RESEARCH ON RECYCLING OF WASTE LEATHER PRODUCED IN LEATHER MANUFACTURING PROCESS BASED ON SUPPLY CHAIN MANAGEMENT

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RESEARCH ON RECYCLING OF WASTE LEATHER PRODUCED IN LEATHER MANUFACTURING PROCESS BASED ON SUPPLY CHAIN MANAGEMENT

ABSTRACT. Leather industry is a consumer-goods sector closely linked with national economic development. With the slowdown of China's economic growth, the leather industry has entered a new normal of steady development under immense pressure. On the upside, the industry can enrich the material life of consumers. On the downside, leather production unleashes a series of threats to the environment. For example, it is urgent to recycle the gigantic amount of waste leather in such an environmentally conscious era. Therefore, this paper presents a model for the manufacturer who produces lots of waste leather in manufacturing, builds another model for the recycler who recovers the waste leather produced by the manufacturer, and combines the two models into an integrated model for recycling of waste leather produced in leather manufacturing process. Then, the model was applied to a numerical analysis.
KEY WORDS: waste leather, leather manufacturing process, supply chain management

CERCETĂRI PRIVIND RECICLAREA DEŞEURILOR DE PIELE GENERATE ÎN PROCESUL DE FABRICARE A PIELII PE BAZA GESTIONĂRII LANŢULUI DE APROVIZIONARE

REZUMAT. Industria de pielărie este un sector al bunurilor de consum, strâns legat de dezvoltarea economică naţională. Odată cu încetinirea creşterii economice a Chinei, industria de pielărie a intrat într-un nou ritm normal de dezvoltare constantă sub o presiune imensă. Avantajul este că industria poate îmbunătăţi viaţa materială a consumatorilor. Dezavantajul este că producţia de piele declanşează o serie de ameninţări pentru mediul înconjurător. De exemplu, reciclarea cantităţii uriaşe de deşeuri de piele este urgentă într-o perioadă în care omenirea este atât de conştientă de mediul înconjurător. Prin urmare, în această lucrare se prezintă un model pentru producătorul care generează o cantitate mare de deşeuri de piele, un alt model pentru reciclatorul care recuperează deşeurile de piele generate de producător şi se combină cele două modele într-un model integrat pentru reciclarea deşeurilor de piele generate în procesul de fabricare a pieilor. Modelul este apoi supus unei analize numerice.
CUVINTE CHEIE: deşeuri de piele, procesul de fabricare a pielii, gestionarea lanţului de aprovizionare

RECHERCHE SUR LE RECYCLAGE DES DÉCHETS DE CUIR GÉNÉRÉS DANS LE PROCESSUS DE FABRICATION DU CUIR À PARTIR DE LA GESTION DE LA CHAÎNE D'APPROVISIONNEMENT

RÉSUMÉ. L'industrie du cuir est un secteur de biens de consommation, étroitement lié au développement économique national. Avec le ralentissement économique de la Chine, l'industrie du cuir est entrée dans une nouveau rythme normal du développement stable sous une pression énorme. L'avantage est que l'industrie peut améliorer la vie matérielle des consommateurs. L'inconvénient est que la production de cuir déclenche un certain nombre de menaces pour l'environnement. Par exemple, le recyclage de la quantité énorme de déchets de cuir est urgente à un moment où l'humanité est si consciente de l'environnement. Par conséquent, cet article présente un modèle pour le producteur qui génère beaucoup de déchets de cuir, un autre modèle pour le recycleur qui récupère les déchets de cuir générés par le fabricant et combine les deux modèles dans un modèle intégré pour le recyclage des déchets de cuir générés dans le processus de fabrication du cuir. Le modèle est ensuite soumis à une analyse numérique.
MOTS CLÉS: déchets de cuir, processus de fabrication du cuir, gestion de la chaîne d'approvisionnement

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INTRODUCTION

Leather is a popular consumer good with excellent flexibility, permeability and heat resistance. The production of the durable material requires a series of meticulous procedures [1-2].

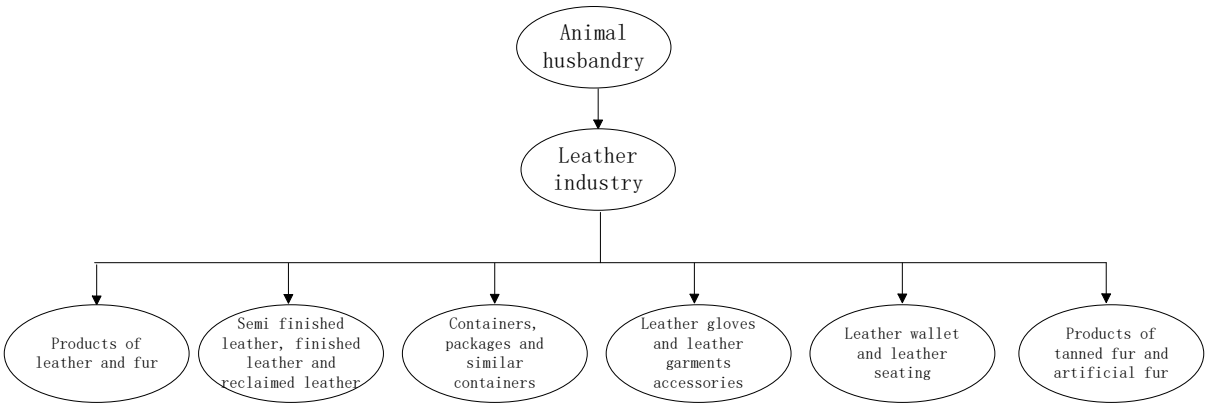

Figure 1. Sketch map of leather industry chain

Since the last century, China has developed into a leading producer of leather products [3-4]. The remarkable achievement is inseparable from the complete industry chain and low labour cost in the country. In recent years, however, the development of China's leather industry has slowed down to single-digit growth, and even negative growth. To reverse the trend and revive its leather industry, China should deepen its structural reform, encourage individual innovation, and promote waste leather recycling [5].

The existing studies mainly discuss the recycling of waste leather in the consumer market [6-7], but rarely tackle the production of waste leather in the leather manufacturing process. The leather waste both possesses pollution potential and economic value. In light of the above, this paper probes into the recycling of waste leather produced in leather manufacturing process. First, an integrated model was established in which the manufacturer produces waste leather and the recycler recovers the produced waste leather; then, the model was improved based on supply chain management, aiming to maximize the overall profit.

Development of Leather Industry in China

The leather industry is a pillar of light industry in China. Recent years have seen the rapid development of China's leather industry, turning the country into a major producer and a promising market of leather [8]. Through structural optimization, many specialized producing areas and consumer markets of leather have formed in China, laying the basis for further development of the industry [9].

Currently, the leather industry contributes a large share (>7%) to China's GDP and directly bears on the national economy. In return, the industry growth is heavily influenced by the overall economic situation. With RMB appreciation and slowdown of global economy, the growth of domestic demand becomes the most important driving force to the leather industry [10].

According to the National Bureau of Statistics of China, the main business income and total profit of leather, fur, feather and related products and footwear manufacturing industry from 2013 to 2016 are shown below.

The growth rates of main business income and total profit are presented in the figure below.

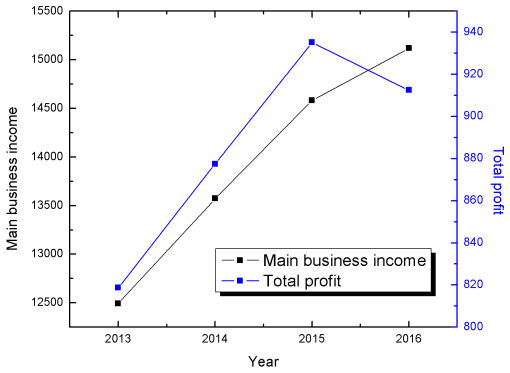

Figure 2. Main business income and total profit

As can be seen from the figure, the main business income and total profit of leather, fur, feather and related products and footwear manufacturing industry in China has been growing at a decreasing rate. In 2016, the total profit growth even entered negative territory.

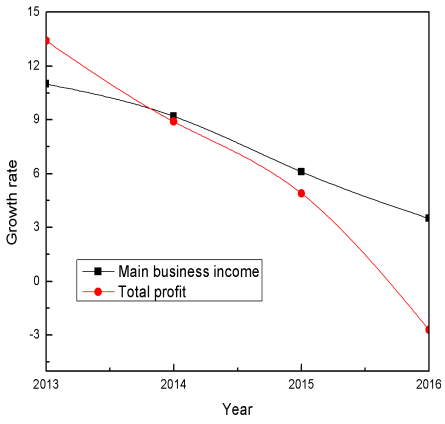

Figure 3. The main business income and its total profit growth rate

Specifically, the growth rate of the main business income dropped from 11% in 2013 to 3.5% in 2016, while that of the total profit declined from 13.4% in 2013 to -2.7% in 2016.

Table 1: Development of leather industry in China

Years	Main business income	Growth rate	Total profit	Growth rate
2013	12493.1	11	818.7	13.4
2014	13572.9	9.2	877.5	8.9
2015	14580.8	6.1	935.2	4.9
2016	15118.8	3.5	912.5	-2.7

The continued decline is attributable to the lack of innovation, poor brand power, surging cost, and weak demand. In particular, the growth rate of the total profit turned negative in June 2016, the first ever negative growth since 1998. Facing the seemingly irreversible downward trend and the pressing need for industry upgrade, China must deepen the supply-side reform, optimize the supply structure, expand domestic demand, encourage technological innovation, promote product upgrading, implement production adjustment, accelerate market transformation, and pursue sustained healthy development.

Recycling of Waste Leather Produced in Manufacturing Process

It is inevitable that a great deal of waste leather will be produced in the manufacturing process of leather products. The waste leather is mainly disposed via landfilling, incineration and chemical treatment. Nevertheless, none of these methods are sufficiently effective. For instance, the incineration of waste leather may produce toxic gases like nitrogen oxides and sulphur oxides. The improper disposal of waste leather poses a great threat to the environment and our health [11].

The leather products are often processed by chrome tanning. The chrome tanned products are hard to decay, well ventilated and resistant to moisture. The question is chromium, as a toxic heavy metal, can easily access human cells, causing damage to the liver, kidneys and other internal organs. The accumulation of chromium in the body may induce cancer and genetic mutations. If not properly treated, the waste leather will also have a negative impact on the environment [12-13].

Figure 3. Piles of waste leather

If the waste leather produced in the leather manufacturing process is properly recycled, there will be immeasurable economic and social benefits. For one thing, proper recycling can fully unlock the recovery value of waste leather, save a wealth of energy, and indirectly promote economic growth. For the other thing, the proper recycling helps to implement the national strategy of sustainable development. As Chinese President Xi Jinping puts it, “Lucid waters and lush mountains are invaluable assets” [14-15].

In general, the following are the meanings to recycle the waste leather produced in leather manufacturing process:

1. Environmental protection: The recycling can eliminate the polluting polymer materials in waste leather, creating a good living environment to mankind. Whereas the production of leather, be it natural or artificial, must consume environmental resources, the recycling of waste leather is bound to alleviate the waste of resources.

2. Economic interests: With the depletion of social and renewable resources, manufacturers are facing increasing pressure on resource acquisition. Many are forced to control resource consumption and make full use of the existing materials. If the massive amount of waste leather is recycled, there will be much less resource consumption and huge economic benefits.

3. Social benefits: Known for its environmental-friendliness, the recycling of the waste leather will definitely promote the brand image, the key to the existence and development of manufacturers. To protect the good image, manufacturers will devote much of their energies to promoting social benefits.

METHOD - MODEL ANALYSIS

This section investigates the recycling of waste leather produced in leather manufacturing process. Both the manufacturer and recycler of leather belong to a supply chain, which covers the entire process from product design, raw material procurement, product fabrication, packaging, to delivery [16-17].

Manufacturer Model

In the daily production of leather products, the manufacturer produces a large amount of waste leather. The production of the waste leather is both a waste of resources and threat to the environment. It is assumed that the manufacturer produces lots of waste leather, and that the waste leather is recycled by a professional third party recycler at the government-guided price.

The relationship between the output and the price can be expressed as:

$$P_x = \alpha - \beta Q_x (\alpha, \beta > 0) \quad (1)$$

where Px is the price of the waste leather sold to the downstream company; Qx is the output of the manufacturer; α is the minimum price when the downstream company does not have the demand; β is the price sensitivity of the output, i.e. the price reduction at each unit of increase in the output. It can be seen from formula (1) that the output is linearly correlated with the price.

Then, the unit production cost, the unit inventory cost and the unit labour cost are denoted as C_m, η_1 and μ_1, respectively. Suppose that the recycler must compensate the manufacturer in the process of recycling.

In the course of recycling, the amount of recycling Q_c depends on the rate of return P_w in the dynamic recycling market. The relationship between the two parameters can be expressed by a resource supply function:

$$Q_c = w + \varphi P_w (w, \varphi > 0) \quad (2)$$

where w is the recycling amount at zero rate of return; ϕ is the sensitivity of the recycling amount to the rate of return, i.e. the recycling amount increment at each unit of increase in the rate of return.

The manufacturer's profit is:

$$\pi = (P_x - C_m - \eta_1 - \mu_1)Q_x + Q_c P_w \quad (3)$$

Under the Nash equilibrium

$$\frac{\partial \pi}{\partial Q_x} = \alpha - 2\beta Q_x - C_m - \eta_1 - \mu_1 \quad (4)$$

if

$$\frac{\partial \pi}{\partial Q_x} = 0 \quad (5)$$

we can get

$$Q_x^* = \frac{\alpha - C_m - \eta_1 - \mu_1}{2\beta} \quad (6)$$

then

$$P_x^* = \frac{\alpha + C_m + \eta_1 + \mu_1}{2} \quad (7)$$

The leather manufacturer can achieve the optimal output at the government-guided price. Therefore, formulas 6 and 7 reflect the best response of the manufacturer to that price.

Recycler Model

In the recycling business, the recycler recovers waste leather produced by the manufacturer. Let C_n be the net cost of recycling a unit of waste leather, and s be the government subsidies on each unit of waste leather recovered by the recycler. Besides, we denote the unit inventory cost, the unit transport cost and the unit labour cost as η_2, ν and $\mu 2$, respectively. However, some of the waste leather recovered by the recycler cannot be converted into useful materials. Hence, the conversion rate is denoted as x, the unit scrap cost is denoted as ρ, and the scrap cost is denoted as $x\rho Q_c$.

The profit of the recycler is expressed as:

$$\pi = (s - P_w - C_n - \eta_2 - \nu - \mu_2)Q_c - \chi\rho Q_c \quad (8)$$

Thus, we have

$$Q_c = w + \varphi P_w \quad (9)$$

Under the Nash equilibrium

$$\frac{\partial \pi}{\partial P_w} = s\varphi - w - 2\varphi P_w - C_n\varphi - \eta_2\varphi - \nu\varphi - \mu_2\varphi - \chi\rho\varphi \quad (10)$$

we have

$$\frac{\partial \pi}{\partial P_x} = 0 \quad (11)$$

then

$$P_x^* = \frac{s\varphi - w - C_n\varphi - \eta_2\varphi - \nu\varphi - \mu_2\varphi - \chi\rho\varphi}{2\varphi} \quad (12)$$

and

$$Q_c^* = \frac{w + s\varphi - C_n\varphi - \eta_2\varphi - \nu\varphi - \mu_2\varphi - \chi\rho\varphi}{2} \quad (13)$$

Since the optimal rate of return appears when the recycler receives government subsidies, it is possible to find the optimal rate of return and the optimal recycling amount in the case of financial subsidies.

Integrated Model

Inspired by the idea of modern supply chain management, the authors pursue the maximum benefit of the whole system rather than that of a single node. Suppose the government subsidies is sQc and the tax is tQx, where t is the unit tax price. According to formula 2, not all waste leather is recovered by the recycler.

The unrecovered waste leather is:

$$(1 - \tau)Q_x \quad (14)$$

Meanwhile, if Ce is the indirect pollution cost of the unrecovered waste leather, and Cj is the indirect pollution cost incurred in the production and sale of new products, then the pollution cost of the entire supply chain is:

$$C_e(\tau Q_x - Q_c) + C_j Q_x \quad (15)$$

whereas the manufacturer's profit is:

$$\pi = (P_x - C_m - \eta)Q_x + Q_c P_w \quad (16)$$

and the recycler's profit is:

$$\pi = (s - P_w - C_n)Q_c \tag{17}$$

then, the profit of the entire supply chain is:

$$\pi_{ALL} = [(P_x - C_m - \eta_1 - \mu_1)Q_x + Q_c P_w] + [(s - P_w - C_n - \eta_2 - \nu - \mu_2)Q_c - \chi\rho Q_c] - sQ_c - [C_e(\tau Q_x - Q_c) + C_j Q_x] \tag{18}$$

EXPERIMENTAL

With Ce=22 and Cj=1.5, numerical experiments were performed on the recycling of waste leather produced in leather manufacturing process. The sensitivity of the parameters was analysed numerically, including the relationship between the sensitivity of the recycling amount to the rate of return ϕ and the profit, and the relationship between the unit inventory cost η1 and profit. The experimental results are shown in Figures 5 and 6.

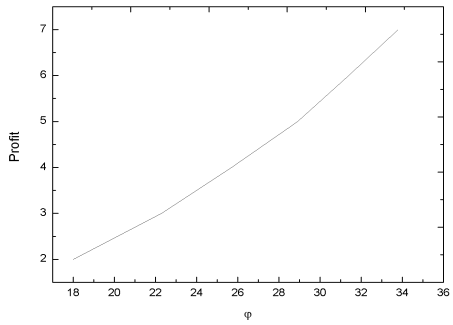

Figure 5. The relationship between the sensitivity of the recycling amount to the rate of return and the profit

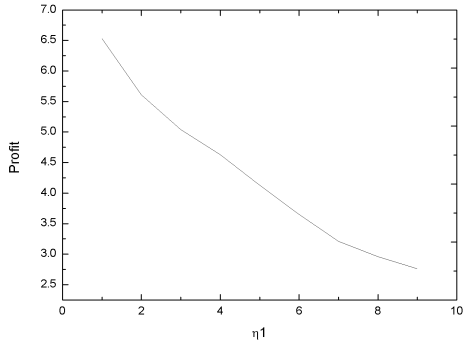

Figure 6. Relationship between the unit inventory cost and the profit

RESULTS AND DISCUSSION

As shown in Figure 5, the profit increases with the increase in φ, indicating that the recycler can recover more waste leather and the supply chain receives greater profit when the manufacturer takes concrete actions on waste leather recycling. According to Figure 6, the profit is negatively correlated with η_1. This means the unit inventory cost has a negative impact on the profit of the entire supply chain.

CONCLUSION

As an important part of China's economy, the leather industry is an engine of the rapid economic development. In recent years, however, the growth of the leather industry in China is under increasing strain. The reasons include but are not limited to the slowdown of demand, the lack of resources, environmental constraint, and soaring cost. In order to save resources, enliven the enterprises and revive the leather industry, this paper studies the recycling of the waste leather produced in leather manufacturing process, and establishes the relevant models.

Hereinto, the authors reviewed the research background, introduced China's leather industry, discussed the recycling of leather waste, established an integrated model, in which the recycler recovers the waste leather produced in leather manufacturing process, and conducted several numerical experiments. The results show that the recycling can increase the profit of the entire supply chain.

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