a^{1*} - c)\mu_i$ , we can easily see that the only difference between the profits of the no refunding and partial refunding strategies is the optimal advance selling price. Obviously,  $p_a^{2*} - p_a^{1*} = \int_l^c cf(v)dv - \int_l^c vf(v)dv \geq 0$ , from which we can easily derive that  $\pi_a^{2*} \geq \pi_a^{1*}$ . Therefore, partial refund strategy is better than no refund strategy.

The reason for Proposition 3 is that, compared with no refunding strategy, partial refunding strategy can reduce consumers' risk in advance purchase caused by valuation uncertainty. So in partial refunding strategy, consumers can bear higher advance selling price, which directly improves the retailer's profit.

### 3.3 Strategy 3: Full Refunding Strategy

In full refunding strategy, the refunding price is the same with the advance selling price  $p_a^3$ . In this case, we must guarantee that  $p_a^3$  is no more than the spot selling

price  $p_s$  ( $p_a^3 \leq p_s$ ). That's to say premium pre-sale in this case is not allowed. That's because when premium pre-sale occurs in full refund strategy, which means the refunding price is higher than the spot selling price, all consumers who advance purchase will return pre-sale coupons and wait to spot buy with a lower price, which is apparently harmful to the retailer. In the full refunding strategy, all consumers who arrive at the advance selling period will advance purchase. At the end of the advance selling period, consumers whose valuation is lower than the refunding price  $p_a^3$  will choose to return. The expected returning rate is given as  $F(p_a^3)$ .

The retailer's expected profit of the advance selling period is expressed as

$$\pi_a^3 = (p_a^3 - p_a^3)F(p_a^3)\mu_i + (p_a^3 - c)\bar{F}(p_a^3)\mu_i = (p_a^3 - c)\bar{F}(p_a^3)\mu_i \quad (22)$$

**Proposition 3** *In the full refund strategy, the optimal buy back price is the minimum of  $\frac{h+c}{2}$  and  $P_s$  which can be expressed as  $p_a^{3*} = \min\{\frac{h+c}{2}, p_s\}$  ( $p_a^{3*} > \max\{c, l\}$ ).*

*Proofs of Proposition 3* To prove concavity, take the first and second derivative of  $\pi_a^3$  with respect to  $p_a^3$ :

$$\frac{\partial \pi_a^3}{\partial p_a^3} = [1 - F(p_a^3) - (p_a^3 - c)f(p_a^3)]\mu_i = \frac{h + c - 2p_a^3}{h - l}\mu_i, \quad (23)$$

$$\frac{\partial^2 \pi_a^3}{\partial^2 p_a^3} = -\frac{2}{h - l}\mu_i < 0. \quad (24)$$

From (24), we can see that  $\pi_a^3$  is a concave function of  $p_a^3$ . Solving the equation  $\frac{\partial \pi_a^3}{\partial p_a^3} = 0$ , we have  $p_a^3 = \frac{h+c}{2}$ . Recalling above constraint  $p_a^3 \leq p_s$ , we can conclude that the optimal advance selling price in full refunding strategy should satisfy that  $p_a^{3*} = \min\{\frac{h+c}{2}, p_s\}$ . Besides, we know that  $p_a^3$  should be larger than the lower limit of consumers' valuation ( $p_a^3 \leq l$ ), otherwise, no one will choose to return. To guarantee that the retailer has positive profit, we set  $p_a^3 > c$ . Therefore, the constraint for optimal advance selling price should be  $p_a^{3*} > \max\{c, l\}$ .

**Proposition 4** *Partial refunding strategy is better than full refunding strategy.*

*Proofs of Proposition 4* We denoted the difference profits of partial refunding strategy and full refunding strategy as  $\Delta\pi = \pi_a^{2*} - \pi_a^{3*}$ , where  $\pi_a^{2*} = (p_a^{2*} - c)\mu_i$  and  $\pi_a^{3*} = (p_a^{3*} - c)\bar{F}(p_a^{3*})\mu_i$ .

Case 1: If  $p_a^{3*} = \min\{\frac{h+c}{2}, p_s\} = \frac{h+c}{2}$ ,  $\frac{\partial \Delta\pi}{\partial c}$  given  $c = 0$  will be expressed as

$$\frac{\partial \Delta \pi}{\partial c} \Big|_{c=0} = \mu_i \left[ - \int_0^l \frac{1}{h-l} dv - 1 - \frac{1}{(p_s - s)} \int_{p_s}^h (v - p_s) \frac{1}{h-l} dv + \frac{h}{2(h-l)} \right],$$

where  $\frac{1}{(p_s - s)} \int_{p_s}^h (v - p_s) \frac{1}{h-l} dv = \frac{1}{2} (h - p_s)^2$ . After some algebra, the expressions for  $\frac{\partial \Delta \pi}{\partial c}$  at two endpoints of  $c$  can be given as

$$\frac{\partial \Delta \pi}{\partial c} \Big|_{c=0} = \mu_i \left[ -\frac{1}{2} - \frac{l}{2(h-l)} - \frac{(h-p_s)^2}{2} \right] < 0, \quad (25)$$

$$\frac{\partial \Delta \pi}{\partial c} \Big|_{c=p_s} = \mu_i \left[ \frac{(h-l) + (p_s-l)}{2(h-l)} - 1 - \frac{(h-p_s)^2}{2} \right] < 0. \quad (26)$$

Taking the second derivative of  $\Delta \pi$  with respect to  $c$ , we have

$$\frac{\partial^2 \Delta \pi}{\partial c^2} = \mu_i \left[ f(c) - \frac{1}{2} \right] = \mu_i \left[ \frac{1}{h-l} - \frac{1}{2} \right] = \mu_i \left[ \frac{1}{2} \left( \frac{1}{\sqrt{3}\sigma_v} - 1 \right) \right]. \quad (27)$$

Given that  $\frac{\partial^2 \Delta \pi}{\partial c^2}$  is a constant, we can tell  $\frac{\partial \Delta \pi}{\partial c}$  is a monotonic function of  $c$ . Also, from (25) and (26), we know the values of  $\frac{\partial \Delta \pi}{\partial c}$  at the two endpoints of  $c$  are both less than zero, so we can say  $\frac{\partial \Delta \pi}{\partial c} < 0$  stands for any  $c \in [0, p_s]$ . Therefore,  $\Delta \pi$  is a decreasing function of  $c$ . When  $c = p_s$

$$p_a^{2*} = \int_l^c cf(v)dv + \int_c^h vf(v)dv - \int_{p_s}^h (v - p_s)f(v)dv = c,$$

$p_a^{3*} = \min \left\{ \frac{h+c}{2}, p_s \right\} = c, \pi_a^{2*} = \pi_a^{3*} = 0$  so  $\Delta \pi|_{c=p_s} = 0$ . In conclusion,  $\Delta \pi = \pi_a^{2*} - \pi_a^{3*} \geq 0$ , and  $\Delta \pi = 0$  only when  $c = p_s$ .

Case 2: If  $p_a^{3*} = \min \left\{ \frac{h+c}{2}, p_s \right\} = p_s, \frac{\partial \pi_a^{3*}}{\partial c} = (-1)\mu_i \frac{h-p_s}{h-l}$ . Taking the first and second derivatives of  $\Delta \pi$  with respect to  $c$  respectively gives

$$\frac{\partial \Delta \pi}{\partial c} \Big|_{c=p_s} = \mu_i \left[ -\frac{(h-p_s)^2}{2} \right] < 0, \quad (28)$$

$$\frac{\partial^2 \Delta \pi}{\partial c^2} = \mu_i f(c) > 0. \quad (29)$$

From (29), we know that  $\frac{\partial \Delta \pi}{\partial c}$  is an increasing function of  $c$ , then  $\frac{\partial \Delta \pi}{\partial c} < 0$  stands for any  $c \in [0, p_s]$  given (28). Therefore  $\Delta \pi$  is a decreasing function of  $c$ .  $\therefore \Delta \pi|_{c=p_s} = 0, \therefore \Delta \pi = \pi_a^{2*} - \pi_a^{3*} \geq 0$  stands for any  $c \in [0, p_s]$  and  $\Delta \pi = 0$  only when  $c = p_s$ .

Combining Case 1 and Case 2, we have  $\Delta\pi = \pi_a^{2*} - \pi_a^{3*} \geq 0$  which shows that partial refunding strategy is better than full refunding strategy.

The refunding price in full refunding strategy is higher than that in partial refunding strategy. Increased refunding price has negative effects on the retailer's profit from two aspects. One is that the number of consumers who return coupons will increase and the other is that the retailer's marginal profit gained from those who return coupons will decrease.

## 4 Conclusions

We assume that market demand is stochastic and consumers' valuation follows normal distribution. We divide all consumers into two categories according to whether they concern about advance selling information or not. We analyze three refunding strategies of a retailer-no refunding, partial refunding strategy and full refunding strategy-applied in the two-period advance selling problem separately and draw some interesting conclusions. We prove that partial refunding strategy excels no refunding strategy for partial refund policy can reduce the risk of advance purchase so that consumers can bear higher pre-sale price. But the refunding price should be lower than the advance selling price. That's to say the retailer's profit in partial refunding strategy is higher than that in full refunding strategy. The reason is that full refunding policy will lead to higher returning rate and lower margin profit gained from consumers who return, which will definitely damage the retailer's profit. Besides, from the numerical analysis section, we can see that premium pre-sale may occur when consumers' valuation is large enough in both no refunding strategy and partial refunding strategy. But in full refunding strategy, advance selling price must be lower than spot selling price, which has a negative effect on the retailer's profit.

## References

1. Xiao-feng Liu, Pei Huang, "A study on dynamic pricing mechanism of perishable goods and consumer's strategic behavior," Ph.D. dissertation, Business Management, Shanghai Jiao Tong University, Shanghai, China, 2007.
2. Xiao-feng Liu, Pei Huang, "Optimal dynamic pricing and inventory policy under strategic customers," *Journal of Management Science in China*, vol. 12, no. 5, pp. 18-26, 2009.
3. Hui Yang, Jing Zhou, Hua-ming Song, "A dynamic pricing model with strategic and myopic consumers," *Journal of Industrial Engineering/Engineering Management*, vol. 24, no. 4, pp. 133-137, 2010.
4. Christopher S Tang, Kumar Rajaram, Aydin Alptekinoglu, Ji-hong Ou, "The benefit of advance booking discount program: model and analysis," *Management Science*, vol. 50, no. 4, pp. 465-478, 2004

5. Xu-ying Zhao, Kathryn E Stecke, "Pre-orders for new to-be-released products considering consumer loss aversion," *Production and Operations Management*, vol. 19, no. 2, pp. 198-215, 2010.
6. Ashutosh Prasad, Kathryn E Stecke, "Advance selling by a newsvendor retailer," *Production and Operations Management*, vol. 20, no.1, pp. 129-142, 2011.
7. Steven M. Shugan, Jin-hong Xie, "Advance pricing of services and other implications of separating purchase and consumption," *Service Research*, vol. 2, no.3, pp. 227-239, 2000.
8. Jin-yong Xie, Steven M Shugan, "Electric tickets, smart cards, and online prepayment: when and how to advance sell," *Marketing Science*, vol.20, no.3, pp. 219-243, 2001.
9. Cui-hong Li, Fu-qiang Zhang, "Advance demand information, price discrimination, and preorder strategies," *Management & Service Operations Management*, vol. 15, no.1, pp. 57-71, 2013.
10. P. Bickel, K. Doksum. *Mathematical Statistics*. Holden-Day, San Francisco, California, 1977, pp.123-135.

# Research on the Monopolist' Repurchase and Remanufacture Decisions Based on Heterogeneous Consumer Considering Buy-Back Cost

Zhao-fang Mao, Xin-Xin Li and Wei Liu

**Abstract** This paper explores the repurchase and remanufacture decision of the monopolist who produce a durable product that can be used for two periods. It turns out that the remanufacture decision is profitable only when the production cost, consumers' opinion on the remanufactured product subject to some conditions. And the revenue under remanufacture decision is increasing as the cost of new product increases. We also find that, it brings market volume increase effect instead of cannibalization, which makes the remanufacture behavior beneficial to the monopolist.

**Keywords** Cannibalization · Durable product · Remanufacture · Repurchase cost

## 1 Introduction

For a long time, remanufacturing has been popular globally. Because in some way it is beneficial to reducing the natural resource usage and alleviate the environment burden. It is estimated that the total annual sales in the US is \$53 billion in 1997, covering more than 72,000 remanufacturing firms. Also some famous companies, such as BMW, IBM, DEC et al. have already proved that remanufacturing is profitable.

However, it is difficult to make the remanufacture decision for the insufficiency of guidance that the managers can follow. All the managers seem afraid that the remanufactured product may bring the cannibalization effect since those product has the similar or the same function as the new product. "Under which conditions will the remanufacture decision brings more benefit than the cannibalization effect?" More management acknowledges are needed for those managers to make differentiated and effective remanufacturing decisions.

Therefore, the goal of this paper is to provide some useful guidance for the manufacturer to make remanufacturing decisions. We will explore profitable conditions for the repurchase and remanufacture decision by taking the following factors

---

Z. Mao · X.-X. Li (✉) · W. Liu

College of Management and Economics, Tianjin University, Tianjin 300072, China  
e-mail: tjuxinxin@163.com

into consideration: (1) The cost of remanufactured product is lower than the new product. (2) Remanufactured product usually have lower valuation from the consumers. (3) The repurchased price of the used product is a decision variable, which will have an impact on the supply of the remanufactured product in the second period.

There have been extensive researches on the remanufactured product. One of the most important direction is that the probability of the remanufacturing. Ayres and Ferrer [1] evaluates the economics of remanufacturing and points out some problematic issues specific to remanufacturing that have a substantial impact on profitability. Ferrer and Ayres [2] analyzes the macroeconomic impact of remanufacturing and confirm the intuition that it promotes demand for labor and reduces the consumption of raw materials. DeboL and Van Wassenhove [3] makes research on the pricing strategy and combined technology choice of the remanufactured product and new product. Ferguson and Toktay [4] analyzes the remanufacture decision of the monopolist when there is a third party that is remanufacturing. Heese et al. [5] explores the effect of the remanufacture decision on the revenue. Guide and Li [6] points out that the heterogeneity of the consumers makes a great difference to the monopolist's remanufacture decision. Another important stream is about studies on the pricing decisions of the monopolist. Ding et al. [7] studies the pricing decision of the monopolist under different market share from the perspective of the consumer. Liu and Tan [8] studies the remanufacturing strategy for monopolist based on the consumers' type. Other related paper includes [9–13].

However, by summarizing the papers mentioned, it can be concluded that the buy-back cost of used product from the consumer is not taken into the model as a decision variable. In their model, they regard the volume of returned product as a given variable, which has nothing to do with the buy-back price. However, in reality, the volume of the returned products is greatly impacted by the price of the monopolist announced. So in this paper, the writer try to answer whether the remanufacture decision is still profitable when the buy-back cost is regarded as a decision variable. And how the best solution changes when the given variables changes.

## 2 Assumptions and Consumer Utility Analyse

### 2.1 *Summary of Nominations*

The nominations in the paper is summarized as Table 1.

### 2.2 *Model Assumptions*

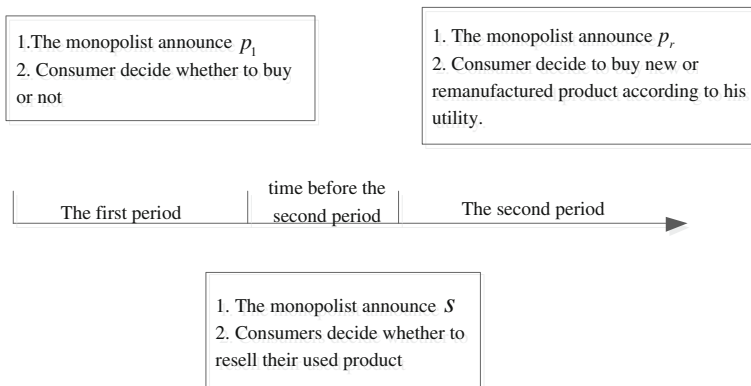
Assuming that the monopolist manufactures a durable product, which can be used for two periods. Consumers who purchases the product in the first period can choose to sell the used product to the monopolist or remain it to the second period.

**Table 1** Nominations in model

Parameters	Definition
$c_n$	Manufacturing cost of new product
$c_r$	Manufacturing cost of remanufactured product
$\delta$	Consumer value discount of used product at the end of first period
$\delta_r$	Consumer value discount of remanufactured product
$p_1$	Sales price of the new product
$p_r$	Sales price of the remanufactured product
$s$	The monopolist's repurchased price of the used product

The salvage of the product at the end of the first period is  $\delta\theta$  and is 0 at the end of the second period.

As for the monopolist, the whole process can be divided into three parts. In the first period, the monopolist announces the price of the product. Before the second period begins, the monopolist decides whether to repurchase the used products from the consumer and remanufacture. If the monopolist does make the remanufacture decision, he will announce the repurchase price  $s$  and the price of the remanufactured product  $p_r$ . If not, the monopolist announces the price for the new product. As for the consumer, they are heterogeneous with respect to their willingness to pay for the new product. For simplicity, we assume it is  $\theta$ , uniformly distributed between 0 and 1. The consumers arrive at the markets in two periods,  $N_1$  and  $N_2$  respectively in the first and second period. The consumers buy one product at most and they decide whether to buy according to the utility model. In the first period, if the consumer's willingness to pay is larger than the price, the consumer will buy the product. At the beginning of the second period, the consumer will sell their used products to the monopolist on the condition that  $s$  is larger. As the second period begins, the consumer will make a decision between the new and remanufactures products after comparing the utility they can obtain. The timeline is as Fig. 1 represents.



**Fig. 1** Timeline of the model