

The Application of the Game Theory onto the Analysis of the Decision Theory of Logistic Packagings

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Abstract For the characters of a logistic system the common decision making is not an instinctive action yet. Choosing a common strategy does not provide the theoretically best result for the individual or for the organization. But this strategy can create a balance state, which is worthy for nobody to differ from in a concrete case. This study is looking for the solution conditions, which are necessary to the development of a strategy that can lead to a balance state in the final result in the course of planning of a logistic transport-packaging. In the study to create the model development we use a game theory method for the detailed analysis of the decision theory problem, and for identifying the possible outcomes of it.

Keywords: logistics, packaging, game theory

1. Introduction

To analyse modern logistic systems, and to evaluate them according to their expense, expected results, and its environmental influence and effects of exterior are only approximate even by using the most complicated decision theory models. 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 and one-way (disposeable) transport-packaging systems. The decision makers are the producer company (supplier) and the company that gets the products (customer). The idea is not a new new one. The decision problem on reuseable and disposable bottles can be analysed according to similar principles [1].

Moreover, it is interesting to see that both the European Union and Hungary do not really motivate the usage of returnable devices. There is no applied regulation in the EU

on the preference of the returnable packaging [2]. The council directive (2004/12/EC) on the packagings and the packaging waste regulation does not prefer the usage of returnable packaging to the recycling of material substance [3].

It is necessary to note that there are essential differences between the application of consumer reuse, and collecting packagings of use of recycling in company-production logistics. According to the effective environment protection regulations there is no sufficient incentive system available for the returnable packaging, but this system is only introduced by an individual (corporate) decision for personal savings. Reuseable pallets, metal and plastic containers were generally used instead of disposable barrels, trays and pallets. This trend seems to prevail reversed.

In spite of having tangible benefits of the returnable packaging device, the application of disposable packagings is of ever growing importance in the industrial practice [4]. The possible reason for this is that the packaging damages are extremely considerable. Furthermore, the customers can handle the one-way devices 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 extremely detailed calculations preceding the single corporate decisions yield savings merely for the individuals. At the same time the decision between the packaging systems, that is, which one-way or returnable devices to select in the actual logistic system, does not definitely yield the results calculated.

2. The game theory as a possible solution

The aim of the application of the game theory is to offer a suitable framework for the introduction of an optimal strategy in the planning process of a life cycle for packaging. It defines, how the decision between returnable and one-way device can achieve the best financial and environmental performance, what conditions the participants (supplier, customer) must meet regarding by keeping their strategy [5]. 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 [6] [7].

We assume that the packaging applicable several times means 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. 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 device.

3. Life cycle analysis and the outcomes of the game

A general life cycle analysis requires some simplification in order to be able to identify the elements, and their interactions at the single levels of the life cycle [8]. We have to analyse a packaging life cycle (figure 1) to assess the quality of the outcomes in the single phases. 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 external force on making decisions and forming the strategy [9] [10]. Orders and regulations affect all events of the game. We have to mention here 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 [11]. Should the supplier collect and reuse the used packaging or rather buy a new one-way packaging from his supplier? Does the customer have to throw away the used packaging or rather send it back to his supplier? Naturally, the decisions always depend on the possible expense factors primarily, which can theoretically provide plenty of possible ways for balance.

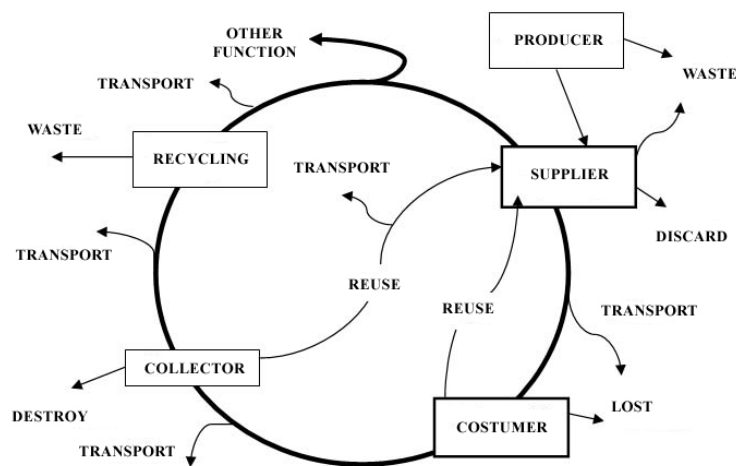


Figure 1. The life cycle diagram of the packaging (source: Authors)

It is important to note that sometimes it is the participants' personal results that determine the best balance solution. In this case everybody selects his own best strategy. This is a very frequent example in the industrial sphere, since mutual relation is regulated according to some kind of contract, in which the own best efficiency controls the parties concerned.

4. The analysis of the return of packaging

The outcome of the game depends on a lot of decision functions variables, which are strongly related to and depend on the return of the packaging. The determination of the final expenses are primarily effected by the expense of returnable devices, the ratio of return, the expense of the return and the probability of return. Then, only the comparison of these results in the forming of the definitive strategy.

As a consequence the supplier's and the customer's options can be modeled as a serial game where the supplier selects the type of the packaging device first, then the customer decides if he sends it back or throws it away after the usage (should it be a one-way or a returnable device).

To illustrate this with a plain example, it means that the supplier wants to minimize the packaging expense of a single package item (C). In this study we do not examine the effect of the other placement expenses (E_e). This way the expense of a one-way packaging item equals the expense of purchase (P_e):

$$C_e = P_e + (e_e), \quad (1)$$

We assume that P_e is of lower value than the expense of a returnable packaging (P_i) (which is stronger, and more durable). By using returnable packaging there are some additional expenses such as the return freight and storage expenses, below indicated with (t_c). If (t_c) is lower than the expense of a new one-way packaging item, the introduction of a new strategy on the usage of returnable packaging is highly motivated.

The theoretical expense of an returnable packaging device can be estimated by the number of the reusing, that is P_T divided by the number of the usages (u). In addition, here we must take (t_c) into account as a derivable expense from every return, just like the umpteenth expense (i) of return.

$$C_T = \frac{P_T}{u} + (u-1) \cdot t_c + (e_T) \quad (2)$$

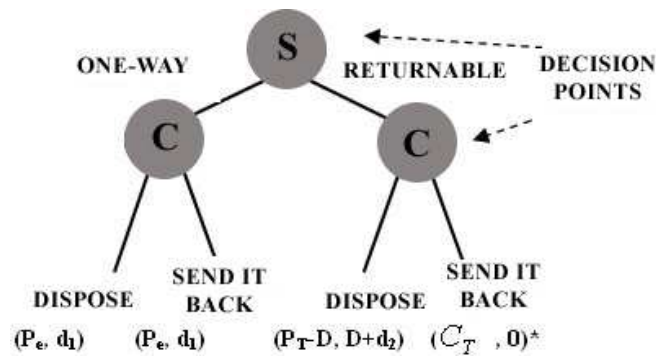
Obviously a packaging extra price (deposit price, D) can be lower or higher than and equal to that of purchasing a new returnable packaging again. However, if the device returns in a condition unsuitable for re-usage or does not return at all, the packaging extra deposit remains with the supplier.

This market process can be defined as a strategic game, which can be interpreted with a tree depicting a cost function value belonging to each single branch in all of its endpoints (Figure 2). According to this, each participant can decide only once, one after the other and the supplier can decide at first.

In the second turn the customer is already aware of the the first turn (supplier's) decision, but is not dependent of on it. Because of this the supplier makes the best decision, selects the best type of packaging system, knowing how the customer reacts to the usage of a returnable or a one-way packaging system.

The customer can choose from m^N strategies where N stands for the number of the decision junctions, and m for the possible number of decisions in the single junctions.

Obviously, the customer has to play the game where his expenses are the least, and his expense originating from the disposal (d_1 , d_2) together with the deposit of the device (D) is less. The disposal expense of the returnable device can be given simply with a formula, $d_2 = d_1/u$, where, reasonably, a single usage expense should be far below that of using a one-way device.



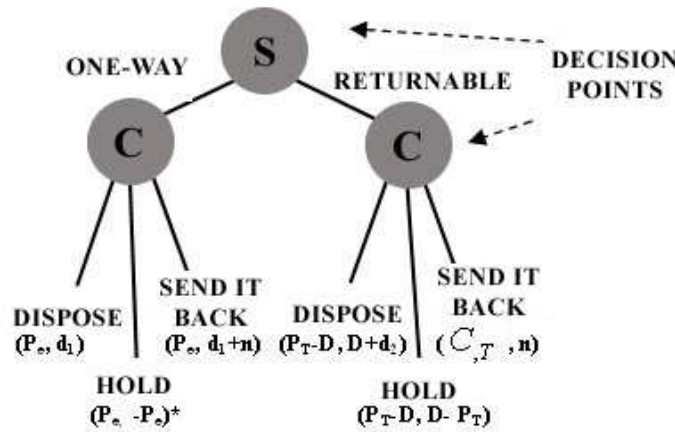
* We can find Nash balance, where D , d_1 , P_T and $P_e > 0$ and $P_T \geq P_e \geq C_T$

Figure 2. Game tree on the return and disposal (source: Authors)

The above tree allows the customer to send back the returnable device, however, it is not deemed by the supplier. So, the customer has to pay the deposit independently of sending back the device or not. Partially the game has four possible outcomes according to the decision tree. The outcomes (results) of the single strategic steps are in the endpoints of the extensive form game. At the same time we can realise that the customers tend to use a dominant strategy. It is indifferent for them whether they send back the device or not, because payments for both cases will be of the same size. That is why the supplier must suppose that the customer plays the dominant strategy. Induction gives this plain game a backward solution, namely, regarding the decision points in subordination, selecting the cheapest expense, heading bottom up. The solution is a Nash balance, in which the supplier selects the returnable device and the customer decides on returning, where none of the players can reduce their expenses by using a new strategy.

5. The effect of value changing of the device

As mentioned before the decision tree applied is an exceptionally simplistic example, since there can occur various and complicated ways of behavior by the parties involved, resulting in a higher number of possible outcomes and effects (Figure 3).



* We can find Nash balance, where $P_T > D$ and

$$P_e > P_T - D$$

$$n > P_T - D$$

$$n > D + d$$

Figure 3. Game tree on changing-value device (source: Authors)

Take the above example when the price of the packaging device is higher than the inbuilt (deposit) price. In this case it is worth for the customer to consider keeping the packaging device, as this gives the most convenient result for him. However, if he keeps the returnable packaging device, this costs (D) for him, which is possible at each place of P_i . Namely, sending back the device can be interpreted that the customer has some loss (of income) of (n). If he sends it back it means lack of income of $+n$ to him because by keeping the device the surplus value could have stayed with him. The expense for the customer is $D - P_T$ if he keeps the device, and $D + d_2$ if he throws it away. Obviously, the customer will never send back while (n) is higher, than $D - P_T$, and higher than $D + d_2$.

In the above case the supplier can decide on using the one-way packaging, which excludes the expense of replacement of the returnable device that would not be sent back by the customer. The supplier will strive for making the price of the returnable device higher than its theoretical price ($D > P_T$), which can motivate the customer to return it, or the supplier can cover his own expense of buying the device again. But it is necessary to notice that too high prices will move us away from the balance, because if the supplier preferred this measurement (which is nevertheless the best outcome for him), no common strategy or interest will be possible with the customer.

6. The returning ratio of device

Determining the packaging price for resale and its deposit is up to the supplier, which has to be calculated according to the willingness of the customer to send back the device by the given price. That is, it shows the sensitivity of the customer, where the high price can prevent the customer from misusing the device, and the device could not be sold. The supplier has to consider several options simultaneously. The above mentioned

consumer sensitivity will be the primary determining factor of the return ratio of the returnable packaging device, which can expand from 0 to 100%. So the outcome of the game depends on the price of the device and the ratio of return (the high return ratio results in the preference of returnable devices, while the low ratio return supports the usage of one-way devices). The total logistic costs of supplier (SC_e) for one-way packaging, containing all the further placement cost (E_e) and variable expenses as well (such as the purchase expense, P_e), and taking the whole amount of devices to be used into account, can be determined as follows:

$$C_e(Q) = P_e \cdot Q + E_e \quad (3)$$

In case of application of returnable packaging the supplier's total cost will decrease according to the ratio of (RV) devices returned. For the present case the usage-ratio is proportional with return ratio, that is $RH \sim RV$. This is the turning ratio of a device detailed above. That is, for example, if 100% of the devices are getting back, the supplier tends to have long-term profit, while his purchase expense will be minimal. In case the returns are under 100%, the growing expenses can be depicted with the number of the average returns. By usage returnable packaging the full logistic expense of supplier (C_T) can be calculated as follows:

$$\sum C_T = P_T(Q) \cdot Q + P_T(Q) \cdot Q \cdot (1 - RV) + t_e(u - 1) \cdot RV \cdot Q + e_i \cdot (Q) \cdot Q \cdot RV' \quad (4)$$

But we have to consider in this case that after the last transport the devices will stay at the depot of customer. In this case there is no return, and theoretically we can find all devices at the customer, which means further expenses like the placement expenses of that quantity. So, we cannot use the RV , but we add RV' into the equation. Obviously $RV \leq RV' \leq 1$, because we probably cannot find all of the devices at his depot, but we can find more as if the consumer would had send them back.

Moreover if the devices get back to the supplier than we have to calculate with $(+u)$ as the last transport cost, and there is no RV' . We have to use RV , and the full logistic expense of supplier can be calculated as follows.

$$\sum C_T = P_T(Q) \cdot Q + P_T(Q) \cdot Q \cdot (1 - RV) + t_e \cdot u \cdot RV \cdot Q + RV \cdot e_i \cdot (Q) \cdot Q \quad (5)$$

7. Changing the deposit value and the returning ratio

The additional expenses like deposit price will reduce willingness for usage, nevertheless, the usage increases the number of returns. Having high deposit prices the customer tends to send back the device, not to lose the deposit. So, the supplier has to determine a deposit price, which reduces the real selling price of the product and also his expense of used packaging, moreover, he imposes this burden on the customer.

Based on this, the ratio of sending back returnable packaging can be estimated as returning can reduce the customer's expenses or probable losses. If the supplier is not able to foresee the customer's final decision (his returning ratio at a given deposit level), then the customer is considered as an independent variable in the equation.

These expenses can be examined by comparing the supplier's total costs with the income from the deposit prices. In this way we can simply define the packaging expenses and actual total expense of operating the packaging system. This can be determined by concerning the difference emerging from the incoming sums (deposits) and the usage of the system (total costs of purchase and operation). We can calculate on income (I_T) from the deposit price staying with us. The expenses are the cost of new purchasing and the return-transportation, etc. The supplier has to find the lowest full cost. We call it modified cost (MC_T) (7).

$$I_T = \frac{(u-1) \cdot Q \cdot (1-RV) \cdot D}{u} + \frac{Q \cdot D \cdot (1-RV')}{u} \quad (6)$$

In this calculation the first part of right side is the all deposits coming from till the last return, and the second is the deposits from the last return, if the customer does not send the devices back.

So, we can calculate the modified cost of supplier as follows:

$$\begin{aligned} MC_T &= \sum C_T - I_T \\ MC_T &\rightarrow \min \end{aligned} \quad (7)$$

When minimizing MC_T we have to find that variable which has effect on the logistic process (on the returning). This parameter is the deposit (D). The RV will depend on the ratio of deposit and the packaging price (P_T).

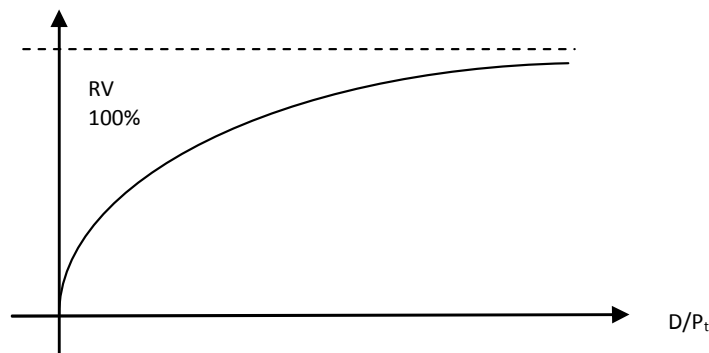


Figure 4. The curve of return ratio in D/P_T

We assume that RV never reaches the 100%. It is possible because the experience shows that there is no case when all of the devices are totally coming back. If we choose a suitable function then we can give the following formula for the RV .

$$RV = \left(\frac{D}{P_T} \right)^\epsilon \quad (8)$$

where (ε) is an elasticity modulus.

We assume that:

$$0 < \varepsilon < 1$$

$$P_T = \text{const.}$$

$$\left(\frac{D}{P_T}\right)^\varepsilon = \frac{D^\varepsilon}{P_T^\varepsilon} \leq 1$$

So we are looking for the minimum value of the equations (7). Here we examine further the case when the devices are not sent back with the last transport. The equations (4), (6) and (8) can be substituted in (7):

$$MC_T = P_i \cdot Q + P_i \cdot Q \cdot \left(1 - \frac{D^\varepsilon}{P_T^\varepsilon}\right) + t_e \cdot (u-1) \cdot Q \cdot \frac{D^\varepsilon}{P_T^\varepsilon} + e_i \cdot Q - \frac{(u-1) \cdot Q \cdot \left(1 - \frac{D^\varepsilon}{P_T^\varepsilon}\right) \cdot D}{u} - \frac{Q \cdot D \cdot (1 - RV')}{u} \quad (9)$$

$$\frac{dMC_T}{dD} = 0$$

$$MC_T' = -\left(\varepsilon \cdot \frac{P_T}{P_T^\varepsilon} \cdot Q \cdot D^{\varepsilon-1}\right) + \frac{\varepsilon \cdot t_e \cdot (u-1) \cdot Q \cdot D^{\varepsilon-1}}{P_T^\varepsilon} - \frac{(u-1) \cdot Q}{u} + (\varepsilon+1) \frac{(u-1) \cdot Q}{P_T^\varepsilon \cdot u} \cdot D^\varepsilon = 0$$

$$MC_T' = D^{\varepsilon-1} \left(\frac{\varepsilon \cdot (t_e \cdot (u-1) \cdot Q - P_T Q)}{P_T^\varepsilon}\right) + D^\varepsilon (\varepsilon+1) \cdot \frac{(u-1) \cdot Q}{u \cdot P_T^\varepsilon} - \frac{(u-1) \cdot Q}{u} = 0 \quad (10)$$

Using the presented analytical way we could find a D_{opt} point. But we must not forget that in this case the level (value) of deposit is the supplier's choice.

Here we have to mention another case, when the level of deposit is determined by legislation or a governmental regulation (D_c : compulsory minimum deposit). In this case there is a minimum deposit level. So we could define three possible way as follows.

- i. if the $D_c < D_{opt}$, than supplier choose the D_{opt} .
- ii. if $D_c = D_{opt}$, than the supplier get automatically into his minimum modified cost.
- iii. if $D_c > D_{opt}$, than supplier cannot get to the optimum point.

In the first case (i), the equation mentioned above (10) is suitable to solve this minimum problem. In the second case (ii), the supplier has not to do anything. Concluding from (iii), the supplier will choose another way to find his minimum cost. This leads far away, for instance the supplier will break the rules or switch over to use a one-way packaging system.

8. Conclusion

We can find numerous process series in the industrial practice and consumer market where the presented model is applicable (e.g. metal waste and battery industry). It is true that the balance is difficult to achieve if the customers or the suppliers are not motivated enough to return devices. Mainly, if throwing away the device makes lower expenses in some individual aspects. This process is even more complicated by the latest reinforcement of regulations on environmental protection, which can be one of the most important factors of development of mutual strategies in the future.

This situation is in constant moving and changing because of new characters appearing in the chain, as, for example, companies for developing returnable packaging or recycling and handling for waste enter the market. These new characters mean an additional decision problem by creation of the mutual balance strategy.

Our next aim should be to improve how the D_c has to be determined. We have to find a way which is the best to achieve a balance between the participants in logistic chain and the state or society. A test calculation series can provide a realistic picture about the adaptability of the presented model.

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