ECONOMIC AND ENVIRONMENTAL SUSTAINABILITY OF A LARGE-SCALE RETAIL STORE

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ABSTRACT

This study investigates the issue of sustainability evaluation in a large-scale retail store (RS), which carries out four main different processes, i.e. Receiving, Backroom storage, Sales area management and Reverse logistics. A computational model is developed under Microsoft Excel™ to assess the costs and the CO_2 emissions of the RS. The application of the model is presented for a reference process (i.e. the Receiving process), while for the remaining processes, we present and discuss only the main results obtained. We found that the highest environmental impact and total cost are due to the Sales area management process, while Reverse logistics contributes to the total cost to a limited extent. The results obtained can provide useful guidelines for RS managers when pondering the optimization of sustainability.

Keywords: sustainability, large-scale retail store, case study, economic and environmental assessment.

1. INTRODUCTION

The term "sustainability" is derived from the Latin verb *sustinere*, composed of *tenere* (to hold), and *sub* (up). It has been used since 1980s referring to human sustainability and has resulted in the most widely quoted definition of sustainable development, which, according to the World Commission on Environment and Development (1987), is "the development that meets the needs of the present generations, without compromising the ability of the future generations to meet their own needs". Sustainable development is widely accepted to include economic development, social and human development, and environmental and ecological health (Goldman and Gorham, 2006).

Logistics and distribution activities are essential for sustaining our daily lives. However, from an environmental point of view, such activities could have a relevant impact, ranging from emissions into the environment, to the consumption of resources, up to the product's end-of-life (Rebitzer et al. 2004). Moreover, logistics systems are likely to generate undesired 'by-products', such as inefficient (or excessive) use of fossil burning fuels or CO_2 emissions (Kim et al. 2010).

From an economic perspective, the cost of logistics and distribution can also be relevant, accounting for approximately 10% of the gross domestic product of industrialized countries (World Economic Forum 2013). The relevant cost and environmental impact fuel a lot of discussions about the efficiency and effectiveness of logistics activities (Borgström 2005; Fugate, Mentzer, and Stank 2010). In response to the above issues, companies are increasingly seeking solutions to reduce their logistic cost and increase sustainability. In some industrial contexts, such as the fashion industry or the food one, the economic and environmental issues are particularly relevant and have been evaluated by the researchers (e.g., Bigliardi and Bottani 2012 or Manfredi and Vignali 2014).

A context that has potential to play a relevant role for sustainability is the retailing field (Erol et al. 2009) and increasingly, sustainability is considered a core value and practice in retailing (Wiese et al. 2012). Pressure on retailers to integrate sustainability into their business practices is also increasing (European Environment Agency 2010). In addition, as retailers are at the crossroads between producers and consumers in a supply chain, their role in promoting sustainable production and logistics is crucial (Bonini and Oppenheim 2008; Jones, Comfort, and Hillier 2009).

In line with the considerations above, in this paper we focus on the evaluation of the economic and environmental sustainability of a particular player in the retailing field, i.e. a large-scale retail store (RS). To be more precise, we illustrate the evaluation of the total cost and CO_2 emissions of the RS by means of an analytic model developed under Microsoft Excel™. The model takes into account the key logistics processes of the RS, although, for the sake of brevity, the details of the computational procedure and of its application are provided only for a reference process (i.e. the Receiving process).

The remainder of the paper is organized as follows. The next section describes the methodology adopted to develop the model. The application of the model to the case of a large-scale RS is described in section 3, together with the results obtained. Discussion, implications, limitations and future research directions are proposed in section 4.

2. METHODOLOGY

2.1. Retail store processes

This study takes into account the key supply chain processes of large-scale RS, i.e. Receiving, Backroom storage, Sales area management and Reverse logistics.

The Receiving process is the first process encountered by an item arriving at the RS (Rouwenhorst, et al. 2000). The receiving activity includes the unloading of products from the transport carrier, updating the inventory record, inspection to find if there is any quantity or quality inconsistency. Transfer and put away involves the transfer of incoming products to storage locations (De Koster, Le-Duc, and Roodbergen 2007). Storage is concerned with the organization of goods held in the warehouse in order to achieve high space utilization and facilitate efficient material handling (Gu, Goetschalckx, and McGinnis 2007). The sales area of a RS is the space on which both the manpower and the consumers stand and move. It is energy intensive and includes ventilation and air conditioning (HVAC) systems, heating and cooling set points and schedules, lighting types, levels and schedules and refrigeration plants (Parker et al. 2017). The return flow of food products is a typical problem of reverse logistics and concerns distribution activities involved in food-packaging returns, recycling/recovery, reuse and/or disposal. Reverse logistics activities are often supported by specific facilities, typically collection centres, where products are recovered, repaired or recycled. Therefore, the network structure needs to be extended with transportation links for return flows from customer locations to collection sites (Fancello et al. 2017).

2.2. Model overview

An evaluation model was developed under Microsoft Excel™ to support the assessment of the economic and environmental sustainability of the RS. This model consists of four spreadsheets. Each of them reproduces one of the RS processes described in the previous section, and computes the relating economic and environmental impact. For the sake of brevity, in the following we will illustrate in detail the application of the model for a representative RS process (i.e. the Receiving process), with the aim to detail the computational steps for the assessment of both the economic and environmental sustainability. For the remaining RS processes, we will present the results obtained from the application of the model, omitting the detailed steps. The notation used in the analysis (limited to the process considered) is shown in Table 1.

Table 1: Nomenclature

Symbol	Description	Unit of measurement
Subscripts		
R	Receiving	-
f	Fresh	-
d	dry	
tot	Total	-
$I,T\text{-}Q;D$	Identification, type and quantity, documents	-
u	Unitary	-
Receiving parameters		
$n_{(pallets/day),R}$	Amount of pallets received	[pallets/day]
$C_{u,litre}$	Fuel cost	[€/l]
D_{litre}	Distance per litre	[km/l]
$n_{(pallets/truck),R}$	Amount of pallets that can be loaded on a truck during receiving	[pallets/truck]
$N_{days/year}$	Working days per year	[days]
D_a	Average distance from retail stores to Distribution Centre	[km]
$n_{(truck/year),R}$	Amount of trucks per year in Receiving Process	[trucks/year]
$C_{(t,tot),R}$	Total cost of transport in Receiving Process	[€/year]
$FC_{truck,f}$, $FC_{truck,d}$	Fuel consumption for a refrigerated truck in different range of temperature	[l/h]
FC_f, FC_d	Annual fuel consumption for fresh/dry products	[litres/year]
$C_{E,f}$, $C_{E,d}$	Cost of energy for transport of fresh/dry products	[€/year]
$C_{m,u}$	Average hourly cost of manpower	[€/h]
$C_{m,R}$	Cost of manpower per year in Receiving	[€/year]
$ER_{I,R}$, $ER_{T\text{-}Q,R}$	Error made in products receiving (identification, type and quantity)	[case/day]
$ER_{D,R}$	Error made in products receiving (documents)	[orders/month]
$T_{(ER,I),R}$, $T_{(ER,T\text{-}Q),R}$	Time required to amend identification/type and quantity errors	[min/case]
$T_{(ER,D),R}$	Time required to amend documents errors	[min/order]
$C_{(ER,I),R}$, $C_{(ER,D),R}$, $C_{(ER,T\text{-}Q),R}$	Cost to amend identification/documents/type and documents errors	[€/year]
$C_{ER,R}$	Total cost to amend errors in received pallets	[€/year]
$C_{tot,R}$	Total cost of the Receiving process	[€/year]

E_f, E_d	Energy absorbed by a truck to transport fresh/dry products	[kWh/year]
I_f, I_d	Environmental impact of fresh/dry products transport	[tonCO_2/year]
$I_{truck,R}$	Environmental impact of a full load truck	[tonCO_2/year]
I_{truck}	Environmental impact of a truck per km	[tonCO_2/km]
$I_{tot,R}$	Total environmental impact	[tonCO_2/year]
t_{trip}	Amount of hours per trip	[h/trip]
$n_{employees,R}$	Number of employees in the Receiving process	-
$h_{day,R}$	Hours per working day in the Receiving process	[h/day]
d_{diesel}	Density of diesel fuel at normal environmental condition	[kg/m^3]
$\%T_i$	Percentage of ignition time of the refrigerator unit of the truck	-

2.3. Preliminary assumptions

The model developed is based on some assumptions, which have emerged both from the analysis of the literature available and from the suggestions provided by the managers of some RSs involved in the study (see the details in section 3.1). They are listed and described in the following.

1. Since the products handled at the RS are of different nature, they have been grouped into two categories, i.e. "fresh" and "dry" products. The amount of fresh products accounts for 15% of the total volume of items handled at the RS, while the percentage of dry ones accounts for 85%;
2. The disposal process for the expired products is typically at the expense of the distribution centre (DC); therefore, it is not considered in this analysis;
3. The present work does not take into account the process of checking the returned products, to identify a possible alternative use (instead of the disposal option). Indeed, this process is typically managed by means of specific agreements between the RS and its suppliers.

3. MODEL APPLICATION

In the following sections, we describe the application of the computational model to a reference process, taken as a case study.

3.1. Input data

The model developed takes several data as input. As far as the numerical values of the input data are concerned, they have been obtained from both a data collection phase and from a careful bibliographic analysis was carried out with the support of the Scopus database (www.scopus.com). To be more precise, a sample of four RSs of different size, i.e. two hypermarkets and two supermarkets, was investigated to collect the most relevant data relating to the supply chain processes under examination. These data were then averaged on the sample of RSs considered. Some previous publications (Bottani and Rizzi 2008; Bottani and Montanari 2010) and other available sources were also used to retrieve the remaining input data. The full list of input data relevant to the Receiving process is provided in Table 2.

Table 2: Input Data for the Receiving Process

Parameter	Numerical value	Measurement unit	Source
$n_{(pallets/day),R}$	168	[pallets/day]	(Bottani and Montanari 2010)
$C_{u,litre}$	1.37	[€/l]	(Ministero dello Sviluppo Economico 2017)
D_{litre}	2.6	[km/l]	(Econoliberal 2012)
$n_{(pallets/truck),R}$	33	[pallets/truck]	calculated using the standard size of a Euro-pallet
$N_{days/year}$	320	[days]	(Bottani and Rizzi 2008)
D_a	103.67	[km]	(ECR Italy 2014)
$FC_{truck,f}$, $FC_{truck,d}$	0.75 (T°=[-25, +3]°C); 2.25 (T°=[+3, +25]°C)	[l/h]	(Tassou, De-Lille, and Lewis 2012)
t_{trip}	3	[h/trip]	Direct observation
$C_{m,u}$	13.17	[€/h]	(Unione Nazionale Cooperative Italiane 2015)
$n_{employees,R}$	5	-	Direct observation
$ER_{I,R}$	0.25	[case/day]	(Bottani and Rizzi 2008)
$ER_{D,R}$	13.8	[order/month]	(Bottani and Rizzi 2008)
$ER_{T\text{-}Q,R}$	13.8	[case/day]	(Bottani and Rizzi 2008)
$T_{(ER,I),R}$	7.5	[min/case]	(Bottani and Rizzi 2008)
$T_{(ER,D),R}$	50.6	[min/order]	(Bottani and Rizzi 2008)
$T_{(ER,T\text{-}Q),R}$	8.75	[min/case]	(Bottani and Rizzi 2008)

I_{truck}	6.22*10^-4	[tonCO_2/km]	(Ciccarello and Caserini 2011)
$h_{day,R}$	8	[h/day]	Direct observation
d_{diesel}	850	[kg/m^3]	(Wang and Economides 2009)
$\%T_i$	60%	-	Direct observation

3.2. Receiving process

In the following, we describe the computational procedure to quantify the costs and emissions arising from the management of Receiving process. As the analysis focuses more on transport activity, it is important to point out that the type of vehicles considered for deliveries to RS is a 33-pallet lorry (see Table 2).

3.2.1. Economic analysis

To compute the relevant costs of the Receiving process, the first step is to calculate the number of trucks per year required to deliver the products to the RS. This could be obtained starting from the amount of pallet received per day and the total amount of pallets loaded on a truck of given capacity.

$$n_{(truck/year),R} = \left\lceil \frac{n_{(pallets/day),R}}{n_{(pallets/truck),R}} \right\rceil * N_{days/year} \quad (1)$$

The total cost of transport for Receiving activities, $C_{(t,tot),R}$ can be computed as follows:

$$C_{(t,tot),R} = \frac{C_{u,litre}}{D_{litre}} * D_a * n_{(truck/year),R} \quad (2)$$

Taking into account assumption #1 in section 2.3, such a cost can be shared among the different categories of products treated, i.e. 15% for fresh products and the remaining 85% for dry ones.

Further economic impacts relating to the receiving activities are caused by the fuel consumption. Because the transport of fresh product requires refrigerated trucks, the fuel consumption should be computed separately for dry and fresh products, as follows:

$$FC_d = FC_{truck,d} * t_{trip} * n_{(truck/year),R} * 0.85 \quad (3)$$

$$FC_f = FC_{truck,f} * t_{trip} * \%T_i * n_{(truck/year),R} * 0.15 \quad (4)$$

Consequently, the impacts account for:

$$C_{E,d} = C_{u,litre} * FC_d \quad (5)$$

$$C_{E,f} = C_{u,litre} * FC_f \quad (6)$$

Another cost component is the cost of employees who carry out receiving operations. Taking into account the number of employees serving this process, the following equation can be used:

$$C_{m,R} = C_{m,u} * h_{day,R} * N_{days/year} * n_{employees,R} \quad (7)$$

During receiving, employees can also work to amend possible errors in the pallets received (documents, product type and quantity, identification). The relating cost was computed for each type of errors, according to the following equations:

$$C_{(ER,T-Q),R} = \frac{T_{(ER,T-Q),R}}{60} * C_{m,u} * ER_{T-Q,R} * N_{days/year} \quad (8)$$

$$C_{(ER,D),R} = \frac{T_{(ER,D),R}}{60} * C_{m,u} * ER_{D,R} * 12 \quad (9)$$

$$C_{(ER,I),R} = \frac{T_{(ER,I),R}}{60} * C_{m,u} * ER_{I,R} * N_{days/year} \quad (10)$$

The total economic impact caused by the error management in Receiving operations accounts for:

$$C_{ER,R} = C_{(ER,T-Q),R} + C_{(ER,D),R} + C_{(ER,I),R} \quad (11)$$

Total economic impact the receiving process at the RS ($C_{tot,R}$) can finally be computed by adding up the contributions listed above:

$$C_{tot,R} = C_{(t,tot),R} + C_{E,d} + C_{E,f} + C_{m,R} + C_{ER,R} \quad (12)$$

3.2.2. Environmental analysis

Besides the economic performance, the environmental sustainability of the Receiving process was evaluated taking into account different contributions relating the transport phase, namely: the environmental impact of fresh and dry products transport (I_f;I_d) and the amount of CO_2 emissions of a full load truck ($I_{truck,R}$). To calculate I_d, the energy absorbed by truck for dry transport (E_d) should be first estimated.

Using the following conversion factors:

$$1\ litre = 1\ dm^3 = 0.001\ m^3 \quad (13)$$

$$1\ tonCO_2 = 42.877\ GJ \text{ (Minambiente 2016)} \quad (14)$$

$$1\ kWh = 3.6 * 10^6\ J \quad (15)$$

the energy absorbed by a truck can be estimated as follows:

$$E_d = \frac{FC_d * 0.001 * d_{diesel} * 42.877}{3.6 * 10^6} \quad (16)$$

Using again a conversion (Emilia Romagna 2015), i.e.:

$$1kWh = 2.642 * 10^{-4}\ tonCO_2 \quad (17)$$

the environmental contribution for the transport of dry products can be calculated as follows:

$$I_d = E_d * 2.642 * 10^{-4} \qquad (18)$$

Following a similar approach, the environmental impact of the fresh products transport (I_f) was computed as follows:

$$E_f = \frac{FC_f * 0.001 * d_{diesel} * 42.877}{3.6 * 10^6} \qquad (19)$$

$$I_f = E_f * 2.642 * 10^{-4} \qquad (20)$$

The environmental impact of all trucks used to collect the pallets from the DC to the RS is finally obtained by adding up the contribution of each truck and taking into account the transport distance, according to the following formula:

$$I_{truck,R} = I_{truck} * D_a * n_{(truck/year),R} \qquad (21)$$

Finally, the total environmental impact was derived by adding up the contributions listed above:

$$I_{tot,R} = I_d + I_f + I_{truck,R} \qquad (22)$$

3.2.3. Results

We now report the main results of the analysis for the receiving process, in terms of the economic contribute (purple highlighting) and the environmental (light blue highlighting) one, with the purpose of evaluating the sustainability of RS. The results, including both the absolute value and the percentage sharing of each component, are shown in table 3.

Table 3: Costs and Emissions for the Receiving Process

Receiving				
Activities	**Costs [€/year]**	**%**	**Emissions [tonCO₂/year]**	**%**
Manpower	168,576.00	58.03	-	-
Transport	104,878.77	36.10	123.80	90.54
Fuel consumption - dry products	5,030.64	1.73	9.82	7.18
Fuel consumption - fresh products	1,597.97	0.55	3.12	2.28
Error management - type and quantity	8,450.75	2.91	-	-
Error management - documents	1,833.51	0.63	-	-
Error management – product identification	131.70	0.05	-	-
Total	**290,499.34**	**100.00**	**136.74**	**100.00**

As shown in Table 3, the activity that entails the greatest cost in the Receiving process is the manpower (168,576.00 €/year), which accounts for 58.03% of the total cost of the process. In addition, the transport activity significantly affects the environmental performance of the process (123.80 $tonCO_2$/year), and its economic impact cannot be neglected as well (36.10%).

3.3. Backroom storage

In a real RS, the storage area is typically used only for handling and storage of dry products. Conversely, fresh products are rarely managed in the RS backroom, being typically received and located directly on the store shelves. The main results obtained by applying the evaluation model to the Backroom storage are shown in the Table 4, for both the economic and environmental aspects of sustainability.

Table 4: Costs and Emissions for the Backroom Storage

Backroom Storage				
Activities	**Costs [€/year]**	**%**	**Emissions [tonCO₂/year]**	**%**
Manpower	168,576.00	49.77	-	-
Inventory	20,000.00	5.90	-	-
Maintenance of fork lift trucks	939.72	0.28	0.77	5.05
Sale losses	722.93	0.21	-	-
General and replenishment operations	148,504.92	43.84	-	-
Energy consumption of the warehouse	-	-	14.50	94.95
Total	**338,743.58**	**100.00**	**15.28**	**100.00**

As shown in Table 4, the activities that generates the highest cost in the Backroom storage are the manpower management (168,576.00 €/year) and the replenishment operations (148,504.92 €/year); such activities account for 49.77% and 43.84% of the total cost of the process, respectively. From an environmental perspective, CO_2 emissions are mainly due to energy consumption of the warehouse (14.50 $tonCO_2$/year).

3.4. Sales area management

Sales area management includes all processes aimed at selling the finished product to the end user. Table 5 provides the results of economic and environmental assessment of this process.

Table 5: Costs and Emissions for the Sales Area Management

Sales Area				
Activities	**Costs [€/year]**	**%**	**Emissions [tonCO₂/year]**	**%**
Manpower	505,728.00	15.75	-	-
Replenishment operations	17,026.18	0.53	-	-
Sale losses	111,412.24	3.47	-	-
Inventory	1,890,000.00	58.87	-	-
Energy consumption related to refrigeration plants	140,987.70	4.39	115.68	12.67
HVAC consumption	281,505.44	8.77	230.97	25.29

related to sales area				
H_2O consumption related to sales area	10,714.91	0.33	8.79	0.96
Lighting of the sales area	253,173.63	7.89	207.73	22.75
Emissions of HFC gas	-	-	350.00	38.33
Total	**3,210,548.10**	**100.00**	**913.17**	**100.00**

As shown in Table 5, the most onerous cost component is the cost of inventory at the RS (1,890,000.00 €/year), followed by the manpower cost (505,728.00 €/year). The most relevant emissions of this process are due to HFC gas for refrigeration (38.33%), HVAC (25.29%) and lighting (22.75%).

3.5. Reverse logistics

Reverse logistics activities, i.e. the return flow from the RS to the DC, are assumed to be performed using *ad hoc* shipments, carried out by a small truck that retrieves the expired product at RS daily and ships it back to the DC for disposal. The distinction between dry and fresh products (as in Receiving Process) is not made. Indeed, as the returned product is typically expired, preserving its organoleptic properties by means of a refrigerated transport is not strictly necessary. The cost of the Reverse logistics process covers mainly the transport cost, as the disposal cost is typically ascribed to the supplier, according to the assumptions made. Table 6 lists the main results for the economic and environmental aspects of this process.

Table 6: Costs and Emissions of the Reverse Logistics Process

Reverse Logistics				
Activities	**Costs [€/year]**	**%**	**Emissions [tonCO_2/year]**	**%**
Transport	17,480.79	94.66	8.03	80.65
Fuel consumption	986.40	5.34	1.93	19.35
Total	**18,466.19**	**100.00**	**9.95**	**100.00**

4. DISCUSSIONS AND CONCLUSIONS

In this paper, we have evaluated the economic and environmental sustainability of a large-scale RS. The analysis takes into account the key supply chain processes of the RS, i.e. Receiving, Backroom storage, Sales area management and Reverse logistics. In particular, we described the application of a computational model, developed in Microsoft Excel™ to evaluate the cost and CO_2 emissions of the RS processes, to a reference process, i.e. the Receiving process. For this process, which is taken as a case study, we have detailed the equations implemented in the model to carry out the computation; for the remaining processes, the detailed computational procedure is omitted, for brevity, and only the main results are presented.

The comparison of the economic outcomes obtained for the four RS processes analysed is shown in Figure 1.

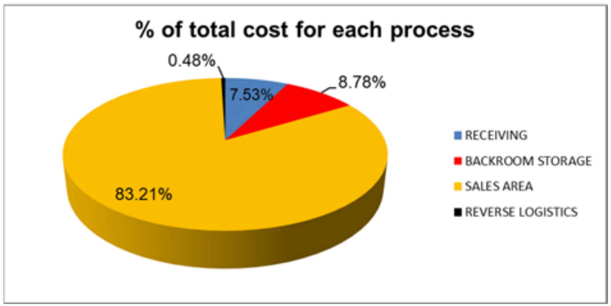

Figure 1: Comparison of the costs of the RS processes

As can be seen from Figure 1, the process with the highest cost is the Sales area management (83.21%), followed by the Backroom storage and Receiving processes, which account for 8.78% and 7.53% of the total cost, respectively. The total cost of the Reverse logistics process is almost null, mainly because of the assumptions made in the evaluation, that the RS does not incur in the cost of the returned products and disposal process.

The comparison of the environmental emissions of the four different processes analysed is shown in Figure 2.

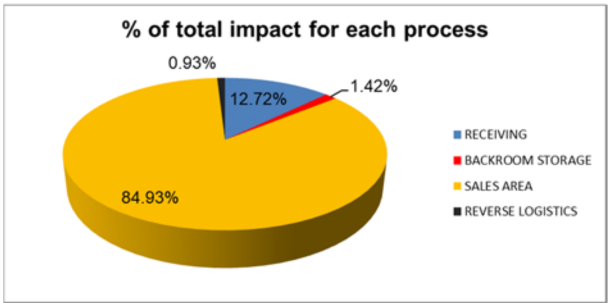

Figure 2: Comparison of the emissions for the RS processes.

As can be seen from Figure 2, the process with the highest CO_2 emission (in percentage) is the Sales area management (84.93%), followed by the Receiving process (12.72%). For the Backroom storage and Reverse logistics processes, the environmental impact is significantly lower than in the remaining processes (1.42% and 0.93% respectively).

The results of the study provide an idea of the total cost and environmental impact of a large-scale RS. Interesting scientific and practical contributions are given: indeed, the outcomes can be used by RS managers to identify the processes on which to concentrate with the aim to reduce the economic and environmental impacts. Moreover, the study also indicates the specific activity or component on which to intervene to remove any inefficiencies, thus optimizing sustainability.

From a technical perspective, some limitations of the analysis should be mentioned. Specifically, the present work does not take into account the processes of disposal or check of the returned products. This could be a future adjustment to be made to the model, in the attempt to evaluate the economic and environmental performance of the whole retail supply chain.

Also, starting from this work, several future research directions could be undertaken. The study developed could be used to analyse RS of different size, with the purpose of evaluating whether the economic and environmental performance may be different depending on the size of the store. Moreover, the choice of the processes could be modified, including further activities in the evaluation.

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