Needs for logistics in Portuguese tire reverse supply chain: A dynamic systems approach

JOÃO MENEZES E LUÍS FERREIRA

ABSTRACT: Quick technological advances and growing consumer demand, among other aspects, have led to a shorter life cycle of certain products. These factors, combined with the increasing interest and concern for environmental issues require a different answer as far as Logistics is concerned. The main subject of this study lies within the 'new' concept of logistics, usually called reverse logistics. Considering the latest European developments regarding the establishment of green reverse logistic chains to collect and treat end of life products, this study deals with the problem of used tire management in Portugal.
The fundamental issue of the efficiency of the reverse logistic system for tire recycling in Portugal, as far as the waste holder's adherence to the system is concerned, led to the development of a model through the system dynamic method to analyse the trade-off effect between law enforcement, the geographic distribution of the collecting points (consumer service through system convenience) and the illegal dumping of used tires (system performance).
The main conclusion of this study can be summarised as follows: contrary to the Portuguese system set-up, it is fundamental to consider the law enforcement applied and the geographic distribution of the collecting points (among other factors) when the logistic network is designed. This is important for a relevant adherence from the first link of the reverse supply chain (consumers and retailers) to a system such as the Portuguese one.

Key words: Reverse Logistics, Systems Dynamics, Tire Recycling

TÍTULO: A necessidade de logística no sistema Português de gestão de pneus usados - Uma abordagem com recurso à dinâmica de sistemas

RESUMO: Os rápidos avanços tecnológicos e a exigência crescente dos consumidores, entre outros aspectos, têm levado ao encurtamento do ciclo de vida de certos produtos. Estes factores, conjugados com o interesse crescente e a importância das questões ambientais, têm vindo a exigir um tipo de resposta diferente por parte da Logística. O prin-

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cipal assunto abordado neste trabalho está precisamente dentro do âmbito do 'novo' conceito de logística que tem, nos últimos anos, sido alvo de amplo interesse, tanto por parte da comunidade académica como por parte das empresas, e que é normalmente designado por logística inversa. Este trabalho, tendo em consideração os últimos desenvolvimentos que têm sido feitos a nível europeu na constituição de cadeias logísticas inversas para recolha e tratamento de produtos em fim de vida, trata da problemática da gestão de pneus usados em Portugal.
A questão fundamental sobre a eficiência da cadeia logística inversa de pneus em Portugal, no que diz respeito à adesão do detentor de resíduos ao sistema, levou à construção de um modelo com recurso à metodologia de Dinâmica de Sistemas que permita analisar o trade-off *entre a fiscalização/valor da multa, a distribuição geográfica dos pontos de recolha (serviço ao cliente, através da conveniência do sistema) e a deposição ilegal de pneus usados (eficiência do sistema).*
A principal conclusão deste estudo pode ser, de uma forma sucinta, resumida da seguinte forma: ao contrário do que foi feito na criação do sistema português de reciclagem de pneus usados, é fundamental que, quando se configura uma cadeia logística deste tipo, se considerem, entre outros factores, variáveis como o nível de fiscalização aplicado e a distribuição geográfica dos pontos de recolha. Isto é importante para se conseguir uma adesão relevante do primeiro nível da cadeia logística inversa (consumidores e retalhistas) a um sistema como o Português.

Palavras-chave: Logística Inversa, Dinâmica de Sistemas, Reciclagem de Pneus

INTRODUCTION

Product Returns exist from the moment a product was manufactured for the first time. What has changed in recent years is the attention that businesses are paying to costs involved in returns. Environmental and legislative pressures play a major role in requiring manufacturers to take back their products at the end of their life cycles. On the other hand, manufacturers also want to present themselves as green corporate citizens.

Once the products are delivered, the firm's responsibility does not end. Taking a life-cycle approach to product distribution is vital along with implementing information programs for customers, suppliers, and vendors. However, economies of scale must be sufficient to make reverse logistics financially viable for any environmental program.

Most supply chains are not designed to handle reverse material flows. To make reverse logistics operate effectively, all the supply channel members must find it financially attractive to participate in and be committed to the process and to the cost minimization in collecting, sorting, and processing activities. The efficiency of the

reverse supply chain system for recycling, like in the tire industry, depends on the system manager ability to coordinate and integrate the referred activities.

In order to collect used tires for recycling, Portugal, like many other European countries, has begun the setup of a private company system, which includes the rubber, retreading and automotive industry representatives as shareholders. However, the system at work was built based on the consumers' legislative responsibility to hand over their used tires to an authorized collecting point. These points were geographically distributed all over the country almost at random. Therefore, considering that the system development was mainly concerned with the financial aspects of proper tire disposal and the fulfilment of both EU Directives and national law objectives, the design and efficiency of the supply chain were forgotten. The result was initially a low performance system, particularly in terms of costs and services to the consumer and consequently of his will to play an active role in the scheme.

LITERATURE REVIEW

The green movement brings some challenges to the traditional logistic systems. First, an environmentally responsible logistic approach affects the way logistic managers do their jobs, since activities, such as the development of less pollutant products and their recyclability are now emphasised (Murphy *et al.*, 1994). Some research goes deeper and explores the interface between logistics and environment in the overall demand-supply chain (Wu and Dunn, 1995). Second, the scope of logistic activities expands its traditional perspective of forward distribution, that is, the flow of goods from producer to consumer, to encompass the reverse distribution concept, i.e., the movement of materials from consumer to producer (Stock, 1992). In this sense, business assumes the so-called 'cradle-to-grave' responsibility, evaluating the environmental trade-offs in the whole product life cycle (Barry *et al.*, 1993).

Conceptually, reverse logistics deals with the design and development of logistic systems for efficient and effective collection, sorting and transport of products and packages in order to reuse them one way or another, postponing the end of the product life cycle. The environmental benefits of this practice are quite obvious: reducing the use of raw materials, disposal of low amounts of residue at landfills and/or less energy consumption for their incineration (Giuntini and Andel, 1995).

The mission of any logistic system - forward or reverse - is always to serve and customise the client/consumer. The consumer's role and the challenge of his customising are particularly important in the reverse logistics system. To begin with, the consumer is the first and decisive link in the overall logistic chain and without his par-

ticipation (through proper sorting and disposing of recyclable materials) the system does not exist at all. Then, parallel to the reverse logistic operation costs, consumer service is a measure of the system performance (Jahre, 1995). Finally, consumer service (through the system's convenience) is the touchstone in creating value for the consumer and, therefore, in getting his participation (Turner *et al.*, 1994).

Although the reverse logistic problematic was first approached during the 1970s (Zikmund and Stanton, 1971), only in the 1990s, with the growth of environmental concern, did the development of reverse distribution channels receive increasing research attention as an important means of integrating economic and ecological needs (Fuller, 1978). Some of the most relevant academic literature related to the issue dealt with in this study and classified in accordance with the main topics investigated, is presented in Table 1.

TABLE 1
Reverse logistics literature

Topics in reverse logistics literature	Authors
1 - Reverse channels configuration	Stock (Stock, 1992), Jahre (Jahre, 1995), Zikmund and Stanton (Zikmund and Stanton, 1971), Fuller (Fuller, 1978)
2 - Impact of environmental issues in logistics management	Menezes *et al.* (Menezes *et al.*, 2003), Wu and Dunn (Wu and Dunn, 1995), Murphy *et al.* (Murphy *et al.*, 1994), Barry *et al.* (Barry *et al.*, 1993)
3 - Environmental regulations and reverse logistics in Europe	Barry *et al.* (Barry *et al.*, 1993), Cairncross (Cairncross, 1992), Wilmshurst and Newson (Wilmshurst and Newson, 1996)
4 - Market trends and opportunities for reverse logistics	Byrne and Deeb (Byrne and Deeb, 1993), Blumberg (Blumberg, 1999)
5 - Transportation issues in reverse logistics	Stock (Stock, 1992), Simchi-Levi *et al.* (Simchi-Levi *et al.*, 2000)

Adapted from Menezes et al. *(Menezes* et al., *2003)*

From a brief review of this literature, it is clear that the consumer's role and consumer service have been overlooked issues in the reverse logistic research.

THE PORTUGUESE REVERSE LOGISTIC SYSTEM FOR TIRES

The company founded to manage the system (Valorpneu) and to deal with all operators who are willing to participate (be they collectors, recyclers, transporters or

energy recover operators) holds a five year licence with the objective of: putting an end to illegal dumping and depositing used tires in landfills (according to 1999/31/EC Directive); collecting used tires in a proportion that should be at least 85% of the total used tires generated; retreading at least 25% of the total used tires generated and recovering the remaining amount of collected tires not retreaded of which at least 60% should be recycled. The total amount of used tires generated annually reported by Portugal reaches approximately 50 000 tonnes.

The physical flow of the used tire management system starts with the delivery of tires to garages by the final consumers. When new tires are sold, the retailer is obliged to accept used ones from the same kind and in the same amount, without extra charge. Also, with the purchase of new tires, the consumer is charged with an environmental fee that varies according to the tire category and is used to finance the integrated system, namely the transportation from the collecting points to the final destination and the used tire processing costs. This fee should be managed without any lucrative purpose and is given to the management company by those who charge it. Anyone owning used tires is legally obliged to deliver them to the appropriate place to companies licensed to receive them and they have to endure all necessary costs. With this in mind, collecting points were created across the whole country to receive used tires without charge. In that way, used tire owners have to incur the cost of storage and transportation to the collecting point. Therefore, the primary transportation contract is the waste owners' responsibility and is liable to free market rules.

The collecting points are responsible for receiving, selecting and storing tires and are paid for these services by the management company; the latter is also responsible for the secondary transportation (from the collecting points to the final destination) and for planning the deliveries to the processing units (recycling, energy recovery and landfill operators). A compensation value is due to the company responsible for the final treatment.

The above system is based on the assumption that the reatreading market continues to work as it is. What has been forgotten is that if the system is to work and its management be able to achieve the defined objectives, the retailers must have a strong will to participate in the recycling scheme. Though this is not directly controlled by Valorpneu, this company can indirectly influence it through a well designed network of collecting points, law enforcement and correct planning awareness campaigns.

RESEARCH HYPOTHESIS AND METHODOLOGY

The methodology of the dynamic systems approach to the development of models was used in this study. The data used in the model built for the Portuguese case was

obtained by carrying out documentary analysis, semi-structured interviews made to the main actors involved in the model and finally through direct observation of the real system at work.

As it is clear that the design of the reverse logistic system is an important issue in getting and enhancing recycling behaviour, the system dynamics approach was used to find answers to the following fundamental question: «Is the reverse logistic system for tire recycling in Portugal efficient from the point of view of the waste holder's adherence to the system?»

This question led to the objective of developing a model from which could: firstly, analyse both the trade-off effect between the law enforcement, the geographic distribution of the collecting points and the illegal dumping of used tires; and secondly, verify the importance of considering the dynamic behaviour of the system when launching awareness campaigns aimed at reducing the quantity of illegally dumped used tires. Consequently, the following hypotheses were stated:

- H1: the geographic distribution of the collecting points, the fine and the degree of law enforcement applied are determinant to the adherence of waste tire owners to the Portuguese tire recycling system;
- H2: considering the system dynamic behaviour is fundamental to determine the moment when an awareness campaign should be launched, its duration and frequency so that success (in terms of reducing the quantity of illegally dumped used tires) could be achieved.

To test the first hypothesis a system dynamic model was developed from which four simulation scenarios were built (Table 2). In these, the fine variable was changed to different amounts (within the legally established range) so that the dynamic behaviour of the variables to be analysed, namely the quantity of illegally dumped used tires, the level of predisposition to deposit legally and the degree of law enforcement associated could significantly change. The developed model was also used to test the

TABLE 2
Group A of scenarios

	Variable
	Fine
Scenario 1	500 €
Scenario 2	2500 €
Scenario 3	3000 €
Scenario 4	5000 €

second hypothesis but this time a set of scenarios were defined in which the moment when the campaign should start, its duration and frequency were changed (Table 3).

TABLE 3
Group B of scenarios

	Variable			
	Fine	Start date	Duration	Frequency
Scenario 5a	500 €	Without campaigns	-	-
Scenario 5b	500 €	2007	1 year	0 years
Scenario 5c	500 €	2007	1 year	2 years
Scenario 6a	2500 €	Without campaigns	-	-
Scenario 6b	2500 €	2006	1 year	0 years
Scenario 6c	2500 €	2006	1 year	3,5 years
Scenario 6d	2500 €	2006	1 year	4 years
Scenario 7a	3000 €	Without campaigns	-	-
Scenario 7b	3000 €	2007	1 year	0 years
Scenario 7c	3000 €	2007	1 year	3 years
Scenario 8a	5000 €	Without campaigns	-	-
Scenario 8b	5000 €	2003	1 year	0 years
Scenario 8c	5000 €	2004	1 year	0 years

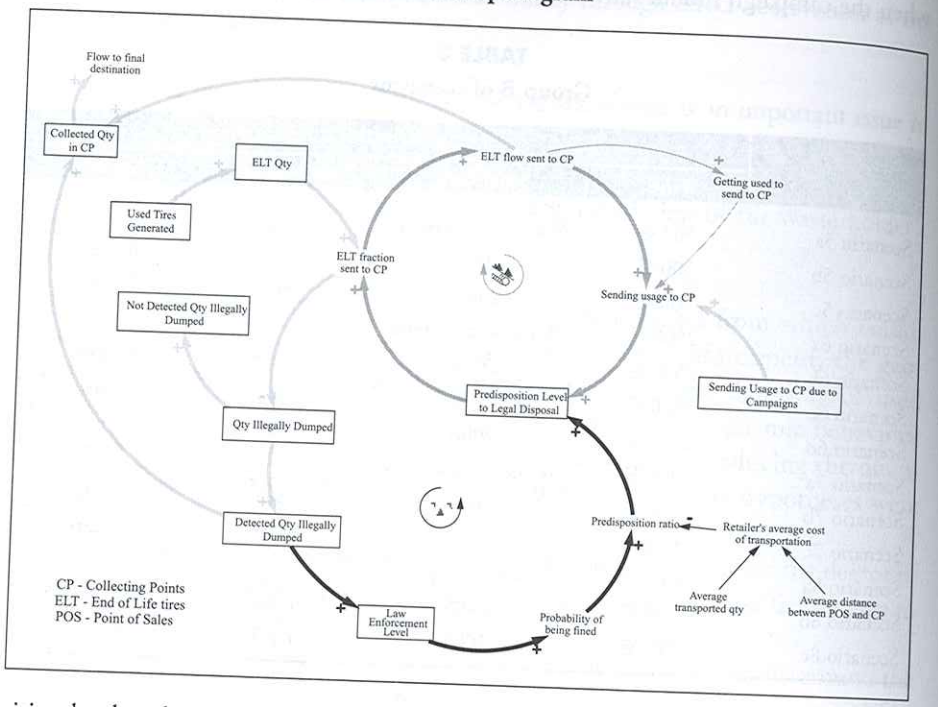
RESULTS

The results that follow were obtained by conducting several simulation runs in the system dynamic model developed. Its Causal Loop and Stock and Flow Diagrams can be seen in Figures 1 and 2 respectively.

The main variable dynamic behaviour (quantity illegally dumped), which at the end of the day allows us to check both whether the waste owners adhered to the system and the system performance, can be seen in Figure 3. This figure enables us to verify that changing the fine significantly changes the quantity of used tires illegally dumped. To calculate the waste owner's transportation costs to the collecting point, the simulation runs for the scenarios under analysis considered an average distance of 100 Km. Although the model is prepared to cope with the transportation cost as a variable, it was decided to freeze these (as the average distance could be determined but the fine could not) in order to better understand the results obtained.

Nevertheless, it must not be forgotten that the fine does not act isolated in the system. In the model developed, both the quantity illegally dumped and the predispo-

FIGURE 1
Causal loop diagram



sition level to deposit legally depend not only on the fine but also on the level of law enforcement applied. Figure 4 shows the dynamic behaviour of these variables for the group A scenarios defined.

As seen in Figure 4, in Scenario 1 the prevailing dynamic behaviour in the quantity illegally dumped variable is quite unstable and shows a reasonable interdependence with the level of law enforcement applied. This is mainly due to the low fine (500€). Scenario 1 shows that, given the geographical distribution of the collecting point, the retailers' adherence to the system follows the behaviour of the law enforcement applied with a certain delay. However, the level of predisposition to keep the law, legally disposing used tires, increases and decreases according to retailers' perception of the authorities' law control.

On the other hand, due to the high fine (5000€), Scenario 4 shows that the trade off between being fined and the transportation cost favours the latter. Therefore, in this scenario it is enough to keep a low and constant level of law enforcement to obtain the retailers' maximum adherence to the system (quantity illegally dumped variable tends to zero).

FIGURE 2
Stock and flow diagram

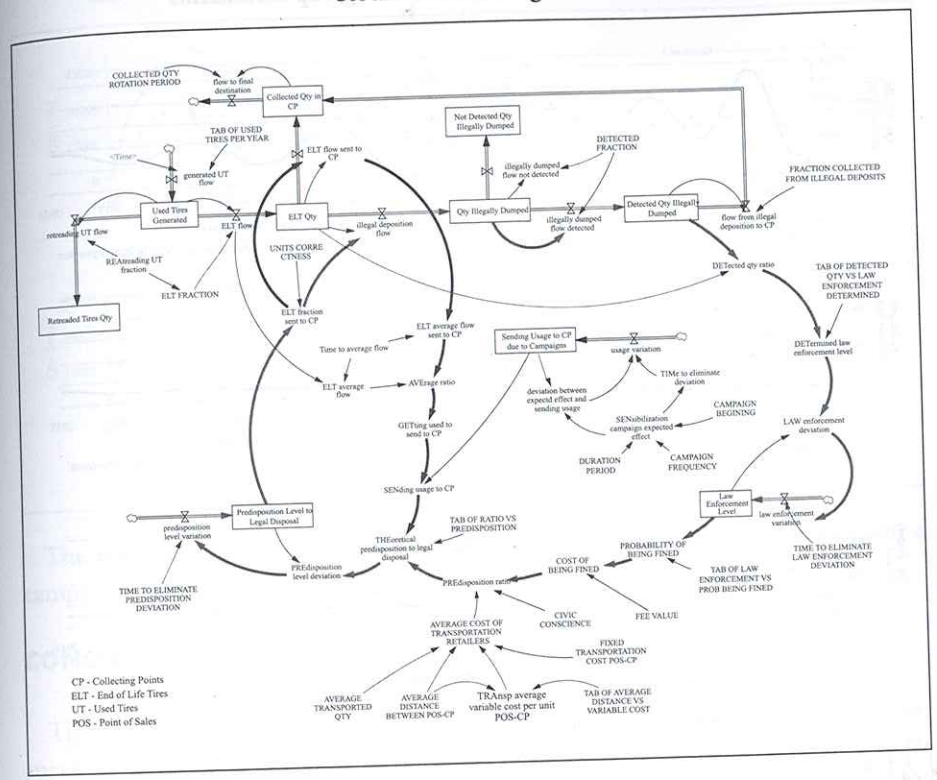
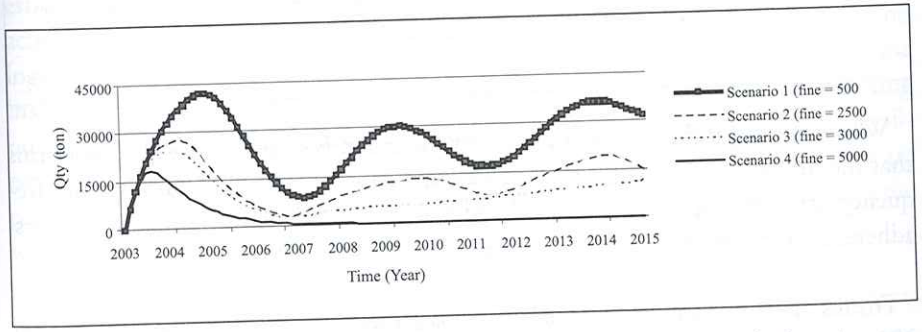


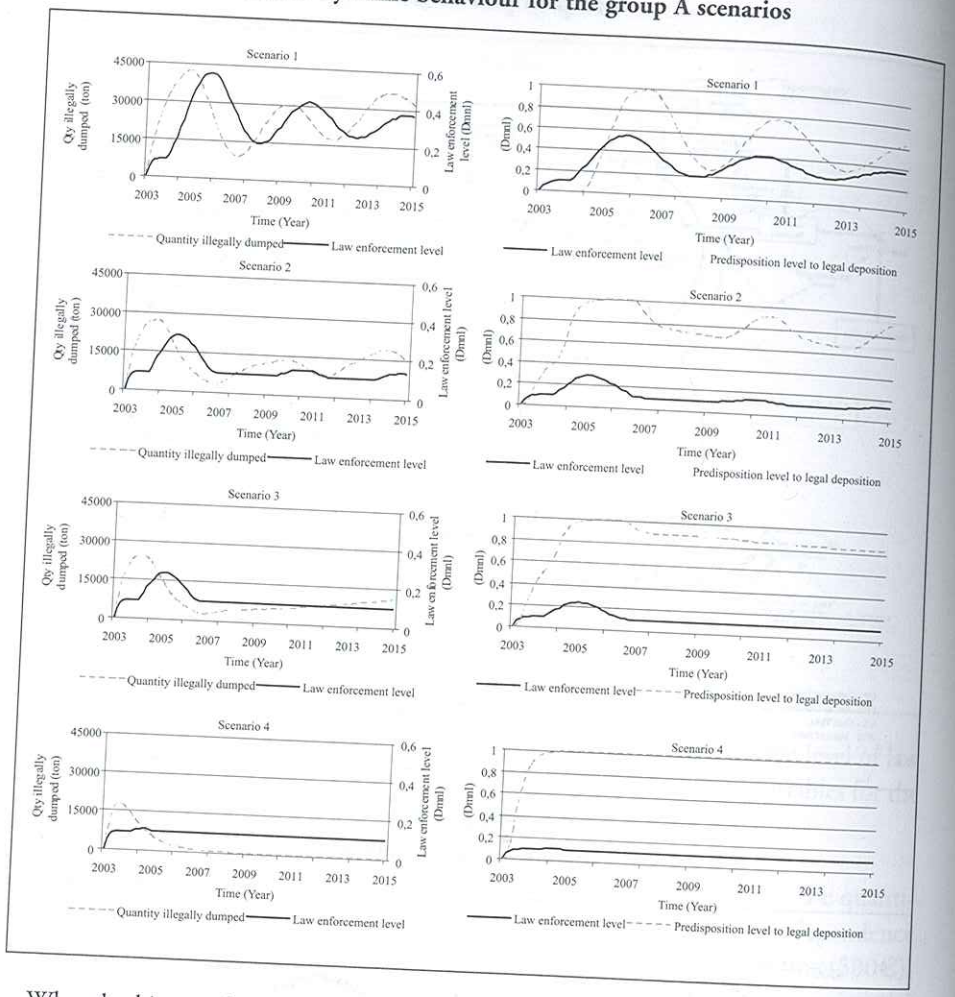
FIGURE 3
Quantity illegally dumped



Scenarios 2 and 3 illustrate intermediate situations where, although there is not a complete adherence to the system, a relatively high level of predisposition to legally dispose of used tires can be obtained by initially having a higher level of law enforcement.

FIGURE 4

Variables' dynamic behaviour for the group A scenarios

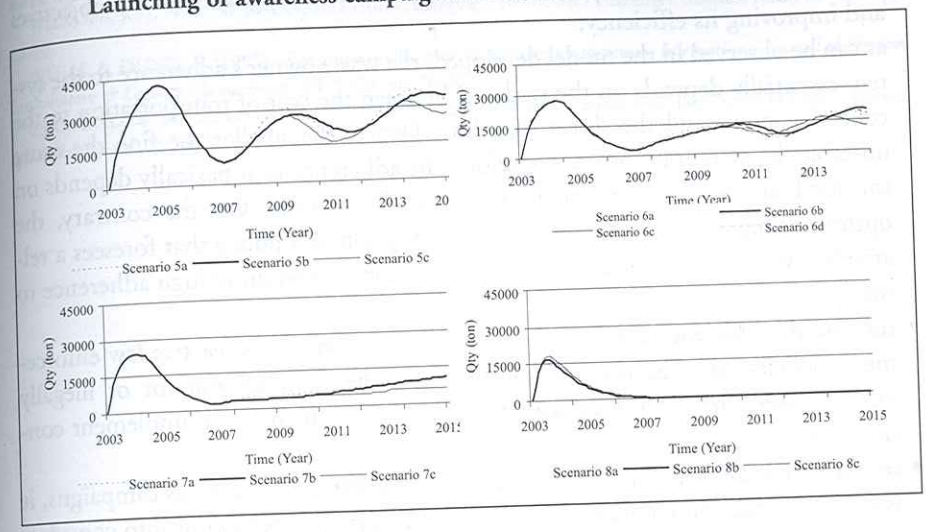


When looking at the results obtained for the group B scenarios, Figure 5 confirms that the moment at which an awareness campaign is launched, its duration and frequency are very important if a good result is to be obtained in terms of retailers' adherence to the system (decrease in the quantity illegally dumped).

For instance, scenario 8c, in which a campaign was introduced for one year in year 2004, is paradigm of a situation that bring no advantages. That is, a campaign launched of this kind aimed at increasing the retailers' adherence to the system would be a waste of resources. On the other hand, scenario 7c is a good example of a campaign where the previously defined objective is achieved.

FIGURE 5

Launching of awareness campaigns effects in the scenarios of group B



The more the system oscillates, the harder it is to determine the exact moment a campaign should be initiated (that is the case of scenarios 5b and 5c).

CONCLUSIONS

Through reverse logistic practices, business worldwide may become more environmentally responsible and reach competitive advantages as a result of a green reputation. In the Portuguese green reverse logistic system built for used tire recovery, the consumer and mainly the tire retailer play a fundamental role. As they are the earliest and decisive links of any return logistic chain, no recycling objectives can be achieved without their adherence and continuous collaboration. Consequently, no logistic system for recycling used tires will survive. In the present research some insights about the importance of both the geographic distribution of collecting points (which has a direct influence on the transportation cost endured by the retailer) and the law enforcement in the Portuguese used tire reverse logistic system are provided through a system dynamic model, thus demonstrating and questioning the way the Portuguese system was designed without considering those issues.

Therefore, the previously stated hypotheses were validated and the following conclusions were drawn:

- as the first reverse supply chain level (waste owner ➡ collecting point) is based on the waste owner's responsibility to deliver the tires to a collecting point, the threat of a fine (seen as a conjugation between the probability of being fined, if the law is

not respected, and the fine amount) is very important in determining the waste owner's adherence to the system and therefore in achieving the system's objectives and improving its efficiency;

- as can be observed in the model developed, the waste owner's adherence to the system essentially depends on the trade off between the cost of transportation to the collecting point and the threat of a fine. Hence, the smaller the fine the more unstable the system becomes. Therefore, the adherence to it basically depends on the level of law enforcement applied at each moment. On the contrary, the option for higher fines together with the adoption of a policy that foresees a relatively low and constant level of law enforcement allows quite high adherence to the system;
- the system's efficiency can increase with the adoption of less reactive law enforcement policies, that is, not so dependant on the detected amount of illegally dumped used tires, or at least with the reduction in the delay to implement control measures;
- in order to decrease the quantity illegally dumped through awareness campaigns, it is necessary that those policies take the system's dynamic behaviour into consideration, so that an appropriate beginning time, duration and frequency can be found;
- in the system modelled, it becomes more important and harder (due to the oscillating behaviour of certain variables) to choose the right time to start a campaign, its duration and frequency when fines are lower.

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