Returnable containers: an example of reverse logistics

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Introduction

The environment is no longer a not-in-my-back yard, or NIMBY, problem. Society, government and industry are increasingly confronted with the results of our throw-away society. Dumping grounds are already congested. Large areas of land are no longer fit for habitation as a result of the enormous pollution of the ground. Water has to be filtered before consumption, fish in large economically important rivers is not consumable, and smog in the urban areas, caused by traffic and industry, creates severe health problems for elderly people and children. Added to this, the world of today has to deal with the destruction of the rain forest, acid rain, ozone depletion, global warming, hazardous waste and the depletion of non-renewable natural resources.

Studies have proved that most, if not all, of the problems mentioned above are directly related to industrial and agricultural emissions[1]. Fortunately, the world has come to a situation in which society feels that a change in attitude towards the environment is an absolute necessity.

One of the solutions that industry has come up with is the collection, recycling and reuse of products and materials. This development is not only stimulated by a growing responsibility towards the environment and regulations from the government; more and more companies see valuable commercial opportunities in collecting, recycling, and reusing products and materials.

In this context, reverse logistics is an important issue. Reverse logistics refers to the logistic management skills and activities involved in reducing, managing and disposing of hazardous or non-hazardous waste from packaging and products. It includes reverse distribution, which causes goods and information to flow in the opposite direction from normal logistic activities. A comprehensive review of concepts, organizations, and activities in the area of reverse logistics has been published by the Council of Logistics Management[2].

In this article we consider a practical application of reverse logistics: the reuse of secondary packaging material. In the next section we present a number of methods that may be used to create a return logistic system for returnable containers. This is followed by a case study involving the design of such a return logistic system in The Netherlands and outlines a quantitative model that can be used to support the related planning process. The final section contains a number of conclusions.

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Returnable containers

Reverse logistics may be applied to several stages of the logistic chain. Both the materials management part and the physical distribution part of the logistic chain are potential areas of application. In this article we study the application of reverse logistics in the area of physical distribution: the reuse of secondary packaging material.

Secondary packaging is packaging material used for packaging products during transport from a sender to a recipient, either in retail or in industry[3]. Traditionally, cardboard boxes are used as secondary packaging material. Since cardboard boxes can be used only once, they are defined as one-way packaging material.

In contrast, returnable packaging is a type of secondary packaging that can be used more than once in the same form. Although returnable packaging may be of different types, such as returnable containers, pallets, or slipsheets, we will use the term returnable containers, irrespective of the actual type of the returnable packaging.

Motivation

An initial question one should ask when thinking about introducing this equipment is whether it offers real environmental benefits. This means that the processes of producing and disposing of returnable containers, together with the additional return logistic activities, should not be more harmful to the environment than the use of one-way packaging material. This question has been investigated by the Frauenhofer Institut, which specializes in studies of material flows and packaging logistics. In 1993 this Institute published the results of an ecological comparison of one-way packaging and returnable containers[4]. On the basis of four criteria, it concluded that returnable containers are less of a burden to the environment than one-way packaging material, provided each container is used a certain minimum number of times during its lifetime. This minimum number is dependent on the type of container. The criteria taken into consideration in this study were energy consumption, emission to the atmosphere, water consumption and pollution, and solid waste.

The use of systems of returnable containers is being prompted by a growing concern for the environment and by regulations from the government. For example, in 1991 the Dutch government and industry signed the Packaging Covenant forcing industry to think of new ways to deal with packaging material[5]. In broad terms, the Packaging Covenant requires that in the year 2000 the total amount of new packaging material in The Netherlands should be reduced by 10 per cent (relative to 1986), and that the total amount of packaging waste to be dumped in the ecosystem should be reduced to zero.

Similarly, the German Packaging Order requires manufacturers to take responsibility for their packaging waste. In order to comply with this, German manufacturers and retailers created the non-profit organization Duales System

Deutschland (DSD) to collect packaging material for recycling. Participating companies pay a per-item fee based on the amount of packaging used and receive in return a green dot (*grüne Punkt*) symbol that appears on their one-way packaging material. The DSD commits itself to collecting and recycling this material. The system is still suffering from a number of growing pains, which, of course, works to the relative advantage of systems employing returnable containers.

But, apart from increasing responsibility towards the environment and legislation, several companies have discovered that the reuse of packaging material can also be commercially rewarding. An example of this is the company John Deere & Co., which has invested $20 million in a returnable container programme with its suppliers of assembly parts. This programme is economically feasible, and a positive cash payoff is expected by the time a comprehensive recycling law comes into effect[6]. Another example is provided by Herman Miller Inc., which claims to have saved over $600,000 in two years using returnable packaging material for steel shelves. Returnable containers are also applied successfully by IBM and Ford[7] and by General Motors and Toyota[8].

Return logistics systems

A consequence of the use of returnable containers is that, after a container has been used for carrying products from a sender to a recipient, the container has to be transported from the recipient to the next sender, who need not be the same as the first one. In addition to transporting the containers, the return logistic system also involves the cleaning and maintenance of containers, as well as their storage and administration.

In the remaining part of this section we examine the possible design of the system. Lützebauer[9] distinguishes three types of systems: switch pool systems, systems with return logistics, and systems without return logistics[10].

Switch pool systems. In a switch pool system every participant has his own allotment of containers, for which he is responsible. Thus cleaning, control, maintenance and storage of the containers are the responsibility of each pool-participant. Pool-participants may be the senders and recipients, or the senders, carriers, and recipients of the goods.

In the first variant only the senders and the recipients have an allotment of containers. A transfer of containers takes place when the goods are delivered to the recipient. The carrier either transports containers filled with goods from the sender to the recipient, or empty containers from the recipient to the sender. In this variant the sender has to guarantee that, in the long run, the number of returned containers equals the number of containers sent out.

In the second variant the carrier also has an allotment of containers. A switch takes place at every exchange of containers. On picking up a containerized load from the sender, the carrier gives the sender a corresponding number of empty containers. Hence, in this case the sender bears no responsibility for administering the return flow of containers.

Systems with return logistics. In such a system the containers are owned by a central agency. This agency is also responsible for the return of the containers after they have been emptied by the recipient. The main prerequisite for such a system is that the recipient bundles the empty containers, and stores them until a sufficient number has accumulated for cost-effective collection. Lützebauer[9] differentiates the following systems:

(1) *Transfer system*. The essence of this system is that the sender always uses the same containers. The transfer system is only concerned with the return of containers from the recipient to the sender. The sender is responsible for the tracking and tracing of containers, their administration, cleaning, maintenance and storage. The sender has also to take care that the number of containers is adequate.

(2) *Depot system*. In this system the containers that are not in use are stored at container depots. From a container depot the sender is provided with the number of containers he needs. After having been transported to the recipient, the empty containers are collected and returned to a container depot. Here the containers are cleaned and maintained, if necessary. Within this system, Lützebauer again distinguishes two variants:

- *Book system*. The essence of this system is a detailed control of the flow of containers by the central agency. The sender has an account with the agency. When a number of containers are delivered to the sender, the quantity involved is debited in the sender's account. When the sender sends the containers to a recipient, the quantity involved is credited in the sender's account, and debited in the recipient's. Therefore the sender has to submit to the agency all the necessary data for each shipment, including the name and address of the recipient, and the number of containers involved. This allows the agency to monitor the movements of the containers.
- *Deposit system*. In this system the sender pays the agency a deposit for every container he uses. The deposit equals at least the value of the containers. The sender debits his recipient for this deposit, who does the same with his recipient, and so on. The moment the containers reach their final destination in the logistic chain, they are collected by the agency. At this point, the agency refunds the deposit to the party from which the containers were collected. The deposit finances loss and theft of the containers. So, a tracking and tracing system to control the flow of containers is unnecessary in this case. Finally the deposit also stimulates the quick return of the containers, so the rate of circulation with be high.

Systems without return logistics. In this system the containers are also owned by a central agency. The user of this system, the sender, rents the containers from the agency. As soon as the sender no longer needs the containers, they are returned to the agency. The sender is responsible for all activities involving the containers, such as return logistics, cleaning, control, maintenance and storage. By using this system, the sender can decrease his fixed costs by renting varying numbers of containers as required.

Summary

The different variants described in this section are summarized in Table I. Which system a sender chooses depends on the type, the weight and the structure of the goods, as well as on the quantities involved, and whether the sender has or does not have a return logistics system. Other variables that may influence the decision on which system, if any, to use are the scope of the system (international, or only national or regional), the co-operation of recipients, the willingness to invest (from both the standpoint of the sender and recipient), the available storage space, the control possibilities, the size of the organization and the acceptance in the market[11].

A case study

In this section we describe a case study carried out for a large logistics service organization in The Netherlands. The case study is related to the design of a return logistics system for returnable containers.

The return logistics operation took the form of a depot system with a deposit structure, as described in the previous section. The returnable containers are collapsible when they are empty. By collapsing the containers, a 75 per cent reduction in their volume is obtained. The containers are available in six different sizes, all based on the dimensions of the Euro-pallet.

Five parties are involved in the system, namely: the central agency; a logistics service organization; the senders of the containers; the recipients; and the carriers that actually transport the full containers from senders to recipients.

System	Essence	Partners	Responsibility	Possibilities
Switch pool	Every partner has an allotment	Sender, recipient	Every partner is responsible for his own allotment	Direct switch
		Sender, carrier and recipient		Exchange-per-exchange switch
With return logistics	Return logistics by agency	Agency, sender, carrier, recipient	Agency	Transfer system
				Depot system with booking
				Depot system with deposit
Without return logistics	Rental of the containers	Agency, sender	Sender, also for the return logistics	Rental of the containers

Table I.
Return logistics systems

The agency is the owner of the containers, and is responsible for all non-logistic operations such as the acquisition of containers, the marketing of the service and its administration.

Most of the logistic operations are subcontracted to the logistics service organization. This organization owns a number of depots, which are used for storing the returnable containers when they are not in use. Furthermore, the organization is responsible for the distribution of the containers to the senders and for the collection of the containers from the recipients. Cleaning and maintenance of the containers are also handled by the organization. The actual shipments of full containers from senders to recipients may be carried out by another carrier.

Information and goods flows

In this section we describe the system in more detail. Suppose a sender s intends to send goods to a specific recipient r, and wants to use returnable containers for packaging these goods. The information and goods flows related to this shipment are represented in Figure 1.

First, the sender notifies Agency A, of the fact that he wants to use returnable containers (1). Then the agency notifies the logistics service organization (2). Next, the logistics service organization distributes the desired number of containers from the nearest container depot d_1 to the sender (3). After having packed the goods to be sent in the containers, the sender sends the goods to the recipient. This shipment may be handled by the logistics service organization,

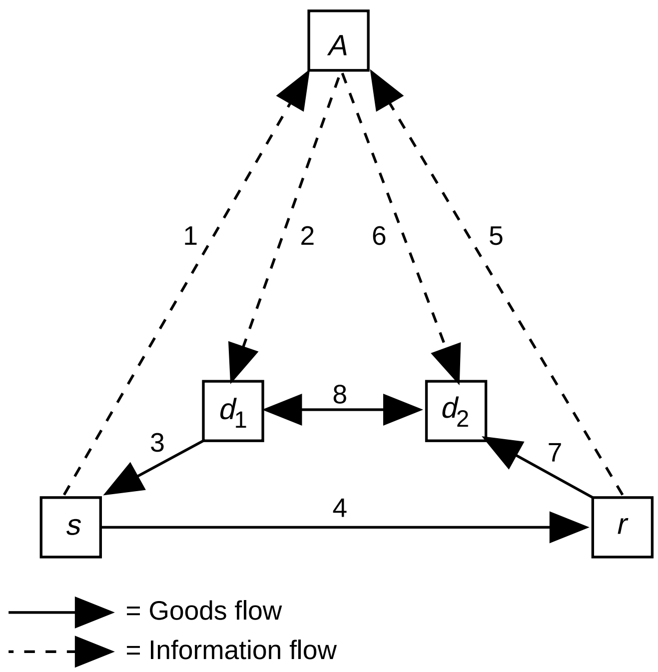

Figure 1.
The flow of information and goods

but it may also be carried out by another carrier (4). After the recipient has received a certain number of containers, he notifies the agency of this fact (5). Next, the logistics service organization is notified by the agency (6). Then the logistics service organization collects the containers from the recipient and takes them to the nearest container depot d_2 (7). Before the containers can be used again, they are cleaned, and, if necessary, also maintained in this container depot.

The logistics service organization is responsible for having the appropriate numbers of containers in stock in the container depots. Hence, if at some point of time the numbers of containers in the depots get unbalanced, then a number of containers may have to be relocated from depots with an excess of containers to the depots with a deficit (8). This transfer of containers is accomplished within the internal distribution system of the logistics service organization.

As mentioned previously, the system is a deposit system. That is, the sender pays a deposit for the containers received. Next, the sender charges his recipient a deposit for the number of containers sent out. Finally, the recipient regains the deposit from the agency after the containers have been collected by the logistics service organization. This closes the "deposit loop". Besides the deposit, the sender also pays the agency a fixed service fee per container for the services provided. Furthermore, the agency pays the logistics service organization a fixed distribution fee for the distribution of the containers, and a fixed collection fee for their collection.

Design of the return logistics system

In this section we present a quantitative model that can be used in the planning of a return logistics system. Examples of important questions within this planning process, both for the agency and the logistics service organization, are the following:

- How many containers should be available in the system?
- How many container depots should there be and where should they be located?
- How should the distribution, collection, and relocation of the containers be organized?
- What are appropriate service, distribution and collection fees?

For the agency the most important questions relate to the number of containers and the appropriate service, distribution, and collection fees. For the logistics service organization the main questions concern the number of container depots and their locations and the appropriate distribution and collection fees.

The logistics service organization owns a large number of distribution centres. Within this organization it was decided that container depots could only be established at these centres. Hence the question of the appropriate number of container depots and their locations can be reformulated as follows:

which of the distribution centres of the logistics service organization should be designated as a container depot?

Several quantitative models have been developed to address these questions. We first developed a simple simulation model. Later on we also developed an optimization model. The latter model is described in the remainder of this section. The main purpose of this model is to establish the required number of containers, the appropriate number of container depots and their locations, and the appropriate service, distribution, and collection fees.

Both the agency and the logistics service organization are interested only in the additional shipments generated by the return logistics system. That is, they want to consider only the distribution, the collection, and the relocation of empty containers. The shipments of full containers from senders to recipients, which may be handled by another carrier, are not directly taken into account.

Data. One necessary input into the model is data representing the expected number of yearly container movements from the possible senders (S) to the possible recipients (r). Here a sender, s, may be an individual sender, but it is also possible that some kind of aggregation has been applied. For example, a sender, s, in the model may represent all real senders with the same postal code. This also applies to the recipients.

Since the system of returnable containers is rather new on the Dutch market, representative historical demand figures are not yet available. However, the logistics service organization knows the yearly amounts of goods that have been transported by this organization in The Netherlands. The logistics service organization also knows in more detail the figures, G_{sr}, representing the yearly amounts of goods (in tons) transported from sender, s, to recipient, r. Now, as a first estimate of the demand for the returnable container service, it is assumed that B_{sr}, representing the numbers of yearly container movements from sender, s, to recipient, r, is proportional to G_{sr}. Hence we have the relation:

$$B_{sr} = p \times G_{sr} \text{ for all senders } s \text{ and recipients } r,$$

where p denotes the proportionality coefficient. Note that two assumptions have to be made here. The first is that the figures G_{sr}, i.e. the shipments carried out by the logistics service organization, are representative of all shipments carried in The Netherlands. Since this organization is by far the largest logistics service organization in The Netherlands, this seems quite realistic. The second assumption is that the shipments that have been carried in The Netherlands are representative of the shipments that will be carried in returnable containers. As soon as more data are available, these assumptions will be verified in more detail.

The figures G_{sr} and B_{sr} are independent of time. This implies that the system is modelled at a single time-period. Furthermore, only one type of container is distinguished. The way in which the demand figures have been compiled makes it impossible to distinguish between the different types of containers. For this type of container, the following cost figures are assumed to be available:

FC_d = fixed costs of having a container depot in distribution centre d.

DC_{ds} = costs of distributing one container from distribution centre d to sender s.

CC_{rd} = costs of collecting one container from recipient r and transporting it to distribution centre d.

RC_{dc} = costs of relocating one container from distribution d to c.

The fixed costs of a container depot include the costs of a cleaning and maintenance facility, and the costs of administration and personnel. Appropriate figures for these costs are available within the logistics service organization.

Model. Given the number of yearly container movements B_{sr} between pairs of senders and recipients, the total number of yearly container movements equals $\sum_s \sum_r B_{sr}$. The minimum number of required containers (B) can be determined by assuming an average velocity of circulation V. The latter figure represents the number of times each container is used per year. Hence:

$$B = \frac{\sum_s \sum_r B_{sr}}{V}.$$

Based on experiences with a similar system in Germany, an average velocity of circulation between 20 and 25 is realistic. Besides the minimum number of containers required, an additional number of containers may be available as a safety stock at the container depots, in order to offset irregularities in the demand or in the velocity of circulation.

Next, we turn to the determination of the number of container depots and their locations. As previously mentioned, a container depot will be established only in distribution centres owned by the logistics service organization. The question is which of these distribution centres should be designated as a container depot.

Since the agency gains a service fee (SF) per box movement from the senders, and has to pay a distribution fee (DF) and a collection fee (CF) per box movement to the logistics service organization, the profit (P_a) of the agency may be expressed by:

$$P_a = (\mathrm{S} - \mathrm{DF} - \mathrm{CF}) \times \sum_s \sum_r B_{sr}. \qquad (1)$$

This expression is independent of the number of container depots and their locations. Furthermore, the profit P_l of the logistics service organization may be express by

$$P_l = (\mathrm{DF} + \mathrm{CF}) \times \sum_s \sum_r B_{sr} - \text{ the total logistics costs.} \qquad (2)$$

Here the first term is also independent of the number of container depots and their locations. As a consequence, a first objective is to choose the number of container depots and their locations in such a way that the total logistics costs are minimized.

A second objective is to determine appropriate figures for the service fee SF, the distribution fee DF, and the collection fee CF. This may be accomplished by considering expressions (1) and (2). The objective now is to choose these figures in such a way that for both the agency and the logistics service organization a positive profit can be earned, given the total logistic costs. Of course, the service fee should be as low as possible, in order to encourage the senders to participate in the system.

The model to support the first objective of minimizing the total logistic costs is a mixed integer programming model based on the following decision variables:

L_d = 0/1 variable indicating if a distribution centre (d) will be a container depot.

D_{ds} = the number of containers distributed from distribution centre d to sender s.

C_{rd} = the number of containers collected from recipient r and transported to distribution centre d.

R_{dc} = the number of containers relocated from distribution centre d to c.

In terms of these decision variables, the problem of minimizing the total logistic costs can be stated as follows:

$$\min \sum_d \sum_s \mathrm{DC}_{ds} \times D_{ds} + \sum_r \sum_d \mathrm{CC}_{rd} \times C_{rd} + \sum_d \sum_c \mathrm{RC}_{dc} \times R_{dc} + \sum_d \mathrm{FC}_d \times L_d \qquad (3)$$

subject to:

$$\sum_d D_{ds} = \sum_r B_{sr} \qquad \text{for all } s \qquad (4)$$

$$\sum_d C_{rd} = \sum_s B_{sr} \qquad \text{for all } r \qquad (5)$$

$$\sum_c R_{cd} = \sum_s D_{ds} \qquad \text{for all } d \qquad (6)$$

$$\sum_c R_{dc} = \sum_r C_{rd} \qquad \text{for all } d \qquad (7)$$

$$\sum_s D_{ds} + \sum_r C_{rd} \le K \times L_d \qquad \text{for all } d \qquad (8)$$

$$L_d \in \{0,1\} \qquad \text{for all } d \qquad (9)$$

$$\text{All variables} \ \geq \ 0. \qquad (10)$$

The objective function (3) expresses the objective of minimizing the total logistic costs, which consist of the distribution costs, the collection costs, the relocation costs, and the fixed costs of the container depots. Restriction (4) ensures that the number of containers distributed to sender s equals the number of containers used by sender *s*. Restriction (5) guarantees that the number of containers collected from recipient *r* equals the number of containers sent to recipient *r*. Restriction (6) shows that the number of containers relocated to container depot *d* equals the number of containers distributed from container depot *d*. Note that containers may be relocated from container depot *d* to container depot *d* with zero relocation costs (i.e. in practice they remain at the same place). Restriction (7) ensures that the number of containers recovered by container depot *d* equals the number of containers relocated from container depot *d*. In restriction (8) the variable *K* represents a very large number. Thus restriction (8) guarantees that containers are distributed to and collected from distribution centre *d* only if the latter acts as a container depot.

The model is a special case of the classical plant location model. For solving such models specific algorithms are available[12].

Application. The model may be used to evaluate several alternative scenarios. For example, an optimistic scenario (high coefficient of proportionality *p*) or a pessimistic scenario (low coefficient of proportionality *p*) may be studied. One may also consider scenarios with high or low velocities of circulation.

Although the model requires further refinement and does not provide a full answer to all the questions posed, it turns out to be a valuable tool for analysis. By experimenting with the model, we found out that initially appointing two container depots is optimal with respect to total logistic costs. Later on, the number of container depots may be increased. Also figures for the service fee SF, the distribution fee, DF, and the collection fee CF, can be determined with the model. Unfortunately, according to the model, the service fee SF would have to be somewhat higher than the average costs of a cardboard box.

The model can be refined in several ways. A first improvement will be achieved by using more sophisticated methods of demand forecasting, based on the experiences with the new system in the Dutch market. Other improvements will be accomplished by introducing several time periods into the model as well as several types of containers, and batchwise distribution, collection, and relocation. This will improve the accuracy of the model. However, we expect the results of these further analyses to be only marginally different from the results found so far.

Open systems

The return system described in this case study is comparable to a system in Germany that was successfully introduced some years ago by the same agency. However, as the systems are organized separately in each country, containers do not normally cross international borders. For example, senders who may want to send containers as far as Spain can hardly use this system, because no international return logistics systems currently exist.

A more open international system will probably develop in the future that will be accessible by any partner, and not restricted by any border.

In this context it should be mentioned that the role of the agency as the initiator and the manager of the system is essential. It is unlikely that a carrier would assume this role. First, most carriers have only a limited service area which prevents the evolution of the system towards an open, international system. If more than one carrier were to introduce a system, they would want to differentiate their own containers from those of the competitors. They might be unwilling to transport their competitor's containers, or even forbid their customers from using any other containers than their own. The result would be numerous closed systems with many different container types and sizes, all exploited by different carriers. The problems for recipients of goods from different senders using containers from different carriers are obvious: every container type would need its own handling system and administration. Thus, an open system should not be restricted to the services of a single carrier. In a well-functioning open system of returnable containers, several carriers will be involved. These carriers may develop close relationships with the agency and with each other.

It can be concluded that an open system of returnable containers can only survive in a larger environment, where each partner pursues his key activity: the owner of the containers manages the system, and the carriers involved take care of the distribution, the collection, the storage and relocation of the containers.

Conclusions

In Germany the system described in the case study has already been operating successfully for a number of years. Of course, there the success is stimulated by strict environmental legislation, and by the problems of the Duales System Deutschland. The success of the system in a different environment, and on a larger scale, is still be be proved.

In this context it is noteworthy that, although the use of returnable containers may seem to be ecologically sound, companies will consider the economic and logistic implications first. From this point of view it is disadvantageous for the sender that the service fee of a returnable container usually needs to be somewhat higher than the cost of a cardboard box. However, the latter may change when a large number of organizations participate in the system. Then it may become feasible to reduce the service fee. Furthermore, the price of cardboard boxes may rise as soon as the market price of waste paper rises.

Another deterrent to all participants is that a certain amount of money has to be invested in the deposits for the containers, which is not necessary if cardboard boxes are used. However, for the recipients this may not be a serious problem, since, in the system examined in this article, the agency intends to return the deposit to the recipients as soon as possible.

These disadvantages may be partially offset by the advantages, which are of a more intangible and qualitative nature. Advantages for the sender are, among others, the just-in-time reception of empty containers, stable pallets, the optimal usage of truck loads, and the redundancy of shrink wraps. Another advantage for the sender is the service to his recipients, who will have no cardboard boxes of which to dispose Furthermore, in some cases the containers may be used within the sender's material handling system, which leads to a reduction in handling activities and costs[13].

Finally, the advantage of the system of returnable containers for the logistics service organization are obvious. If the distribution and the collection fees are sufficiently high, then this organization makes a profit on each container distributed or collected. For the logistics service organization the required investments in the system are relatively low.

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