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Game theory Framework for Corrugated Packaging in Polyester Sector

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ABSTRACT: In this paper a conceptual framework is used for guiding the management by providing a visual representation of theoretical constructs (and variables) of closed-loop reusable packaging prospective in polyester sector. This model condenses the more relevant issues arising when reuse is carried out in industrial practice by using game theory method for the detailed analysis of the decision theory problem, and for identifying the possible outcomes from it. The model intends to be a guideline for practitioners dealing with such kind of challenges and constitutes a first step towards the mitigation of the problematic issues involved in reuse or recycles. In the further developments of this research, we propose solutions to some of the issues identified here.

Keywords: Game theory, packaging, Reuse, Recycle, Life-cycle Management

I. INTRODUCTION

It is a myth that packaging cost cannot be reduced. To analyse modern packaging systems, and to evaluate them according to their conversion cost, expense, expected results, and its environmental influence and effects of exterior are only approximate even by using the most complicated decision theory models. The conversion cost of modeled polyester products is not upto the benchmark set by the 'best-in-class' figures achieved in other polyester groups. Moreover, catering to the latest technology also demands much more improvements in quality, high speed runnability & cost-wise benefits to avail continued preference of the customer for our products. For this, the businesses want to reduce the packing cost, thus the conversation cost and downstream performance needs to improve. In a lot of cases these endeavours can face difficulties at operative decision levels already in the early phase of the analyses, not reaching the upper management's level. The game theory in this study wishes to examine the system's inclination between the elements (supplier-customer) in order to promote the common profit of the system (its result), meanwhile not allowing to hurt the parties' own usefulness.

In the model, the decision alternatives presuppose decisions between systems of returnable packing accessories and non-returnable (disposeable) boxes logistic-packaging systems is considered. The decision makers are the polyester producing company (supplier) and the texturiser that gets the products (customer). The idea is not a new one. The decision problem on reuseable and disposable products can be analysed according to similar principles [2, 5]. The likelihood of competing firms' voluntary adoption of cost-saving environmental technologies ware also challenged using game theory [4].

Inspite of having tangible benefits of the returnable packaging accessories, the application of disposable packagings is of ever growing importance in the industrial practice [7]. The possible reason for this is that the packaging accessory damages are extremely considerable. Furthermore, the customers can handle the one-way accessories much more easily after a single usage, since these are not necessary to store, direct or prepare and additional costly actions are just rarely required.

The model presented in this paper offers extremely detailed calculations considering the financial and environmental benefits of product takeback a 'first glimpse' into the potential for successful introduction of this project to their customers. At the same time, the decision between the packaging systems, that is, which one-way or returnable accessories to select in the actual logistic system, does not definitely yield the results calculated.

II. LIFE CYCLE MANAGEMENT AND GAME THEORY

Game theory is suitable for analysis of problems that have three basic characteristics [5]
(i) A relatively small number of agents interacting strategically in a system characterized by hidden information and motives not completely revealed by prices [6];
(ii) An awareness among agents that their decisions affect each others' costs and benefits [1];
(iii) The potential for coexistence of multiple strategies that yield 'best' benefits, dependent on other agents' actions [3].
The aim of this study is to explore the use of game theory to offer a suitable framework for the introduction of an optimal strategy in the planning process of a life cycle for corrugated packaging. In this study, we use the case to analyze, how the decision between returnable and non-returnable packing accessories can achieve the best financial and environmental performance, what conditions the participants (supplier, customer) must meet by keeping their strategy [11]. It needs consideration which conditions can lead to a balance, where reactions of one party are a combination of strategies to the other party's actions. We are looking for a balance state, where it is not worth deviating from the combination of strategies [8] [3].
We assume that the packaging applicable several times implicates higher expenses to the customers, nevertheless, they can decide to send it back to the supplier, so that this sum can be refundable as a deposit.
Brainstorming to identify causes of returnable packaging accessories were found to be (i) Poor collection and coordination (ii) Accumulation at customer/ Irregularity in supply of packing accessory by customers (iii) Delay lifting by supplier (iv) Accessories lying for longer period at customers end (v) Mixing of other supplier's material. Thus, the game depends mostly on the customer's willingness to send back and pay more for expensive packaging, or the supplier persuades customers to return and reuse the accessories.
Beverage packaging legislation in several US states in the 1980s [14] imposed refundable deposits on disposable packaging to address consumer behavior at end-of-life, and ultimately impacted the bottling industry's costs and created a new industry of deposit container reclaimers. Broader packaging recycle requirements in Germany and other European countries in the early 1990s [10], and restrictions on virgin packaging production and disposal in the Netherlands [9], were enacted to drive manufacturers to more environmental friendly packaging decisions, yet also established new links among consumers, retailers, and recyclers. This range of available and potential lifecycle management policy approaches clearly create conditions by which the packaging lifecycle players' actions are interdependent and awareness of each other's roles in the lifecycle is increased.
The private sector decision making contexts addressed by life cycle analysis (LCA) must also eventually take the economic consequences of alternative products or product designs into account, thus LCA requires some simplification in order to be able to identify the elements, and their interactions at the single levels of the life cycle [12]. We have to analyse a packaging life cycle (Fig. 1) to assess the quality of the outcomes in the single phases.

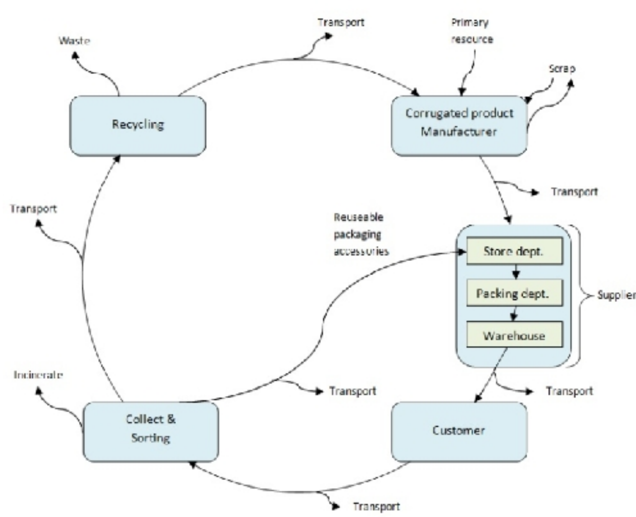

Fig. 1. Product lifecycle diagram for corrugated packaging.

That is, how the packaging is wandering and what underlying information we should look for, that we can assign values to. Our aim is to identify the points of the cycle where some parties are of strategic importance while others are not. In the present case, for example, the governmental interventions as bounding force are essential in terms of the sustainable development, but they are not affected by the strategy of the examined two characters. The governmental acts from the parties' aspect are considered as on external force for making decisions and forming the strategy [4, 15]. Orders and regulations affect all events of the game. We have to mention here that the characters like product compilers and recyclers as well, who have an important role, but they do not play a strategic role and do not have a direct effect on the price of the packing implements (or on the expense of the full life cycle).

The supplier's and a customer's strategies and their results depend on the transactions which can be interpreted in the above chain [13]. Various doubts have been raised regarding re-use of used packaging; whether it is to be disposed off or send back to customer or rather a non-returnable packaging is to be brought from the supplier. The decision on these always depend on various factors, the main being the expenditure factor.

The industrial sphere of the economy requires participant's best efficiency which controls the parties concern, it is his personal results which determine best balance solution as everybody selects according to his own best strategy.

III. RECYCLING OF BULK UNIT PACKAGING MATERIAL

The outcome of the theory and the final expenditure depends on functions variables like expenditure of returnable accessories, the ratio, expenditure, and the probability of return. Then, only the comparison of these, results in the framing of a state-of-the-art strategy.

Subsequently, these options of the supplier and the customer can be termed where the supplier selects the type of packing accessories first and later on the customer decides whether it is to be sent back of disposed of after its usage.

A closely related method was used in [2] to define the notions involved in this article. Initially, as an example, supplier wants to minimize the expenses of carton packing as well as bulk unit packing as C_{1i} and C_{2i} without taking the effect of the other placement expenses e_e into consideration.

In this manner, it has been found that the expense of carton and bulk unit packing equals that of purchase as P_{e1} and P_{e2}:

$$C_{e1} + C_{e2} = P_{e1} + P_{e2} + e_e \qquad \ldots(1)$$

We consider purchase value P_{e1} and P_{e2} as lesser than the expenditure of a carton P_{t1} and bulk unit packaging P_{t2}. The usage of this carton and bulk unit packaging also cost some additional expenditure like that of return freight and storage charges, which is indicated below with t_C. The introduction of a new policy on the usage of returnable device would be highly encouraged if the value of t_C is less than the cost of a new carton and/or bulk unit packaging.

The number of times carton and returnable packaging accessories used determines its theoretical expenditure i.e. P_{T1} and P_{T2} divided by the number of its usages u [5] and taking into t_C as a derivable expenditure from every return.

$$C_{T1} + C_{T2} = \frac{P_{T1} + P_{T2}}{u} + (u-1)\,t_c + e_T \qquad \ldots(2)$$

A packaging extra price may be lower or higher or even equal to that of purchasing a new returnable packaging. But the packaging extra deposit D remains with the supplier where a situation such arise that the accessories become unsuitable for re-usage or it does not return at all.

The market process may be termed as a strategic game, which can be clarified by a tree denoting a cost function value pertaining to each single branch at each of its endpoints (Fig. 2), wherein each participant can decide only once, and the supplier can decide at the first instance.

In the second instance, the customer is being already aware of the earlier decision of the supplier and, the later being aware of the customers reaction to usage of a returnable or a non-returnable packaging system, selects the best type. The customer may at his discretion choose from m^N strategies where N denotes the number of the decision junctions, and m for the possible number of decisions in the single junctions [5]. The customer has to play the game in such a manner that his expenditure is the least, and also the expenditure resulting from the disposal (d_1, d_2) together with that of the accessories D is less. This can be denoted simply by formula, $d_2 = d_1 / u$, wherein, a single usage expenditure should be much below that of using a non-returnable accessories [2].

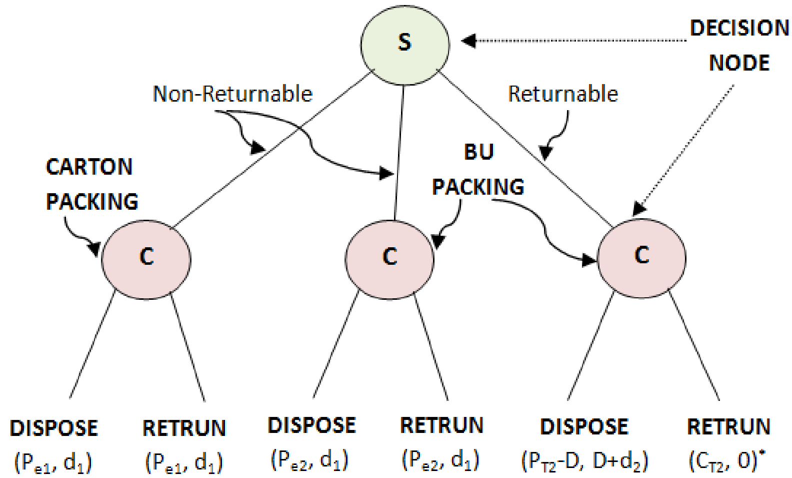

Fig. 2. Game tree on the return and disposal.

* We can find Nash balance, where D, d_1, $(P_{T1}+P_{T2})$ and $(P_{e1}+P_{e2})>0$ and $(P_{T1}+P_{T2}) \geq (P_{e1}+P_{e1}) \geq (C_{T1}+C_{T2})$

The above tree facilitates the customer to send back the returnable accessories. The same conditions are however not assumed by the supplier. Hence, the customer has to pay the deposit independently of sending back the accessories or not. As per the decision trees there are six possible results of the game which are at the endpoints of the game. The supplier should assume that the customer tends to use a dominant strategy. Induction gives the game a background solution, for example considering the decision points.

The solution is a Nash balance, ultimately results in the supplier selecting the returnable accessories and the customer choose on returning, in such a manner were none of the player can reduce their expenditure by using a new strategy.

IV. THE EFFECT OF VALUE CHANGING OF THE ACCESSORIES

The decision tree indicated in Figure 3 is the simplest example as it can lead into various and complicated ways of behavior by parties involved leading to a large number of possible outcomes.

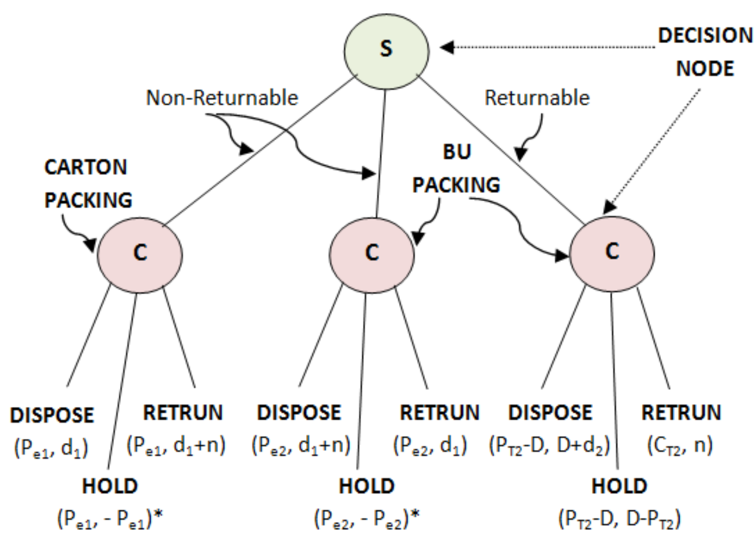

Fig. 3. Game tree on changing-value accessories.

*We can find Nash balance, where $(P_{T1}+P_{T2})>D$ and

$$(P_{e1}+P_{e2})>(P_{T1}+P_{T2})-D$$
$$n>(P_{T1}+P_{T2})-D$$
$$n>D+d$$

In situations where the price of the packaging accessories are more than the inbuilt or deposit price, the customer can consider keeping the packaging accessories, as it provides them with the most satisfying results. On the other hand, if they intend to keep the returnable packing accessories, it proves dearer for them, as there is a likelihood of the same at each place of P_i. For e.g. by sending back the accessories it can be construed that there is some loss for the customer as it indicates lack of income of $+n$ to him. Such is the situation because by keeping the accessories, the surplus value could have remained with the customer. The cost involved by the customer would be $D-P_{T1}-P_{T2}$ if he keeps the accessories, and $D+d_2$ if it is otherwise. Certainly, the customer would never send back if (n) is higher, than $D-P_{T1}-P_{T2}$, and higher than $D+d_2$.

In the aforestated situation, the supplier may at his discretion use the non-returnable accessories, which does not take into account, the replacement cost of the returnable accessories that is not being sent back by the customer. The supplier will work hard for increasing the cost of the returnable accessories compared to its hypothetical price *i.e.* D > P_{T1} + P_{T2}, which may encourage the customer to return it, or the supplier can compensate for his own cost by buying the accessories again. But it is also for essential to see that the prices should not be raised too high, as in that situation no common policy will be possible with the customer.

V. THE RETURNING RATIO OF ACCESSORIES

The supplier may at his discretion, decide the packing price for resale and its deposit, which has to be worked out as per the customers will to send back the accessories by the given price. Thus, it indicates the customer's sensitivity, where the high cost can prevent him from misusing the accessories, and it cannot be sold. The aforesaid condition will be the primary deciding factor of the return ratio of the returnable packaging accessories, which can enlarge from 0 to 100%. Thus, the effect of the game depends on the price of the accessories and the ratio of return. The total transportation costs of supplier C_e for non-returnable packaging Q, including all additional replacement cost E_e and also variable costs P_e and taking into account the entire amount accessories to be used, may be decided in the following manner [2]

$C_e = (P_{e1} + P_{e1})\, Q + E_e$ …(3)

Using the returnable packaging will reduce as per the ratio of R accessories returned. This is the turning ratio of accessories illustrated above. For example if 100% of the accessories are getting back over the long-term, the supplier is inclined to have maximum profit, whereas his purchase outlay will be minimum. In the condition where lower the returns rate, the growing cost can be represented by the no. of average returns with the application of returnable packaging the entire transportation expenditure of C_{T1} and C_{T2} can be analysed as follows:

$$C_{T1}+C_{T2}=(P_{T1}+P_{T2})\,Q\,(2-R)+t_e(u-1)\,R\,Q+e_t\,Q\,R' \quad \text{…(4)}$$

But we have to consider in this situation that after the last transport of the accessories will stay at customer's store, wherein there is no return and we can find all accessories at the customer's depot which indicate additional cost like the posting expense of that quantity. Hence, we cannot use the R, but add R' into the equation. Clearly $R \leq R' \leq 1$, as we possibly cannot find all the accessories at consumer store, but we can find many customer sent them back.

Further, if the accessories reach the supplier, we have to work out with + u as the last transport cost, and there is no R'. In that situation, we have to use R, and the supplier's total transport cost would be worked out as

$$C_{T1}+C_{T2}=(P_{T1}+P_{T2})\,Q\,(2-R)+t_e\,u\,Q\,R+e_t\,Q\,R \quad \text{…(5)}$$

VI. CHANGING THE DEPOSIT VALUE AND THE RETURNING RATIO

The additional costs like deposit price will lessen willingness for usage, yet, the usage increases the number of returns. Owing to high deposit prices the customer is inclined to send back the accessories, for not losing the deposit. Hence, the supplier has to decide such a deposit price. Further, such a burden is imposed on the customer by the supplier himself.

On the basis of the above, the ratio of sending back returnable accessories can be assessed as returning may lessen the customer's cost or possible losses. If the supplier fails to predict the customer's final decision, then he is regarded as an independent variable in equation.

These costs can be judged by comparing supplier's total expenses with the income from the deposit prices. This enables us to define the packing costs and actual total operating arising from the deposit and the usage of the system. By keeping deposit price with us, we can work out on income I_T. The cost involved here are that of new purchasing and return transportation etc. The supplier has to find the least total cost which we can also call modified cost MC_T as shown in equation (7).

$$I_T = \frac{(u-1)\,Q\,(1-R)\,D}{u} + \frac{Q\,(1-R')\,D}{u} \quad \ldots(6)$$

In this analysis, the first part on the right side stands for all deposits coming from upto the last return, and the second part indicates the deposit from the last return if the customer is not standing back the accessories. Thus we can work out supplier modified cost as follows

$$\left.\begin{aligned} MC_T &= (C_{T1} + C_{T2}) - I_T \\ MC_T &= \min \end{aligned}\right\} \quad \ldots(7)$$

When minimizing MC_T we have to search that variable which has effect on the transportation process on the returning accessories. This factor is the deposit D and the R will depend on the ratio of deposit and the packaging price $(P_{T1} + P_{T2})$.

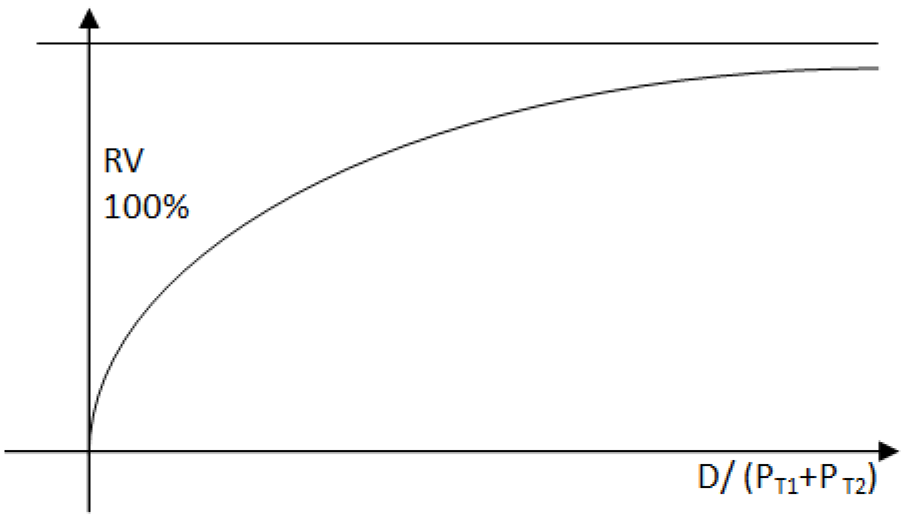

Fig. 4. The curve of return ratio in $D/(P_{T1}+ P_{T2})$.

We consider that R never reaches the 100%. It is likely because the experience illustrates that there is no case when all of the accessories are totally coming back. If we select an appropriate function, the following formula for the R can be depicted as

$$R = [D \setminus (P_{T1} + P_{T2})]^{\varepsilon} \quad \ldots(8)$$

where (ε) is an elasticity modulus.

$$0 < \varepsilon < 1$$

We presume that:

$(P_{T1} + P_{T2}) =$ constant

$$[D \setminus (P_{T1} + P_{T2})]^{\varepsilon} = D^{\varepsilon} \setminus (P_{T1} + P_{T2})^{\varepsilon} \le 1$$

Hence we are searching for the minimum value of the equations (7). Here, we explore the condition further if the accessories are not sent back with the last transport. The equations (4), (6) and (8) can be substituted in (7):

$$\begin{aligned} MC_T = {} & P_t\,Q + P_t\;Q[1 - D^{\varepsilon}/(P_{T1} + P_{T2})^{\varepsilon}] + t_e\,(u-1)\;Q\;[D^{\varepsilon}/(P_{T1} + P_{T2})^{\varepsilon}] + e_T\,Q \\ & - \frac{(u-1)\,Q\;[1 - D^{\varepsilon}/(P_{T1} + P_{T2})^{\varepsilon}]\,D}{u} - \frac{Q\,(1-R')\,D}{u} \end{aligned} \quad (9)$$

$$\left.\begin{aligned}
&\frac{dMC_T}{dD}=0\\
&MC_T{}'=-\frac{\varepsilon(P_{T1}+P_{T2})\,Q\,D^{\varepsilon-1}}{(P_{T1}+P_{T2})^{\varepsilon}}+\frac{\varepsilon\,t_c\,(u-1)\,Q\,D^{\varepsilon-1}}{(P_{T1}+P_{T2})^{\varepsilon}}-\frac{(u-1)Q}{u}+\frac{(\varepsilon+1)(u-1)QD^{\varepsilon}}{(P_{T1}+P_{T2})^{\varepsilon}\,u}=0\\
&MC_T{}'=-\frac{D^{\varepsilon-1}(P_{T1}+P_{T2})\,Q}{(P_{T1}+P_{T2})^{\varepsilon}}+\frac{D^{\varepsilon-1}\varepsilon\;t_c(u-1)\,Q}{(P_{T1}+P_{T2})^{\varepsilon}}+\frac{D^{\varepsilon}(\varepsilon+1)(u-1)Q}{u\,(P_{T1}+P_{T2})^{\varepsilon}}-\frac{(u-1)\,Q}{u}=0
\end{aligned}\right\}\quad(10)$$

VII. CONCLUSION

In this article, we attempted to find several ways in the industrial and customer market sphere where the presented model is applicable. Obviously its balance cannot be achieved easily if not encouraged to return packaging accessories, especially if throwing away the packaging accessories reduces its expenses. The situation becomes even more complex by the latest reinforcement of regulated based on environmental protection. This in turn may result in formation of an important factor of development of mutual strategies in the future. This condition keeps on moving and changing constantly as new characters emerge in the chain, as, for example, companies entering the market for increasing returnable packing or recycling and usage of left over. These new characters mean an additional decision problem by creation of the mutual balance strategy [2].

Our future research should be to develop how D_c has to be found out. We have to look for a way which would be the most suitable to attain a balance between the applicant in transportation supply chain and the state or society. A test calculation series can give a true image about flexibility of the model presentation.

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